Connecticut Children's
MEDICAL CENTER

BEST CHILDREN'S HOSPITALS U.S.News ORTHOPEDICS 2011-12

Division of Orthopaedic Surgery and Sports Medicine
282 Washington Street, Hartford, CT 06106 • 860.545.9100 • 860.545.9095 *fax*
310 Western Blvd., Building G, Glastonbury, CT 06033 • 399 Farmington Ave., 3rd Floor, Farmington, CT 06032
4 Corporate Drive, 2nd Floor, Ste. 282, Shelton, CT 06484

Jeffrey D. Thomson, MD
Director

Mark C. Lee, MD
Philip W. Mack, MD
Kristan A. Pierz, MD
Janet L. Zahradnik, MD
Bruce E. Bowman, PA-C
Amy R. Shannon, APRN

Elite Sports Medicine
Carl W. Nissen, MD
Director

David H. Wang, MD, MS
Imran Hafeez, MD

AJ Ricciuti, PA-C, ATC

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OFFICE OF HEALTH CARE ACCESS

November 21, 2012

Lisa Davis, MBA, BSN, RN
Deputy Commissioner
Office of Health Care Access
Department of Public Health
410 Capitol Avenue, MS#13HCA
P. O. Box 340308
Hartford, CT 06134

Re: Certificate of Need Application
CT Children's Medical Center: Establishment of a Pediatric MRI in Farmington, CT

Dear Deputy Commissioner Davis:

The purpose of my letter is to provide you with some supporting information regarding trends in MRI imaging in the pediatric population and to address the need for an additional pediatric MRI for CT Children's Medical Center.

I am Director of Pediatric Orthopaedic Surgery at Connecticut Children's Medical Center, a position I have held for the past 10 years. I have been with Connecticut Children's Medical Center since it opened in 1996. During this time frame, I have seen a significant shift in practice utilizing MRI much more than ever before.

This shift is occurring because physicians have recognized the inherent dangers of radiation. We take many measures to shield and protect the children from radiation, but nonetheless, each exposure is additive. Parents are also demanding that we minimize radiation. The average Connecticut parent is very sophisticated and expects the best healthcare possible for their child, which of course, we all support. As a pediatric orthopaedic surgeon, I treat children with scoliosis and I am fully aware of a 2003 article in Health Physics entitled, "Cancer Risks from Medical Radiation." It cites an excess risk of breast cancer reported among women who had scoliosis and required frequent diagnostic x-rays during their child and adolescence. Although the data cited in this article is slightly dated, the concern still remains. At Connecticut Children's Medical Center, we have undertaken a study to better quantify the amount of radiation a patient is receiving, as well as methods to reduce their exposure.

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OFFICE OF HEALTH CARE ACCESS

We have also reached our capacity for MRIs at Connecticut Children's. As a surgeon who deals with emergencies, we often have to obtain an emergency MRI. Because the schedule of cases is so numerous, adding an emergency case then delays the MRI for elective cases. This results in patient and parent dissatisfaction.

The proposed MRI scanner in Farmington, CT will significantly improve access to pediatric MRIs for our patients, increase the speed of diagnosis, and protect children from radiation danger.

Sincerely,

Jeffrey D. Thomson, MD
President, Connecticut Children's Specialty Group
Director, Pediatric Orthopaedic Surgery
Connecticut Children's Medical Center

JDT/tlm

YALE NEW HAVEN HEALTH

December 14, 2012

RECEIVED
DEC 14 2012
OFFICE OF HEALTH CARE ACCESS

Ms. Kimberly Martone
Director of Operations
Office of Healthcare Access
410 Capitol Avenue
MS #13HCA
P.O. Box 340308
Hartford, CT 06106

Re: Yale-New Haven Hospital (YNHH)
Acquisition of a Dedicated 3 Tesla MRI for the Children's Hospital

Dear Ms. Martone:

Enclosed please find the original, four (4) hard copies and an electronic copy on CD of the Certificate of Need (CON) application for YNHH's proposal to acquire a dedicated 3 Tesla MRI scanner to meet the growing demand for pediatric MRI and to better serve its pediatric patients and improve the patient and family experience at Yale-New Haven Children's Hospital (YNHCH).

Please do not hesitate to contact me with any questions or concerns. I can be reached at (203) 863-3908.

Thank you for your time and support of this project.

Sincerely,

Nancy Rosenthal

Nancy Rosenthal
Senior Vice President – Health Systems Development

Enclosures

789 Howard Avenue
New Haven, CT 06519

Application Checklist

Instructions:

1. **Please check each box below, as appropriate; and**
2. **The completed checklist *must* be submitted as the first page of the CON application.**

☒ **Attached is the CON application filing fee in the form of a certified, cashier or business check made out to the "Treasurer State of Connecticut" in the amount of $500.**

For OHCA Use Only:

Docket No.: 12-31810-CON **Check No.:** 1626801
OHCA Verified by: KR **Date:** 12-14-12

☒ **Attached is evidence demonstrating that public notice has been published in a suitable newspaper that relates to the location of the proposal, 3 days in a row, at least 20 days prior to the submission of the CON application to OHCA. (*OHCA requests that the Applicant fax a courtesy copy to OHCA (860) 428-7053, at the time of the publication)***

☒ **Attached is a paginated hard copy of the CON application including a completed affidavit, signed and notarized by the appropriate individuals.**

☒ **Attached are completed Financial Attachments I and II.**

☒ **Submission includes one (1) original and four (4) hard copies with each set placed in 3-ring binders.**

Note: A CON application may be filed with OHCA electronically through email, if the total number of pages submitted is 50 pages or less. In this case, the CON Application must be emailed to ohca@ct.gov.

Important: For CON applications(less than 50 pages) filed electronically through email, the singed affidavit and the check in the amount of $500 must be delivered to OHCA in hardcopy.

☒ **The following have been submitted on a CD**

1. **A scanned copy of each submission in its entirety, including all attachments in Adobe (.pdf) format.**
2. **An electronic copy of the documents in MS Word and MS Excel as appropriate.**

YALE-NEW HAVEN HOSPITAL
Acquisition of a Dedicated 3 Tesla MRI for Yale-New Haven Children's Hospital

Certificate of Need Application

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PUBLIC NOTICES

System – Mortgagee's Registered Agent, Connecticut, 1 Corporate Center, Hartford, CT 06103-3290; Baham Investments, LLC – Mortgagee, 958 Dixwell Avenue, Hamden, CT 06514; AND Hillel J. Auerbach – Registered Agent for Mortgagee, 555 Long Wharf Drive, Floor 12, New Haven, CT 06511-6104; Wells Fargo Foothill, Inc. – Holder of unreleased mortgage from prior owner, 2450 Colorado Avenue, Suite 3000W, Santa Monica, CA 90404; AND Corporation Service Company – Mortgagee's Registered Agent, California, CSC-Lawyers Incorporating, 2710 Gateway Oaks Drive, Suite 150N, Sacramento, CA 95833-3502; AND Corporation Service Company – Mortgagee's Registered Agent, Connecticut, 50 Weston Street, Hartford, CT 06102-1504.

7. The condemner has determined that the amount of the compensation to be paid to the persons entitled thereto for such property is $192,500.00 and this sum is being deposited with the Clerk of the Superior Court in accordance with the provisions of General Statutes § 8-130.

Housing Authority of the City of New Haven

Request for Proposals

Legal Services for Energy Performance Contracting

Solicitation # OP-12-RFP-0008

The Housing Authority of the City of New Haven (HANH) is currently seeking bids for **Legal Services for Energy Performance Contracting**. Sealed bids will be received until **November 27, 2012 @ 3:00 PM**. A pre-bid conference will be held at **360 Orange Street, New Haven, CT 06511** on **November 14, 2012 @ 11:00 AM**. A complete copy of the requirement may be obtained from HANH's front desk at 360 Orange Street beginning on **November 7, 2012 @ 3:00 p.m.** Additional questions should be emailed only to Karen DuBois-Walton at bids@newhavenhousing.org no later than **November 19, 2012 @ 5:00 p.m.** All answers to the questions will be posted on HANH's Website: **www.elmcitycommunities.com**. Please click on the link for Vendors and then Current Bids.

improvements thereon, situated in said City of West Haven, County of New Haven and State of Connecticut, bounded and described as follows:

Known as Lots 220 and 221:

North: by Milford Turnpike, 43.2 feet;
West: by Rockview Street, 107.83 feet;
South: by Lot 219 on said map, 86.44 feet;
East: by land of owners unknown, 107.83 feet.

Known as 516 Orange Avenue.

6. The names of all persons having a record interest in the property are the following: Radio Communications Corporation – Owner, 24 Rockdale Road, West Haven, CT 06516; AND 23 Daytona Street, West Haven, CT 06516-2310; AND Robert C. Knapp – Registered Agent for Owner, 24 Rockdale Road, West Haven, CT 06516; AND Lillian Knap – Mortgagee, 8 Hickory Lane, Ansonia, CT 06401.

7. The condemner has determined that the amount of the compensation to be paid to the persons entitled thereto for such property is $275,000.00 and this sum is being deposited with the Clerk of the Superior Court in accordance with the provisions of General Statutes § 8-130.

PUBLIC NOTICE

Pursuant to section 19a-638 of Connecticut General Statutes, Yale-New Haven Hospital will submit the following Certificate of Need application:

Applicant(s): Yale-New Haven Hospital

Address: 20 York Street

Town: New Haven

Proposal: Acquisition of Dedicated 3 Tesla MRI for Children's Hospital

Estimated Total Project Cost/Expenditure: $5,875,828

first presentation.

The final step of pulling together the report is determining the boundaries of the proposed historic district.

The proposal is then put to a vote. If two-thirds of the review board are in favor, then the process will proceed to a public hearing.

District Commission.

Newer properties can be included in a historic district as well.

"It's all about what people feel is important and properties they want to protect," said Lind.

Call Ebony Walmsley at 203-789-5734. Follow her on Twitter @nhEbony12.

Amateur Hour covers lockpicking

The Institute Library's monthly series, Amateur Hour, will feature competitive lockpicker and scholar of locks, Schuyler Towne, at 7 p.m. Wednesday. Host Joshua Foer will interview Towne and lead a discussion with audience members.

Doors open at 6:30. Beer and wine will be available for purchase ($5 per drink), complimentary light refreshments.

Schuyler Towne will discuss the history of lock design and manufacture and demonstrate his special skills, with audience members encouraged to bring their own heavy locks.

Towne is a founding board member of the Open Organization of Lockpickers, U.S. Chapter, and launched Non-Destructive Entry magazine in 2007.

Tickets are $5 for Institute Library members and $10 for non-members. Tickets are available at the library and online at amateurhourfour.eventbrite.com. To become a member of the Institute Library, visit www.instituteli-brary.org/join.html.

Call to place your ad today **203-777-3278**

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A GUIDE TO LOCAL BUSINESSES & SERVICES

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STATE LIC #0761

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No job too big or too small
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Dave 203-410-9323 cell
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GUTTERS/ROOFING
LEAK DAMAGE
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REPAIRS
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Llc. 570192

To Place Your ad here call

203-789-5469

TREE REMOVAL

Storm Cleanup
Tree Removal
Chippings
Call Bill
203-915-9597

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240 CONDOMINIUMS FOR RENT

RENT NOW!

NEW HAVEN - 2BR, 2nd flr. stove, refrig. gas hot water baseboard heat. $950 mo. Lease. Security, no pets. Call Richard 203-734-8371

WEST HAVEN Bull Hill Lane, 2 BR, 1.5 bath, gar w/storage, new efficient furnace, A/C $1200 mo 2 mo sec, Good credit, 2 yr lease 203-645-8559

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LEGALS

PUBLIC NOTICE

Pursuant to section 19a-638 of Connecticut General Statutes, Yale-New Haven Hospital will submit the following Certificate of Need application:

Applicant(s): Yale-New Haven Hospital

Address: 20 York Street

Town: New Haven

Proposal: Acquisition of Dedicated 3 Tesla MRI for Children's Hospital

Estimated Total Project Cost/Expenditure: $5,875,828

LEGALS

Legal Notice

Town of Branford
Request for Bids

"Geosynthetic Fabric Installation"

The Town of Branford is requesting bid proposals for **"Geosynthetic Fabric Installation"** on Point Pleasant Road, Branford, CT. Specifications may be obtained from the Finance Department, Branford Town Hall, 1019 Main Street, Branford, CT or on the Town's website at **www.branford-ct.gov**.

Bids are to be submitted in a sealed envelope marked **"Geosynthetic Fabric Installation"** to the Finance Department, Attention, Purchasing Clerk, 1019 Main Street, Branford, CT 06405 by **1:00 p.m., Thursday December 6, 2012.** Bids will be publicly opened and read at 1:30 p.m. on

245 HOUSES FOR RENT



MILFORD - 1+ bdrm, heat and all utilities included. Dead end street. Laundry, $1200/mo. 1st last and sec. non-smoking, pets on approval. Call 203-521-8513

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Garage
Immediate Occupancy
$85.00 month
CALL 203-777-4599

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645 GENERAL HELP WANTED

INTERNET MARKETING & LEAD MANAGER – Well-established, 30+ year residential real estate company is seeking an energetic individual to develop & facilitate an internet marketing strategy and increase our lead conversion rate. Should have a thorough working knowledge of SEO strategies, PPC advertising, social media and Google Analytics. Will be responsible for maximizing the company web site, overseeing the Lead Management Program, tracking leads from all incoming sources, working closely with agents and managers to increase lead conversion and educate agents on how to gain more leads via social media. Real estate knowledge is helpful but not required. Must work well with people and be able to communicate effectively. Exciting opportunity for motivated individual. Competitive compensation package plus incentives. Please send
resume and salary requirement to:
careers@weichertrp.com

LEGALS

LEGAL NOTICE

Notice of Sale or other Disposition, Pursuant to Connecticut State Sec. 42-159 to 42-169.

Notice is given that MJM Self-Storage of Clinton LLC will sell at Public Auction the personal property in the units to satisfy unpaid storage rentals of delinquent

LEGALS

INVITATION TO BID

Street and sidewalk cleaning and rubbish removal

The District will receive bids for these services until 3PM on Friday, Nov. 30, 2012 at the District offices at 1205 Chapel Street at which time bids will be opened, reviewed publicly, and disclosed to participants. Bid documents, specifications, and project details are available at the Chapel West Special Services District office, Call 787-3000 for an appointment or further information.

LEGALS

LIQUOR PERMIT

Notice of Application
This is to give notice that I,
XIAO LING FANG
66 WASHINGTON RD
HAMDEN, CT 06518-3030
Have filed an application placarded 11/16/2012 with the Department of Consumer Protection for a RESTAURANT WINE & BEER PERMIT
for the sale of alcoholic liquor on the premises at
2779 DIXWELL AVE.
HAMDEN, CT 06518-3340
The business will be owned by: BO JIE LLC.
Entertainment will consist of: None
Objections must be filed by:
12/27/2012
XIAO LING FANG

LEGAL NOTICE

TOWN OF GUILFORD REQUEST FOR QUALIFICATIONS RFQ #4-1213 THIRD PARTY STRUCTURAL ENGINEERING REVIEW SERVICES FOR THE NEW GUILFORD HIGH SCHOOL

The Town of Guilford ("Owner") requests Statements of Qualification for Third Party Structural Engineering Services for the new **Guilford High School** ("GHS"). The Owner is seeking to identify **Structural Engineering Consultants** ("SEC") to provide third party structural engineering services for threshold structural review of design development and construction documents for the new GHS.

Hard copies of the complete Request for Qualifications package will be available on Friday, November 16, 2012 at the Office of the First Selectman or may be accessed from the

ANSONIA

LEGAL NOTICE CITY OF ANSONIA

The City of Ansonia Board of Aldermen on November 13, 2012 approved changes to Ordinance Sections 9-15, 9-17, 9-18, 9-20, 9-21 and 9-22 pertaining to rescue duties and responsibilities of the Ansonia Rescue Medical Services and the Ansonia Fire Department. The full text of the ordinance is on file in the office of the Town and City Clerk of the City of Ansonia and online on the City of Ansonia website.

Dated at Ansonia, Connecticut this 14th day of November 2012.

THE CITY OF ANSONIA

James T. Della Volpe, Mayor

2523157

ANSONIA

LEGALS

PUBLIC NOTICE

Pursuant to section 19a-638 of Connecticut General Statutes, Yale-New Haven Hospital will submit the following Certificate of Need application:

Applicant(s): Yale-New Haven Hospital

Address: 20 York Street

Town: New Haven

Proposal: Acquisition of Dedicated 3 Tesla MRI for Children's Hospital

Estimated Total Project Cost/Expenditure: $5,875,828

LEGALS

AUTHORIZING ORDINANCE OF THE EAST HAVEN TOWN COUNCIL

At its duly called and held meeting on November 13 2012, The East Haven Legislative Town Council adopted an ordinance authorizing the following transfer at the recommendation of the Board of Finance:

AFFIDAVIT

AFFIDAVIT

Applicant: **Yale-New Haven Hospital**

Project Title: **Acquisition of a Dedicated 3 Tesla MRI for the Children's Hospital**

I, **James Staten** (Individual's Name), **Chief Financial Officer** (Position Title – CEO or CFO)

of **Yale-New Haven Hospital** (Hospital or Facility Name) being duly sworn, depose and state that

Yale-New Haven Hospital's (Hospital or Facility Name) information submitted in this Certificate of Need Application is accurate and correct to the best of my knowledge.

Signature Date

Subscribed and sworn to before me on _____

Notary Public/Commissioner of Superior Court

My commission expires: _____

FILING FEE

07-14-3774B 06-2005

Bank of America **Cashier's Check** No. 1626801

Notice to Purchaser: In the event this check is lost, misplaced or stolen, a sworn statement and 90-day waiting period will be required prior to replacement. This check should be negotiated within 90 days.

Date DECEMBER 13, 2012

30-1/1140
NTX

Banking Center YALE NEW HAVEN HOSPITAL

0021178 00005 0001626801

Remitter (Purchased By) TESLA MRI

$ **500.00**

Pay **FIVE HUNDRED DOLLARS AND 00 CENTS**

To The Order Of **TREASURER, STATE OF CONNECTICUT**
****

Authorized Signature

Bank of America, N.A.
San Antonio, Texas

VOID AFTER 90 DAYS

07-14-3774B 06-2005

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THE ORIGINAL DOCUMENT HAS REFLECTIVE WATERMARK ON THE BACK

THE ORIGINAL DOCUMENT HAS REFLECTIVE WATERMARK ON THE BACK

CERTIFICATE OF NEED

State of Connecticut
Office of Health Care Access
Certificate of Need Application

Instructions: Please complete all sections of the Certificate of Need ("CON") application. If any section or question is not relevant to your project, a response of "Not Applicable" may be deemed an acceptable answer. If there is more than one applicant, identify the name and all contact information for each applicant. OHCA will assign a Docket Number to the CON application once the application is received by OHCA.

Docket Number:	TBD
Applicant:	Yale-New Haven Hospital
Contact Person:	Nancy Rosenthal
Contact Person's Title:	Senior Vice President – Health Systems Development
Contact Person's Address:	Department of Planning & Business Development 2 Howe Street
Contact Person's Phone Number:	203-863-3908
Contact Person's Fax Number:	203-863-4736
Contact Person's Email Address:	Nancy.Rosenthal@greenwichhospital.org
Project Town:	New Haven, CT
Project Name:	Acquisition of a Dedicated 3 Tesla MRI for the Children's Hospital
Statute Reference:	Section 19a-638, C.G.S.
Estimated Total Capital Expenditure:	$5,875,828

Project Description: Acquisition of Equipment

a. Please provide a narrative detailing the proposal.

Yale-New Haven Children's Hospital (YNHCH) is one of only two children's hospitals in the State of Connecticut. It is an integral component of the Yale-New Haven Health System, one of the premier health systems in the United States. To support YNHCH's position as a specialized provider of high quality pediatric care, great emphasis and effort is placed on recruiting world renowned leaders in pediatric medicine. Community-based physicians and full-time faculty of the Yale School of Medicine work side-by-side to deliver care in a state-of-the-art facility. Physicians treat a wide array of illness, including rare and difficult to treat cancers and metabolic disorders. *US News & World Report* ranks YNHCH among the best in the nation, with special recognition of its diabetes and endocrinology program. Other programs to receive recognition include gastroenterology, neonatology, nephrology, orthopedics, pulmonology, and urology. YNHCH also strives to provide an environment that addresses the emotional needs of pediatric patients and their families and subscribes to the philosophy that children should be cared for and treated in specially designed pediatric facilities with specially trained pediatric staff.

Consistent with its philosophy of care, YNHCH is requesting a dedicated pediatric 3.0 Tesla (T) MRI machine to meet the demand for pediatric MRI and to better serve its pediatric patients. The proposed scanner will be used exclusively by pediatric patients in order to provide more child-friendly and clinically appropriate care, and to provide a much improved environment for pediatric patients undergoing an MRI exam.

MRI is increasingly preferred over Computed Tomography (CT) as an imaging modality for children since it does not involve exposure to radiation. As one of Connecticut's two specialty children's hospitals, YNHCH's MRI service serves pediatric patients in need of diagnosis and monitoring of numerous routine and complex clinical conditions, including those related to oncology, neurology, cardiology and musculoskeletal conditions. Growth in demand for YNHCH pediatric services and the increasing clinical preference for MRI over other types of imaging modalities for children have resulted in substantial growth in YNHCH's MRI services, with a 24% increase in pediatric scans between FY 2009 and FY 2012 at YNHH.

Currently, pediatric patients are served on various MRI machines located in multiple buildings on the YNHH campus. They are scanned among adult inpatient, outpatient, ED and trauma patients, and as a result are exposed to a variety of ill adults. Receiving an MRI exam alongside adult surgical, oncology and trauma patients is frightening for children and can increase anxiety about their own scan. Ideally, pediatric patients' MRI needs should be addressed within the confines of the YNHCH in a pediatric-focused and pediatric-centered environment using dedicated pediatric staff. Pediatric scans also frequently require sedation or general

anesthesia and can be more time consuming than adult scans. Scheduling and adequately serving pediatric patients with the current configuration is quite difficult.

The proposed pediatric MRI suite will be located in the YNHCH (also known as the West Pavilion), in a setting that is specifically designed for children, using dedicated pediatric staff, and no exposure to adult patients. As a result, pediatric MRI exams will be centralized into a single location and service, which will positively impact the patient and family experience and enhance the efficiency of the pediatric MRI service.

In addition, due to consistently strong demand for MRI services at YNHH and YNHCH, there is frequently a backlog of approximately one to three weeks to schedule outpatient pediatric MRIs. This backlog is considerably longer for those cases that require sedation or anesthesia. The availability of a dedicated pediatric MRI unit will help ensure prompt scheduling of exams for children and will eliminate any backlog.

b. Provide letters that have been received in support of the proposal.

There is significant support from pediatric physicians and letters of support have been obtained from several physicians and can be found in Appendix I.

c. Provide the Manufacturer, Model, Number of slices/tesla strength of the proposed scanner (as appropriate to each piece of equipment).

The proposed scanner is a Siemens Skyra 3.0 Tesla MRI.

d. List each of the Applicant's sites and the imaging modalities and other services currently offered by location.

The applicant offers MRI services at multiple sites which are outlined in the Table A below.

Table A: YNHH MRI Locations and Equipment

YNHH MRI Service Locations	MRI Scanners
Yale-New Haven Hospital 20 York Street New Haven, CT 06510	MRI Center 1 – 3.0T closed MRI Center 2 – 1.5T closed MRI Center 3 – 1.5T closed MRI Smilow 1 – 3.0T closed (Breast only) MRI Smilow 2 – 3.0T closed MRI Smilow 3 – 1.5T closed MRI Smilow 4 – 3.0T closed Operating Room – Intraoperative MRI only
Temple Radiology 111 Goose Lane	1.5T closed

YNHH MRI Service Locations	MRI Scanners
Guilford, CT 06437 – outpatient only	
Temple Radiology 60 Temple Street New Haven, CT 06510 – outpatient only	1.5T closed 0.6T Stand-Up Unit (to be replaced and relocated to 6 Devine Street in North Haven)

Note: YNHH is a joint venture partner in the Saint Raphael Magnetic Resonance Center (SRMRIC) which operates two scanners on the Saint Raphael's campus; a 1.5T and a 3.0T. Currently these scanners operate independently from YNHH's Department of Diagnostic Imaging.

Although MRI services are offered at different YNHH locations, pediatric MRI services must be offered in conjunction with pediatric anesthesia and sedation services, which are only available on the main Hospital campus at 20 York Street in New Haven.

2. **Clear Public Need**

a. Explain why there is a clear public need for the proposed equipment. Provide evidence that demonstrates this need.

Yale-New Haven Hospital is requesting a dedicated pediatric 3.0 Tesla MRI for its Children's Hospital to meet the growing demand for pediatric MRI and to better serve its pediatric patients and improve the patient and family experience at YNHCH. Need for the proposed MRI is based on the following main factors:

- **Growth of MRI as a preferred imaging modality for children;**
- **High utilization of existing main campus MRI scanners; and**
- **The need to improve the delivery of pediatric MRI services.**

Growth of MRI as a Preferred Imaging Modality for Children

Recent advances in magnetic resonance imaging technology and increasing concerns about exposure to ionizing radiation have led to a significant increase in the demand for MRI scans in the pediatric population over other imaging modalities that expose patients to radiation, such as Computed Tomography (CT). Developments such as specialized pediatric coils and monitors, rapid pulse sequences, functional and metabolic imaging, and novel contrast agents (both intravenous and enteric) have led to an increase in MRI imaging of the body, brain, spine, and bones. In addition, newer applications such as MRI urography and MRI enterography have replaced other types of diagnostic tests that exposed children to ionizing radiation. At YNHCH, MRI is also used to assess pediatric heart function, with steady growth in these types of cases in recent years.

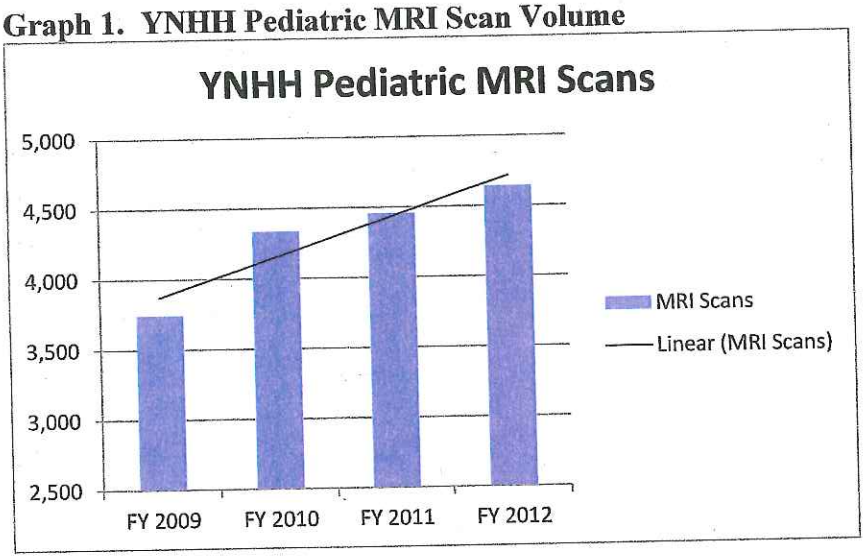
The Image Gently campaign was launched in January of 2008 and is an initiative of the Alliance for Radiation Safety in Pediatric Imaging. The goal of Image Gently is to increase awareness and promote radiation safety for children. According to the Image Gently website (www.pedrad.org) more than 18,000 medical professionals have taken a pledge to make imaging decisions which reduce radiation exposure and

to communicate the importance of this practice in their professional circles. This initiative has helped to educate health professionals and parents and has contributed to the shift away from radiation imaging modalities in children.

MRI volumes in YNHH's pediatric population have increased substantially in recent years. Scan volume totaled just over 3,700 in FY 2009 and in FY 2012 exceeded 4,640. This increase of ~ 24% in just three years is evidence of the growing demand for pediatric MRI services.

Graph 1 below illustrates the steady and significant growth in pediatric MRI scan volume.

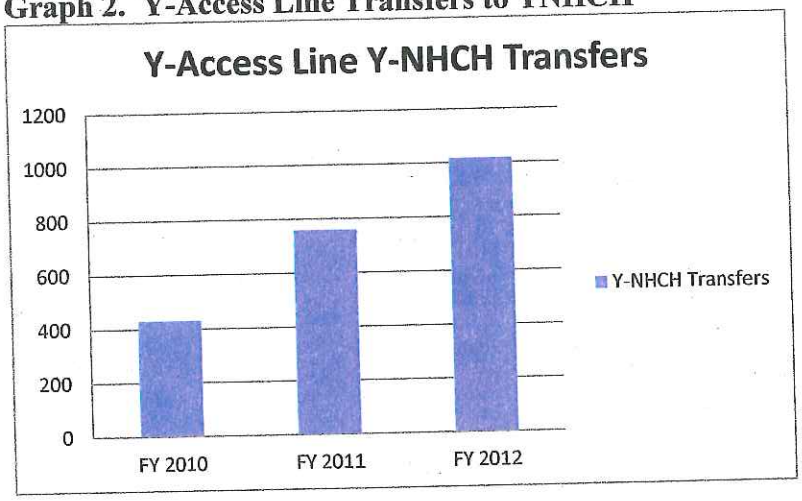
Graph 1. YNHH Pediatric MRI Scan Volume



Demand for pediatric MRI services is expected to continue to grow at YNHCH. The shift from CT to MRI is expected to continue and YNHCH has continued to experience overall growth in its services, particularly in outpatient areas. The Y-Access Transfer Line, which coordinates the transfer and admission of acutely ill patients to YNHH/YNHCH and provides referring physicians with ongoing access and communication regarding their patients' conditions, has seen a dramatic increase (136% between FY 2010 and 2012) in the number of acutely ill children transferred to YNHCH from other institutions due to YNHCH's unique capabilities to care for complex pediatric cases.

Graph 2 below summarizes the Y Access Transfer Line volumes between FY 2010 and FY 2012.

Graph 2. Y-Access Line Transfers to YNHCH



The increase in acutely ill pediatric transfers to YNHCH is another factor driving up the demand for pediatric MRI services, particularly those requiring anesthesia. Y Access Line transfers are projected to continue to positively impact MRI volumes.

<u>High Utilization of Existing Main Campus MRI Scanners</u>

Currently, pediatric patients must obtain an MRI scan from one of the scanners at the main hospital campus. They are located in two main areas: the MRI Center (outpatients only and located in Fitkin basement across the street from the main inpatient hospital campus) and Smilow Cancer Hospital. Both of these areas serve primarily adults and are not designed to serve children. The majority (~65%) of pediatric MRI scans are completed on the scanners in the Smilow Cancer Hospital. This is due to the fact that approximately 30% of the pediatric MRI scans require anesthesia or sedation (~20% of the 30% is general anesthesia) and a pediatric anesthesiologist or nurse anesthetist must be present to administer the anesthesia or sedation. The Smilow Cancer Hospital is currently the only area where anesthesia or sedation services can be safely administered for pediatric MRI patients.

In determining the need for a new MRI scanner, the Hospital first assessed its existing main campus units to see whether any could be permanently assigned to the pediatric population. An analysis of utilization levels on these scanners showed high rates and therefore no one scanner can be dedicated to pediatric cases. It is important to recognize the YNHH's existing MRI scanners are operating from early in the morning until 11 pm every day. One scanner is staffed and operates 24 hours per day, seven days per week. Hours of operation for each of the MRI areas are noted in Table B below.

Table B: YNHH MRI Main Campus Locations and Hours of Operation

MRI Locations	Hours of Operation
Yale-New Haven Hospital MRI Center	Mon-Th: 7 am to 11 pm; Fri: 7 am to 7 pm; Sat: 7 am to 3 pm
Yale-New Haven Hospital Smilow Cancer Hospital	One scanner operates 24/7 Others: Monday through Sunday: 7am

MRI Locations	Hours of Operation
	– 11pm, Breast MRI: Mon – Th: 7am – 7pm, Fri: 7am – 3pm, Sat: 8am – Noon

The scanners are operating at high utilization levels despite the extensive hours of operation. Table C below summarizes utilization levels based on FY 2012 MRI scan volumes and hours of operation.

Table C: FY 2012 Utilization Levels of YNHH Main Campus MRIs

YNHH							
MRI Utilization - York Street Campus							
	MR Center 1	MR Center 2	MR Center 3	Smilow 1	Smilow 2	Smilow 3	Smilow 4
	2012						
					Open 24/7		
Equipment	3.0 T	1.5 T	1.5T	3.0 T-Breast	3.0 T	1.5 T	3.0 T
Scheduled Hours/Week (see below)	85	85	85	60	168	112	112
Weeks/Year	51	51	51	51	51	51	51
Time (hrs)/Scan	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100% Capacity: Scans/Week	85	85	85	60	168	112	112
100% Capacity: Scans/Year	4,335	4,335	4,335	3,060	8,568	5,712	5,712
Actual Volume*	3,645	3,899	3,565	3,640	6,290	5,766	5,661
% Utilization (@100%)	84%	90%	82%	119%	73%	101%	99%

As OHCA has recognized, 85% utilization is considered an appropriate level to add additional capacity. Utilization of the MRIs in the MRI Center ranged between 82% and 90% utilization in FY 12. MRI scanners in Smilow, where most children are currently scanned are operating between 73% and 119% utilization. The one scanner at 73% utilization operates at this level because of its extensive hours of operation - 24 hours per day, 7 days per week.

Note: The two scanners at the Saint Raphael campus are also operating at almost 100% utilization and are not appropriate for pediatric use due to the lack of pediatric anesthesiology services at that campus. Given these high utilization levels, there is no opportunity to use an existing scanner as a dedicated pediatric scanner.

Given the high utilization levels, especially in the Smilow Cancer Hospital, there is a two to three week backlog for elective pediatric MRI exams.

<u>Need to Improve the Delivery of Pediatric MRI Services</u>

As previously described, pediatric patients requiring MRI services must currently be scanned in adult-oriented areas at YNHH. Although this practice has been in

place for many years, it is not ideal and has been identified as an area targeted for improvement. YNHH and YNHCH have waited for MRI volume to grow to a level commensurate with this request for an additional, dedicated pediatric MRI scanner.

As previously described, the current configuration and location of MRI equipment requires that children be scanned on a variety of MRI scanners located in adult areas. This practice creates a number of challenges for both the patients and the staff. The process of obtaining an MRI scan on a child varies significantly from that of an adult. Currently, when a child requires an MRI, a team of pediatric providers, including a pediatric anesthesiologist or nurse anesthetist, a child life specialist and specialized nursing staff must be scheduled and physically located in the MRI area.

As noted, a significant percentage of pediatric MRI scans require anesthesia or sedation since it is not possible for young children to remain still during a one hour scan. Pediatric patients who receive anesthesia or conscious sedation must fast prior to their MRI exam, starting the night before and continuing into the morning of the scan. As a result, there is significant demand to schedule early morning MRI exams so that fasting patients do not have to go longer than necessary without eating. It is particularly difficult for children to be fasting for long periods of time, especially if they are scheduled for an outpatient exam that could possibly get delayed by an unscheduled emergency patient. Given the high utilization of existing scanners, there is little opportunity to accommodate all fasting patients early in the day. The proposed dedicated pediatric MRI will help significantly to accommodate fasting patients early in the day and minimize the stress and discomfort to patients and families.

From a patient- and family-centered perspective, the current process poses challenges and concerns. In addition to scheduling and care coordination challenges, the adult care MRI environment presents a number of issues for the pediatric patients and their parents/family including:

- **Transport to an adult area away from other pediatric services;**
- **Exposure to ill adults, particularly oncology patients, which is often frightening for children; and**
- **Physical facilities that do not offer any décor (e.g. child art) or furniture/equipment (e.g. large adult size furniture) which help to reduce fear and anxiety in children.**

As previously mentioned, YNHCH's philosophy of care is to provide dedicated pediatric trained staff in facilities that are pediatric-focused and child-centered to promote feelings of safety and comfort. In addition, YNHCH seeks to provide an optimal patient and family experience whenever possible, which includes ensuring an appropriate environment of care for that patient population.

The proposed dedicated 3T MRI scanner will permit patients and families to receive MRI services at the YNHCH. The proposed equipment is a Magnetom Skyra 3 T

system which offers a short and open bore to minimize feelings of claustrophobia. This is especially important for children who are not sedated during the exam as they can easily become frightened in a long, closed bore configuration. Patient safety will be enhanced by the undockable table on the proposed unit. In the event of an adverse reaction to anesthesia or other emergency during the exam, staff can "undock" or detach the table and move the patient quickly out of the room. The Hospital's current MRI units do not feature undockable tables. The scanner will be equipped with all necessary coils to perform all pediatric exams required. The 3T strength is especially important for neurological imaging in children.

b. Provide the utilization of existing health care facilities and health care services in the Applicant's service area.

YNHCH is one of only two children's hospitals in the State of Connecticut and therefore possesses a level of expertise and experience in the care of infants, children and adolescents that is not generally available at other hospitals. YNHCH provides most of the inpatient care to children in the Greater New Haven and Fairfield county areas. Anesthesia and sedation services provided in conjunction with pediatric MRI services are not provided by other outpatient MRI providers in the community.

The applicant does not have access to utilization statistics of other community based MRI providers.

c. Complete **Table 1** for each piece of equipment of the type proposed currently operated by the Applicant at each of the Applicant's sites.

Please see below. However, as earlier stated, the ability to provide pediatric anesthesiology and sedation services is a prerequisite to providing a dedicated pediatric MRI service. Therefore, pediatric MRI services are only offered on the Hospital's main campus.

Table 1: Existing Equipment Operated by the Applicant

Provider Name Street Address Town, Zip Code	Description of Service *	Hours/ Days of Operation **	Utilization FY12***	Pediatric Utilization FY12***
Yale-New Haven Hospital 20 York Street New Haven, CT 06510	MRI Center 1 – 3.0T closed MRI Center 2 – 1.5T closed MRI Center 3 – 1.5T closed MRI Smilow 1 *(breast)* – 3.0T closed MRI Smilow 2 – 3.0T closed MRI Smilow 3 – 1.5T closed MRI Smilow 4 – 3.0T closed	MRI Center Mon-Th 7 am to 11 pm; Fri 7 am to 7 pm; Sat. 7 am to 3 pm Smilow Mon-Sun 7 am to 11 pm	3,645 3,899 3,565 3,640 6,290 5,766 5,661	389 426 399 64 1,618 550 838
Temple Radiology 111 Goose Lane Guilford, CT 06437	1.5T closed	Mon & Fri 7 am to 5p m; Tues – Th 7 am to 8 pm	4,092	216****

Provider Name Street Address Town, Zip Code	Description of Service *	Hours/ Days of Operation **	Utilization FY12***	Pediatric Utilization FY12***
Temple Radiology 60 Temple Street New Haven, CT 06510	1.5T closed 0.6T Stand-Up Unit (to be replaced and relocated to 6 Devine Street in North Haven)	Mon & Fri 7 am to 8 p m; Tues – Th 7 am to 5 pm	3,101 1,131	128**** 13****

* Include equipment strength (e.g. slices, tesla strength), whether the unit is open or closed (for MRI)
** Days of the week unit is operational, and start and end time for each day; and
*** Number of scans/exams performed on each unit for the most recent 12-month period (identify period).
****These volumes represent cases performed on adolescents or teenagers, who do not require sedation

d. Provide the following regarding the proposal's location:

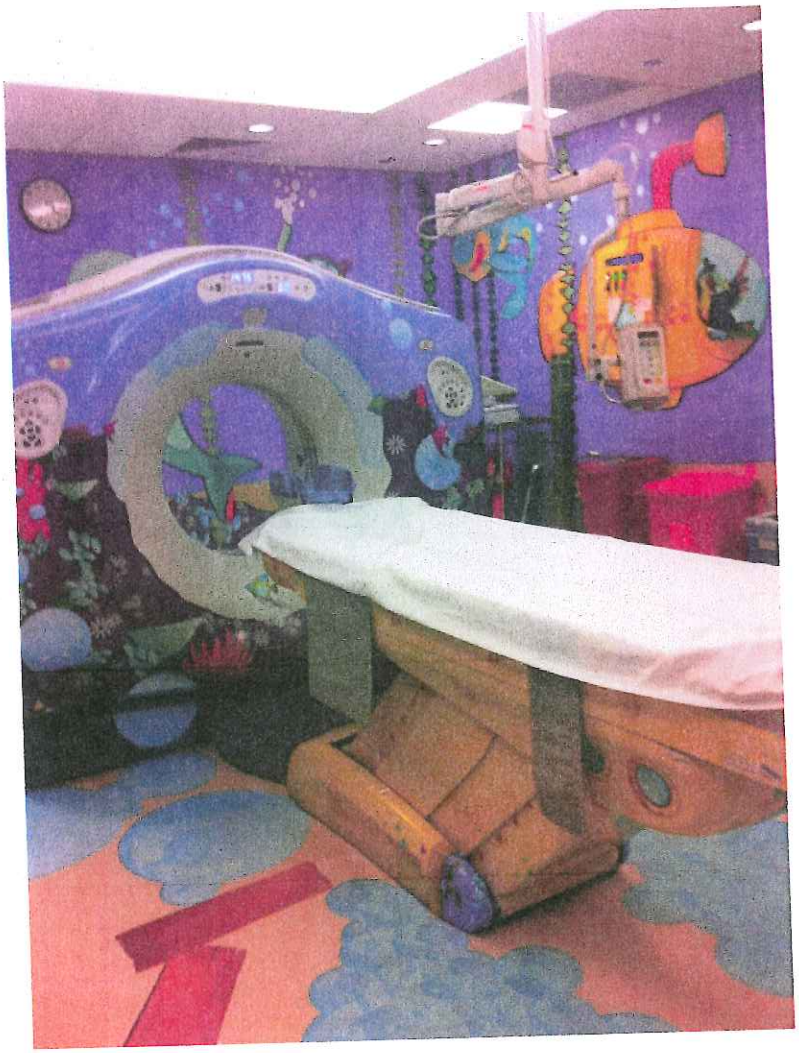
i. The rationale for locating the proposed equipment at the proposed site;

It is important to note the limitations of providing pediatric MRI exams on the Hospital MRI scanners listed above, particularly on babies and young children who require sedation or anesthesia for their scan. Three of the scanners are located in the MRI Center in the basement of the Fitkin Building. While this center is part of the YNHH campus, it is in a remote location across the street from the main hospital. Complications can occur during any type of anesthesia administration, so scanning pediatric patients in a setting that is not in close proximity to emergency support resources is not optimal. Therefore, these three scanners are less appropriate for use by many pediatric patients.

The breast MRI in Smilow Cancer Hospital is dedicated to performing breast MRI exams and biopsies and is not used for general pediatric MRI imaging. Children have been scanned on this MRI only when there is no availability elsewhere. The three remaining MRI units are located a single suite in the Smilow with a shared prep and recovery space. As a result, both prior to and after their scan, children and their families are routinely exposed to acutely ill oncology, trauma and surgical patients, among others, many of whom are in stretchers and may be accompanied by complex medical equipment or devices (such as Gamma Knife patients, who have a halo-type device attached to their skull). It is less than ideal to serve young patients in this setting, as they are often intimidated and frightened by the close proximity of visibly ill adult patients, which can exacerbate the stress they are experiencing related to their MRI exam.

A significant proportion of pediatric patients undergoing an MRI exam require anesthesia or sedation services, which must be provided by a pediatric anesthesiologist or APRN. This practice limits the Hospital locations where pediatric MRI services can be provided. Only the main campus of YNHH provides dedicated pediatric anesthesiology services.

By locating the scanner in the YNHCH, the MRI and scan room can be decorated with child friendly décor which will minimize fear and anxiety for the children and their families. The following photograph is an example of a pediatric focused scanner at another facility. YNHCH plans to have children and their families help choose the specific décor for the scanner.



All of the reasons noted above support the location of the proposed MRI directly in the YNHCH.

ii. The population to be served, including specific evidence such as incidence, prevalence, or other demographic data that demonstrates need;

The current and projected pediatric population for the Hospital's historical core service area is shown below, as defined by children age 0-17. Given the Hospital's position as one of only two children's hospitals in the state, patients from well beyond the Hospital's historical core service area seek care at YNHH; therefore, the pediatric population for the rest of the state is shown as well.

	Town	0-17 Population	
		2011	2016
YNHH Historical Core Service Area Towns	New Haven	30,214	29,572
	Ansonia	4,358	4,231
	Derby	2,678	2,569
	Oxford	3,155	3,243
	Seymour	3,471	3,376
	Cheshire	6,634	6,349
	Meriden	14,623	14,403
	Wallingford	10,066	9,803
	Branford	5,657	5,415
	Guilford	5,082	4,936
	Madison	4,959	4,863
	North Branford	1,874	1,829
	Northford	1,543	1,486
	Centerbrook	150	155
	Clinton	3,075	2,971
	Deep River	971	914
	Essex	556	539
	Ivoryton	797	794
	Killingworth	1,720	1,700
	Old Saybrook	2,128	2,055
	Westbrook	1,322	1,302
	Milford	12,044	12,029
	Bethany	1,395	1,374
	East Haven	5,886	5,794
	Hamden	11,628	11,357
	North Haven	5,019	4,931
	Orange	3,022	2,936
	West Haven	11,551	11,264
	Woodbridge	2,240	2,171
	Total	**157,818**	**154,361**
	Total, All Other CT Towns	**668,097**	**648,274**
	Grand Total, CT	**825,915**	**802,635**

Specific utilization rates for the pediatric population cannot be determined as this data is not publicly reported.

iii. How and where the proposed patient population is currently being served;

The proposed patient population is currently being served as inpatients and outpatients at the YNHCH on the main campus.

iv. All existing providers (name, address) of the proposed service in the towns listed above and in nearby towns;

To the best of our knowledge, no facilities in the historical core service area provide pediatric anesthesiology and pediatric MRI services.

v. The effect of the proposal on existing providers; and

Because YNHH is one of only two dedicated children's hospitals in the state, its pediatric MRI services are not replicated at other area hospitals. As a result, there should be no effect on general MRI providers in the service area.

vi. If the proposal involves a new site of service, identify the service area towns and the basis for their selection.

Not applicable. The proposal does not involve a new site of service.

e. Explain why the proposal will not result in an unnecessary duplication of existing or approved health care services.

YNHH is one of only two dedicated children's hospitals in Connecticut that provide pediatric anesthesia and MRI services. The proposal will not result in unnecessary duplication as the Hospital is proposing to dedicate a MRI machine for its pediatric patients. Currently, pediatric patients are served on MRI machines located in different adult areas. The proposal would therefore consolidate these patients onto the dedicated pediatric MRI as well as accommodate the existing pediatric MRI backlog. Additionally, capacity constraints on other MRI scanners on the main campus will be somewhat relieved by shifting the pediatric volume to a dedicated scanner at the YNHCH.

3. Actual and Projected Volume

a. Complete the following tables for the past three fiscal years ("FY"), current fiscal year ("CFY"), and first three projected FYs of the proposal, for each of the Applicant's existing and proposed pieces of equipment (of the type proposed, at the proposed location only). In Table 2a, report the units of service by piece of equipment, and in Table 2b, report the units of service by type of exam (e.g. if specializing in orthopedic, neurosurgery, or if there are scans that can be performed on the proposed scanner that the Applicant is unable to perform on its existing scanners).

Table 2a shows pediatric volume for each of YNHH's MRI units.

Table 2a: Historical, Current, and Projected Volume, by Equipment Unit

Equipment Unit	Actual Volume (Last 4 Completed FYs)				Current FY* (1 Month)	Projected Volume		
	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014[1]	FY 2015	FY 2016
MRI Center 1	543	515	483	389	24	397	401	405
MRI Center 2	426	388	353	426	36	435	439	443
MRI Center 3	594	519	428	399	35	407	411	415
MRI Smilow 1 *(breast MRI, opened 12/2009)*	0	21	37	64	7	65	66	67
MRI Smilow 2	1,247	1,297	1,534	1,618	122	1651	1667	1684
MRI Smilow 3	486	619	557	550	50	561	567	572
MRI Smilow 4 *(opened 12/2009)*	0	601	727	838	68	855	863	872
Temple MRIs	448	377	338	357	34	364	368	371
Proposed Pediatric MRI	0	0	0	0		0	0	0
Total MRI	3,744	4,337	4,457	4,641	376	4,734	4,782	4,829

[1] – Pedi MRI assumed to be operational for full year 2014.

* For periods greater than 6 months, report annualized volume, identifying the number of actual months covered and the method of annualizing. For periods less than six months, report actual volume and identify the period covered.

** If the first year of the proposal is only a partial year, provide the first partial year and then the first three full FYs. Add columns as necessary.

*** Identify each scanner separately and add lines as necessary. Also break out inpatient/outpatient/ED volumes if applicable.

**** Fill in years. In a footnote, identify the period covered by the Applicant's FY (e.g. July 1-June 30, calendar year, etc.). **YNHH Fiscal Year is October 1 through September 30.**

Table 2b shows all pediatric volume by inpatient, outpatient and emergency department.

Type of Scan	Actual Volume (Last 4 Completed FYs)				CFY (1 Month)	Projected Volume		
	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014[1]	FY 2015	FY 2016
Inpatient	760	1,034	939	1,077	97	1,099	1,110	1,121
Outpatient	2,937	3,246	3,388	3,370	263	3,438	3,472	3,507
ED	47	57	130	194	16	198	200	202
Total	3,744	4,337	4,457	4,641	376	4,734	4,782	4,829

Table 2c shows <u>all pediatric volume</u> by type of scan for each of YNHH's MRI units.

Table 2c: Historical, Current, and Projected Volume, by Type of Scan/Exam

Type of Scan	Actual Volume (Last 4 Completed FYs)				CFY (1 Month)	Projected Volume		
	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014[1]	FY 2015	FY 2016
Neurologic	2,795	3,312	3,311	3,445	286	3,514	3,549	3,585
Musculoskeletal	644	609	609	628	51	641	647	653
Body	210	323	424	451	34	460	465	469
Cardiovascular	95	93	113	115	5	117	118	120
Breast				2		2	2	2
Total MRI	3,744	4,337	4,457	4,641	376	4,734	4,782	4,829

* For periods greater than 6 months, report annualized volume, identifying the number of actual months covered and the method of annualizing. For periods less than six months, report actual volume and identify the period covered.
** If the first year of the proposal is only a partial year, provide the first partial year and then the first three full FYs. Add columns as necessary.
*** Identify each type of scan/exam (e.g. orthopedic, neurosurgery or if there are scans/exams that can be performed on the proposed piece of equipment that the Applicant is unable to perform on its existing equipment) and add lines as necessary.
**** Fill in years. In a footnote, identify the period covered by the Applicant's FY (e.g. July 1-June 30, calendar year, etc.). **YNHH Fiscal Year is October 1 through September 30.**

b. Provide a breakdown, by town, of the volumes provided in Table 2a for the most recently completed full FY.

Pediatric MRI volume by town for Fiscal Year 2012 (10 months) is provided in Appendix II.

c. Describe existing referral patterns in the area to be served by the proposal.

As stated elsewhere, there are a limited number of facilities that provide pediatric anesthesiology and MRI services. Therefore, most pediatric MRI cases in the state are referred to YNHH and Connecticut Children's Medical Center in Hartford.

d. Explain how the existing referral patterns will be affected by the proposal.

Current referral patterns of existing providers should not be affected by the proposal.

e. Explain any increases and/or decreases in volume seen in the tables above.

As previously stated, pediatric MRI volume has been growing steadily over the past several years. This is due to several factors including:

- **Shift to MRI from other modalities (improved radiation safety)**
- **Growth of YNHCH services overall**
- **Growth in pediatric Y Access Line transfer cases**

f. Provide a detailed explanation of all assumptions used in the derivation/ calculation of the projected volume by scanner and scan type.

Pediatric MRI volumes are conservatively projected to grow 1.0% each year (FY 2013 – FY 2017). Pediatric MRI scan volume has grown between 3% and 4% annually between FY 2010 and FY 2012. A conservative annual increase of 1% has been included in this CON application.

g. Provide a copy of any articles, studies, or reports that support the need to acquire the proposed scanner, along with a brief explanation regarding the relevance of the selected articles.

Several articles have been included in Appendix III. The articles address the following topics:

- **Choice of MRI for pediatric patients and radiation safety**
- **Pediatric MRI imaging considerations**

4. Quality Measures

a. Submit a list of all key professional, administrative, clinical, and direct service personnel related to the proposal. Attach a copy of their Curriculum Vitae.

Marna P. Borgstrom, CEO
Richard D'Aquila, President and COO
James Staten, Senior Vice President, Finance and CFO
Peter N. Herbert, MD, Chief of Staff
James A. Brink, MD, FACR, Professor and Chairman, Yale University School of Medicine, Department of Diagnostic Radiology
Jeffrey C. Weinreb, MD, Chief of Magnetic Resonance Imaging

A Curriculum Vitae for each person listed above is included in Appendix IV.

b. Explain how the proposal contributes to the quality of health care delivery in the region.

The proposed 3T scanner will provide improved image quality compared to the most of the scanners currently being used. This state-of-the-art scanner offers a number of special features including: the resolution and image contrast on T2 weighted images (used for detecting edema in patients with suspected myocarditis); MRI angiography images (used to evaluate the vasculature before and after surgical repairs); and delayed enhancement images (used to detect irreversible myocardial damage). Pediatric and neonatal cardiac imaging requires increased coordination between radiology and anesthesia. Most exams not only require anesthesia but also repeated periods of apnea and only a subset of our pediatric anesthesiologists are able to provide this service. Additionally, the exams are most optimally performed early in the morning as prolonged periods of NPO can result in mild dehydration which makes it difficult to obtain apnea in these patients due to physiology related

to their underlying heart disease. Because the current scanners facilitate both adult and pediatric patients it is often difficult to secure morning slots. A dedicated pediatric scanner would facilitate this coordination for the reasons previously discussed.

As stated previously, the proposed scanner offers additional safety features such as an undockable table and the short and wide bore will reduce episodes of claustrophobia.

All of these features will add to improved quality images.

5. Organizational and Financial Information

a. Identify the Applicant's ownership type(s) (e.g. Corporation, PC, LLC, etc.).

b. Does the Applicant have non-profit status?
☒ Yes (Provide documentation) ☐ No

c. Provide a copy of the State of Connecticut, Department of Public Health license(s) currently held by the Applicant and indicate any additional licensure categories being sought in relation to the proposal.

A copy of YNHH's DPH license is included in Appendix V.

d. Financial Statements

i. If the Applicant is a Connecticut hospital: Pursuant to Section 19a-644, C.G.S., each hospital licensed by the Department of Public Health is required to file with OHCA copies of the hospital's audited financial statements. If the hospital has filed its most recently completed fiscal year audited financial statements, the hospital may reference that filing for this proposal.

YNHH has filed FY 2011 audited financial statements with OHCA. FY 2012 audited statements are not yet completed but will be filed with OHCA once complete and approved.

ii. If the Applicant is not a Connecticut hospital (other health care facilities): Audited financial statements for the most recently completed fiscal year. If audited financial statements do not exist, in lieu of audited financial statements, provide other financial documentation (e.g. unaudited balance sheet, statement of operations, tax return, or other set of books.)

e. Submit a final version of all capital expenditures/costs as follows:

Table 3: Proposed Capital Expenditures/Costs

Medical Equipment Purchase	$
Imaging Equipment Purchase	2,392,690
Non-Medical Equipment Purchase	
Land/Building Purchase *	
Construction/Renovation **	3,483,138
Other Non-Construction (Specify)	
Total Capital Expenditure (TCE)	**$ 5,875,828**
Medical Equipment Lease (Fair Market Value) ***	$
Imaging Equipment Lease (Fair Market Value) ***	
Non-Medical Equipment Lease (Fair Market Value) ***	
Fair Market Value of Space ***	
Total Capital Cost (TCC)	
Total Project Cost (TCE + TCC)	**$ 5,875,828**
Capitalized Financing Costs (Informational Purpose Only)	
Total Capital Expenditure with Cap. Fin. Costs	$

* If the proposal involves a land/building purchase, attach a real estate property appraisal including the amount; the useful life of the building; and a schedule of depreciation.
** If the proposal involves construction/renovations, attach a description of the proposed building work, including the gross square feet; existing and proposed floor plans; commencement date for the construction/ renovation; completion date of the construction/renovation; and commencement of operations date.
*** If the proposal involves a capital or operating equipment lease and/or purchase, attach a vendor quote or invoice; schedule of depreciation; useful life of the equipment; and anticipated residual value at the end of the lease or loan term.

A vendor quote has been included as Appendix VI.

Building work required to install the proposed MRI pediatric scanner will involve 1,955 square feet and will include the following major activities:

- **Renovation of existing offices and support spaces on West Pavilion 2 to accommodate a new 3T magnet including related equipment & control rooms along with an admin work room, reading room, consult room, prep/recovery, and storage janitor's closet and re-work the pediatric cardiac catheterization lab, and clean utility room.**

- **Construction work will include:**
  - **Demolition of existing offices, storage room, consult room, clean utility, janitor's closet, soiled utility and prep/recovery area. Demolition work includes removal of existing partitions, millwork, floors, ceilings, doors, HVAC, electrical and plumbing systems.**
  - **Construction of a new R/F shielded room for new magnet. Constructing new partitions as required. Installing new millwork, floors, ceilings and doors. Installing new and/or renovate existing HVAC system as required to support the new magnet and renovated spaces. Installing new and/or renovate existing plumbing and fire protection systems to support new magnet and**

renovated spaces. Installing new and/or renovate existing electrical systems to support new magnet and renovated spaces including lighting and power.

Appendix VII includes existing and proposed floor plans.

An estimated construction schedule is included below:

Construction Activity	Target Date(s)
Construction Planning	March 2013
Construct Space	March – Sept 2013
Equipment delivery and installation	Sept. 2013
Initiate Pediatric MRI	October 1, 2013

f. List all funding or financing sources for the proposal and the dollar amount of each. Provide applicable details such as interest rate; term; monthly payment; pledges and funds received to date; letter of interest or approval from a lending institution.

Funding sources will be 20% from operating funds and 80% funded depreciation by YNHH.

g. Demonstrate how this proposal will affect the financial strength of the state's health care system.

The current practice of transporting pediatric patients outside the YNHCH into an adult oriented MRI facility has led to inefficiencies in workflow, reduced productivity of staff, and increased stress and anxiety for patients and families. All of these factors can negatively impact the operation of this service. Overall improvements to patient throughput and staff productivity improve the financial strength of the institution which positively impacts the financial strength of the state's health care system.

6. Patient Population Mix: Current and Projected

a. Provide the current and projected patient population mix (based on the number of patients, not based on revenue) with the CON proposal for the proposed program.

Table 4: Patient Population Mix

	Current** FY 2013	Year 1 FY 2014	Year 2 FY 2015	Year 3 FY 2016
Medicare*	0%	0%	0%	0%
Medicaid*	35%	35%	35%	35%
CHAMPUS & TriCare	1%	1%	1%	1%

	Current** FY 2013	Year 1 FY 2014	Year 2 FY 2015	Year 3 FY 2016
Total Government	**36%**	**36%**	**36%**	**36%**
Commercial Insurers*	61%	61%	61%	61%
Uninsured	2%	2%	2%	2%
Workers Compensation	0%	0%	0%	0%
Total Non-Government	**64%**	**64%**	**64%**	**64%**
Total Payer Mix	100%	100%	100%	100%

* Includes managed care activity.
** New programs may leave the "current" column blank.
*** Fill in years. Ensure the period covered by this table corresponds to the period covered in the projections provided.

b. Provide the basis for/assumptions used to project the patient population mix.

Patient population mix is not expected to change. The proposed MRI scanner will serve the existing patient population.

7. **Financial Attachments I & II**

a. Provide a summary of revenue, expense, and volume statistics, without the CON project, incremental to the CON project, and with the CON project. **Complete Financial Attachment I.** (Note that the actual results for the fiscal year reported in the first column must agree with the Applicant's audited financial statements.) The projections must include the first three full fiscal years of the project.

Please see Appendix VIII for Financial Attachment I.

b. Provide a three year projection of incremental revenue, expense, and volume statistics attributable to the proposal by payer. **Complete Financial Attachment II.** The projections must include the first three full fiscal years of the project.

Please see Appendix IX for Financial Attachment II.

c. Provide the assumptions utilized in developing **both Financial Attachments I and II** (e.g., full-time equivalents, volume statistics, other expenses, revenue and expense % increases, project commencement of operation date, etc.).

Please see Appendix X for assumptions utilized in Financial Attachments I and II.

d. Provide documentation or the basis to support the proposed rates for each of the FYs as reported in Financial Attachment II. Provide a copy of the rate schedule for the proposed service(s).

The Hospital files its Chargemaster with OHCA on an annual basis. All rates for MRI scans are included in the Chargemaster on file.

e. Provide the minimum number of units required to show an incremental gain from operations for each fiscal year.

The minimum number of MRI cases required to show an incremental gain from operations for each fiscal year is provided below.

Minimum Number of Units required			
	2014	2015	2016
Expenses from operations	$1,627,123	$2,020,902	$2,060,199
Cases Needed to show incremental gain from operations	803	969	959
Average Revenue per case by year	$2,025	$2,086	$2,149
Volume	1,805	1,823	1,841
Revenue	$ 3,655,208	$ 3,802,512	$ 3,955,753

f. Explain any projected incremental losses from operations contained in the financial projections that result from the implementation and operation of the CON proposal.

Not applicable. There are no projected incremental losses from operations.

g. Describe how this proposal is cost effective.

The proposal will contribute to operational efficiencies and cost effectiveness given better management of resources including pediatric radiologists, pediatric anesthesiologists and pediatric APRNs qualified to provide pediatric sedation. Pediatric dedicated staff will no longer have to travel to areas outside the YNHCH which will improve their productivity. The pediatric oriented MRI, scan room, and support spaces will facilitate the administration of sedation or anesthesia, reduce patient anxiety and improve the throughput of pediatric MRI patients.

APPENDIX I

MD LETTERS OF SUPPORT

Yale Neurosurgery

A PRACTICE OF THE YALE MEDICAL GROUP

Yale School of Medicine
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November 1, 2012

Epilepsy
Dennis Spencer MD
Kenneth Vives MD
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Neurovascular
Ketan Bulsara MD
Murat Gunel MD
Charles Matouk MD
(203) 737-2096

Oncology
Joseph Piepmeier MD
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Pediatric
Charles Duncan MD
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Katie Hagenow APRN
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Spine
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Kenneth Vives MD
Maxwell Laurans MD
(203) 785-2807

Stereotactic Radiosurgery
Veronica Chiang MD
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Functional
Kenneth Vives MD
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Lisa Davis, MBA, BSN, RN
Deputy Commissioner
Office of Health Care Access
Department of Public Health
410 Capitol Avenue, MS#13HCA
PO Box 340308
Hartford, CT 06134

Dear Deputy Commissioner Davis:

I write to you to state the critical importance and need for a dedicated pediatric MRI unit in the Children's Hospital at Yale New Haven. I have been the Chief of Pediatric Neurosurgery at this institution for over 30 years, and the Director for the Neurosurgery Residency Program for over 12 years. I order several hundred computerized imaging studies each year at this institution for children. In addition to the clinical service at the Children's Hospital, I also investigate the adaptations of developing brain to injury.

I was part of the faculty at Yale when the first magnetic resonance imaging device was delivered in the 1980s. I saw the first CT scanners arrive in the late 1970s, as a resident at Duke. These devices have greatly expanded the ability we all have to care for those with neurologic and other illnesses and to decrease the burden of these illnesses. While the CT scan is a critical part of our armamentarium in treating many disorders, including those of the brain, it has significant risk in terms of ionizing radiation to developing brain. For over a decade we have sought to minimize this exposure. We began with developing, along with others, means for carrying out very rapid MRIs in small children. These are fast spin T2 imaging techniques and we term them "quick brain MRIs". We are able to carry out these studies in almost all children without the need for sedation and avoid most CT scans that would otherwise be essential for following trauma, hydrocephalus, tumors, and congenital malformations.

Additionally, over the past three to four years as some new technologies have developed with MRIs, we are now able to similarly evaluate the spine. So called STIR images have become the "gold standard" for detecting trauma in the spine. As a consequence, we were able to entirely eliminate or drastically reduce ionized radiation to children who have sustained trauma. We now, in fact, extend this to total spine MRIs for children where there is a concern for non-accident trauma or whether the injury leads us to be suspicious of injury other than to the neck.

This great emphasis on the utilization of MRI in children places a great stress on the resources available at the diagnostic imaging facilities at this hospital and has not provided for dedicated pediatric service. In order to avoid delays in needed imaging in order to maximize MRIs in the imaging of children and thereby minimize CT scans, I respectfully request the approval of the Certificate of Need for a dedicated MRI for the Pediatric Clinical Services at the Children's Hospital at Yale-New Haven. This will greatly enhance the safety for children in our state and decrease the burden of illness they experience.

Sincerely yours,

Charles C. Duncan, M.D.
Professor of Neurosurgery and Pediatrics
Director, Residency Program

Yale SCHOOL OF MEDICINE
Department of Pediatrics

CLIFFORD W. BOGUE, MD
Associate Professor of Pediatrics
Interim Chair, Department of Pediatrics
Physician-in-Chief, Yale-New Haven Children's Hospital

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courier
Laboratory for Medicine and Pediatrics
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June 22, 2011

Norma Gyle, Deputy Commissioner
Office of Healthcare Access
410 Capital Avenue, MS #13HCA
P.O. Box 340308
Hartford, CT 06106

Dear Ms. Gyle:

I write to you on behalf of Yale-New Haven Children's Hospital and the Department of Pediatrics at the Yale School of Medicine. The demand for magnetic resonance imaging for our pediatric patients is increasing, due in large part to radiation concerns from other imaging modalities. YNHCH has reached the point where it can utilize one scanner dedicated to imaging children, to be located specifically within the Children's Hospital.

Currently our pediatric patients who need magnetic resonance imaging to promptly diagnose and treat their conditions receive imaging services in adult-oriented MRI locations. Most YNHH MR scanners are centrally located in Smilow Cancer Hospital. While the facility is beautiful and the staff is wonderful, Smilow Cancer Hospital caters to a specific population – adults with cancer. This can cause anxiety for our pediatric patients. For example, while enroute to Smilow, children may encounter head and neck cancer patients in head molds who are waiting for their radiology treatments and other sick adults with various stages of cancer. An MR scanner dedicated to children will allow us to provide an improved standard of care for our pediatric patients and further support our commitment to creating a patient- and family-centered care environment in the Children's Hospital. A pediatric scanner in YNHCH will provide a pediatric-focused environment - from the patient population, to the surrounding décor and atmosphere, to the highly skilled pediatric anesthesiologists needed for sedation.

I ask for your support of this important Certificate of Need application.

Thank you,

CWBogue

Clifford W. Bogue, M.D.
Physician-in-Chief, Yale-New Haven Children's Hospital
Interim Chair, Department of Pediatrics, Yale School of Medicine

Yale University

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August 15, 2012

Lisa Davis, MBA, BSN, RN
Deputy Commissioner
Office of Health Care Access
Department of Public Health
410 Capitol Avenue, MS#13HCA
P.O. Box 340308
Hartford, CT 06134

Dear Deputy Commissioner Davis:

Please accept this letter as a sign of my most enthusiastic support for the request to acquire an MRI dedicated to pediatric clinical services. There are a number of compelling reasons for such an essential service in a Children's Hospital.

1. There has been and will likely continue to be an increase in the utilization of MRI as a preferred imaging technique in contrast to CT scanning for sophisticated studies, especially those related to neurological/neurosurgical, oncologic and cardiovascular disease. This relates to the benefit of having no radiation exposure, which is especially important for children in general, and particularly those with chronic illnesses, as well as the capacity for subsequent reconstruction of image. Indeed, there has been a 25% increase in demand for MRI procedures in the past 2 years.
2. The dedicated magnet will contribute to marked efficiency because of the supporting professional staff, including anesthesiologists, nurse sedation specialists, child life and MRI technologists who are critical to having safe and maximally useful procedures. The use of the dedicated magnet will also reduce risks to the young and more fragile or unstable infants and children because they will not be rescheduled based on other demands after they have been kept NPO, or sedated or transported to the facility from an intensive care unit. In short, these infants will not be subject to the vicissitudes of a busy adult service that is competing for resources.
3. Finally, this will also permit the creation of an environment that is both friendly to children and families, and be readily equipped for their needs so that there is minimal time expended to adapt the ambiance when multiple patients are using the facility.

In sum, I believe that any first-rate Children's Hospital with the patient volume and degree of tertiary and quaternary care requires a dedicate MRI facility for infants and children. If there is any additional information I can provide, please let me know. Please also accept my gratitude for your efforts to develop this.

Yours sincerely,

George Lister, M.D.
Chair, Department of Pediatrics

Yale SCHOOL OF MEDICINE
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Lisa Davis, MBA, BSN, RN
Deputy Commissioner,
Office of Healthcare Access Department of Public Health
410 Capitol Avenue, MS#13HCA
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Hartford, CT 06134

November 20, 2012

Dear Ms. Davis,

I am thrilled to have the opportunity to articulate the need for a designated pediatric magnetic resonance imaging (MRI) scanner for the Yale-New Haven Children's Hospital. As the medical director and section chief of Pediatric Emergency Medicine I know first-hand that the need is great. We have recently recognized a 400% increase in the need for this technology and level of service. As a tertiary care children's hospital and level I trauma center, I honestly can't imagine how we could possibly fulfill the needs of our patients without an MRI in close proximity to the Pediatric ED.

We are seeing increasing numbers of children being referred in for specialized imaging. We have young children who are particularly susceptible to the ill effects of radiation who present unexpectedly as the victims of non-accidental as well as accidental injury who require emergency imaging of their central nervous system (brain as well as spine).

We also have a cadre of patients with chronic illnesses who require active surveillance of their medical and/or surgical condition through imaging and need to be able to offer them an MRI in a timely fashion.

It would be ideal to have a magnet on the ground floor adjacent to the children's ED but we understand that that is not possible. Having a scanner on the second floor of the children's hospital would allow us to obtain necessary and at times life-saving imaging in an expedited and safe fashion.

Respectfully Submitted,

Karen Santucci

Karen Santucci, MD
Associate Professor of Pediatrics
Medical Director and Section Chief,
Pediatric Emergency Medicine

Yale SCHOOL OF MEDICINE

YALE-NEW HAVEN CHILDREN'S HOSPITAL

MICHAEL G. CATY, MD, MMM, FACS
Robert Pritzker Professor and Chief
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November 19, 2012

Lisa Davis, MBA, BSN, RN
Deputy Commissioner, Office of Healthcare Access
Department of Public Health
410 Capitol Avenue, MS#13HCA
P.O. Box 340308
Hartford, CT 06134

Dear Deputy Commissioner Davis:

I am writing to indicate my strong support for the request of the Yale-New Haven Hospital to acquire a MRI machine to support the clinical mission of the Children's Hospital at Yale-New Haven Hospital.

The acquisition of a dedicated MRI is essential to the functioning of our Children's hospital for many compelling reasons.

As the medical community and lay public are increasingly aware of the long term effects of ionizing radiation, we and other institutions see an increasing need to provide highly accurate diagnostic studies that reduce, or in the case of MRI, eliminate ionizing radiation.

As a Level 1 trauma center for children, we see an ever-expanding need for the use of MRI to evaluate head trauma and spinal trauma. The clinical entity of SCIWORA (spinal cord injury without radiologic abnormality) defines a unique occurrence in children whereby plain x-rays show no injury, but the spinal cord is injured. MRI is the best imaging modality to rule out this injury that may result in paralysis if improperly diagnosed. In addition, MRI offers dramatically improved visualization of brain tissue, essential to the initial diagnosis and follow-up of traumatic brain injury.

Acquisition of a dedicated MRI machine will allow it to be co-located with the appropriate support services in the Children's hospital. Proximity to the operating room will increase the safety of patients who require pediatric anesthesia or sedation during their MRI exam. Access to appropriate support services such as MRI technologists and Child Life support used to the care of children will create a child-friendly environment. In many instances, sedation can be avoided with appropriate Family Centered care and patients who may have required anesthesia may only require sedation. The potential immediate and long-term hazards of anesthesia can thus be mollified or eliminated.

I would strongly urge your support of the acquisition of a dedicated MRI machine to be located in the Yale-New Haven Children's Hospital. The complexity of our patients and the increasing demand for highly accurate diagnostic studies that do not involve ionizing radiation demonstrates the acute need for this acquisition in our highly specialized environment for children

Sincerely yours,

Michael G. Caty, M.D., M.M.M.
Robert Pritzker Professor of Pediatric Surgery, and Chief
Section of Pediatric Surgery
Yale University School of Medicine
Chief of Pediatric Trauma
Yale-New Haven Hospital
Surgeon-in-Chief,
Yale-New Haven Children's Hospital

APPENDIX II

PEDIATRIC MRI TOWN OF ORIGIN (FY 12)

YNHH Main Campus

Pedi Volume, by Town

FY 2012 10 months

Town	10 Months Pedi FY 2012
Grand Total	**3,555**
NEW HAVEN	414
BRIDGEPORT	275
WEST HAVEN	182
HAMDEN	157
MILFORD	136
STAMFORD	109
NORWALK	106
WATERBURY	92
EAST HAVEN	91
NORTH HAVEN	84
WALLINGFORD	84
FAIRFIELD	71
STRATFORD	68
MADISON	67
TRUMBULL	64
DANBURY	57
GUILFORD	56
BRANFORD	56
ORANGE	53
MERIDEN	48
SHELTON	40
GROTON	39
CHESHIRE	39
MONROE	38
SEYMOUR	34
DERBY	32
WESTPORT	32
ANSONIA	31
NEW LONDON	30
RIDGEFIELD	27
BETHEL	24
DARIEN	23
OXFORD	23
NORTHFORD	23
WOLCOTT	22
BROOKFIELD	22
NAUGATUCK	21
GALES FERRY	19
MIDDLETOWN	19

Town	Pedi FY 2012
OLD SAYBROOK	19
WILTON	19
DURHAM	18
CLINTON	18
WOODBRIDGE	17
SANDY HOOK	17
KILLINGWORTH	16
WATERFORD	16
WOODBURY	16
WESTON	15
NORWICH	15
NEW MILFORD	15
SOUTHINGTON	14
BETHANY	14
COLCHESTER	13
NEW FAIRFIELD	13
NEWTOWN	13
MYSTIC	13
OLD LYME	12
NEW CANAAN	12
ELLINGTON	11
STONINGTON	11
WATERTOWN	10
UNCASVILLE	9
BEACON FALLS	9
EASTON	9
ENFIELD	8
GREENWICH	8
REDDING	7
HIGGANUM	7
WEST BABYLON	7
WESTBROOK	7
JEWETT CITY	7
W HARTFORD	7
ELIZABETHTOWN	7
MANCHESTER	7
TAFTVILLE	7
SOUTHBURY	7
NORTH BRANFOR	7
PROSPECT	7
FARMINGTON	6
BRIDGEWATER	6
GLASTONBURY	6
THOMASTON	6
DEEP RIVER	6
OAKDALE	6

Town	Pedi FY 2012
CANTERBURY	6
COVENTRY	6
NORTH BRANFORD	6
BOZRAH	5
AVON	5
TORRINGTON	5
MARLBOROUGH	5
LEBANON	5
BROOKLYN	5
PLANTSVILLE	5
HARTFORD	4
BOLTON	4
IVORYTON	4
PAWCATUCK	4
VERNON ROCKVILLE	4
CROMWELL	4
BERLIN	4
WARWICK	4
EAST HAMPTON	3
PLAINFIELD	3
ANDOVER	3
NO BRANFORD	3
BOONTON	3
MILLBURN	3
VOLUNTOWN	3
EL PASO	3
NEW HARTFORD	3
PORT CHESTER	3
PLAINVILLE	3
NIANTIC	3
OAKVILLE	3
CORNWALL ON HUDSON	3
STAFFORD	3
WESTERLY	3
WALDEN	3
MIDDLE HADDAM	2
NEWINGTON	2
NEW CANNAN	2
SOUTH WINDSOR	2
COLBROOK	2
RIVERSIDE	2
LISBON	2
KENSINGTON	2
WEST SIMSBURY	2
SOUTH SALEM	2
PARAMUS	2

Town	Pedi FY 2012
LITCHFIELD	2
CHESTER	2
VERNON	2
MIDDLEBURY	2
WETHERSFIELD	2
TERRYVILLE	2
ROXBURY	2
EAST HADDAM	2
BRISTOL	2
RYE	2
NEW YORK	2
LYME	2
WILLINGTON	2
WINDSOR	2
LEDYARD	2
NO BRUNSWICK	2
WEST HARTFORD	2
ARDSLEY	2
WILLIMANTIC	2
WOOD RIVER JUNCTION	1
EAST HARTFORD	1
NORTH FRANKLI	1
ROUND ROCK	1
OLD GREENWICH	1
SHERMAN	1
CLINTONDALE	1
NOANK	1
SOMES	1
POUND RIDGE	1
CANTON	1
SOMERS	1
SOUTHPORT	1
GRANBY	1
WEST CORNWALL	1
SCOTLAND	1
MARRIOTTSVILLE	1
DAYVILLE	1
PEARL RIVER	1
BALTIC	1
BARRINGTON	1
QUAKER HILL	1
YAUCO	1
NEW BRITAIN	1
HOPEWELL JUNC	1
EAST LYME	1
GUAYNABO	1

Town	Pedi FY 2012
HADDAM	1
NORTH STONING	1
PORTLAND	1
STATEN ISLAND	1
PROVIDENCE	1
ST. LAZARE	1
UNCASVILE	1
BETHLEHEM	1
SCARSDALE	1
HEBRON	1
ESSEX	1
GOSHEN	1
CANAAN	1
PRESTON	1
LAKE FOREST	1
CANUY	1
SHREWSBURY	1
SALEM	1
BELLPORT	1
WINTERVILLE	1
NEW WINDSOR	1
BANGUOU	1
VASHON	1
LEMOYNE	1

APPENDIX III

ARTICLES

Pediatric imaging: Current and emerging techniques

Shenoy-Bhangle A, Nimkin K, Gee MS

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PubMed ID : ****
DOI: 10.4103/0022-3859.65273
J Postgrad Med 2010;56:98-102

ABSTRACT

Imaging has always been an important component of the clinical evaluation of pediatric patients. Rapid technological advances in imaging are making noninvasive evaluation of a wide range of pediatric diseases possible. Ultrasound and magnetic resonance imaging (MRI) are two imaging modalities that do not involve ionizing radiation and are preferred imaging modalities in the pediatric population. Computed tomography (CT) remains the imaging modality with the highest increase in utilization in children due to its widespread availability and rapid image acquisition. Emerging imaging applications to be discussed include MR urography, voiding urosonography with use of ultrasound contrast agents, CT dose reduction techniques, MR enterography for inflammatory bowel disease, and MR cine airway imaging.

KEY WORDS: Computed tomography, magnetic resonance imaging, pediatric radiology, ultrasound

With the development and widespread availability of advanced imaging techniques, imaging has become an increasingly important component of the clinical evaluation of pediatric patients. Among imaging modalities, computed tomography (CT) has undergone some of the most explosive growth. This has been attributed to increasing availability of multi-detector CT scanners in medical centers and the ability of multidetector CT to provide rapid, high-quality image acquisition. It is estimated that 100 million CT examinations are performed annually in the world, with over 10% of examinations performed on patients under 18 years of age (reviewed in[1]). The radiation risk for patients associated with diagnostic examinations has recently become an active area of investigation. A recent study examining the cancer risk of low-dose radiation exposure concluded that there is a non-zero risk of malignancy with radiation exposures as low as 50-100 mSv, levels that are likely to be reached in medical patients undergoing serial CT examinations over the course of their lifetimes.[2] Children in particular are known to be more sensitive to the effects of radiation than adults,[3] such that the lifetime cancer mortality risk is significantly higher for children than adults for a given radiation dose. Factors underlying this difference include longer incubation times to develop cancer, altered patient body habitus, and increased number of dividing cells. One study using linear extrapolation models to determine cancer mortality risk from pediatric CT scans estimated that the lifetime cancer risk from a single abdominal CT in a one-year-old child is 1 in 550, and that 500 children under 15 years old in the United States will die of a cancer attributable to the radiation from an abdominal or head CT exam.[4]

Because of the concern regarding radiation risks associated with CT, attention has been focused on utilizing alternate imaging modalities without ionizing radiation exposure. In this regard, ultrasound and magnetic resonance imaging (MRI) both are commonly used in clinical practice to diagnose disease in pediatric patients. Both imaging modalities, in addition to their avoidance of ionizing radiation exposure, have superior soft tissue contrast to CT. Advantages of ultrasound include ease of performance, ability to image dynamic processes in real-time, and the lack of need for patient sedation. However, because of the limited depth of penetration and field of view, ultrasound is not an ideal screening modality and is more suited for targeted evaluation of a particular body region. MRI, like CT, is better suited as a screening tool because of its ability to provide high-resolution images of the body in three dimensions. Although MRI has historically been underutilized in children because of long scan times and motion artifacts frequently necessitating patient sedation, recent technical advances have made rapid, motion-free image acquisition possible.[5] Finally, technical innovations in scanning hardware as well as software reconstruction algorithms have led to a significant reduction in radiation dose associated with CT scanning, making CT a more attractive imaging option for children. The emerging applications in pediatric imaging discussed in this article stem from these technical innovations, as well as the general desire to diagnose pediatric diseases in a noninvasive manner.

Emerging Applications

MR urography

MR urography is an evolving technique aimed at avoiding radiation in the pediatric population besides being noninvasive while optimizing imaging of the genitourinary tract. Some indications for this study include evaluation of congenital anatomic abnormalities, vesicoureteric reflux and obstructive uropathy with the ability to provide predictive information about which children will benefit from surgery. Technical innovations including diaphragmatic tracking, parallel or propeller imaging, faster gradients, higher field strength along with the ability to do dynamic imaging to study split renal function, glomerular filtration rate or urinary drainage improve applicability in infants and children.[6] Two types of techniques are commonly employed: 1) Static fluid or T2-weighted imaging and 2) Excretory urography or T1-weighted post-contrast imaging [Figure 1]. Static-fluid MR urography can be used to assess nonfunctioning systems and to document the course and insertion of ureters in an obstructed system. Excretory urography using saline and furosemide in conjunction with intravenous contrast administration enables evaluation of dynamic obstructions such as obstruction by a crossing vessel in the setting of uretero-pelvic junction obstruction. It also enables plotting of time-signal intensity curves to assess renal function in the setting of obstruction as well as to assess vesico-ureteric reflux.[7-8] Advantages of MR urography include avoidance of ionizing radiation and contrast media while the pitfalls include case-specific use of sedation, technical demands to produce high-quality images and artifacts that can complicate interpretation.[9]

Voiding urosonography

Vesicoureteral reflux (VUR) is a common pediatric problem. Due to the possibility of renal damage due to VUR and consequently renal function impairment and hypertension various diagnostic studies are in place to rule out this problem. Three different diagnostic modalities are currently employed in the imaging of VUR. The two radiological modalities, voiding cystourethrography (VCUG) and radionuclide cystography (RNC) have been in use for several decades. Since the mid-1990s, voiding urosonography (VUS) has been gradually emerging as a further diagnostic option for reflux. VCUG and RNC are indicated primarily in the following cases: (1) first examination for VUR in boys, (2) specific request for urethral and/or bladder imaging, (3) inadequate visualization of the bladder or one of the kidneys on US. A recent study by Papadopoulou and colleagues[10] demonstrates a radiation-free method of diagnosis and follow-up of VUR in children, using VUS with harmonic imaging (VUS-HI) in conjunction with a sonographic contrast agent. VUS-HI was performed after intravesical administration of 1 ml of a sonographic contrast agent (sulphur-hexafluoride gas microbubbles, SonoVue, Bracco, Italy). They concluded that this method had a higher sensitivity compared to VCUG, so it could be used as an alternative radiation-free imaging technique to elicit VUR. Indications for using VUS as a primary imaging modality compared to VCUG include females having a reflux examination for the first time, follow-up VUR, and screening high-risk populations.[11]

CT dose modulation

Multiple strategies have been employed to reduce radiation exposure associated with CT.[12] One approach is automatic tube current modulation, in which the X-ray beam intensity (measured as CT tube-current product) varies as a function of the particular body region being imaged. For example, in the thorax, the lung parenchyma does not attenuate X-ray photons effectively relative to solid abdominal organs. Thus, a chest CT does not require as high a tube-current product as an abdominal CT in order to obtain comparable image quality. The X-ray beam intensity can be modulated individually for each patient based on their cross-sectional anatomy in three dimensions, with angular beam modulation in the XY plane as the tube rotates about the patient and longitudinal modulation in the Z plane as the patient passes through the CT gantry.[13] Another method to reduce radiation dose is modification of CT imaging technique based on patient weight. This technique is based on the premise that multiple CT imaging parameters (tube current, voltage, pitch) can be adjusted based on the weight and cross-sectional diameter of the patient without significantly affecting image

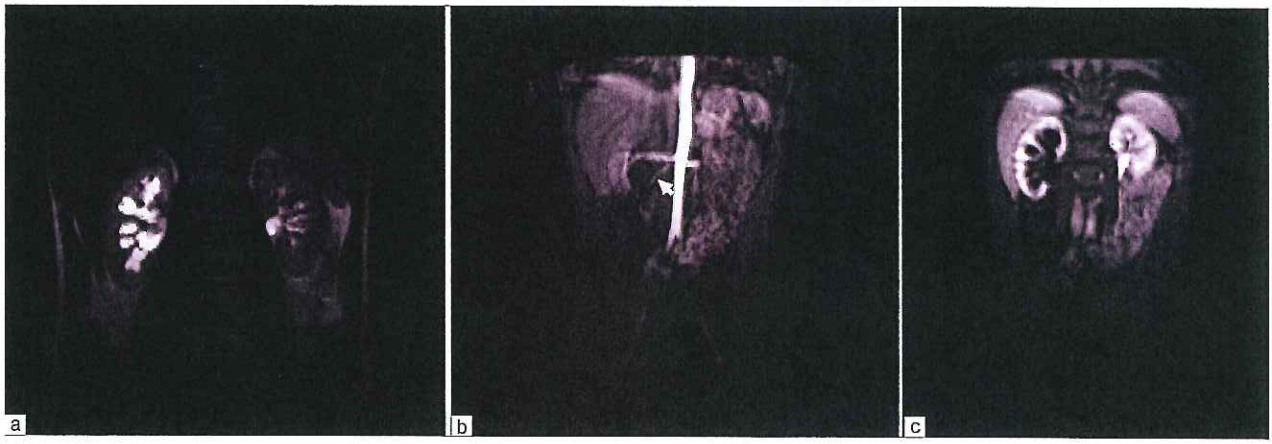


Figure 1: MR urography. Coronal T2-weighted (a) and T1 fat-suppressed post-gadolinium images obtained during angiographic (b) and excretory (c) phases demonstrate an accessory right renal artery (b, arrow) causing right ureteropelvic junction obstruction characterized by hydronephrosis (a) and delayed urinary contrast excretion (c).

quality (reviewed in[1]). Many institutions (including ours) have adopted the use of color-coded CT technique charts for pediatric patients based on weight and study indication, leading to decreased and less variable CT dose exposure compared with standard protocols [Figure 2].[14,15]

One clinical area where CT dose reduction has been implemented is during serial imaging of children with ventriculoperitoneal shunts to assess shunt patency. In a study conducted by Udayasankar and colleagues it was demonstrated that a low-dose (80mAs versus 120mAs) head CT protocol for pediatric patients undergoing follow-up scans of a shunt for hydrocephalus resulted in diagnostically acceptable images with reduction in radiation dose of approximately 63%.[16] Although image quality ratings of a low-dose study were lower than those of standard-dose scans, the quality of images was adequate for the assessment of ventricular volume and shunt patency.

MR enterography for Crohn's disease

Crohn's disease (CD) is a form of inflammatory bowel disease with a bimodal demographic distribution with an initial peak incidence occurring in patients 15-30 years old and a later peak in the fifth to sixth decade of life,[17] leading to a significant incidence and prevalence within the pediatric population. CD is characterized by a chronic relapsing disease, with patients often experiencing episodic symptom recurrence over their lifetime. Imaging plays an important role in the evaluation of symptomatic CD patients, including initial primary diagnosis (including presence, severity, and extent of disease), as well as determination of disease activity, therapy response, and extraintestinal complications in patients with known disease.[18,19] Over the last decade CT has become the primary imaging modality for evaluating gastrointestinal tract pathology due to its widespread availability, fast scanning time, and ability to produce high-resolution three-dimensional images.[20] Currently, routine CT evaluation of CD includes assessment of bowel wall thickening, perienteric and pericolonic mesenteric inflammation; lymph node size and number; extraluminal collections (fistulae, abscesses, sinuses); and extraintestinal complications.[21] Although CT has proved to be an effective imaging modality for CD, one significant limitation is the ionizing radiation exposure. Recent data suggest a nonzero radiation-induced cancer risk at exposure levels as low as 50 mSv, a cumulative dose which is often exceeded in patients diagnosed with CD during childhood (Pierce DA, Radiation Res 2000)[22]).

The recent development of MRI pulse sequences that provide motion-free, high-resolution images with T1 or T2 contrast has made MR imaging of intestinal pathology possible.[23] MRI is already in routine clinical use for detecting perianal and perirectal fistulae in IBD patients, which are very difficult to detect by CT.[24,25] MR enterography (MR-E) is a specific MRI technique for imaging the bowel that combines large volume oral contrast distention of the bowel with intravenous gadolinium administration to increase sensitivity for detecting bowel wall abnormalities.[26] One study comparing MR enterography with fluoroscopic barium small bowel series in adult CD patients demonstrated MRI to be comparable for detection of abnormal bowel but superior for detection of extraintestinal disease.[27] Another study comparing contrast-enhanced MRI and CT in adult CD patients demonstrated MRI to be superior for detection of mild, but not severe, bowel inflammatory changes.[28] At our institution we are currently comparing MR enterography and CT enterography for evaluation of pediatric CD severity and activity [Figure 3].

MRI cine airway imaging

The cine MRI technique involves rapid imaging of a single slab of tissue to observe structural changes over time. This technique is routinely used in cardiac imaging to detect structural as well as wall motion abnormalities. More recently, cine MRI has been applied to imaging of the airway. One condition affecting the airway in children that is well-evaluated by cine MRI is obstructive sleep apnea (OSA), in which the upper airway becomes intermittently narrowed or occluded during sleep causing pauses in breathing and sleep disturbance. Indications for cine

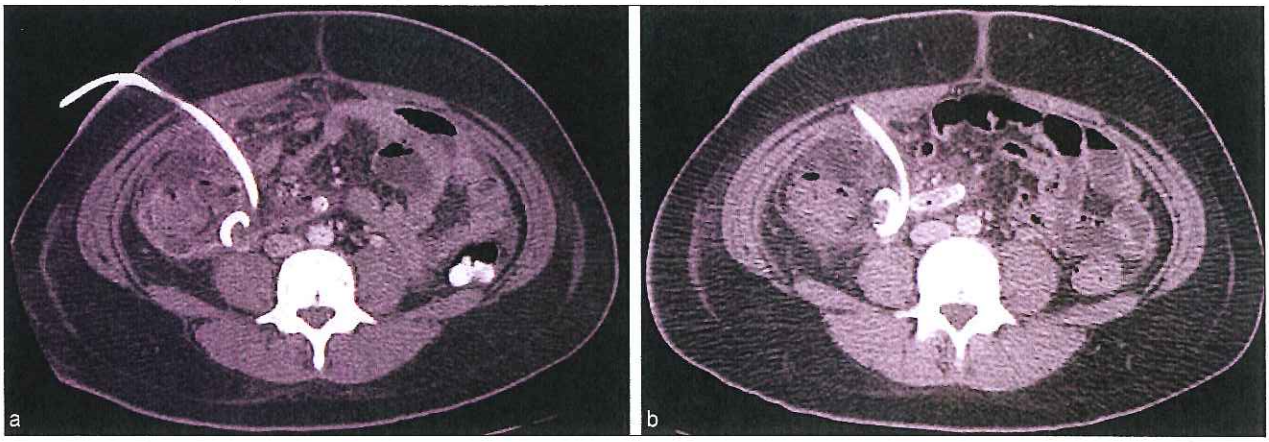


Figure 2: CT dose modulation. Comparable images from serial abdominal CT examinations performed on the same-patient, using standard-technique (a) and weight-based technique with automatic dose modulation (b). The latter is associated with 56% reduction in CT dose to the patient. Images courtesy of Sjirk Westra, MD

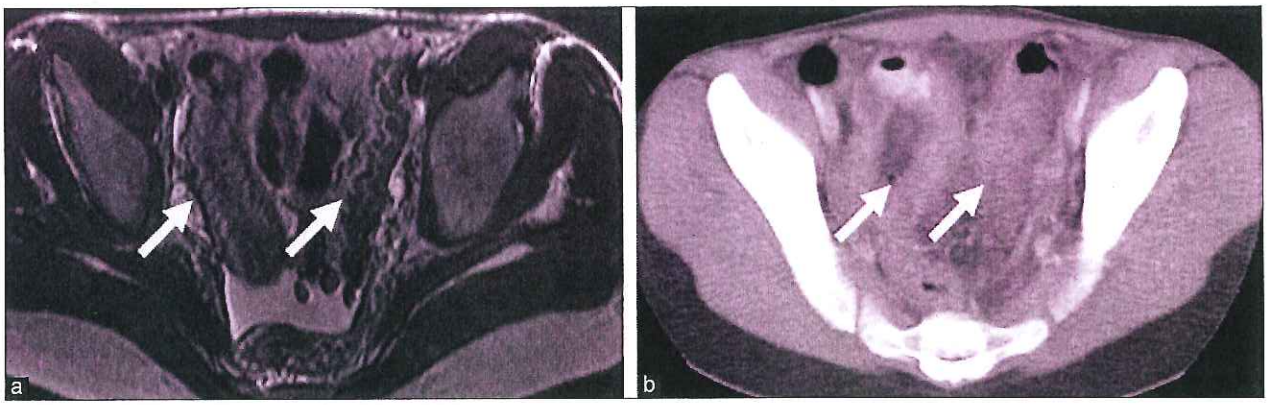


Figure 3: MR enterographic evaluation of Crohn's disease imaging features. Serial MR enterography (a) and contrast enhanced CT (b) exams in a patient with known Crohn's disease both demonstrate prominent wall thickening (arrows) involving the distal ileum and sigmoid colon consistent with acute inflammation

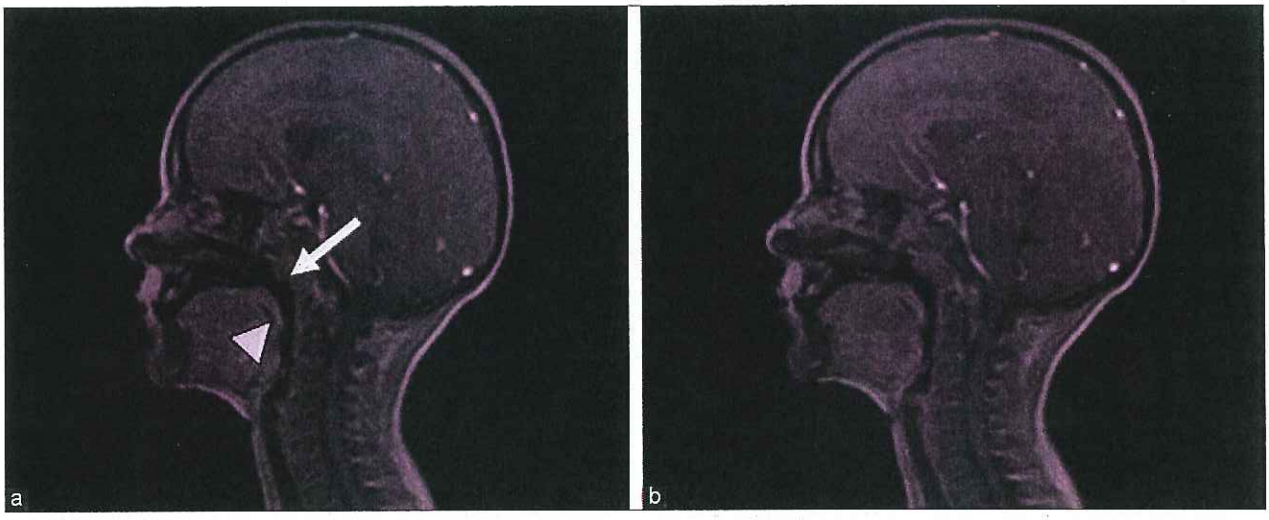


Figure 4: Cine MRI airway fluoroscopy. Serial static images from a cine sequence obtained during inspiration (a) and expiration (b) demonstrate normal caliber airway in this patient without obstructive sleep apnea. Anatomic landmarks to be evaluated include the uvula (arrowhead) and adenoids (arrow)

MRI in OSA patients include pre-surgical planning, persistent OSA despite surgery, and OSA associated with obesity.[29] Another condition that can be evaluated by cine airway MRI is velopharyngeal insufficiency (VPI), in which structural or functional abnormalities of the soft palate and pharyngeal walls inhibit normal velopharyngeal sphincter function and lead to speech disorders.[30] Cine MRI is indicated in children with speech disorders in which VPI is suspected, both to confirm the diagnosis as well as to detect anatomic abnormalities that would be amenable to surgical repair rather than speech therapy.

For cine airway MRI, a 10-15-mm image slab is selected in the sagittal midline or transverse plane, and images are acquired at a rate of 1/sec for 30-60 sec. The images are then displayed in cine format for dynamic evaluation of the oral and nasal airways, and the hypopharynx. OSA patients are imaged during conscious sedation, while VPI patients are imaged awake, at rest and during phonation. In OSA patients, dynamic imaging is used to detect narrowing or collapse of the nasopharynx or hypopharynx during respiration [Figure 4]. Additionally, the adjacent anatomic structures are evaluated to detect features predisposing to airway collapse such as tonsillar/adenoid hypertrophy, glossoptosis, and elongated soft palate/uvula. In VPI patients, dynamic imaging is used to assess the degree of motion of the pharyngeal walls and soft palate, and to evaluate VP sphincter closure. The palate is also specifically evaluated to assess for a small submucosal cleft palate that could produce VPI.

Conclusion

In summary, increasing concern about the effects of ionizing radiation on children has prompted evaluation of alternative imaging modalities to CT for pediatric imaging such as ultrasound and MRI, which have superior soft tissue contrast to CT and can assess both anatomy and function, and are increasingly being utilized to evaluate common pediatric disorders. MR urography is an emerging application in the direction of avoiding radiation while optimizing various pediatric conditions affecting

the genitourinary tract. Voiding urosonography obviates use of radiation and thus can be used in optimizing follow-up workup of reflux studies. Use of ultrasound contrast media for the same increases the sensitivity and specificity of this study. A variety of hardware and software technical innovations have led to a significant reduction in CT radiation exposure. Complications of CD can be optimally evaluated with contrast-enhanced MRI, obviating the need for barium studies and CT. Upper airway disorders, likewise, can be evaluated with cine MRI which may ultimately replace more complex, time-consuming radiographic procedures. With the rapid advances in medical imaging technology, radiology will continue to play a key role in the diagnosis and treatment of pediatric diseases.

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References

1. Kalra MK, Maher MM, Rizzo S, Saini S. Radiation exposure and projected risks with multidetector-row computed tomography scanning: clinical strategies and technologic developments for dose reduction. J Comput Assist Tomogr 2004;28:S46-9.
2. Pierce DA, Preston DL. Radiation-related cancer risks at low doses among atomic bomb survivors. Radiat Res 2000;154:178-86.
3. Brenner DJ. Estimating cancer risks from pediatric CT: going from the qualitative to the quantitative. Pediatr Radiol 2002;32:228-3; discussion 242-4, 2002.
4. Brenner DJ, Elliston CD, Hall EJ, Berdon WE. Estimates of the cancer risks from pediatric CT radiation are not merely theoretical: comment on "point/counterpoint: in x-ray computed tomography, technique factors should be selected appropriate to patient size. against the proposition". Med Phys 2001;28:2387-8.
5. MacKenzie JD, Vasanawala SS. Advances in pediatric MR imaging. Magn Reson Imaging Clin N Am 2008;16:385-402, v.
6. Riccabona M. (Paediatric) magnetic resonance urography: just fancy images or a new important diagnostic tool? Curr Opin Urol 2007;17:48-55.
7. Leyendecker JR, Barnes CE, Zagoria RJ. MR urography: techniques and clinical applications. Radiographics 2008;28:23-46; discussion 46-27.
8. Grattan-Smith JD, Little SB, Jones RA. MR urography in children: how we do it. Pediatr Radiol 2008;38:S3-17.
9. Leyendecker JR, Clingan MJ. Magnetic resonance urography update-are we there yet? Semin Ultrasound CT MR 2009;30:246-57.
10. Papadopoulou F, Anthopoulou A, Siomou E, Efremidis S, Tsamboulas C, Darge K. Harmonic voiding urosonography with a second-generation contrast agent for the diagnosis of vesicoureteral reflux. Pediatr Radiol 2009;39:239-44.
11. Darge K. Diagnosis of vesicoureteral reflux with ultrasonography. Pediatr Nephrol 2002;17:52-60.
12. McCollough CH, Primak AN, Braun N, Kofler J, Yu L, Christner J. Strategies for Reducing Radiation Dose in CT. Radiol Clin North Am 2009;47:27-40.
13. Paterson A, Frush DP. Dose reduction in paediatric MDCT: general principles. Clin Radiol 2007;62:507-17.
14. Frush DP, Soden B, Frush KS, Lowry C. Improved pediatric multidetector body CT using a size-based color-coded format. AJR Am J Roentgenol 2002;178:721-6.
15. Kalra MK, Prasad S, Saini S, Blake MA, Varghese J, Halpern EF, *et al.* Clinical comparison of standard-dose and 50% reduced-dose abdominal CT: effect on image quality. AJR Am J Roentgenol 2002;179:1101-6.
16. Udayasankar UK, Braithwaite K, Arvaniti M, Tudorascu D, Small WC, *et al.* Low-dose nonenhanced head CT protocol for follow-up evaluation of children with ventriculoperitoneal shunt: reduction of radiation and effect on image quality. AJNR Am J Neuroradiol 2008;29:802-6.
17. Friedman S, Blumberg RS. Inflammatory Bowel Disease. In: E Braunwald, Fauci AS, Kasper DL, Hauser SL, Longo DL, Jameson JL (eds.), Harrison's Principles of Internal Medicine, 15 edition, New York: McGraw-Hill; 2001. p. 1679-92.
18. Patak MA, Mortele KJ, Ros PR. Multidetector row CT of the small bowel. Radiol Clin North Am 2005;43:1063-77, viii.
19. Mackalski BA, Bernstein CN. New diagnostic imaging tools for inflammatory bowel disease. Gut 2006;55:733-41.
20. Horton KM, Fishman EK. The current status of multidetector row CT and three-dimensional imaging of the small bowel. Radiol Clin North Am 2003;41:199-212.
21. Gore RM, Balthazar EJ, Ghahremani GG, Miller FH. CT features of ulcerative colitis and Crohn's disease. AJR Am J Roentgenol 1996;167:3-15.
22. Brenner DJ. Should computed tomography be the modality of choice for imaging Crohn's disease in children? The radiation risk perspective. Gut 2008;57:1489-90.
23. Furukawa A, Saotome T, Yamasaki M, Maeda K, Nitta N, Takahashi M, *et al.* Cross-sectional imaging in Crohn disease. Radiographics 2004;24:689-702.
24. Koelbel G, Schmiedl U, Majer MC, Weber P, Jenss H, Kueper K, *et al.* Diagnosis of fistulae and sinus tracts in patients with Crohn disease: value of MR imaging. AJR Am J Roentgenol 1989;152:999-1003.
25. Szurowska E, Wypych J, Izycka-Swieszewska E. Perianal fistulas in Crohn's disease: MRI diagnosis and surgical planning: MRI in fistulazing perianal Crohn's disease. Abdom Imaging 2007.
26. Fidler J. MR imaging of the small bowel. Radiol Clin North Am 2007;45:317-31.
27. Bernstein CN, Greenberg H, Boult I, Chubey S, Leblanc C, Ryner L. A prospective comparison study of MRI versus small bowel follow-through in recurrent Crohn's disease. Am J Gastroenterol 2005;100:2493-502.
28. Low RN, Francis IR, Politoske D, Bennett M. Crohn's disease evaluation: comparison of contrast-enhanced MR imaging and single-phase helical CT scanning. J Magn Reson Imaging 2000;11:127-35.
29. Donnelly LF. Obstructive sleep apnea in pediatric patients: evaluation with cine MR sleep studies. Radiology 2005;236:768-78.
30. Atik B, Bekerecioglu M, Tan O, Etlik O, Davran R, Arslan H. Evaluation of dynamic magnetic resonance imaging in assessing velopharyngeal insufficiency during phonation. J Craniofac Surg 2008;19:566-72.

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National Cancer Institute at the National Institutes of Health

Radiation Risks and Pediatric Computed Tomography (CT): A Guide for Health Care Providers

Reviewed: 06/07/2012

The use of pediatric CT, which is a valuable imaging tool, has been increasing rapidly. However, because of the potential for increased radiation exposure to children undergoing these scans, pediatric CT is a public health concern. This page discusses the value of CT and the importance of minimizing the radiation dose, especially in children. It will address the following issues:

- CT as a diagnostic tool
- Unique considerations for radiation exposure in children
- Radiation risks from CT in children
- Immediate strategies to minimize CT radiation exposure to children

CT as a Diagnostic Tool

CT can be a life saving tool for diagnosing illness and injury in children. For an individual child, the risks of CT are small and the individual risk-benefit balance favors the benefit when used appropriately.

Approximately 5 to 9 million CT examinations are performed annually on children in the United States. The use of CT in adults and children has increased about eightfold since 1980, with annual growth estimated at about 10 percent per year. Much of this increase is due to its utility in common diseases, as well as to technical improvements.

Despite the many benefits of CT, a disadvantage is the inevitable radiation exposure. Although CT scans comprise up to about 12 percent of diagnostic radiological procedures in large U.S. hospitals, it is estimated that they account for approximately 49 percent of the U.S. population's collective radiation dose from all medical x-ray examinations. CT is the largest contributor to medical radiation exposure among the U.S. population.

Unique Considerations for Radiation Exposure in Children

Radiation exposure is a concern in both adults and children. However, there are three unique considerations in children.

- Children are considerably more sensitive to radiation than adults, as demonstrated in epidemiologic studies of exposed populations.
- Children have a longer life expectancy than adults, resulting in a larger window of opportunity for expressing radiation damage.
- Children may receive a higher radiation dose than necessary if CT settings are not adjusted for their smaller body size.

As a result, the risk for developing a radiation-related cancer can be several times higher for a young child compared with an adult exposed to an identical CT scan.

In the last decade improvements in CT equipment have allowed for better images at lower doses. The use of appropriate settings has also become much more widespread, resulting in reductions in doses for children. There is no need for higher doses in children, and appropriate settings should always be used.

Regardless of the lower doses, multiple scans to an individual patient present a particular concern. In addition, the use of more than one scan (that is, more than one contrast "phase") during a single examination will further increase the radiation dose. In the vast majority of cases, a single scan should be sufficient during pediatric CT.

Radiation Risks from CT in Children

Major national and international organizations responsible for evaluating radiation risks agree that there probably is no low-dose radiation "threshold" for inducing cancers. In other words, no amount of radiation should be considered absolutely safe.

The first study to assess directly the risk of cancer after CT scans in childhood found a clear dose-response relationship for both leukemia and brain tumors: risk increased with increasing cumulative radiation dose. For a cumulative dose of between 50 and 60 milligray or mGy (mGy is a unit of estimated absorbed dose of ionizing radiation) to the head, the investigators reported a threefold increase in the risk of brain tumors; the same dose to bone marrow (the part of the body responsible for generating blood cells) resulted in a threefold increase in the risk of leukemia. For both findings, the comparison group consisted of individuals who had cumulative doses of less than 5 mGy to the relevant regions of the body.

The number of CT scans required to give a cumulative dose of 50-60mGy depends on the type of CT scan, the age of the patient, and the scanner settings. If typical current scanner settings are used for head CT in children, then two to three head CT scans would result in a dose of 50-60mGy to the brain. The same dose to red bone marrow would be produced by five to 10 head CT scans, using current scanner settings for children under age 15.

Previously, the potential cancer risk from CT use has been estimated using risk projection models derived primarily from studies of survivors of the atomic bomb explosions in Japan. The risks observed in the study described above were consistent with those previous estimates.

It is important to stress that the absolute cancer risks associated with CT scans are small. The lifetime risks of cancer due to CT scans, which have been estimated in the literature using projection models based on atomic bomb survivors, are about 1 case of cancer for every 1,000 people who are scanned, with a maximum incidence of about 1 case of cancer for every 500 people who are scanned.

The benefits of properly performed and clinically justified CT examinations should always outweigh the risks for an individual child; unnecessary exposure is associated with unnecessary risk. Minimizing radiation exposure from pediatric CT, whenever possible, will reduce the projected number of CT-related cancers.

Immediate Measures to Minimize CT Radiation Exposure in Children

Physicians, other pediatric health care providers, CT technologists, CT manufacturers, and various medical and governmental organizations share the responsibility to minimize CT radiation doses to children. Several immediate steps

can be taken to reduce the amount of radiation that children receive from CT examinations:

- *Perform only necessary CT examinations.* Communication between pediatric health care providers and radiologists can determine the need for CT and the technique to be used. There are standard indications for CT in children, and radiologists should review reasons prior to every pediatric scan and be available for consultation when indications are uncertain. When appropriate, other modalities such as ultrasound or magnetic resonance imaging (MRI), which do not use ionizing radiation, should be considered.
- *Adjust exposure parameters for pediatric CT based on*
  - Child size: guidelines based on individual size / weight parameters should be used.
  - Region scanned: the region of the body scanned should be limited to the smallest necessary area.
  - Organ systems scanned: lower mA and/or kVp settings should be considered for skeletal, lung imaging, and some CT angiographic and follow up examinations.
- *Scan resolution*: the highest quality images (i.e., those that require the most radiation) are not always required to make diagnoses. In many cases, lower-resolution scans are diagnostic. Providers should be familiar with the dose descriptors available on CT scanners and minimize the use of CT examinations that use multiple scans obtained during different phases of contrast enhancement (multiphase examinations). These multiphase examinations result in a considerable increase in dose and are rarely necessary, especially in body (chest and abdomen) imaging.

Issues to discuss with parents:

- *Is CT the best examination to diagnose conditions in the child?*
- *Will the CT examination be adjusted based on the size of the child?*
- *Will the examination be performed at a reputable facility and by a radiologist and radiology team familiar with pediatric CT?*

It should be noted that there have been studies in which parents were given information regarding the risks and benefits of CT, and this did not result in reduced compliance, but did result in parents asking more informed questions of the care providers.

Long-Term Strategies to Minimize CT Radiation

In addition to the immediate measures to reduce CT radiation exposure in children, long-term strategies are also needed.

- Encourage the development and adoption of pediatric CT protocols.
- Encourage the use of selective strategies for pediatric imaging, such as for the pre-surgical evaluation of appendicitis.
- Educate through journal publications and conferences within and outside radiology specialties to optimize exposure settings and assess the need for CT in an individual patient. Disseminate information through associations, organizations, or societies involved in health care of children, including the American Academy of Pediatrics, the American Academy of Family Physicians, , and the American College of Emergency Physicians. Provide readily available information sources, such as the Alliance for Radiation Safety in Pediatric Imaging.
- Conduct further research to determine the relationship between CT quality and dose, to customize CT scanning for individual children, and to further clarify the relationship between CT radiation and cancer risk.

Conclusion

Although CT remains a crucial tool for pediatric diagnosis, it is important for the health care community to work together to minimize the radiation dose to children. Radiologists should continually think about reducing exposure as low as reasonably achievable by using exposure settings customized for children. All physicians who prescribe pediatric CT should continually assess its use on a case-by-case basis. Used prudently and optimally, CT is one of the most valuable imaging modalities for both children and adults.

Related Resources

Society for Pediatric Radiology
1891 Preston White Drive
Reston, Virginia 20191
http://www.pedrad.org

References

Amis ES, Jr., Butler PF, Applegate KE, et al. American College of Radiology white paper on radiation dose in medicine. *Journal of the American College of Radiology* 2007; 4:272-284.

Arch ME, Frush DP. Pediatric body MDCT: A 5-year follow-up survey of scanning parameters used by pediatric radiologists. *American Journal of Roentgenology* 2008:191;611-617

Berrington de González A, Mahesh M, Kim KP, Bhargavan M, Lewis R, Mettler F, Land C. Projected cancer risks from computed tomographic scans performed in the United States in 2007. *Archives of Internal Medicine* 2009; 169: 2071-7.

Brenner DJ, Doll R, Goodhead DT, et al. Cancer risks attributable to low doses of ionizing radiation: Assessing what we really know. *Proceedings of the National Academy of Sciences of the United States of America* 2003; 100:13761-13766.

Brenner DJ, Elliston CD, Hall EJ, Berdon WE. Estimated risks of radiation-induced fatal cancer from pediatric CT. *American Journal of Roentgenology* 2001; 176:289-296.

Brenner DJ, Hall EJ. Current concepts - Computed tomography - An increasing source of radiation exposure. *New England Journal of Medicine* 2007; 357:2277-2284.

Brody AS, Frush DP, Huda W, Brent RL, Radiology AAoPSo. Radiation risk to children from computed tomography. *Pediatrics* 2007; 120:677-682.

Cardis E, Vrijheid M, Blettner M, et al. The 15-country collaborative study of cancer risk among radiation workers in the nuclear industry: Estimates of radiation-related cancer risks. *Radiation Research* 2007; 167:396-416.

Chodick G, Ronckers C, Ron E, Shalev V. The utilization of pediatric computed tomography in a large Israeli Health Maintenance Organization. *Pediatric Radiology* 2006; 36:485-490.

Chodick G, Ronckers CM, Shalev V, Ron E. Excess lifetime cancer mortality risk attributable to radiation exposure from

computed tomography examinations in children. *Israel Medical Association Journal* 2007; 9:584-587.

da Costa e Silva EJ, da Silva GA. Eliminating unenhanced CT when evaluating abdominal neoplasms in children. *American Journal of Roentgenology* 2007; 189:1211-1214.

Donnelly LF, Emery KH, Brody AS, et al. Minimizing radiation dose for pediatric body applications of single-detector helical CT: Strategies at a large children's hospital. *American Journal of Roentgenology* 2001; 176:303-306.

Frush DP, Applegate K. Computed tomography and radiation: understanding the issues. *Journal of the American College of Radiology* 2004; 1:113-119.

Frush DP, Donnelly LF, Rosen NS. Computed tomography and radiation risks: What pediatric health care providers should know. *Pediatrics* 2003; 112:951-957.

Garcia Peña BM, Cook EF, Mandl KD. Selective imaging strategies for the diagnosis of appendicitis in children. *Pediatrics* 2004; 113:24-28.

Goske MJ, Applegate KE, Boylan J, et al. The 'Image Gently' campaign: increasing CT radiation dose awareness through a national education and awareness program. *Pediatric Radiology* 2008; 38:265-269.

Huda W, Vance A. Patient radiation doses from adult and pediatric CT. *American Journal of Roentgenology* 2007; 188:540-546.

Larson DB, Rader SB, Forman HP, Fenton LZ. Informing parents about CT radiation exposure in children: It's OK to tell them. *American Journal of Roentgenology* 2007; 189:271-275.

McNitt-Gray MF. AAPM/RSNA physics tutorial for residents: Topics in CT - Radiation dose in CT1. *Radiographics* 2002; 22:1541-1553.

Mettler FA, Jr., Wiest PW, Locken JA, Kelsey CA. CT scanning: patterns of use and dose. *Journal of Radiological Protection* 2000; 20:353-359.

NAS. Health risks from exposure to low levels of ionizing radiation: BEIR VII phase 2. Washington D.C.: *National Academy of Sciences*, 2005.

NCRP. Ionizing radiation exposure of the population of the United States. NCRP Report 160. National Council on Radiation Protection and Measurements. Bethesda, Maryland, 2009.

Paterson A, Frush DP, Donnelly LF. Helical CT of the body: Are settings adjusted for pediatric patients? *American Journal of Roentgenology* 2001; 176:297-301.

Pearce MS, Salotti JA, Little MP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. *Lancet* (published online June 7th 2012).

Pierce DA, Preston DL. Radiation-related cancer risks at low doses among atomic bomb survivors. *Radiation Research* 2000; 154:178-186.

Preston DL, Ron E, Tokuoka S, et al. Solid cancer incidence in atomic bomb survivors: 1958-1998. *Radiation Research* 2007; 168:1-64.

Rogers LF. Taking care of children: Check out the parameters used for helical CT. *American Journal of Roentgenology* 2001; 176:287-287.

Slovis TL. The ALARA (as low as reasonably achievable) concept in pediatric CT intelligent dose reduction. Multidisciplinary conference organized by the Society of Pediatric Radiology. August 18-19, 2001. *Pediatric Radiology* 2002; 32:217-317.

Strauss KJ, Goske MJ. Estimated pediatric radiation dose during CT. *Pediatric Radiology* 2011; 41(suppl2):S472-482.

Thomas KE, Wang BB. Age-specific effective doses for pediatric MSCT examinations at a large children's hospital using DLP conversion coefficients: a simple estimation method. *Pediatric Radiology* 2008; 38:645-656.

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REVIEW

Evaluation of pediatric bone lesions

Mary R. Wyers

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Abstract The radiologist is commonly confronted with bone lesions in children. Knowledge of the age of the patient, the lesion location, and various imaging characteristics are all important in making an accurate diagnosis, and determining benign from malignant etiologies should be a primary goal. Various imaging features seen on cross-sectional imaging, including marrow edema, periosteal reaction patterns, and fluid-fluid levels, are discussed. The advantages of different imaging modalities, including CT and MRI, are reviewed.

Keywords Bone lesion · Tumor · MRI · CT

Introduction

Bone lesions in children are very common and include true bone tumors and tumor-like lesions. Up to 42% of all bone lesions, including both benign and malignant etiologies, occur in the first two decades of life [1]. This may be underestimated, since many benign-appearing lesions are not biopsied or recorded in databases. More than half of all childhood bone neoplasms are benign [2]. The most common benign bone lesions in children include osteochondroma, non-ossifying fibroma, Langerhans cell histiocytosis, unicameral bone cyst, and aneurysmal bone cyst. The most common primary malignant lesions include osteosarcoma and Ewing sarcoma.

In most cases, the differential diagnosis of a bone lesion can be narrowed based on knowledge of the age of the patient, the location of the lesion within the body and within a bone, and general radiographic characteristics. While some bone lesions follow very typical imaging patterns and are easy to diagnose, others are more complicated. Primary bone lesions may be complicated by pathologic fractures, which can increase the amount of edema and blood products in and around a lesion, complicating the imaging characteristics. In such cases, a broader differential diagnosis may be necessary. Benign lesions that may present with a pathologic fracture include unicameral bone cyst, non-ossifying fibroma, aneurysmal bone cyst, and fibrous dysplasia. Malignant bone tumors less commonly present with a pathologic fracture, although making an accurate diagnosis before treatment of the fracture is more important. Other complicating issues include distinguishing a primary bone lesion from osteomyelitis, due to a wide overlap of imaging features. Bone lesions complicated by a secondary aneurysmal bone cyst also may have confusing imaging characteristics. The workup of a bone lesion is typically a team approach, with the clinician, radiologist and pathologist working together to make the diagnosis. The bone pathologist requires good clinical and radiological information in interpreting a biopsy specimen. The highest accuracy in diagnosing bone lesions has been shown to be at dedicated bone tumor centers [3].

Imaging modalities

The choice of an appropriate imaging modality to evaluate a bone lesion is important. Plain films are still considered

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best for defining the characteristics and assessing the true nature of a primary bone lesion [4]. If a lesion is clearly benign radiographically, cross-sectional imaging should not be necessary. Bone scintigraphy has a role in the evaluation of metastatic disease or a multifocal process, but its lack of specificity limits its use in the initial workup of a single bone lesion. CT and MRI each have specific advantages and disadvantages.

CT may be helpful in providing more detailed "radiographic" information [5]. However, the decision to do a CT in children should be weighed against the amount of anticipated useful information in order to avoid unnecessary radiation. Certain areas of the body may be difficult to profile by plain films due to overlapping structures, and the cross-sectional abilities of CT allow such areas as the pelvis or spine to be better depicted. CT can better define the location of a lesion, such as involving the periosteal, cortical, or medullary portion of the bone. CT can also evaluate changes in the cortex more accurately, including focal destruction or endosteal scalloping. In fact, CT is often better than MRI in assessing subtle cortical erosion or diagnosing a nondisplaced pathologic fracture, especially if the cortex is very thin. Early periosteal reaction is best visualized on CT, which has good spatial resolution and often better visualization of the bony cortex, which may be obscured on plain films. CT can detect more subtle matrix mineralization, particularly in bone or cartilage forming tumors, which may not be visible on plain film or MRI (Fig. 1). CT is also the best modality to guide bone biopsies.

MRI is the modality of choice when a malignant bone tumor is suspected; it is best for a staging evaluation. It is the most sensitive modality for evaluation of bone marrow changes and defining the extent of a lesion. MRI has the best contrast resolution for demonstrating an adjacent soft tissue mass as well as invasion of adjacent neurovascular structures or an adjacent joint space. Considerations for doing MRI in children include the need for sedation in younger children, and more difficulty in obtaining quality images on smaller body parts. Optimization of MR technique is very important in children, where standardized protocols are more difficult to fit to each case due to different-sized patients, and greater flexibility and involvement by the radiologist is needed in altering imaging parameters.

Although MRI is considered the most advanced imaging modality, it is often not the most specific. Many lesions demonstrate low T1 and high T2 signal and are fairly nonspecific. Edema, pus and tumor infiltration can all demonstrate these signal characteristics. When a bone lesion contains certain specific tissue components, such as blood products, vascular tissue, cysts, fat, or non-mineralized cartilage matrix, MRI may be able to make a more specific diagnosis. For example, a lesion with low signal on T1 and T2 may contain osteoblastic matrix, fibrous matrix or blood products [6]. Bone islands and healing non-ossifying fibromas are typical benign lesions that may have low signal on both T1-weighted (T1-W) and T2-weighted (T2-W) sequences. Osteosarcoma is an example of a malignant lesion that may have areas of low T1 and T2 signal due to osteoblastic matrix. Lesions containing fat, which have high signal on T1 and suppression with fat-saturation techniques, are usually either lipomas, hemangiomas, or bone infarcts.

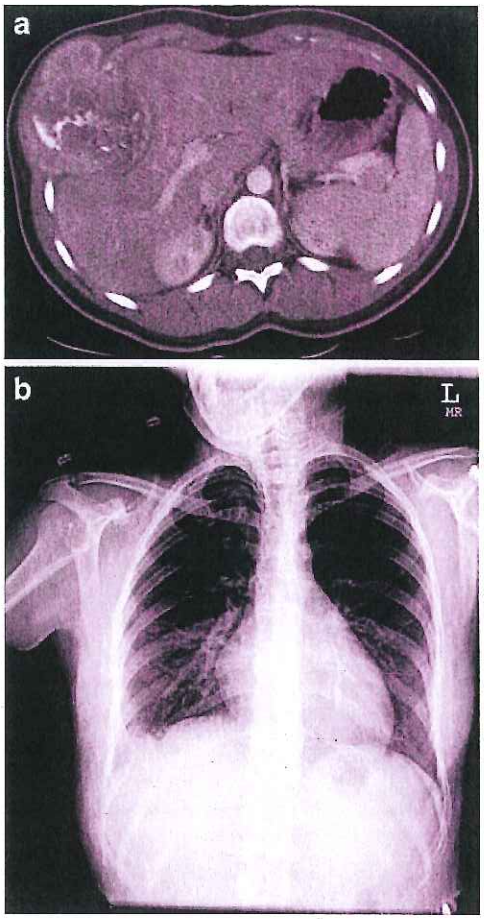


Fig. 1 Chondrosarcoma arising from a lower right rib. **a** The mass is well depicted on CT and is seen to contain small whirls and arcs of chondroid matrix. **b** The mass in the lower right chest is poorly profiled by the correlative plain film due to the location and many overlapping structures

Both CT and MRI have a role in evaluation of a bone following tumor resection. CT can detect subtle areas of new bone destruction at a bone-cement interface [5]. MRI is very sensitive for detection of T2 signal changes, although the findings are not specific. In general, if there is a mass present, a recurrence should be suspected. Some authors have advocated using dynamic gadolinium-enhancement techniques, since tumor will enhance earlier

than reactive tissue. However, these techniques are technically challenging and time consuming and cannot completely replace biopsy/histology for diagnosing tumor recurrence [4].

Diagnostic accuracy: benign versus malignant

The radiologist can be most helpful by determining which lesions can be ignored and which ones deserve a biopsy or further treatment, either because of a suspicion of malignancy or because of a risk for pathologic fracture. Typical radiographic characteristics of benign lesions include a well-defined or sclerotic border, sharp zone of transition, and lack of periosteal reaction or solid periosteal reaction. Characteristics of more aggressive lesions include poor definition, cortical destruction, spiculated or interrupted periosteal reaction, and presence of a soft tissue mass.

While MRI is generally believed by clinicians to be the most advanced and best imaging modality to diagnose a bone lesion accurately, this is not necessarily true. In a study by Ma and colleagues [7], the accuracy of MRI was evaluated prospectively. Readers were asked to assess imaging characteristics on MRI and determine if a lesion was benign or malignant. The lesions were correctly assessed only 55% of the time, with malignancy overestimated in 39% of the cases [7]. If plain films and clinical information were included, the accuracy would have improved with correct assessment of malignancies in 73% of the cases. Features on MRI such as T1 and T2 signal intensity, homogeneity versus heterogeneity, and surrounding marrow edema were not shown to be helpful in assessing malignant from benign. In addition, while many malignant bone tumors are poorly defined on plain radiographs, they are often more sharply defined on MRI, leading to confusion.

Specific imaging features

Several imaging features are more nonspecific than generally believed and deserve a more complete discussion in the assessment of whether a lesion is benign or malignant.

Marrow edema

Reactive marrow edema is actually unknown in etiology. When peritumoral edema has been biopsied, some studies have demonstrated normal histology and others have found tumor infiltration [8]. In general, lesions that cause an

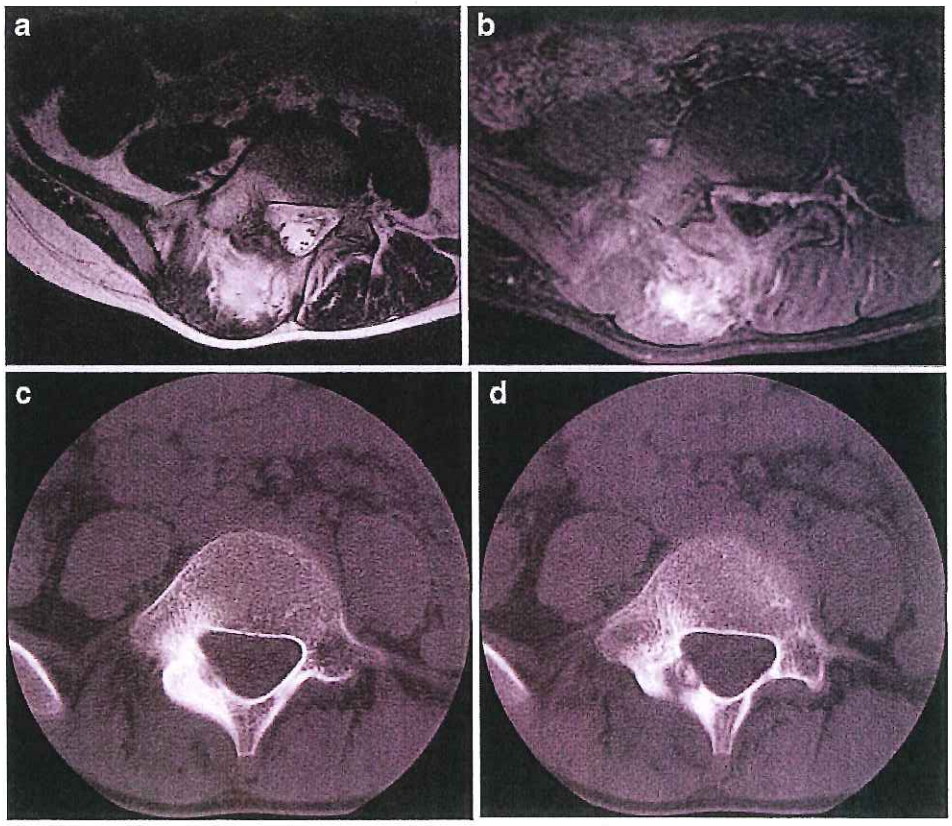


Fig. 2 Osteoid osteoma of the spine at the L5 level. **a** Axial T2-W MR image demonstrates diffuse, marked edema on the right at the L5 level, involving both the soft tissues and the bone, including the right aspect of the vertebral body, pedicle and lamina. **b** Post-gadolinium MR image shows enhancement throughout the same areas. The nidus itself is not seen by MR (**c** and **d**). CT demonstrates sclerosis and thickening of the right lamina and pedicle at L5, and more clearly demonstrates the nidus in the right lamina, centrally within the sclerosis

inflammatory reaction tend to have more reactive marrow edema. Possible etiologies include local trabecular destruction, capillary leakage, or elevated intramedullary pressure with release of inflammatory mediators [8, 9].

MRI is the best imaging modality for evaluation of marrow edema. Water-sensitive sequences such as T2 with fat saturation or short tau inversion recovery (STIR) can depict marrow edema with high sensitivity. Marrow edema does not change the normal architecture of the marrow space, and also tends to enhance in a homogeneous fashion. Since a bone lesion and the surrounding marrow edema may both demonstrate high T2 signal and enhancement, the lesion margins may be difficult to see on T2-weighted images. The T1-W sequence is sometimes better for assessing the true lesion margin. In studies obtained with dynamic gadolinium injection, the peritumoral edema has been shown to be differentiated from the primary lesion by an enhancement curve with a slope of 20% or less than the actual lesion [10].

The amount of surrounding bone marrow edema compared to the size of a lesion has been shown to be inversely proportional to the likelihood of malignancy [8, 9]. So, a large amount of reactive edema around a small lesion more likely indicates a benign etiology. A lesion with a small amount of surrounding edema is nonspecific, however, and may be either benign or malignant. There are several classic benign bone lesions of childhood that have a large amount of surrounding edema and can appear more aggressive than they actually are. These include chondroblastoma, osteoid osteoma/osteoblastoma, Langerhans cell histiocytosis, and some aneurysmal bone cysts. Lesions with a pathologic fracture, stress fractures, and osteomyelitis can also have a large amount of associated edema and have confusing imaging characteristics. Osteoid osteoma is frequently misdiagnosed at MRI because the large amount of edema may obscure the nidus. In some studies, CT has been shown to be more accurate than MRI in assessing the location of the nidus [5]

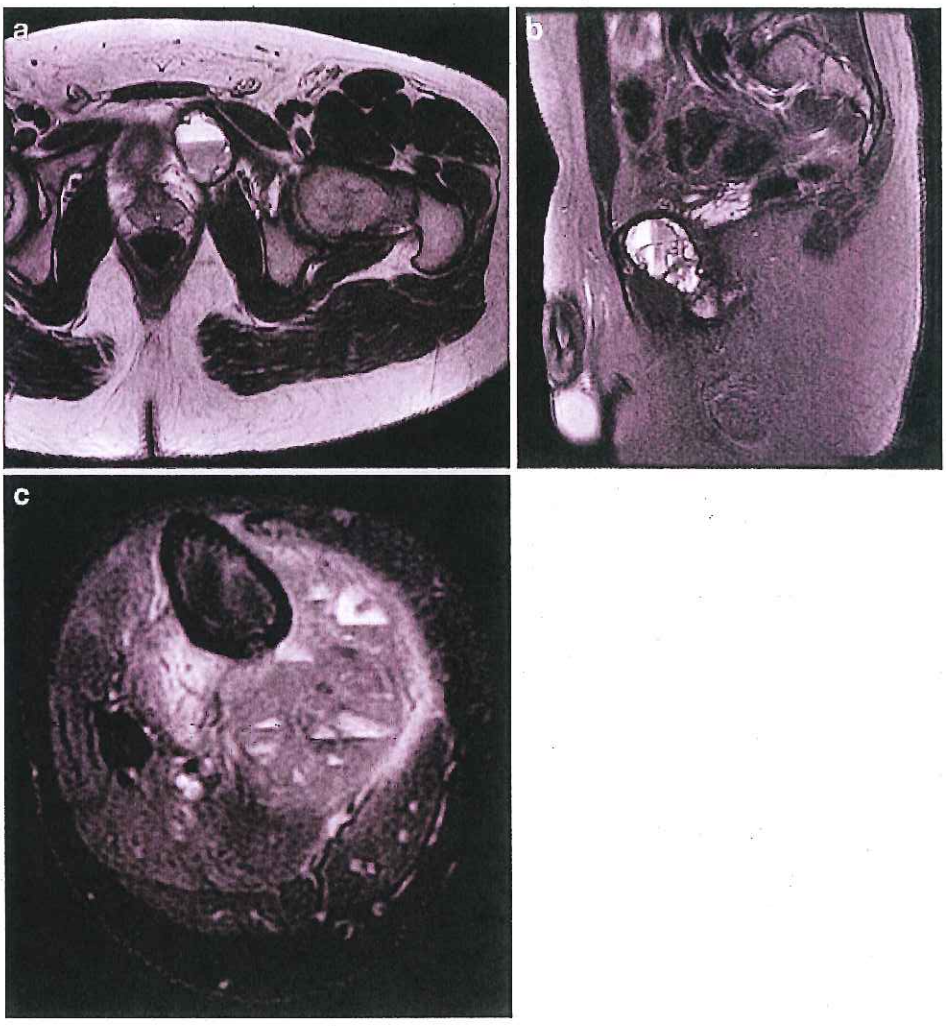


Fig. 3 Benign and malignant etiologies of FFLs. **a** and **b** Axial and sagittal T2-W MR images showing a primary aneurysmal bone cyst of the left pubic bone with multiple FFLs occupying the entirety of the lesion. **c** Axial T2-W MR image showing an osteosarcoma demonstrating FFLs that comprise less than one-third of the whole lesion

(Fig. 2). Also, an intraarticular osteoid osteoma may cause a large amount of adjacent joint effusion and synovitis, and therefore may not be recognized.

Periosteal reaction

The term "periosteal reaction" can include either new bone formation or elevation of the periosteum related to infiltration and extension of tumor or infection to the cortex of the bone. Periosteal reaction is visible earlier in children, where elevation of the periosteum occurs more easily due to a looser attachment than in adults [11]. Many different types of periosteal reaction have been described, including single layer, multilayer, solid, spiculated, interrupted, etc. In general, the type or characteristic of the periosteal reaction is not specific. Benign and malignant lesions can have a high degree of overlap in the type of periosteal reaction pattern, although some generalizations can be made. Solid periosteal reaction typically is associated with a benign or slow-growing lesion. Spiculated, sunburst, and interrupted (Codman's triangle) patterns are typically associated with rapidly growing aggressive tumors or infections. However, in a series by Wenaden et al. [11], there were a large number of aggressive lesions that had benign-appearing periosteal reaction, or none at all. Therefore, caution is suggested when interpreting periosteal reactions around a lesion.

Fluid-filled levels

The prevalence of fluid-fluid levels (FFLs) in bone lesions ranges from 3–11% [12, 13]. In general, FFLs are best seen on T2-weighted images. While FFLs are classically seen in aneurysmal bone cysts (ABCs), other lesions can also have FFLs, including malignant tumors such as telangiectatic osteosarcomas. The actual composition of the fluid may be serous, hemorrhagic or necrotic fluid. In malignant lesions, there is more likely to be hemorrhagic or necrotic liquid, and therefore the superior level of a fluid-fluid level is more often hyperintense to muscle on both T1- and T2-W images [12]. In benign lesions, the characteristics of the fluid are more nonspecific.

In a study by O'Donnell and Saifuddin [13], the percent of a bone lesion occupied by FFL was correlated with the pathology of the lesion. They found that the greater the percentage of FFL within a bone lesion, the more likely the lesion was to be benign [13]. More specifically, if at least two-thirds of the lesion contained FFLs, 89% of those lesions were benign. Conversely, if a lesion was comprised of less than one-third FFLs and the rest solid, 67% of those lesions were malignant (Fig. 3). Extensive necrosis within a malignant tumor can also lead to more extensive FFLs, however, and can be misleading. In addition, aneurysmal bone cysts may be secondary, arising as a reactive process to a primary bone lesion or even trauma, leading to difficulty in interpretation. Approximately one-third of ABCs are secondary and have a preexisting lesion that can be identified, most commonly giant cell tumor. Other common associated primary lesions include osteoblastoma, angioma and chondroblastoma [14]. However, because the secondary ABC may become large, distort the architecture of the bone, and even lead to bone destruction, it can actually obscure the primary lesion both radiographically and pathologically. Therefore, FFLs are a nonspecific finding that may be seen in primary or secondary aneurysmal bone cysts, as well as in other benign and malignant lesions.

Conclusion

Bone lesions in children are very common. The role of the radiologist includes working with the clinician and pathologist to help make an accurate diagnosis, acting as consultant to suggest the best imaging modalities for the suspected diagnosis, and defining the extent of disease. Determining benign from malignant lesions is one of the most important goals. Knowledge of the age of the patient, the lesion location, and various imaging characteristics will help to narrow the differential diagnosis. Attention to meticulous MR technique for quality images and correlation with clinical history and plain radiographs should be emphasized.

References

1. Vlychou M, Athanasou NA (2008) Radiological and pathological diagnosis of paediatric bone tumours and tumour-like lesions. Pathology 40:196–216
2. Slovis T (2008) Caffey's pediatric diagnostic imaging, 11th edn. Mosby/Elsevier, Philadelphia, pp 2912–2969
3. van den Berg H, Slaar A, Kroon HM et al (2008) Results of diagnostic review in pediatric bone tumors and tumorlike lesions. J Pediatr Orthop 28:561–564
4. Helms C, Major N, Anderson M et al (2009) Musculoskeletal MRI. Saunders/Elsevier, Philadelphia, pp 123–152
5. Woertler K (2003) Benign bone tumors and tumor-like lesions: value of cross-sectional imaging. Eur Radiol 13:1820–1835
6. Wootton-Gorges SL (2009) MR imaging of primary bone tumors and tumor-like conditions in children. Magn Reson Imaging Clin N Am 17:469–487
7. Ma LD, Frassica FJ, Scott WW et al (1995) Differentiation of benign and malignant musculoskeletal tumors: potential pitfalls with MR imaging. Radiographics 15:349–366
8. James SLJ, Panicek DM, Davies AM (2008) Bone marrow oedema associated with benign and malignant bone tumours. Eur J Radiol 67:11–21
9. James SLJ, Hughes RJ, Ali KE (2006) MRI of bone marrow oedema associated with focal bone lesions. Clin Radiol 61:1003–1009
10. Alyas F, James SL, Davies AM et al (2007) The role of MR imaging in the diagnostic characterisation of appendicular bone tumours and tumour-like conditions. Eur Radiol 17:2675–2686

11. Wenaden AET, Szyszko TA, Saifuddin A (2005) Imaging of periosteal reactions associated with focal lesions of bone. Clin Radiol 60:439–456
12. Van Dyck P, Vanhoenacker FM, Vogel J et al (2006) Prevalence, extension and characteristics of fluid-fluid levels in bone and soft tissue tumors. Eur Radiol 16:2644–2651
13. O'Donnell P, Saifuddin A (2004) The prevalence and diagnostic significance of fluid-fluid levels in focal lesions of bone. Skeletal Radiol 33:330–336
14. Kransdorf MJ, Sweet DE (1994) Aneurysmal cone cyst: concept, controversy, clinical presentation, and imaging. AJR 164:573–580

Suggested Reading

15. Miller SL, Hoffer FA (2001) Malignant and benign bone tumors. Radiol Clin North Am 39:1–34
16. Hayes CW, Conway WF, Sundaram M (1992) Misleading aggressive MR imaging appearance of some benign musculoskeletal lesions. Radiographics 12:1119–1134
17. Azouz EM (2002) Magnetic resonance imaging of benign bone lesions: cysts and tumors. Top Magn Reson Imaging 13:219–230

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MINISYMPOSIUM

CT and MRI of paediatric Crohn disease

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Abstract Over the past two decades there has been considerable evolution in cross-sectional imaging modalities for the evaluation of Crohn disease (CD) in children. CT and MRI have contributed to conventional techniques so that now radiology has an even greater role in the management of CD, monitoring disease progression and detecting complications. The role of CT and MRI, their limitations, and the various imaging features that the radiologist should be aware of are discussed in this review.

Keywords Crohn disease · CT · MRI · Child

Introduction

Crohn disease (CD) is a chronic inflammatory bowel disease (IBD) that may involve any part of the gastrointestinal (GI) tract from mouth to anus and is characterized by recurrent episodes of exacerbation and remission. The distal ileum and colon are the most frequently affected parts. CD is characterized by chronic segmental inflammation that may progressively extend through all layers of the intestinal wall and involve extraintestinal structures.

According to their site, typical CD lesions can be classified as superficial, transmural, or extramural [1]. Superficial lesions represent the early stage of the disease, and include mucosal aphthous erosions, and blunting, flattening, thickening, and distortion of the valvulae conniventes. Transmural abnormalities appear as the disease progresses and include longitudinal and transverse ulcers causing the so-called 'cobblestone' appearance, bowel-wall thickening, stenoses of the intestinal lumen, prestenotic dilations, and increased bowel-wall vascularization. Extramural manifestations include increased mesenteric vascularity causing the so called 'comb' sign, mesenteric fibrofatty proliferation, and complications such as abscesses and fistulae.

Early diagnosis, complete demonstration of the extent of the disease, detection of its extramural complications, periodic reevaluation, and identification of recurrence are the goals of imaging studies in the evaluation of CD. Advances in bowel imaging have greatly improved the service that radiologists are able to offer to paediatric gastroenterologists dealing with children affected by CD. Current diagnostic imaging modalities available to the clinicians include—besides conventional barium studies—sonography, CT, MRI, FDG-PET, and ^{99m}Tc white-cell scintigraphy. The role of CT and MRI, and the variety of abnormalities that can be evaluated with these methods, form the basis of this review.

Imaging modalities

Barium examinations of the GI tract have been the cornerstone of the radiological evaluation of patients with suspected CD. Currently, patients with suspected CD routinely undergo endoscopy of the upper GI tract and colonoscopy with ileoscopy, where direct mucosal visualization and biopsy provide the diagnosis in many cases. Therefore, the upper GI component of a radiological study and the barium enema may be avoided in most cases.

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However, according to the ESPGHAN (European Society for Paediatric Gastroenterology, Hepatology and Nutrition) criteria for diagnosis of CD in children, a small-bowel follow-through or enteroclysis should still be performed when there is endoscopic evidence of CD or inconclusive endoscopic findings to rule out small-bowel disease [2]. Endoscopy and barium studies permit excellent evaluation of bowel mucosa and luminal calibre, but they can provide only indirect information about transmural and extramural extension of the disease. Absence of ionizing radiation and the ability to evaluate both gut wall and extramural extension of the disease make sonography a valuable imaging technique. However, sonography is an operator-dependent technique and even a skilled operator may miss bowel abnormalities if they are located behind air-filled bowel loops. Reliable assessment of disease extension and pathological changes involving bowel wall, mesenteric attachments and adjacent structures is essential to evaluate disease activity and to plan treatment, and it is well accomplished with cross-sectional imaging modalities such as CT and MRI that allow direct evaluation of mural and extramural involvement along the whole bowel.

CT

CT enteroclysis was initially described in Germany and named "CT Sellink", honouring one of the originators of enteroclysis [3]. With this technique it is mandatory to obtain good distension of bowel loops because nondilated loops are a potential source of diagnostic errors; they can be misinterpreted as abscesses, masses, or enlarged lymph nodes [4]. Therefore, as in enteroclysis, CT was initially performed with administration of large quantities of opaque contrast medium via a nasojejunal tube, making it an invasive procedure, especially in children [5]. Furthermore, intraluminal opaque contrast media made it very difficult to evaluate contrast enhancement of bowel wall following intravenous injection of iodinated contrast medium, which is an important indicator of the degree of inflammatory activity of the disease.

More recently, satisfactory small-bowel distension has been reported using a 0.5% solution of hydroxypropylmethylcellulose in water as a low-density oral contrast medium [6], making this method more tolerable for children. Methylcellulose solution is an excellent contrast

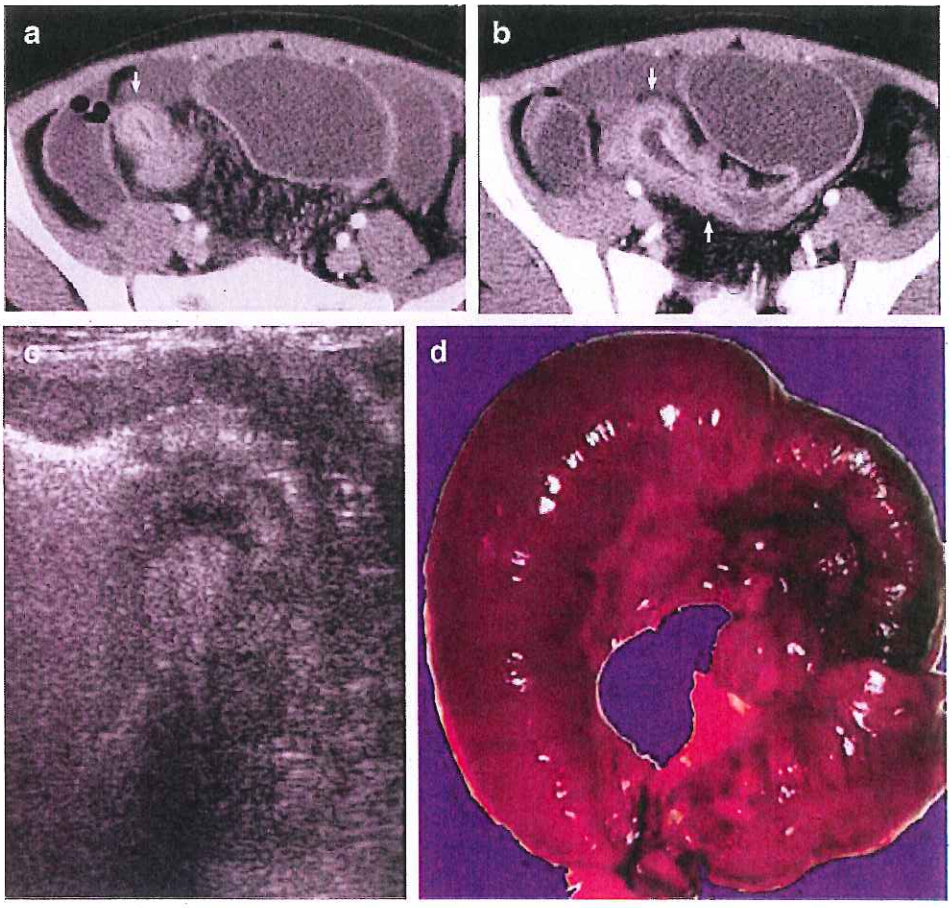


Fig. 1 A 12-year-old child with CD. Contrast-enhanced CT images (single-slice scanner). **a, b** The walls of the terminal ileum and caecum (*white arrows*) are diffusely thickened (stratified contrast enhancement) with a luminal stricture that causes obstruction. Dilated fluid-filled loops of bowel are seen proximal to the narrow segment. Enlarged vessels course through prominent mesenteric fat. **c** US of the distal ileum shows bowel-wall thickening, loss of the normal gut signature, and a fixed narrowed lumen, which is seen as an echogenic central line. **d** The resected specimen of terminal ileum

medium for CT enteroclysis: it is nonabsorbable, thus avoiding the risk of haemodilution, and has the same density as water, thus providing good differentiation between the bowel content and the contrast-enhanced intestinal wall [7].

CT imaging may also be limited by motion artefacts from respiration and bowel peristalsis that may impair the quality of the study; breath-hold acquisition and the preliminary administration of hypotonic agents, such as *n*-butyl-joscine or glucagon, are thus recommended. Superficial mucosal lesions are the earliest macroscopic manifestation of CD, but are, in most cases, not detectable with CT.

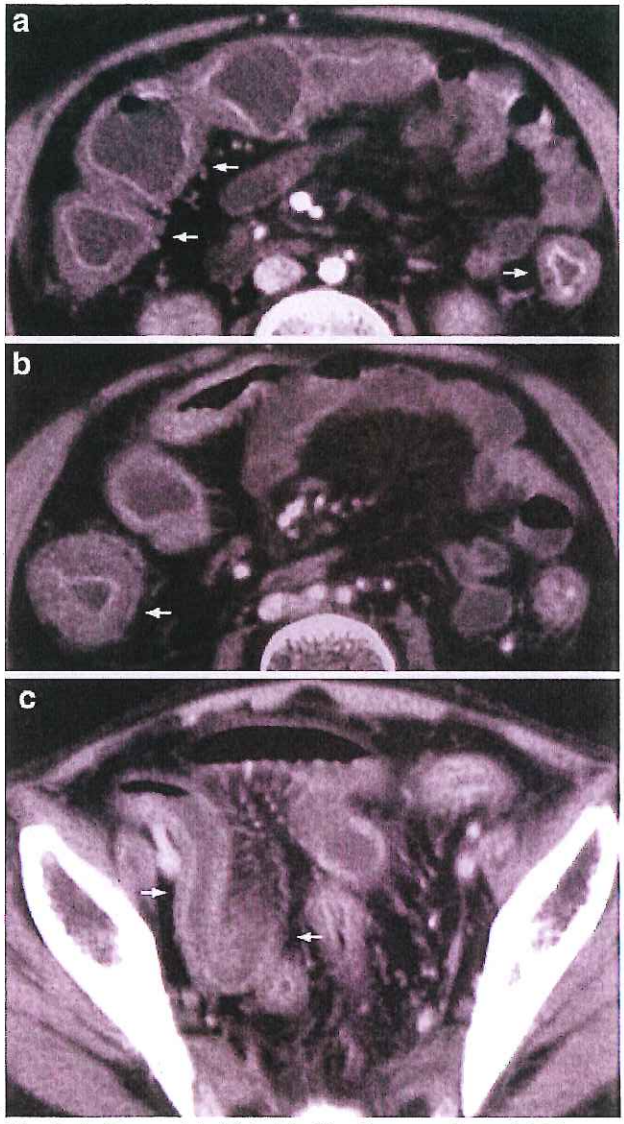


Fig. 2 A 14-year-old child with CD. Contrast-enhanced CT images (single-slice scanner). Circumferential wall thickening of the large bowel (**a**, **b**) and the terminal and distal ileum (**c**). Mural stratification of bowel loops (target sign) is evident due to low attenuation of the oedematous submucosa (*arrows*). Fibrofatty proliferation separates the loops; the comb sign is also evident

Consequently, when the disease is limited to the mucosa, CT scans are usually normal [4].

Transmural abnormalities are very well depicted with CT. Thickening of the bowel wall (>3 mm) is observed more frequently in the terminal ileum, but other portions of the small bowel, colon, duodenum, and stomach may be similarly affected [8] (Figs. 1 and 2). During the acute phase the affected segment shows mural stratification and often has a target or double-halo appearance. The mucosa appears as a ring of soft-tissue density surrounded by a low-density ring with attenuation near that of water or fat (corresponding to submucosal oedema or fat infiltration), which in turn is surrounded by a higher-density ring representing the muscularis propria [4] (Fig. 2). Inflamed mucosa and serosa may show significant contrast enhancement after an intravenous bolus of contrast medium. In patients with longstanding CD, mural stratification is lost. Homogeneous attenuation of thickened bowel wall after intravenous contrast medium enhancement suggests irreversible fibrosis; the affected segment may appear stenotic, and prestenotic dilation may be observed before the stenotic segment [4].

Fibrofatty proliferation of the mesentery, also known as creeping fat of the mesentery, is an extramural lesion commonly seen in advanced CD that causes separation of small-bowel loops (Fig. 2). On CT scans the sharp interface between bowel and mesentery appears blurred because of the influx of inflammatory cells and oedema [4]. Another extramural lesion involving the mesentery is the so-called comb sign, which is well shown on contrast-enhanced CT scans and appears as hypervascularity characterized by vascular dilatation, tortuosity, and wide spacing of the vasa recta [9]. Enlarged lymph nodes may also be present.

Abscesses, phlegmons, fistulae and sinus tracts may complicate CD. On CT scans, abscesses appear as circumscribed round or oval masses with a hypodense central area that contains necrotic material and a peripheral rim of enhancement when there is a well-formed capsule [4]. Abscesses are most commonly located in the ischiorectal fossa and adjacent to stenotic bowel segments [10]. In 30–50% of cases, bubbles of gas as an air–fluid level within the abscess or dispersed through the collection can be observed (Fig. 3). This gas may be formed by bacteria, but often is secondary to a communication between the GI tract and the skin. If US-guided drainage is not possible, CT is the standard technique for guided drainage [11].

In contradistinction to abscess, a phlegmon is an ill-defined inflammatory mass in the mesentery or omentum. On CT scans it causes loss of definition of adjacent organs and a smudgy or streaky appearance of the adjacent mesenteric or omental fat [4].

Fistulae and sinus tracts affect approximately 20–40% of patients with CD. The involved sites are many: enteroenteric, enterocolic, colocolic, enterovesical, enterovaginal, enter-

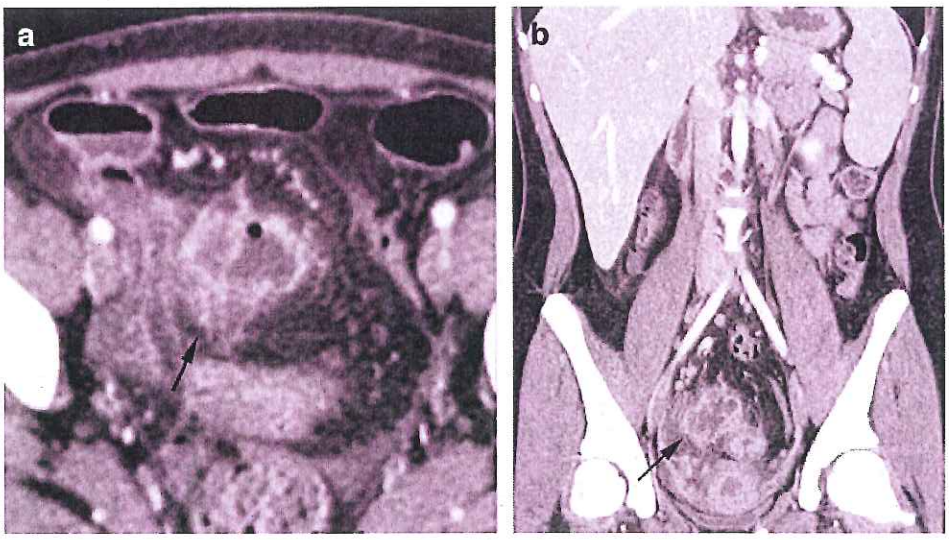


Fig. 3 A 14-year-old child with CD. Contrast-enhanced CT images (64-slice MDCT). **a** Pelvic abscess (*arrow*) with gaseous content surrounded by fibrofatty proliferation. **b** Coronal reformatted image shows the abscess (*arrow*) surrounded by bowel loops with circumferential wall thickening and the target sign

ocutaneous, anorectal, duodenopancreatic, gastrocolic, and, very rarely, colobronchial and enterospinal [12]. When surgical intervention is planned, CT imaging is a very useful diagnostic tool that is superior to conventional techniques in defining precisely the course and anatomic relationships of fistulae and sinus tracts.

A few recent studies in adults have investigated the correlation between signs of "radiologic visible intestinal inflammatory activity" and clinically evaluable disease activity as expressed by parameters such as endoscopic and biopsy findings, or laboratory parameters. Bodily et al. [13] have shown that quantitative measures of mural attenuation and wall thickness on contrast-enhanced CT enterography are strongly correlated with ileoscopy and histological findings, and are sensitive markers of bowel inflammation. Similar results have been reported by Choi et al. [14], and comparable results have been reported by Colombel et al. [15], who also stressed that evidence of fibrofatty proliferation correlates with high levels of C-reactive protein and thus with active inflammation.

The ability of CT to depict activity of CD, its lesions and complications, some of which might be otherwise undetectable with conventional techniques, emphasizes its critical role in the diagnosis and follow-up of patients. Furthermore, the availability of two- and three-dimensional reconstructions with helical multislice CT increases confidence in assessing the presence and extent of the disease. However, it is necessary to consider radiation dose. CD is a chronic condition that may require many radiological investigations over time with a resultant high cumulative dose, especially in children. In defining a protocol for abdominal CT in children, both radiologists and clinicians should realize that image quality is not the only aim when it is known that ionizing radiation may cause cancer in around 1/1,000 of children at a dose close to that of one CT scan. Reducing the dose undoubtedly causes a reduction in the signal-to-noise ratio; it is the radiologist's duty to accept as much noise as will still allow the specific study to be diagnostic [16]. Several scan parameters should be optimized to reduce dose in children. The kVp should be adapted to the diameter of the patient; a lower kVp often allows improved image quality at the same or even lower dose. The tube current (mAs) is the most critical parameter, with different settings suggested according to each scanner, the region to be studied and the age of the patient [17]. The shortest rotation time available should be used in children, as this serves to reduce motion artefacts. In modern scanners, the use of both xy-plane and z-axis dose modulation also plays an important role in dose reduction. A rule of thumb to reduce dose is to acquire relatively noisy thin slices and subsequently to reformat them into thicker images with a better signal-to-noise ratio [18].

$CDTI_w$ is a physical parameter that represents the CT dose index weighted for central and peripheral locations on a round phantom. It reflects the selection of scanning parameters during one rotation and is thus very useful for comparing the relative exposure due to different protocols. Similarly, $CTDI_{vol}$ is another CT dose index and is the ratio $CDTI_w$/pitch. Another fundamental parameter to characterize volume exposure is the dose-length product (DLP), which is the product of $CDTI_w$ or $CTDI_{vol}$ and the length of the scan. DLP can be translated into effective dose by means of factors and methods available in the literature [19]. Recently, the SFIPP (Société Francophone d'Imagerie Pédiatrique et Prénatale) reported acceptable values of $CTDI_{vol}$ and DLP in children imaged with abdominal multislice CT [20] (Table 1).

In March 2007 we acquired a 64-slice CT scanner (Somatom Sensation 64, Siemens, Erlangen, Germany), and we are currently optimizing our CT protocols. Our preliminary results in terms of $CTDI_{vol}$, DLP and effective dose in abdominal CT are shown in Table 1. A comparison

Table 1 Radiation doses in paediatric abdominal CT

Source	Age (years)	$CDTI_{vol}$ (mGy)	DLP (mGy.cm)	Effective dose (mSv)
SFIPP	1	4 (±1.5)	80 (±30)	
	5	5 (±2)	135 (±54)	
	10	7 (±3)	245 (±105)	
Personal experience	7	4.5	150	3
	14	8.6	344	5.2

between abdominal multislice CT and barium meal in children shows that the effective dose of abdominal multislice CT is five- to tenfold higher at least, considering the typical effective dose of a barium meal in children as 0.7 mSv [21].

The relatively high radiation exposure is a limitation to the use of CT enteroclysis in imaging CD in children, and, in fact, most data regarding this method come from studies in adults. Similarly, in our department we do not routinely undertake CT enteroclysis in children with CD. However, we prefer to perform CT when CD is complicated by abscesses and phlegmons because CT is faster and more easily available.

MRI

Lack of ionizing radiation, multiplanar imaging, and superior soft-tissue contrast make MR a potentially ideal technique for studying both the small and large bowel, particularly in children. However, until recently, MR imaging in IBD was impaired by motion artefacts and lack of good oral contrast agents. Nowadays, the availability of fast breath-hold sequences and suitable oral contrast agents has renewed interest in MR as an imaging modality in the study of the bowel [22, 23].

T2-weighted (T2-W) imaging is complemented in most cases by gadolinium-enhanced T1-weighted (T1-W) images in combination with fat saturation. An essential prerequisite for an adequate MR study is optimal distension of bowel loops in order to properly evaluate wall thickness and mural contrast enhancement. In MR enteroclysis, polyethylene glycol (PEG) solution has become a widely used contrast medium [23, 24] as it rapidly progresses along the bowel, is iso-osmotic, and is not absorbable. Furthermore, PEG is ideally suited to children as it can be orally administered thanks to its acceptable taste, thus avoiding the need of duodenojejunal fluoroscopic catheterization [25]. PEG is a biphasic oral contrast agent that produces a dark lumen on T1-W images and a bright lumen on T2-W images. Motion artefacts from bowel peristalsis can be avoided by intravenous injection, just before the examination, of *n*-butylscopolamine [25] or subcutaneous injection of glucagon [23]; both induce intestinal paralysis.

With the possible exception of distortion of mucosal folds, the early superficial lesions of CD are usually not consistently depicted by MRI enteroclysis due to its inadequate spatial resolution [23]. On the contrary, transmural abnormalities, including cobblestoning, thickening, stenosis, prestenotic dilatation and increased parietal enhancement, are well depicted by MRI (Figs. 4, 5, 6 and 7). MRI enteroclysis has an excellent ability to differentiate active inflammation from fibrosis in a thickened bowel segment. Koh et al. [26] observed in adults that the layered pattern of enhancement on gadolinium-enhanced T1-W images is highly specific for active disease. Similarly, bright bowel wall due to increased signal of water on T2-W sequences suggests disease activity. This distinction may have management implications in that the finding of a fibrotic stenosis suggests surgery while inflammation would prompt a more aggressive medical approach. Extramural manifestations and complications such as fibrofatty proliferation, comb sign, mesenteric lymph nodes, abscesses, fistulae and sinus tracts are easily detected (Figs. 8 and 9).

In both adults and children, MRI has been shown to be superior to CT and fistulography in assessing perineal complications of CD, as well as fistulae and sinus tracts, and avoids substantial radiation to the pelvis [27, 28]. Therefore, MRI has become a cornerstone in the evaluation of patients with perianal CD as it is noninvasive and accurate in depiction

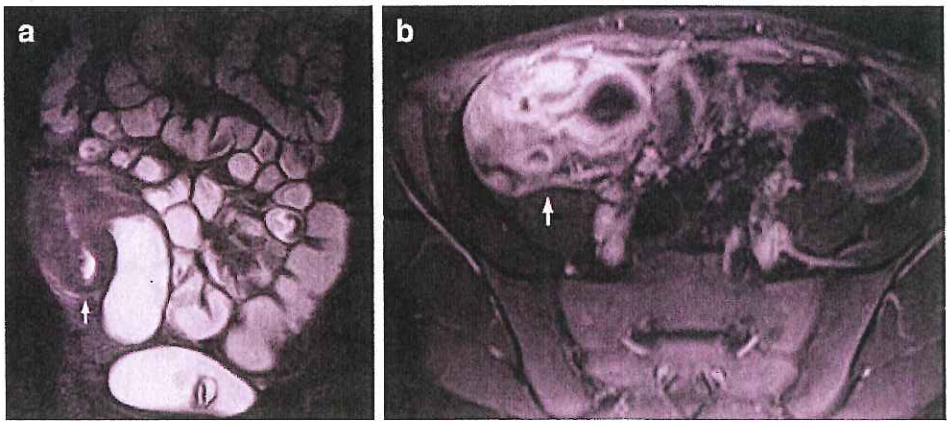


Fig. 4 A 15-year-old child with CD. MRI. **a** Coronal single-shot fast spin-echo T2-W image (EXPRESS) shows severe thickening of the caecal wall (*arrow*) and stenosis of the terminal ileum. **b** Axial T1-W RF spoiled FAST contrast-enhanced image shows marked thickening and intense contrast enhancement in the wall of the caecum (*arrow*) and terminal ileum

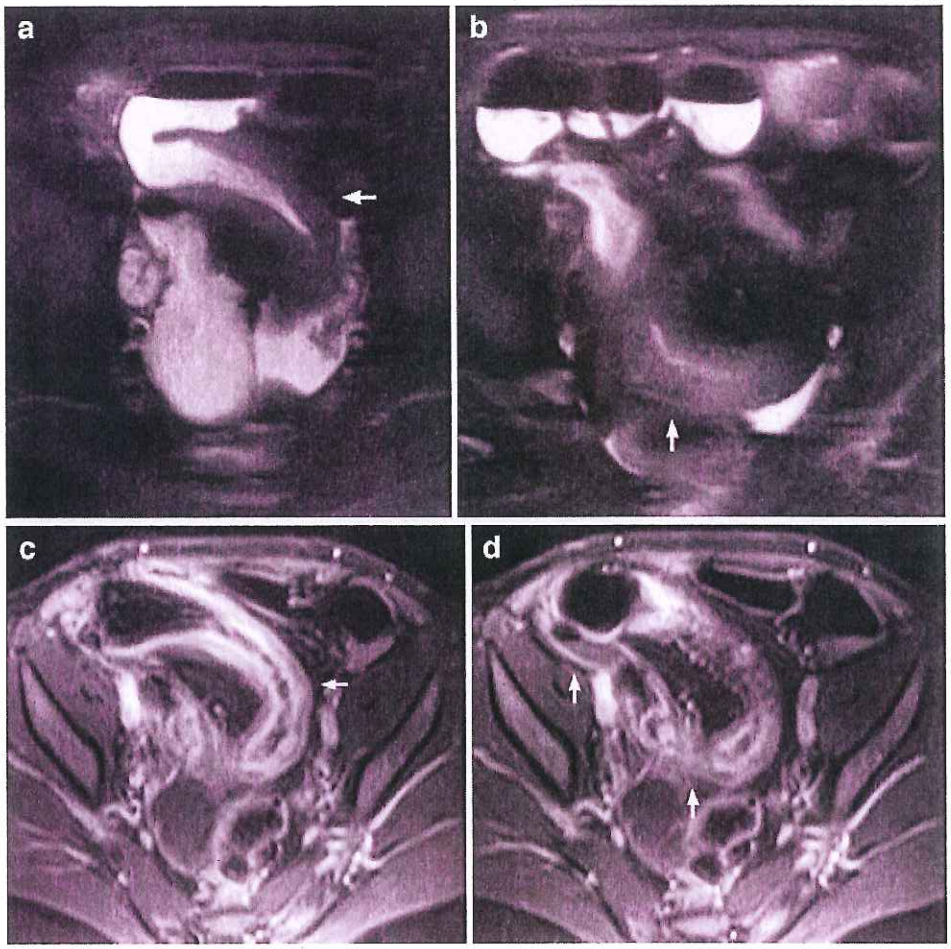


Fig. 5 A 14-year-old child with CD. MRI. **a, b** Axial single-shot fast spin-echo T2-W images (EXPRESS) show stenosis and wall thickening of the distal ileum (*arrows*) with preceding dilatation of the prestenotic segment. **c, d** Axial RF spoiled FAST contrast-enhanced images. The distal ileum shows wall thickening with stratified contrast enhancement (*arrows*); the mucosa of the bowel wall enhances more strongly than the other layers

of fistulae and abscesses (Figs. 10 and 11). For imaging of perianal CD, external phased-array coils are preferred to endoluminal coils as sinuses and fistulae are often complex and can continue outside the field of view of endoluminal coils. A nonangulated sagittal T2-W sequence is recommended at the beginning of the examination so that the axial and coronal sequences can be orientated perpendicular and parallel to the anal canal, respectively, with the advantage of imaging in surgically relevant planes [29].

The majority of studies concerning the role of MRI in chronic IBD reflect adult practice. A few studies have addressed the comparison between MRI and small-bowel enteroclysis [30, 31]. All these studies have shown markedly higher rates of fistula identification, with evidence in several patients of transmural and/or extramural abnormalities not shown with small-bowel enteroclysis only. Another recent study [32] compared MRI with small-bowel follow-through. MRI was able to provide

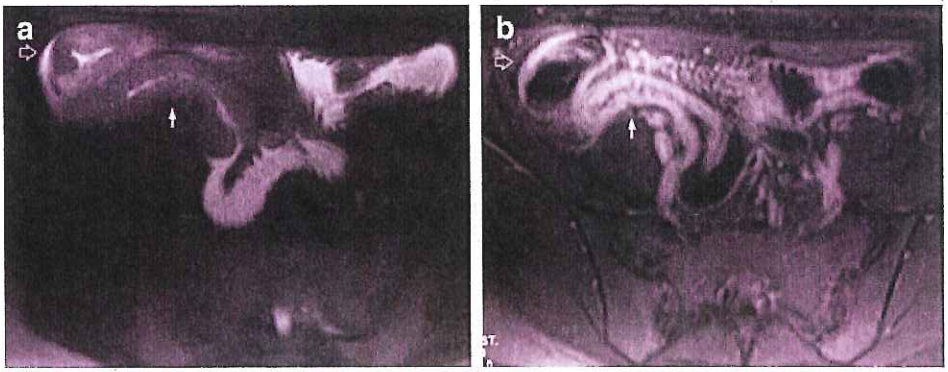


Fig. 6 A 16-year-old child with CD. MRI. **a, b** Axial single-shot fast spin-echo T2-W image (**a**) and axial RF spoiled FAST contrast-enhanced image (**b**) show wall thickening (marked contrast enhancement) of the terminal ileum (*white arrows*) and caecum (*white open arrows*)

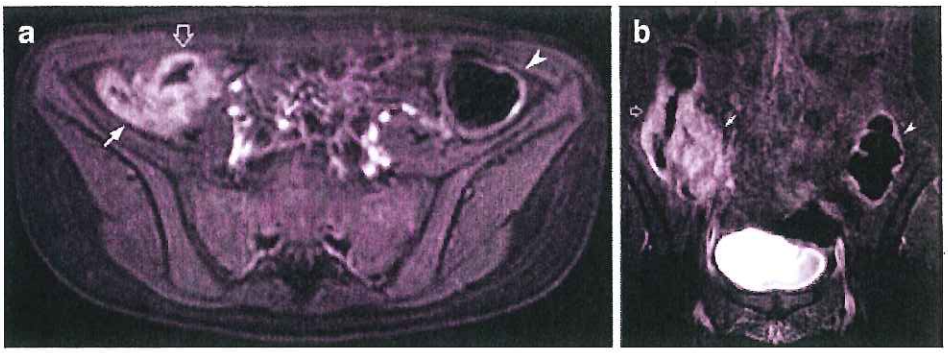


Fig. 7 A 16-year-old child with CD. MRI. **a**, **b** Axial (**a**) and coronal (**b**) gadolinium-enhanced 3-D gradient-echo (THRIVE) images show significant mural thickening with intense contrast enhancement of the terminal ileum (*arrows*) and caecum (*white open arrows*). Marked enhancement of the thickened descending colon is evident (**b** *arrowheads*)

enhanced information in several patients, including active inflammation in stenotic segments based on wall enhancement patterns, vasa recta changes, and lymphadenopathy.

There is just a single study in adults that compared MRI and multidetector spiral CT enteroclysis using well-defined imaging signs in terms of sensitivity, specificity and interobserver agreement [33]. The study included 55 consecutive patients. For bowel-wall thickening, pathological bowel-wall enhancement and lymphadenopathy, sensitivity and interobserver agreement were better with multidetector CT than with MRI, whereas specificity was comparable between the two methods. Sensitivity for intraperitoneal fluid was similar with both methods, with similar specificity and interobserver agreement. The authors of that study concluded that bowel lesions are better detected with multidetector CT thanks to its higher spatial resolution and faster acquisition time, although with the major drawback of a considerable radiation dose.

So far, only a few studies in children affected by chronic IBD have tried to correlate and validate the results of MRI with reference standards. Durno et al. [34] tried to determine whether MRI can differentiate CD from ulcerative colitis (UC) in a very limited number of patients, using ileocolonoscopy with biopsy as the reference. MRI was able to recognize UC in all four children affected, whereas their results in ten children with CD were very disappointing, MRI being able to recognize CD in only five. Furthermore, the degree of parietal enhancement in patients with CD did not correlate with the degree of inflammation determined at endoscopy. Recently, Laghi et al. [35] used MRI to study the terminal ileum in children with CD in order to correlate MRI findings with ileal endoscopy and histology, and with the paediatric CD activity index. Their results in 26 affected children showed a sensitivity and specificity of MRI of 84% and 100%, respectively. In addition, MRI findings correlated markedly with the paediatric CD activity index.

We recently reported our preliminary experience in assessing the ability of MRI enteroclysis to detect bowel abnormalities in children affected by CD. We studied 22 children with a known history of CD and verified the concordance between MRI findings and endoscopy, and B-mode and Doppler sonography. Our results showed that superficial lesions were not detectable with MRI, whereas the MRI findings of stenoses, bowel-wall thickening, bowel-wall hyperaemia, extramural lesions and complications were highly concordant with the findings of endoscopy and sonography. Therefore, our experience suggests that MRI is at least comparable with these techniques in detecting intra- and extramural manifestations of CD [25].

Initially, our MRI studies were carried out using a Marconi-Picker 1.5-T unit (Marconi-Picker, Cleveland, Ohio)

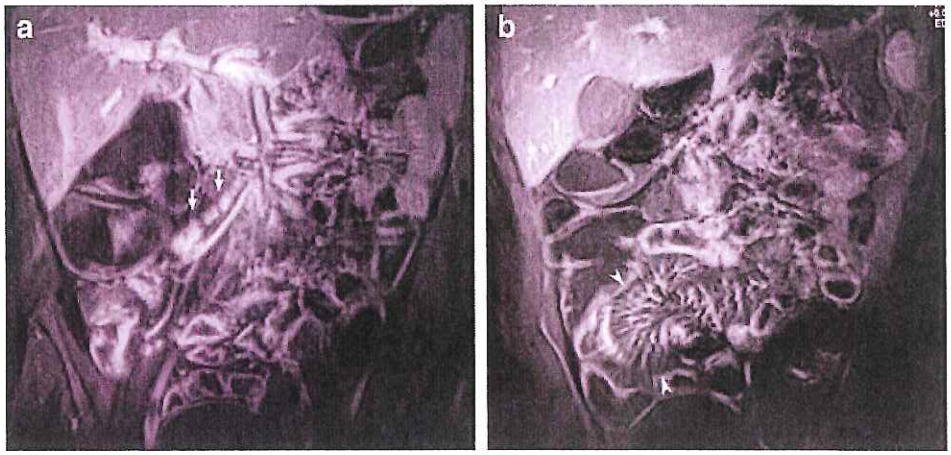


Fig. 8 A 15-year-old child with CD. MRI. **a**, **b** Coronal RF spoiled FAST contrast-enhanced images reveal enlarged mesenteric lymph nodes (*arrows*) and hypertrophied hypervascular mesentery (fibro-fatty proliferation) (*arrowheads*)

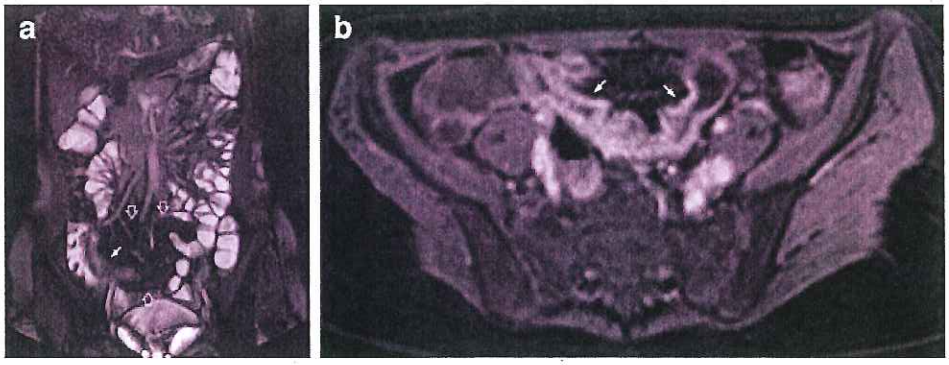


Fig. 9 A 15-year-old child with CD. MRI. **a** Coronal balanced fast-field-echo image shows thickening of the terminal ileum (*arrow*) and fibrofatty proliferation (*white open arrows*). **b** Axial gadolinium-enhanced 3-D gradient-echo (THRIVE) image shows thickened and intensely enhancing walls of the terminal ileum

with a maximum gradient field strength of 16 mT. Patients were studied in the supine position with a phased-array body coil. Breath-hold coronal and axial single-shot fast spin-echo T2-W sequences (proprietary name: EXPRESS) were followed, after intravenous injection of gadolinium chelate (0.3 mmol/kg) for contrast enhancement of the bowel wall, by spoiled gradient-echo (proprietary name: RF Spoiled FAST, *F*ourier *a*cquired *s*teady-state *t*echnique) breath-hold sequences. The lack of artefacts from magnetic susceptibility and bowel peristalsis potentially makes half-Fourier acquisition single-shot fast spin-echo T2-W sequence an ideal acquisition modality for evaluation of abdominal CD. However, a limitation of this sequence is its sensitivity to intraluminal flow voids and the lack of information on the mesentery due to K-space filtering effects [36].

Subsequently, we acquired a Philips 1.5-T Achieva unit (Philips, Best, the Netherlands) with a gradient field strength of 32 mT. For T2-W images, we used initially a single-shot technique (proprietary name: Single Shot Turbo Spin-Echo) with parallel imaging (proprietary name: SENSE). Although parallel imaging techniques allow shorter scan times with shorter breath-holds and a reduction in RF power, the signal-to-noise ratio is adversely affected [29]. For T2-W imaging, we currently use a completely refocused steady-state gradient-echo sequence (proprietary name: Balanced Fast Field Echo). This sequence produces contrast that is a function of the T1/T2 ratio for each tissue. As repetition time and echo time are extremely short, T1 is almost constant so the T1/T2 ratio reflects T2 differences in the tissue. Motion artefacts are minimal as a consequence of the short acquisition time, and there is no sensitivity to intraluminal flow voids thanks to the balanced and symmetrical gradient design. The balanced fast field echo sequence is very effective at showing the bowel wall, mesentery and lymph nodes [29]. For T1-W images, we presently use a T1-W 3-D gradient-echo technique (proprietary name: THRIVE, *T*1 *h*igh-*r*esolution *i*sotropic *v*olume *e*xcitation) and SENSE parallel imaging that provide increased through-plane and in-plane resolution with a higher signal-to-noise ratio than 2-D techniques [29].

Very recently there has been concern that intravenous administration of gadolinium chelates could be linked with the development of nephrogenic systemic fibrosis (NSF) in patients with severe renal function impairment [37]. The main hypothesis is that NSF might occur following systemic gadolinium dechelation causing intoxication with renal dysfunction at the core of this condition. Released gadolinium might overwhelm the cells of the phagocytic system, depressing the reticuloendothelial system and causing activation of a foreign body fibrous reaction. The delayed excretion of these agents in patients with renal impairment increases the contact time in the body and thus

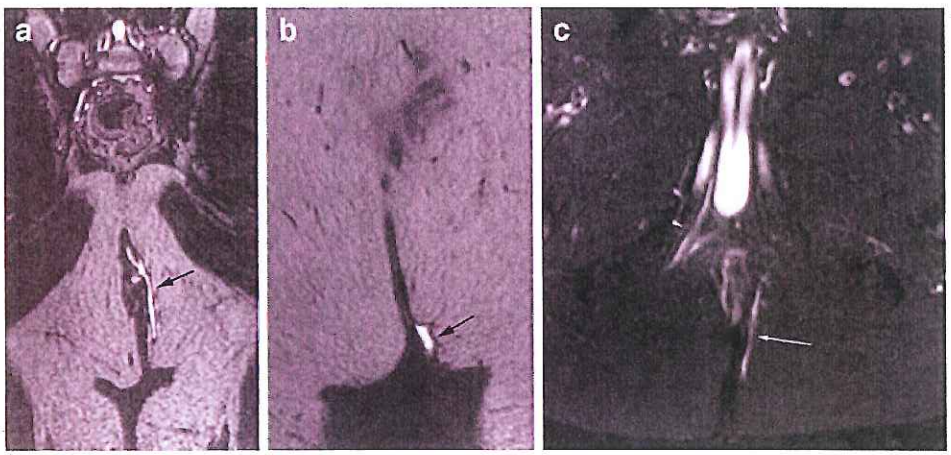


Fig. 10 A 13-year-old child with CD. MRI. **a**, **b** Coronal T2-W images show a transphincteric perianal fistula (*arrow*). **c** Axial T2-W fat-suppressed image demonstrates another fistula that extends superiorly into the right anterior recess of the ischioanal fossa (*arrowhead*)



Fig. 11 A 12-year-old child with CD. Coronal gadolinium-enhanced 3-D gradient-echo (THRIVE) MR image shows large abscesses throughout the ischioanal fossa with extension above the laevator ani. The rectum (*arrowhead*) is shifted to the right

the risk of adverse reactions. So far, in over 90% of all those with NSF linked to the use of gadolinium compounds, the NSF occurred after gadodiamide administration. However, there are single cases reports of NSF occurring after gadopentate dimeglumine and gadoversetamide administration. All these gadolinium chelates are characterized by a linear structure that appears to be less stable than the macrocyclic agents such as gadoteridol, gadobutrol and gadoterate meglumine in which Gd^{3+} is caged in a cavity with strong bonds. Therefore, free gadolinium ions might be released more readily from compounds with a linear structure, and this might favour the occurrence of toxic manifestations, although this is not yet proven [38]. Therefore, since April 2007 we have administered a macrocyclic compound such as gadoterate meglumine at a dose reduced from 0.3 mmol/kg to 0.1 mmol/kg (standard dose) and have not experienced significant deterioration of contrast enhancement. Furthermore, we screen kidney function with blood creatinine measurement in each patient in whom contrast-enhanced MRI is planned. Our present protocol for MRI enteroclysis is summarized in Table 2.

Conclusion

The literature on imaging of chronic IBD with CT or MRI has expanded rapidly in the past few years. In comparison with MRI, multidetector CT appears to have an unparalleled sensitivity and specificity in detecting the typical abnormalities of CD. However, the substantial radiation dose makes it an unsuitable method for repeated studies, especially in children. On the other hand, there is increasing evidence that MRI can reliably and accurately show most lesions of CD, with greater accuracy than barium radiographic studies for the detection of extraluminal complications including fistulae and abscesses. Furthermore, lack of ionizing radiation makes it an excellent modality particularly in children who may require repeated studies through their life. Nevertheless, no definite guidelines have been established concerning the role of cross-sectional techniques in children with chronic IBD. A very recent medical position paper from the ESPGHAN on recommendations for diagnosis of IBD in children concludes that MRI may be a promising modality but further validation studies are needed before drawing final conclusions.

Table 2 Authors' protocol for MRI enteroclysis

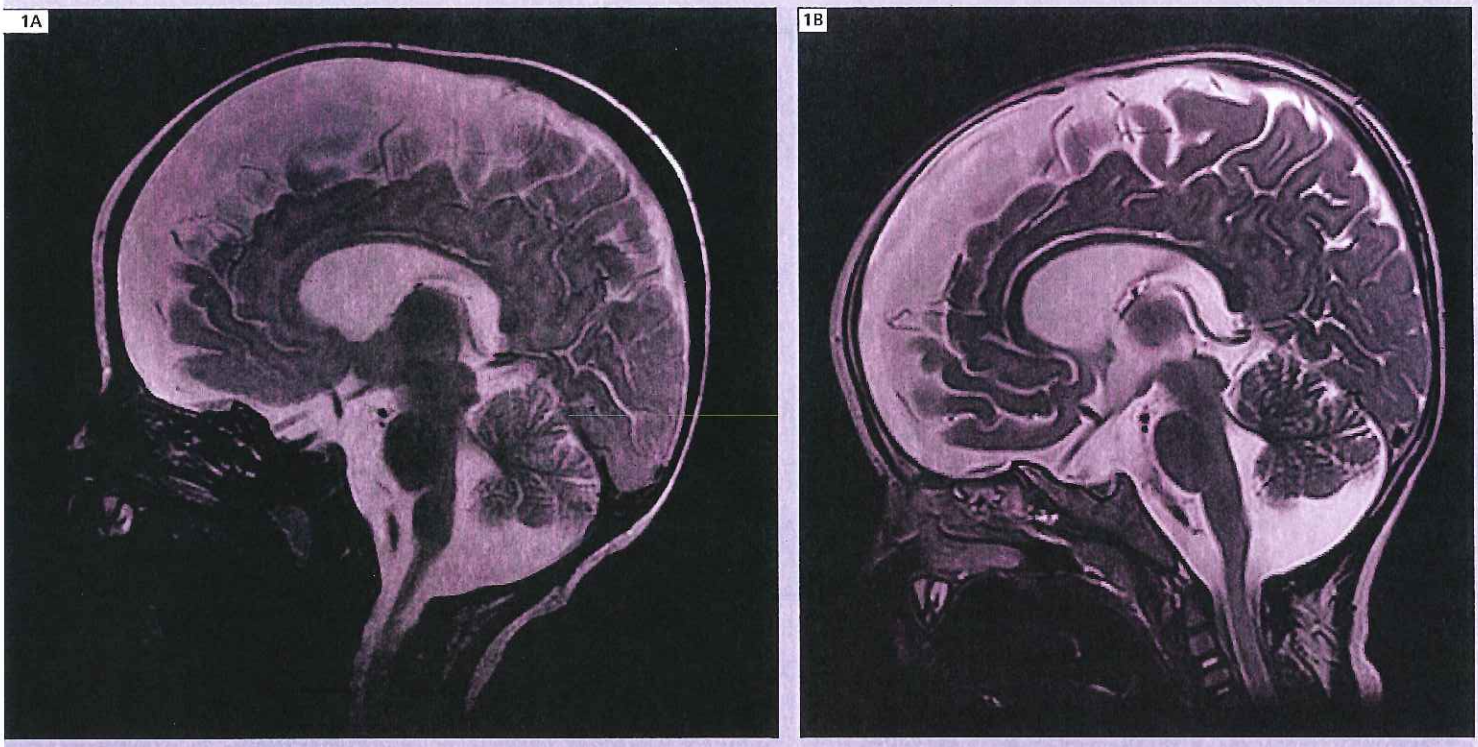
Stage	Protocol details	
Bowel preparation	Fasting	
	Empty bladder	
	Oral administration of 750–1,000 ml iso-osmotic polyethylene glycol solution, two-thirds 60 min and one-third 15 min before MRI	
	Intravenous administration of 10 mg (patient 8–14 years of age) or 20 mg (patient >14 years of age) of *n*-butylscopolamine to the patient when lying on the MRI table	
MRI study	Body coil, FOV 320 mm (variable according to body size), matrix 256×256	
	T2-W imaging	Axial and coronal completely refocused steady-state gradient-echo sequence (Balanced Fast Field Echo), slice thickness 4 mm, gap 0.4 mm
	T1-W imaging	Axial breath-hold T1-W 3-D gradient-echo technique (THRIVE) with parallel imaging, slice thickness 2 mm, gap 0 mm
	Contrast enhancement	0.1 mmol/kg of gadoterate meglumine (infusion speed 2 ml/s)
	Immediately after contrast medium administration	Two further acquisitions at 1-min intervals using THRIVE and parallel imaging
	After 5 min	Axial, breath-hold, THRIVE with parallel imaging

In our experience, MRI has proved to be a method at least complementary to endoscopy, sonography and barium studies. At our institution, MRI is now routinely performed at diagnosis to evaluate the small bowel in children for better evaluation of disease extension or during follow-up if there is sonographic evidence of relapse or complications, leaving CT and barium radiographic studies for just a very few selected cases.

In the future, the availability of stronger magnetic fields and gradients as well as more advanced reconstruction and acquisition algorithms could further improve resolution of subtle morphological changes that are presently not detectable in most cases, making MRI the preferred method for complete evaluation of the bowel.

References

1. Golberg HI, Caruthers SB, Nelson JA et al (1979) Radiographic findings of the National Cooperative Crohn's disease study. Gastroenterology 77:925–937
2. IBD Working Group of the European Society for Paediatric Gastroenterology, Hepatology and Nutrition (2005) Inflammatory bowel disease in children and adolescents: recommendations for diagnosis – the Porto criteria. J Pediatr Gastroenterol Nutr 41:1–7
3. Thiele J, Kloppel R, Schulz HG (1993) CT-Sellink – a new method of evaluating intestinal wall. Rofo 159:213–217
4. Gore RM, Balthazar EJ, Ghahremani GG et al (1996) CT features of ulcerative colitis and Crohn's disease. AJR 167:3–15
5. Bender GN, Timmons JH, Williard WC et al (1996) Computed tomographic enteroclysis: one methodology. Invest Radiol 31:43–49
6. Reittner P, Goritschnig T, Petritsch W et al (2002) Multiplanar spiral CT enterography in patients with Crohn's disease using a negative oral contrast material: initial results of a non-invasive imaging approach. Eur Radiol 12:2253–2257
7. Rollandi GA, Curone PF, Biscaldi E et al (1999) Spiral CT of the abdomen after distension of small bowel loops with transparent enema in patients with Crohn's disease. Abdom Imaging 24:544–549
8. Klein VHM, Wein B, Adam G et al (1995) Computed tomography of Crohn's disease and ulcerative colitis. Fortschr Rontgenstr 163:9–15
9. Meyers MA, McGuire PV (1995) Spiral CT demonstration of hypervascularity in Crohn disease: "vascular jejunization of the ileum" or the "comb sign". Abdom Imaging 20:327–332
10. Schreyer AG, Seitz J, Feuerbach S et al (2004) Modern imaging using computer tomography and magnetic resonance imaging for inflammatory bowel disease. Inflamm Bowel Dis 10:45–54
11. Horton KM, Corl FM, Fishman EK (2000) CT evaluation of the colon: inflammatory disease. Radiographics 20:399–418
12. Gore RM, Laufer I (1994) Ulcerative and granulomatous colitis: idiopathic inflammatory bowel disease. In: Gore RM, Levine MS, Laufer I (eds) Textbook of gastrointestinal radiology. Saunders, Philadelphia, pp 1098–1141
13. Bodily K, Fletcher J, Solem C et al (2006) Crohn disease: mural attenuation and thickness at contrast-enhanced CT enterography. Correlation with endoscopic and histologic findings of inflammation. Radiology 238:505–516
14. Choi D, Soon JL, Young AC et al (2003) Bowel wall thickening in patients with Crohn's disease: CT patterns and correlation with inflammatory activity. Clin Radiol 58:68–74
15. Colombel JF, Solem CA, Sandborn WJ et al (2006) Quantitative measurement and visual assessment of ileal Crohn's disease activity by computed tomography enterography: correlation with endoscopic severity and C reactive protein. Gut 55:1561–1567
16. Vock P (2005) CT dose reduction in children. Eur Radiol 15: 2330–2340
17. Frush DP (2002) Pediatric CT: practical approach to diminish the radiation dose. Pediatr Radiol 32:714–717
18. Vock P, Wolf R (2007) Dose optimization and reduction in CT of children. In: Tack D, Gevenois PA (eds) Radiation dose from adult and pediatric multidetector computed tomography. Springer, Berlin, pp 223–236
19. Chapple CL, Willis S, Frame J (2002) Effective dose in pediatric computed tomography. Phys Med Biol 47:107–115
20. Brisse H (2006) Guide des procedures radiologiques SFR/INRS Scanographie Pédiatrique. http://www.sfip-radiopediatrie.org
21. European Guidelines for the Optimisation of Fluoroscopic Imaging in Paediatrics (1999) Research contract FIP4-CT00092. Draft final report. DG XII, Brussels
22. Debatin JF, Patak MA (1999) MRI of the small and large bowel. Eur Radiol 9:1523–1534
23. Prassopoulos P, Papanikolau N, Grammatikakis J et al (2001) MR enteroclysis imaging of Crohn disease. Radiographics 21:161–172
24. Potthast S, Rieber A, von Tirpitz C et al (2002) Ultrasound and magnetic resonance imaging in Crohn's disease: a comparison. Eur Radiol 12:1416–1422
25. Magnano GM, Granata C, Barabino A et al (2003) Polyethylene glycol and contrast-enhanced MRI of Crohn's disease in children: preliminary experience. Pediatr Radiol 33:385–391
26. Koh DM, Miao Y, Chinn RJ et al (2001) MR imaging evaluation of the activity of Crohn's disease. AJR 177:1325–1332
27. Koelbel G, Schmiedl U, Majer MC et al (1989) Diagnosis of fistulae and sinus tracts in patients with Crohn disease: value of MR imaging. AJR 152:999–1003
28. Essary B, Kim J, Anupindi S et al (2007) Pelvic MRI in children with Crohn disease and suspected perianal involvement. Pediatr Radiol 37:201–208
29. Horsthuis K, Lavini C, Phil M et al (2005) MRI in Crohn's disease. J Magn Reson Imaging 22:1–12
30. Rieber A, Wruk D, Potthast S et al (2000) Diagnostic imaging in Crohn's disease: comparison of magnetic resonance imaging and conventional techniques. Int J Colorectal Dis 15:176–181
31. Ochsenkuhn T, Herrmann K, Schoenberg SO et al (2004) Crohn disease of the small bowel proximal to the terminal ileum: detection by MR-enteroclysis. Scand J Gastroenterol 39:953–960
32. Bernstein CN, Greenberg H, Boult I et al (2005) A prospective comparison of MRI versus small bowel follow through in recurrent Crohn's disease. Am J Gastroenterol 100:2493–2502
33. Schmidt S, Lepori D, Meuwly JY et al (2003) Prospective comparison of MR enteroclysis with multidetector spiral-CT enteroclysis: interobserver agreement and sensitivity by means of "sign-by-sign" correlation. Eur Radiol 13:1303–1311
34. Durno CA, Sherman P, Williams T et al (2000) Magnetic resonance imaging to distinguish the type and severity of pediatric inflammatory bowel disease. J Pediatr Gastroenterol Nutr 30: 170–174
35. Laghi A, Borrelli O, Paolantonio P et al (2003) Contrast enhanced magnetic resonance imaging of the terminal ileum in children with Crohn's disease. Gut 52:393–397
36. Masselli G, Brizi GM, Parrella A et al (2004) Crohn disease: magnetic resonance enteroclysis. Abdom Imaging 29:326–334
37. Grobner T (2006) Gadolinium – a specific trigger for the development of nephrogenic fibrosing dermopathy and nephrogenic systemic fibrosis? Nephrol Dial Transplant 21:1104–1108
38. Bongartz G (2007) Imaging in the time of NFD/NFS: do we have to change our routines concerning renal insufficiency? MAGMA 20:57–62



1 Longer TR and TE times are generally required when imaging very young children. The high water content in neonatal brains, coupled with the lack of fatty myelin results in a reduction in contrast-to-noise ratio (CNR) and grey/white matter differentiation. Restore pulses on T2w imaging can improve CSF contrast and allow shorter TR times to reduce scan time.

Techniques in Pediatric MRI – Tips for Imaging Children

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Royal Children's Hospital, Melbourne, Australia

Magnetic resonance imaging (MRI) examinations of children require a particular set of skills and expertise in order to successfully obtain diagnostic images with minimal distress to the patients and their family. There have been many developments in MRI in recent years, which have lead to a dramatic increase in the number and types of referrals we are now seeing for pediatric MR examinations. This paper provides an overview of the challenges that pediatric patients raise in the MR setting, and some of the different techniques that may be employed to overcome these difficulties. While some technical modifications are described, the focus is on practical recommendations that can assist young children to comply with the MR procedure, and minimize the use of anesthesia with this vulnerable population. Pediatric MR imaging can be considered a series of subspecialties. Each area, neurology, cardiac, MSK, oncology, all have their own subtle nuances that alter as patients mature. In our facility we routinely scan patients from the early fetal* stages right through to young (and not so young) adults with complex congenital conditions. Each of these fields, and stages of development requires their own specialized skills, knowledge, and equipment to be performed appropriately, however, there is a number of common challenges and techniques that apply to imaging pediatric patients.

Challenges of scanning children

Safety

MRI of children poses a number of specific safety issues with patient heating being the primary concern. Neonates and infants in particular have immature thermoregulation mechanisms, and higher core body temperatures making them particularly sensitive to RF heating effects [1]. These mechanisms are further affected by sedation and anesthesia common in pediatric imaging [2], or when babies are swaddled for imaging [1]. Children also have a greater surface area to weight ratio than adults. This means for a given weight we often need to expose a greater surface area of the patients to the RF field. This can lead to increased heating in children, and decrease their ability to dissipate this heat. There is intrinsic uncertainty in current specific absorption rate (SAR) predictions based on extrapolated data from phantom models [3] particularly due to factors such as body shape, size, composition, and position within the MR scanner. While definitive data on safety risks are not yet available, close monitoring of children, particularly critically ill or compromised infants, is desirable when using higher field strengths and high SAR scan techniques [1].
Anesthesia is an important safety consideration in pediatric MRI. While serious complications such as death are rare, there are significantly higher rates of morbidity, particularly amongst neonates, when compared to adult anesthesia [2]. Aside from adverse events there are a number of common side effects including nausea, vomiting, drowsiness and agitation upon awakening, which affect about one third of pediatric patients [2]. The challenge of monitoring patients in the MR environment coupled with the reduced ability for the patient to communicate adverse events creates significant additional risks [4]. If sedation is required, the associated risks need to be taken into account when deciding to image young children.

Anatomy

Normal structures in children are smaller than in the average adult. This creates a challenge both in terms of the available signal, and the limits of our scan resolution. Anatomy is further complicated by congenital anomalies and malformations as well as developmental changes [5].
At birth we are about 75% water and we dry out as we age to about 55–65% water for an average adult. This is best appreciated in the neonatal brain. The high water content, and lack of fatty myelin, requires an increase in TE on T2-weighted imaging to around 150–160 ms to improve contrast. With so much of the available hydrogen in loosely bound water, there often is not much to influence relaxation. The use of fast recovery (restore) pulses at the end of the echo train improves the signal-to-noise ratio (SNR) while allowing for shorter TRs to be used (Fig. 1).
T1 contrast can be particularly flat requiring an increase in TR to around 1,200 ms at 1.5 Tesla. The use of inversion recovery techniques, and magnetization prepared 3D imaging such as MPRAGE, are evident at many institutions, particularly at higher field strengths [5].

Pathology

Children are notoriously poor reporters of symptomatology, and their often vague and non-specific symptoms can belie the seriousness of their condition. Clinical examination is often very difficult, so MRI requests are seldom specific. There are many transient appearances on MR images that can be considered normal at some stages of development and abnormal at others. Recognizing the appearance of normal from abnormal development on MR images and determining the optimal sequences and factors to best display them presents a challenge to technologists with little pediatric experience.
An awareness of the conditions that are commonly found in the pediatric population is necessary to tailor scans appropriately.

Physiology

Pulse rate, blood flow, and respiration rates are considerably faster in children, with normal heart rates that can be in excess of 140 bpm and respiratory rates of 40/min [5]. Children typically find it difficult to satisfactorily hold their breath, creating significant challenges in cardiac,



2 Coronal PD-weighted image of an osteo-chondral defect (OCD) of the distal phalynx of the right toe.

chest and abdominal imaging. Increased flow rates lead to artifacts from blood vessels and cerebrospinal fluid (CSF) pulsations, creating difficulties with spine and Time-of-Flight (TOF) vessel imaging [5]. Differences and evolution in pediatric physiology may also lead wto changes in the mechanism of injury, or the types of injuries that occur in children, such as growth plate injuries and osteo-chondral defects (OCD) [6].

Behavioral

Sedation or anesthetic is commonly required for younger children or those with significant behavioral problems. Factors such as temperament, stress, pain, and illness play an important role in patient compliance, creating difficulties in establishing definitive age limits for identifying which children will require these procedures [7]. Encouraging children to co-operate for an MRI examination and identifying those who cannot are arguably the most significant challenges in pediatric MRI.

Techniques in scanning children without sedation

Preparation

At our institution we begin scanning without sedation from about five years of age, although some positive outcomes have been obtained with patients as young as three years. Adequate preparation of children for the MRI procedure has been vital in achieving these results. Our facility employs the services of educational play therapists who use a range of resources to assist children to comply with the procedure, such as brochures, MRI toys and storybooks, discussions with parents, and, most importantly, the 'mock MRI' procedure.

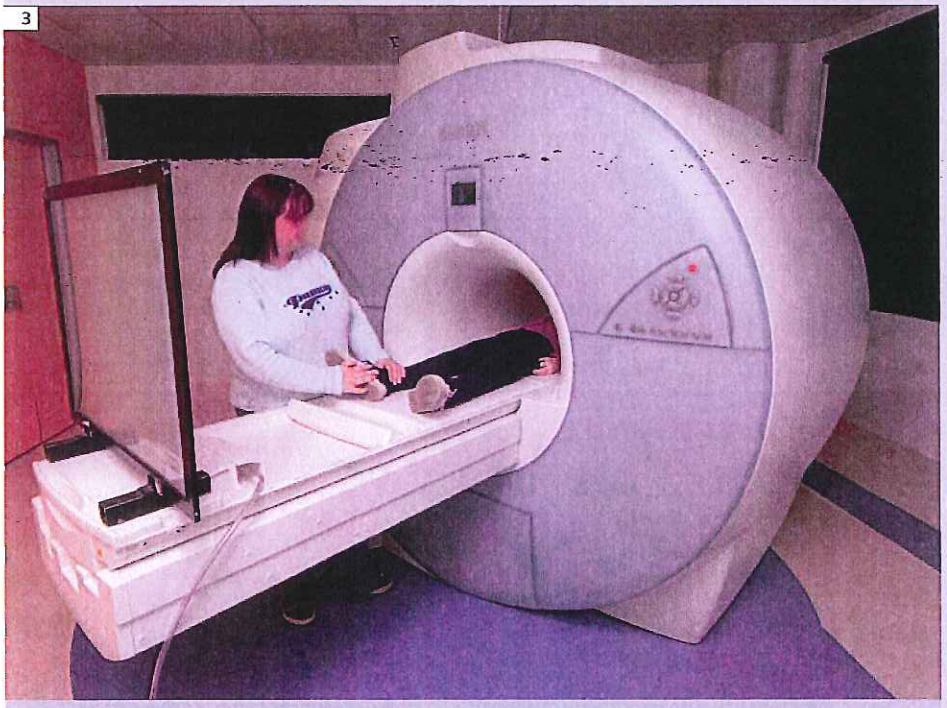
Simulation

The 'mock MRI' procedure involves children undergoing a simulated scan with the assistance of a play therapist prior to the actual diagnostic scan. It acts as both a screening tool, to assist in identifying children who are likely to be able to comply with the MRI procedure, and also helps to prepare these children, by familiarizing them with the environment, sounds, and equipment, while teaching them skills (such as breathing, relaxation, or distraction) to cope with the actual procedure (Fig. 2). Use of the 'mock' magnet has led to a marked reduction in the numbers of patients who have required anesthetic [7] and reduced the time required for the diagnostic scan [8]. Several pediatric facilities in various countries have introduced a mock procedure in their facilities in recent years [9].

Communication

Specialist staff and equipment are clearly helpful in assisting children to comply with an MR scan. However, for technologists, an awareness of how to talk to children and adolescents at different stages of development and the use of psychological techniques, such as distraction and relaxation, can be the critical factor determining whether a young person is willing, or able, to carry out the procedure. Many children are withdrawn or uncommunicative when nervous about a medical procedure, and taking the time to help the child to feel safe and secure in the environment is important. Compliance with preschool children may be facilitated by engaging in pretend play, where the child can be encouraged to frame the experience in familiar and nonthreatening ways [10]. Nonverbal communication comprises a significant proportion of a child's interaction with the world at this stage, and young children can pick up on their parents' anxiety or the technologist's impatience through nonverbal clues. They may not understand these feelings and can interpret them as anger or fear of the examination. Professionals who work with children typically take steps to ensure that both their verbal communication and body

3



3 Mock MRI simulator – this procedure identifies patients that are able to comply with the requirements of an MRI examination, as well as prepare them for the clinical scan, saving unnecessary appointments and valuable scanner time.

Table 1: Communicating with children

Engage with the child	Get down on their level	Use simple language	Maintain eye contact
Frame the experience	Help them verbalize their experience	Involve the child's past experiences / play	Smile
Empower the child	Offer limited choices	Praise good behavior	Be positive "I know you can do this"

language are reassuring and convey calmness and confidence (Table 1). Positive reinforcement, where the child is praised for their efforts at each step, can be very helpful.

School age children are able to engage more actively in the procedure, and may respond well to efforts to increase their perceived control. Medical examinations often take the locus of control away from the patient, and this is particularly true in pediatrics where someone else usually makes the decisions for the patient. Empowering children by offering some choice in how they can have the scan can be helpful. This is particularly important during adolescence; a period of rapid social and physical changes [10], when increased autonomy is important, yet can be hampered by serious illness. Adolescents are less likely than children or adults to blindly follow instructions, and may be reluctant to accept or comply with the scan in the absence of a flexible approach, where the technologist is sensitive to their concerns.

Distraction and relaxation

Distraction can be a powerful tool for reducing anxiety and increasing patient compliance. Distraction techniques can be either active or passive. Passive techniques such as audiovisual aids are useful during the scan when patients are required to lie still in the bore. Having a point of interest (such as a parent or video screen) is helpful in maintaining the patient in one position. Active techniques which require patient participation such as relaxation breathing, guided imagery, or complex puzzle tasks, are useful in relaxing children before MRI or performing interventions such as intravenous cannulation and general anesthetic (GA) inductions.

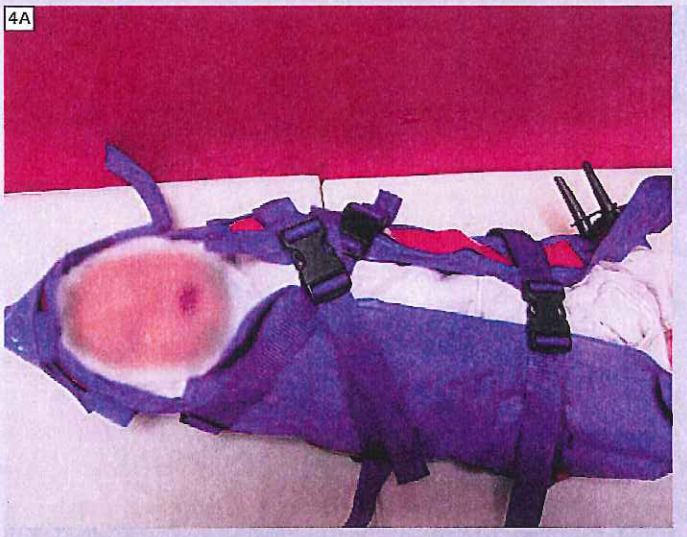
Successful use of intravenous (IV) contrast

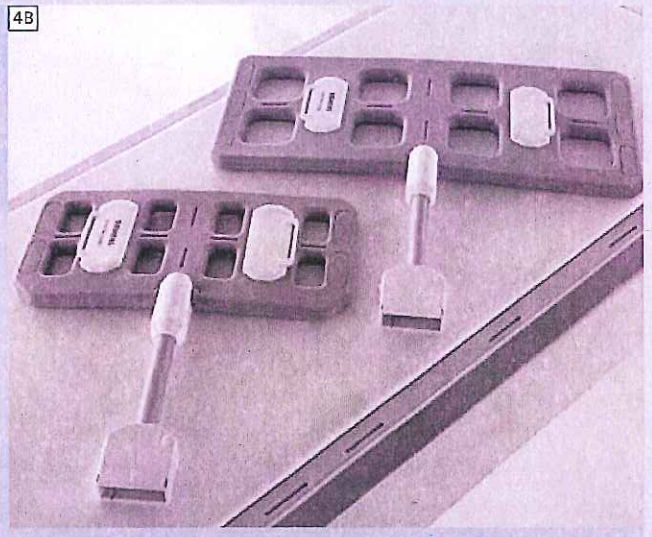
IV cannulation is a major cause of anxiety in young patients presenting for MRI examination. Limiting the use of IV contrast in pediatric examinations can often mean the difference between a successful awake scan and a rebook for sedation. This requires the support of the radiologists to make decisions regarding whether the benefits of contrast are worth the potential distress to the patient. Where contrast is necessary, it is often helpful to separate the procedures of IV placement and the MR exam by either placing the cannula before the examination or offering a break between the pre and post contrast scans. Many children respond well to being able to choose an IV site. Active distraction techniques can be helpful, and there are several aids available to assist with the pain, such as local anesthetic creams, ice, or nitrous oxide.

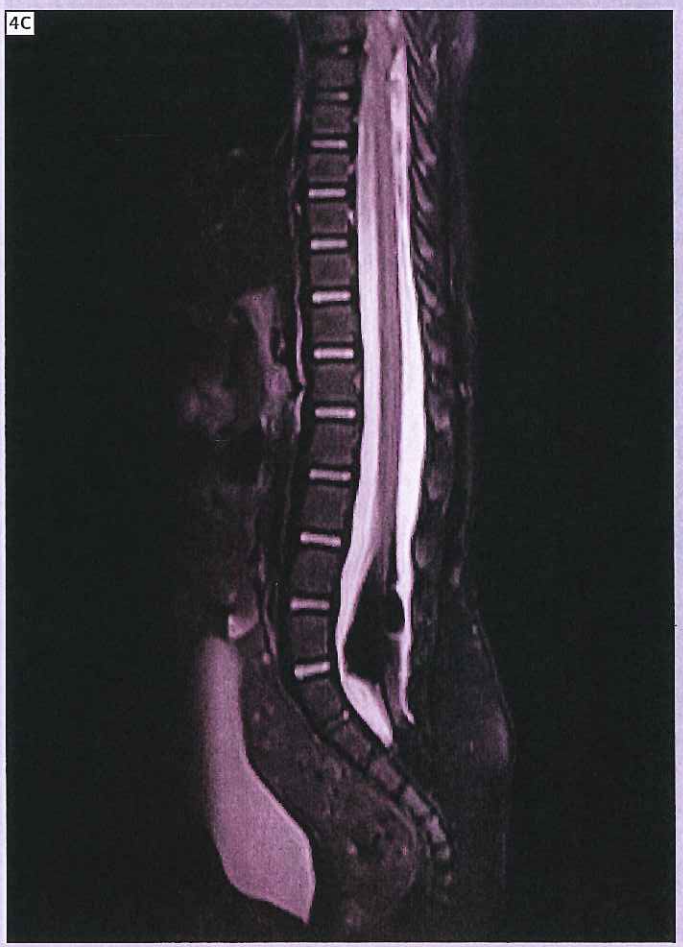
Protocols and sequences

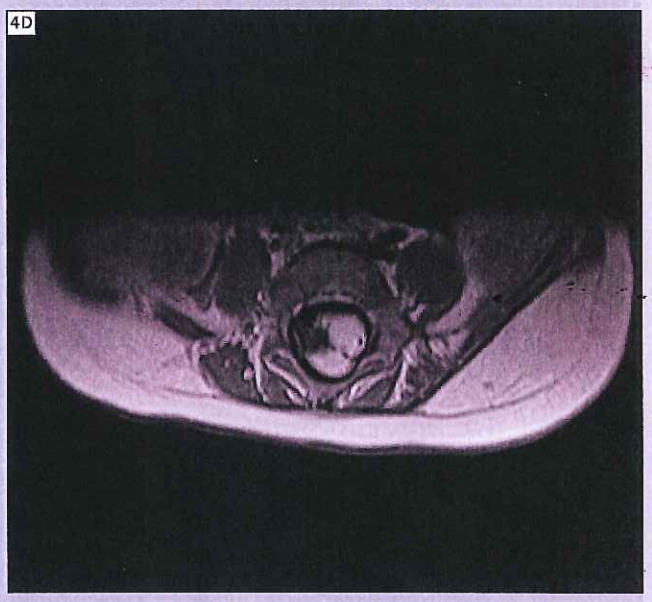
Protocol based scanning can be difficult in presenting pediatric patients, as the required sequences differ dramatically depending upon pathology, patient age, compliance, and the clinical questions being asked. It is often necessary for the technologist or radiologist to screen the examination as it progresses and tailor the sequences for the patient and pathology. A wide field-of-view scan can be helpful to obtain an overview to screen for other pathologies, particularly in children who are difficult to examine clinically. Children can be unpredictable in how long they will remain still, so it is important to prioritize sequences with the highest diagnostic yield such as T2, FLAIR, and diffusion. Scanning in multiple planes or using 3D sequences can help delineate disorders as well as minimize the chance of pathology being missed through partial voluming or interslice gap.

Often it is necessary to modify a protocol or sequence when imaging children of different sizes or capabilities. It is important to strike a balance between optimum image resolution and scan time.









4 Images of a 3-month-old child with a lipomatous tether of the spinal cord. The patient was scanned awake in a bean bag restraint **(4A)** using the 4-channel flex array **(4B)** positioned flat beneath. The high SNR afforded by this coil allowed high resolution thin slice imaging and the addition of iPAT to reduce scan time. Siemens Tim architecture allows flexibility to use coils in a number of orientations, or in combination with other coils, vital for imaging pediatric anatomy.

When modifying pulse sequences, the following suggestions may be helpful:

- Select pulse sequences that closely match the FOV required and the coil being used. The less changes you need to make to a sequence, the less chance for error.
- Concentrate on maintaining voxel size and signal-to-noise when changing field-of-view or matrix size, and consider using interpolation to maintain signal and resolution. The day optimizing throughput (Dot) engines on the newer Siemens scanners can be used to automate many of these decisions.
- Utilize recovery pulses, where available, to achieve reduction in TR times and to collect the images in multiple concatenations. When combined with interleaving this dramatically reduces the chance of crosstalk when using minimal slice gaps.
- Use the shortest TE that will maintain image contrast to boost signal and reduce image blur.

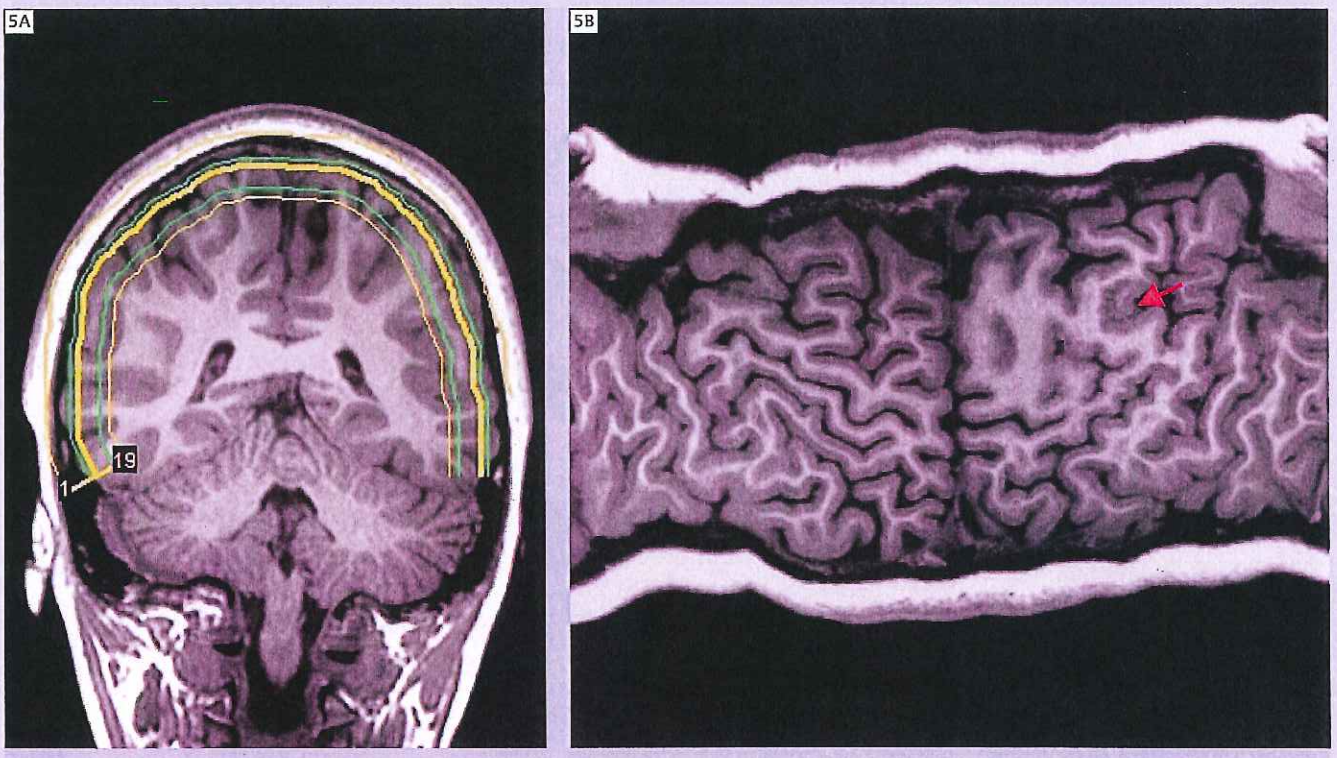
Scanning techniques

Coil selection

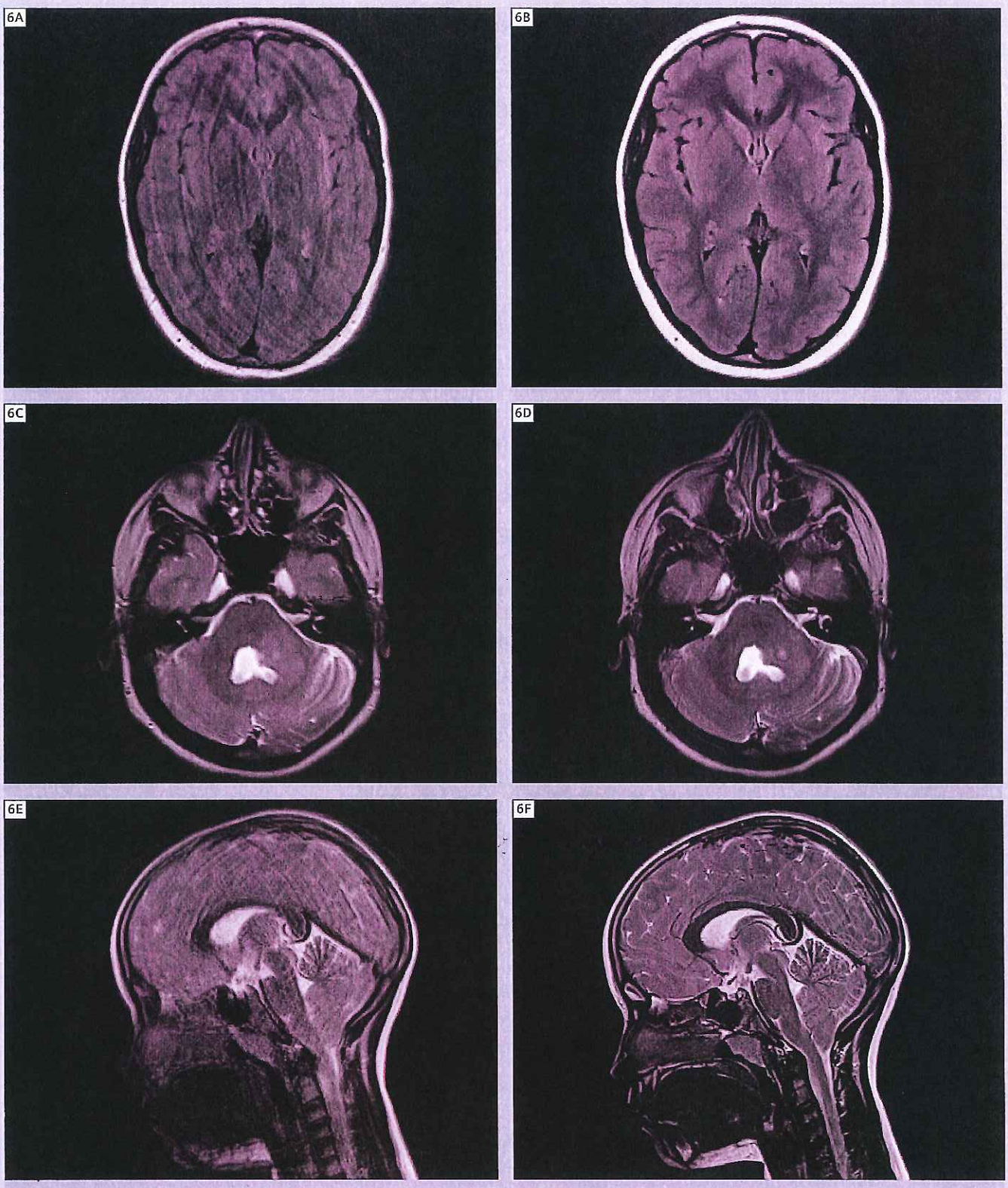
Novel uses of MR coils are possible and often necessary in pediatric imaging. Choosing a coil that closely matches the FOV you are imaging is important in extracting the maximum signal from your patients. Use of multichannel arrays is desirable when available to take advantage of parallel imaging techniques (Fig. 4).

Volume imaging

3D imaging can be utilized in all areas of the body. The use of 3D sequences permits reformatting, which can be helpful



5 Volume imaging: Reformatting of 3D imaging is useful in the investigation of complex congenital conditions. The curved reformat of the T1-weighted MPRAGE sequence allows appreciation of the disorganised left cerebral cortex, and helped in identification of a region of polymicrogyria which was the seizure focus in this 12-year-old girl.



6 Motion correction – *syngo* BLADE can be used to provide a limited study in uncooperative patients (**6A, 6B**), but is particularly useful in imaging posterior fossa lesions in pediatric patients where complex and high flow from CSF and vascular structures cause artifacts that may obscure some lesions (**6C, 6D**). High parallel imaging factors can also be utilised with multiple excitations to average out motion artifacts (**6E** None, **6F** PAT3).

in reviewing and diagnosing complex congenital conditions, and may reduce the number of 2D sequences performed. It allows for high resolution, no gap imaging which can be used to accurately measure lesion size, and monitor changes in follow up imaging (Fig. 5).

BLADE

Rotating k-space techniques are utilised in pediatric MR imaging to reduce artifacts from physiological motion in the brain, as well as other body areas such as the shoulder, chest, abdomen, and pelvis. It is particularly useful with younger patients scanned at 3T where complex and turbulent flow artifacts can mask pathology [11]. Recent studies show improvement in lesion conspicuity in the posterior fossa through reduction in pulsation artifacts [12]. Disadvantages of BLADE include increased scan time, altered image contrast, increased SAR, and reduction in sensitivity to some pathology, particularly haemorrhage [13]. Motion reduction with propeller sequences can be utilized to obtain limited diagnostic information in moving patients; however, their limitations restrict widespread use for correcting voluntary patient motion in pediatric patients (Fig. 6).

Parallel imaging

The advent of parallel imaging techniques and multiple element, phased array coils has transformed pediatric imaging in recent years, providing a boost in either signal or speed. Parallel imaging techniques combine signals from several coil elements to produce an image with increased SNR, or allow partial sampling to reduce scan time. The use of parallel image acceleration and multiple acquisitions can be used to average motion artifacts in pediatric imaging. Parallel imaging techniques can also be exploited to reduce the duration of breathhold imaging, allowing dynamic capture of fast moving pediatric anatomy. Parallel imaging also reduces inhomogeneity artifacts such as seen in diffusion-weighted imaging [14].

Time resolved angiography

When imaging arterio-venous malformations and vascular shunts it is important for treatment and management to identify feeder vessels as well as the direction of blood flow. Rapid heart rates and high flow rates in children often make imaging of complex vasculature difficult with traditional MR angiography techniques. Time resolved contrast-enhanced MR angiography (MRA) techniques can provide anatomical as well as functional assessment of these vascular conditions [14].

High field strength imaging (3T)

Higher field strengths offer the opportunity to address many of the difficulties encountered with pediatric MR imaging. The increased SNR allows for smaller voxels and increased resolution, or reduced averages for increased speed. Parallel imaging factors can be increased further reducing scan time. Prolonged T1 times facilitate better background suppression for MRA and improved visualization of paramagnetic contrast agents [5]. The advantages offered by higher field strengths have lead to the viability of several new techniques in pediatric MRI. Unfortunately, higher field strengths can also present a number of challenges. The increased field strength leads to greater RF deposition, resulting in increased heating (SAR), which can cause sequence limitation in pediatric imaging. B_1-field inhomogeneities, chemical shift, motion artifacts and susceptibility artifacts are more pronounced at higher field strengths. However, there are a number of new techniques, which offer potential to mitigate against these difficulties. Prolonged T1 relaxation at higher field strengths creates challenges in image contrast, particularly in the neonatal brain [5].

Emerging techniques in pediatric MRI

SWI

Susceptibility-weighted imaging is being increasingly utilized in pediatric patients for imaging trauma, vascular disease such as haemorrhage, telangiectasia, and cavernous and venous angiomas, tumors and epilepsy imaging, as well as investigating metabolic disorders (Figs. 7, 8). The use of the phase images can be used to differentiate calcification from haemhorrage in lesions [15].

Parallel transmit technology

The use of multiple coil elements to transmit part of the RF pulse results in shorter pulse durations, reductions in SAR, and corrections of patient-related inhomogeneities [16]. This addresses some major challenges of pediatric MRI, particularly at higher field strengths.

Diffusion Tensor Imaging

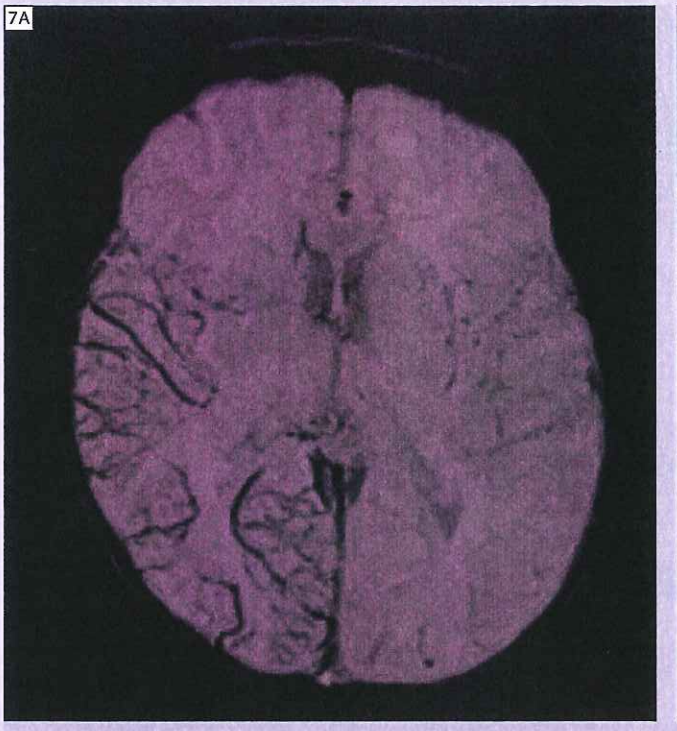
DTI has provided insights into connectivity and plasticity in the developing brain. It is now entering the clinical realm in the assessment of traumatic brain injury, epilepsy and white matter disease [14].

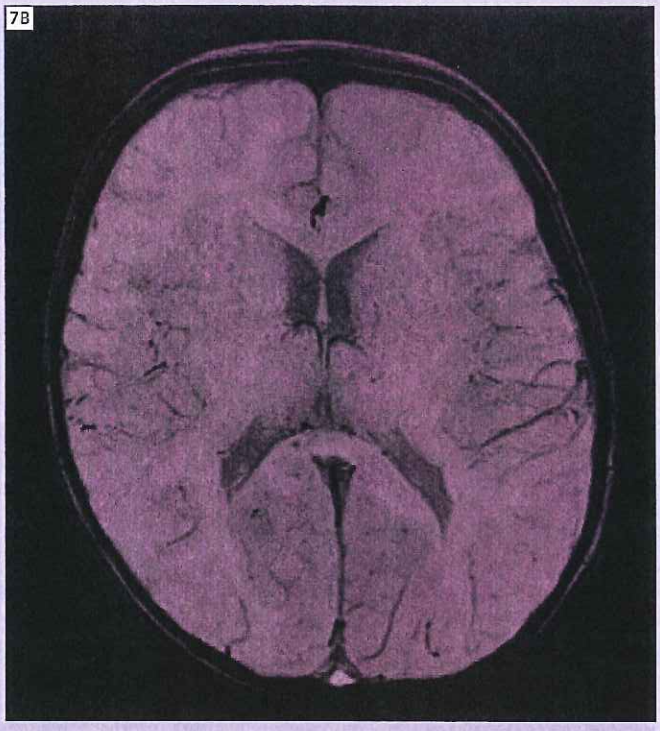
Arterial Spin Labeling

ASL provides functional information of blood perfusion by magnetically tagging inflowing blood upstream from the region of interest. Persistence of the 'tag' limits its use in adults; however, this is of less concern in pediatric patients, due to fast flows and relatively short perfusion distances [5]. This technique offers the potential to investigate regions of hypo- and hyper-perfusion, in conditions such as stroke or tumors, without the use of intravenous contrast media; however, further validation is required to demonstrate the clinical utility of this technique in pediatric patients [17].

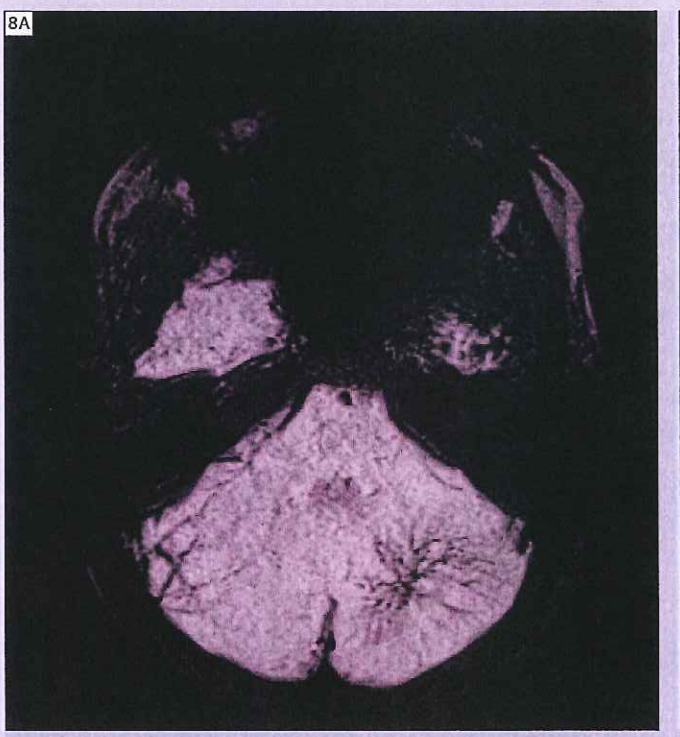
MR urography

Magnetic resonance urography provides both anatomical and functional assessment of the kidneys and urinary collecting system. The multi-planar capabilities



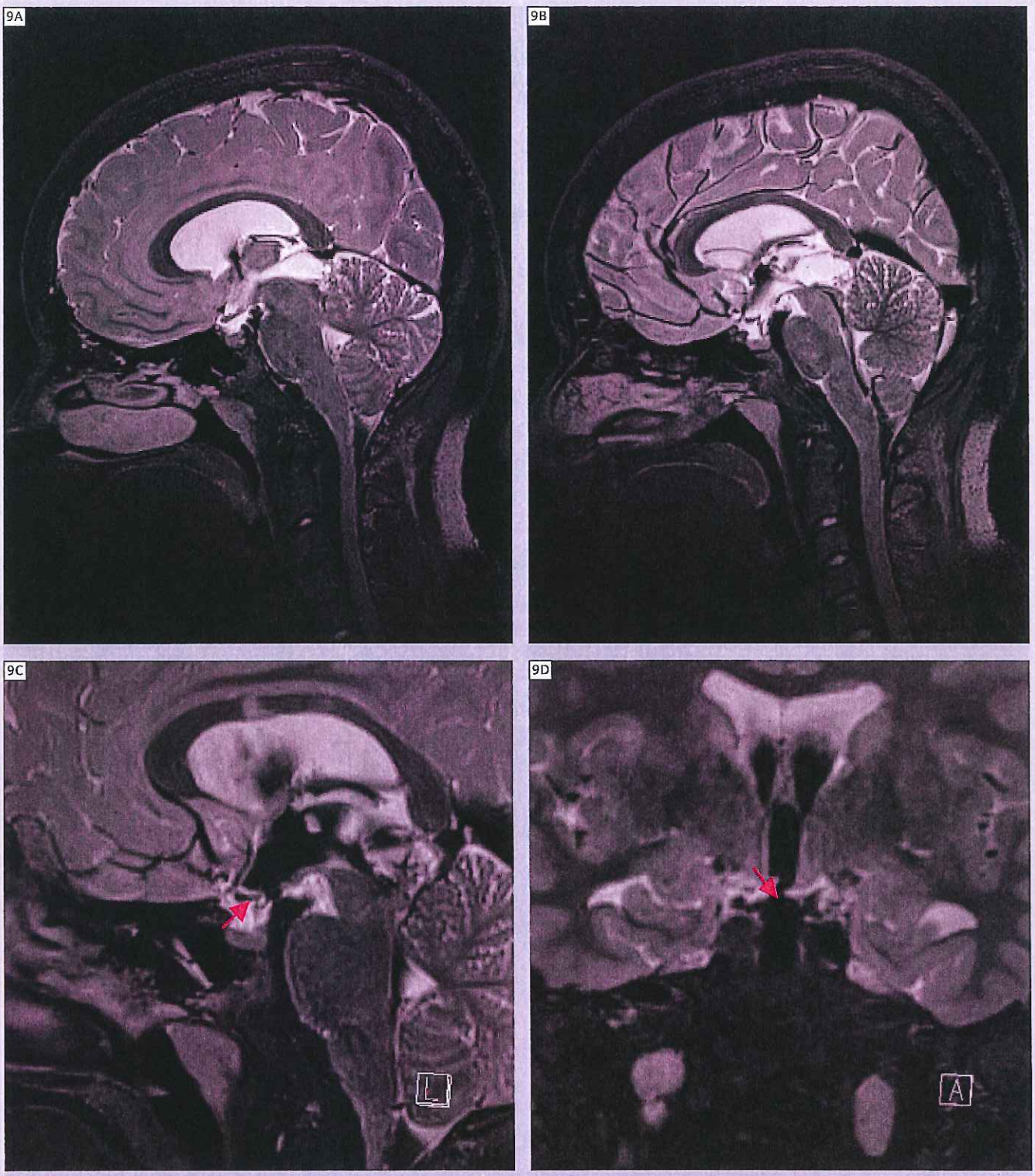


7 Images of a 1-month-old who presented with acute seizures. T2w, T1w and diffusion-weighted imaging were unremarkable. Susceptibility-weighted imaging **(7A)** shows increased venous drainage in the right temporal-parietal region. **(7B)** The same patient imaged 48 hours later after seizure control with phenobarbital showing normalization of the cerebral flow. The sensitivity of *syngo* SWI is being increasingly utilized in the pediatric population.





8 Venous angioma as imaged on *syngo* SWI **(8A)** and T2w sequences **(8B)**. The ability to obtain this level of detail has allowed us to reduce our reliance on intravenous contrast agents to delineate these lesions.



9 These images are of a patient with a pineal cyst causing obstruction of the cerebral aqueduct with associated enlargement of the lateral and third ventricles. The sensitivity to flow of the T2w SPACE sequence can be used to demonstrate the obstruction in the pre surgical images **(9A)** as well as the increased retrograde flow through the foramen of Monro. The post surgical image **(9B)** shows the reduction in the size of the cyst as well as the restored flow to the cerebral aqueduct. The 3D sequence can be easily reformatted to show the site of the fenestration of the third ventricle **(9C, 9D** arrows). Third ventricultomies have been traditionally difficult to demonstrate with standard 2D and phase contrast imaging, however, with a single 3D acquisition we can now easily answer all of the questions of the neurosurgeon.

of MRI are ideal for displaying complex congenital anomalies of the genito-urinary tract. This information can be used to predict outcome and select patients that are most likely to benefit from surgical intervention [18].

MR enterography

Crohn's disease is a serious and lifelong condition affecting the digestive system. It affects primarily the ileum and colon causing inflammation, ulceration and can lead to abscess formation or fistulae to other organs. Approximately 30% of patients with Crohn's disease will present before the age of 20. MRI provides the ability to diagnose and monitor this condition as well as complications such as peri-anal fistulae without exposing the patient to radiation [19].

Conclusion

Magnetic resonance imaging referrals for children continue to rise. The lack of ionizing radiation coupled with the high level of detail afforded by MR imaging has made it the examination of choice for a growing number of pediatric presentations. Most children who require magnetic resonance imaging will be examined in specialist pediatric centers or hospitals; however, heightened pressure on specialist centers has lead to many children being scanned in non-specialist facilities where technologists may have little experience in pediatric imaging. These referrals need to be treated differently to standard adult imaging requests in order to ensure diagnostic imaging with minimal distress and intervention to the patient. There is no 'one size fits all' approach to imaging children and pediatric MRI requires dedicated specialist knowledge, flexibility, and expert input from the technologist. An awareness of the challenges in pediatric MRI and experience in pediatric imaging techniques is vital to successful examination in this population. MRI in children can be extremely challenging physically, mentally, and emotionally, even for a seasoned pediatric technologist; however, these very challenges are also what make pediatric imaging such an interesting and rewarding field for MR technologists.

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References

1 Machata AM, Willshke H, Kaban B, Prayer D, Marhofer P (2009) " Effect of Brain MRI on Body Core Temperature in Sedated Infants and Children" British Journal of Anaesthesia 102(3):385-9.
2 Cohen MM, Cameron Cal B, Duncan PG (1990) "Pediatric Anesthesia Morbidity and Mortality in the Perioperative Period" Anesthesia and Analgesia 70"160-7.
3 Homman H, Bornert P, Eggers H, Nehrke K, Dossel O, Graesslin I (2011) "Toward individualised SAR models and in vivo validation" Magnetic resonance in Medicine doi: 10.1002/mrm.22948.
4 Serafini G, Ongaro C, Mori A, Rossi C, Cavalloro F, Tagliaferri C, Mencherini S, Braschi A (2005) "Anesthesia for MRI in the Pediatric Patient" Minerva Anesthesiology Jun 71(6) 361-6.
5 Dagia C, Ditchfield M. (2008) "3T MRI in paediatrics: Challenges and clinical applications" European Journal of Radiology doi:10.1016/j.ejrad.2008.05.019.
6 Hussain HM, Barnes CE (2007) "Pediatric skeletal trauma- Plain film to MRI" Applied Radiology 36(8):24-33.
7 Carter AJ, Greer ML, Gray SE, Ware, RS (2010) "Mock MRI: reducing the need for anaesthesia in children" Pediatric Radiology Aug;40(8):1368-74.
8 de Amorim e Silva,C.T.J., Mackenzie,A., Hallowell,L.M., Stewart, S.E., Ditchfield, M.R. (2006) "Practice MRI: Reducing the need for sedation and general anaesthesia in children undergoing MRI" Australasian Radiology 50(4),319-323.
9 Hallowell, L.M., Stewart, S.E., de Amorim e Silva, C.T., Ditchfield, M.R. (2008) "Reviewing the process of preparing children for MRI" Pediatric Radiology 38(3), 271-279.
10 Gable S (2010) "Communicating effectively with children" University of Missouri, Columbia, Outreach and Extension information sheet.
11 Vertinsky AT, et al. (2009) "Performance of PROPELLER relative to standard FSE T2-weighted imaging in pediatric brain MRI" Pediatric Radiology. Oct;39(10):1038-47.
12 Von Kalle T, et al. (2010) "Diagnostic Relevant Reduction of Motion Artifacts in the Posterior Fossa by *syngo* BLADE Imaging" MAGNETOM Flash 43(1/2010):6-11.
13 Forbes KP, et al. (2003) "Brain Imaging in the Unsedated Pediatric Patient: Comparison of Periodically Rotated Overlapping Parallel Lines with Enhanced Reconstruction and Single-Shot Fast Spin-Echo Sequences" American Journal of Neuroradiology 24:794-798.
14 Shenoy-Bangle A, Nimkin K, Gee MS (2010) "Pediatric Imaging: Current and Emergent Trends" Journal of Postgrad Medicine 56:98-102.
15 Zhen Wu, Sandeep Mittal, Karl Kish, Yingjian Yu, J. Hu, Mark Haake (2009) "Identification of Calcification with Magnetic Resonance Imaging Using Susceptibility-Weighted Imaging: A Case Study" Journal of Magnetic Resonance Imaging 29(1): 177-182.
16 Wald LL, Adalsteinsson E (2009) "Parallel Transmit Technology for High Field MRI" MAGNETOM Flash 40(1/2009):124-135.
17 Chen J, et al. (2009) "Arterial Spin Labelling Perfusion MRI in Pediatric Arterial Ischemic Stroke- Initial Experiences" Journal of Magnetic Resonance Imaging February; 29(2) 282-290.
18 Grattan-Smith JD, Jones R (2008) "Magnetic resonance urography in Children" Magnetic Resonance Imaging Clinics of North America 16 515-531.
19 Sinha R (2009) "Role of MRI in Chron's disease" Clinical Radiology 64 (4):341-352.

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*MR scanning has not been established as safe for imaging fetuses and infants under two years of age. The responsible physician must evaluate the benefit of the MRI examination in comparison to other imaging procedures.

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SPECIAL REPORT

Guidelines for imaging infants and children with recent-onset epilepsy

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Summary

The International League Against Epilepsy (ILAE) Subcommittee for Pediatric Neuroimaging examined the usefulness of, and indications for, neuroimaging in the evaluation of children with newly diagnosed epilepsy. The retrospective and prospective published series with n ≥30 utilizing computed tomography (CT) and magnetic resonance imaging (MRI) (1.5 T) that evaluated children with new-onset seizure(s) were reviewed. Nearly 50% of individual imaging studies in children with localization-related new-onset seizure(s) were reported to be abnormal; 15–20% of imaging studies provided useful information on etiology or and seizure focus, and 2–4% provided information that potentially altered immediate medical management. A significant imaging abnormality in the absence of a history of a localization-related seizure, abnormal neurologic examination, or focal electroencephalography (EEG) is rare. Imaging studies in childhood absence epilepsy, juvenile absence epilepsy, juvenile myoclonic epilepsy, and benign childhood epilepsy with centrotemporal spikes (BECTS) do not identify significant structural abnormalities. Imaging provides important contributions to establishing etiology, providing prognostic information, and directing treatment in children with recently diagnosed epilepsy. Imaging is recommended when localization-related epilepsy is known or suspected, when the epilepsy classification is in doubt, or when an epilepsy syndrome with remote symptomatic cause is suspected. When available, MRI is preferred to CT because of its superior resolution, versatility, and lack of radiation.

KEY WORDS: Epilepsy, Imaging, Children, Infants.

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For the purposes of this discussion, localization-related epilepsy refers to simple partial, complex partial, and secondarily generalized epilepsy, and is often alternately called focal or partial epilepsy. The etiology for the localization-related epilepsies may be "remote" symptomatic (e.g., a past historical event, such as ischemia or encephalitis, or an underlying structural abnormality, such as a brain tumor), idiopathic (genetic), or cryptogenic (nonlesional, symptomatic cause is suspected but not confirmed). The idiopathic (genetic) epilepsies may be primary generalized (e.g., juvenile absence) or localization related [e.g., benign childhood epilepsy with centrotemporal spikes (BECTS)]. Some of the catastrophic pediatric epilepsy syndromes in which generalized seizures are prominent such as infantile spasms and Lennox-Gastaut syndrome, may have a symptomatic cause.

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Here we propose guidelines for imaging children with newly diagnosed epilepsy. We confine our discussion to children with afebrile seizures and those in whom acute symptomatic causes have been excluded (such as hyponatremia, meningitis). We also exclude evaluation of children with neonatal seizures. We presume that electroencephalography (EEG) will be obtained to assist in establishing the diagnosis of seizures, characterizing syndromes, and providing prognosis (King et al., 1998; Hirtz et al., 2000; Jallon et al., 2001). The role of advanced imaging techniques—including specialized structural magnetic resonance (MR) imaging, high-field magnetic resonance imaging (MRI), magnetic resonance spectroscopy (MRS), functional MRI (fMRI), positron emission tomography (PET), and single photon emission computed tomography (SPECT)—for the evaluation of the child with catastrophic (recent, abrupt onset, frequent, associated with developmental arrest, and difficult to control) or medically refractory epilepsy for whom epilepsy surgery is a consideration will be the topic of a later document. Prior guidelines have primarily focused on adults with epilepsy and the evaluation of patients considered for epilepsy surgery (Recommendations for neuroimaging of patients with epilepsy, 1997; Guidelines for neuroimaging evaluation of patients with uncontrolled epilepsy considered for surgery, 1998). The role of imaging in the setting of the first unprovoked afebrile seizure has recently been reviewed (Hirtz et al., 2000); here we update that discussion based on MEDLINE search and focus on recent-onset epilepsy, but also include imaging data on children with new-onset seizures (Bernal & Altman, 2003). We provide guidelines for optimal care, but acknowledge that these may not be practicable or readily available especially when resources are scarce.

It is important to stress that few studies have prospectively examined substantial pediatric epilepsy populations with a primary view to evaluate imaging (Wang et al., 1997; King et al., 1998; Berg et al., 2000; Shinnar et al., 2001; Chang et al., 2002). Aside from studies in emergency departments where CT is the imaging modality of choice (McAbee et al., 1989; Warden et al., 1997; Garvey et al., 1998; Maytal et al., 2000; Chang et al., 2002; Sharma et al., 2003), none have sought to define indications for MRI and thus are uncontrolled studies and do not meet criteria for class 1 studies (Landfish et al., 1992; Gibbs et al., 1993; Bronen et al., 1996; Caraballo et al., 1997; Harvey et al., 1997; Garvey et al., 1998; Guidelines for neuroimaging evaluation of patients with uncontrolled epilepsy considered for surgery, 1998; King et al., 1998; Kramer et al., 1998; Berg et al., 2000; Hirtz et al., 2000; Jallon et al., 2001; Chang et al., 2002; Kuzniecky & Knowlton, 2002; Bernal & Altman, 2003; Gelisse et al., 2003; Eltze et al., 2005; Korff & Nordli, 2005). Table 1 lists prospective and retrospective studies since 1989 that incorporate some form of imaging using CT and/or MRI that involve more than 30 children. Studies that include patients evaluated before 1989 do not include current MRI technology with 1.5 Tesla. It is uncertain at present to what extent 3 Tesla MRI or higher strength magnets will affect clinical imaging practices and standards. Important for childhood epilepsies is recognition of the high incidence of "idiopathic" epilepsies in contrast to localization-related epilepsy and epilepsy syndromes that may have a remote symptomatic cause (Stroink et al., 1998; Shinnar et al., 1999; Berg et al., 2000, 2001a; Jallon et al., 2001; Arts et al., 2004).

Most published pediatric imaging studies are directed toward evaluation of the first seizure and are targeted to identify an acute symptomatic cause such as febrile illness (encephalitis, meningitis), trauma, or central nervous system (CNS) hemorrhage that will influence immediate treatment. These studies principally assess the utility of CT; MRI, when performed, is typically obtained on a selected subset of these children. These studies are instructive, as children with recently diagnosed epilepsy are likely to have a similar spectrum of static findings indicating remote cause, and some will have subacute etiologies, such as tumor, vascular malformation, or vasculitis that warrant change in medical/surgical management. Approximately one-third of children in studies from emergency departments who are evaluated for a "first" seizure will be recognized as having epilepsy. These studies show that CT identifies clinically relevant abnormalities in 7–24% of children but alters immediate medical management in only a minority. These studies also suggest that it is possible to identify children who are unlikely to benefit from CT imaging: older than 2 years, generalized seizures, normal examination, and either generalized EEG abnormalities or normal EEG (McAbee et al., 1989; Warden et al., 1997; Garvey et al., 1998; Maytal et al., 2000; Chang et al., 2002; Sharma et al., 2003).

Imaging is most often abnormal in children with localization-related or remote symptomatic epilepsy. In contrast, imaging in the typical idiopathic generalized epilepsies is normal (see subsequent text). Close to 50% of imaging studies in children with localization-related new-onset seizures/epilepsy will be abnormal; 15–20% will provide useful information on etiology and focus, and 2–4% will alter immediate medical management (King et al., 1998; Berg et al., 2000; Shinnar et al., 2001; Chang et al., 2002). It is rare to find a significant imaging abnormality in the absence of a history of a localization-related seizure, abnormal neurologic examination, or focal EEG. Infants may be a higher risk population, as it is unusual for infants to have a primary generalized epilepsy; rather they are more likely to have a localization-related epilepsy, an epileptic syndrome with remote symptomatic cause, or metabolic disorder (Korff & Nordli, 2005). Furthermore, infants are more likely to have focal malformation of

Table 1. Summary of imaging studies involving substantial children and adolescents, for evaluation of first seizure and epilepsy; listed by year, and whether prospective or retrospective studies; only King and Wang set out to systematically evaluate MRI as a primary aim

Study	Age	Design	Epilepsy	Location	Number	CT (abnormal)	MRI (abnormal)
Sztriha et al., 2002	c	Prospective	TLE	Community	30	NA	30 (13/10*)
Chang et al., 2002	c/t	Prospective	1st seizure	ED	712	653 (156/77*)	390 (191 /108*)
Shinnar et al., 2001	c/t	Prospective	1st seizure	Community	412	159 (35)	59 (20)
Berg et al., 2000	c/t	Prospective	All seizures	Community	613	197 (NA)	388 (80/62*)
King et al., 1998	c/t/a	Prospective	All seizures	Clinic	300	>42 (NA)	263 (35*)
Wang et al., 1997	c	Prospective	Partial epilepsy	Clinic	300	128 (NA)	300 (125)
Harvey et al., 1997	c	Prospective	TLE	Community	63	48 (11/10*)	58 (23 /22 *)
Sharma et al., 2003	c/t	Retrospective	1st seizure	ED	500	475 (38*)	NA
Maytal et al., 2000	c/t	Retrospective	1st seizure	ED	66	66 (14)	NA
Al-Sulaiman & Ismail, 1999	c	Retrospective	New dx epilepsy	Community	263	162 (64/23*)	NA
Kramer et al., 1998	c/t	Retrospective	Partial epilepsy	Clinic	143	101 (NA)	42 (NA)
Stroink et al., 1998	c/t	Prospective	1st seizure	Clinic	156	112 (12)	NA
Garvey et al., 1998	c/t	Retrospective	1st seizure	ED	107	107 (19)	NA
Warden et al., 1997	c/t	Retrospective	1st seizure	ED	203	203 (25)	NA
Resta et al., 1994	c/t	Retrospective	Partial epilepsy	Clinic	111	98 (20)	111 (57)
Gibbs et al., 1993	c/t	Retrospective	1st seizure	Clinic	157$	121 (26/19*)	NA
Landfish et al., 1992	c/t	Retrospective	1st seizure	ED	56	23 (0)	2(0)
McAbee et al., 1989	c/t	Retrospective	1st seizure	ED	101	101 (7)	NA

c, child; t, teen (adolescent); a, adult; ED, emergency department; dx, diagnosis; TLE, temporal lobe epilepsy; NA, not available.

* clinically significant (for those that note clinical significance).

Comments:

King: 59 children (20%) sample; of the total, 35 were clinically significant. 26/154 (17%) partial, 9/59 unclassified (CT with no MRI) added two more; CT missed 12 of 28 abnormal MRIs; 19 had tumor or vascular malformation and so changed medical management.

Warden: 30% of patients were febrile.

Garvey: Eight ultimately not seizures, 49 provoked (including fever), 50 unprovoked.

McAbee: 80 afebrile, 21 complicated febrile (one with abnormal imaging study had fever).

Resta: 30 with normal CT had abnormal MRI.

Wang: >30 children treatable disease: tumor, vascular malformation, vasculitis; another 35 focal cortical dysplasia/mesial temporal sclerosis (MTS).

Chang: 38 patients with abnormal MRI had normal CT.

Stroink: CT abnormalities mostly nonspecific (e.g., atrophy).

Gibbs: Identified 964 children and teens who had EEG, 182 had a single seizure, 530 had epilepsy; they report on 157 with (persistent) focal EEG.

Harvey: CT and MRI both identified tumors and dysplasia, CT did not identify any MTS, but did identify calcification not seen on MRI presumed to be hamartoma in one child.

cortical development (MCD) as a cause of seizures than are older pediatric populations (Vanderver et al., 2003).

Reasons for Structural Neuroimaging

Structural neuroimaging plays an important role in the evaluation, management, and treatment of the child with epilepsy. The role of neuroimaging is to detect an underlying cerebral lesion(s) that may be causally related to the child's seizure disorder or associated neurodevelopmental impairment. Imaging is obtained to establish etiology, to provide prognosis, and to plan appropriate clinical care. For example, children with remote symptomatic localization-related epilepsy have a poorer prognosis than children with idiopathic or cryptogenic epilepsy (Shinnar et al., 1994; Sillanpaa et al., 1998; Berg et al., 2001b; Arts et al., 2004). However, which patients require neuroimaging, when imaging should be obtained, and the optimal imaging modality are often debated.

Imaging early in the course of epilepsy is directed at identifying an etiology for seizures that requires other medical or surgical attention. It is important to bear in mind the distinction between:

1 Identifying an abnormality on an imaging study that is nonspecific (e.g., periventricular leukomalacia, atrophy).
2 Identifying (or confirming) static remote lesions (e.g., porencephaly, MCD).
3 Finding a focal lesion responsible for the seizures that does not require immediate intervention but would be potentially amenable to epilepsy surgery (e.g., focal cortical dysplasia or mesial temporal sclerosis).

4 Finding a subacute or chronic process that has therapeutic implications [e.g., requires more immediate intervention (brain tumor), or that has important diagnostic or prognostic implications (e.g., leukodystrophies, metabolic disorder)].
5 Identifying an acute process that requires urgent intervention (e.g., hydrocephalus, acute stroke or hemorrhage, encephalitis, metabolic cytopathy) or need for additional urgent diagnostic evaluation and counseling.

The last two of these reasons provide the impetus for imaging after the first seizure; the others may be reserved for once the diagnosis of epilepsy is established.

Indications for Structural Neuroimaging

Imaging is most useful for children with a suspected or confirmed localization-related or remote symptomatic generalized epilepsy. Early in the course of epilepsy it may be difficult to decide whether a child has a localization-related epilepsy. Therefore, it is proposed that children with epilepsy undergo neuroimaging if one or more of the following are present (Table 2):

1 If there is any evidence to suggest the epilepsy is localization related (e.g., focal), with the exception of typical benign idiopathic partial epilepsy (see subsequent text). The basis for establishing localization-related seizures includes the characteristics of the seizure, abnormalities on EEG, focal examination (including Todd's paralysis), and history or examination to suggest remote symptomatic cause (such as extreme prematurity, meningitis, encephalitis, complicated febrile convulsion, or significant head injury).
2 Abnormal neurologic examination, including focal deficits, stigmata of neurocutaneous, cerebral malformation syndrome, or a history of significant developmental delay, arrest, or regression.
3 Children younger than 2 years, excluding those with simple febrile seizures.
4 Children with characteristics of a symptomatic generalized epilepsy syndrome, including infantile spasms or early Lennox-Gastaut syndrome (e.g., tonic, atonic, mixed seizures), as focal MRI findings may be found in a substantial proportion of these children.
5 Failure to control seizures, worsening seizures, changes is seizure manifestations, or developmental regression also merit neuroimaging if not previously performed.
6 Finally, new-onset seizures/epilepsy presenting with evidence for a medical emergency such as increased intracranial pressure or status epilepticus always merit emergency imaging.

Table 2. Summary of populations who do and do not warrant imaging

Imaging indicated	Imaging not indicated
Localization related seizures[a]	Childhood absence epilepsy
Focal history, abnormal exam, focal EEG abnormalities[a]	Juvenile absence epilepsy
Developmental regression	Juvenile myoclonic epilepsy
<2 years old	BECTS
Symptomatic generalized epilepsy syndrome	
Increased intracranial pressure	
History of status epilepticus	
Atypical course for BECTS/IGE	

[a]Except for BECTS.

Situations Where Imaging May Not Be Necessary

A substantial proportion of children with newly diagnosed epilepsy have an idiopathic focal or generalized epilepsy (King et al., 1998; Stroink et al., 1998; Shinnar et al., 1999; Berg et al., 2000; Jallon et al., 2001). The natural history of these syndromes has resulted in their "benign" designation: they are outgrown, readily treated, and not associated with neurologic deterioration, and imaging is unremarkable (Loiseau et al., 1983, 1988; Shinnar et al., 1994; Sillanpaa et al., 1998). Recent imaging data at 1.5 T supports the absence of significant imaging abnormalities when the clinical presentation is typical, the neurologic examination is normal, and characteristic electrographic features are present (King et al., 1998; Berg et al., 2000) (Table 2). These include BECTS, childhood absence epilepsy (CAE), juvenile absence epilepsy (JAE), and juvenile myoclonic epilepsy (JME). Although approximately 15% of the patients with BECTS exhibit abnormal MRI, the structural abnormalities found do not influence the favorable prognosis of the epilepsy (Gelisse et al., 2003). Similarly, a study using statistical MRI maps of gray matter provides evidence for the existence of structural abnormalities in idiopathic generalized epilepsy (Woermann et al., 1998), especially in JME (Woermann et al., 1999). However, MRI is normal in all of the patients with IGE in whom routine visual analysis of MRI has been performed (King et al., 1998; Berg et al., 2001a; Wieshmann, 2003), provided patients have not experienced focal seizures or focal spikes on EEG (Berg et al., 2000). There is a cautionary note: Because some nonidiopathic epilepsies may sometimes mimic these idiopathic epilepsy syndromes, MRI is recommended in these patients if they present any atypical features such as abnormal neurologic or intellectual development, difficult-to-treat seizures, or unusual course. There is insufficient evidence to comment on the role of not imaging in other less common "benign" or generalized epilepsies and which may be difficult to differentiate from symptomatic epilepsies [e.g., other idiopathic focal epilepsies (childhood epilepsy with occipital paroxysms), primary reading epilepsy, and

idiopathic generalized epilepsies (benign neonatal convulsions, benign myoclonic epilepsies of infancy and epilepsy with seizures precipitated by specific modes of activation)] (Caraballo et al., 1997).

Recommendations for Imaging

MRI is considered the imaging modality of choice because of superior anatomic resolution and characterization of pathologic processes (Table 1). CT confers some advantages with regard to identifying blood and calcification (as found in congenital infection). Studies in adults with childhood-onset epilepsy and in children in both recent-onset and chronic epilepsy find that MRI identifies more abnormalities than CT. Furthermore CT does not identify abnormalities found on MRI (Resta et al., 1994; Bronen et al., 1996; Wang et al., 1997; Berg et al., 2000; Shinnar et al., 2001; Chang et al., 2002; Kuzniecky & Knowlton, 2002). MRI will identify focal cortical dysplasia, mesial temporal sclerosis, small tumors (such as oligodendrogliomas and gangliogliomas), and vascular malformations (AVM, cavernous angioma); CT will not or may not identify these. However, CT is more widely available than MRI, is less expensive, and is less likely to require sedation for younger children.

Therefore, a minimum standard is to use history, examination, and EEG to characterize the epilepsy in order to identify patients with BECTS or IGE in whom imaging is not useful versus those with a localization-related epilepsy for whom imaging is likely to be abnormal and contribute to establishing cause and identify the seizure focus. CT with and without contrast can be performed on these patients if MRI is not available, recognizing that some symptomatic causes for epilepsy—such as MTS, small tumors, small or subtle focal cortical dysplasia—will not be identified. When resources are very limited an argument can been made to obtain imaging when a trial of one or two medications has been ineffective. There are no data, however, upon which to base this supposition. Identifying a static lesion will not affect immediate medical therapy. In this setting, imaging is pursued to identify children in need of surgical intervention, such as tumor or vascular malformation, and to identify children with other medical conditions that require intervention or evaluation of other organ systems (e.g., tuberous sclerosis), although here the diagnosis can often be established by other clinical features and laboratory examination. Here MRI remains superior to CT, but CT serves as a screening modality. MRI would be performed if there were persistent seizures, a deteriorating neurological examination to define abnormalities found on CT, or, if resources are available, when there is clinical suspicion of a focal process.

There is no agreement on specific imaging protocols or specifics of the MRI sequences proposed, but there is general agreement that the following be performed (Bronen et al., 1996): An anatomic, thin-slice volumetric T_1-weighted gradient-recalled-echo sequence, axial and coronal T_2-weighted sequence, fluid attenuated inversion recovery (FLAIR) sequence (axial, and coronal if possible), and high resolution oblique coronal T_2-weighted imaging of the hippocampus (fast or turbo spin echo weighted sequence). Maximal slice thickness should not exceed 4–5 mm. In cases of focal epilepsy, thinner slices (2 or 3 mm) or else three- dimensional (3D) volume acquisitions (with thickness of 1–2 mm) may be necessary to identify or characterize subtle cortical malformations. There is debate, and there are limited data, about the utility of newer sequences such as magnetization transfer imaging and diffusion tensor imaging. When metabolic disorders are suspected MRS may be helpful.

Children younger than 2 years require special sequences, as immature myelination affects the ability to identify common causes of epilepsy. Lesions may "appear" or "disappear" with the changing pattern of myelination, they may be seen as "enhanced myelination" indicative of areas of possible cortical malformation, and may not appear on scans acquired at an older age (Sankar et al., 1995; Takanashi & Barkovich, 2003; Eltze et al., 2005). In addition to a 3D dataset, imaging in children younger than 2 years should include sagittal, axial, and coronal T_1-weighted sequences. Volumetric T_1-weighted sequences are less useful before age one year due to incomplete myelination on T_1 sequences. MR imaging (especially high-resolution T_2 images) performed early in the first year of life in infants with epilepsy is important to identify areas of cortical or subcortical dysplasia, which can become difficult to identify after myelination. Conversely, if MR imaging before the age of 2 years is normal, and seizures persist, then MRI may be repeated at 6-month intervals, and certainly after age 24–30 months when more mature myelination can reveal otherwise unsuspected cortical dysplasia. Repeat imaging in older children is a topic for the evaluation of chronic epilepsy and is not considered here.

Gadolinium contrast is reserved for circumstances where tumor, vascular malformations, inflammation, and infectious concerns arise or are suspected based on review of noncontrast studies. Routine administration of Gadolinium contrast provides little advantage in children with epilepsy. For younger children (generally <7 years) sedation requires a dedicated pediatric sedation team and/or skilled pediatric anesthesia. Infants, especially those younger than 3 months, may not need sedation if the infant is fed just before imaging. It is preferable, especially for younger children, that studies be interpreted by professionals skilled in interpreting pediatric imaging studies.

Summary and Conclusion

Structural neuroimaging is recommended for all children with recently diagnosed localization-related or generalized epilepsy who do not have the clinical and EEG features characteristic of classical idiopathic focal or generalized epilepsy (BECTS, CAE, JAE, or JME) and for any child younger than 2 years of age. These children have the highest likelihood of identifying a symptomatic etiology for their seizures. The imaging modality of choice is MRI because of its superior resolution compared to CT. However when scarce resources may preclude MRI, CT can be used in its place. Children younger than the age of 2 years require different MR imaging sequences because of the affect of developmental myelination on the ability to detect certain lesions such as cortical dysplasia. Imaging is performed to establish etiology, assist in determining prognosis, and identifying patients in whom alteration in medical or surgical management would ensue.

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We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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References

Al-Sulaiman AA, Ismail HM. (1999) Clinical pattern of newly-diagnosed seizures in Saudi Arabia: a prospective study of 263 children. *Childs Nerv Syst* 15:468–471.

Arts WF, Brouwer OF, Peters AC, Stroink H, Peeters EA, Schmitz PI, van Donselaar CA, Geerts AT. (2004) Course and prognosis of childhood epilepsy: 5-year follow-up of the Dutch study of epilepsy in childhood. *Brain* 127:1774–1784.

Berg AT, Testa FM, Levy SR, Shinnar S. (2000) Neuroimaging in children with newly diagnosed epilepsy: a community-based study. *Pediatrics* 106:527–532.

Berg AT, Shinnar S, Levy SR, Testa FM, Smith-Rapaport S, Beckerman B. (2001a) Early development of intractable epilepsy in children: a prospective study. *Neurology* 56:1445–1452.

Berg AT, Shinnar S, Levy SR, Testa FM, Smith-Rapaport S, Beckerman B, Ebrahimi N. (2001b) Two-year remission and subsequent relapse in children with newly diagnosed epilepsy. *Epilepsia* 42:1553–1562.

Bernal B, Altman NR. (2003) Evidence-based medicine: neuroimaging of seizures. *Neuroimaging Clin N Am* 13:211–224.

Bronen RA, Fulbright RK, Spencer DD, Spencer SS, Kim JH, Lange RC, Sutilla C. (1996) Refractory epilepsy: comparison of MR imaging, CT, and histopathologic findings in 117 patients. *Radiology* 201:97–105.

Caraballo RH, Cersosimo RO, Medina CS, Tenembaum S, Fejerman N. (1997) Idiopathic partial epilepsy with occipital paroxysms. *Rev Neurol* 25:1052–1058.

Chang T, Acosta MT, Rosser T, Conry JA, Pearl PL, Weinstein SL, Kolodgie M, Johnson P, Vezina LG, Dubovsky EC, Gaillard WD. (2002) Neuroimaging in children during the acute evaluation of new onset seizures. *Ann Neurol* 52:S134.

Eltze CM, Chong WK, Bhate S, Harding B, Neville BG, Cross JH. (2005) Taylor-type focal cortical dysplasia in infants: some MRI lesions almost disappear with maturation of myelination. *Epilepsia* 46:1988–1992.

Garvey MA, Gaillard WD, Rusin JA, Ochsenschlager D, Weinstein S, Conry JA, Winkfield DR, Vezina LG. (1998) Emergency brain computed tomography in children with seizures: who is most likely to benefit? *J Pediatr* 133:664–669.

Gelisse P, Corda D, Raybaud C, Dravet C, Bureau M, Genton P. (2003) Abnormal neuroimaging in patients with benign epilepsy with centrotemporal spikes. *Epilepsia* 44:372–378.

Gibbs J, Appleton RE, Carty H, Beirne M, Acomb BA. (1993) Focal electroencephalographic abnormalities and computerised tomography findings in children with seizures. *J Neurol Neurosurg Psychiatry* 56:369–371.

Guidelines for neuroimaging evaluation of patients with uncontrolled epilepsy considered for surgery. (1998) Commission on Neuroimaging of the International League Against Epilepsy. *Epilepsia* 39:1375–1376.

Harvey AS, Berkovic SF, Wrennall JA, Hopkins IJ. (1997) Temporal lobe epilepsy in childhood: clinical, EEG, and neuroimaging findings and syndrome classification in a cohort with new-onset seizures. *Neurology* 49:960–968.

Hirtz D, Ashwal S, Berg A, Bettis D, Camfield C, Camfield P, Crumrine P, Elterman R, Schneider S, Shinnar S. (2000) Practice parameter: evaluating a first nonfebrile seizure in children: report of the quality standards subcommittee of the American Academy of Neurology, The Child Neurology Society, and The American Epilepsy Society. *Neurology* 55:616–623.

Jallon P, Loiseau P, Loiseau J. (2001) Newly diagnosed unprovoked epileptic seizures: presentation at diagnosis in CAROLE study. Coordination Active du Reseau Observatoire Longitudinal de l' Epilepsie. *Epilepsia* 42:464–475.

King MA, Newton MR, Jackson GD, Fitt GJ, Mitchell LA, Silvapulle MJ, Berkovic SF. (1998) Epileptology of the first-seizure presentation: a clinical, electroencephalographic, and magnetic resonance imaging study of 300 consecutive patients. *Lancet* 352:1007–1011.

Korff C, Nordli DR Jr. (2005) Do generalized tonic-clonic seizures in infancy exist? *Neurology* 65:1750–1753.

Kramer U, Nevo Y, Reider-Groswasser I, Sheuer E, Meyer JJ, Leitner Y, Phatal A, Harel S. (1998) Neuroimaging of children with partial seizures. *Seizure* 7:115–118.

Kuzniecky RI, Knowlton RC. (2002) Neuroimaging of epilepsy. *Semin Neurol* 22:279–288.

Landfish N, Gieron-Korthals M, Weibley RE, Panzarino V. (1992) New onset childhood seizures. Emergency department experience. *J Fla Med Assoc* 79:697–700.

Loiseau P, Pestre M, Dartigues JF, Commenges D, Barberger-Gateau C, Cohadon S. (1983) Long-term prognosis in two forms of childhood epilepsy: typical absence seizures and epilepsy with rolandic (centrotemporal) EEG foci. *Ann Neurol* 13:642–648.

Loiseau P, Duche B, Cordova S, Dartigues JF, Cohadon S. (1988) Prognosis of benign childhood epilepsy with centrotemporal spikes: a follow-up study of 168 patients. *Epilepsia* 29:229–235.

Maytal J, Krauss JM, Novak G, Nagelberg J, Patel M. (2000) The role of brain computed tomography in evaluating children with new onset of seizures in the emergency department. *Epilepsia* 41:950–954.

McAbee GN, Barasch ES, Kurfist LA. (1989) Results of computed tomography in "neurologically normal" children after initial onset of seizures. *Pediatr Neurol* 5:102–106.

Recommendations for neuroimaging of patients with epilepsy. (1997) Commission on Neuroimaging of the International League Against Epilepsy. *Epilepsia* 38:1255–1256.

Resta M, Palma M, Dicuonzo F, Spagnolo P, Specchio LM, Laneve A, Bellomo R, Lauriero F, La Selva L. (1994) Imaging studies in partial epilepsy in children and adolescents. *Epilepsia* 35:1187–1193.

Sankar R, Curran JG, Kevill JW, Rintahaka PJ, Shewmon DA, Vinters HV. (1995) Microscopic cortical dysplasia in infantile spasms: evolution of white matter abnormalities. *AJNR Am J Neuroradiol* 16:1265–1272.

Sharma S, Riviello JJ, Harper MB, Baskin MN. (2003) The role of emergent neuroimaging in children with new-onset afebrile seizures. *Pediatrics* 111:1–5.

Shinnar S, Berg AT, Moshe SL, Kang H, O'Dell C, Alemany M, Goldensohn ES, Hauser WA. (1994) Discontinuing antiepileptic drugs in children with epilepsy: a prospective study. *Ann Neurol* 35:534–545.

Shinnar S, O'Dell C, Berg AT. (1999) Distribution of epilepsy syndromes in a cohort of children prospectively monitored from the time of their first unprovoked seizure. *Epilepsia* 40:1378–1383.

Shinnar S, O'Dell C, Mitnick R, Berg AT, Moshe SL. (2001) Neuroimaging abnormalities in children with an apparent first unprovoked seizure. *Epilepsy Res* 43:261–269.

Sillanpaa M, Jalava M, Kaleva O, Shinnar S. (1998) Long-term prognosis of seizures with onset in childhood. *N Engl J Med* 338:1715–1722.

Stroink H, Brouwer OF, Arts WF, Geerts AT, Peters AC, van Donselaar CA. (1998) The first unprovoked, untreated seizure in childhood: a hospital based study of the accuracy of the diagnosis, rate of recurrence, and long term outcome after recurrence. Dutch study of epilepsy in childhood. *J Neurol Neurosurg Psychiatry* 64:595–600.

Sztriha L, Gururaj AK, Bener A, Nork M. (2002) Temporal lobe epilepsy in children: etiology in a cohort with new-onset seizures. *Epilepsia* 43:75–80.

Takanashi J, Barkovich AJ. (2003) The changing MR imaging appearance of polymicrogyria: a consequence of myelination. *AJNR Am J Neuroradiol* 24:788–793.

Vanderver A, Chang T, Kennedy C, Acosta M, Conry JA, Pearl PL, Weinstein SL, Kolodgie MJ, Pastor W, Johnson P, Vezina LG, Gaillard WD. (2003) MR Imaging for the diagnosis of cerebral dysplasia in new onset seizures in children. *Ann Neurol* 54:S114.

Wang PJ, Liu HM, Fan PC, Lee WT, Young C, Tseng CL, Huang KM, Shen YZ. (1997) Magnetic resonance imaging in symptomatic/cryptogenic partial epilepsies of infants and children. *Zhonghua Min Guo Xiao Er Ke Yi Xue Hui Za Zhi* 38:127–136.

Warden CR, Brownstein DR, Del Beccaro MA. (1997) Predictors of abnormal findings of computed tomography of the head in pediatric patients presenting with seizures. *Ann Emerg Med* 29:518–523.

Wieshmann UC. (2003) Clinical application of neuroimaging in epilepsy. *J Neurol Neurosurg Psychiatry* 74:466–470.

Woermann FG, Sisodiya SM, Free SL, Duncan JS. (1998) Quantitative MRI in patients with idiopathic generalized epilepsy. Evidence of widespread cerebral structural changes. *Brain* 121:1661–1667.

Woermann FG, Free SL, Koepp MJ, Sisodiya SM, Duncan JS. (1999) Abnormal cerebral structure in juvenile myoclonic epilepsy demonstrated with voxel-based analysis of MRI. *Brain* 122:2101–2108.

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EDUCATIONAL REVIEW

Imaging of the urinary tract: the role of CT and MRI

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Abstract Computed tomography (CT) and magnetic resonance imaging (MRI) are increasingly valuable tools for assessing the urinary tract in adults and children. However, their imaging capabilities, while overlapping in some respects, should be considered as complementary, as each technique offers specific advantages and disadvantages both in actual inherent qualities of the technique and in specific patients and with a specific diagnostic question. The use of CT and MRI should therefore be tailored to the patient and the clinical question. For the scope of this article, the advantages and disadvantages of these techniques in children will be considered; different considerations will apply in adult practice.

Keywords Magnetic resonance imaging · Computed tomography · Ultrasonography · Child · Kidney · Urinary tract · Diagnostic imaging

Introduction

Computed tomography (CT) was invented by Sir Godfrey Hounsfield and was introduced into medical practice in 1973 [1–3]. The technique relies on the original theory that one can determine what is inside a box by taking X-ray "readings" at all angles around the object (tomograms). A computer then takes input from the X-rays at various angles to create an image of the object in slices, hence the name computed tomography. CT is therefore an X-ray technique and uses ionizing radiation. X-rays (whether conventional, plain radiographs or CT) give pictorial information on the density of an object or material. A CT image is therefore a pictorial demonstration of all the densities in the object, with high-density material (bone, calcium, metalwork) being represented as white and low-density materials being dark grey or black (air, fat). Their density can be measured in Hounsfield units (HU), and this can give the radiologist important information about the type of material (or tissue). Water is used as the reference point and has a value of between –7 and +7 HU (typically 0 HU), bone and other calcification will be of higher density (≥500 HU), fat will be of lower density (–25 to –250 HU), and soft tissues are in the range +10 to +60 HU.

Modern CT scanners are very fast and can scan the abdomen and pelvis in typically 5–7 s once the planning view (the 'scout' or 'scanogram') has been set up. This has great advantages in children, as for the most part, children will not need to have a general anesthetic to ensure they keep still. Babies can undergo "feed and wrap" and will generally sleep through the scan; toddlers and preschool children can be scanned with encouragement and caregiver support (or occasionally with mild sedation), and older children are easily able to tolerate the short scan times. Modern scanners typically have a slice thickness of <1 mm (0.6–0.75 mm) depending on the manufacturer. This allows for very detailed information that can be reconstructed in other planes, such as sagittal and coronal projections, which are often very helpful to the physician in understanding the image. Three dimensional (3D) images can also be produced in postprocessing, allowing rotating visualization of any part of the image that is required. CT provides a high spatial resolution image (the ability to distinguish two structures an arbitrarily small distance from each other as

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separate) with low noise, giving exquisite anatomical depiction, but it cannot give as much information with respect to processes within different tissues types, such as inflammation or necrosis, unless these are quite pronounced. The use of intravenously administered contrast medium helps in this respect and would be given routinely unless the main clinical question was regarding calcification or high-density objects (such as when looking for renal calculi). There is almost no indication in children for doing both pre- and postcontrast scans as part of the same examination. The only occasion for routinely performing a precontrast (unenhanced) scan is when evaluating calculi, and if the examination is solely for that purpose, then there is no indication to routinely perform a postcontrast scan as well. Conversely, if there is no diagnostic concern regarding calculi, then only a postcontrast scan should be performed, as there is so little additional diagnostic yield (if any) from doing both a pre- and postcontrast scan, and the significant radiation dose from the additional precontrast scan cannot be justified. All patients should be asked for any history of contrast allergy (or other severe allergies) before contrast is given intravenously (IV). Contrast is always most safely administered in the setting of good effective volume and hydration. Moreover, in the setting of a depressed glomerular filtration rate (GFR), consideration should be given to both hydration and alkalinization and, in some instances, there may be a role for the use of postcontrast dialysis. Planning for imaging children with depressed GFR is best accomplished in a multidisciplinary fashion, with input from both radiologist and nephrologist. Intravenously administered contrast must not be given in severe renal failure unless the patient will subsequently be dialyzed. In mild renal failure, a risk assessment (based on the potential benefit of the examination) must be performed by the clinician, and the patient must be well hydrated beforehand. CT is a high-radiation-dose technique and as such is used much more cautiously and infrequently in children than in adults, with children being many times more biosensitive to radiation than adults. Background radiation is typically 2–3 mSv per year, and a CT scan of the abdomen and pelvis is approximately 2–6 mSv, or the equivalent of 200–300 chest X-rays. Much effort is being made by pediatric radiologists to reduce radiation doses in children, especially in CT imaging, and information regarding this can be found at http://www.pedrad.org/associations/5364/ig/. Consideration should be given to performing specialized imaging studies that are elective in nature in facilities with pediatric expertise and pediatric imaging protocols, if these are available.

Magnetic resonance imaging (MRI) provides much greater contrast between different soft tissues [4] than does CT, as it relies on obtaining a radiofrequency (RF) signal from alignment and subsequent relaxation of protons in hydrogen atoms in water in the body. Soft tissue throughout the body will have varying water contents depending on cell types and the processes going on in and around those cells (e.g. normal different tissues, inflammation, tumor, infection, etc). An MR scanner uses a powerful magnetic field to align the nuclear magnetization of protons of hydrogen atoms in water (intra- and extracellular), and RF fields are then applied to alter the alignment of this magnetization, causing hydrogen nuclei to produce a rotating magnetic field that is detectable by the scanner. When RF fields are reversed, the protons relax to their normal state and give off a tiny RF signal that is detected by the scanner and is used to construct the image. Different tissues return to their equilibrium state at different rates. By changing the parameters of the scan, this effect is used to create an image that depicts the different tissues by showing the contrast between them. In a typical MRI scan, several different pulse sequences are performed to best exploit the different signals between tissues and give the most information. The main advantage of MRI over CT is that it gives far better contrast resolution (the ability to distinguish the differences between two arbitrarily similar but not identical tissues) and thus its ability to demonstrate changes between normal and pathological tissues. A sequence may last between a few seconds to several minutes, with most routine sequences lasting 1–3 min. Between five and ten sequences would usually be performed. MRI can produce images in any plane desired, and this is achieved by the radiographer or technician when setting up scan parameters. Sequences can be selected specifically to demonstrate particular qualities of tissues, such as water content. For example, with particular values of the echo time (TE) and the repetition time (TR), which are basic parameters of image acquisition, a sequence may take on the property of T2 weighting. On a T2-weighted scan, water- and fluid-containing tissues are bright (most modern T2 sequences are actually fast T2 sequences), and fat-containing tissues are dark. The reverse is true for T1-weighted images. Damaged tissue tends to develop edema, which makes a T2-weighted sequence sensitive for pathology and generally able to distinguish pathologic tissue from normal tissue. Heavily T2-weighted sequences are especially useful in the urinary tract, as water-containing structures are bright white, such as the collecting system and the bladder.

MRI contrast agents are frequently used. Most common of these is gadolinium, which is given intravenously. These agents work by shortening the T1 or T2 relaxation time of protons nearby. Reduction of T1 relaxation time results in a hypersignal with a reduced T2 relaxation time, thus reducing both T2 and T2* signals. Gadolinium is therefore of most benefit in T1-based sequences. A rare but severe complication of gadolinium use is nephrogenic systemic

fibrosis (NSF), which causes fibrosis in various tissues and organs. Patients with poor renal function are considered a greater risk of NSF, and therefore, gadolinium contrast agents must only be used with caution in these patients. As a result, gadolinium-containing contrast is now considered contraindicated in patients with an estimated GFR <60 ml/min and especially <30 ml/min [5]. Depressed GFR encompasses both acute and chronic kidney injury. As such, individuals with transient renal dysfunction should also be considered at risk, even though their usual GFR may be normal.

MRI scans will usually take 30–45 min and therefore generally require a general anesthetic in children from approximately 1–6 or 7 years of age. Older children are usually able to cooperate, but if they are unable to remain still and limit any movement for this length of time, they may also require a general anesthetic. Younger children (<12 months) may undergo feed and wrap or sedation. Further details of the practical aspects are covered in the pediatric MRI literature [6–8] (Table 1).

Imaging the urinary tract – which modality to use for first-line examination?

In imaging the urinary tract in children, the modality of choice for the initial examination will almost universally be ultrasound (US). US is inexpensive, immediate, painless, requires no sedation or anesthetic, is widely available, and is radiation free. In children, the urinary tract is easily visualized, as usually children have less body fat than adults, and the kidneys and bladder are relatively superficial structures. Children should be scanned both supine and prone, and the posterior approach (with the child lying prone) often gives the best anatomical detail of the kidneys. US can be used to scan in any plane at the discretion of the operator, and whereas the technique is entirely operator dependent, most centers have staff with a high level of skill. In most pediatric centers, it is considered completely unacceptable to proceed to CT or MRI in routine practice unless US had already been performed and had been unable to fully answer the diagnostic question. Acute multiorgan trauma would be the main exception to this. It is common practice in adult medicine to perform a CT scan of the abdomen and pelvis as the first-line examination for renal colic. In children, the first-line examination, even in renal colic, should ideally be US (on radiation dose risk vs. benefit considerations), recognizing that a few children will still need to proceed to CT. However, there is some variation in this practice between North America and Europe and on the availability of US expertise out of hours. Renal colic in children is much less common than in adults, even in children with known stone disease, and their stones pass more readily. US can show renal calculi with exquisite detail, demonstrating stones down to approximately 1–2 mm in diameter, and is also highly sensitive in the bladder. It is less sensitive, however, in the ureters, which may be obscured by bowel and other pelvic

Table 1 Comparison of advantages and disadvantages between computed tomography (CT) and magnetic resonance (MR) imaging modalities

CT	MR
Uses ionizing radiation, high-dose procedure	Uses magnetic resonance, no ionizing radiation
Excellent spatial resolution	Excellent contrast resolution
Actual scanning time measured in seconds (typically <10 s)	Actual scanning time measured in minutes (typically 45 min)
Rarely requires general anesthetic in children	Frequently requires general anesthetic in children, depending on age
Excellent at showing calcification	Poor at showing calcification (signal void)
Poor at showing edema or pathological changes in specific tissue types	Excellent at showing edema and pathological changes in specific tissue types
Usually requires intravenous contrast (unless looking for calcification when not required)	Usually requires intravenous administration of contrast (but certain sequences can be tailored if this is contraindicated)
No known risk of nephrogenic systemic fibrosis (NSF)	Risk of NSF (rare, but renal patients believed to be at increased risk)
Widely available	Less widely available, especially for children
Less expensive	Expensive
Usually available as an emergency imaging technique	Not routinely available as an emergency technique
No significant contraindications	Contraindicated in patients with any internal ferrous objects (pacemakers, defibrillators, recent orthopedic metalware, other implanted metallic devices, metallic foreign bodies)
Open-style scanners	Generally quite enclosed scanners – risk of claustrophobia
Can only scan in one plane (but can do reconstructed images later)	Can scan in any plane
Few artefacts	Prone to artefacts depending on sequence type (especially motion artifact)

structures, so in the context of a normal US and ongoing clinical features suggestive of calculi (colicky pain, hematuria, known existing stone disease), CT may still be indicated. There is further discussion of this topic in the section "Calcification in the urinary tract". US is the first-choice examination for all other pathologies relating to the kidney and urinary tract.

The use of CT and MR for specific clinical indications

Congenital conditions

In pediatric practice, many congenital conditions of the urinary tract are demonstrated in utero on antenatal scans, whereas some are only detected in infancy or later due to subsequent complications. Ninety percent of fetal kidneys can be identified by 17–20 weeks of gestation and 95% by 22 weeks. Both antenatally and postnatally, US remains the examination of choice in demonstrating kidney and urinary tract anatomy. Structural urinary tract anomalies include renal dysplasia, renal hypoplasia, renal aplasia, multicystic dysplastic kidney, pelviureteric junction obstruction, duplication anomalies, fusion anomalies, renal ectopia, ureteroceles, cystic kidney diseases, and posterior urethral valves. All of these may be demonstrated by US, with additional information being acquired in some cases by other modalities (such as nuclear medicine imaging or fluoroscopy). MRI may subsequently be useful in these patients, as illustrated in Fig. 1 for cystic disease, either in the further workup following US [7, 9] when the clinical question has not been resolved, or when the child presents with (or has) complications that remain unexplained by US or require further delineation [10–12]. Heavily T2-weighted sequences (water-based sequences) are very useful in demonstrating dilatation of the urinary tract secondary to congenital anomalies, such as duplex kidneys with dilated moieties and occult moieties in a previously undiagnosed duplex kidney [13] (Fig. 2), and for demonstrating the exact anatomy of fusion anomalies, such as a crossed, fused, ectopic kidney and horseshoe kidney [4, 6].

CT arteriography (CTA) is sometimes performed in instances of known horseshoe kidney when surgery is being planned. This is to optimally delineate the multiple vessels that often supply these kidneys before surgery is undertaken. Pelviureteric junction obstruction can usually be diagnosed adequately on US, but a crossing vessel may be demonstrated by MRI (Fig. 3) [14], which cannot be visualized by US; in very gross hydronephrosis, MRI may give a better demonstration of the anatomy (Fig. 4).

Very complex urogenital anomalies, such as cloacal anomalies in female patients, are usually imaged by US and fluoroscopy in the first instance, but further cross-sectional imaging is invariably required. MRI may offer satisfactory depiction of the anatomy, but frequently, the workup has to occur very soon after birth so that an intermediate management plan can be made before definite surgery can be performed when the infant is older. In this situation,

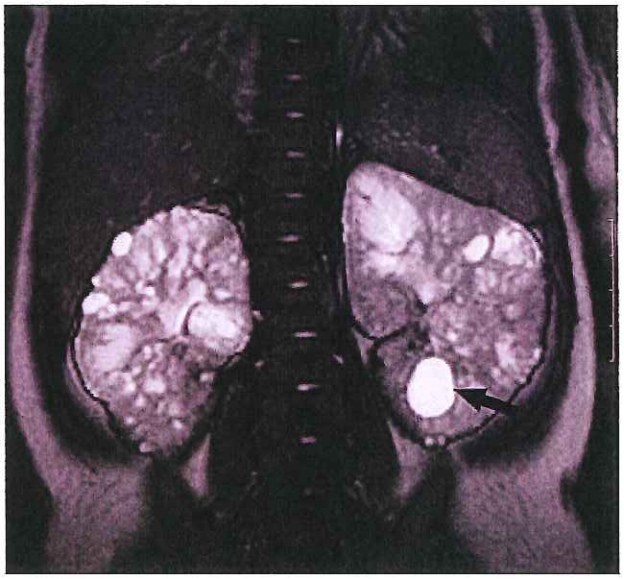


Fig. 1 Magnetic resonance image: coronal T2 sequence in a 6-month-old girl with autosomal dominant polycystic kidney disease showing multiples high-signal cysts throughout both kidneys



Fig. 2 Magnetic resonance imaging: an unexpected right-sided duplex kidney in a 7-month-old girl whose anatomy could not be delineated by ultrasound, with a tiny lower moiety that is almost hidden by the dilated upper moiety (*arrow*)

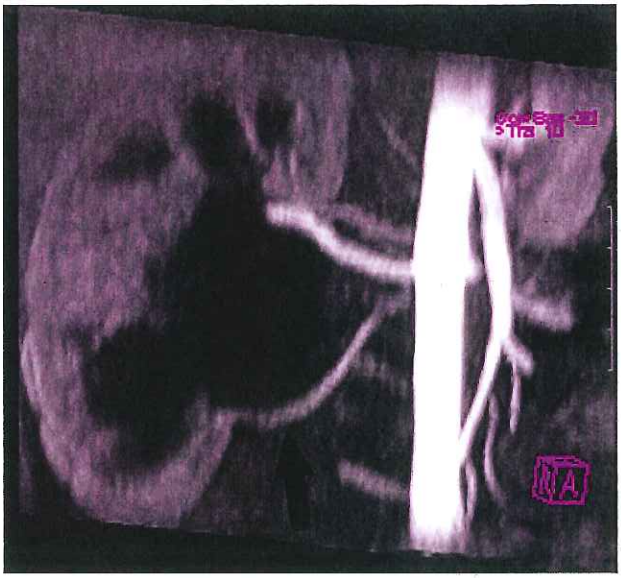


Fig. 3 Magnetic resonance imaging: a 9-year-old boy with right-sided flank pain with a reconstructed postcontrast image showing an inferior pole "crossing" vessel (artery) (*arrow*) causing right-sided hydronephrosis

MRI is rarely able to offer sufficient spatial resolution to allow full understanding of the anatomy in these very small patients. In a few very select cases, CT, with a combined distal loopogram and micturating cystogram performed at the time of the scan, as well as contrast intravenously with the scan delayed to excretory phase, can offer exceptional 3D visualization of the entire urogenital tract (Fig. 5). There is little value in a conventional CT alone in these cases, and the routine use of CT is absolutely not advocated.

Infection

Most commonly, infection of the lower urinary tract presents clinically and is treated empirically. However, in a few more complicated cases, US will be performed to look for complications, such as abscess formation or pyelonephritis, within the kidneys and for the presence of underlying contributory factors, such as stone disease or previously undiagnosed structural anomalies. In most instances, US is able to resolve these clinical issues and is clearly the modality of choice for assessing infection (both in the acute stage and at follow-up). If US cannot answer the diagnostic question, further cross-sectional imaging may sometimes be useful. In the acute setting, with a very ill patient and suspected sepsis related to the urinary tract, CT may add further information regarding, for example, abscess rupture or retroperitoneal fluid (or pus) collections (Fig. 6). CT is useful in showing calcification and extrarenal complications in xanthogranulomatous pyelonephritis, if this has not already been confirmed by US. MRI may be of value after the acute

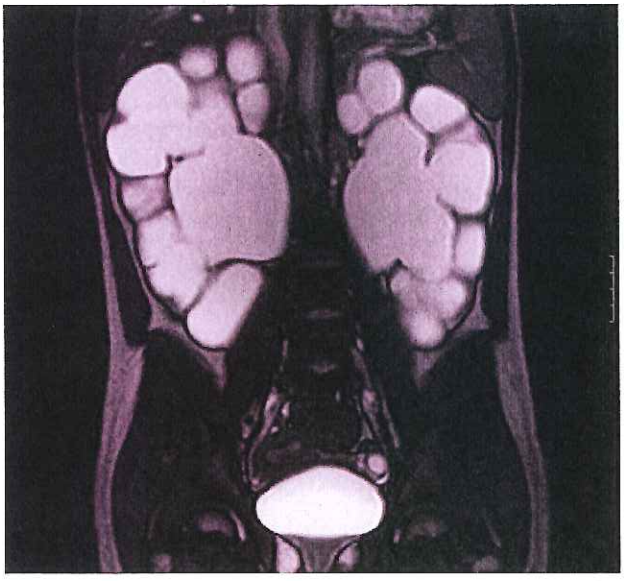


Fig. 4 Magnetic resonance imaging: T2-weighted sequence demonstrating the extent of bilateral pelviureteric junction obstruction, nondilation of ureters, and normal bladder, confirming the obstruction to be at the renal pelvis on both sides

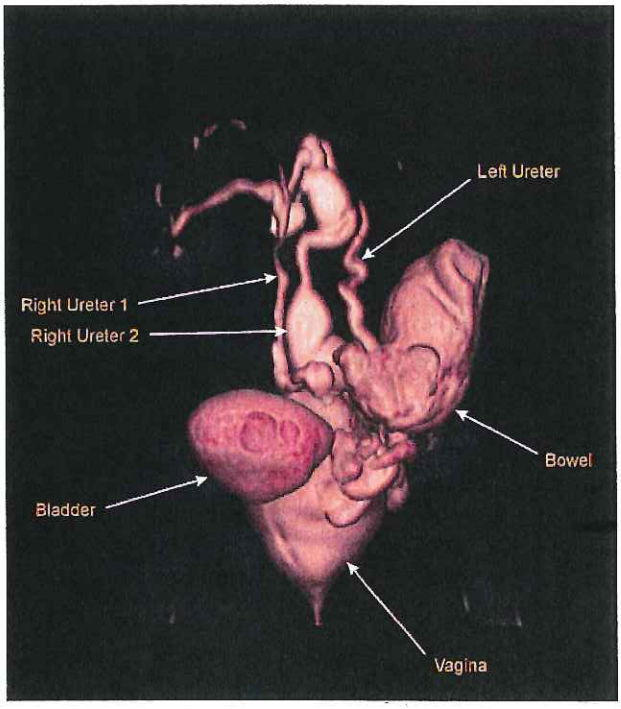


Fig. 5 Computed tomography: Reconstructed 3D images showing the complicated anatomy of the urogenital tract in a 3-month-old girl with a cloacal anomaly; the entire urogenital system is demonstrated in one study

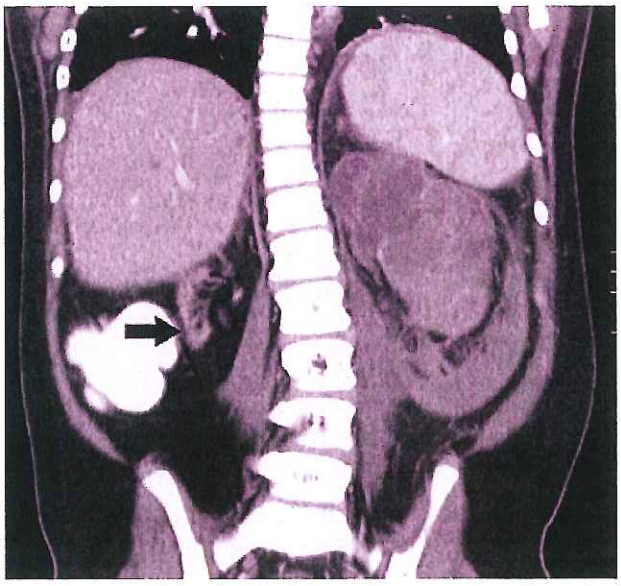


Fig. 6 Computed tomography: a 15-year-old girl with chronic renal failure on peritoneal dialysis with recent onset of abdominal pain and signs of sepsis. The shriveled right kidney (*arrow*) is the expected size of both kidneys, but the left kidney shows acute pyelonephritis and is therefore enlarged, dilated, pus-filled, and has ruptured into the retroperitoneum

episode for demonstrating underlying structural anomalies if these have not been determined by US.

Trauma

In the acute setting of trauma in children, US is once again the first-line technique in the emergency room. US can quickly demonstrate whether the kidney is still vascularized, if there is physical damage (fracture, laceration, avulsion) of the kidney, and provide some information regarding surrounding complications. If the trauma is believed to be confined solely to the kidney and the child is stable, it may not be necessary to proceed to any further immediate imaging. However, it is frequently the case that these patients have been involved in a complex trauma, and as such, multiple injuries may have occurred. In most cases, major renal injuries are associated with injuries to other major organs, and renal trauma occurs in 8–10% of patients with significant blunt or penetrating abdominal trauma [15, 16]. In this instance, CT is usually performed straight from the emergency room. CT will demonstrate direct trauma to the kidney and to any other intra-abdominal organs and may show retroperitoneal injuries or complications better than US [17]. Typical findings include contusions (shown as ill-defined or sometimes sharply marginated areas of reduced enhancement and excretion), nonexpanding subcapsular hematomas (appearing as a hyperattenuating fluid collection between the renal parenchyma and the renal capsule, at times deforming the underlying kidney), perinephric hematomas (an ill-defined, hyperattenuating fluid collection located between the Gerota fascia and the renal parenchyma), renal lacerations (jagged or linear parenchymal disruptions that can contain fresh or clotted blood), renal lacerations with collecting system involvement (which frequently produce extravasation of urine or contrast agent), and renal segmental infarction appearing as well-delineated, linear or wedge-shaped, often multifocal and nonenhancing areas that extend through the parenchyma in a radial or segmental orientation. Thrombosis, dissection, and laceration of segmental renal arteries are primary causes of segmental infarctions, and such infarctions are frequently associated with other renal injuries. Severe injuries include a shattered or devascularized kidney (which appears nonenhancing, with CTA showing a blind-ending renal artery), ureteropelvic junction (UPJ) avulsions, and complete laceration or thrombosis of the main renal artery or vein. CT of the urinary tract should usually be obtained in severe pelvic trauma prior to surgery. MRI has no indication in the acute setting of trauma. Very occasionally, it may have some value in the follow-up of renal trauma, but in children, this would usually be by US.

Vascular

Both CT and MRI can give excellent information with respect to normal vascular supply to the kidneys and wider urinary tract and in the context of vasculopathies. US would be the first-line investigation, but if anatomical delineation is required – for example, for surgical planning – then CT or MRI can be performed at the surgeon's and radiologist's discretion. CT will give better spatial resolution with the CT scan being performed in the arterial phase and allows 3D reconstruction of the vascular tree but at a considerable radiation dose. The clinician must be sure that sufficient information cannot be obtained by another method before proceeding. MRI is increasingly able to offer detailed vascular information with no radiation dose, and this should be considered as an entirely viable alternative in cooperative children (Fig. 7). At the time of writing this article, conventional angiography remained the gold standard for demonstrating subtle abnormalities in the renal vasculature, but it is both invasive and carries a relatively high radiation dose. However, in the diagnosis of subtle renal artery stenosis, for small arteriovenous malformations of the kidney, and for tiny aneurysms such as in polyarteritis nodosa or Wegner's granulomatosis, it is still the investigation of choice. It is no longer indicated in the diagnosis or workup of renal tumors prior to surgery.

MRI plays an important role in the workup of children waiting for renal transplant. Whereas initial assessment of their native vessels [aorta, inferior vena cava (IVC), iliac

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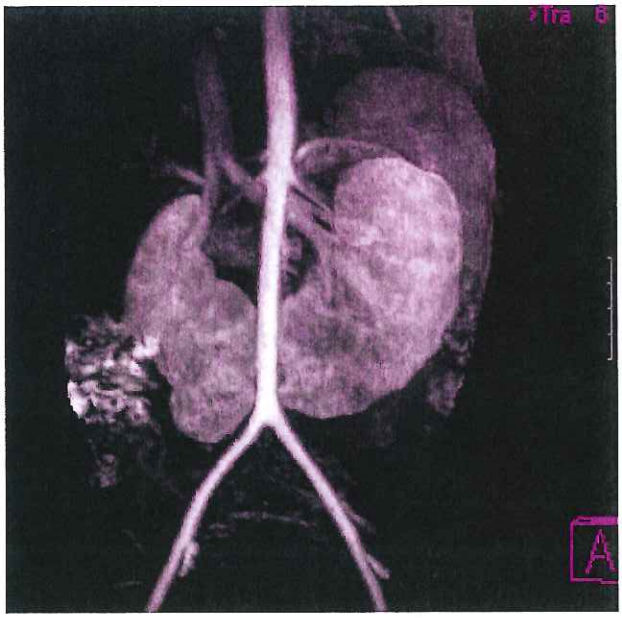


Fig. 7 Magnetic resonance imaging: gadolinium-enhanced MR angiography demonstrating arterial anatomy in an 11-year-old girl with a known horseshoe kidney

and femoral vessels] may be by US, proceeding to MRI may be necessary if the US is technically inadequate (due to the presence of bowel gas or other structures) or if it is indeterminate. Conventionally, gadolinium contrast agents have been given to best illustrate the vessels, but in patients who are known to be in renal failure (hence the need for transplant), gadolinium is no longer given due to the risk of NSF. In these patients, MR angiography (MRA) is still achieved using tailored sequences [true fast imaging with steady-state precession (FISP) and time-of-flight (TOF) sequences], which obviate the need for intravenously administered contrast. It is also helpful in patients who have had renal transplant and in whom the anatomy may be difficult to demonstrate by US.

Calcification in the urinary tract

Stone disease and calcification relating to the urinary tract in children deserves special mention, as its imaging management differs to that in adults. US is a highly effective imaging tool when looking for calcification (nephrocalcinosis) and calculi within the kidney. Subtle nephrocalcinosis may be demonstrated by using a high-resolution probe when it has not been demonstrated by a conventional linear probe, and the pediatric sonographer should always use both techniques if nephrocalcinosis is being sought. There is no indication to use CT or MRI when diagnosing nephrocalcinosis in children unless there is a specific concern regarding the additional presence of calculi, which may be difficult to delineate by US in the presence of particularly florid nephrocalcinosis.

Children's smaller body habitus allows good visualization of even tiny calculi within the collecting system, parenchyma, and bladder. If the ureters are dilated, US may also show calculi in the upper and lower third of the ureter but remains consistently poor at demonstrating calculi in the middle third of the ureter. In a select group of patients, it may be appropriate to proceed to CT, but CT should not be routine imaging for stone disease children. It is, however, highly sensitive (97%) and specific (96%) for urinary tract calculi and is undoubtedly an excellent technique in this respect [18]. Children who may benefit from CT include those with a high body mass index (BMI) in whom US cannot sufficiently penetrate soft tissues for adequate visualization, those in whom US is not tolerated, children with severe scoliosis in whom there is not a suitable acoustic window to access the kidneys, children who continue to have symptoms of stone disease in which no calculi have been demonstrated by repeated US, and children in whom a history of stone disease is known but symptoms are out of proportion to US findings. It must be remembered that many children will have recurrent calculi, and it is therefore highly undesirable to perform a high radiation dose examination on every occasion for an underlying benign condition with a normal life expectancy. If CT is requested, it should be performed with a low-dose technique and without intravenously administered contrast (which would obscure any calcific focus) [19, 20].

Neoplastic

Many tumors may involve the urinary tract depending on the organ of origin and the age of the child. Renal malignancies represent about 6% of cancer diagnoses in children <15 years of age. Wilms tumor is by far the most common of the renal tumors, representing approximately 95% of cases overall and 96% in children <5 years (Fig. 8).

In all instances, the first imaging should be by US, which can confirm the presence of the mass and can usually (but not always) determine the organ of origin. However, further cross-sectional imaging is indicated for further anatomical delineation, information on tissues characteristics, and to establish staging. In centers with pediatric MRI, this is absolutely the imaging modality of choice: it provides a wealth of information regarding the tumor itself, provides a base-line for follow-up (thus avoiding repeated CTs), and can provide accurate staging. Sequences will typically include T1- and T2-weighted sequences, short-tau inversion recovery (STIR) sequences, apparent diffusion coefficient (ADC) sequences, and postgadolinium contrast-enhanced 3D fast low-angle shot (FLASH) sequences in a combination of axial and coronal planes. ADC sequences

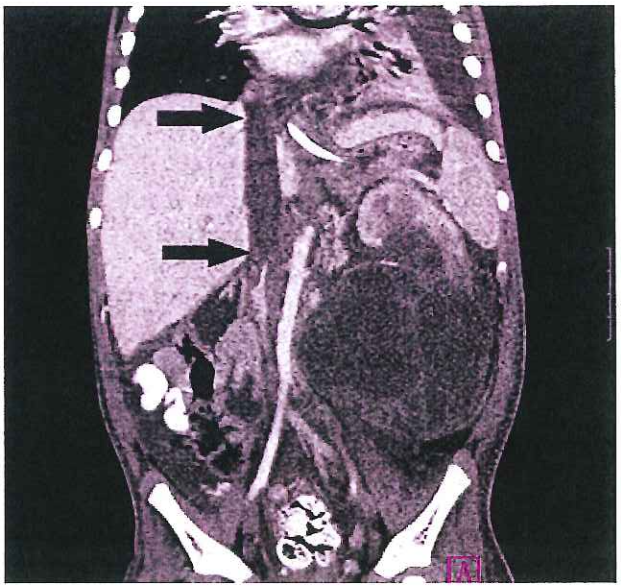


Fig. 8 Computed tomography showing the extent of a large, left-sided Wilms tumor in a 2-year-old girl with thrombus extending the full length of the inferior vena cava (IVC) and into the right atrium (*between arrows*)

are relatively new in abdominal imaging (but have been used extensively in the brain for some time). These sequences give information about how easily water can diffuse in and between cells; thus, a tumor with densely packed cells will return low signal intensity and will appear dark on this MRI sequence. If it, or a part of it, is undergoing necrosis, it will return a higher (whiter) signal intensity. This is especially useful when monitoring a tumor to assess its response to treatment such as chemotherapy and to follow-up for recurrence. MRI can give information as to IVC and renal vein patency (Fig. 8) if this has not already been determined with certainty by US. Detailed MRA may also be performed, if necessary, to allow surgical planning. In centers with no access to MRI, then CT still provides good information, recognizing that it cannot supply tissue-specific information as MRI and that it incurs a heavy radiation burden. Follow-up of treated tumors should be by US where possible, although many cancer protocols determine that MRI (or CT) should be performed at specifically determined intervals.

Renal functional MRI

US, CT, and MRI all provide good anatomic images [21] of the kidney and urinary tract, but MRI (both in adults and children) has developed very rapidly over recent years and has great potential in the near future to change the way the urinary tract is imaged after the initial US. Uniquely, MRI can also give functional information on the kidneys [4, 22], unlike the other cross-sectional modalities. Traditionally, nuclear medicine studies have been employed for this purpose, but they give poor spatial resolution and provide only relative information rather than absolute values with respect to renal function. MRI is therefore alone in being able to give both anatomical and functional information. Functional renal imaging techniques such as contrast-enhanced MR renography [23, 24], and unenhanced techniques such as diffusion-weighted imaging (DWI) and blood-oxygen-level-dependent (BOLD) imaging, have shown considerable promise in evaluating renal function in health and disease. Whereas this is a relatively new area in clinical terms, it is rapidly advancing and crossing over from being a research technique to offering a real clinical alternative to existing techniques for assessing renal function [25]. Technically, it is no different performing this in children than in adults, but – as with all MRI in children – the rate-limiting step for the technique is the child's ability to remain completely still through a long scan without the need for general anesthesia. It is likely, therefore, that it will be incorporated into the repertoire of renal imaging for older children in the reasonably near future but probably not for younger children unless there is a very specific indication.

1. Contrast-enhanced MR renography:

   The basis of the technique relies on dynamic contrast enhancement of the kidneys using MRI to monitor transit of contrast material, typically a gadolinium chelate, through the renal cortex, the medulla, and the collecting system. Most gadolinium contrast agents are cleared by glomerular filtration and pass through capillaries and renal tubules, causing renal tissue signal intensity to increase. By analyzing renal tissue enhancement as a function of time, clinically important single-kidney parameters such as renal blood flow [24], GFR, and cortical and medullary blood volumes can be determined and can be plotted graphically to generate various functional parameter curves. Split renal function can be calculated [25]. Current indications in adult imaging include functional imaging in renal artery stenosis and assessing potential allograft dysfunction in the early postoperative period, potentially avoiding the need for biopsy to distinguish between acute tubular necrosis and acute rejection. It should be noted that as this technique relies on administration of gadolinium as a contrast agent, it is not suitable for patients with renal failure, due to the risk of NSF.
2. Diffusion-weighted MRI:

   DWI has traditionally been used in imaging stroke victims, as it is very sensitive in detecting acute ischemia. The ADC calculation can be used in vivo for quantifying the combined effects of capillary perfusion and diffusion. This technique was referred to above in tumor assess-

ment; however, it also has applications in assessing renal insufficiency with studies showing good correlation between GFR and ADC values, highlighting the potential role for evaluating renal dysfunction in native kidneys. DWI also appears to have a future role in renal allograft evaluation and renal artery stenosis.

3. Blood-oxygen-level-dependent (BOLD) MRI:

   BOLD MRI can be used for noninvasive but direct measurement of renal oxygenation [26]. It exploits the paramagnetic effect of deoxyhemoglobin for acquisition of images sensitive to local oxygen concentration. Again, it has application in the context of renal artery stenosis and renal allograft dysfunction but also in diabetic nephropathy

Conclusion

Imaging of the urinary tract in children relies on US as the first-line imaging modality; however, MRI has an invaluable role to play, with CT playing a lesser part. Considerations specific to children revolve around radiation dose issues with CT and the need (or not) for a general anesthetic in MRI. It is crucial that the clinical question is clearly established and the study chosen is tailored to the specific child after discussion between the clinician and the radiologist. MRI is the technique of choice for imaging tumors and congenital anomalies when these cannot be satisfactorily delineated by US, and it should generally be regarded as an excellent advanced problem-solving technique. CT is indicated in multisystem trauma and in some children with renal calculi. Functional MRI is rapidly developing in the adult world, and some applications are becoming relevant in children. Center-specific expertise may lead to a certain study being performed in one setting versus a different study in another. This factor may be an important consideration in choosing which modality is appropriate. For elective imaging, referral of the patient to a center with pediatric expertise for superior study should be considered, if it is a realistic option. Ultimately, it is the collaboration between the nephrologist and the radiologist that will lead to the best imaging modality for each patient.

Self-assessment questions

(Answers appear following the reference list)

1. Which examination has the highest sensitivity for detecting renal-tract calculi in children?
   a. CT with contrast enhancement
   b. CT without contrast enhancement
   c. CT with contrast enhancement and delayed images to show the level of obstruction
   d. MRI using a T1-weighted sequence
   e. US in the hands of an experienced operator who is aware of the clinical history
2. Which patient cannot have an MRI examination?
   a. A child with claustrophobia
   b. A child with end-stage renal failure in whom gadolinium is therefore contraindicated
   c. A baby 5 days old who is on a ventilator
   d. A child who had a CT the previous day
   e. A child with a pacemaker
3. Which series has the highest radiation dose?
   a. Enhanced CT of the abdomen and pelvis with a delayed series
   b. Enhanced CT of the abdomen and pelvis without a delayed series
   c. MRI with T1, T2, post-gadolinium TI and ADC sequences, in coronal and axial planes, of the abdomen and pelvis, with a delayed series
   d. Unenhanced CT of the abdomen only, followed up by unenhanced CT of the abdomen (only) 4 weeks later
   e. MRI of the abdomen and pelvis followed up by CT of the abdomen and pelvis 6 weeks later
4. Which of the following is poorly demonstrated on MRI?
   a. Urine
   b. Blood
   c. Calcium
   d. Renal medulla
   e. Renal cortex
5. Regarding NSF, which of the following is false?
   a. NSF does not occur in healthy patients with normal renal function
   b. The risk of NSF is increased in patients with a low GFR
   c. The relationship between NSF and MRI contrast agents has only been recognized in the last 5 years
   d. The risk of NSF is not reduced by dialysis
   e. All types of gadolinium contrast agents pose a similar risk of NSF in patient with renal failure

References

1. Ambrose J, Hounsfield G (1973) Computerized transverse axial tomography. Br J Radiol 46:148–149
2. Hounsfield GN (1973) Computerized transverse axial scanning (tomography). 1. Description of system. Br J Radiol 46:1016–1022
3. Hounsfield GN (1980) Computed medical imaging. Science 210:22–28
4. Grattan-Smith JD, Jones RA (2006) MR urography in children. Pediatr Radiol 36:1119–1132, quiz 1228–1229

5. Kanal E, Barkovich AJ, Bell C, Borgstede JP, Bradley WG Jr, Froelich JW, Gilk T, Gimbel JR, Gosbee J, Kuhni-Kaminski E, Lester JW Jr, Nyenhuis J, Parag Y, Schaefer DJ, Sebek-Scoumis EA, Weinreb J, Zaremba LA, Wilcox P, Lucey L, Sass N (2007) ACR guidance document for safe MR practices: 2007. AJR Am J Roentgenol 188:1447–1474
6. Grattan-Smith JD, Little SB, Jones RA (2008) MR urography in children: how we do it. Pediatr Radiol 38(Suppl 1):S3–S17
7. Grattan-Smith JD, Jones RA (2008) Magnetic resonance urography in children. Magn Reson Imaging Clin N Am 16:515–531
8. Grattan-Smith JD (2008) MR urography: anatomy and physiology. Pediatr Radiol 38(Suppl 2):S275–S280
9. Grattan-Smith JD, Jones RA (2008) MR urography: technique and results for the evaluation of urinary obstruction in the pediatric population. Magn Reson Imaging Clin N Am 16:643–660
10. Greenbaum LA (2008) Renal dysplasia and MRI: a clinician's perspective. Pediatr Radiol 38(Suppl 1):S70–S75
11. Little SB, Jones RA, Grattan-Smith JD (2008) Evaluation of UPJ obstruction before and after pyeloplasty using MR urography. Pediatr Radiol 38(Suppl 1):S106–S124
12. Cerwinka WH, Damien Grattan-Smith J, Kirsch AJ (2008) Magnetic resonance urography in pediatric urology. J Pediatr Urol 4:74–82, quiz 82-83
13. Lipson JA, Coakley FV, Baskin LS, Yeh BM (2008) Subtle renal duplication as an unrecognized cause of childhood incontinence: diagnosis by magnetic resonance urography. J Pediatr Urol 4:398–400
14. Calder AD, Hiorns MP, Abhyankar A, Mushtaq I, Olsen OE (2007) Contrast-enhanced magnetic resonance angiography for the detection of crossing renal vessels in children with symptomatic ureteropelvic junction obstruction: comparison with operative findings. Pediatr Radiol 37:356–361
15. Kawashima A, Sandler CM, Corl FM, West OC, Tamm EP, Fishman EK, Goldman SM (2001) Imaging of renal trauma: a comprehensive review. Radiographics 21:557–574
16. McAninch J (1996) Renal injuries. In: Gillenwater J, Grayhack J, Howards S, Duckett J (eds) Adult and pediatric urologyMosby. St Louis, Mo, pp 539–553
17. Lee YJ, Oh SN, Rha SE, Byun JY (2007) Renal trauma. Radiol Clin North Am 45:581–592
18. Smith RC, Verga M, McCarthy S, Rosenfield AT (1996) Diagnosis of acute flank pain: value of unenhanced helical CT. AJR Am J Roentgenol 166:97–101
19. Kalra MK, Maher MM, D'Souza RV, Rizzo S, Halpern EF, Blake MA, Saini S (2005) Detection of urinary tract stones at low-radiation-dose CT with z-axis automatic tube current modulation: phantom and clinical studies. Radiology 235:523–529
20. Memarsadeghi M, Heinz-Peer G, Helbich TH, Schaefer-Prokop C, Kramer G, Scharitzer M, Prokop M (2005) Unenhanced multidetector row CT in patients suspected of having urinary stone disease: effect of section width on diagnosis. Radiology 235:530–536
21. Kirsch AJ, Grattan-Smith JD, Molitierno JA Jr (2006) The role of magnetic resonance imaging in pediatric urology. Curr Opin Urol 16:283–290
22. Rohrschneider WK, Haufe S, Clorius JH, Troger J (2003) MR to assess renal function in children. Eur Radiol 13:1033–1045
23. Jones RA, Schmotzer B, Little SB, Grattan-Smith JD (2008) MRU post-processing. Pediatr Radiol 38(Suppl 1):S18–S27
24. Martin DR, Sharma P, Salman K, Jones RA, Grattan-Smith JD, Mao H, Lauenstein TC, Burrow BK, Tudorascu DL, Votaw JR (2008) Individual kidney blood flow measured with contrast-enhanced first-pass perfusion MR imaging. Radiology 246:241–248
25. Chandarana H, Lee VS (2009) Renal functional MRI: Are we ready for clinical application? AJR Am J Roentgenol 192:1550–1557
26. Hofmann L, Simon-Zoula S, Nowak A, Giger A, Vock P, Boesch C, Frey FJ, Vogt B (2006) BOLD-MRI for the assessment of renal oxygenation in humans: acute effect of nephrotoxic xenobiotics. Kidney Int 70:144–150

Answers

1. b. CT without contrast enhancement has the highest sensitivity for detecting calculi but carries a heavy radiation dose penalty. It is therefore NOT the first examination of choice in children. US should always be used in the first instance, and CT only when there is still diagnostic difficultly. Contrast may obscure the presence of stones, as it is also of high density (white).
2. e. A pacemaker is generally considered an absolute contraindication to MRI, as it may become deprogrammed or pulse erratically in the strong magnetic field. (In absolutely exceptional cases, a clinical decision can be made to turn some pacemakers off or turn them to fixed-pulse mode). A child with claustrophobia may have MRI under sedation or general anesthetic if clinically indicated. Modern sequences often obviate the need for gadolinium in patients with end-stage renal failure. The age of the patient and the previous imaging history would not affect the clinical decision to request MRI.
3. a. This series involves scanning through the abdomen and pelvis on two occasions. The absence or presence of intravenously administered contrast agent makes no difference to radiation dose. MRI does not involve radiation.
4. c. Calcium (such as in renal calculi) contains no water and therefore does not have protons that are easily influenced by magnetic fields, and as such, it returns almost no signal (signal void) on all sequences and is difficult to detect.
5. e. Not all gadolinium contrast agents are the same. Omniscan and Magnevist are thought to pose increased risk due to the chelate to which the gadolinium is attached, with these compounds being more likely to release free gadolinium ions into the body. Dotarem is currently considered to be the least likely agent to allow release of free gadolinium ions.

Children With Headache Suspected of Having a Brain Tumor: A Cost-Effectiveness Analysis of Diagnostic Strategies

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ABSTRACT. *Objective.* To assess the clinical and economic consequences of 3 diagnostic strategies—magnetic resonance imaging (MRI), computed tomography followed by MRI for positive results (CT-MRI), and no neuroimaging with close clinical follow-up—in the evaluation of children with headache suspected of having a brain tumor. Three risk groups based on clinical variables were evaluated.

Materials and Methods. A decision-analytic Markov model and cost-effectiveness analysis was performed incorporating the risk group prior probability, MRI and CT sensitivity and specificity, tumor survival, progression rates, and cost per strategy. Outcomes were based on quality-adjusted life year (QALY) gained and incremental cost per QALY gained.

Results. For low-risk children with chronic nonmigraine headaches of >6 months' duration as the sole symptom (prior probability of brain tumor 0.01%), no neuroimaging with close clinical follow-up was less costly and more effective than the 2 neuroimaging strategies. For the intermediate-risk children with migraine headache and normal neurologic examination (prior probability of brain tumor 0.4%), CT-MRI was the most effective strategy but cost >$1 million per QALY gained compared with no neuroimaging. For high-risk children with headache of <6 months' duration and other clinical predictors of a brain tumor such as an abnormal neurologic examination (prior probability of brain tumor 4%), the most effective strategy was MRI, with cost-effectiveness ratio of $113 800 per QALY gained compared with no imaging.

Conclusion. Our analysis suggests that MRI maximizes QALY gained at a reasonable cost-effectiveness ratio in children with headache at high risk of having a brain tumor. Conversely, the strategy of no imaging with close clinical follow-up is cost saving in low-risk children. Although the CT-MRI strategy maximizes QALY gained in the intermediate-risk patients, its additional cost per QALY gained is high. In children with headache, appropriate selection of patients and diagnostic strategy may maximize quality-adjusted life expectancy and decrease costs of medical workup. *Pediatrics* 2001; 108:255–263; *headache, children, cost-effectiveness analysis.*

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ABBREVIATIONS. CT, computed tomography; MRI, magnetic resonance imaging; CT-MRI, CT followed by MRI for positive results; QALY, quality-adjusted life year; CEA, cost-effectiveness analysis; LY, life year.

Headache is a very common symptom among children and adults, accounting for 18 million (4%) of the total outpatient visits in the United States each year.[1] It has been estimated that 11.3 million people nationwide experience moderate to severe migraine headaches.[2] In the United States, adolescent boys and girls have a headache prevalence of 56% and 74% and a migraine prevalence of 3.8% and 6.6%, respectively.[1] In Scandinavia, 38% of 7-year-olds have headaches, and 1.4% to 3% have migraine.[3,4] The direct and indirect annual cost of migraine has been estimated at >$5.6 billion.[5]

A primary concern in children with headache is the possibility of a brain tumor.[6,7] Although brain tumors constitute the largest group of solid neoplasms in children and are second only to leukemia in overall frequency of childhood cancers, the annual incidence is low at 3 per 100 000.[6] Several studies have demonstrated improved survival in patients who have totally resectable brain neoplasm and lower tumor stage compared with patients with more advanced disease.[8–11] Brain tumors also may produce mass effect and bleed, increasing the risk of brain herniation.[12] Early detection may improve patient outcome because late diagnosis of a brain tumor may affect brain tumor resectability, neoplasm stage, and risk of cerebral herniation. However, because the overall incidence of brain tumors among children with headache is low, clinicians may be trapped between ordering imaging studies with some inherent risks (sedation, contrast use, and false-positive rate) and early detection of intracranial tumors.

The value of neuroimaging in evaluating headache in children is controversial. Some retrospective studies have concluded that neuroimaging studies have a limited role in children with headache.[13,14] These studies have been limited by a sample size that yielded no brain tumors. Another study suggests dividing children with headache into high- and low-risk groups according to clinical predictors of surgical space-occupying lesions.[15] This study suggests that neuroimaging should be reserved for high-risk patients.[15] Furthermore, if neuroimaging is indicated, controversy exists about the choice of computed tomography (CT) or magnetic resonance im-

aging (MRI). CT traditionally has been the imaging study of choice because of its availability and lower cost per case.[16] However, CT has disadvantages, including posterior fossa beam hardening artifacts and potential iodinated contrast reaction.[17,18] MRI with its high soft-tissue characterization, multiplanar capability, and lack of ionizing radiation has emerged as the technically optimal imaging modality.[19] However, its added cost and time, higher sedation rate, and limited availability has hampered its universal use as the first imaging modality.[16]

Our objective was to assess the clinical role and economic consequences of 3 diagnostic strategies: MRI, CT followed by MRI for positive results (CT-MRI), and no imaging with close clinical follow-up in children with headache suspected of having an intracranial tumor. Specifically, we sought to assess the effectiveness (quality-adjusted life years [QALY] gained), lifetime costs, and cost-effectiveness of these 3 diagnostic strategies in children with headache at low, intermediate, and high risk of having a brain tumor.

MATERIALS AND METHODS

Model

Cost-effectiveness analysis (CEA) is a method used to evaluate the outcomes and costs of interventions designed to improve health.[20–23] Primary and secondary (medical publications) data are used to construct a comprehensive decision-analytic model. The results of an analysis are summarized in a series of cost-effectiveness ratios that show the cost of achieving 1 unit of health outcome (eg, the cost per QALY gained) for different risk groups and strategies.[20–23]

A decision-analytic Markov model was constructed to calculate QALY gained and long-term costs of 3 diagnostic strategies in children with headache suspected of having a brain tumor.[20–23] Brain tumors were defined as brain neoplasms and vascular malformations such as arteriovenous malformations (Tables 1 and 2). The model was constructed by using the computer program Decision Analysis by TreeAge ([DATA]; TreeAge Software, Williamstown, MA) to examine and compare the diagnostic performance (sensitivity and specificity) of the imaging tests, the complications associated with these tests, and the probability of detecting an early brain tumor. The 3 strategies included: brain MRI, CT-MRI, and no imaging with close clinical follow-up. Patients with MRI findings consistent with a brain tumor were assumed to have a brain biopsy. Figure 1 shows a simplified representation of the decision tree.

Children with headache were divided into low-, intermediate-

TABLE 1. Summary of Data Used in the Analysis

Variable	Baseline Value	Analysis Range	Source
Prior probability of brain tumor			
Low-risk group*	1/10 000	0.5–2/10 000	25, 26
Intermediate-risk group†	4/1000	1–6/1000	14, 25, primary data
High-risk group‡	4/100	1–8/100	15, primary data
Diagnostic tests			
MRI§			
Sensitivity	0.92	0.82–1.0	15, 27, 28
Specificity	0.99	0.81–1.0	15, 27
CT§			
Sensitivity	0.81	0.65–1.0	15, 27, 28
Specificity	0.92	0.72–1.0	15, 27, 28
Percentage CT with contrast	28%‖	0–100%	Primary data
Percentage MRI with contrast	9%‖	0–100%	Primary data
Percentage CT with sedation	6%‖	0–100%	Primary data
Percentage MRI with sedation	12%‖	0–100%	Primary data
Natural history			
Delayed in tumor diagnosis¶	14%	1–30%	6
Probability herniation#	0.50%	0–2%	12
Risks			
MRI contrast material death	0.25/1 000 000	0.1–0.5/1 000 000	29, 30
MRI contrast material severe reaction	0.25/100 000	0.2–0.3/100 000	29, 30
CT contrast material death	0.9/100 000	0.3–2.6/100 000	31, 32
CT contrast material severe reaction	31/100 000	2–62/100 000	31, 32
Death from sedation	1/1 000 000	0.5–2/1 000 000	41, 42
Systemic complication from sedation	1/1000	0.5–2/1000	41, 42
Brain biopsy death	0.5%	0.1–1%	34, 43
Brain biopsy severe complication	3%	0.5–5%	34, 43
Health utilities			
Nonmedulloblastoma tumors			
No residual tumor	0.93	0.8–1	37
Residual tumor	0.51	0.3–0.7	37
Medulloblastoma tumor			
Nonmetastatic	0.76	0.6–1	37
Metastatistic	0.31	0.1–0.5	37

* Patients with nonmigraine headache for >6 months as the sole symptom and normal neurologic examination.
† Patients with migraine symptoms and a normal neurologic examination.
‡ Patients with headache and clinical predictors of a surgical space-occupying lesion. The 7 predictors include headache of less than 6 months duration, sleep-related headache, vomiting, confusion, absence of visual symptoms, absence of family history of migraine, and abnormal neurologic examination.
§ Based on calculations made from the available literature.
‖ Baseline value obtained from the primary data source.
¶ Probability of having a favorable prognosis tumor progress to an unfavorable tumor if not diagnosed at clinical presentation.
# Herniation from tumor mass effect or bleeding (ie, hemorrhagic tumor or vascular malformation).

TABLE 2. Summary of Brain Tumor Data Used in the Analysis

Variable	5-Year Survival	Estimated Population*	Source
Neoplasm (proportion of total brain tumors)			
Medulloblastoma (20%)			
Local with no metastasis	59%	82%	11
Metastatic	36%	18%	11
Posterior fossa pilocytic astrocytoma (20%)			
Total excision	95%	69%	8
Partial excision	80%	31%	8
Ependymoma (10%)			
Local with gross total resection	75%	47%	9
Residual disease after resection	0–2%	53%	9
Supratentorial pilocytic astrocytomas (10%)			
Total excision	99%	22%	10
Subtotal excision	95%	78%	10
Craniopharyngioma (10%)	95%		35
Grade III astrocytoma and mixed oligoastrocytomas (10%)	52%		10
Grade III glial tumor (10%)	25%		10
Grade IV glial tumor (10%)	10%		10, 36

* At initial presentation.

and high-risk groups based on clinical predictors and on their estimated probability of having a brain neoplasm (Table 1). Markov (state-transition) models[24] were used to calculate the lifetime cost and QALY gained for the 3 risk groups.

The CEA was performed from a societal perspective. Costs were expressed in 1997 US dollars. Costs and QALY gained were discounted at 3% per year.[21] Incremental cost-effectiveness ratios were calculated as the additional cost of a strategy divided by the additional effectiveness compared with the next most effective strategy.[23] According to the Panel on Cost-Effectiveness in Health and Medicine (US Public Health Service),[23] when the strategy under study is both more effective and less costly than the alternative, it is said to dominate the alternative strategy.[23] When the strategy under study has a lower incremental cost-effectiveness ratio and a greater effectiveness, it is said to have extended dominance over the alternative strategy.[23] Cost-effectiveness ratios were expressed as cost per QALY gained.

Data

Primary and secondary data sources were used. Primary information included a hospital-based database of 315 children with headache who were imaged with MRI and CT.[15] Secondary data sources included medical publications from 1962 to 1997 reporting on headache and brain tumors. Sensitivity analyses were performed to explore the effects of varying the model estimates over clinically plausible ranges and determine the robustness of the results.[23] Model baseline values and ranges are summarized in Table 1.

Prior Probability of Brain Tumor

Estimates of the prior probability of a brain tumor in children with headache were derived from the primary and secondary data sources (Table 1). Three risk populations were determined. Low-risk children were characterized as having had nonmigraine headaches for >6 months as the sole symptom and a normal neurologic examination.[14,15] For this group, the estimated prevalence (prior probability) of a brain tumor is 0.01% (1/10 000).[25,26] Intermediate-risk patients were characterized as having migraine headache and a normal neurologic examination with an estimated prevalence (prior probability) of brain tumor of 0.4% (4/1000).[14,25] Migraine headaches were defined as recurrent headaches that are often pulsating, unilateral, and associated with symptoms such as nau-

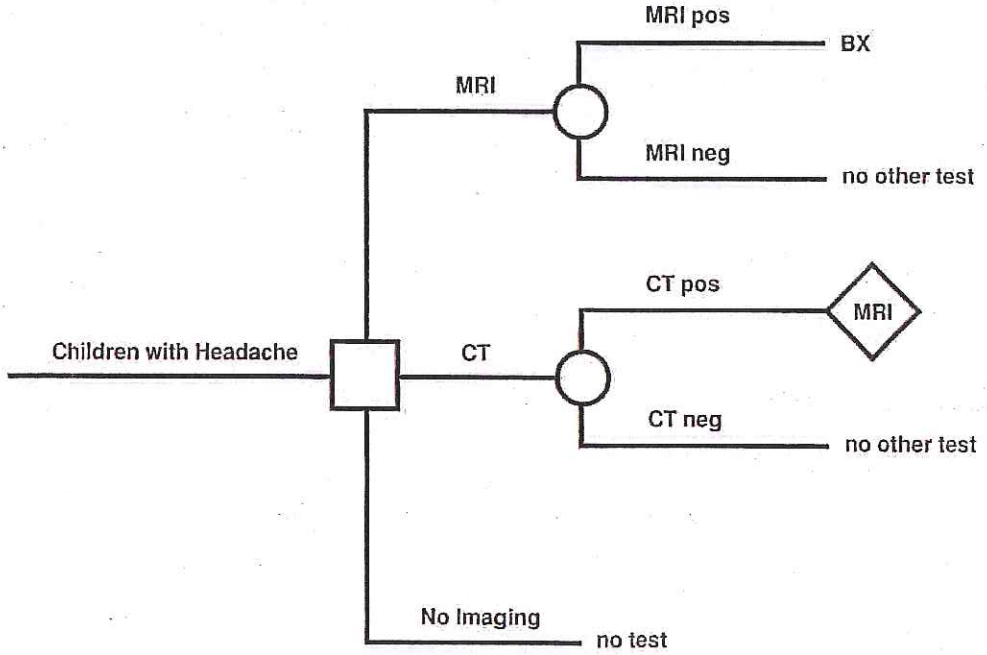


Fig 1. Three strategies for studying children with headache suspected of having a brain tumor. BX indicates biopsy; pos, positive; neg, negative.

sea, light and sound sensitivity, and visual or neurologic symptoms.[25] High-risk children were characterized by headaches for <6 months and at least 1 other clinical predictor of a surgical space-occupying lesion.[15] These predictors included sleep-related headache, vomiting, confusion, absence of visual aura, absence of family history of migraine, and abnormal neurologic examination.[15] The probability of a brain tumor among high-risk patients has been estimated at 4% (4/100).[15] Ranges considered plausible for each risk group were studied with sensitivity analysis.

Diagnostic Tests

MRI and CT sensitivity for brain tumors has been estimated in the range of 82% to 100% and 65% to 100%, respectively.[15,27,28] MRI and CT specificity has been estimated in the range of 81% to 100% and 72% to 100%, respectively.[15,27] Because there are no large series assessing the joint diagnostic performance of MRI and CT, conditional independence between these tests was assumed for the case where a positive CT examination was followed by a MRI test (Fig 1).

The mortality and morbidity for the different diagnostic procedures were based on the use of contrast and the need for sedation (Table 1). Severe adverse reactions and death are higher with CT iodinated contrast than MRI gadolinium-based contrast.[29–32] Because MRI tends to be a longer study than CT, sedation rates are higher with the former test. The potential risk of death from radiograph radiation was not included in the analysis of the CT strategy because the radiation dosage is relatively low and it is comparable to the risk of other normal activities in life.[33]

Long-Term Outcomes

The base-case patient was a 5-year-old child without coexistent disease. The probability of dying of causes other than brain tumor was obtained from the US vital statistic data (National Center for Health Statistics). Model parameters, including prevalence, stage distribution, 5-year survival data, and herniation risk of brain tumors were based on values obtained from the primary and secondary data sources used (Tables 1 and 2). We projected long-term outcomes such as life years (LYs) and QALY gained using a conservative horizon of 20 years.

In the pre-CT and pre-MRI era, the Childhood Brain Tumor Consortium study demonstrated 14% of children to have a 1-year delay in the diagnosis of brain tumor from the initiation of clinical findings.[6] Five-year brain tumor survival data (Table 2) demonstrate differences between local versus metastatic medulloblastomas and total versus partial resection for pilocytic astrocytomas and ependymomas.[8–11,34–36] Therefore, for the 8 most common pediatric brain neoplastic types,[34] we assumed that pilocytic astrocytoma, medulloblastoma, and ependymoma (60% of all tumors) can have a worse prognosis if diagnosed late (Table 2). For those tumors, based on the Brain Tumor Consortium results,[6] we assumed a 14% probability of having a localized or resectable disease (favorable prognosis) progress to either metastatic or partially resectable disease (unfavorable prognosis) if not diagnosed at clinical presentation. To ensure a conservative model, the rest of the brain neoplasms were considered to have the same 5-year survival rate regardless of time of diagnosis (Table 2).[8–11,35,36] Estimated population distributions of cancer stage at initial presentation were determined from the published literature (Table 2).[8–11,35,36]

Intracranial tumors may cause brain herniation because of mass effect (ie, large brain neoplasm) or bleeding (ie, hemorrhagic neoplasm or vascular malformation). The brain herniation mortality has been estimated to be between 0.2% and 1%.[12]

QALY gained was estimated using the Health Utilities Index, which is based on children with neoplasm (Table 1).[37] The Health Utilities Index was used to determine the quality weight (utility) from the treating physician's perspective. A health-quality weight (utility) can range from 0 (death) to 1 (perfect health). The quality weight (utility) for a year of life spent in a favorable prognosis versus unfavorable prognosis tumor state was incorporated into the Markov model. Health utilities were subdivided into nonmedulloblastoma and medulloblastoma tumor populations. This was done because of the more aggressive and debilitating nature of the treatment and disease process in patients with medulloblastoma (Table 2).[11] Quality-of-life weights and disease-specific mortalities were assumed to persist only for the first 5 years after diagnosis, after which time the child was assumed to be cured.

Costs

Costs (not charges) of the radiologic and nonradiologic (ie, hospitalization, surgery, chemotherapy, radiation therapy, laboratories, and pharmacy) procedures were estimated from the Boston Children's Hospital cost accounting system. Fixed, variable, and overhead costs were analyzed. Cost data for the different diagnostic studies, favorable versus unfavorable brain tumor treatment, sedation, and adverse contrast media reaction are summarized in Table 3.

The cost of the radiologic studies included the technical and professional fee. Costs incurred by patients with favorable and unfavorable prognosis brain tumors were obtained. We used an estimate of $32 000 for the first-year cost of a favorable prognosis brain tumor and an annual cost of $4000 for subsequent years (Table 3). We used an estimate of $45 000 for the first-year cost of an unfavorable prognosis brain tumor and an annual cost of $8000 for subsequent years (Table 3). These costs included hospitalization, surgery, chemotherapy, radiation therapy, laboratories, pharmacy, imaging, and follow-up visits.

Sensitivity Analysis

One-way sensitivity analysis was performed for each parameter of the model over a clinically plausible range of values (Table 1). The effect of these changes on outcomes, costs, and cost-effectiveness ratios were analyzed.

RESULTS

Baseline Analysis

Results for the low-,intermediate-, and high-risk groups (hypothetical cohorts) are shown in Table 4.

Low-Risk Children

The most effective diagnostic strategy for the low-risk cohort was no imaging with close clinical follow-up. This strategy was also associated with the lowest cost when compared with CT and MRI. Given the very low prevalence (prior probability) of a brain tumor in this group of 0.01% (1/10 000), the risk from sedation, contrast, and false-positive test results plus the added costs of CT and MRI outweigh the benefit of detecting a rare brain tumor early.

Intermediate-Risk Children

The most effective diagnostic strategy for children with headache in this group was CT-MRI. Given the low number of brain tumors in this group at 0.4%

Table 3. Summary of Cost Data Used in the Analysis

Variable	Baseline Value	Sensitivity Analysis Range
CT brain without contrast	$460	320–550
CT brain with contrast	$620	400–760
MRI brain without contrast	$720	550–850
MRI brain with contrast	$1100	900–1200
Sedation	$85	50–140
Cost of favorable prognosis brain tumor*	$32 000	22 000–42 000
Yearly cost of favorable prognosis brain tumor	$4000	3000–8000
Cost of unfavorable prognosis brain tumor*	$45 000	35 000–55 000
Yearly cost of unfavorable prognosis brain tumor	$8000	5000–12 000
Cost of managing severe adverse reactions to contrast material or sedation	$2500	1000–5000

* First year.

TABLE 4. Cost-Effectiveness in QALYs*

Intervention	Total Cost	Total Effectiveness (QALY)	Incremental Cost	Incremental Effectiveness (QALY)	Cost-Effectiveness Ratio (Incremental Cost/Incremental Effectiveness)
Low-risk group (prior probability 0.01%)					
No imaging	$7	15.0285	—	—	—
MRI	$861	15.02776	—	—	Dominated
CT-MRI	$1304	15.02848	—	—	Dominated
Intermediate-risk group (prior probability 0.4%)					
No imaging	$269	15.00349	—	—	—
MRI	$1150	15.00378	—	—	Extended dominance
CT-MRI	$1588	15.00431	$1319	0.00082	$1 600 000†
High-risk group (prior probability 4%)					
No imaging	$2694	14.77259	—	—	—
MRI	$3819	14.78248	$1125	0.00989	$113 800†
CT-MRI	$4212	14.78116	—	—	Dominated
High-risk group (prior probability 8%)					
No imaging	$5389	14.51604	—	—	—
MRI	$6775	14.53658	$1386	0.02054	$67 000†
CT-MRI	$7117	14.53321	—	—	Dominated

* Costs and effects are per person in the target population.
† Cost-effectiveness ratios are rounded.

(4/1000), the CT-MRI strategy was more effective than MRI alone because of the fewer false-positive MRI test results with the former. The fewer false-positive MRI test results in the CT-MRI strategy resulted in less unnecessary brain biopsies, thereby decreasing morbidity, mortality, and cost from this invasive procedure. Although the CT-MRI strategy is the most effective strategy, its cost-effectiveness ratio is high, at >$1 million per QALY saved compared with no imaging.

High-Risk Children

The most effective strategy for high-risk children was MRI. MRI was also less costly than the CT-MRI strategy, given the CT false-positive rate, which leads to further unnecessary workup with MRI. The cost-effectiveness ratio of MRI compared with no imaging was $113 800 per QALY gained.

Sensitivity Analysis

An increase in the number of predictors has been highly correlated with an increased risk of brain tumor.[15] Assessment of this variable revealed that the cost-effectiveness ratio decreased from $113 800 to $67 000 per QALY saved when the pretest probability increased from 4% to 8%, respectively (Table 4). Lower cost-effectiveness ratios were noted as the increasing number of brain tumor predictors increases the prior probability (Table 5).

One-way sensitivity analyses for high-risk patients are shown in Table 5. An increase in the probability of having a favorable prognosis tumor progress to an unfavorable prognosis tumor if not diagnosed at clinical presentation decreases the cost-effectiveness ratio of MRI. The same applies to the percentage of death caused by brain herniation. As the percentage of patients' risk of dying from brain tumor–induced herniation increases, the MRI strategy cost-effectiveness ratio decreases.

MRI was ruled out by dominance or extended dominance if its specificity was lower than 97%. The greater the MRI specificity, the lower the cost-effectiveness ratios for the MRI strategy became. Likewise CT was no longer dominated if its specificity was greater than 97%. Results were not significantly sensitive to the sensitivity of MRI or CT.

The MRI diagnostic strategy in high-risk patients showed some sensitivity to changes in brain biopsy mortality. An increase in intracranial biopsy mortality resulted in a higher cost-effectiveness ratio for MRI. This was explained on the basis of decreased effectiveness and increased costs in patients with false-positive MRI results undergoing unnecessary brain biopsies with a higher mortality risk.

Extending the time horizon of the study 3 times the conservative assumption of 20 years showed a decrease in the cost-effectiveness ratio of MRI to $65 000 per QALY gained. When only LYs saved without quality adjustment was considered in the analysis for high-risk patients, MRI was still the preferred strategy but with a higher cost-effectiveness ratio (Table 5).

Sensitivity analysis of the cost variables revealed that MRI became more cost-effective (lower cost-effectiveness ratio) as its cost equaled the cost of doing a CT examination. Decreases in the favorable prognosis brain neoplasm costs and increases in the unfavorable neoplasm costs reduced the MRI strategy cost-effectiveness ratio. Sensitivity analysis of the imaging contrast and sedation variables revealed few changes in our base-case results.

DISCUSSION

The value of neuroimaging in evaluating headache in the child suspected of having a brain tumor is controversial.[6,7,14,15] Some studies conclude that neuroimaging studies have a very limited role in low-risk children with chronic headaches,[14] whereas other studies emphasize the importance of imaging children with nonchronic headache and clinical pre-

TABLE 5. Sensitivity Analysis of High-Risk Group

Variable	Incremental Cost-Effectiveness Ratio ($/QALY)	
	CT-MRI	MRI
Delayed tumor diagnosis*		
1%	2 886 000	Dominated
5%	Dominated	391 880
14%†	Dominated	113 800
30%	Dominated	45 800
Prior probability of brain tumor		
10%	Dominated	58 900
15%	Dominated	47 400
30%	Dominated	38 300
Death caused by brain herniation		
0	Dominated	134 200
0.5%†	Dominated	113 800
2%	Dominated	79 300
MRI specificity		
95%	174 000	Dominated
96%	174 000	Extended dominance
97%	1 215 000	157 000
99%	Dominated	113 000
100%	Dominated	96 000
CT specificity		
95%	Dominated	113 800
97%	Extended dominance	113 800
98%	110 600	134 600
99%	99 500	206 600
100%	88 400	278 700
MRI sensitivity		
82%	Dominated	125 900
85%	Dominated	121 900
92%	Dominated	113 800
100%	Dominated	106 000
CT sensitivity		
65%	Dominated	113 800
90%	Dominated	113 800
95%	Dominated	113 800
100%	Dominated	113 800
Neurosurgery mortality		
0.025 × baseline	Dominated	97 000
0.5 × baseline	Dominated	102 000
2 × baseline	Dominated	149 000
Study horizon		
20 y†	Dominated	113 800
30 y	Dominated	88 000
60 y	Dominated	65 000
Health utilities		
No utilities (cost/life year saved)	Dominated	167 000
Highest and lowest utility‡	Dominated	91 500
MR/CT cost§		
1/1	Dominated	88 000
1.7/1†	Dominated	113 800
2/1	Dominated	139 000
3/1	177 000	280 000
Cost of favorable neoplasm treatment		
0.025 × baseline	Dominated	108 400
0.5 × baseline	Dominated	110 200
2 × baseline	Dominated	121 100
Cost of unfavorable neoplasm treatment		
0.025 × baseline	Dominated	126 900
0.5 × baseline	Dominated	122 500
2 × baseline	Dominated	96 400
CT contrast		
0%	Dominated	113 817
28%†	Dominated	113 811
50%	Dominated	113 806
100%	Dominated	113 794
MR contrast		
0%	Dominated	110 300
9%†	Dominated	113 800
50%	Dominated	129 600
100%	Dominated	148 900
MR/CT sedation ratio		
1/1	Dominated	113 800
2/1†	Dominated	113 811
4/1	Dominated	113 831
Patients sedated for CT or MRI		
0%	Dominated	113 300
6%	Dominated	113 800
50%	Dominated	117 760
100%	Dominated	122 300
Annual discount rate		
0%	Dominated	87 700
3%†	Dominated	113 800
5%	Dominated	133 000

* Probability of having a favorable prognosis tumor progress to an unfavorable prognosis tumor if not diagnosed at clinical presentation.
† Baseline estimate based on pretest probability of 4%.
‡ Highest and lowest utility for favorable versus unfavorable brain tumor, respectively.
§ MR/CT cost ratio using CT costs as the baseline.

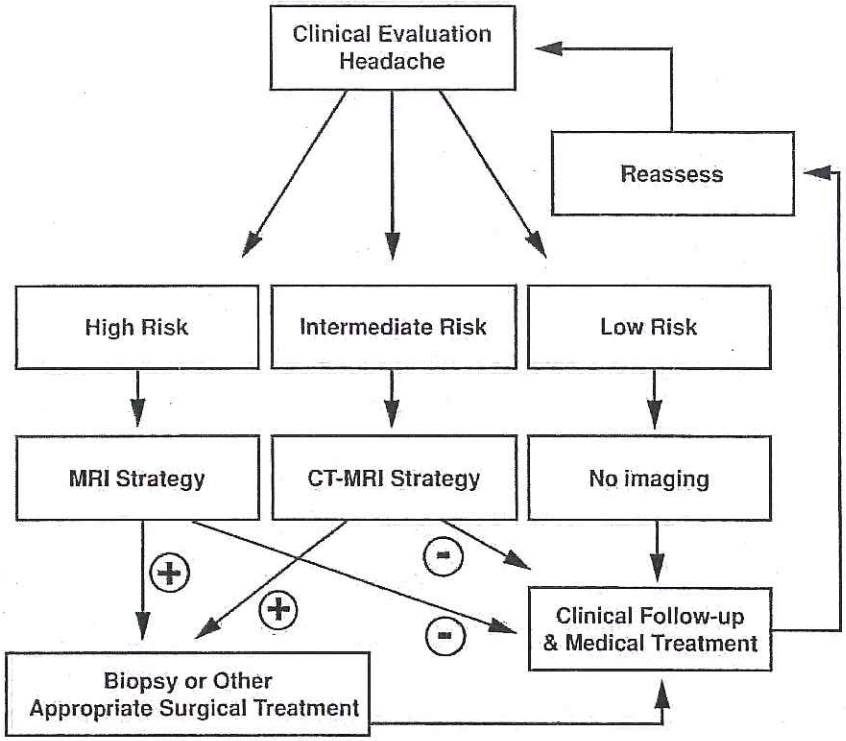


Fig 2. Suggested decision tree for use in children with headache. For patients in the high- and intermediate-risk group, neuroimaging is suggested. For patients in the low-risk group or those with negative findings from imaging studies, clinical follow-up with periodic reassessment is recommended.

dictors of a surgical brain tumor such as an abnormal neurologic examination.[7,15] Changes in our approach to health care emphasize the need to consider long-term outcomes and costs in evaluating medical diagnostic strategies. Accordingly, we performed a decision analytic Markov model and CEA of 3 risk groups incorporating the quality-of-life adjustments and costs associated with early versus late brain tumor diagnosis and treatment.

The low-risk group with baseline pretest probability of 0.01% (1/10 000) consisted of patients with the sole finding of chronic headaches of >6 months' duration.[25,26] The most effective strategy was no imaging with close clinical follow-up. Furthermore, this strategy was cost-saving when compared with the CT-MRI and MRI strategies because of its greater effectiveness at a lower cost. Therefore, the risks of false-positive neuroimaging results, contrast use, and sedation outweigh the benefit of early diagnosis of a rare brain tumor in this risk group (Table 4).

The intermediate-risk group with baseline pretest probability of 0.4% (4/1000) consisted of children with migraine headaches and a normal neurologic examination.[14,25] CT-MRI was a slightly more effective diagnostic strategy than MRI alone. However, the cost-effectiveness ratio of the CT-MRI strategy was >$1 million per QALY saved.

The high-risk group with baseline prevalence (prior probability) of 4% consisted of children with headache of <6 months' duration and at least 1 other clinical predictor suggestive of a surgical brain tumor such as an abnormal neurologic examination.[15] MRI maximized QALY gained compared with CT-MRI or no imaging in this risk group. An increase in the number of predictors has been highly correlated with an increased risk of brain tumor.[15] Assessment of this variable revealed a decrease in the cost-effectiveness ratio from $113 800 to $67 000 per QALY saved when the prior probability was increased from 4% to 8% (Table 4).

The cost-effectiveness ratios allow comparisons with alternative health care programs and may assist in resource allocation decisions.[23] The high-risk group cost-effectiveness ratios compared favorably with other well-accepted diagnostic procedures. For example, annual mammography for women 55 to 64 years old costs $110 000 per LY saved (updated to 1993 US dollars),[38] annual cervical cancer screening for women beginning age 20 costs $220 000 per LY saved (updated to 1993 US dollars),[38,39] and colonoscopy for colorectal cancer screening for people older than 40 years costs $90 000 per LY saved (updated to 1993 US dollars).[38,40]

In the high-risk group we found our analysis to be sensitive to the percentage of favorable prognosis tumors that progressed to unfavorable prognosis because of delayed diagnosis and treatment, and increased risk of death from brain herniation. That is, the incremental cost-effectiveness ratio for MRI was lower for patients who had a greater probability of progression because of delayed tumor diagnosis and treatment, and greater risk of dying from brain herniation (Table 5).

We also found in our high-risk group that the diagnostic performance of the neuroimaging tests affected our base case-results. MRI became a dominated strategy if its specificity was <97%. CT was no longer dominated if its specificity was greater than 97%. A decrease in the MRI test sensitivity revealed an increase in the cost-effectiveness ratio of the MRI strategy (Table 5). Therefore, the exact diagnostic performance (sensitivity and specificity) of MRI and

CT for a specific institution or individual may affect the diagnostic strategy of choice and its cost-effectiveness.[15,27,28]

Results were somewhat sensitive to changes in the MRI to CT cost ratios. For example, if CT and MRI costs were equal, the MRI cost-effectiveness ratio for the high risk group would decrease to 88 000 per QALY gained (Table 5). The impact of the MRI to CT cost ratios on the cost-effectiveness ratio should be kept in mind in countries with different neuroimaging costs and equipment availability.[16]

In the high-risk group, our analyses were not very sensitive to the percentage of patients needing sedation or contrast (Table 5). This is explained by the low risk of radiologic sedation, MRI contrast, and CT nonionic contrast media in this risk group.[29–32,41]

These results are summarized in Fig 2 as a suggested decision tree for use in children with headache. The decision tree reinforces the primary importance of carefully acquiring a medical history and performing a thorough examination, including a detailed neurologic examination. For patients in the high-risk group, neuroimaging with MRI is suggested, whereas in the intermediate-risk group CT-MRI may be indicated. For children in the low-risk group or those with negative findings from neuroimaging studies, close clinical follow-up with periodic reassessment is recommended. In children with headache, appropriate selection of patients for imaging based on these risk groups may maximize QALY gained by reducing potential risks associated with false-positive results, use of contrast material and sedation, and decrease costs of medical workup.

Future studies are needed. First, our CEA demonstrated differences in the diagnostic strategy of choice and its cost-effectiveness ratio based on the diagnostic performance (sensitivity and specificity) of the tests. Prospective studies comparing the diagnostic performance and receiver operator characteristic curve of experienced and less experienced readers for CT, MRI, and CT-MRI are needed.

Second, because the spectrum of children with headache is so broad, other clinical risk groups must be studied and their prevalence (prior probability) of brain tumor determined. Large prospective cohort studies in children with other well-defined headache disorders are needed for this purpose. Such studies might ultimately form the basis for valuable evidence-based practice guidelines for the large population of children evaluated for headache each year in the United States and other countries.

CONCLUSION

Our analysis suggests that MRI maximizes quality-adjusted life expectancy at a reasonable cost-effectiveness ratio in children with headache at high risk of having a brain tumor. Conversely, the strategy of no imaging with close clinical follow-up is cost saving in low-risk children. Although the CT-MRI strategy maximizes quality-adjusted life expectancy in the intermediate-risk patients, its additional cost per QALY gained is high. In children with headache, appropriate selection of patients and diagnostic strategy may maximize quality-adjusted life expectancy and decrease costs of medical work up.

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REFERENCES

1. Linet MS, Stewart WF, Celentano DD, Ziegler D, Sprecher M. An epidemiologic study of headache among adolescents and young adults. *JAMA*. 1989;261:2211–2216
2. Stewart WF, Lipton RB, Celentano DD, Reed ML. Prevalence of migraine headache in the United States. Relation to age, income, race, and other sociodemographic factors. *JAMA*. 1992;267:64–69
3. Bille B. Migraine in school children. *Acta Paediatr Scand*. 1962;51:3–144
4. Sillanpaa ML. Headache in children. In: Olesen J, ed. *Headache Classification and Epidemiology*. New York, NY: Raven; 1994:273–281
5. de Lissovoy G, Lazarus SS. The economic cost of migraine: present state of knowledge. *Neurology* 1994;44:S36–S62
6. The Childhood Brain Tumor Consortium. The epidemiology of headache among children with brain tumor. *J Neurol Oncol*. 1991;10:31–46
7. Honig PJ, Charney EB. Children with brain tumor headaches: distinguishing features. *Am J Dis Child*. 1982;136:121–124
8. Garcia DM, Latifi HR, Simpson JR, Picker S. Astrocytomas of the cerebellum in children. *J Neurosurg*. 1989;71:661–664
9. Healey EA, Barnes PD, Kupsky WK, et al. The prognostic significance of postoperative residual tumor in ependymoma. *Neurosurgery*. 1991;28:666–672
10. Shaw EG, Daumos-Duport C, Scheithauer BW, et al. Radiation therapy in the management of low-grade supratentorial astrocytomas. *J Neurosurg*. 1989;70:853–861
11. Evans AE, Jenkin DT, Sposto R, et al. The treatment of medulloblastoma. Results of a prospective randomized trial of radiation therapy with and without CCNU, vincristine, and prednisone. *J Neurosurg*. 1990;72:572–582
12. Menkes JH. *Textbook of Children Neurology*. 5th ed. Baltimore, MD: Williams & Wilkins; 1995:17–723
13. Chu ML, Shinnar S. Headaches in children younger than 7 years of age. *Arch Neurol*. 1992;49:79–82
14. Maytal J, Bienkowski RS, Patel M, Eviatar L. The value of brain imaging in children with headaches. *Pediatrics*. 1995;96:413–416
15. Medina LS, Pinter JD, Zurakowski D, Davis RG, Kuban K, Barnes PD. Children with headache: clinical predictors of surgical space-occupying lesions and the role of neuroimaging. *Radiology*. 1997;202:819–824
16. Bell RA. Economics of MRI technology. *J Magn Reson Imaging*. 1996;1:10–25
17. Dunnick NR, Connan RH. Cost, corticosteroids, and contrast media. *AJR Am J Roentgenol*. 1994;162:527–529
18. McClennan BL. Adverse reactions iodinated contrast material. Recognition and response. *Invest Radiol*. 1994;29:S46–S50
19. American College of Physicians. Magnetic resonance imaging of the brain and spine. A revised statement. *Ann Intern Med*. 1994;120:872–875
20. Weinstein MC, Fineberg HV. *Clinical Decision Analysis*. Philadelphia, PA: Saunders; 1980
21. Weinstein MC, Stason WB. Foundations of cost-effectiveness analysis for health and medical practices. *N Engl J Med*. 1977;296:716–721
22. Drummond MF, Stoddart GL, Torrance GW. *Methods for the Economic Evaluation of Health Care Programmes*. Oxford, United Kingdom: Oxford Medical Publications; 1987
23. Gold MR, Siegel JE, Russell LB, Weinstein MC. *Cost-Effectiveness in Health and Medicine*. New York, NY: Oxford University Press; 1996
24. Sonnenberg FA, Beck JR. Markov models in medical decision making: a practical guide. *Med Decis Making*. 1993;13:322–338
25. Frishberg BM. The utility of neuroimaging in the evaluation of headache in patient with normal neurologic examinations. *Neurology*. 1994;44:1191–1197
26. Sturman MF. *Effective Medical Imaging: A Signs and Symptoms Approach*. Baltimore, MD: Williams & Wilkins; 1992:151–154
27. Haughton VM, Rimm AA, Sobocinski KA, et al. A blinded clinical comparison of MR imaging and CT in neuroradiology. *Radiology*. 1986;160:751–755
28. Orrison WW, Stimac GK, Stevens EA, et al. Comparison of CT, low-

field-strength MR imaging and high-field-strength MR imaging. Work in progress. *Radiology*. 1991;181:121–127
29. Carr JJ. Magnetic resonance contrast agents for neuroimaging. *Neuroimaging Clin N Am*. 1994;4:43–54
30. Murphy KJ, Brunberg JA, Cohan RH. Adverse reaction to gadolinium contrast media: a review of 36 cases. *AJR Am J Roentgenol*. 1996;167:847–849
31. Caro JJ, Trindade E, McGregor M. The risks of death and of severe nonfatal reactions with high- versus low-osmolality contrast media: a meta-analysis. *AJR Am J Roentgenol*. 1991;156:825–832
32. Hunink GM, Bos JJ. Triage of patients to angiography for detection of aortic rupture after blunt chest trauma: cost-effectiveness analysis of using CT. *AJR Am J Roentgenol*. 1995;165:27–36
33. Poznanski A. Approaches to minimizing risk in pediatric radiology. In: *American College of Radiology Primer in Radiation Risk*. Reston, VA: American College of Radiology; 1996:19
34. Heideman RL, Pocker RJ, Albright LA, Freeman CR, Rorke LB. Tumors of the central nervous system. In: Pizzo PA, Poplock DG, eds. *Principles and Practice of Pediatric Oncology*. 3rd ed. Philadelphia, PA: Lippincott-Raven Publishers; 1997:633–697
35. Hetelekidis S, Barnes PD, Tao ML, et al. 20-year experience in childhood craniopharyngioma. *Int J Radiat Oncol Biol Phys*. 1993;27:189–195
36. Devaux BC, O'Fallon JR, Kelly PJ. Resection, biopsy, and survival in malignant glial neoplasms. *J Neurosurg*. 1993;78:767–775
37. Feeny VH, Torrance GW, Furlong WJ. Health utilities index. In: Spilker B, ed. *Quality of Life and Pharmacoeconomics in Clinical Trials*. 2nd ed. Philadelphia, PA: Lippincott-Raven Publishers; 1996:239–251
38. Tengs TO, Adams ME, Pliskin JS, et al. Five hundred life-saving interventions and their cost-effectiveness. *Risk Anal*. 1995;15:369–390
39. Eddy DM. Appropriateness of cervical cancer screening. *Gynecol Oncol*. 1981;12:S168–S187
40. England WL, Halls JJ, Hunt VB. Strategies for screening for colorectal carcinoma. *Med Decis Making*. 1989;9:3–13
41. Cote CJ. Sedation for the pediatric patient: a review. *Pediatr Clin North Am*. 1994;41:31–58
42. Holzman RS. Morbidity and mortality in pediatric anesthesia. *Pediatr Clin North Am*. 1994;41:239–256
43. Broggi G, Franzini A, Migliavacca F, Allegranza A. Stereotactic biopsy of deep brain tumors in infancy and childhood. *Childs Brain*. 1983;10:92–98

1500 EXTRA INFANTS WITH CEREBRAL PALSY EACH YEAR IN THE UNITED STATES?

We estimate that 800 infants weighing less than 1000 g, at least 40% of these infants receive steroids, or 800 infants a year . . . 70 extra infants in Canada every year will have neurodevelopmental impairment as a result of postnatal steroid treatment, and 110 extra infants will have cerebral palsy. These estimates should be multiplied by approximately 14 to estimate the annual number of affected infants in the United States.

Barrington KJ. The adverse neurodevelopmental effects of postnatal steroids in the preterm infant: a systematic review. *BMC Pediatr*. 2001;1:1

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Childs Nerv Syst (2009) 25:941–947
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ORIGINAL PAPER

MRI to demonstrate diagnostic features and complications of TBM not seen with CT

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Abstract
Background Computed tomography (CT) findings in children with tuberculous meningitis (TBM) often do not explain the clinical presentation and may even be normal. Magnetic resonance imaging (MRI) has the potential to diagnose TBM with greater sensitivity than CT and also to detect more infarcts.
Aim The aim of this study was to determine whether MRI demonstrates features and complications of TBM not present on CT.
Materials and methods Retrospective, blinded evaluation and comparison of CT and MRI findings in children with TBM were performed.
Results Of 30 children included, MRI demonstrated eight more with basal enhancement and four more with infarctions. Overall, MRI demonstrated an additional 104 sites of infarction (of a total 172) than CT. Of these, 89 were acute and visualized only on diffusion-weighted image. MRI showed five more patients with unilateral and two more with bilateral basal ganglia infarcts than CT as well as 19 brainstem infarcts. Hydrocephalus was equally detected by MRI and CT.
Conclusion MRI is superior to CT for diagnosing TBM (by detecting basal enhancement in more patients) and prognosis (by detecting many more infarcts in strategic locations). The role of CT is defined for the acute setting in detecting hydrocephalus for surgical management.

Keywords Meningitis · Tuberculosis · Basal enhancement · Infarction · DWI · Hydrocephalus

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Introduction

The Western Cape region in South Africa has one of the highest recorded tuberculosis (TB) incidences in the world [1]. The incidence of TB is increasing in both the developing and developed world. Children and infants are particularly at high risk for acquiring the disease [2, 3]. Up to 79% of children diagnosed with tuberculous meningitis (TBM) are less than 5 years of age [4, 5]. Young age and late-stage presentation are associated with a poor outcome [6]. Pulmonary TB tends to be the commonest form of TB, but the highest morbidity and mortality occurs with TBM [1–3, 7, 8]. Intracranial tuberculosis is caused by hematogeneous spread from a primary focus elsewhere in the body, with the lungs being in most cases the primary focus. However, in many cases, there is no evidence of extracranial focus [9]. Neurological sequelae such as marked generalized impaired cognitive and motor impairment are reported in TBM survivors [10]. The high morbidity and mortality of this treatable disease justify early diagnosis and treatment [3, 8, 11, 12].

In the literature, the use of computed tomography (CT) in diagnosing TBM and its complications is well established. Magnetic resonance imaging (MRI) studies describing the findings of TBM have been published by

various authors, e.g., Schoeman et al. [11], Tayfun et al. [9], Gupta et al. [13], and Chang et al. [14]. Publications on comparing CT vs. MRI findings of specifically diagnostic criteria and complications of TBM are few especially on an exclusive pediatric population, and small numbers of children are included [14, 15]. Some publications concentrate on other MRI features of central nervous system (CNS) TB such as tuberculomas [16–18] or infarcts and their distribution only [19].

This comprehensive retrospective study specifically evaluates and compares TBM features and its complications on CT and MRI in an exclusively pediatric population and also explores the use of the diffusion-weighted image (DWI) sequence in identifying infarcts known to predict outcome.

Aim

The aim of this study was to determine whether magnetic resonance imaging demonstrates features and complications of tuberculous meningitis not present on computer tomography.

Materials and methods

This retrospective study was performed at a teaching hospital in Cape Town, South Africa. Children with TBM, less than 14 years old who had both MRI and CT done within 72 h of each other, were included. The initial CT (pre- and postcontrast) study should have been followed by the MRI study within 72 h, as this is the usual waiting time for MRI.

Intravenous water-soluble nonionic low osmolar medium at 1 mg/kg and gadolinium gadopentate at 0.1 mmol/kg were the contrast agents used, respectively, for CT and MRI studies. MRI and CT studies were performed according to a departmental protocol specifying sequence and method, respectively.

Criteria for TBM diagnosis included: Either positive *Mycobacterium tuberculosis* culture in cerebrospinal fluid (CSF) or gastric aspirate, or clinical and CSF criteria suggestive of TBM (high protein and low glucose, ploecytosis >20 cells/mm^3 with lymphocyte predominance) with two or more of the following:

(1) Recent evidence of poor weight gain on the weight centiles
(2) A positive purified protein derivative skin test (Mantoux >15 mm or >5 mm in a HIV-infected child)
(3) A chest radiograph compatible with a diagnosis of primary tuberculosis (e.g., a military picture or enlarged hilar lymph nodes with or without segmental lobar involvement)
(4) Close household TB contact (sputum-positive adult)
(5) Cranial CT or MRI findings suggestive of TBM

Reading of the studies was done by a pediatric radiologist with expertise in TB imaging and pediatric neuroradiology experience. Independent blinded readings of CT and MRI studies were performed in a random order.

The following parameters were evaluated: Hydrocephalus, basal enhancement (post contrast), granulomata, and infarcts. In particular, infarcts were evaluated using MRI DWI (infarct-sensitive sequence) and T2 sagittal (specifically for corpus callosum and brainstem pathology).

MRI studies were performed on a 1,5T superconducting magnet, Symphony Siemens unit (Erlagen, Germany). CT (axial plane) pre- and postcontrasted (CT/CECT) studies were performed on either Astion or Aquillion CT scanner units (Toshiba, Japan). MRI sequences include: axial planes T1-weighted (T1W), T2-weighted (T2W), fluid-attenuation inversion recovery (FLAIR), DWI, T1W + Gad (T1W plus Gd-diethylene triamine pentaacetic acid (DTPA)/gadolinium) and sagittal plane T2W as per departmental protocol.

Results

Thirty children with TBM were included, of which 14 were boys and 16 girls. Their ages ranged between 4 months to 13 years 10 months, with the average age being 4 years 7 months. There were 11 cases of proven TBM with five positive CSF cultures, eight positive gastric washing cultures (two both CSF and gastric aspirate culture with positive results). Nineteen were probable TBM cases (All with a positive clinical history, 20+ve Mantoux tests, 27+ve CSF chemistry, and 8+ve chest radiographs).

CT and MRI findings for the 30 patients are summarized in Table 1. Basal meningeal enhancement was seen in eight more patients on MRI than on CECT (Fig. 1a, b). MRI additionally demonstrated 26 patients with cranial nerve enhancement not recorded on CT. MRI showed seven more patients with granulomata. Hydrocephalus was demonstrated equally on CT and MRI in 23 patients. There were only four

Table 1 CT and MRI findings in 30 Children with TBM

	CT	MRI	Difference
Basal enhancement	21	29	8
Hydrocephalus	23	23	0
Infarcts	21	25	4
Granuloma(s)	5	12	7

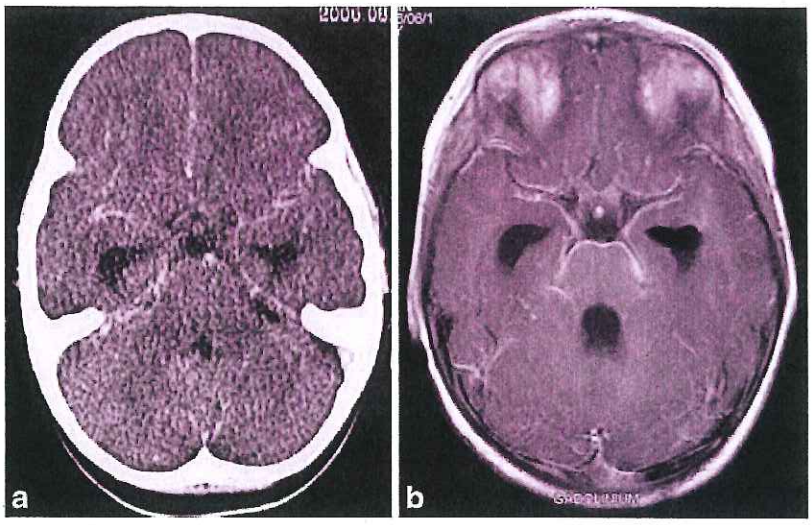


Fig. 1 CT and MRI for detecting basal enhancement. **a** Post-contrast CT does not demonstrate any convincing features of basal enhancement. **b** Postgadopentate MRI in the same patient as **a** demonstrates obvious enhancement of the meninges lining the temporal and frontal lobes as well as the brainstem, consistent with TBM

more patients with infarcts demonstrated using MRI, but more infarcts in number were evident on MRI. Table 2 summarizes the number of patients with infarcts in important locations, while Table 3 indicates the number of infarcts detected overall using each modality and Table 4 the number of infarcts involving the prognostically significant basal ganglia and internal capsules (Fig. 2a–c).

MRI showed five more patients with unilateral and two more with bilateral basal ganglia infarcts, 12 more with unilateral and four more with bilateral thalamic infarcts, six more corpus callosum, 12 more brainstem, and ten more patients with cerebral infarcts than did CT.

A total of 172 infarcts were seen on MRI, and 144 of these were acute (DWI+ve; Fig. 3a–c), 25 sub-acute (high T2 and FLAIR, DWI−ve), and three chronic (high T2, low FLAIR, DWI−ve). There were 104 more infarcts seen in total on MRI than on CT. Of these infarcts, 89 were acute and 15 sub-acute/chronic.

There were 29 more basal ganglia infarcts seen on MRI than on CT. In total, MRI showed most infarcts in the lentiform nuclei (31), followed by the internal capsule (27) and caudate nucleus locations (25). MRI also demonstrated 16 thalamic, 19 brainstem (Fig. 4a–c), and 30 cerebral hemispheric infarcts not demonstrated by CT.

Discussion

The early diagnosis of TBM remains difficult, and delays in the diagnosis and treatment are directly related to a poor outcome [1, 8]. The value of CT in early diagnosis of TBM and its potential complications is well established [1–3, 13, 20–22].

The common triad of neuroradiological findings is:

1. Basal meningeal enhancement
2. Infarctions
3. Hydrocephalus.[3, 8]

Pathogenesis of the above characteristic findings is thought to be the result of hematogenous spread of tuberculosis from the lung to the CNS causing small tuberculous/granulomatous lesions (Rich's foci) to develop in the leptomeninges, brain parenchyma (cortex), or spinal cord. The "Rich focus" ruptures into the

Table 2 Number of patients with Infarcts in Specific Locations Demonstrated using CT and MRI

	CT (21)	MRI (25)	Difference
Basal ganglia	17	22	5
Bilateral basal ganglia	10	12	2
Thalami	2	14	12
Bilateral thalami	1	5	4
Corpus callosum	2	8	6
Brainstem	3	15	12
Cerebellum	0	1	1
Cerebral	4	14	10

Table 3 Total number of infarct lesions demonstrated by CT and MRI categorized into "acute," "subacute," and "chronic" by the imaging appearances

	Total	Acute DWI+ve	Sub-acute High T2; FLAIR DWI−ve	Chronic High T2; Low FLAIR DWI−ve
CT+ve	68	55	13	
MRI+ve	172	144	25	3
Difference CT−ve	104	89	15	

Table 4 Infarcts involving the basal ganglia and internal capsules for CT and MRI

	CT	MRI	Difference
Total	54	83	29
Caudate nucleus	12	25	13
Lentiform nucleus	25	31	6
Internal capsule	17	27	10

subarachnoid space to set off the fibrogelatinous exudative process [3, 22–25]. In the diffuse form, the basal cisterns are fully or partially filled by fibrogelatinous exudates [14, 20, 22, 26], which can also extend to other CSF spaces [1, 3, 13]. The radiological features are those of "high density in basal cisterns" on non-enhanced CT (NECT) [8] and basal meningeal enhancement postcontrast. Our results show that the diagnosis of basal meningeal enhancement on CECT is poorer than MRI, with only 70% enhancement in comparison with 97% on contrasted MRI studies (Table 1). Similar figures are reported in a paper published by Offenbacher et al. comparing CECT and contrasted MRI [27]. Other studies with CECT showed varying results: 37% in 30 children [28], 17% in a review including 214 children [29], and 93% in 33 children with TBM in a 20-year survey [7]. Meningeal enhancement varied from smooth to nodular, and even a distinctive milliary meningeal pattern was seen. In general, Gd-DTPA-enhanced MRI is considered superior to contrast-enhanced CT for detection of meningeal enhancement, owing this to its multiplanar imaging capability, greater inherent contrast resolution, and lack of bone artifacts [3, 13, 14, 18, 27], and this is now supported by our results (Fig. 1a,b).

MRI also revealed various cranial nerves enhancing in 26 patients, of which cranial nerve II enhancement was a prominent feature. Clinically, cranial nerve involvement is seen in 17–70% of TBM patients. Cranial nerves II, III, IV, and VII are most frequently affected. [3, 13, 22, 30], but this clinical finding has not yet been corroborated radiologically. MRI also demonstrated more enhancing granulomata in seven more patients than did CT using gadolinium. Granulomata are considered a less common but reliable feature for diagnosing CNS TB.

For urgent management of the serious complication of hydrocephalus in TBM, CT is sufficient as hydrocephalus is equally well picked up by CT and MRI (Table 1) in 77% of the patients. In our study, nine patients needed extraventricular drains inserted after CT diagnosis of hydrocephalus. Early shunting in patients with noncommunicating hydrocephalus is still indicated, even in light of high a complication rate [31]. Urgent CT for the purpose of demonstrating hydrocephalus which is surgically treatable as an emergency procedure is still indicated when after-hours MRI availability and speed of examination become considerations.

The complication of vasculitis/(pan) arteritis with subsequent infarction or thrombosis is very common and adds to the mortality and morbidity associated with TBM [3, 11, 13, 19, 32]. The identification of early or new infarcts is of prognostic significance to the clinician [2, 11]. A recent review article by Burrill et al. [33] reports that ischemic infarcts are seen in 20–40% of TBM patients on CT. In our study, 83% of the patients had infarcts on MRI vs. 70% on

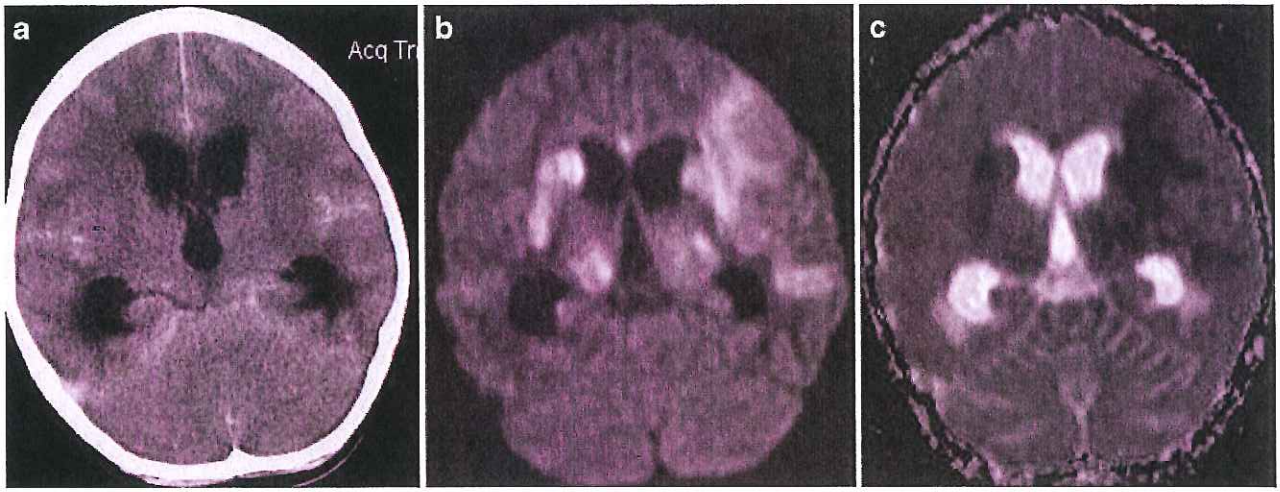


Fig. 2 MRI demonstrating bilateral infarcts not visible on CT. **a** No infarctions were diagnosed on this CT even though in retrospect there is some subtle low density involving the left frontal white matter. **b** DWI in the same patient as **a** demonstrates an abnormal signal in the basal ganglia and thalami bilaterally as well as in the left frontal and temporal lobes. **c** Apparent diffusion coefficient (ADC) map in the same patient shows low signal in the same areas indicating restricted diffusion consistent with acute infarction in the context of TBM

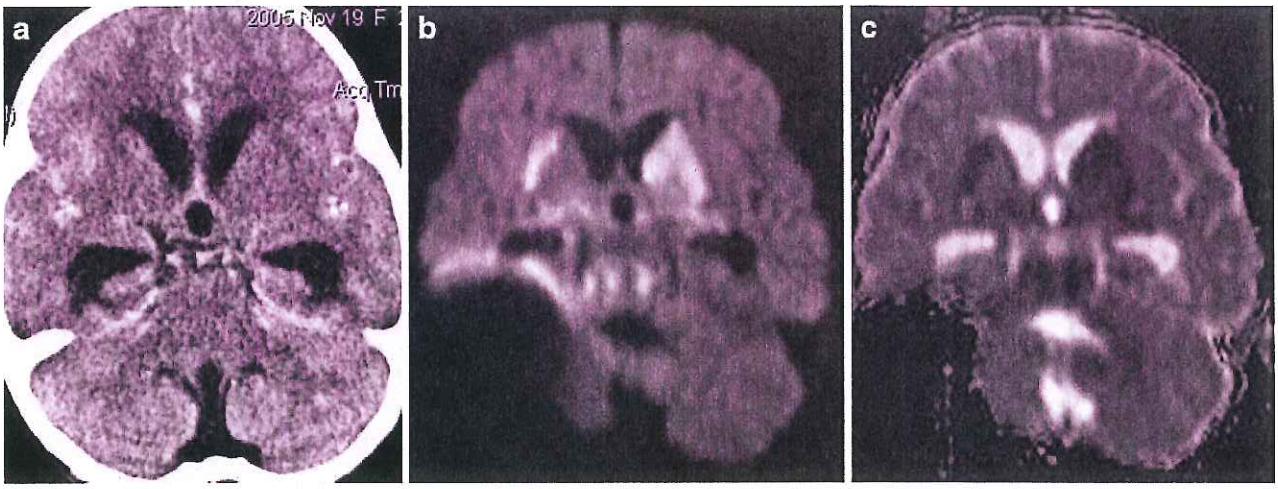


Fig. 3 Acute infarction in TBM missed on CT. **a** CT fails to demonstrate any infarction or convincing features of basal enhancement. **b** DWI in the same patient as in **a** demonstrates abnormal signal bilaterally in the basal ganglia and the brainstem. **c** ADC map confirms the restricted diffusion, consistent with infarction in the setting of TBM

CT. Even though MRI demonstrated infarcts in only four more patients than did CT, it is important to note that CT is missing many more infarcts. In total, 172 infarcts were counted on MRI, which included acute, sub-acute, and chronic infarcts. CT missed 60% of all infarcts, and 86% of these were DWI positive (acute; Figs. 2 and 3). The locations of infarcts of the 30 patients are tabulated in Tables 2 and 3. CT missed infarcts in important locations, missing a total of 29 basal ganglia, 16 thalamic, 19 brainstem, and 30 cerebral infarcts.

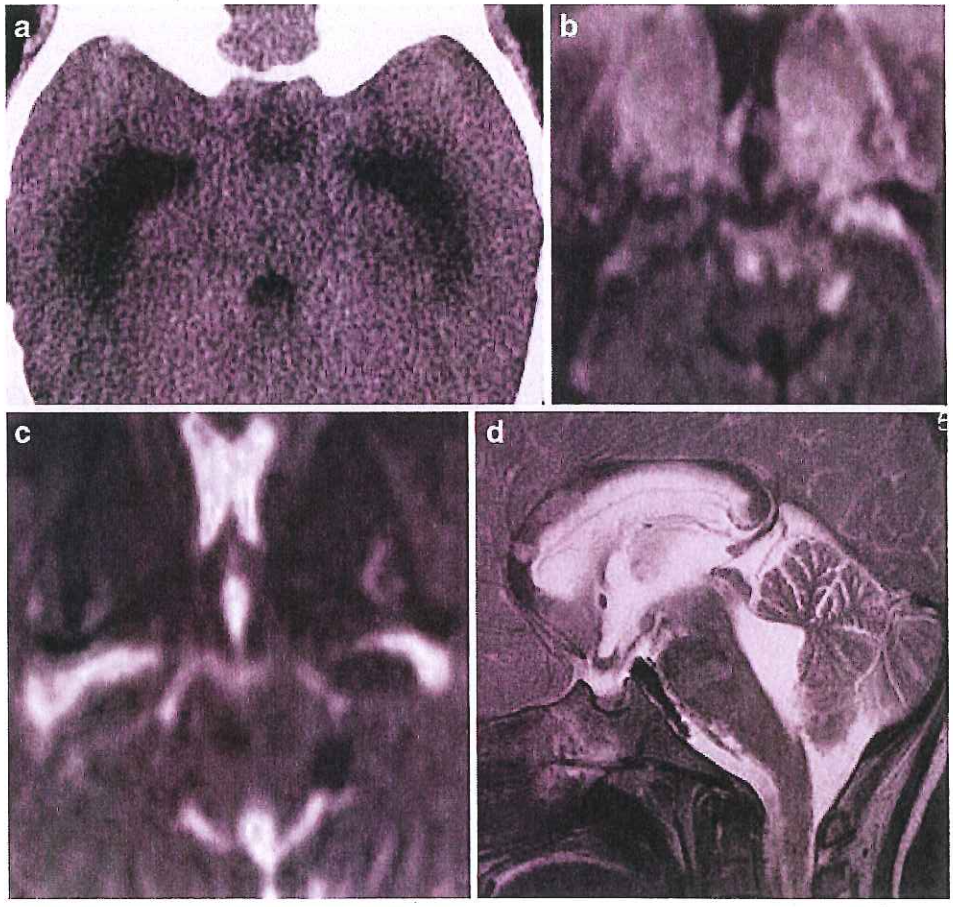


Fig. 4 MRI demonstrating brainstem and corpus callosum infarctions not demonstrated on CT. **a** CT fails to demonstrate any brainstem abnormality. **b** DWI in the same patient as **a** demonstrates abnormal signal in the brainstem bilaterally. **c** ADC confirms the restricted diffusion in the brainstem consistent with infarction in a patient with TBM. **d** Sagittal T2-weighted image confirms brainstem abnormality and also demonstrates abnormality consistent with infarction involving the corpus callosum

In this study, 48% of infarcts involved the basal ganglia. In the literature, the basal ganglia and internal capsule locations account for majority of infarct locations related to TBM [3, 13, 19, 30, 33]. In our study, more lentiform nucleus than internal capsule and caudate nucleus infarcts were recorded. Basal ganglia infarcts are specifically important when they are bilateral, as this constitutes a very poor prognosis [2, 11]. In our study, 12 patients (40%) had bilateral basal ganglia infarcts, and in two patients, these were only identified on MRI (Figs. 2 and 3).

Another important infarct region is the brainstem which is notoriously poorly demonstrated on CT [32]. CT missed 80% of the brainstem infarcts in this study. Of these, 64% were acute infarcts and showing restricted diffusion on DWI (Fig. 4a–c). The sagittal T2W MRI imaging is particularly good to pick up brainstem pathology (Fig. 4d). It is, however, difficult to confirm changes on DWI due to the angle of image acquisition for DWI designed to minimize artifacts. These are of great clinical significance but may also be obvious from the clinical findings. However, we are now able to explain the severe clinical scenario where previously CT may have been "normal."

Conclusion

Data from this study clearly shows that MRI is superior to CT/CECT in the diagnosis of TBM and its complications. It is a more sensitive imaging modality in detecting basal meningeal enhancement, granulomata, and infarcts for diagnosis and prognosis in pediatric TB meningitis. MRI picks up infarcts missed by CT and in particular the acute infarcts demonstrated by DWI on MRI. Infarcts affecting the patient's prognosis, e.g., bilateral basal ganglia and brainstem infarcts, are detected on MRI. CT remains an important emergency investigation in the initial evaluation of TBM for suggesting the diagnosis early and determining the presence hydrocephalus (for possible surgical intervention) as it is accessible and rapid.

References

1. Przybojwski S, Andronikou S, Wilmshurst J (2006) Objective CT criteria to determine the presence of abnormal basal enhancement in children with suspicious tuberculous meningitis. Pediatr Radiol 36:687–696
2. Andronikou S, Wieselthaler N (2004) Modern imaging of tuberculosis in children: thoracic, central nervous system and abdominal tuberculosis. Pediatr Radiol 34:861–875
3. Bernaerts A, Vanhoenacker FM, Parizel PM, van Goethem JW, van Altena R, Laridon A, de Roeck J, Coeman V, de Schepper AM (2003) Tuberculosis of the central nervous system: overview of neuroradiological findings. Eur Radiol 13:1876–1890
4. Schoeman CJ (1990) The epidemiology and outcome of childhood tuberculous meningitis. The Pelonomi Hospital experience. S Afr Med J 78(5):245–247
5. Berman S, Kibel MA, Fourie PB, Strebel PM (1992) Childhood tuberculosis and tuberculous meningitis: high incidence rates in the Western Cape of South Africa. Tuber Lung Dis 73(6):349–355
6. Deeny JE, Walker MJ, Kibel MA, Molteno CD, Arens LJ (1985) Tuberculous meningitis in children in the Western Cape. Epidemiology and outcome. S Afr Med J 68(2):75–78
7. Farinha NJ, Razali KA, Holzel H, Morgan G, Novelli VM (2000) Tubercolosis of the central nervous system in children: a 20 year survey. J Infect 41:61–68
8. Andronikou S, Smith B, Hatherhill M, Douis H, Wilmshurst J (2004) Definitive neuroradiological diagnostic features of tuberculous meningitis in children. Pediatr Radiol 34:876–885
9. Tayfun C, Ucoz T, Tasar M, Atac K, Ogur, Ozturk T, Yinanc MA (1996) Diagnostic value of MRI in tuberculous meningitis. Eur Radiol 6:380–386
10. Schoeman CJ, Herbst I, Nienkemper DC (1997) The effect of tuberculous meningitis on cognitive and motor development of children. S Afr Med J 87(1):70–72
11. Schoeman JF, Van Zyl LE, Laubscher JA, Donald PR (1995) Serial CT scanning in childhood tuberculous meningitis: prognostic features in 198 cases. J Child Neurol 10:320–329
12. Kingsley DPE, Hendrickse WE, Kendall BE, Swash M, Singh V (1987) Tuberculous meningitis: role of CT in management and prognosis. J Neurol Neurosurg Psychiatry 50:30–36
13. Gupta RK, Gupta S, Singh D, Sharma B, Kohli A, Gujral RB (1994) MR imaging and angiography in tuberculous meningitis. Neuroradiol 36:87–92
14. Chang KH, Han MH, Roh JK, Kim IO, Han MC, Choi KS, Kim CW (1990) Gd-DTPA enhanced MR imaging in intracranial tuberculosis. Neurorad 32:19–25
15. Hooijboer PGA, Van Der Vliet AM, Sinnige LGF (1996) Tuberculous meningitis in native Dutch children: a report of four cases. Pediatr Radiol 26:542–546
16. Gupta RK, Jena A, Sharma A, Guha DK, Khushu S, Gupta AK (1988) MR imaging of intracranial Tuberculomas. J Comput Assist Tomogr 12:280–285
17. Gupta RK, Prakash M, Mishra AM, Husain M, Prasad KN, Husain N (2005) Role of diffusion weighted imaging in differentiation of intracranial tuberculoma and tuberculous abscess from cysticercus granulomas-a report of more than 100 lesions. Eur J Radiol 55:384–392
18. Wasay M, Kheleani BA, Moolani MK, Zaheer J, Pui M, Hasan S, Muzaffar S, Bakshi R, Sarawari AR (2003) Brain CT and MRI findings in 100 consecutive patients with intracranial tuberculoma. J Neuroimaging 13:240–247
19. Chan KH, Cheung RTF, Lee R, Mak W, Ho SL (2005) Cerebral infarcts complicating tuberculous meningitis. Crerbrovasc Dis 19:391–395
20. Rovira M, Romero F, Terrent O, Ibarra B (1980) Study of tuberculous meningitis by CT. Neuroradiol 19:137–141
21. Jinkins JR (1991) Computed tomography of intracranial tuberculosis. Neuroradiology 33:126–135
22. De Castro CC, De Barros NC, De Sousa Campos ZM, Cerri GG (1995) CT scans of intracranial tuberculosis. Radiol Clin North Am 33:753–769

23. Andronikou S, Wieselthaler N, Smith B, Douis H, Fieggen AG, van Toorn R, Wilmshurst J (2005) Value of early follow-up CT in paediatric tuberculous meningitis. Pediatr Radiol 35:1092–1099
24. Reid H, Fallen RJ (1992) Bacterial infections. In: Adams JH, Duchen L (eds) Greenfield's Neuropathology, 5th edn. Oxford University Press, New York, p 317
25. Donald PR, Schaaf HS, Schoeman JF (2005) Tuberculous meningitis and military tuberculosis: the Rich focus revisited. J Infection 50:193–195
26. Cho IC, Chang KH, Kim YH, Kim SH, Yu IK, Han MH (1998) MRI features of choroid plexitis. Neuroradiol 40:303–307
27. Offenbacher H, Fazekas F, Schmidt R, Kleinert R, Payer F, Kleinert G, Lechner H (1991) MRI in tuberculous meningoencephalitis: report of four cases and review of neuroimaging literature. J Neurol 238:340–344
28. Norman J, Waecker JR, Conner JD (1990) Central nervous system tuberculosis in children: a review of 30 cases. Pediatr Infect Dis J 9:539–543
29. Ozates M, Kemaloglu S, Gurkan, Ozkan U, Hosoglu S, Simsek MM (2000) CT of the brain in tuberculous meningitis. A review of 289 patients. Acta Radiol 41:13–17
30. Jinkins JR, Gupta R, Chang KH, Roderigues-Carbajal J (1995) MR imaging of central nervous system tuberculosis. Radiol Clin North Am 33:771–786
31. Gelabert M, Castro-Gago M (1998) Hydrocephalus and tuberculous meningitis in children. Report on 26 cases. Childs Nerv Syst 4:268–270
32. Schoeman J, Hewlitt R, Donald P (1988) MR of childhood tuberculous meningitis. Neuroradiol 30:473–477
33. Burrill J, Williams CJ, Bain G, Conder G, Hine AL, Misra RR (2007) Tuberculosis: a radiological review. Radiographics 27:1255–1273

APPENDIX IV

CVs

MARNA PARKE BORGSTROM

Home: 458 Three Mile Course
Guilford, Ct. 06437

(203) 453-8782

Business: Yale-New Haven Hospital
20 York Street
New Haven, CT 06510
(203) 688-2608

EDUCATION

1977-1979 Yale University School of Medicine
Department of Epidemiology and Public Health
Program in Hospital Administration, M.P.H.

1972-1976 Stanford University
Bachelor of Arts in Human Biology awarded June, 1976

EXPERIENCE

2005-Present (YNHHS) President and Chief Executive Officer: Yale New Haven Health System

Yale New Haven Health System is a regional, integrated health care delivery system composed of three local health care delivery networks, as well as a physician foundation, Northeast Medical Group. Anchored by Yale-New Haven Hospital, including its York and Chapel Street campuses, the Yale-New Haven Children's Hospital, and the Yale-New Haven Psychiatric Hospital totaling 1517-beds, the System includes a Bridgeport network led by the 425-bed Bridgeport Hospital and a Greenwich network anchored by 180-bed Greenwich Hospital. Northeast Medical Group employs 400 physicians.

Feb. 2012 - Present Chief Executive Officer: Yale-New Haven Hospital and Delivery Network (YNHH)

2005- Feb. 2012 President and Chief Executive Officer: Yale-New Haven Hospital and Delivery Network (YNHH)

Yale-New Haven, a private not-for-profit 1008-bed hospital founded in 1826. It serves as the primary teaching hospital for the Yale University School of Medicine and provides primary through tertiary and quaternary services.

1993-2005 Executive Vice President & Chief Operating Officer: Yale-New Haven Hospital
Executive Vice President and Secretary: Yale-New Haven Health Services Corporation

Responsible for New Haven Delivery Network operations including Yale-New Haven Hospital operations, finance, human resources and planning and marketing; and Yale-New Haven Ambulatory Services Corporation, which operates two independent surgery centers and a large, full-service radiology business in New Haven and Guilford. Served as the senior Hospital interface for Yale School of Medicine operational issues.

Represented the YNHH Delivery Network in all Health System strategic and operational activities.

1992-1993 Senior Vice President, Administration: Yale-New Haven Hospital
Senior Vice President and Secretary: Yale-New Haven Health Services Corporation

Responsible for Hospital strategic planning and marketing, facilities planning and design, risk management and medical-legal affairs, managed care contracting, Service Quality Improvement, Community Relations, Public Affairs and Engineering.

Project Executive for implementation of Yale-New Haven's $156 million Facilities Renewal Project.

1985-1992 Vice President, Administration: Yale-New Haven Hospital

Responsible for Hospital strategic planning and marketing, facilities planning and design, risk management and medicolegal affairs, managed care contracting, Service Quality Improvement, Community Relations, Public Affairs and Engineering. Provided administrative leadership to Yale-New Haven Health Services Corporation corporate affairs and strategic initiatives.

1984-1985 Assistant Vice President: Yale-New Haven Hospital

Directed the development and implementation of annual Hospital business plan format derived from strategic plan. Completed $6 million renovation of Hospital clinical laboratories. Represented Hospital on underwriting and eligibility and finance activities in malpractice insurance captive.

Dec. 1982-1984 Associate Administrator: Yale-New Haven Hospital

Responsible for Hospital planning activities, including Strategic Planning and general facilities planning and related capital budget activities. Also responsible for Clinical Laboratories ($23 million gross revenue and $11 million expense) and Risk Management and Medicolegal Affairs.

Dec. 1980-Nov. 1982 Assistant Administrator: Yale-New Haven Hospital

Responsible for planning and implementing $11 million renovation program done in concert with major facility replacement project, and for planning and overseeing the move of five major departments and three clinical services (including 80 ICU beds) to a new $73 million facility, during the Spring of 1982. Prepared and presented to the Health Systems Agency and Commission on Hospitals and Health Care, three Certificates of Need; all were approved. Also responsible for Hospital space planning and management, and provided general staff support to the Executive Vice President.

Jan. 1980-Dec. 1980 Administrative Associate: Yale-New Haven Hospital

Provided general staff support to Executive Vice President. Major activities included employee fundraising and campaign to support $73 million facility replacement and renovations program (50% of Hospital employees contributed almost $500,000) and preparation of capital and operating budget materials.

Jan. 1979-Dec. 1980 Administrative Resident: Yale-New Haven Hospital

Summer 1978 Administrative Intern: Alexian Brothers Hospital, San Jose, California

PROFESSIONAL AWARDS:

1992 Up and Comers Award - Sponsored by Modern Healthcare and 3M Health Systems
Women In Leadership Award, 1993 - YWCA
Junior Achievement Hall of Fame, 1998
20 Noteworthy Women, New Haven Business Times, 1999
Gateway Community College Hall of Fame, 2002

Hill Health Center Leadership Award, 2006
Connecticut Women in Leadership, 2009 (Women & Families Center Award)
Girl Scouts of Connecticut Women of Achievement Award, 2010
Anti-Defamation League Torch of Liberty Award, 2010
Business New Haven's Business Person of the Year, 2010
American Hospital Association 2010 Grassroots Champion Award
Doctor of Humane Letters, Quinnipiac University, 2011
Greater New Haven Chamber of Commerce Community Leadership Award, 2012
United Way Alexis de Tocqueville Herbert H. Pearce Award, 2012

MAJOR PROFESSIONAL AFFILIATIONS, BOARDS AND ACTIVITIES:

Yale-New Haven Hospital Board of Trustees (1994 – present)
Yale New Haven Health System Board of Directors (2005 - present)
The Connecticut Hospital Association (2006 – present) Immediate Past Chair, Board of Trustees and member of Executive Committee
VHA, Inc. (Dallas, Texas), Board of Directors (2009 -)
Council of Teaching Hospitals Administrative Board (2008 - present) Chair as of 11/12
Association of American Medical Colleges Board of Directors, 2010-present
Coalition to Protect America's Health, 2011-present
Healthcare Executives Study Society (2006-present)
Fellow – American College of Healthcare Executives

University Appointments

Yale University – Lecturer, Yale School of Public Health, Department of Health Policy and Management.

PERSONAL:
Married: Eric N. Borgstrom (5/27/78)
Children: Christopher (4/14/85) and Peter (8/4/89)

CURRICULUM VITAE

RICHARD D'AQUILA
282 Boston Post Road
Westbrook, CT 06498
Telephone: (860) 669-0871

PERSONAL DATA:
Married
U.S. Citizen
Birth Date: 6/29/55

BUSINESS ADDRESS:

Yale-New Haven Hospital
20 York Street
New Haven, CT 06510
Telephone: (203)-688-2606

PROFESSIONAL EXPERIENCE:

February, 2012

President and Chief Operating Officer
Yale-New Haven Hospital
Executive Vice President
Yale New Haven Health System

May, 2006 to
February, 2012

Executive Vice President and Chief Operating Officer
Yale-New Haven Hospital/Yale New Haven Health System

Organizational Profile

Yale New Haven Health System (YNHHS) is a 1597-bed delivery network formed in 1995 which consists of Yale-New Haven, Bridgeport and Greenwich Hospitals. YNHHS has revenues in excess of $2.3 billion in FY '11 based on 90,000 discharges and 1.3 million outpatient visits. Yale-New Haven Hospital is a 1,008-bed tertiary referral medical center that includes the 201-bed Yale New Haven Children's Hospital and the 76-bed Yale New Haven Psychiatric Hospital. Both Yale New Haven Health System and Yale-New Haven Hospital are formally affiliated with Yale University School of Medicine.

Responsibilities

Overall responsibility for all aspects of day to day operations for Yale-New Haven Hospital (YNHH) and the senior network leader at the Yale New Haven Health System representing the YNHH delivery network. Hospital leadership responsibilities include direct accountability for the senior leadership team, strategic planning, organizational performance, quality improvement, labor relations and human resources management, system integrations, external relations and service line development. Senior leadership and implementation responsibility for all aspects of the hospital's annual business (operating) plan. Senior level oversight of the hospital's facility plan including

construction of a 112-bed, $450 million Comprehensive Cancer Pavilion commencing construction in the fall of 2006.

August, 2000 to April, 2006

Senior Vice President/Chief Operating Officer
New York Presbyterian Hospital/
Weill Cornell Medical Center
New York, New York

Organizational Profile
New York Presbyterian Hospital is a 2,369 bed Academic Medical Center created from the merger between the New York Hospital and the Presbyterian Hospital in the City of New York. The Weill Cornell Medical Center consists of an 880 bed acute care facility in Manhattan and the 239 bed Westchester Division campus in White Plains specializing in behavioral health.

Responsibilities
Overall responsibility for all aspects of day to day operations for the Weill Cornell Medical Center and the Westchester Division, a two campus Academic Medical Center of 1120 beds. Direct responsibility for a total operating expense budget in excess of $450,000,000 and revenues of $850,000,000. Senior leadership and implementation for all aspects of the Medical Center's operating plan including quaternary and tertiary service development, medical staff relations and recruitment, employee relations and labor strategy. System level member of the Corporate Management Team with involvement in strategic and facilities planning, service line development, information technology and performance improvement.

May 1992 to June 2000

Executive Vice President/Chief Operating Officer
St. Vincent's Medical Center
Bridgeport, Connecticut

President
Vincentures, Inc.

President
St. Vincent's Development Corporation, Inc.

Chief Operating Officer of 391 bed, university-affiliated acute care hospital and health system. President/CEO of affiliated subsidiaries with management responsibility at

the Medical Center and corporate level. Medical Center responsibilities including day to day operations oversight for patient care services; support services and facilities planning and development. Corporate responsibilities including information systems, ambulatory network development, managed care contracting network oversight and real estate/satellite facility development.

January 1987-April 1992

President/CEO
Health Initiatives Corporation
Providence, Rhode Island

Chief Executive Officer of a consulting practice specializing in strategic planning, business development and project implementation assistance for acute care and specialty hospitals, state planning agencies and private investors. Specific responsibilities included:

- Practice Leadership
- Engagement Planning and Management
- Project Supervision and Control
- Client Interface
- Practice Marketing and Business Development

June 1984-December 1986

Vice President
The Mount Sinai Hospital Corporation
Hartford, Connecticut

June 1981-June 1984

Vice President, Division of Planning and Community Services
The Mount Sinai Hospital
Hartford, Connecticut

June 1979-June 1981

Assistant Executive Director
The Mount Sinai Hospital
Hartford, Connecticut

January 1979-May 1979

Administrative Resident
The Mount Sinai Hospital
Hartford, Connecticut

OTHER APPOINTMENTS:

November 2000
To Present

Member, Board of Directors
Voluntary Hospitals of America/Metro New York
New Rochelle, New York

January 1995- June 2000	**Member, Board of Directors** Goodwill Industries Bridgeport, Connecticut
December 1993- June 2000	**Founding Board Member** Park City Primary Care Center Bridgeport, Connecticut
May, 1992- June 2000	**Member, Board of Directors** St. Vincent's Development Corporation Vincentures, Inc. Omicron, Inc. Connecticut Health Enterprises Bridgeport, Connecticut
January 1992- December 1994	**Member, Board of Directors** Visiting Nurses Association of Fairfield County Bridgeport, Connecticut
January 1989- December 1991	**Member, Board of Directors** Easter Seal Society/Meeting Street Rehabilitation Center, Inc. of Rhode Island Providence, Rhode Island
January 1980- December 1989	**Member, Board of Directors** Combined Hospitals Alcohol Program Hartford, Connecticut
September 1985- December 1986	**President, Board of Directors** Regional Alcohol and Drug Abuse Resources, Inc. Hartford, Connecticut
September 1981- December 1986	**Adjunct Faculty/Lecturer** University of Hartford, Barney School of Business and Public Administration West Hartford, Connecticut
January 2001 - Present	**Adjunct Faculty/Residency Preceptor and Lecturer** Robert F. Wagner Graduate School of Public Service New York University New York, N.Y.
December 2000 - Present	**Adjunct Faculty/Lecturer** Weill Medical College of Cornell University Department of Public Health, New York New York, N.Y.

EDUCATION:

Yale University School of Medicine
Graduate Program in Hospital Administration
Academic Distinctions: Research Excellence Award (1979)
1979 Graduate

Central Connecticut State University
Bachelor of Arts: Economics/Business
Academic Distinctions: Omicron Delta Epsilon
Economics Honor Society
1977 Graduate

PROFESSIONAL AFFILIATIONS:
Fellow, American College of Health Care Executives
Yale Hospital Administration Alumni Association
Connecticut Hospital Association
Habitat of Greater New Haven

CURRICULUM VITAE

NAME: James M. Staten
BIRTHDATE: September 26, 1958
EDUCATION: 1980 – B.S. – Business / Economics / State University College of NY

Yale New Haven Health System (YNHHS) and Yale-New Haven Hospital (YNHH)

October 2000 - Present

Executive Vice President of Finance and Corporate Services, YNHHS
Senior Vice President and CFO, YNHH

Yale New Haven Health system is a regional, integrated health care system composed of three regional health care delivery networks. The New Haven-based delivery system is anchored by Yale-New Haven Hospital, the Yale-New Haven Children's Hospital, and the Yale-New Haven Psychiatric Hospital, which total 944-beds. The system includes a Bridgeport-based delivery system led by the 425-bed Bridgeport Hospital and Greenwich-based delivery system anchored by 160-bed Greenwich Hospital. The System is also affiliated with the Westerly Hospital in Rhode Island. The Yale New Haven Health System has a formal affiliation with the Yale University School of Medicine, as does Yale-New Haven Hospital which serves as the Medical School's primary teaching hospital. System services include acute care hospitals, ambulatory surgery and outpatient diagnostic imaging centers, as well as primary care centers. In total, the System has 1,500 beds, 74,000 admissions, 10,000 employees, assets of $1.6 billion, and annual net revenues of over $1.4 billion.

Responsible for financial and corporate services of YNHHS including managed care, information systems, materials management, admitting/registration, and medical records, as well as all financial responsibilities such as accounting, budgeting, financial and operational reporting, tax, reimbursement, and treasury.

OTHER EMPLOYMENT

New York-Presbyterian Hospital (NYPH) and New York-Presbyterian Healthcare System (NYPHS)

July 1999 – October 2000 Senior Vice President of Finance

Responsible for assuring the financial viability of a $3 billion Health System, including monitoring financial condition of approximately 15 corporately-controlled Sponsored/Member Hospitals and other healthcare related organizations. Report regularly to the NYPHS Board and NYPH Board Executive Committee on financial performance.

January 1997 - June 1999 Vice President of Financial Planning
June 1993 - December 1996 Director of Financial Planning

Responsible for complete integration of financial planning at all Sponsored Hospital Members including NYPH and leading the financial group of approximately 70 professionals in performing budget, reimbursement, managed care contracting, decision support and business plan development functions.

Ernst & Young

January 1991 - June 1993 Senior Manager - Consulting Services

Directed and coordinated Ernst & Young's New York State Reimbursement Consulting Services.

Pannell Kerr Forster

October 1980 – December 1990 Partner

Elected Partner in June 1990 after working 10 years in the firm's large healthcare practice as a certified public accountant. 11th Largest Public Accounting Firm in United States during late 1980s.

PROFESSIONAL MEMBERSHIPS

American Institute of Certified Public Accountants (1982 – 1998)
New York State Society of Certified Public Accountants (1982 – 1996)
- Healthcare Committee (1988 – 1991)
- Chairman of the Hospital Sub-Committee (1990/1991)

Healthcare Financial Management Association (1984 – 1994)
- Chairman of various Committees (1984 – 1994)
- Trustee (1990/1991)
- President Elect (1993/1994)

Greater New York Hospital Association
- Fiscal Policy Committee (1993 – 2000)
- Managed Care Committee (1995 – 2000)

Connecticut Hospital Association
- Finance Committee (2000 – 2004)
- Special Committee on Medicaid Reimbursement (2000 – 2004)

Blue Ribbon Committee on the Future of Healthcare in Connecticut (2000 – 2003)

OTHER PROFESSIONAL ACTIVITIES

Presenter at New Jersey Health Care Financing Authority on Medicare Payment System
Presenter on Hospital Reimbursement Issues for the NYS Society of CPAs
Presenter on Accounts Receivable Issues for the Connecticut Hospital Association
Guest Speaker at NYU's graduate program in Hospital Administration on Healthcare Financing
Guest speaker at Cornell University's Sloan Program in Health Services on Managed Care
Presenter on Mergers and Acquisitions to New York State Hudson Valley HFMA
Guest speaker at Chicago Municipal Bond Analysts Society on New York State Hospital Deregulation
Guest speaker at Yale's School of Epidemiology and Public Management on Health Systems

CURRICULUM VITAE

BIOGRAPHICAL

NAME:	Peter N. Herbert	**BIRTHDATE:**	December 8, 1941
HOME ADDRESS:	57 Island View Avenue Branford, CT 06405	**BIRTH PLACE:** **CITIZENSHIP:**	Troy, New York U.S.A.
BUSINESS ADDRESS:	Yale-New Haven Hospital CB1063 20 York Street New Haven, CT 06510	**PERSONAL:**	Married, 4 children
BUSINESS PHONE:	(203) 688-2604		
NPI #:	1033191465		

EDUCATION AND TRAINING

UNDERGRADUATE:

1959-1963	Rensselaer Polytechnic Institute, Troy, NY	B.S., 1963 Biology

GRADUATE:

1963-1967	Yale University School of Medicine New Haven, CT	M.D., 1967 Medicine Dr. Patrick J. Mulrow, Thesis Advisor

POSTGRADUATE:

1967-1969	Intern and Resident Yale-New Haven Hospital New Haven, CT	Phillip K. Bondy, M.D. Internal Medicine
1969-1972	Clinical Associate National Heart, Lung and Blood Institute Bethesda, MD	Donald S. Fredrickson, M.D. Robert I. Levy, M.D. Molecular Disease Branch

APPOINTMENTS AND POSITIONS

ACADEMIC:

1973-1977	Molecular Disease Branch NHLBI Bethesda, MD	Section Chief
1974-1977	Clinical Service Molecular Disease Branch NHLBI Bethesda, MD	Chief
1977-1983	Brown University Providence, RI	Associate Professor
1983-1986	Brown University Providence, RI	Program Director, General Clinical Research Unit, (GCRC)
1983-1990	Brown University Providence, RI	Professor

1986-1990	Brown University Providence, RI	Associate Program Director GCRC and Director, GCRC Nutrition Center
1990-2004	Brown University Providence, RI	Adjunct Professor
1991-Present	Yale University New Haven, CT	Clinical Professor

HOSPITAL APPOINTMENTS:

1977-1990	Miriam Hospital Providence, R.I.	Attending Staff
1990-1995	Miriam Hospital Providence, R.I.	Courtesy Staff
1990-present	Hospital of Saint Raphael New Haven, CT	Attending Staff
1991-present	Yale-New Haven Hospital New Haven, CT	Attending Staff
1993-1999	Veterans Affairs Medical Center West Haven, CT	Attending Staff

NON-ACADEMIC POSITIONS:

1969-1977	United States Public Health Service	Surgeon
1977-1990	The Miriam Hospital Providence, RI	Director, Division of Nutrition & Metabolism
1990-1999	Hospital of Saint Raphael New Haven, CT	Chairman, Department of Medicine
1999-present	Yale-New Haven Hospital	Chief of Staff/Senior Vice President, Medical Affairs
1999-present	Yale-New Haven Health System	Senior Vice President Medical Affairs

SPECIALTY CERTIFICATION:

1972	American Board of Internal Medicine No. 38937

MEDICAL OR OTHER PROFESSIONAL LICENSURE:

1977-1994	State of Rhode Island and Providence Plantations Department of Health No. MD5749
1989-1991	Commonwealth of Pennsylvania No. MD-044076-E
1968-present	State of Connecticut No. 13647

MEMBERSHIPS IN PROFESSIONAL AND SCIENTIFIC SOCIETIES

American Federation of Clinical Research
American College of Physicians (Fellow) No. 027692 (1972)
American Heart Association (RI Board of Governors)
Council on Epidemiology, AHA (Fellow) (1985)
American Diabetes Association
American Society for Clinical Investigation (1986)
American Association for the Advancement of Science
New York Academy of Sciences
American College of Nutrition (Fellow) (1986)
Society of Behavioral Medicine (Fellow) (1985)

Updated: 7/27/05

PUBLICATIONS

Refereed Articles

1. Philip, B.A., Herbert, P., and Hollingsworth, J.W.: Separation of contaminating pyrogenic material from commercial bovine serum albumin. Proc. Soc. Exp. Biol. Med. 123: 774-778, 1968.

2. Anderson, R.C., Herbert, P.N., and Mulrow, P.J.: A comparison of properties of renin obtained from the kidney and uterus of the rabbit. Am. J. Physiol. 215: 774-778, 1968.

3. LaRosa, J.C., Levy, R.I., Herbert, P.N., Lux, S.E., and Fredrickson, D.S.: A specific apoprotein activation for lipoprotein lipase. Biochem. Biophys. Res. Commun. 41: 57-62, 1970.

4. Herbert, P.N., Levy, R.I., and Fredrickson, D.S.: Correction of COOH-terminal amino acids of human plasma very low density apolipoproteins. J. Biol. Chem. 246: 7068-7069, 1971.

5. Windmueller, H.G., Herbert, P.N., and Levy, R.I.: Biosynthesis of lymph and plasma lipoprotein apoproteins by isolated perfused rat liver and intestine. J. Lipid Res. 14: 215-223, 1973.

6. Herbert, P.N., Shulman, R.S., Levy, R.I., and Fredrickson, D.S.: Fractionation of the C-apoproteins from human plasma very low density lipoproteins: artifactual polymorphism from carbamylation in urea-containing solutions. J.Biol. Chem. 248: 4941-4946, 1973.

7. Levy, R.I., Fredrickson, D.S., Stone, N.J., Bilheimer, D.W., Brown, W.V., Glueck, C.J., Gotto, A.M., Herbert, P.N., Kwiterovich, P.O., Langer, T., LaRosa, J., Lux, S.E., Rider, A.K., Shulman, R.S., and Sloan, H.R.: Cholestyramine in type II hyperlipoproteinemia: a double-blind trial. Ann. Int. Med. 79: 51-58, 1973.

8. Krauss, R.M., Herbert, P.N., Levy, R.I., and Fredrickson, D.S.: Further observations on the activation and inhibition of lipoprotein lipase by apolipoproteins. Circ. Res. 33: 403-411, 1973.

9. Shulman, R.S., Herbert, P.N., Fredrickson, D.S., Wehrly, K., and Brewer, H.B., Jr.: Isolation and alignment of the tryptic peptides of alanine apolipoprotein, and apolipoprotein from human plasma very low density lipoproteins. J. Biol. Chem. 249: 4969-4974, 1974.

10. Brewer, H.B., Jr., Shulman, R.S., Herbert, P.N., Ronan, R., and Wehrly, K.: The complete amino acid sequence of alanine apolipoprotein (apo C-III), an apolipoprotein from human plasma very low density lipoproteins. J. Biol. Chem. 249-4975-4984, 1974.

11. Herbert, P.N., Windmueller, H.G., Bersot, T.P., and Shulman, R.S.: Characterization of the rat apolipoproteins: I. The low molecular weight proteins of rat plasma high density lipoproteins. J. Biol.Chem. 249: 5718-5724, 1974.

12. Shulman, R.S., Herbert, P.N., Wehrly, K., and Fredrickson, D.S.: The complete amino acid sequence of C-I (apo Lp-Ser), and apolipoprotein from human very low density lipoproteins. J. Biol. Chem. 250: 182-190, 1975.

13. Herbert, P.N., Forte, T.M., Shulman, R.S., LaPiana, M.J., Gong,E.L., Levy, R.I., Fredrickson, D.S., and Nichols, A.V.: Structural and compositional changes attending the ultracentrifugation of very low density lipoproteins. Prep. Biochem. 5: 93-129, 1975.

14. Yee, R.D., Herbert, P.N., Bergsma, D.R., and Biemer, J.J.: Atypical retinitis pigmentosa in familial hypobetalipoproteinemia. Am. J. Ophthalmol. 82: 64-71, 1976.

15. Witters, L.A., Herbert, P.N., Shulman, R.S., Krauss, R.M., and Levy, R.I.: Therapeutic failure in familial type II hyperlipoproteinemia. Metabolism. 25: 1017-1026, 1976.

16. Rosseneu, M., Soetewey, F., Peeters, H., Bausserman, L.L., and Herbert, P.N.: Interaction of the apoproteins of very low density and high density lipoproteins with synthetic phospholipids. Eur. J. Biochem. 70: 285-289, 1976.

17. Papadopoulos, N.M., and Herbert, P.N.: The beta-lipoprotein doublet in type 3 hyperlipoproteinemia. Clin. Chem. 23: 978-981, 1977.

18. Assmann, G., Herbert, P.N., Fredrickson, D.S., and Forte, T.: Isolation and characterization of abnormal high density lipoprotein in Tangier disease. J. Clin. Invest. 60: 242-252, 1977.

19. Musliner, T.A., Church, E.C., Herbert, P.N., Kingston, M.J., and Shulman, R.S.: Lipoprotein lipase cofactor activity of a carboxylterminal peptide of apolipoprotein C-II. Proc. Natl. Acad. Sci. (USA) 74: 5358-5362, 1977.

20. Henderson, L.O., Herbert, R.N., Fredrickson, D.S., Heinen, R.J., and Easterling, J.F.: Abnormal concentration and anomalous distribution of apolipoprotein A-I in Tangier disease. Metabolism. 27: 165-174, 1978.

21. Heinen, R.J., Herbert, P.N., Fredrickson, D.S., Forte, T., and Lindgren, F.T.: Properties of the very low and low density lipoproteins in Tangier disease. J. Clin. Invest. 61: 120-132, 1978

22. Dyck, P.J., Ellefson, R.D., Yao, J.K., and Herbert, P.N.: Adult-onset Tangier disease: I. Morphometric and pathologic studies suggesting delayed degradation of neutral lipids after fiber degeneration. J. Neuropath. & Exptl. Neurol., Vol. XXXVII, No. 2, 119-137, 1978

23. Yao, J.K., Herbert, P.N., Fredrickson, D.S., Ellefson, R.D., Heinen, R.J., Forte, T., and Dyck, P.J.: Biochemical studies in a patient with a Tangier syndrome. J. Neuropath. & Expt1.., Vol. XXXVII, No. 2, 138-154, 1978.

24. Herbert, P.N., Forte, T., Heinen, R.J., and Fredrickson, D.S.: Tangier disease: One explanation of lipid storage. The N. Engl. J. Med. 299: 519-521, 1978.

25. Musliner, T.A., Herbert, P.N., and Church, E.C.: Activation of lipoprotein lipase by native and acylated peptides of apolipoprotein C-II. Biochim. Biophys. Acta 573-: 501-509, 1979.

26. Rosseneu, M., Vercaemst, R., Caster, H., Lievens, M.-J., Van Tornout, P., and Herbert, P.N.: Fluorescence depolarization studies of fluidity and phase transition in human apoprotein phospholipid complexes. Eur. J. Biochem. 96: 357-362, 1979.

27. Herbert, P.N., and Henderson, L.O.: Plasma triglycerides do not regulate high density lipoprotein levels. The Lancet i: 1368-1369, 1979.

28. Musliner, T.A., Herbert, P.N., and Kingston, M.J.: Lipoprotein substrates of lipoprotein lipase and hepatic triglyceride lipase from human post-heparin plasma. Biochim. Biophys. Acta 575: 277-288, 1979.

29. Henderson, L.O., LaGarde, E., and Herbert, P.N.: Artifactual reduction of HDL cholesterol estimates after dextran sulfact-Mg2+ precipitation. Am. J. Clin. Pathol. 73: 664-668, 1980.

30. Thompson, P.D., Cullinane, E., Henderson, L.O., and Herbert, P.N.: Acute effects of prolonged exercise on serum lipids. Metabolism 29: 662-665, 1980.

31. Henderson, L.O., Saritelli, A.L., LaGarde, E., Herbert, P.N., and Shulman, R.S.: Minimal within-day variation of high density lipoprotein cholesterol and apolipoprotein A-I levels in normal subjects. J. Lipid Res. 21: 953-955, 1980.

32. Bausserman, L.L., Herbert, P.N., and McAdam, K.P.W.J.: Heterogeneity of human serum amyloid A. proteins. J. Exp. Med. 152: 641-656, 1980.

33. Cullinane, E., Lazarus, B., Thompson, P.D., Saritelli, A., and Herbert, P.N.: Acute effects of a single exercise session on serum lipids in untrained men. Clin. Chim. Acta l09: 341-344, 1981.

34. Rosseneu, M., Vercaemst, R., Vinaimont, N., Van Tornout, P., Henderson, L.O., and Herbert, P.N.: Quantitative determination of human plasma apolipoprotein A-I by laser immunonephelometry. Clin. Chem. 27: 856-859, 1981.

35. Bausserman, L.L., Herbert, P.N., and McAdam, K.P.W.J.: Serum amyloid A polymorphism in a subject with a naturally occurring inflammatory response. Clin. Chim. Acta 118: 201-207, 1982.

36. Musliner, T.A., Garner, P.A., Henderson, L.O., and Herbert, P.N.: Radioimmunoassay of apolipoprotein A-II. Arteriosclerosis 2: 160-169, 1982.

37. Friedland, M.L., and Herbert, P.N.: Lipoprotein abnormalities associated with a viral syndrome. JAMA 248: 82, 1982.

38. Bausserman, L.L., Saritelli, A.L., Herbert, P.N., McAdam, K.P.W.J., and Shulman, R.S.: NH2-terminal analysis of four of the polymorphic forms of human serum amyloid A proteins. Biochim. Biophys. Acta 704: 556-559, 1982.

39. Ansbacher, L.E., Singsen, B.H., Hosler, M.W., Grimminger, H., and Herbert, P.N.: Familial erythrophagocytic lymphohistiocytosis: an association with serum lipid abnormalities. Pediatrics 102: 270-273, 1983.

40. Shulman, R.S., Herbert, P.N., Capone, R., McClure, D., Hawkins, C., Henderson. L.O., Saritelli, A.L., and Campbell, J.L.: Effects of propranolol on blood lipids and lipoproteins in myocardial infarction. Circulation 67:6 Part 2: I-19-21, 1983.

41. Thompson, P.D., Lazarus, B., Cullinane, E., Henderson, L.O., Musliner, T., Eshleman, R., and Herbert, P.N.: Exercise, diet, or physical characteristics as determinants of HDL-levels in endurance athletes. Atherosclerosis 46: 333-339, 1983.

42. Bausserman, L.L., Herbert, P.N., Forte, T., Klausner, R.D., McAdam, K.P.W.J., Osborne, J.C., Jr., and Rosseneu, M.: Interaction of the serum amyloid A proteins with phospholipid. J. Biol. Chem. 258: 10681-10688, 1983.

43. Kantor, M.A., Cullinane, E.M., Herbert, P.N., and Thompson, P.D.: Acute increase in lipoprotein lipase following prolonged exercise. Metabolism 33: 454-457, 1984

44. Rosseneu, M., Vinaimont, N., Musliner, T.A., Bernier, D., Herbert, P.N., and Belpaire, F.: Immunonephelometry of apolipoprotein A-II in plasma. Clin Chem. 30/2: 234-237, 1984.

45. Thompson, P.D., Cullinane, E., Eshleman, R., and Herbert, P.N.: Lipoprotein changes when a reported diet is tested in distance runners. Am. J. Clin. Nutr. 39: 368-374, 1984.

46. Bausserman, L.L., and Herbert, P.N.: Degradation of serum amyloid A and apolipoproteins by serum proteases. Biochemistry 23: 2241-2245, 1984.

47. Thompson, P.D., Cullinane, E.M., Eshleman, R., Sady, S.P., and Herbert, P.N.: Effects of caloric restriction or exercise cessation on the serum lipid and lipoprotein concentrations of endurance athletes. Metabolism 33: 943-950, 1984.

48. Bausserman, L.L., Herbert, P.N., Rodger, R., and Nicolosi, R.J.: Rapid clearance of serum amyloid A from high density lipoproteins. Biochim. Biophys. Acta 792: 186-191, 1984.

49. Follick, M.J., Abrams, D.B., Smith, T.W., Henderson, L.O., and Herbert, P.N.: Contrasting short- and long-term effects of weight loss on lipoprotein levels. Arch. Intern. Med. 144: 1571-1574, 1984.

50. Herbert, P.N., Bernier, D.M., Cullinane, E.M., Kantor, M.A. and Thompson, P.D.: High density lipoprotein metabolism in runners and sedentary men. JAMA 252: 1034-1037, 1984.

51. Thompson, P.D., Cullinane, E.M., Eshleman, R., Kantor, M.A., and Herbert, P.N.: The effects of high carbohydrate and high fat diets on the serum lipid and lipoprotein concentrations of endurance

athletes. Metabolism 33:1003-1010, 1984.

52. Sady, S.P., Cullinane, E.M., Herbert, P.N., Kantor, M.A., and Thompson, P.D.: Training, diet and physical characteristics of distance runners with low or high concentrations of high density lipoprotein cholesterol. Atherosclerosis 53: 273-281, 1984.

53. Jonas, A., Sweeny, S.A., and Herbert, P.N.: Discoidal complexes of A and C apolipoproteins with lipids and their reactions with lecithin: cholesterol acyltransferase. J. Biol. Chem. 259: 6369-6375, 1984.

54. Herbert, P.N., Hyams, J.S., Bernier, D.N., Berman, M.M., Saritelli, A.L., Lynch, K.M., Nichols, A.V., and Forte, T.M.: Apolipoprotein B-l00 deficiency: intestinal steatosis despite apolipoprotein B-48 synthesis. J. Clin. Invest. 76: 403-412, 1985.

55. Thompson, P.D., Kantor, M.A., Cullinane, E.M., Sady, S.P., Saritelli, A., and Herbert, P.N.: Postheparin plasma lipolytic activities in physically active and sedentary men after varying and repeated doses of intravenous heparin. Metabolism 35: 999-1004, 1986.

56. Kantor, M.A., Cullinane, E.M., Sady, S.P., Herbert, P.N., and Thompson, P.D.: Exercise acutely increases HDL-cholesterol and lipoprotein lipase activity in trained and untrained men. Metabolism 36: 188-192, 1987.

57. Herbert, P.N., and Friedland, M.L.: Reversible deficiency of serum high density lipoproteins in Hodgkin's disease. Cancer Investigation 4(4): 301-303, 1986.

58. Sady, S.P., Thompson, P.D., Cullinane, E.M., Kantor, M.A., Domagala, E., and Herbert, P.N.: Prolonged exercise augments plasma triglyceride clearance. JAMA 256: 2552-2555, 1986.

59. Hegele, R.A., Huang, L-S., Herbert, P.N., Blum, C.B., Buring, J.E., Hennekens, C.H., and Breslow, J.L.: Apolipoprotein B-gene DNA polymorphisms associated with myocardial infarction. N. Engl. J. Med. 315: 1509-1515, 1986.

60. Bausserman, L.L., Saritelli, A.L., Van Zuiden, P., Gollaher, C.J., and Herbert, P.N.: Degradation of serum amyloid A by isolated perfused rat liver. J. Biol. Chem. 262: l583-1589, 1987.

61. Zannie, E.E., Zannis, V.I., Blum, C.B., Herbert, P.N., and Breslow, J.L.: Effect of egg cholesterol and dietary fats on plasma lipids, lipoproteins and apoproteins of human subjects consuming natural diets. J. Lipid Res. 28: 518-527, 1987.

62. Chong, K.S., Nicolosi, R.J., Rodger, R.F., Arrigo, D.A., Yuan, R.W., MacKey, J.J., and Herbert, P.N.: Effect of dietary fat saturation on plasma lipoproteins and high density lipoprotein metabolism of the rhesus monkey. J. Clin. Invest. 79: 675-683, 1987.

63. Herbert, P.N., Bausserman, L.L., Lynch, K.M., Saritelli, A.L., Kantor, M.A., Nicolosi, R.J., and Shulman, R.S.: Homologues of the human C and A apolipoproteins in the M.fasicularis (cynomolgus) monkey. Biochemistry 26: 1457-1463, 1987.

64. Stacpoole, P.W., Alig, J., Kilgore, L.L., Ayala, C.M, Herbert, P.N., Zech, L.A., and Fisher, W.R.: Lipodystrophic diabetic mellitus. Investigations of lipoprotein metabolism and the effects of omega-3 fatty acid administration in two patients. Metabolism 37: 944-951, 1988.

65. Smith, S.J., Cooper, G.R., Henderson, L.O., Hannon, W.H., and the Apolipoprotein Standardization Collaborating Group: Alaupovic, P., Assmann, G., Bachorik, P.S., Calvert, G.D., Connelly, P.W., Demacker, P.N.M., Dolphin, P.J., Fruchart, J.C., Gauldie, J., Ginsberg, H., Goldberg, R.B., Havekes, L., Herbert, P.N., et al. An international collaborative study on standardization of apolipoproteins A-I and B. Part I. Evaluation of a lyophilized candidate reference and calibration material. Clin. Chem. 33: 2240-2249, 1987.

66. Thompson, P.D., Cullinane, E.M., Sady, S.P., Flynn, M.M., Bernier, D.N., Kantor, M.A., Saritelli, A.L., and Herbert, P.N.: Modest changes in high-density lipoprotein concentration and metabolism with prolonged exercise training. Circulation 78: 25-34, 1988.

67. Bausserman, L.L., Bernier, D.N., McAdam, K.P.W.J., and Herbert, P.N.: Serum amyloid A and high-

density lipoproteins during the acute phase response. Eur. J. Clin Invest. 18: 619-626, 1988.

68. Thompson, P.D., Cullinane, E.M., Sady, S.P., Chenevert, C., Saritelli, A.L., Sady, M.A., and Herbert, P.N.: Contrasting effects of testosterone and oral anabolic steroids on serum lipoproteins. JAMA 261: 1165-1168, 1989.

69. Sady, S.P., Hanumara, R.C., and Herbert, P.N.: Mathematical models of the relationship between HDL-cholesterol and serum triglycerides: an empirical evaluation. Mathl. Comput. Modeling 12: 1103-1112, 1989.

70. Bausserman, L.L., Sadaniantz, A., Saritelli, A.L., Martin, V.L., Nugent, A.M., Sady, S.P., and Herbert, P.N.: Time course of serum amyloid A response in myocardial infarction. Clin. Chim. Acta 184: 297-306, 1989.

71. Hyams, J.S., Treem, W.R., Andrews, W.S., and Herbert, P.N.: Lipid abnormalities in pediatric hepatic allograft recipients. J. Pediatr. Gastroenterol. Nutr. 9: 441-444, 1989.

72. Terpstra, A.H.M., Nicolosi, R.J., and Herbert, P.N.: In vitro incorporation of radiolabeled cholesterol esters into high and low density lipoproteins. J. Lipid Res. 30: 1663-1671, 1989.

73. Longcope, C., Herbert, P.N., McKinlay, S.M., and Goldfield, S.R.W.: The relationship of total and free estrogens and sex hormone-binding globulin with lipoproteins in women. J. Clin. Endocrin. Metab. 71: 67-72, 1990.

74. Levinson, P.D., Iosiphidis, A.H., Saritelli, A.L., Herbert, P.N., and Steiner, M.: Effects of n-3 Fatty Acids in Essential Hypertension. Am. J. Hypertension. 3:754-760, 1990.

75. Thompson, P.D., Cullinane, E.M., Sady, Stanley P., Flynn, M.M., Chenevert, C.B. and Herbert, P.N. HDL metabolism in endurance athletes and sedentary men. Circulation, 84:140-152, 1991.

76. Thompson, P.D., Gadaleta, P.A., Yurgalevitch, S., Cullinane, E.M. and Herbert, P.N. The effects of exercise and lovastatin on serum creatine kinase activity. Metabolism, 40:1333-1336, 1991.

77. Niaura, R., Herbert, P., Saritelli, A., Goldstein, M., Flynn, M., Follick, M., Gorkin, L., Ahern, D. Lipid and lipoprotein responses to episodic occupational and academic stress. Arch. Intern. Med. 151: 2172-2179, 1991.

78. Buring, J.E., O'Connor, G.T., Goldhaber, S.Z., Rosner, B., Herbert, P.N., Blum, C.B., Breslow, J. and Hennekens, C.H.: Decreased HDL2 and HDL3 cholesterol, apo-AI and apo-AII and increased risk of myocardial infarction. Circulation, 85:22-9, 1992.

79. Niaura, R., Herbert, P.N., McMahon, N., and Sommerville, L.: Repressive coping and blood lipids in men and women. Psychosomatic Medicine, 54:698-706, 1992.

80. Levinson, P.D., McGarvey, S.T., Carlisle, C.C., Eveloff, S.E., Herbert, P.N., and Millman, R.P. Adiposity and cardiovascular risk factors in men with obstructive sleep apnea. CHEST, 103:1336-1342, 1993.

81. Boden, W.E., Moss, A.J., Herbert, P.N., Saritelli, A., Oakes, D., Eberly, S. and the Multicenter Diltiazem Post-Infarction Trial Research Group. Effect of long-term diltiazem administration on serum lipids in post- infarction survivors, Am J Cardiol, 73(7):513-14, 1994.

82. Saliba, B., Herbert, PN. Oxacillin Hepatoxicity in H IV-infected Patients. Ann Int Med, 120(12);1048, 1994.

83. Cullinane, EM, Yurgalevitch S.M., Saritelli, A.L., Herbert, P.N., and Thompson, P.D. Variations in plasma volume affect total and LDL cholesterol concentrations during the menstrual cycle. Metabolism, 44(8): 965-971, 1995.

84. Thompson, P.D., Yurgalevitch, S.M., Flynn, M.F., Zmuda, J.M., Spannus-Martin, D., Saritelli, A., Herbert, P.N. and Bausserman, L. The effect of prolonged exercise training without weight loss on high density lipoprotein metabolism in overweight men. Metabolism 46:217-223, 1997.

85. Bausserman, L.L., Saritelli, A.L., and Herbert, P.N. Effects of stanozolol on serum lipoproteins in hepatic lipase deficiency. Metabolism 46(9):992-996, 1997.

86. Flynn, M.M., Zmuda, J.M., Milosavljevic, D., Caldwell, M.J., and Herbert, P.N. Lipoprotein response to a National Cholesterol Education Program Step II diet with and without energy restriction. Metabolism 48(7):822-826, 1999.

87. Zmuda, J.M., Yurgalevitch, S.M., Flynn, M.M., Bausserman, L.L., Saratelli, A., Spannaus-Martin, D.J., Herbert, P.N., Thompson, P.D. Exercise training has little effect on HDL Levels and Metabolism in Men with Initially Low HDL Cholesterol. Artherosclerosis 137:215-221, 1998.

Reviews, Invited Published Papers, Proceedings of Conference and Symposia, Monographs, Books and Book Chapters

1. Brewer, H.B., Jr., Shulman, R., Herbert, P.N., Ronan, R., and Wehrly, K.: The complete amino acid sequence of an apolipoprotein obtained from human very low density lipoprotein (VLDL). In Zambotti, V., Tettamanti, G., and Arrigoni, M. (Eds.): Glycolipids, Glycoproteins and Mucopolysaccharides of the Nervous System (Advances in Experimental Medicine Biology), New York, Plenum Publishing Corp., 1972, vol. 25, pp. 280-281.

2. Fredrickson, D.S., Lux, S.E., and Herbert, P.N.: The apolipoproteins. In Holmes, W., Paoletti, R., and Kritchevsky, D. (Eds.): Pharmacological Control of Lipid Metabolism (Advances in Experimental Medicine & Biology), New York, Plenum Publishing Corp., 1972, vol. 26. pp. 25-56.

3. Levy, R.I., Fredrickson, D.S., Shulman, R., Bilheimer, D.W., Breslow, J.L., Stone, N.J., Lux, S.E., Sloan, H.R., Krauss, R.M., and Herbert, P.N.: Dietary and drug treatment of primary hyperlipoproteinemia. Ann. Int. Med. 77: 267-294, 1972

4. Herbert, P.N., and Frederickson, D.S.: The hypobetalipoproteinemias. In Schettler, G., Greten, H., Schlierf, G., and Swidel, D. (Eds.): Handbuch der Inneren Medizin 7/4: Fettstoffwechsel, Heidelberg, Springer-Verlag, 1976, pp. 485-521.

5. Herbert, P.N.: Hyperlipoproteinemia: a return to the basics. In Rose, L., and Lavine, R. (Eds.): New Concepts in Endocrinology and Metabolism, New York, Grune & Stratton, Inc., 1977, pp. I53-I66.

6. Herbert, P.N., Gotto, A.M., and Fredrickson, D.S.: Familial lipoprotein deficiency (abetalipoproteinemia, hypobetalipoproteinemia and Tangier disease). In Stanbury, J.B., Wyngaarden, J.B., and Frederickson, D.S. (Eds.): The Metabolic Basis of Inherited Disease, New York, McGraw-Hill, 1978, pp. 544-588 (Ch. 28).

7. Herbert, P.N., Bausserman, L.L., Henderson, L.O., Heinen, R.J., LaPiana, M.J., Church, E.C., and Shulman, R.S.: Apolipoprotein Quantitation. In Peeters, H. (Ed.): The Lipoprotein Molecule, London, Plenum Pub. Corp., 1978, pp. 35-56.

8. Fredrickson, D.S., and Herbert, P.N.: Genetic dyslipoproteinemias. In Dietschy, J.M., Ontko, J.A., and Gotto, A.M. (Eds.): Disturbances in Lipid and Lipoprotein Metabolism, Bethesda, Maryland, American Physicological Society, 1978, pp. 199-212 (Ch. 12).

9. Herbert, P.N.: Is risk factor modification indicated after myocardial infarction? In Zohman, L.R., and Kattus, A.A. (Eds.): Progress in Cardiac Rehabilitation, New York, Stratton Intercontinental Medical Book Corp., 1979, vol. II, pp. 82-94 (Ch. 7).

10. Herbert, P.N., Heinen, R.J., Bausserman, L.L., Henderson, L.O., and Musliner, T.A.: Abetalipoproteinemia and hypobetalipoproteinemia: questions still exceed insights. In Gotto, A.M., Jr., Smith, L.C., and Allen, B. (Eds.): Atherosclerosis, V. Proceedings of the Fifth International Symposium on Atherosclerosis, New York, Springer-Verlag, 1980, pp. 684-688.

11. McAdam, K.P.W.J., Bausserman, L., Herbert, P.N., and Green, K.M.: Polymorphism of SAA within human high density lipoprotein. In Glenner, G., Pinho e Costa, P. and Falcao de Freitas, A. (Eds.): Amyloid and Amyloidosis. Proceedings of the Third International Symposium on Amyloidosis. Amsterdam Excerpta Medica, 1980, pp. 302-321.

12. Herbert, P.N., Henderson, L.O., Musliner, T.A., and Shulman, R.S.: Apolipoproteins - Analysis and possible impact on the early diagnosis of atherogenic risk. Munch. Med. Wschr. I22: S209-2I3, 1980.

13. McAdam, K.P.W.J., Li, J., Knowles, J., Foss, N.T., Dinarello, C.A., Rossenwasser, L.J., Selinger, M.J., Kaplan, M.M., Goodman, R., Herbert, P.N., Bausserman, L.L., and Nadler, L.M.: The biology of SAA: Identification of the inducer, in vitro synthesis and heterogeneity demonstrated with monoclonal antibodies. In Kushner, I., Volanakis, J.E.; and Gewurz, H. (Eds.): C-Reactive Protein and the Plasma Protein Response to Tissue Injury, New York, The New York Academy of Sciences, 1980, pp. 126-136.

14. Herbert, P.N., Assmann, G., Gotto, A.M., Jr., and Fredrickson, D.S.: Familial lipoprotein deficiency (abetalipoproteinemia and Tangier disease). In Stanbury, J.B., Wyngaarden, J.B., Fredrickson, D.S., Goldstein, J.L., and Brown, M.S. (Eds.): The Metabolic Basis of Inherited Disease, New York, McGraw-Hill, 1982, pp. 589-621 (Chap. 29).

15. Herbert, P.N., Thompson, P.D., and Shulman, R.S: Determinants of plasma high density lipoprotein concentrations. In Peeters, H., and Gresham, G. (Eds.): Arterial Pollution, London, Plenum Publishing Corp.,1983, pp. 183-211.

16. Herbert, P.N., and Bausserman, L.L.: The apolipoproteins - taxonomy and functions. In Peeters, H., and Gresham, G. (Eds.): Arterial Pollution, London, Plenum Publishing Corp., 1983, pp. 143-182.

17. Herbert, P.N.: Abetalipoproteinemia and Tangier disease. In Dyck, P.J., Thomas, P.K., and Lambert, E.H. (Eds.): Peripheral Neuropathy, New York, McGraw-Hill, 1984, pp. 1728-1744.

18. Herbert, P.N.: Converting the diet-heart hypothesis to a theorem. In Perkins, E.G., and Visek, W.J. (Eds.): Dietary Fats and Health, American Oil Chemists' Society, 1983, Chap. 30, pp. 512-517.

19. Herbert, P.N.: Experience with individual lipid-lowering drugs: Probucol. Cardiovasc. Rev. & Reports January: 38-39, 1983.

20. Herbert, P.N., and Terpstra, A.H.M.: Diet and exercise in the treatment of hyperlipoproteinemia. Drug Therapy 14: 42-52, 1984.

21. Herbert, P.N.: Eating disorders. In Andreoli, T.E., Carpenter, C.C.J., Plum F., and Smith L.H. (Eds.): Cecil Essentials of Medicine, Philadelphia, W.B. Saunders Co., 1989, pp. 420-424 (Ch. 59).

22. Herbert, P.N.: Disorders of lipid metabolism. In Andreoli, T.E., Carpenter, C.C.J., Plum F., and Smith L.H. (Eds.): Cecil Essentials of Medicine, Philadelphia, W.B. Saunders Co., 1989, pp. 431-435 (Ch. 62).

23. Niaura, R., Stoney, C.M., and Herbert, P.N. Lipids in psychological research: The last decade. Bio. Psych. 34:1-43, 1992.

24. The Apoprotein and Antibody Standardization Program Planning Committee. The Apoprotein and Antibody Standardization Program. Arteriosclerosis 9:144-145, 1989.

25. Yao, J., Herbert, P.: Lipoprotein Deficiency and Neuromuscular Manifestations. In Dyck, P.J. and Thomas, P.K. (Eds.): Peripheral Neuropathy, Philadelphia, W.B. Saunders Co., 1993, pp. 1179-1193 (Ch. 62).

26. Flynn, M.M. and Herbert, P.N.: Effects of lowering dietary fat on health status. In Low-Calorie Foods Handbook, Ed. A.M. Altschul, 1993, pp. 479-495 (Ch. 23).

27. Herbert, P.N.: Section on Metabolic Diseases. Chap. 56, Introduction. Chap. 57, Eating Disorders. Chap. 58, Principles of Alimentation and Hyperalimentation. Chap. 59, Hyperuricemia and Gout. Chapt. 60, Disorders of Lipid Metabolism. Chap. 61, Disorders of Metals and Metalloproteins. Chap. 62, Disorders of Amino Acid Metabolism. Chap. 63, Disorders of Carbohydrate Metabolism. Chap. 64, Inherited Disorders of Connective Tissue. In Andreoli, T.E., Bennett, J.C., Carpenter, C.C.J., Plum, F. and Smith, L.H. (Eds.): Cecil Essentials of Medicine, Third Edition, Philadelphia, W.B. Saunders Co., 1993.

28. Herbert, P.N.: Section on Metabolic Diseases. Chap. 56, Introduction. Chap. 57, Eating Disorders. Chap. 58, Principles of Alimentation and Hyperalimentation. Chap. 59, Hyperuricemia and Gout. Chapt. 60, Disorders of Lipid Metabolism. Chap. 61, Disorders of Metals and Metalloproteins. Chap. 62, Disorders of Amino Acid Metabolism. Chap. 63, Disorders of Carbohydrate Metabolism. Chap. 64, Inherited Disorders of Connective Tissue. In Andreoli, T.E., Bennett, J.C., Carpenter, C.C.J., Plum, F. and Smith, L.H. (Eds.): Cecil Essentials of Medicine, Fourth Edition, Philadelphia, W.B. Saunders Co., 1996.

29. Herbert, P.N.: Section on Metabolic Diseases. Chap. 58, Principles of Alimentation and Hyperalimen-tation. Chap. 59, Hyperuricemia and Gout. Chap. 61, Disorders of Metals and Metalloproteins. Chap. 62, Disorders of Amino Acid Metabolism.. Chap. 64, Inherited Disorders of Connective Tissue. In Andreoli, T.E., Bennett, J.C., Carpenter, C.C.J., Plum, F. and Smith, L.H. (Eds.): Cecil Essentials of Medicine, Fifth Edition, Philadelphia, W.B. Saunders Co., 1999 (in press).

30. Citkowitz, E. and Herbert, P.N.: Lipoproteins and Apoproteins. In Gorlin, R., Dangas, M.D., Toutouzas, P.K., Konstadoulakis, M.M. (Eds.): Contemporary Concepts in Cardiology - Pathophysiology and Clinical Management, Kluwer Academic Publishers, 1999, pp. 28-68 (Ch. 3).

pnh:kfq (10/28/99)

PROFESSIONAL ACTIVITIES

TEACHING (1977-1989):

Undergraduate	**(Brown University)**
1984	Nutrition in Biology, Health and Politics (Summer, 2 Months, Course Director)
1984-1999	Biomed 6 - Introduction to Human Physiology (Lecturer)
1985-1989	Human Nutrition (Lecturer)
1980, 1982, 1983	Biomed 196 - Independent Study (Preceptor)
Graduate and Medical School	**(Brown University)**
1987-1989	Biomed 363B - Organ System Pharmacology (Lecturer)
1978-1981	Biomed 371 - Cardiology (Lecturer)
1986-1989	Biomed 130 - Medical Biochemistry (Section Lecturer)
1979-1981	Biomed 364 - Nutrition (Co-Director)
1977-1989	Biomed 301 - Medicine (Core Clerkship Preceptor)
1986-1989	Biomed 370 - Introduction to Clinical Medicine (Physical Diagnosis Course Preceptor)
1989-1999	Biomed 372 - Endocrinology (Lecturer)
Graduate and Medical School	**(Yale University)**
1991-present	Pharmacology 501 (Lecturer)
1991-1993	Introduction to Clinical Medicine (Nutrition Workshop Leader)
1991-1995	Clinical Examination Course (Clinical Tutor)
1991-present	Internal Medicine - Core Medical Clerkship
1992-1994	Cardiovascular Disease Epidemiology 522b Yale University School of Public Health (Lecturer)
1995-1999	Doctor-Patient Encounter Course
1997-1999	Clinical Advisor Program
1995-present	Professional Responsibility course (Seminar Leader)

Ph.D. Thesis Direction
Linda L. Bausserman (George Washington University)

Postgraduate

Preceptor, Primary Care Clinic, HSR
Preceptor for Cardiology and Endocrinology Fellows in Lipid Clinic
Internal Medicine Medical Director and Teaching Attending
Research Elective for Residents
Board Review and Other CME Lectures
Beeson/Peters Firm Attending, Yale-New Haven Hospital

Other

Board of Rhode Island Schools of Medicine Technology (Lipid Lectures)

RESEARCH

1. **Grants**

1979-1982	HL23789 - Lipids and lipoproteins in myocardial infarction	N.I.H.
1981-1988	HL26516 - Transport and catabolism of serum amyloid A	N.I.H.
1983-1985	Plasma cholesterol ester metabolism	A.H.A.
1979-1983	R.J. Reynolds multi-disciplinary program in cardiovascular disease	R.J. Reynolds
1981-1989	HL28467 - Lipoproteins in active men: Role of exercise and diet	N.I.H
1983	Development of Outpatient Nutrition Center	Champlin Foundation
1983-1990	RR02038 - The General Clinical Research Center; Program Director; Associate Program Director	N.I.H.
1987-1988	HL-32141 (sub grant) - Validation and field test for risk appraisal instruments	N.I.H.
1986-1988	Diet and coronary heart disease	A.H.A.
1980-1989	HL23269 (sub grant) - Pawtucket Heart Health Program	N.I.H.
1987-1989	Lipids and apolipoprotein in the Diltiazem Post-Infarction Trial	Marion Laboratories
1988-1989	Evaluation of XU-62-320 Study No. 12	Sandoz Pharmaceuticals
1990-1991	Comparison of Safety and Efficacy of XU 62-320 and Lovastatin	Sandoz Pharmaceuticals
1990-1991	Fluvastatin Study No. 26	Sandoz Pharmaceuticals
1992-1995	Coping Style Stress Responsiveness and Lipids	NIH

2. **Extramural Grant Reviewing (1985-1997)**

1985-1989	AHR for March of Dimes, U.S.- Israel BSF, VA
1985	NHLBV41: HV-85-2 Apoprotein and Antibody Standardization Program (AHR)
1985	RR: GCRC - Francis Scott Key Medical Center
1985	NHLBI: HL-25P - Nutrition and cardiovascular disease (AHR)
1986	NHLBI: HV-87-01 - Clinical Trails Review Committee (AHR - Chairman)
1987	NHLBI: Clinical Trails Review Committee (AHR)
1987	RR: GCRC - Washington University

1988	NHLBI: SRG - Demonstration and education and "Physicians role in lowering elevated lipids by diet" (AHR - Chairman)
1988	AHA: New England Regional Review
1988-1991	NIH: Nutrition Study Section
1989	NHLBI: SRC - Demonstration and education and "Physicians role in lowering elevated lipids by diet" (AHR - Chairman)
1990	NHLBI: 89-HL-I5P - Postprandial lipoproteins and atherosclerosis (AHR)
1990	NHLBI: SRG - Demonstration and Education Research (AHR - Chairman)
1993	NHLBI: Special Emphasis Panel (CARDIA) (AHR)
1996	NHLBI: Special Emphasis Panel (Dietary Effects on Lipoproteins and Thrombogenic Activity)
1997	NIH: Study of Women's Health Across the Nation - Advisory Panel

3. **Research Consultation**

1986-1988	NHLBI: DECA, Ad-Hoc Committee Member
1985-1988	NHLBI: Apoprotein and Antibody Standardization Planning Committee Member
1987-1990	AHA (RI): Research Committee (Chairman 1987-1989)
1986-1989	Rhode Island Partnership for Science and Technology (Institutional Representative)
1989	NHLBI: Workshop on Biochemical Markers of Compliance to Modified Fat Diets - Chairman

SERVICE:

1. **University and Medical School**
   Clinical Faculty Promotion Committee (Chairman)
   Academic Standing Committee
   Brown Biology Forum
   Section of Medicine Research Committee (Chairman)
   General Clinical Research Center - Scientific Advisory Council (1983- 1990)
   Department of Medicine Senior Faculty Promotions Committee (1984-1989)
   Brown University M.D. - Ph.D. Committee
   Medical Faculty Council
   Yale University School of Medicine Alumni Council (1994-present; Secretary 1997-1999)
   APT Foundation Central Medical Unit (1993-present)
   Yale University School of Medicine - Medical School Council (1997)
   Yale University School of Medicine - Board of Permanent Officers (1992-)

2. **Search Committees**

Chief of Neurology (1), Chief of Cardiology (1), Chief of Medicine (1), GCRC Program Director (1), Cardiologists (4), Endocrinologists (3), Hematology (1), Nephrology (1), Infectious Disease (3), General Internal Medicine (6), Emergency Medicine (1)

3. **Hospital Committees**

Miriam Hospital
Clinical Research Review Board (IRB)
Research Building (Chair)
Pharmacy
Nutrition
Medical Staff Selection
Internship Selection
Biomedical Research Support Grant (Chair and Principal Investigator)
Division Directors
University Physicians Foundation, Inc. (Department of Medicine Practice Plan - Vice President)
University Physicians Foundation, Inc. (Finance Committee - Chairman)
University Physicians Foundation, Inc. (Board of Directors)
Attending
Continuing Medical Education
Medical Advisory
Department of Medicine Research Committee (Chairman)
Academic Medicine Task Force
Capital Campaign (1989-1990)

Hospital of Saint Raphael
Executive
Medical Board
Administrative Council
Human Investigation
Ethics
Pharmacy and Therapeutics
Risk Management
Credentials
Quality Assurance - A
Quality Assurance - B
Clinical Chairmen
Graduate Medicine Education
Attending
Continuing Medical Education
Chair, Emergency Department Search Committee
Residency Recruitment and Review
Chair, Cardiology Fellowship Research Committee
Senior Staff
Computer Systems
Clinical Operations Group
Hospital Quality Improvement
Information Systems Task Force
Nuclear Medical Record Task Force Chair

Yale-New Haven Hospital
Board of Trustees

4. **Community**

American College of Physicians, Connecticut Chapter

1995 -	Scientific Program Judge
1993 - 1995	Scientific Program Committee (Chair, 1993)
1993 - present	Governor's Council

5. **Yale-New Haven Hospital/Yale University School of Medicine**

Search Committees:
Chair/Chief, Department of Surgery
Chair/Chief, Department of Obstetrics and Gynecology
Chair/Chief, Department of Radiology
Chair/Chief, Department of Internal Medicine
Chair, Section of Cardiology
Chair/Chief, Department of Child Psychiatry and Child Study Center
Chief, Department of Dentistry
Chair/Chief, Department of Laboratory Medicine
Chair/Chief, Department of Ophthalmology
Chair/Chief, Department of Pediatrics
Chief Medical Information Officer

Committee Memberships:
Chair, General Clinical Research Center Advisory Committee (GAC), 1993-1995
Board of Governors, Yale Medical Group
Comprehensive Cancer Center Dean's Committee
New Clinical Program Development Fund – Development Committee
Yale University School of Medicine Strategic Planning Committee
Yale Alumni in Medicine, Executive Committee and Secretary
Yale-New Haven Health System Quality Council
Yale-New Haven Hospital Performance Leadership Group
Yale-New Haven Hospital Patient Safety Steering Committee
Yale-New Haven Health System, Executive Committee
Yale-New Haven Hospital Senior Operations Group
Clinical Performance Improvement Steering Committee
Chair, Clinical Information Systems Steering Committee
Medical Center Insurance Corporation, Patient Safety Committee

Director, Ambulatory Services Corporation Board
President, Yale-New Haven Medical Services, PC
President, Yale-New Haven Nursing Home, PC

Community:
Columbus House, Board of Directors
Columbus House, Capital Campaign Committee
CT State Quality in Health Care Advisory Committee

Updated: 4/4/12

Last Updated: May, 2012

JAMES A. BRINK, M.D., F.A.C.R.

CURRICULUM VITAE

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Yale University School of Medicine
Department of Diagnostic Radiology
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E-mail: james.brink@yale.edu

Birthdate & Place: September 13, 1959 Indianapolis, IN

Citizenship: US

Education:

Dates Attended	Institution	Degree Conferred Title or Status
1977-1980	Purdue University West Lafayette, Indiana	Bachelor of Science in Electrical Engineering, Highest Distinction
1980-1984	Indiana University School of Medicine Indianapolis, Indiana	Doctor of Medicine, Highest Distinction
2002	Yale University New Haven, Connecticut	Master of Arts (Honorary)

Career:

1980	Research Assistant	Biomedical Engineering, Purdue University, W. Lafayette, Indiana
1981-1985	Research Associate	Life Sciences Research Division, Indianapolis Center for Advanced Research, Indiana/Purdue University, Indianapolis, Indiana
1984-1985	Intern	Internal Medicine Methodist Hospital of Indiana Indianapolis, Indiana
1985-1989	Resident	Diagnostic Radiology Massachusetts General Hospital Boston, Massachusetts

1985-1990	Clinical Fellow	Department of Radiology Harvard Medical School Boston, Massachusetts
1987-1988	Chief Resident	Department of Radiology Massachusetts General Hospital Boston, Massachusetts
1989-1990	Abdominal Imaging Fellow	Abdominal Radiology Massachusetts General Hospital Boston, Massachusetts
1990-1997	Attending Staff Radiologist	Barnes Hospital St. Louis, Missouri
1990-1997	Consulting Staff Radiologist	St. Louis Children's Hospital St. Louis, Missouri
1990-1995	Assistant Professor of Radiology	Mallinckrodt Institute of Radiology Washington University School of Medicine, St. Louis, Missouri
1994-1997	Attending Staff Radiologist	Jewish Hospital of St. Louis St. Louis, Missouri
1995-1997	Associate Professor of Radiology	Mallinckrodt Institute of Radiology Washington University School of Medicine, St. Louis, Missouri
1996-1997	Co-Director, Computed Body Tomography	Mallinckrodt Institute of Radiology Washington University School of Medicine, St. Louis, Missouri
1997-present	Attending Staff Radiologist	Yale New Haven Hospital New Haven, Connecticut
1997-2001	Associate Professor of Radiology	Department of Radiology Yale University School of Medicine New Haven, Connecticut
1997-2002	Vice-Chairman, Clinical Affairs	Department of Radiology Yale University School of Medicine New Haven, Connecticut
1997-2002	Associate Chief	Dept. of Diagnostic Imaging Yale New Haven Hospital New Haven, Connecticut
1998 (July –Dec.)	Acting Chair (during Chair's sabbatical)	Department of Radiology Yale University School of Medicine New Haven, Connecticut
2000-2005	Chief, Abdominal Imaging	Department of Radiology Yale University School of Medicine New Haven, Connecticut

2001-present	Professor of Radiology	Department of Radiology Yale University School of Medicine New Haven, Connecticut
2003-2005	Interim Chief	Dept. of Diagnostic Imaging Yale New Haven Hospital New Haven, Connecticut
2003-2005	Interim Chair	Department of Radiology Yale University School of Medicine New Haven, Connecticut
2006-present	Chief	Dept. of Diagnostic Imaging Yale New Haven Hospital New Haven, Connecticut
2006-present	Chair	Department of Radiology Yale University School of Medicine New Haven, Connecticut

Licensure and Certification:

1988	Massachusetts License Registration #60065
1989	American Board of Radiology, Board Certified in Diagnostic Radiology
1990	Missouri License Registration #R3K91
1997	Connecticut License #035829

Professional Societies and Organizations:

1987-present	Radiological Society of North America
1989-2002	International Society of Biliary Radiology
1991-present	American College of Radiology
1992-present	American Roentgen Ray Society
1993-present	Society of Gastrointestinal Radiologists
1995-present	Society of Computed Body Tomography and Magnetic Resonance
2003-present	Association of University Radiologists
2003-present	Society of Chairs of Academic Radiology Departments

Honors and Awards:

1977-1980	Departmental Honors Program, Purdue University
1977	Purdue President's Honor Award Scholarship
1978	Eta Kappa Nu (Electrical Engineering Honorary)
1978	Tau Beta Pi (Engineering Honorary)
1979	Phi Kappa Phi (Academic Honors Society)
1980	E.B. Rinker Medical Scholarship
1981	AMA Research Fellowship
1982	Anna M. Rott Medical Scholarship

1983	Dr. Karl R. Ruddell Research Scholarship
1984	Alpha Omega Alpha Medical Honor Society
1984	IndianaUniversity School of Medicine Academic Achievement Award
1989,1990	RSNA Research Fellowship Award
1992	Cum Laude Award, Society of Computed Body Tomography. Brink JA, Heiken JP, Balfe DM, Sagel SS, DiCroce J, Vannier MW: Spiral CT: decreased spatial resolution in vivo due to broadening of section-sensitivity profile
1992	Cum Laude Award, Society of Computed Body Tomography. Heiken JP, Brink JA, McClennan BM, Sagel SS, Forman HP, DiCroce J. Dynamic contrast-enhanced CT of the liver: comparison of injection rates and uniphasic and biphasic injection protocols
1992	Editor's Recognition Award for Distinction in Reviewing, *Radiology*
1993	Hounsfield Award, Society of Computed Body Tomography. Brink JA, Deyoe LA, Heiken JP, Yoffie RL, Vannier MW. Spiral CT Angiography for Renal Arterial Stenosis: In Vitro Assessment of Technical Parameters
1993-1995	Editor's Recognition Award for Special Distinction in Reviewing, *Radiology*
1994	*AJR* Reviewer with Perfect Review Evaluations
1994	Contrast Award, Society of Computed Body Tomography. Brink JA, Heiken JP, Forman HP, Sagel SS, Molina PA, Brown PC. Reduction of Intravenous Contrast Material Required for Hepatic Spiral CT
1995	Elected as fellow of the Society for Computed Body Tomography and Magnetic Resonance
1996	Cum Laude Award, Society of Computed Body Tomography. Bae KT, Heiken JP, Brink JA. Computer Simulation of CT Contrast Enhancement: Prediction of Aortic and Hepatic Enhancement During Abdominal CT.
1996	Hounsfield Award, Society of Computed Body Tomography. Brink JA, Horesh L, Heiken JP, Glazer HS, Wang G. Depiction of Pulmonary Emboli with Helical CT: Optimization of Window Width and Level in a Porcine Model.
1997	Cum Laude Award, Society of Computed Body Tomography. McFarland EG, Siegel CL, Fisher AJ, Brink JA, Humphrey PA, Heiken JP. Qualitative Evaluation of Cystic Renal Masses by CT.
2000	Cum Laude Award, Society of Computed Body Tomography. McFarland EG, Brink JA, Heiken JP, Balfe DM, Santillan C, McDermott R, Pilgrim T. Diagnostic Performance and Interobserver Variability in Prospective Comparison of Spiral CT Colonography and Colonoscopy.
2001	Moncada Award, Society of Computed Body Tomography. McDermott RA, McFarland EG, Brink JA, Heiken JP, Balfe DM, Santillan C, Pilgram TK. Evaluation of Polyp Size Measurement in Multi-observer Prospective Study of CT Colonography.
2002	Cum Laude Award, Society of Computed Body Tomography. Bhalla S, McFarland EG, Feng F, McDermott R, Ju A, Menias C, Hara AK, Huete A,

Brink JA, Littenberg B, Pilgrim TK. Prospective MDCT Study of CT Colonography Compared to Colonoscopy: Diagnostic Performance of Experienced and Recently Trained Readers.

2003 Elected as "Fellow" of the American College of Radiology

2007-2008 Elected to Best Doctors in America

2008 Elected as "Honorary Member" of the Italian Society of Medical Radiology

2008 Editor's Recognition Award for Reviewing with Distinction, *Radiology*

2010 Editor's Recognition Award for Reviewing with Distinction, *Radiology*

2011-2012 Best Doctor's in America

2012 Holmes Lecturer, New England Roentgen Ray Society

Patents:

1997 U.S. Patent Number 5,687,208, "Method of and Apparatus for Predicting Computed Tomography Contrast Enhancement with Feedback, Inventors: Kyongtae T. Bae, Jay P. Heiken, James A. Brink, Issued November 11, 1997

Grant Support:

1987-1988 Co-Principal Investigator, "Physical Characteristics of Gallstones Removed at Cholecystectomy," 1 year, Dornier, Inc., Marietta, Georgia, $20,000.

1989-1991 Principal Investigator, "Gallstone and Stone Fragment Quantification for Non-Surgical Gallstone Therapies", 2 years, Radiological Society of North America Research Fellowship Award, Chicago, Illinois, $75,000.

1992-1993 Investigator (5% FTE), "Dynamic Contrast-Enhanced CT of the Liver: Comparison of Volumes and Concentrations of Contrast Media," 0.5 years, Mallinckrodt Medical Corporation, St. Louis, Missouri, $46,000.

1992-1995 Principal Investigator (20% FTE), "Optimization of IV Contrast Administration for Spiral CT of the Chest and Abdomen," 3 years, Sanofi-Winthrop Corporation, New York, New York, $326,000.

1992 Co-Investigator, "Clinical Evaluation of Spiral Computed Body Tomography," 6 months, Siemens Medical Systems, Iselin, New Jersey, $30,000.

1993 Co-investigator (15% FTE), "Perfluorooctylbromide as a Gastrointestinal Radiographic Contrast Agent: Comparison with Standard Water Soluble Iodinated X-ray Agents," 3 months, Alliance Pharmaceutical Corporation, San Diego, California, $47,000.

1993 Co-Investigator, "Clinical Evaluation of Spiral Computed Body Tomography," 6 months, Siemens Medical Systems, Iselin, New Jersey, $30,000.

1994 Co-Investigator (7.5% FTE), "Evaluation of Hepatoma in a Woodchuck Model with MR and Spiral CT," Mallinckrodt Medical, Inc., St. Louis, Missouri.

1994	Co-Investigator, "Phase III Clinical Trial of SonoRx Oral Ultrasound Contrast Agent," Bracco Diagnostics, Plainsboro, New Jersey, $49,000.
1994-1995	Principal Investigator, "Development of an Animal Model for Depiction of Pulmonary Emboli with Spiral CT," Siemens Medical Systems, Iselin, New Jersey, $30,000.
1995	Principal Investigator (15% FTE), "Dose-Optimization for Depiction of Pulmonary Emboli with Spiral CT," Mallinckrodt Medical, Inc., St. Louis, Missouri, $106,000.
1995	Co-Investigator, (5% FTE), "Hepatic Enhancement with a Constant Dose (mgI/sec) of Contrast Material: Effect of Contrast Concentration (240 vs. 350 mgI/ml)," Mallinckrodt Medical, Inc., St. Louis, Missouri, $25,525.
1996-1997	Co-Investigator, (10% FTE), "Dual Phase Spiral CT of the Kidneys," Mallinckrodt Medical, Inc., St. Louis, Missouri, $112,579.
1996-1997	Principal Investigator (15% FTE), "Computer Simulation of Contrast Enhancement during Hepatic CT Scanning: Validation Study," Mallinckrodt Medical, Inc., St. Louis, Missouri, $116,656.
1998	Co-Principal Investigator, "Contrast-Enhanced Helical CT vs. Ventilation-Perfusion Scintigraphy in Patients Suspected of Acute Pulmonary Embolism: A Comparative Cost-Benefit and Outcomes Pilot Study, Mallinckrodt Medical, Inc. St. Louis, Missouri, $10,880.
1998-1999	Consultant for Teleradiology / Telemedicine ($30,000), Dept. of Surgery, Yale University School of Medicine
1998-1999	Consultant ($15,000), "Spiral CT Colography (Virtual Colonoscopy) for Detection of Colorectal Polyps, National Institutes of Health. P.I. = Elizabeth McFarland, M.D. (PLCO grant: NO1-CN-25516)
2000-2002	Consultant ($24,000), Grant Renewal: "Spiral CT Colography (Virtual Colonoscopy) for Detection of Colorectal Polyps, National Institutes of Health. P.I. = Elizabeth McFarland, M.D. (PLCO grant: NO1-CN-25516)

Editorial Responsibilities:

1990	Reviewer, *New England Journal of Medicine*
1991-1995	Reviewer, *Journal of Vascular and Interventional Radiology*
1991-present	Reviewer, *Radiology*
1993-present	Reviewer, *American Journal of Roentgenology*
1993-1994	Reviewer, *Critical Reviews in Diagnostic Imaging*
1995-present	Reviewer, *Journal of Computer Assisted Tomography*
1995-2000	Reviewer, *IEEE Transactions on Medical Imaging*
1995	Reviewer, *Journal of the American Medical Association*
1996-present	Reviewer, *Abdominal Imaging*
1996-2006	Panelist for Body Imaging Exhibits, *Radiographics*
1996-1999	Editorial Board, Associate Editor for Gastrointestinal Radiology, *Radiology*
2000-2001	Consultant to the Editor, *Radiology*
2008	Honorary Member, Advisory Board for International Journal of BioSciences and Technology
2009-present	Editorial Board, *Journal of the American College of Radiology*

Administrative Responsibilities:

National / International:

Academy of Radiology Research

2003-2008	Board of Directors, Academy of Radiology Research, (Representative of the Society of Computed Body Tomography and Magnetic Resonance}
2004	Nominating Committee, Academy of Radiology Research

American Board of Radiology

2003	Guest Examiner, American Board of Radiology, Oral Board Exam
2006-2007	Examiner, American Board of Radiology, Oral Board Exam

American College of Radiology

1992-1995	Human Resources Committee, Interventional Radiology Commission, American College of Radiology
1996-1997	Continuous Professional Improvement program, Expert Panelist, American College of Radiology
1998-2005	Commission on Standards and Accreditation, CT Accreditation Committee, American College of Radiology
1998-2002	Commission on Standards and Accreditation, CT Physics Subcommittee, American College of Radiology
2003-present	Executive Committee, Radiological Society of Connecticut (Connecticut State Chapter of the American College of Radiology)
2005	Body Imaging Commission, Abdominal Imaging Committee, American College of Radiology
2006	Commission on Standards and Accreditation, Metrics Committee, Champion for CT Radiation Dose Reduction, American College of Radiology
2008-present	Chair, Commission for Body Imaging, Board of Chancellors, American College of Radiology
2008-2010	Image Metrix, Board of Directors, American College of Radiology
2008-2010	Scenario Planning Committee, American College of Radiology
2009-present	Scenario and Strategic Planning Committee, American College of Radiology
2010	Chair, Ad Hoc Financial Oversight Committee for ACR-ARRS Strategic Integration Merger
2010-2011	Audit Committee, American College of Radiology
2010-present	Chair, Committee on International Education and Meetings, American College of Radiology
2010-present	Executive Committee, American College of Radiology

2011-present	Board of Directors, American Institute for Radiologic Pathology, American College of Radiology

American Roentgen Ray Society

2002	Co-Director, Categorical Course in Computed Body Tomography, American Roentgen Ray Society
2002	Director, Symposium on Radiation Dose with Computed Tomography, American Roentgen Ray Society
2003	Corporate Relations Committee, American Roentgen Ray Society
2004-2009	Chair, Corporate Relations Committee, American Roentgen Ray Society
2004-present	Executive Council, American Roentgen Ray Society
2006-present	Board of Trustees, The Roentgen Fund, American Roentgen Ray Society
2006-2011	Inter-organizational Research Council (IORC), representative of the American Roentgen Ray Society
2007-2011	Chair, International Relations Committee, American Roentgen Ray Society
2009-2010	Vice President, American Roentgen Ray Society
2010-2011	President-Elect, American Roentgen Ray Society
2011-2012	President, American Roentgen Ray Society

National Council for Radiation Protection and Measurements

2002	Program Committee, NCRP Symposium on Computed Tomography: Patient Dose
2005-2017	Elected Member, National Council on Radiation Protection and Measurements (NCRP)
2007	Program Committee, Annual Meeting of the National Council on Radiation Protection and Measurements
2009-2012	Chair, NCRP Scientific Committee 4-3: Diagnostic Reference Levels in Medical Imaging: Recommendations for Application in the United States, National Council on Radiation Protection and Measurements
2011-present	Board of Directors, National Council for Radiation Protection
2011-present	Vice-President for Radiation Protection in Medicine, National Council for Radiation Protection

International Society of Radiology

2010-present	Chair, International Commission for Radiological Education, International Society of Radiology
2010-present	Executive Committee, International Society of Radiology

Radiological Society of North America

2004-2005	Refresher Course Committee, Radiological Society of North America (Gastrointestinal Track Subcommittee Chair)
2005-2006	Vice-Chair, Refresher Course Committee, Radiological Society of North America
2005-2006	Education Council and Subcommittee on Maintenance of Certification, Radiological Society of North America
2006-2009	Chair, Refresher Course Committee, Radiological Society of North America
2009-present	Co-Chair, Joint Task Force on Adult Radiation Protection ('Image Wisely'), Radiological Society of North America
2010	Search Committee, Editor for *Radiographics,* Radiological Society of North America

Society of Chairmen of Academic Radiology Departments

2009-2010	Scenario Planning Committee, Society of Chairman of Academic Radiology Departments
2010-present	Chair, Low Dose Strategic Initiative Group, Society of Chairmen of Academic Radiology Departments

Society of Computed Body Tomography and Magnetic Resonance

1998-2000	Research Committee, Society of Computed Body Tomography and Magnetic Resonance (Chair: 1999 – 2000)
2001-2002	Nominating Committee, Society of Computed Body Tomography and Magnetic Resonance
2003-2005	Corporate Relations Committee, Society of Computed Body Tomography and Magnetic Resonance
2005-2007	Board of Directors (Secretary-Treasurer), Society of Computed Body Tomography and Magnetic Resonance

Miscellaneous

1987-1988	Steering Committee, American Association of Academic Chief Residents in Radiology
2000-2001	Imaging Services Steering Committee, University Heath System Consortium
2003-2012	Committee on Image Quality and Patient Dose in CT, International Commission on Radiation Units
2003-2004	Scientific Program Committee, Society of Gastrointestinal Radiology
2005-present	Vice President, New England Roentgen Ray Society
2010	External Reviewer, University of Colorado, Department of Diagnostic Radiology
2012	Expert Panel, International Atomic Energy Agency, Radiation Protection of Patients

University:

1995-1996	Clinical Advisory Board, Project Spectrum, Washington University School of Medicine
1997-1998	Medical School Council, Yale University School of Medicine
1998-1999	Faculty Computing Committee, Yale University School of Medicine
1998-1999	Search Committee, William's Professor of Medical Informatics, Yale University School of Medicine
2000-2001	Strategic Development Committee, Yale Faculty Practice
2001-2002	Tenure Allotment Committee, Yale University School of Medicine
2002	Contracting Committee, Yale Medical Group
2002	Credentials Committee, Yale Medical Group
2002	Clinical Program Model Committee, Yale Medical Group
2003-2011	Board of Governors, Yale Medical Group
2003-present	Magnetic Resonance Research Center Advisory Committee
2005-present	Yale Cancer Center, Clinical Leadership Committee
2006-2007	Chair, LCME Accreditation Committee for the MD Degree, Yale University School of Medicine
2007-2009	Executive Committee, Board of Governors, Yale Medical Group
2008-2009	Yale University Budget Committee
2008-present	Co-Chair, Yale-Pfizer Bioimaging Alliance
2009-2012	Yale Medical Group, Board of Governors, Elected Representative of Hospital-Based Departments
2009-2012	Yale University Conflict of Interest and Conflict of Commitment Committee
2010-2011	Chair, Clinical Information Systems Committee, Yale Medical Group
2010-2011	Search Committee for Chief Information Officer, Yale University
2010-2011	Chair, Search Committee for Chair of Urology, Yale University School of Medicine

Hospital:

1987-1988	Executive Committee on Teaching and Education, Massachusetts General Hospital
1987-1988	Emergency Services Committee, Massachusetts General Hospital

1997-1998	Emergency Services Review Committee, Yale New Haven Hospital
1998	Peripherally Inserted Central Venous Access Committee, Yale New Haven Hospital
1998-2002	Risk Management Committee, Yale New Haven Hospital
1998-2001	Space and Facilities Renovation Committee, Yale New Haven Hospital
1998-2000	Telemedicine Committee, Yale New Haven Hospital
1998-1999	Chair, Subcommittee for Telemedicine Research, Yale New Haven Hospital
2000-2001	Six Sigma Quality Improvement, Project Leader and Green Belt Trainee
2002-2003	Health Insurance Portability and Accountability Act (HIPAA) Privacy Task Force
2003-present	Medical Board, Yale-New Haven Hospital
2006-2010	Sunrise Clinical Management Leadership Group
2006-2007	Clinical Neuroscience Service Line Planning Committee, Yale-New Haven Hospital
2006-2007	Clinical Oncology Service Line Planning Committee, Yale-New Haven Hospital
2007-present	Institutional Practice Quality and Peer Review Committee, Yale-New Haven Hospital
2010-present	Physician Advisory Group for Implementation of Epic EMR, Yale-New Haven Health System
2011-present	Administrative Committee, Medical Board, Yale-New Haven Hospital

Department:

1987-1990	Education Committee, Department of Radiology, Massachusetts General Hospital
1987-1990	Holmes Lecturer Committee, Department of Radiology, Massachusetts General Hospital
1987-1990	Library Committee, Department of Radiology, Massachusetts General Hospital
1993	Strategic Planning Task Force on Research, Mallinckrodt Institute of Radiology
1994-1997	Educational Resource Committee, Mallinckrodt Institute of Radiology
1995	Incentive Committee, Mallinckrodt Institute of Radiology
1995-1996	Clinical Research Committee, Mallinckrodt Institute of Radiology

1996	Strategic Planning Task Force on Finance, Mallinckrodt Institute of Radiology
1997-2001	Imaging Products Committee, Department of Diagnostic Radiology, Yale University School of Medicine
1997-2001	Research Management Committee, Department of Diagnostic Radiology, Yale University School of Medicine
1997-2002	Co-chair, Infrastructure Committee, Department of Diagnostic Radiology, Yale University School of Medicine
1997-2002	Chair, Clinical Management Committee, Department of Diagnostic Radiology, Yale University School of Medicine
2000-2002	Chair, Emergency Radiology Quality Assurance Committee
2000-2002	Chair, Department of Radiology Compensation Committee
1997-2005	Clinical Director, Picture Archive and Communication Systems, Department of Diagnostic Radiology, Yale University School of Medicine
1997-2005	Clinical Director, 3-D Imaging Laboratory, Department of Diagnostic Radiology, Yale University School of Medicine

Corporate Advisory Boards:

1992	CT Advisory Board, Sanofi-Winthrop Pharmaceuticals, Inc., New York, NY.
1991-1994	Spiral CT Advisory Board, Siemens Medical Systems, Inc., Iselin, NJ.
1996-2007	Medical Advisory Board, Vital Images, Inc., Fairfield, Iowa
1997-2008	CT Advisory Board, General Electric Corporation, Milwaukee, WI
2004	PET/CT Think Tank, PETNET Solutions, Knoxville, TN
2007-2009	Calgary Scientific, Calgary, Alberta, Canada
2010-present	Comparative Effectiveness Research Advisory Board, General Electric Corporation, Milwaukee, WI
2011-present	Image Metrix, Scientific Advisory Board, American College of Radiology

Teaching Responsibilities:

1987-1988	"Barium Examination of the Colon," Core Clerkship in Radiology (Radiology #500 M.3), Harvard Medical School Massachusetts General Hospital, Boston, MA.
1987-1988	Resident Mini-course Coordinator, Department of Radiology, Massachusetts General Hospital, Boston, MA
1988	"Physical basis and comparative physical parameters of electromagnetic, piezoelectric, and spark-gap discharge shock-wave lithotripsy." Abdominal

	Radiology Research Conference, Massachusetts General Hospital, Boston, MA
1989	"GI Neoplasms--Diagnostic and Interventional Radiology," Clinical Course in GI Neoplasms, Department of Radiation Medicine, Massachusetts General Hospital, Boston, MA
1990	"Imaging in the Era of Non-Surgical Gallstone Therapy," In-Service Update, Ambulatory Care Center, Massachusetts General Hospital, Boston, MA
1990	"Ultrasound Physics," Basic Science of Radiology Course, Department of Radiology, Massachusetts General Hospital, Boston, MA
1991-1993	"Abdominal Radiology," Washington University School of Medicine, 3rd year rotation in Diagnostic Radiology, Mallinckrodt Institute of Radiology, St. Louis, MO
1991-1993	"Medical House Staff Conference," Barnes Hospital, Washington University School of Medicine, St. Louis, MO
1993-1995	"Medical Scientist Training Program (MSTP) Radiology Elective," Washington University School of Medicine, St. Louis, MO
1996	"3-D Imaging of the Tracheo-Bronchial Tree," CT Technologists In-Service, Barnes Jewish Hospital, St. Louis, MO
1996	"CT Pelvimetry," CT Technologists In-Service, Barnes Jewish Hospital, St. Louis, MO
1999	"Abdominal Radiology," Radiology Workshop for the Digestive Disease Module, Yale University School of Medicine, New Haven, CT
2003-2004	"Contrast Optimization in Computed Tomography", and "CT Colonography". Seminars in Biomedical Engineering, BME 480/580, Yale University
2004	"Seminar on Virtual Colonoscopy". Gastroenterology Section, Department of Internal Medicine, Yale University School of Medicine
2005-present	Biomedical Engineering Senior Seminar (BENG480); 1 hour (Multislice CT: Technical Principles)

Thesis Advisor for Yale Medical Students:

1998	Jason Oliphant, "Stairstep artifact in helical CT virtual colonoscopy"

<u>Invited Professorships and Lectureships:</u>

1. High-frequency ultrasonic imaging. Methodist Hospital of Indiana, Indianapolis, IN, April, 1985.

2. Non-surgical gallstone therapies. Grand Rounds, Somerville Hospital, Somerville, MA, March, 1988.

3. Physical characteristics of gallstones removed at cholecystectomy: implications for shock-wave lithotripsy. 1st International Biliary Lithotripsy Symposium, Boston, MA, July, 1988.

4. Biliary Lithotripsy. North Shore Radiological Society, Salem, MA, November, 1988.

5. Imaging in the era of gallbladder lithotripsy. Methodist Hospital of Indiana, Indianapolis, IN, December, 1988.

6. Biliary Lithotripsy. Grand Rounds, Pomona Valley Hospital Medical Center, Pomona, CA, July, 1989.

7. Modern Treatment of Biliary Lithiasis, GI-Surgical Rounds, Newton-Wellesley Hospital, Newton, MA, October, 1989.

8. Non-surgical Gallstone Therapies, Medical Grand Rounds, Salem Hospital, Salem, MA, March, 1990.

9. Radiology and Gallbladder Lithotripsy, Scientific Session, Long Island Radiologic Society, Woodbury, NY, May, 1990.

10. Gallstone Imaging Characteristics, IV International Symposium on Biliary Stone Therapy, Mayo Clinic, Rochester, MN, October, 1991.

11. CT of the Peritoneal Ligaments, Refresher Course, American Roentgen Ray Society, Orlando, FL, May, 1992.

12. Visiting Professor. Baptist Medical Center of Oklahoma, Oklahoma City, OK, October, 1992.

13. Imaging of the Pancreatico-biliary System, CT of the Peritoneal Ligaments, and Imaging of the Urinary Tract, Annual Meeting of the Oklahoma State Radiological Society, Oklahoma City, OK, October, 1992.

14. Spiral Computed Body Tomography, Imaging Techniques Seminar, Carle Clinic, Champagne, IL, October, 1992.

15. Visiting Professor, Grand Rounds: Spiral Computed Body Tomography, Massachusetts General Hospital, Harvard Medical School, Boston, MA, June, 1993.

16. Visiting Professor, Spiral Computed Body Tomography, William Beaumont Army Medical Center, El Paso, TX, September 1993.

17. Spiral Computed Body Tomography: Applications in the Chest and Abdomen, City-Wide Radiology Conference, St. Louis, Missouri, December, 1993.

18. Spiral CT: Technical Aspects. Friday Afternoon Symposium, 79th Scientific Assembly of the Radiological Society of North America, Chicago, IL, December 1993

19. CT Angiography, New York Roentgen Society, New York, New York, January, 1994.

20. Visiting Professor, Spiral CT of the Chest and Abdomen, New York University, New York, New York, January, 1994.

21. Spiral CT, Greater St. Louis Society of Radiologists, St. Louis, MO, January, 1994.

22. Cross Sectional Angiography Workshop, Society of Cardiovascular and Interventional Radiology, San Diego, CA, March, 1994.

23. Spiral CT Overview, Orange County Radiological Society, Orange County, CA, March, 1994.

24. Visiting Professor, CT of the Peritoneal Ligaments, University of California at Irvine, Irvine, CA, March, 1994.

25. Radiologic Imaging in Diagnosis and Management of Acute Pancreatitis, Refresher Course and Update in Gastrointestinal Surgery, Washington University School of Medicine, St. Louis, MO, March, 1994.

26. Visiting Professor, Spiral CT, London Clinic and Royal Marsden Clinic, London, England, September, 1994.

27. Spiral CT of Uretero-pelvic Junction Obstruction. 12th World Congress of Endourology and ESWL, St. Louis, MO, December, 1994.

28. Spiral CT Angiography and other topics, Intermountain Imaging Conference, Steamboat Springs, CO, February, 1995.

29. Spiral CT. Kansas Radiologic Society - South Central Kansas Radiologic Society, Wichita, KA, March, 1995.

30. Spiral CT Angiography--Plenary Session and Workshop. Society of Cardiovascular and Interventional Radiology, Ft. Lauderdale, FL, March, 1995.

31. Decimosexto Curso de Diagnostico por Imagenes. Rosario, Argentina, August, 1995.

32. TAC Spirale 1995: Stato Dell'Arte. University of Brescia, Italy, September, 1995.

33. New Orleans Fall Radiology Conference. New Orleans, LA, October, 1995.

34. Visiting Professor, Grand Rounds: New Applications for Spiral CT in Body Imaging. Yale University School of Medicine. New Haven, CT, November, 1995.

35. 13 Curso de Diagnostico por Imagem. Sao Paolo Brazil, December, 1995

36. Spiral CT of the Chest, Spiral CT Angiography. Annual Meeting of the Society of Computed Body Tomography and Magnetic Resonance, Scottsdale, AZ, March 1996.

37. Spiral CT Angiography, Contrast Media Physiology, Siemens CT Users Meeting, Scottsdale, AZ, June 1996.

38. Spiral CT of the Abdomen, CT/MR of the Small Bowel, Spiral CT of the Chest, Spiral CT Angiography. Society of Computed Body Tomography and Magnetic Resonance--Summer Practicum, Aspen, CO, August 1996.

39. MRI met Diepgang. Vaals, The Netherlands, September, 1996.

40. TAC Convenzionale, TAC Spiral e Risonanza Magnetica: L'Addome Oncologico. Venezia, Italy, October, 1996.

41. Practical Issues in Leading-Edge Radiology, Mallinckrodt Institute of Radiology Symposium, St. Louis, MO, October, 1996.

42. Helical CT Angiography of the Chest and Abdomen. Kansas City Radiological Society, Kansas City, KA, February, 1997.

43. MR and CT of the Bile Ducts: State of the Art -- 1997. Society of Gastrointestinal Radiologists, Cancun, Mexico, March, 1997

44. Whole Body Computed Tomography and Magnetic Resonance Imaging—17th Annual Course, Perthshire, Scotland, March, 1997

45. Problematic Renal Mass Evaluation, Aortic Dissection--CT, CT/MR of Pancreatic Neoplasms, CTA/MRA of the Renal Arteries and Abdominal Aorta, Annual Meeting of the Society of Computed Body Tomography and Magnetic Resonance, Washington, DC, April, 1997.

46. Biliary Tract Imaging: A Mutimodality Approach, Refresher Course, Annual Meeting of the American Roentgen Ray Society, Boston, MA, May, 1997.

47. Principles of Spiral/Helical CT, Abdominal and Interventional Radiology Minicourse, Massachusetts General Hospital, Boston, MA, June, 1997.

48. Helical CT and Body MR Imaging, University of Pittsburg Summer Imaging Course, Keystone, CO, July, 1997.

49. Spiral CT 1997: Diagnostic Update. University of Brescia, Italy, September, 1997.

50. CT/MRI Head to Toe Course, New York University School of Medicine, New York, NY, December 1997.

51. Spiral CT: The Nuts and Bolts, Radiology Grand Rounds, Hospital for the University of Pennsylvania, Philadelphia, PA, January, 1998.

52. Computed Body Tomography 1998: The Cutting Edge, Johns Hopkins University, Orlando, FL, February, 1998.

53. Biliary Tract Imaging, Society of Gastrointestinal Radiologists, Rancho Mirage, CA, February, 1998

54. Indeterminate Renal Masses and CT of the Small Bowel, Colorado Society of Radiologists, Denver, CO, March, 1998

55. Clinical Essentials of Spiral CT, Institute for Advanced Medical Education, Ft. Lauderdale, FL, March, 1998

56. Diseases of the Abdomen and Pelvis, International Diagnostic Course in Davos, European Association of Radiologists, Davos, Switzerland, March, 1998

57. Biliary Tract Imaging: A Mutimodality Approach, Refresher Course, Annual Meeting of the American Roentgen Ray Society, San Francisco, CA, April, 1998

58. Clinical Image Management and Communication Systems, First International Symposium on Telemedicine, Athens, Greece, April, 1998

59. Third Annual Summer Abdominal Imaging Conference, University of Pennsylvania, Jackson Hole, WY, July, 1998

60. Practical Applications for Digital Imaging in Radiology, University of Brescia, Italy, September, 1998.

61. Clinical Spiral CT Update – 1998, University of California in Los Angeles, Los Angeles, CA, October, 1998

62. Yale Telemedicine Training Course, Department of Surgery, Yale University School of Medicine, New Haven, CT, November, 1998

63. Diseases of the Abdomen and Pelvis, International Diagnostic Course in Davos, European Association of Radiologists, Davos, Switzerland, March, 1999

64. CT of the Peritoneal and Retroperitoneal Spaces, and Indeterminate Renal Masses, Annual Meeting of the Society of Computed Body Tomography and Magnetic Resonance, New Orleans, LA, April, 1999

65. Clinical Information and Image Management Systems, Yale Endo-Laparoscopic Center Telemedicine Course, New Haven, CT, August, 1999

66. Virtual Colonoscopy: Early Comparison Between Real and Virtual Colonoscopy, Annual Meeting of the Society of Laparoscopic Surgery, New York, NY, December, 1999

67. Spiral CT of the Abdomen: An Old Dog with Some New Tricks. Greater Cincinatti Radiological Society, Cincinatti, OH, January, 2000

68. Visiting Professor, University of Cincinatti, Cincinatti, Ohio, January, 2000

69. Spiral CT of the Abdomen: What's New. Dallas-Fort Worth Radiological Society, Dallas, TX, January, 2000

70. Grand Rounds and Visiting Professor, Parkland Hospital, University of Texas Southwestern Medical Center, Dallas, TX, January, 2000

71. Moderator, Unknown Film Panel – Computed Tomography, New England Roentgen Ray Society, Boston, Massachusetts, February, 2000

72. Whole Body Computed Tomography and Magnetic Resonance Imaging—20th Annual Course, Perthshire, Scotland, March, 2000

73. Visiting Lecturer, 10th Congress of the Asean Association of Radiology, Bangkok, Thailand, March 2000

74. Diagnostica per immagini della patologia pancreatica e biliare: aggiornamenti 2000, Ospedale di Treviglio, Treviglio, Italy, April, 2000

75. Radiologia digitale, PACS, teleradiologia con internet: stato dell'arte nell'anno 2000, Ospedale Civile di Brescia-Radiologia Prima, Brescia, Italy, May 2000

76. Intraabdominal Pathways for the Spread of Disease, Visiting Professor, Incontro con l'Esperto, University of Verona, Verona, Italy, May 2000

77. Intraabdominal Pathways for the Spread of Disease, Radiology Grand Rounds, New York University, New York, NY, June, 2000

78. 22nd Annual Diagnostic Imaging Seminar, University of Pennsylvania Medical Center, Martha's Viineyard, MA, July, 2000

79. CT in the Year 2000: Multidetector and Trauma CT. Convegno Annuale del Gruppo Radiologi Lombardi, Milano, Italy, October, 2000

80. Multidetector CT: Impact on Radiation Dose for Virtual Colonoscopy. 2nd International Symposium on Virtual Colonoscopy, Boston, MA, October, 2000

81. Imaging the Invisible: Mesenteries and Peritoneum of the Upper Abdomen. Refresher Course, 86th Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL, November, 2000

82. CT/MR Imaging of Problematic Renal Masses and CT of the Peritoneal Ligaments, Grand Rounds, Hartford Hospital, Hartford, CT, January, 2001

83. Multidetector-Row Spiral CT: New Challenges and Opportunities. Grand Rounds, Boston University School of Medicine, Department of Radiology, March, 2001

84. PACS Workstations: Performance and Design. Annual Meeting of the Society of Computed Body Tomography and Magnetic Resonance, Scottsdale, AZ, March, 2001.

85. 3-D CT Imaging of the Chest, Imaging of Pulmonary Emboli, and CT/US Imaging of the Bile Ducts. In "Imaging Ducts, Vessels, and Volumes—The New Approach." University of Verona, Verona, Italy, May, 2001.

86. Principles of Contrast Material Administration and Scan Timing for Spiral CT and Multidetector CT. 2nd Bracco Symposium on Multidetector CT, Barcelona, Spain, May, 2001.

87. Optimization of Technical Parameters for Multidetector CT. 1st Italian Conference on Utilization of Multidetector CT, Alessandria, Italy, May, 2001.

88. Multidetector CT: Application and Impact, and CT Angiography for Renovascular Hypertension. United Kingdom Radiological Congress (UKRC), London, England, May, 2001.

89. Multidetector CT: New Challenges and Opportunities. Grand Rounds, Yale University School of Medicine, Department of Diagnostic Radiology, September, 2001.

90. Principles of Contrast Medium Administration and Scan Timing for Single and Multidetector-Row Spiral CT. International Symposium on Multidetector-Row CT in the New Millennium. Tokyo, Japan, September, 2001.

91. CT after 6PM: Traumatic and Non-traumatic Imaging Applications. Milano, Italy, September, 2001.

92. MRI/CT Update, 2001, Body / Neuro Imaging. Brigham and Women's Hospital, Harvard Medical School, Boston, MA, October, 2001

93. Imaging the Invisible: Mesenteries and Peritoneum of the Upper Abdomen. Refresher Course, 87th Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL, November, 2001

94. Multidetector CT: New Challenges and Opportunities. Grand Rounds, University of Alabama, Birmingham, Alabama, December, 2001.

95. Optimized Use of Contrast Material in Single and Multislice CT, and Multislice CT: Dose Considerations, 25th Annual Meeting, Society of Computed Body Tomography and Magnetic Resonance, Charleston, South Carolina, March, 2002

96. Spread of Metastatic Disease in the Abdomen, International Diagnostic Course in Davos, European Association of Radiologists, Davos, Switzerland, April, 2002

97. Multidetector CT: General Principles. Categorical Course in Body CT, Annual Meeting of the American Roentgen Ray Society, Atlanta, GA, April, 2002

98. The Future of Medical Imaging, General Electric Lecture, Annual Meeting of the American Roentgen Ray Society, Atlanta, GA, April, 2002

99. Principles of Contrast Administration for MDCT of the Liver, Society of Gastrointestinal Radiologists, Orlando, FL, April, 2002

100. Multidetector CT: New Challenges and Opportunities. Grand Rounds, Medical College of Georgia, Augusta, Georgia, May, 2002

101. Volumetric Multislice CT: General Principles and Radiation Dose Considerations, Volumetric Multislice CT: Principles of Contrast Medium Administration and Scan Timing, Volumetric Multislice CT: Imaging Applications in the Thorax. Third International Workshop on Multislice CT 3D Imaging and Virtual Endoscopy, Rome, Italy, June, 2002

102. Use of High Concentration Contrast Medium: Principles and Rationale – Body CT, Third Annual Symposium on Multislice CT, Paris, France, June, 2002

103. Contrast Optimization and Scan Timing for Single and Multislice CT. International Congress of Radiology, Cancun, Mexico, July, 2002

104. Multidetector CT: New Challenges and Opportunities. Grand Rounds, University of Colorado, Denver, Colorado, July, 2002

105. Multidetector CT Angiography: Principles and Pitfalls, and Radiation Dose Issues with Multidetector CT. Society of Computed Body Tomography and Magnetic Resonance Summer Practicum, Napa, California, August, 2002

106. Multidetector CT Overview, Volumetric CT Imaging of the Thorax, CTA of the Abdominal Aorta and Major Branches. "Gourmet" Body Imaging: Volumetric CT and MR Applications. Convegno Annuale del Gruppo Regionale Radiologi Lombardi della Sirm, Milano, Italy, September, 2002

107. CT Colonography, Multidetector CT Overview, Volumetric CT Imaging of the Thorax, CTA of the Abdominal Aorta and Major Branches. Tomografia Computerizada y Resonancia Magnetica: Estado Actual. Curso Internacional, Hospital Clinico San Carlos, Madrid, Spain, October, 2002

108. Techniques for Peforming and Interpreting CT Colonography, Principles and Radiation Dose with Multislice CT. Medically-principled CT Screening: Theory, Techniques, and Controversies. Society of Computed Body Tomography and Magnetic Resonance Boston, Massachusetts, November, 2002

109. The American College of Radiology Computed Tomography Accreditation Program. Computed Tomography: Patient Dose. NCRP Symposium, Arlington, Virginia, November, 2002

110. Clinical Information and Image Management: Experience at Yale University, and Integrated Health Care Enterprise: Clinical Opportunities and Challenges. La Tradizione Si Rinnova: dalla Pellicola Radiografica all'Ospedale Filmless. Alessandria, Italy, December, 2002

111. Multidetector CT: New Opportunities and Challenges. Grand Rounds, Thomas Jefferson University, Philadelphia, PA, January, 2003

112. MDCT: Basic Principles, Radiation Dose Considerations for Body CT, and CT Colonography: Technique for Performance and Interpretation, 26th Annual Meeting,

Society of Computed Body Tomography and Magnetic Resonance, Rancho Mirage, California, March, 2003

113. Keynote Address: "Radiation Dose with Multislice CT: How High Is It?", New Issues Forum: "Radiation Dose with Multislice CT", Categorical Course--Oncologic Radiology: "Patterns of Spread of Metastatic Disease in the Abdomen", Instructional Course: "Peritoneal Spaces and Ligaments". 103rd Annual Meeting of the American Roentgen Ray Society, San Diego, CA, May, 2003

114. MDCT: Principles and Techniques, MDCT: Radiation Dose Considerations, MDCT: Principles of Contrast Administration and Scan Timing, Techniques for Performing and Interpreting CT Colonography, MDCT Angiography of the Aorta and Major Branches. New York University Summer Radiology Practicum, Prout's Neck, ME, June, 2003

115. G. Leland Melson Visiting Professor and Lecturer. Multislice CT: Radiation Dose Considerations and Future Directions. Mallinckrodt Institute of Radiology, Washington University School of Medicine, St. Louis, MO, September, 2003

116. Contrast Optimization and Scan Timing, and CT Colonography: Technical Considerations. "Advances in Multidetector CT", Institute for Advanced Medical Education. Washington, DC, September, 2003

117. Volumetric Multislice CT: Recent Advancements and Future Directions, Radiation Dose Considerations for Screening with Multislice CT, Coronary Screening: Pros and Cons, Clinical Image and Information Management Systems: Keys to Successful Integration. "Screening CT and Other Volumetric CT Applications". Convegno Annuale del Gruppo Regionale Radiologi Lombardi della Sirm, Milano, Italy, September, 2003

118. Volumetric Multislice CT: Recent Advancements and Future Directions. Meeting of the Radiological Society of Connecticut, Berlin, CT, October, 2003

119. 4, 8, and 16-slice MDCT: Technology, Techniques, and Future Directions; MDCT: Radiation Dose. "New Opportunities for CT, MR, and PET/CT". Society of Computed Body Tomography and Magnetic Resonance, Boston, MA, October, 2003

120. Cross-Sectional Imaging of the Biliary Tract. Refresher Course, 89th Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL, November, 2003

121. Radiation Dose Considerations for Body CT, Society of Gastrointestinal Radiologists, Scottsdale, AZ, March, 2004

122. Pathways for the Intraabdominal Spread of Malignancy, Radiation Dose Considerations for Body CT, 27th Annual Meeting, Society of Computed Body Tomography and Magnetic Resonance, Las Vegas, NV, March, 2004

123. Clinical Information and Image Management Systems. Clinical Experience at Yale University, Integrated healt care enterprise. Clinical Opportunities and Challenges. Dipartimento di Diagnostica per Immagini Policlinico di Modena – Azienda Ospedaliera, Modena, Italy, March, 2004

124. Virtual Colonoscopy. Grand Rounds, Middlesex Hospital, Middletown, CT, April, 2004

125. Multidetector-row CT: New Challenges and Opportunities, Intraabdominal Pathways for the Spread of Disease. Visiting Professor andGrand Rounds, Department of Diagnostic Imaging, Brown Medical School, April, 2004

126. Principles of Contrast Media Administration and Scan Timing, Techniques for Performing and Interpreting CT Colonography, Multi-slice CT: Radiation Dose Considerations. 5th Annual Course "Multislice Helical CT: Basics to Advanced", Las Vegas , NV, April, 2004

127. Multidetector CT and 3D Imaging in the Abdomen. 104th Annual Meeting of the American Roentgen Ray Society, Miami, FL, May, 2004

128. MDCT: Basic Principles, MDCT: Radiation Dose Considerations, Clinical Image and Information Management Systems: Keys to Successful Integration. SCBT/MR Fourteenth Summer Practicum, Vancouver, Canada, August, 2004

129. American Roentgen Ray Society, CT Angiography: Protocols and Contrast Considerations. Practical Applications in Diagnostic Imaging, Indianapolis, IN, September, 2004

130. American Roentgen Ray Society: Practical Applications in Diagnostic Imaging. CT Angiography: Protocols and Contrast Considerations. Chicago, IL, October 2004

131. American Roentgen Ray Society: Practical Applications in Diagnostic Imaging. CT Angiography: Protocols and Contrast Considerations. Boston, MA, October, 2004

132. Biliary Tract Imaging 2004. Refresher Course, 90th Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL, November, 2004

133. Multislice CT Angiography of the Aorta and Major Branches, Multislice CT: Technology, Techniques and Future Directions, CT Colonography: Techniques for Performance and Interpretation. 25th Annual Course in Computed Tomography, Magnetic Resonance Imaging & Positron Emission Tomography, Gleneagles, Scotland, March 2005

134. Dose Considerations in MDCT. Abdominal Radiology Course 2005, The Society of Gastrointestinal Radiologists, San Antonio, Texas, March 2005

135. Radiation Safety, CT Colonography. MDCT: A Practical Approach 2005, Society of Computed Body Tomography and Magnetic Resonance, Scottsdale, Arizona, April, 2005

136. Principles of Contrast Media Administration and Scan Timing, CT Angiography of the Aorta and Major Branches, Multislice CT: Radiation Dose Considerations. 6th Annual Multi-Slice Helical CT 2005: Basics to Advanced, Las Vegas, Nevada, May, 2005

137. Multislice CT: Present and Future, Multislice CT: How to Optimize Techniques, CT-Colonography: How to Perform and Interpret, Aorta and Major Branches: Multislice CT-Angiography, Biliary Tract: The Role of Multislice CT Imaging. 8th International Course: Advances in CT & MRI, Barcelona, Spain, May, 2005

138. MDCT: Principles, Protocols, and Applications. 105th Annual Meeting of the American Roentgen Ray Society, New Orleans, LA, May, 2005

139. Pathways for the Intra-abdominal Spread of Disease. The Robert Shapiro Lecture, Hospital of Saint Raphael, New Haven, Connecticut, June, 2005

140. Optimizing Contrast Medium Delivery for Cardiac CT Angiography. Cardiac CT Angiography: A Practical Approach. American Roentgen Ray Society, Washington DC, September, 2005

141. Image Display, Disaster Recovery and Redundancies, Image Distribution, Organizational Issues. PACS Evolution and Revolution. Garda, Italy, October, 2005

142. Optimizing Contrast Medium Delivery for Cardiac CT Angiography. Cardiac CT Angiography: A Practical Approach. American Roentgen Ray Society, Las Vegas, NV, February, 2006

143. Spread of Metastatic Disease in the Abdomen, International Diagnostic Course in Davos, European Association of Radiologists, Davos, Switzerland, April, 2006

144. MDCT Principles, Protocols, and Applications. Instructional Course, American Roentgen Ray Society, Vancouver, Canada, May, 2006

145. How Anatomy Determines the Spread of Peritoneal Disease, European Society of Gastrointestinal and Abdominal Radiology, Crete, Greece, June, 2006

146. Optimizing Contrast Medium Delivery for Cardiac CT Angiography. Cardiac CT Angiography: A Practical Approach. American Roentgen Ray Society, Chicago, IL, September, 2006

147. Contrast Optimization and Scan Timing in Coronary CT Angiography. 13th Chinese Congress of Radiology, Wuhan, Hubei, China, October, 2006

148. Contrast Optimization and Scan Timing in Coronary CTA; Coronary Screening: Pros and Cons; Volumetric Multislice CT: Recent Advancements & Future Directions, Beijing and Shaoyifu Hospitals, Beijing and Hangzhou, China, respectively, October, 2006

149. 64 Slice CT: Principles and Techniques, Contrast Administration for Coronary CTA, CT Colonography: Techniques for Performance and Interpretation, CTA of the Aorta and Great Vessels. Multirow CT: 64 and Beyond, Milano, Italy, November, 2006

150. Contrast Optimization and Scan Timing in Coronary CTA. Connecticut State Radiological Society, Berlin, CT, November, 2006

151. Adult CT: Controlling Dose and Image Quality. Refresher Course, 92th Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL, November, 2006

152. 64 Slice MDCT: Principles, Techniques, and Future Directions. Grand Rounds – Harborview Medical Center, University of Washington, Seattle, WA, December 2006

153. Optimizing Contrast Medium Delivery for Cardiac CT Angiography. Cardiac CT Angiography: A Practical Approach. American Roentgen Ray Society, San Diego, CA, February, 2007

154. CT Colonography: Performance and Interpretation; Radiation Dose Reduction for CT Examinations. Society of Computed Body Tomography and Magnetic Resonance, Orlando, FL, February, 2007

155. The Use and Misuse of Radiation in Medicine. Third Annual Warren K. Sinclair Keynote Lecture, National Council for Radiation Protection, Arlington, VA, April, 2007

156. Imaging the Peritoneal Cavity: Pearls and Pitfalls. Abdominal Radiology Course – Society of Gastrointestinal Radiologists, Bonita Springs, FL, April, 2007

157. MDCT Techniques 2007: Dose Reduction, Protocols, 3D Imaging. Instructional Course, American Roentgen Ray Society, Orlando, FL, May, 2007

158. Coronary CT Angiography: Optimal Use of IV Contrast Material; CT Colonography: Techniques for Performance and Interpretation; CT as an Exemplar for Use & Misuse

of Radiation in Medicine. SCBT/MR Seventeenth Summer Practicum, Banff, Canada, August, 2007

159. Optimizing Contrast Medium Delivery for Cardiac CT Angiography. Cardiac CT Angiography: A Practical Approach. American Roentgen Ray Society, Milwaukee, WI, September, 2007

160. MDCT Technology Update: 64 and Beyond. SCBT/MR Fall MDCT Symposium, Boston, MA, September, 2007

161. Imaging of Aortic Disease: CT and MR. Summit on Acute Aortic Diseases, Lux Et Veritas. Yale University School of Medicine, Department of Cardiothoracic Surgery, New Haven, CT, November, 2007

162. Adult CT: Controlling Dose and Image Quality--Refresher Course, and The Use and Misuse of Radiation in Medicine—International Roundtable. 93rd Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL, November, 2007

163. CT as an Exemplar of the Use and Misuse of Radiation in Medicine, and Intra-abdominal Pathways for the Spread of Disease. Brown Medical School and Rhode Island Hospital, Grand Rounds Presentation and Visiting Professorship, Providence, RI, January, 2008

164. The Use and Misuse of Radiation in Medicine. Yale University School of Medicine, Department of Surgery, Grand Rounds, New Haven, CT, February, 2008

165. Imaging the Peritoneal Cavity: Pearls and Pitfalls. Abdominal Radiology Course – Society of Gastrointestinal Radiologists, Palm Springs, CA, February, 2008

166. Optimizing Contrast Medium Delivery for Cardiac CT Angiography. Cardiac CT Angiography: A Practical Approach. American Roentgen Ray Society, Ft. Lauderdale, FL, February, 2008

167. The Use and Misuse of Radiation in Medicine. University of Massachusetts, Department of Diagnostic Radiology, Grand Rounds, Worchester, MA, March 2008

168. Coronary CT Angiography: Optimal Use of IV Contrast Material, Coronary CT Angiography: Radiation Dose Considerations, Society of Computed Body Tomography and Magnetic Resonance, Charleston, SC, April, 2008

169. CT as an Exemplar for the Use and Misuse of Radiation in Medicine. Department of Diagnostic Radiology, Grand Rounds, Brigham and Women's Hospital, Boston, MA, April, 2008

170. CT as an Exemplar for the Use and Misuse of Radiation in Medicine. Department of Diagnostic Radiology, Grand Rounds, Massachusetts General Hospital, Boston, MA, April, 2008

171. MDCT Technology: Optimizing Contrast Utilization, CT as an Exemplar of Use and Misuse of Radiation in Medicine, Future Directions in Multichannel CT. 9th Annual Clinical Advances in Multi-Slice / Multi-Channel CT and CTA, Las Vegas, NV, April, 2008

172. Technical Comparison of 64 Slice CT Scanners: X-Ray Source and Detectors, Trends in MDCT Utilization and Technique: Mandate for Radiation Dose Control, Radiation Dose Monitoring and Reporting for MDCT: Local, National and Global Initiatives. 10th

Annual International Symposium on Multidetector-Row CT (Stanford Department of Radiology), Las Vegas, NV, May, 2008

173. Radiation Dosimetry Associated with Cardiac CT Angiography. Cardiovascular Imaging: Integration of SPECT, PET, and CT in Clinical Practice – Symposium in Honor of Frans J. Th. Wackers, MD (Yale Department of Internal Medicine), New Haven, CT, June, 2008

174. Intra- and Subperitoneal Pathways for the Intra-Abdominal Spread of Metastatic Disease, Cancer Risk from Diagnostic Imaging: Risk and Management of Medical Radiation, Multislice CT: Technology Update. International Oncologic Imaging Course, Milano and Cagliari, Italy, June, 2008

175. CT as an Exemplar for the Use and Misuse of Radiation in Medicine. Keynote Address, American Board of Radiology Summit Meeting, Chicago, IL, August, 2008

176. PACS: Yale Experience, Image Display, Disaster Recovery and Redundancies. Digital X-ray and PACS Forum 2008, Curitiba, Brazil, August, 2008

177. Applications for Audience Response Systems in Radiology Education. RSNA Faculty Development Workshop, Chicago, IL, September, 2008

178. Controversies in Radiation Dose and Risk Estimates for CT. General Electric Academic Advisory Council, Niskayuna, NY, October, 2008

179. Multislice CT: Technology Update and Future Directions, Intraperitoneal Pathways for the Spread of Disease in the Abdomen. New Horizons in Radiology, Berlin, Germany, October, 2008

180. Use and Misuse of Radiation in Medicine. Internal Medicine Grand Rounds, University of Arizona, Tucson, AZ, October, 2008

181. Multi-slice CT: Optimizing the Use of Intravenous Contrast Material. Huangguoshu International Interdisciplinary Conference on Biomedical Mathematics, Guizhou, China, November, 2008

182. Clinical Practice: Controlling Adult Radiation Dose and Study Quality--Refresher Course. 94th Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL, December, 2008

183. Multislice CT: Technology Update and Future Directions, CT as an Exemplar of the Use and Misuse of Radiation in Medicine, Extraperitoneal Pathways for the Spread of Disease in the Abdomen. 9th Annual Vail 2009:New Advances in MR and CT Symposium, Vail, CO, February, 2009.

184. CT as an Exemplar of the Use and Misuse of Radiation in Medicine, Intra-abdominal Pathways for the Spread of Disease. Radiology Grand Rounds. Unversity of Michigan, Ann Arbor, MI, February, 2009.

185. Future Directions in Multislice CT, Coronary CT Angiography: Optimal Use of IV Contrast Material, Coronary CT Angiography: Radiation Dose Considerations. 2nd Annual Pan Arab Congress – Pan Arab Association of Radiological Societies, Alexandria, Egypt, April, 2009.

186. Coronary CT Angiography: Optimal Use of IV Contrast Material, Coronary CT Angiography: Radiation Dose Considerations. Ain Shams Specialized Hospital, Cairo, Egypt, April, 2009.

187. CT as an Exemplar of the Use and Misuse of Radiation in Medicine, Intra-abdominal Pathways for the Spread of Disease. Klatte/Campbell Lecture. Indiana University, Indianapolis, IN, April, 2009.

188. Introduction to Academic Radiology. American Roentgen Ray Society, Boston, May, 2009

189. CT as an Exemplar for the Use and Misuse of Radiation in Medicine. Washington DC Metropolitan Radiological Society, Washington, DC, September, 2009

190. Visiting Professor, Intraperitoneal Pathways for the Spread of Disease, George Washington University, Washington, DC, September, 2009

191. Uses and Misuses of CT in Medicine, Computed Tomography in Emergency Medicine: Ensuring Appropriate Use, National Council of Radiation Protection, Bethesda, MD, September, 2009

192. Visiting Professor, Intraperitoneal Pathways for the Spread of Disease, Georgetown University, Washington, DC, September, 2009

193. Radiation Safety, Utilization, and Waste. Society of Chairmen of Academic Radiology Departments, Kohala Coast, Hawaii, October, 2009

194. Controlling CT Radiation Dose: Emphasis on Head and Neck Imaging, American Society of Head and Neck Radiology, New Orleans, LA, October, 2009

195. Scenario Planning for SCARD and ACR, Association of Administrators in Academic Radiology, Kohala Coast, Hawaii, October, 2009

196. Practical Approach to Optimizing Radiation Dose for Body CT: Cardiac Protocols, Radiological Society of North America, Chicago, IL, December, 2009

197. Optimizing Contrast Medium Delivery for Cardiac CT Angiography. Cardiac CT Angiography: A Practical Approach. American Roentgen Ray Society, Phoenix, AZ, February, 2010

198. Multislice CT: Optimizing Utilization of IV Contrast Material, Intraperitoneal Pathways for the Spread of Disease in the Abdomen, Multislice CT: Technology Update and Future Directions, CT as an Exemplar of the Use and Misuse of Radiation in Medicine. Vail 2010: Multislice CT in Clinical Practice. Vail, CO, February, 2010

199. Coronary CT Angiography: Optimal Use of IV Contrast Material, Coronary CT Angiography: Radiation Dose Considerations, Future Directions in Multislice CT. Annual Meeting of the Society of Computed Body Tomography and Magnetic Resonance, San Diego, CA, March, 2010.

200. Spread of Metastatic Disease in the Abdomen, International Diagnostic Course in Davos, European Association of Radiologists, Davos, Switzerland, March, 2010.

201. Intra-Abdominal Pathways for the Spread of Disease (Part I & II), Future Directions and Radiation Dose Considerations for Multi-slice CT. Visiting Professor, Michigan State University, Lansing, MI, April, 2010

202. Multislice CT: Optimizing Utilization of IV Contrast Material, Radiation Safety, Utilization and Control. Connecticut Society of Radiologic Technologists. Middletown, CT, April, 2010

203. CT as an Exemplar of the Use and Misuse of Radiation in Medicine. Visiting Professor, University of Chicago, Chicago, IL, April, 2010

204. CT Imaging - The Benefits are Worth the Responsibilities. American Association of Physicists in Medicine CT Dose Summit, Atlanta, GA, April, 2010

205. Retroperitoneal Spaces -- Beyond the Visceral Organs: The Mesentery and Peritoneum. Annual meeting of the American Roentgen Ray Society. San Diego, CA, May, 2010

206. CCTA:Protocols – Contrast Media Optimization, Radiation Dose. SCBT/MR Summer Practicum, Jackson Hole, Wyoming, August, 2010

207. Radiation Safety, Utilization and Control in Medical Imaging. Yale Cancer Center Grand Rounds, Yale University School of Medicine, October, 2010

208. Future Directions in Multislice CT Technology; Radiation Safety, Utilization and Control, Intra-abdominal pathways for the spread of disease. Korean Society of Radiology, Seoul, Korea, October, 2010

209. Update on "Image Wisely". Optimizing Radiation Use During Fluoroscopic Procedures Consensus Panel. Society of Interventional Radiology Foundation. Herndon, Virginia, October, 2010

210. Coronary CT Angiography: Optimal Use of IV Contrast Material, Coronary CT Angiography: Radiation Dose Considerations, Radiation Safety, Utilization and Waste, Future Directions in Multislice CT. Chest and Cardiac CT: State of the Art, 2010. Milano and Cagliari, Italy, November, 2010

211. Coronary CT Angiography: Optimal Radiation Dose Considerations. Coronary Artery Imaging: Low Dose CT and New Concepts in Advanced High-Resolution Imaging of Coronary Plaque. Rome, Italy, November, 2010

212. Image Wisely Kickoff, Safety in Medical Imaging, Practical Approach to Optimizing Radiation Dose for Body CT: Cardiac Protocols, Radiological Society of North America, Chicago, IL, December, 2010

213. Observations from the ACR CT Accreditation Program: Areas of Success and Areas for Improvement. NIBIB Summit on Management of Radiation Dose in Computerized Tomography: Toward the Sub-mSv Exam. Bethesda, Maryland, February, 2011

214. Growing Issue and Growing Awareness. Developing an Action Plan for Radiation Safety in Cardiovascular Medicine. DCRI/ACC/AHA Think Tank. Tyson's Corner, VA, February, 2011

215. Image Wisely: A campaign to Promote Safe and Appropriate Use of Medical Imaging in Adults, Future Development in CT. Canadian Association of Radiologists, 74th Annual Scientific Meeting, Montreal, Canada, April, 2011

216. Retroperitoneal Spaces -- Beyond the Visceral Organs: The Mesentery and Peritoneum. Annual meeting of the American Roentgen Ray Society. Chicago, IL, May, 2011

217. Image Wisely: A Campaign to Increase Awareness about Adult Radiation Protection. ARRS-ACR 2011 Symposium: Radiation Dose and CT Scanning—Perspectives on the Problem and Potential Solutions. Washington, DC, May, 2011.

218. Radiation Safety, Utilization and Control in Medical Imaging. Medical Grand Rounds, Texas Health Presbyterian Hospital, Dallas, TX, June, 2011.

219. Clinical Keynote Address: Image Wisely. Annual Meeting of the Florida Radiological Society. Key Biscayne, FL, July, 2011.

220. Key Elements in the Success or Failure of Mergers. 2011 Intersociety Summer Conference. Sundance, Utah, August 2011.

221. Cancer Risk Potential with CT. First Annual International Symposium on Radiation Safety in CT. Massachusetts General Hospital, Boston, MA, September, 2011.

222. CT Imaging: The Benefits Are Worth the Responsibilities, Adapting Scanner Settings to Match Clinical Indication - How Much Variation is Needed. 2001 AAPM Dose Summit, Denver, CO, October, 2011

223. CT Imaging: The Benefits Are Worth the Responsibilities. Masters in Body Imaging – 34th Annual Course of the Society of Computed Body Tomography and Magnetic Resonance, Washington, DC, October, 2011.

224. PACS Implementation: How to Avoid Bumps in the Road. Rationale and Evolution, Image Display, and Organizational Issues. Ospedale Maggiore Policlinico, Milano, Italy, November, 2011

225. Image Wisely Update, Keeping the Benefits of Medical Imaging in Perspective, Radiological Society of North America, Chicago, IL, November, 2011

226. The Physician's Perspective on What to Report. National Academies' Beebe Symposium on Tracking Radiation Exposures from Medical Diagnostics, Washington, DC, December, 2011

227. Radiation Safety, Utilization, and Control. Visiting Professor, University of Vermont, Burlington, VT, January 2012

228. CT Dose Disasters We Have Seen – How Bad Could It Get?, The Image Wisely Campaign. Hot Topics in Body CT: Ultra Low-Dose CT and Dual Energy CT in Your Daily Practice. SCBT/MR, Ft. Myers, FL, February, 2012

229. The Need for Imaging Algorithms. Technical Meeting on Radiation Protection of Patients through the Development of Appropriateness Criteria in Diagnostic Imaging, International Atomic Energy Agency, Vienna, Austria, March, 2012

230. Consolidation of Academic and Non-academic Hospitals into Accountable Care Organizations (ACOs). Association of University Radiologists, San Antonio, TX, March, 2012

231. Holmes Lecture: Minimizing Radiation Dose for Effective Medical Imaging – Efforts of the Image Wisely Campaign. New England Roentgen Ray Society, Boston, MA, April, 2012

232. Low Dose Radiation – Clinical Dose Monitoring. Abdominal Imaging 2012: The Current Knowledge Base that Supports Safe and Clinically Effective Practice. American College of Radiology, Washington, DC, April, 2012

233. CT Dose Reduction in the Abdomen and Pelvis: Patient Tracking and Rationale Exam Selection. American Roentgen Ray Society, Vancouver, BC, May, 2012

234. Coronary CT Angiography: Optimal Use of Contrast Material and Radiation Dose Considerations. International Society of Radiology, Sao Paulo, Brazil, May, 2012

Bibliography:

Original Articles:

1. Dines KA, Sheets PW, **Brink JA**, Hanke CW, Condra KA, Clendenon JL, Goss SA, Smith DJ, Franklin TD: High frequency ultrasonic imaging of skin: experimental results. Ultrasonic Imaging 1984;6: 408-434

2. **Brink JA**, Sheets PW, Dines KA, Etchison MR, Hanke CW, Sadove AM: Quantitative assessment of burn injury in porcine skin with high frequency ultrasonic imaging. Invest Radiol 1986;21: 645-651

3. **Brink JA**, Simeone JF, Mueller PR, Richter JM, Prien EL, Ferrucci JT: Physical characteristics of gallstones removed at cholecystectomy: implications for shock-wave lithotripsy. AJR 1988;151: 927-931

4. Mueller PR, Silverman SG, Tung GA, **Brink JA**, Cardenosa G, Saini S, Forman BH, Hahn PF: New universal precaution aspiration tray. Radiology 1989;173: 278-279

5. **Brink JA**, Simeone JF, Mueller PR, Saini S, Tung GA, Spell NO, Ferrucci JT: Routine gallbladder sonographic techniques fail to quantify stone size and number: a retrospective study of 111 surgically proved cases. AJR 1989;153: 503-506

6. Simeone JF, **Brink JA**, Mueller PR, Compton C, Hahn P, Saini S, Silverman SG, Tung G, Ferrucci JT: The sonographic diagnosis of acute gangrenous cholecystitis: importance of the Murphy sign. AJR 1989;152: 289-290

7. Lee MJ, Mueller PR, Saini S, Morrison M, **Brink JA**, Hahn PF: Occlusion of biliary endoprostheses: presentation and management. Radiology 1990;176: 531-534

8. **Brink JA**, Simeone JF, Saini S, Mueller PR, de Correia-Kamat MR, Malt RA, Staritz M, Delius M, Ferrucci JT: Cavitation bubbles simulate gallstone fragments during extracorporeal shock-wave lithotripsy: physical basis and in vitro demonstration. Radiology 1990;174: 787-791

9. Tung GA, Mueller PR, **Brink JA**, Saini S, Ferrucci JT: Gallstone fragmentation with contact electrohydraulic lithotripsy: in vitro study of physical and technical factors. Radiology 1990;174: 781-785

10. Weinstein DF, **Brink JA**, Richter JM: Non-surgical treatment of cholelithiasis: an analysis of clinical opportunity. International Journal of Technology Assessment in Health Care 1990;6: 643-654

11. Goldberg MA, Mueller PR, Saini S, Lee MJ, Girard MJ, Dawson SL, Hallisey MJ, Cortell ED, Hahn PF, **Brink JA**: Importance of daily rounds by the radiologist after interventional procedures of the abdomen and chest. Radiology 1991;180: 767-770

12. Kammer B, Saini S, **Brink JA**, Knoefel WT, Ferrucci JT, Simeone JF, Mueller PR: Optimal technique for detection of gallstones at injection cholecystography: in vitro analysis. Radiology 1991;180: 43-45

13. Lee MJ, Saini S, **Brink JA**, Hahn PF, Simeone JF, Morrison MC, Rattner D, Mueller PR: Treatment of critically ill patients with sepsis of unknown cause: value of percutaneous cholecystostomy. AJR 1991;156: 1163-1166

14. Lee MJ, Saini S, **Brink JA**, Morrison MC, Hahn PF, Mueller PR: Malignant small bowel obstruction and ascites: not a contraindication to percutaneous gastrostomy. Clinical Radiology 1991;44:332-334

15. Morrison MC, Mueller PR, Lee MJ, Saini S, **Brink JA**, Dawson SL, Cortell ED, Hahn PF: Sclerotherapy of malignant pleural effusion through sonograpically placed small-bore catheters. AJR 1992;158: 41-43

16. **Brink JA,** Heiken JP, Balfe DM, Sagel SS, DiCroce J, Vannier MW: Spiral CT: decreased spatial resolution in vivo due to broadening of section-sensitivity profile. Radiology 1992;185: 469-474

17. Surratt RS, Middleton WD, Darcy MD, Melson, GL, **Brink JA.** Morphologic and hemodynamic findings at sonography before and after placement of a transjugular intrahepatic porto-systemic shunt. AJR 1993;160: 627-630

18. Heiken JP, **Brink JA**, McClennan BM, Sagel SS, Forman HP, DiCroce J. Dynamic contrast-enhanced CT of the liver: comparison of injection rates and uniphasic and biphasic injection protocols. Radiology 1993;187:327-331

19. **Brink JA,** Kammer B, Mueller PR, Balfe DM, Prien EL, Ferrucci JT. Prediction of gallstone composition: synthesis of computed tomographic and radiographic features. Radiology 1994;190:69-75

20. **Brink JA,** Kammer B, Mueller PR, Prien EL, Ferrucci JT. Dissolution of calcified gallstones. Part I: Correlation of in vitro dissolution kinetics in methyl tert-butyl ether with patterns of calcification by computed tomography. Invest Radiol 1994;29:448-453

21. Kammer B, **Brink JA**, Knoefel WT, Mueller PR, Prien EL, Ferrucci JT. Dissolution of calcified gallstones. Part II: Evaluation of edetic acid preparations for dissolution of residue after in vitro methyl tert-butyl ether treatment. Invest Radiol 1994;29:454-458

22. Polacin A, Kalender WA, **Brink JA**, Vannier MA. Measurement of slice sensitivity profiles in spiral CT. Med Phys 1994;21:133-140.

23. **Brink JA**, Heiken JP, Semenkovich J, Teefey SA, McClennan BM, Sagel S. Abnormalities of the diaphram and adjacent structures: findings on multiplanar spiral CT. AJR 1994;163:307-310.

24. Forman HP, Heiken JP, **Brink JA**, Glazer HS, Fox LA, McClennan BL. Computed tomographic screening for co-morbid disease in patients with prostatic carcinoma: Is it cost effective? AJR 1994;162:1125-1128.

25. Wang G, **Brink JA**, Vannier MW. Theoretical FWTM values in helical CT. Med Phys 1994;21:753-754.

26. Schlueter FJ, Wang G, Hsieh PS, **Brink JA**, Balfe DM, Vannier MW. Longitudinal image deblurring in spiral CT. Radiology 1994;193:413-418.

27. Brink JA, Heiken JP, Semenkovich J, Teefey SA, McClennan BM, Sagel S. Abnormalities of the diaghram and adjacent structures: findings on multiplanar spiral CT. AJR 1994;163:307-310.

28. **Brink JA**, Lim JT, Wang G, Heiken JP, Deyoe LA, Vannier MW. Technical optimization of spiral CT for depiction of renal artery stenosis: in vitro analysis. Radiology 1995;194:157-163.

29. Heiken JP, **Brink JA**, McClennan BL, Sagel SS, Crowe TM, Gaines MV. Dynamic incremental CT: Effect of volume and concentration of contrast material and patient weight on hepatic enhancement. Radiology 1995;195:353-357.

30. **Brink JA**, Heiken JP, Forman HP, Sagel SS, Molina PL, Brown PC. Hepatic spiral CT: reduction of dose of intravenous contrast material. Radiology 1995;197:83-88.

31. Teefey SA, **Brink JA**, Borson RA, Middleton WD. Diagnosis of venoocclusive disease of the liver after bone marrow transplantation: value of duplex sonography. AJR 1995;164:1397-1401.

32. Teefey SA, Soper NJ, Middleton WD, Balfe DM, **Brink JA**, Strasberg SM, Callery M. Imaging of the common bile duct during laparoscopic cholecystectomy: sonography vs. videofluoroscopic cholangiography. AJR 1995;165:847-851.

33. Teefey SA, Roarke MC, **Brink JA**, Middleton WD, Balfe DM, Thyssen EP, Hildebolt CF. Bowel wall thickening: differentiation of inflammation from ischemia with color Doppler and duplex ultrasound. Radiology 1996;198:547-551.

34. Oser RF, Zuckerman DA, Gutierrez FR, **Brink JA**. Anatomic distribution of pulmonary emboli at pulmonary angiography: implications for cross-sectional imaging. Radiology 1996;199:31-35.

35. Quillin SP, **Brink JA**, Heiken JP, Siegel CL, McClennan BL, Clayman RV. Helical (spiral) CT angiography: identification of crossing vessels at the ureteropelvic junction. AJR 1996;166:1125-1130.

36. Luker GD, Bae KT, Siegel MJ, Don S, **Brink JA**, Wang G, Herman TE. Ghosting of pulmonary nodules with respiratory motion: comparison of helical and conventional CT using an in vitro pediatric model. AJR 1996; 167:1189-1193.

37. Siegel CL, McDougall EM, Middleton WD, **Brink JA**, Quillin SP, Teefey SA, Wolf JS, Clayman RV. Preoperative assessment of ureteropelvic junction obstruction with endoluminal sonography and helical CT. AJR 1997; 168:623-626.

38. Siegel CL, McFarland EG, **Brink JA**, Fisher AJ, Humphrey P, Heiken JP. CT of cystic renal masses: analysis of diagnostic performance and interobserver variation. AJR 1997; 169:813-818.

39. McFarland EG, Wang G, **Brink JA**, Balfe DM, Heiken JP, Vannier MW. Spiral CT colonography: central axis determination and digital unraveling of the colon. Academic Radiology 1997; 4:367-373.

40. **Brink JA**, Woodard PK, Horesh L, Heiken JP, Glazer HS, Anderson DC, Wang G, Schwartz DM. Depiction of pulmonary emboli with spiral CT: optimization of display window settings in a porcine model. Radiology 1997; 204:703-708.

41. Schlueter FJ, Zuckerman DA, Horesh L, Gutierrez FR, Hicks ME, **Brink JA**. Digital subtraction vs. film-screen angiography for detecting acute pulmonary emboli: evaluation in a porcine model. JVIR 1997; 8:1015-1024.

42. McFarland EG, **Brink JA**, Loh J, Wang G, Balfe DM, Heiken JP, Vannier MW. Spiral CT colography for detection of colonic polyps: evaluation of processing parameters with perspective volume rendering. Radiology 1997; 205:701-707.

43. Bae KT, Heiken JP, **Brink JA**. Aortic and hepatic peak enhancement at CT: effect of contrast medium injection rate -- pharmacokinetic analysis and experimental porcine model. Radiology 1998; 206:455-464.

44. Bae KT, Heiken JP, **Brink JA**. Aortic and hepatic contrast enhancement at CT [Part I]: prediction using a computer model. Radiology 1998; 207:647-655.

45. Bae KT, Heiken JP, **Brink JA**. Aortic and hepatic contrast enhancement at CT [Part II]: effect of reduced cardiac output. Radiology 1998; 207:657-662.

46. **Brink JA**, Wang G, McFarland EM. Optimal slice spacing in single-detector helical CT. Radiology 2000; 214:575-578.

47. Whiting BR, McFarland EG, **Brink JA**. Influence of image acquisition parameters on CT artifacts and polyp detection in spiral CT colonography: in vitro evaluation. Radiology 2000; 217:165-172.

48. Kalyanpur A, Neklesa VP, Taylor CR, Daftary AR, **Brink JA**. Evaluation of JPEG and wavelet compression of direct-digital body CT images for teleradiologic transmission. Radiology 2000; 217:772-779.

49. McFarland EG, **Brink JA**, Heiken JP, Balfe DM, Hirselj D, Pilgram TK, Weinstock L, Littenberg B. Spiral CT colonography: reader reliability and diagnostic performance with 2D and 3D image displays. Radiology 2001; 218:375-383.

50. Yoon LS, Haims AH, **Brink JA**, Rabinovici R, Forman HP. Evaluation of an emergency radiology quality assurance program at a level one trauma center—abdominal and pelvic CT studies. Radiology 2002; 224:42-46.

51. McFarland EG, Pilgram TK, **Brink JA**, McDermott RA, Santillan CV, Brady PW, Heiken JP, Balfe DM, Weinstock LB, Thyssen EP, Littenberg B. CT colonography: multiobserver diagnostic performance. Radiology 2002; 225:380-390.

52. Bae KT, Heiken JP, **Brink JA**. Enlargement of the inferior vena cava in contrast-enhanced abdominal CT. Academic Radiology 2002;9:S223-S226

53. Kalyanpur A, Weinberg J, Neklesa VP, **BrinkJA**, Forman HP. Emergency radiology coverage: technical and clinical feasibility of an international teleradiology model. Emergency Radiology, published on-line, July 22, 2003.

54. Johnson CD, Toledano AY, Herman BA, Dachman AH, McFarland EG, Balfe DM, Barish M, **Brink JA**, Ernst RD, Fletcher JG, Halvorsen RA, Hara AK, Hopper KD, Koehler RE, Lu DS, Macari M, MacCarty RL, Miller FH, Morrin M, Paulson EK, Yee J, Zalis M. Computerized tomographic colonography: performance evaluation if a retrospective multicenter setting. Gastroenterology 2003; 125: 688-695.

55. Iannaccone R, Laghi A, Catalano C, **Brink JA**, Mangiapane F, Trenna S, Piacentini F, Passariello R. Detection of colorectal lesions: lower-dose multi-detector row helical CT colonography compared with conventional colonoscopy. Radiology 2003; 229: 775-781.

56. Lee CI, Haims AH, Monico EP, **Brink JA**, Forman HP. Diagnostic CT scans: assessment of patient, physician, and radiologist awareness of radiation dose and possible risks. Radiology 2004; 231: 393-398.

57. Katz S, Saluja S, **Brink JA**, Forman HP. Radiation dose associated with unenhanced CT for suspected renal colic: impact of repetitive studies. AJR 2006;186:1120-1124.

58. Israel GM, Herlighy S, **Brink JA.** Does a combination of dose modulation with fast gantry rotation time limit CT image quality? AJR 2008;191:140-144.

59. Johnson KM, Dowe DA, **Brink JA**. Traditional clinical risk assessment tools do not accurately predict coronary atherosclerotic plaque burden: a computed tomographic angiography study. AJR 2009;192:235-243.

60. Israel GM, Cicchiello L, **Brink JA**, Huda W. Patient size and radiation exposures in chest/abdomen/pelvis/ CT examinations performed with automatic exposure control. AJR 2010;195:1342-1346.

61. Goodman TR, Forman HP, Stein S, Bronen R, **Brink JA**. An 'a la carte' academic radiology compensation plan: something for everyone. JACR 2010;7:885-890.

62. Berland LL, Silverman SG, Gore RM, Mayo-Smith WW, Megibow AJ, Yee J, **Brink JA**, Baker ME, Federle MP, Foley WD, Francis IR, Herts BR, Israel GM, Krinsky G, Platt JF, Shuman WP. Managing incidental findings on abdominal CT: White paper of the ACR incidental findings committee. JACR 2010;7:754-73.

63. Duncan JR, Balter S, Becker GJ, Brady J, **Brink JA**, Bulas D, et al. Optimized radiation use during fluoroscopic procedures: proceedings from a multidisciplinary consensus panel. JVIR, 2011;22:425-429.

64. Goodman TR, Scoutt LM, **Brink JA**. A survey of emergency physician-performed ultrasound: implications for academic radiology departments. JACR 2011;8:631-634.

65. Mahajan A, Starker LF, Ghita M, Udelsman R, **Brink JA**, Carling T. Parathyroid 4DCT: evaluation of radiation dose exposure during preoperative localization of parathyroid tumors in primary hyperparathyroidism. World Journal of Surgery 2012, in press.

66. Impact of Adaptive Statistical Iterative Reconstruction (ASIR) on Radiation Dose in Evaluation of Trauma Patients. Maxfield MW, Schuster KM, McGillicuddy EA, Young CJ, Ghita M, Bokhari J, Oliva I, **Brink JA**, Davis KA. Journal of Trauma and Acute Care Surgery 2012, in press.

Case Reports:

1. Quillin SP, **Brink JA**: Hepatoma complicating Byler disease. AJR 1992;159:432-433.

2. Alpers D, **Brink JA**, Becich M: Nausea and vomiting in a 69-year-old man following cholecystectomy. Am J Med 1994;96:471-481.

3. Bemporad JA, Zreik TG, **Brink JA**. Laparoscopic hernias: two case reports and a review of the literature. JCAT, 1999; 23:86-89.

4. Gumbs AA, Kim J, Kiehna E, **Brink JA**, Salem RR. Autoimmune pancreatitis presenting as simultaneous masses in the pancreatic head and gallbladder. J Pancreas (Online) 2005; 6:6001-6005.

Reviews, Chapters, Books:

1. Franklin TD, **Brink JA**, Cuddeback JL, Sanghvi NT, Weyman AE: Tissue parameter characterization by ultrasound: state-of-the-art in cardiology. In: *Cardiovascular Diagnosis by Ultrasound*, Hanrath P (ed). Martinus Nijoff Publishers, The Hague, 1982

2. **Brink JA**, DeLuca SA: Thymoma. American Family Physician 1987;36: 125-126

3. Curran JG, Blunck CE, **Brink JA**, Harbury O, Philips CD, Fulp CF: Communication from the American Association of Academic Chief Residents in Radiology: resident perception of problem issues. Invest Radiol 1988; 23: 950-954

4. Morrison MC, Lee MJ, Saini S, **Brink JA**, Mueller PR: Percutaneous balloon dilatation of benign biliary strictures. Radiology Clinics of North America 1990;28: 1191-1201

5. **Brink JA**.: Biliary tract imaging: comuted tomography and magnetic resonance imaging. In: *Lippincott's Reviews: Radiology*, Baumgartner BR, Torres WE (eds). Lippincott, New York, 1991

6. **Brink JA**, Ferrucci JT: Gallstone Imaging: current concepts. In: *Problems in General Surgery,* Speranza V (ed). Lippincott, New York, 1991

7. **Brink JA**, Simeone JF: The gallbladder: anatomy and examination technique. In: *Radiology: Diagnosis, Imaging, Intervention*, Taveras JM, Ferrucci JT (eds), Lippincott, New York, 1991.

8. Mueller PR, Lee MJ, Saini S, **Brink JA**, Hahn, PF, Dawson SL, Kammer B, Morrison MC, Shortsleeve M, Ferrucci JT: Percutaneous contact dissolution of gallstones: complexity of radiologic care. RadioGraphics, 1991;11: 759-770

9. Simeone JF, **Brink JA**: The gallbladder: pathology. In: *Radiology: Diagnosis, Imaging, Intervention*, Taveras JM, Ferrucci JT (eds). Lippincott, New York, 1991

10. Lee MJ, Saini S, **Brink JA**, Morrison MC, Goldberg M, Mathisen D, Mueller PR: Interventional radiology of the pleural space: management of thoracic empyema with image guided catheter drainage. Seminars in Interventional Radiology 1991;8:29-35

11. Heiken JP, **Brink JA**, Vannier MW: Spiral computed tomography: state-of-the-art. Radiology 1993;189:647-656

12. **Brink JA**., Borrello JA: MR imaging of the biliary system. In: *MRI Clinics of North America--Extrahepatic Abdominal MR Imaging*, Mirowitz SA (ed). Saunders, Philadelphia, 1995

13. **Brink JA**, Heiken JP, Wang G, McEnery KW, Schlüeter FJ, Vannier MW: Spiral (helical) CT: Principles and technical considerations. Radiographics 1994;14:887-893.

14. Heiken JP, **Brink JA**, Sagel SS: Spiral CT: Abdominal applications. Radiographics 1994;14:919-924.

15. **Brink JA**: Helical/spiral CT: technical principles. In: *Helical/Spiral CT: A Practical Approach*, Zeman RK (ed). McGraw-Hill, New York, 1995

16. **Brink JA:** Technical aspects of helical (spiral) CT. Radiology Clinics of North America, 1995;33(5):825-841.

17. **Brink JA**, Semin MD, Simeone JF: The gallbladder: anatomy and examination technique. In: *Radiology: Diagnosis, Imaging, Intervention*, Taveras JM, Ferrucci JT (eds), Lippincott, New York, 1997

18. **Brink JA**, Semin MD, Simeone JF: The gallbladder: pathology. In: *Radiology: Diagnosis, Imaging, Intervention*, Taveras JM, Ferrucci JT (eds). Lippincott, New York, 1997

19. **Brink JA**, Semin MD: Biliary stone disease. In: *Hepatobiliary Imaging,* Gazelle GS, Mueller PR, Saini S (eds). Thieme, New York, 1997.

20. Wolf JS, Siegel CL, **Brink JA**, Clayman RV. Imaging for ureteropelvic junction obstruction in adults. J Endourol 1996;10:93-104.

21. Aliperti G, Zuckerman GR, Willis JR, **Brink JA**, Enteroscopy with enteroclysis. Gastrointestinal Endoscopy Clin North Am 1996; 6:803-810.

22. **Brink JA**. Spiral CT Angiography of the Abdomen and Pelvis: Interventional Applications. Abdominal Imaging, 1997; 22:365-372.

23. **Brink JA**, McFarland EG, Heiken JP. Helical/spiral computed body tomography. Clin Radiol 1997; 52:489-503.

24. **Brink JA**, Heiken JP, Silverman PM: Protocols for Helical CT of the Abdomen and Pelvis. In: *Helical (Spiral) Computed Tomography: A Practical Approach to Clinical Protocols,* Silverman PM (ed). Lippincott, New York, 1998.

25. **Brink JA.** Physicians as managers and their training. RBMA Bulletin 1998; 33: 20-21.

26. McFarland, EG, **Brink JA**. Helical CT colonography (virtual colonoscopy): the challenge that exists between advancing technology and generalizability. AJR 1999:173;549-559.

27. **Brink JA**, McFarland EG, Satava R. Advances in surgical techniques and technology: virtual colonoscopy. Contemporary Surgery 2000: 56;310-321.

28. **Brink JA**, Siegel CL. CT of the upper urinary tract. In: *Clinical Urography,* Pollack H, McClennan BL (eds), Saunders, Philadelphia, 2000

29. **Brink JA**. Multidetector CT: General Principles. In: *Body CT Categorical Course Syllabus*, Birnbaum BA, **Brink JA**, Johnson CD, Kazerooni EA, eds. American Roentgen Ray Society, Atlanta, 2002.

30. Nelson RC, **Brink JA**, Silverman PM. Multislice Computed Tomography of the Abdomen and Pelvis. In *Multislice Computed Tomography: A Practical Approach to Clinical Protocols,* Silverman PM (ed). Lippincott, Philadelphia, 2002.

31. **Brink JA**. Use of high concentration contrast media (HCCM): principles and rationale – body CT. In: *Multidetector computed tomography: advances in imaging technology.* Bonomo L, Foley DW, Imhof H, Rubin G (eds). Royal Society of Medicine Press, London, 2003

32. **Brink JA**. Contrast optimization and scan timing for single and multidetector-row computed tomography. JCAT 2003: 27S; 3-8.

33. **Brink JA**. A word about radiation dose. In: *Atlas of Virtual Colonoscopy,* Dachman AH (ed), Springer, New York, 2003

34. **Brink JA**. Multislice CT: General Principles and Radiation Dose Considerations. In:*Syllabus-3rd International Workshop on Multislice CT, 3D Imaging, Virtual Endoscopy,* Pavone P, Debatin S (eds). Springer, Milano, 2003

35. **Brink JA**. Multislice CT: Principles of Contrast Media Administration and Scan Timing. In:*Syllabus-3rd International Workshop on Multislice CT, 3D Imaging, Virtual Endoscopy,* Pavone P, Debatin S (eds). Springer, Milano, 2003

36. **Brink JA**. Volumetric Multislice CT: Imaging Applications in the Tracheobronchial Tree. In:*Syllabus-3rd International Workshop on Multislice CT, 3D Imaging, Virtual Endoscopy,* Pavone P, Debatin S (eds). Springer, Milano, 2003

37. **Brink JA**. Science to Practice: What multi-detector row CT parameters are best for detection of colon polyps? Radiology 2003; 229: 1-2.

38. Kalyanpur A, Neklesa VP, Pham DD, Forman HP, Stein ST, **Brink JA**. Implementation of an international teleradiology staffing model. Radiology, 2004, 232:415-419.

39. **Brink JA**. A word about radiation dose. In: *Fundamentals of Virtual Colonoscopy,* Dachman AH (ed), Springer, New York, 2004

40. McCollough CH, McNitt-Gray MF, Bush K, Ruckdeschel T, Payne JT, **Brink JA**, Zeman RK. The phantom portion of the American College of Radiology (ACR) Computed Tomography (CT) accreditation program: Practical tips, artifact examples, and pitfalls to avoid. Med Phys 2004, 31:2423-2442.

41. **Brink JA**. PET/CT unplugged: the merging technologies of PET and CT imaging. AJR 2005; 184:S135-S137.

42. Goodman TR, **Brink JA**. Adult CT: Controlling Dose and Image Quality. In: Frush DP, Huda W, eds. 2006 Categorical Course in Diagnostic Radiology Physics: From Invisible to Visible - The Science and Practice of X-ray Imaging and Radiation Dose Optimization. Chicago, IL: RSNA Publications; 2006: 157-166.

43. **Brink JA,** Goodman TR. The Use and Misuse of Radiation in Medicine. Health Physics 2008; 95:495-501.

44. McCollough CH, Fletcher JG, **Brink JA**. Medical Justification of CT Imagingand Use of Appropriateness Criteria in the USA. In: Justification of Medical Exposure in Diagnostic Imaging, Proceedings of an International Workshop on Justification of Medical Exposure in Diagnostic Imaging, International Atomic Energy Agency, Vienna, 2009: 47-58.

45. **Brink JA**. Multi-slice CT: Optimizing the Use of Intravenous Contrast Material. Biomedical Mathematics: Promising Directions in Imaging, Therapy Planning and Inverse Problems", Yair Censor, Ming Jiang and Ge Wang (Editors), Medical Physics Publishing, Madison, Wisconsin, 2010: 101-112.

46. **Brink JA,** Goske MJ, Patti JA. Informed decision making trumps informed consent for medical imaging with ionizing radiation. Radiology 2012; 262:11-14.

47. **Brink JA,** Boice JD. Science to Practice: Can Antioxidant Supplements Protect Against the Possible Harmful Effects of Ionizing Radiation from Medical Imaging? Radiology 2012, in press.

Editorials:

1. **Brink JA**, Ferrucci JT: CT Imaging of gallstones: what does it really add? Applied Radiology 1990;19:22-25.

2. **Brink JA**, Ferrucci JT: role of CT in assessing gallstones: CT is of only limited value. Radiology Report 1990;2:427-431.

3. **Brink JA**, Ferrucci JT: Computed tomography for gallstone composition: a dissenting view. Radiology 1991;178:633-634.

4. Bae KT, **Brink JA**, Heiken JP. Definition of "equilibrium point" [reply]. Radiology 1996;200:288.

5. **Brink JA**. Increased CT contrast enhancement of "normal" hepatic parenchyma may herald "occult" metastases. Radiology 1997;205:37-38.

6. **Brink JA**. Liver window settings at hepatic CT: added value or marginal cost? Radiology 1999;210:593-594.

7. **Brink JA**. Telethinking. Telemedicine and e-Health. 2006; 12/5:512-514.

8. **Brink JA**. The Art and Science of Medical Guidelines: What We Know and What We Believe. Radiology 2010;254:20-21.

9. **Brink JA**, Amis ES. Image Wisely: A Campaign to Increase Awareness about Adult Radiation Protection. Radiology 2010; 257:601-602.

10. **Brink JA**, Goske MJ, Patti JA. Informed consent for radiologic procedures. JAMA 2011; 305:888

11. **Brink JA**. Professional practice performance: is good enough? AJR 2011;197:1288-1290.

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New Haven, CT 06520-8042
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BORN: February 12, 1952
New York, NY

EDUCATION

1970 - 74 MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Cambridge, MA
S.B. Life Sciences

1974 – 78 MOUNT SINAI SCHOOL OF MEDICINE
New York, NY
M.D.

POSTGRADUATE TRAINING

1978 – 79 LONG ISLAND JEWISH MEDICAL CENTER
New Hyde Park, NY
Internal Medicine Internship

1979 – 81 LONG ISLAND JEWISH MEDICAL CENTER
New Hyde Park, NY
Resident in Diagnostic Radiology

1981- 82 LONG ISLAND JEWISH MEDICAL CENTER
New Hyde Park, NY
Chief Resident, Diagnostic Radiology

1982 – 83 HOSPITAL OF THE UNIVERSITY OF PENNSYLVANIA
Philadelphia, PA.
Fellow, Ultrasound/CT

ACADEMIC APPOINTMENTS

1983 - 86	UNIVERSITY OF TEXAS SOUTHWESTERN MEDICAL SCHOOL Dallas, TX Assistant Professor of Radiology
1986-88	COLUMBIA UNIVERSITY COLLEGE FOR PHYSICIANS AND SURGEONS New York, NY Associate Professor of Radiology
1988 – 91	NEW YORK UNIVERSITY SCHOOL OF MEDICINE New York, NY Associate Professor of Radiology
1991 -2002	NEW YORK UNIVERSITY SCHOOL OF MEDICINE New York, NY Professor of Radiology
2002-	YALE UNIVERSITY SCHOOL OF MEDICINE New Haven, CT Professor of Radiology

CLINICAL APPOINTMENTS

1983-1986	PARKLAND MEMORIAL HOSPITAL Dallas, TX Co-Director of MRI and Attending Radiologist
1986 - 87	ST. LUKE'S/ROOSEVELT HOSPITAL CENTER New York, NY Director of MRI and Attending Radiologist
1988 -2002	NEW YORK UNIVERSITY MEDICAL CENTER New York, NY Director of MRI and Attending Radiologist
1998 – 2000	NEW YORK UNIVERSITY MEDICAL CENTER New York, NY Co-Chairman Department of Radiology
2002-	YALE-NEW HAVEN HOSPITAL New Haven, CT Chief, MRI Section

2005-	YALE-NEW HAVEN HOSPITAL New Haven, CT Chief, Body Imaging Section (2005-) Director of Imaging Services, Department of Diagnostic Radiology

LICENSURE: Connecticut #040768

CERTIFICATION:

1979	Diplomate, National Board of Medical Examiners
1983	Diplomate, American Board of Radiology

AWARDS AND HONORS

1969	National Science Foundation Research Fellowship Waldemar Medical Research Foundation, Woodbury, NY
1972, 73	Varsity Letter in Lacrosse, M.I.T.
1974	Phi Beta Kappa, M.I.T.
1974	President, Phi Lambda Upsilon (Honorary Chemical Society), M.I.T.
1974 - 78	Frederick H. King Merit Scholarship Award Mount Sinai School of Medicine
1975	Indian Health Service Fellowship Navajo Reservation, Window Rock, Arizona
1978	Mount Sinai-Hadassah Medical Center Exchange Program Jerusalem, Israel
1996-2005	*Radiology* Editor's Recognition Award with "Special Distinction"
1992	International Society for Magnetic Resonance in Medicine Fellow of the Society Award
1993,94,95,97,98,01,02	SCBT/MR Research Cum Laude Award
1996, 98	Giovanni Di Chiro Award for Outstanding Scientific Research Published in-Journal of Computer Assisted Tomography
1999	SCBT/MR Moncada Research Award

2001	Fellow, American College of Radiology
2004, 2005	Distinguished Committee Service Award, American College of Radiology
2004	M.A. *Privatim* (honorary Master's degree) from Yale University
2004	RSNA Fellow Research Trainee Prize-Aman Daftary. (Outcome of Biopsies Prompted by findings on Breast MRI)
2004	Certificate of Outstanding Contribution, ACRIN (American College of Radiology Imaging Network)
2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012	New York Magazine-Best Doctor's in New York
2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012	Castle Connolly's Guide - America's Top Doctors for Cancer
2005	Medical Student Research Trainee Prize-Jorge Galvez (Correlation of Incomplete Infarction on MRI and Long-term Symptom Recurrence Among Three Different Embolic Agents for Uterine Artery Embolization)
2006	*JACR* Recognition of Exceptional Manuscript Review
2007	Certificate of Appreciation for Service as a Member of the *Journal of Magnetic Resonance Imaging* Editorial Board
2011	Certificate of Excellence from Joseph A. Zaccagnino Patient Patient Safety & Clinical Quality Conference-Recucing Scheduling Time for Inpatients Requiring an MRI Exam

MEMBERSHIPS

Radiological Society of North America
American Roentgen Ray Society
International Society for Magnetic Resonance in Medicine
Society for Computed Body Tomography/MR
American College of Radiology

PROFESSIONAL ACTIVITIES

Yale School of Medicine

Senior Appointments and Promotions Committee (2005-2007)
Clinical Program Director, Annual Symposium on Nephrogenic Systemic Fibrosis and Allied Systemic Fibrosing Disorders (2009-11)
ACRIN Institution Protocol Principal Investigator (2005-)
Yale Liver Center, Member (2009-)
Yale Cancer Center Imaging Core, Member (2010-)

Yale School of Medicine Department of Diagnostic Radiology

Director, Performance Quality Improvement (2012-)
Director, Abdominal and MRI Fellowship Programs (2002-)
Diagnostic Radiology Internal Appointments and Promotions Committee (2006-)
Diagnostic Radiology Appointments and Promotions Committee (2006-)
Radiology Residency Programmatic Committee (2008-)
Cardiac Imaging Steering Committee (2006-)
Contrast Media Commitee (2006-)
Incentive Plan Task Force (2006-7)
CPOE Evaluation Committee (2006-7)
Translational Research Scientist in CV Disease Search Committee (2006-9)
Clinical Vice-Chair Search Committee (2005-6)
Radiology Clinical Research Committee (2003-)

Medical Student Thesis Advisor
- Brent Little (2003-4)
- Farah Datko (2004-5)
- Karen Shoebotham (2007-8)

Host for 2004 RSNA Derek Harwood-Nash International Fellow
- (Dr. Adina Loana Chirita)

Yale-New Haven Hospital

Medical Staff Credentials Committee (2011-)
MR/OR Steering Committee (2010-)
Operating Room MR Evaluation Committee (2007-9)

Yale Medical Group

Strategic Planning Committee of the YMG Board of Governors (2009-11)

Mount Sinai-NYU Health
Strategic Information Management Planning Steering Committee (2000-1)
HIPAA Task Force (2001-2)

New York University Medical Center
Cardiovascular Center Planning Group
Chairman: Credentials Committee (2000-01)
Chairman: Radiology Reengineering Project (1996 - 99)
Radiology Reengineering Steering Committee (1996 - 99)
Clinical Facilities Planning and Development Steering Committee
Chairman: Radiology Subcommittee (1999 -01)
Emergency Department Productivity Improvement Team (1999-01)
Quality Assessment and Improvement Committee Legal Defense Subcommittee (1994 -2000)
MRI Safety Committee (2001-02)

New York University School of Medicine
Committee on Admissions (1989 -2002)
Faculty Advisor for Student Advisory College Program (1990 -2002)
Scientific Advisor for RSNA Research and Education Fund Medical Student Departmental Award (1997 - 99)
Scientific Advisor for Philips Medical Systems/RSNA Seed Grant Award (1997 - 99)
Continuing Medical Education Committee of the LCME Accreditation Task Force (1998 - 99)
Clinical Teaching Committee of the LCME Accreditation Task Force (1998-9)

NYU Postgraduate School of Medicine
Program Director: CT/MRI Head-to-Toe (1996 -2002)
Program Director: MRI Clinical State-of-the-Art (1988 - 97)
Program Director: Current Topics in Diagnostic Imaging (1997 - 98)
Program Director: Strategic Business Management for Radiology (I996)

New York Roentgen Society
President (1999 -2000)
President-Elect (1997 - 8)
Program Director: NYRS Spring Conference (1999 - 2000)
Executive Committee (1997-2001)

American College of Radiology
Vice President (2007-8)
Executive Committee (2003-6, 2007-8)
Board of Chancellors (2000-6, 2007-8)
Chairman, Commission on Quality and Safety (2001-6)
Chairman, National Radiology Data Registry Steering Committee (2007-)
Co-Chairman, NKF/ACR Working Group to Limit the Risk of NSF (2007-9)
Blue Ribbon Panel on Radiation Dose (2006-7)

Board of Chancellors Nominating Committee (2008)
Co-Chairman, ACR Forum
- Quality and Safety in Radiology (2003)
- The Future of Imaging Screening (2004)
- Disruptive Technologies and Radiology (2005)
- Cardiovascular Imaging (2006)
- Leadership in Radiology (2007)
- Future Practice Models for Radiology (2008)
- New Payment Models for Physicians and Radiologists (2009)
- Radiologist-Hospital Relationships (2010)
- Generational Issues and Radiology (2011)
- Radiology in 2022 (2012)

Chairman, Task Force on Quality Issues (2004-5)
Chairman, ACR Categorical Course: Non-Invasive Cardiac Imaging for Radiologists (2005)
Chairman, 2004 ACR Categorical Course: Current Concepts in Body MRI
Chairman, Task Force on Accreditation Issues (2002)
Chair, Ad Hoc Committee on Cardiac Imaging (2005)
Chairman, Orthopedic MRI Workgroup (2002-3)
Co-Chairman, Commission on Standards and Accreditation (2000 -01)
Chairman, Committee on MRI Accreditation (1999 -2000)
Co-Chairman, Comm on Standards & Accreditation for Neuro & MRI (1999 -2001)
Chairman, Subcommittee for MRI Clinical Image Evaluation (1993 - 9)
Co-Chairman, ACR PI-RADS Steering Committee (2011-)
ACR-LIRADS Steering Committee (2008-)
ACR-LIRADS Reporting Committee (2011-)
Committee on Drugs and Contrast Media (2010-)
ABIMF Choosing Wisely Workgroup (2011-)
ACR International Education and Meetings Committee (2010-)
NRDR User Meeting Organization Committee (2012)
Committee on Breast MR Accreditation (2007-2011)
Advisory Committee on Diagnostic Imaging Policy, ACR Government Relations Commission (2005-10)
ACR Foundation Funding Group (ACR-FFG)(2008-)
ACRIN Fund for Imaging Innovation Research Selection Committee (2006-8)
ACRIN Fund for Imaging Innovation (2006-7)
ACR Subcommittee on MR Safety (2006-)
MRI Accreditation Program Reviewer (1999-)
Uniform Protocols for Imaging in Clinical Trials Oversight Committee (2006-)
Journal of the ACR Search Committee (2002-3)
ACR- BCBSA Workgroup (2004-5)
ACR Appropriateness Criteria Relational Database Workgroup (2004-5)
Committee on Awards and Honors (2003-5)
Committee for the ACR Practice Guideline for Performing FDG-PET/CT in Oncology (2006-7)

ACR/SNM Joint PET/CT Workgroup (2003-5)
Professional Self-Evaluation Committee (2002-5)
Commission on Molecular Imaging (2001-)
Task Force on Molecular Imaging (2001)
College Nominating Committee (2001-2002)
ACR Editorial Board for Education Projects (2001-2)
MRA Accreditation Subcommittee (2000-2006)
Cardiac MR Accreditation Subcommittee (2000-2006)
Subcommittee on BI-RADS (1999-2010)
CSC Subcommittee for Revision of the ACR Standard for Diagnostic Medical Physics Performance Monitoring of MRI Equipment (1999-2001)
New York State Alternate Councilor at Large (1999 -2001)
Neurorad and MRI Commission, Body MRI Subcommittee Chairman (1999 -2002)
Task Force on Revenue Enhancement (2000-1)
Task Force for Committee for Cardiovascular Imaging (1999 -2000)
Committee on Standards and Accreditation of the Commission on Neuroradiology and MRI (1993-99)
Committee on MRI Accreditation of the Commission on Standards and Accreditation (1997 -99)
Subcommittee on Clinical Trials (1998-99)
MR II Syllabus Committee (1995 - 9)
Comm on Human Resources of the Commission on Neuro & MR (1991-95)

National Kidney Foundation-American College of Radiology Workgroup on NSF
Co-Chairman (2006-9)

American College of Radiology Association
Vice President (2007-8)

Radiological Society of Connecticut
Executive Board and Legislative Committee (2005-8)

Society for Computed Body Tomography/Magnetic Resonance
President (2007-8)
Executive Board (2002-2009)
President Elect (2006-7)
Vice-President (2004-5)
Vice-President Elect Designate (2002-3)
Government Relations Committee (2011-)
Credentials and Membership Committee (1993 - 6), Chairman (1995 - 6)
Program Director:Summer Practicum. Williamsburg, VA. Aug 9-13, 2009
Course Director: Annual Meeting, Orlando, FL March 2007
CME Steering Committee (2007-)
Finance Committee (1995 –1997, 2002-)

Research-Scientific Committee (2006-7, 2010)
Chair CME Committee (2004-6)
CME Committee (2002-3)
Rules and Bylaws Committee (1998 -2000)

Society for Magnetic Resonance Imaging
Secretary (1990-91)
Executive Committee (1990 - 91)
Board of Directors (1988,1990-93)
Chairman, Evening Tutorial Program (1987, 88, 89)
Chairman, Publications Committee (1988)
Chairman, Educational Program (1990)
Chairman, Medical Sciences Council (1990 - 91, 93 - 4)
Safety Committee (1988 -1994)
Editor, Newsletter (1988 - 89)
Chairman, Local Program Committee (1991 - 92)
Chairman, Rules Committee (1991 - 93)
Chairman, JMRI Format Subcommittee (1992-93)
Chairman, Technical Exhibit Committee (1993)

International Society for Magnetic Resonance in Medicine
Chairman, Ad Hoc Committee on Credentialing Issues (2010-)
NSF Working Group (2009-)
Moderator, Industrial Forum (2000)
Finance Committee (2000 -2002)
Committee on MR Accreditation (1999 -2001)
MR Safety Committee (1994 - 6)
Local Program Committee, Chairman (1990)

AMA Physician Consortium for Performance Improvement
ACR Representative (2005-6)
CMS Technical Expert Panel (2005-6)

Tufts Evidence-based Practice Center (EPC)/AHRQ
Investigational and Existing Imaging Techniques for the Primary Diagnosis and Staging of Hepatocellular Carcinoma
Panel Member (2012)

Brain Trust on Prostate Imaging and Image-Guided Treatment (2005-6)
Co-sponsored by: AdMeTech Foundation, Prostate Cancer Foundation and Telemedicine and Advanced Technologies Research Center of Department of Defense

Blue Ribbon Steering Committee for 3T Prostate MRI Study (2007-)
International Working Group, AdMeTech Foundation

The Sun Valley Group for Performance Improvement in Radiology
Founding Member (2005-7)

International Working Group for Breast MRI-Office of Women's Health
Lesion Diagnosis Working Group (1998 -2000)

International Prostate MRI Working Group (2008-)

Radiological Society of North America
RSNA Research Development Committee (2011-)
RSNA Film Panel (2008)
Moderator for RSNA Symposium on Nephrogenic Systemic Fibrosis (2007)
Medical advisor: RSNA-ACR Public Information Website Committee for RadiologyInfo.org.(2010-)
Radiology Reporting Initiative Subcommittee for Abdominal MRI (2009-)
RadLex MRI Modality Committee (2007-)
RSNA Research and Education Foundation/Evaluation Comm (1999-2002)
Research and Education Fund Grant Reviewer (1998 -)

American Roentgen Ray Society
Course Chairman, Practical Breast MRI Course, Las Vegas, NV Feb, 2008
Education Evaluation Subcommittee (2006-)
Co-Chairman, Categorical Course, Annual Meeting (1997)

National Institutes of Health Diagnostic Radiology Study Section
Special Reviewer (1993 - 6)

National Cancer Institute Gastrointestinal Steering Committee
Hepatobiliary Task Force (2007-)
Workshop Co-Leader, Optimal Assessment of Drug Activity-Imaging. State-of-the-Science Meeting on Human Hepatocellular Carcinoma. Washington, DC. December 12-13, 2008

ACR Imaging Network (ACRIN)
Chair-CT/MRI Committee (2003-6)
Abdominal Committee (2006-)
ACRIN Yale University School of Medicine Principal Investigator (2004-)
Hepatobiliary Task Force (2007-)
Genitourinary Committee (2003-6)

National Cancer Institute, Diagnostic Imaging Branch of the Radiation Research Program Breast MRI Advisory Group
(1993 - 6)

New York State Radiologic Society
Delegate (1999)
Alternate Delegate (1997)

International Course on Advances in MRI and CT, Barcelona, Spain
Director (1995,1997,1998,1999, 2001,2003, 2005)

European Working Group on Management in Radiology
Steering Committee (1998 -2000)

New York CT/MRI Club
Founder and Co-Chairman (1994 - 6)

International Center for Continuing Medical Education
Board of Directors (1996-2000)
Program Director:
MRI Summit (2006)
MRI for Consultants (2003)
Essential Radiology: Optimal Imaging and Cutting Edge Techniques (2002)
Cardiovascular Applications of MRI (2001)
MR Advocacy Development (2000)
MR Angiography Advancing Clinical Applications (1999)
MRA Experts Meeting (1997, 8)

New York Heart Association
Criteria Committee (1993 - 6)

The American Society of Anesthesiologists
Consultant: Practice Advisory for Anesthetic Care in MRI (2008)

Cancer Research UK (CR-UK) and the Engineering & Physical Sciences Research Council (EPSRC) Cancer Imaging Centre and Programme
Grant reviewer (2008-)

Global Fibrosis Foundation
Medical Advisory Board (2010-)

American Association for the Study of Liver Diseases.

Program Co-Director: Emerging Trends in Liver Imaging. Atlanta, GE. September 8, 2012

EDITORIAL POSITIONS: Radiology
Consultant to the Editor (2012-)
Associate Editor (2005-2011)
Senior Consultant to the Editor (1994-97)
Editorial Board (1989-93)

Hepatology
Editorial Board (2011-)

Medscape Radiology

Editorial Advisory Board (2000-2009)(2012-)

Journal of the American College of Radiology
Editorial Board (2003-6)

Journal of Magnetic Resonance Imaging
Associate Editor (1993-2007)
Editorial Board (1991-93)

Journal of Computer Assisted Tomography
Editorial Board (1992-2006)

MRI Clinics of North America
Editor-in-Chief (1993-98)

Abdominal Imaging
Editorial Board (1993-6)

Topics in Magnetic Resonance Imaging
Editorial Advisory Board (1988-93)
Guest Editor 2:3 1990

RSNA Today Video
Editorial Board (1989-93)

MR
Editorial Advisory Board (1991-95)

REVIEWER

Radiology (1984-)
Obstetrics and Gynecology (1986-99)
American Journal of Roentgenology (1986-)
Journal of Computer Assisted Tomography(1988-2007)
Journal of Magnetic Resonance Imaging (1991-)
Magnetic Resonance in Medicine (1994-)
RadioGraphics (1996-)
Cancer (2004-2008)
European Journal of Radiology (2007-)
Hepatology (2001-)

RESEARCH SUPPORT

GRANTOR: American Cancer Society
Project Title: Institutional Research Grant #IN 142, 1985-6
Role: Principal Investigator
Date/Amount: 1985 –1986 / $5,000

GRANTOR: Berlex Laboratories, Inc.
Project Title: Phase II Clinical Trials GD-DTPA

Role:	Co-Investigator
Date/Amount:	1985 –1986 / $120,000
GRANTOR:	Salutar, Inc.
Project Title:	Phase III Clinical Trials of S-041 MRI Intravenous Contrast Agent
Role:	Principal Investigator
Date/Amount:	1988 –1989 / $80,000
GRANTOR:	NCI
Project Title:	1UO1 CA49079-03 Imaging Trials in Pancreatic and Colorectal cancer
Role:	Co-investigator
Date/Amount:	1989 –1994 / $300,000
GRANTOR:	Sterling Drug, Inc.
Project Title	Contrast Enhanced MRI of the Liver with S-095 (Mn-DPDP) by Intravenous Administration: An Open Phase 11 trial in Adult Patients with Known or Suspected Focal Liver Disease
Role:	Principal Investigator
Date/Amount:	1990 –1991 / $72,000
GRANTOR:	Schering AG
Project Title:	The Effect of MRI Combined with Gadopentatate Dimeglumine on Gross Fetal Morphology and Chromosome Morphology in Animal Specimens
Role:	Principal Investigator
Date/Amount:	1991 / $20,000
GRANTOR:	Squibb Diagnostics
Project Title:	ProHance in MRI of Liver Pathology.
Role:	Principal Investigator
Date/Amount:	1992 / $62,000
GRANTOR:	Squibb Diagnostics
Project Title:	Clinical Investigation of ProHance in the Detection of Cerebral Metastases in Patients with Primary Carcinoma of the Lung Who Are Candidates for Surgical Resection
Role:	Principal Investigator
Date/Amount:	1992 –1993 / $91,500
GRANTOR:	Squibb Diagnostics
Project Title:	Phase 11 Clinical Investigation of BMS 180549 as an MR Contrast Agent in Evaluating Intrathoracic Lymph Nodes in Patients with Primary Lung Carcinoma
Role:	Principal Investigator
Date/Amount:	1993 –1994 / $32,000
GRANTOR:	Sanofi-Winthrop, Inc.
Project Title:	Contrast Enhanced MRI of the Liver with Intravenous WIN 59010-2 Injection: a Multicenter Open Label Study in Adults with Known or Suspected Focal Liver Lesions
Role:	Principal Investigator
Date/Amount:	1993 –1994 / $80,000
GRANTOR:	Squibb Diagnostics

Project Title:	Phase III Safety and Efficacy Investigation of LumenHance in Patients Undergoing MRI of the Abdomen and Pelvis
Role:	Principal Investigator
Date/Amount:	1993 –1994 / $34,800
GRANTOR:	Pharmacyclics
Project Title:	Phase 11/111 Clinical Investigation of Gadolite Oral Suspension for MT imaging of the Gastrointestinal Tract
Role:	Co-Investigator
Date/Amount:	1994 –1995 / $40,000
GRANTOR:	Berlex Laboratories, Inc.
Project Title:	An Open Label Study of the Safety and Efficacy of Intravenous Gadopentetate Dimeglumine (Magnevist) Enhanced Breast MRI in Patients Who Will Undergo a Surgical Procedure
Role:	Principal Investigator
Date/Amount:	1994 –1997 / $I54,570
GRANTOR:	Advanced Magnetics, Inc.
Project Title:	Phase III Safety and Efficacy Investigation of Code 7227 (Superparamagnetic Biodegradable Dextran Coated Iron Oxide Particle) as a Magnetic Resonance Enhancement Agent for Imaging the Liver and Spleen
Role:	Principal Investigator
Date/Amount:	1995 / $27,000
GRANTOR:	Medrad, Inc.
Project Title:	Optimization of Dosing for Gadolinium-Enhanced MRA and MRI Using a Power Injector
Role:	Co-Investigator
Date/Amount:	1996 / $20,000
GRANTOR:	Berlex Laboratories, Inc.
Project Title:	Multicenter Open-Label Study of GD-EOB-DTPA with a Single I.V. Injection in Patients with Known Focal Liver Lesions Who Are Scheduled for Liver Surgery
Role:	Co-Investigator
Date/Amount:	I998–1999 / $80,000
GRANTOR:	Epix Medical, Inc.
Project Title:	Multicenter, Comparative, Two Arm, Phase 3 Study to Determine the Safety and Efficacy of AngioMARK-Enhanced MRA for Evaluation of Aortoiliac Occlusive Disease in patients with Known or Suspected Peripheral Vascular disease of Aortic Aneurysm
Role:	Principal Investigator
Date/Amount:	2000-01/$120,000
GRANTOR:	NCI/ACRIN
Project Title:	ACRIN 6659: Multicenter Study of *In Vivo* MR Spectroscopy for the Evaluation of Prostate Cancer
Role:	Principal Investigator

Date/Amount: 2002-2006/$300,000

GRANTOR: Epix Medical, Inc.
Project Title: A Phase II Study for the Sequence Optimization of MS-325 (gadofosveset) for Imaging the Arterial Wall
Role: Site Principal Investigator
Date/Amount: 2004-2005/$25,000

GRANTOR: Repligen Corporation
Project Title: A Phase III Study to Assess the Safety and Efficacy of RG1068 (Synthetic Human Secretin)-Enhanced Magnetic Resonance Cholangiopancreatography (MRCP) in the Evaluation of patients with a History of Acute Recurrent Pancreatitis
2007-8/$10,000
Role: Site Principal Investigator
Date/Amount: 2006/$10,000

GRANTOR: Bayer HealthCare Pharmaceuticals Inc.
Project Title: Prospective non-randomized observational (pharmacoepidemiologic) cohort study (open-label, multicenter) to assess the magnitude of potential risk with the administration of Magnevist® Injection in patients with moderate to severe renal impairment for the development of nephrogenic systemic fibrosis (NSF) or cutaneous changes suggestive of NSF
Role: Site Principal Investigator
Date/Amount 2008-2010/$10,000

GRANTOR: NCI/ACRIN
Project Title: ACRIN 6690:A Prospective, Multicenter Comparison of Multiphase Contrast-Enhanced CT and Multiphase Contrast-Enhanced MRI for Diagnosis of Hepatocellular Carcinoma and Liver Transplant Allocation
Role: Site Principal Investigator
Date/Amount: 2011-12 /$100,000 (projected)

GRANTOR: NIH
Project Title: Prostate Edema Associated with Interstitial Brachytherapy
Role: Co-Investigator
Date/Amount: 2011/

PUBLICATIONS
(* Student, Resident or Fellow working under direct supervision of Dr. Weinreb)

1. **Weinreb JC**, Kumari S, Phillips G, Pochaczevsky R, Portal vein measurements by real-time sonography. AJR 1982; 139:497-499.

2. Pillari G, **Weinreb JC**, Vernace F, Kumari S, Phillips G, Cruz V. CT of gastric masses: image patterns and a note on potential pitfalls. Gastrointestinal Radiology 1983; 8:11-17.

3. Kumari S. Phillips G, **Weinreb JC**, Pochaczevsky R. Lyn MK. Gray scale sonography in the diagnosis and differential diagnosis of left upper quadrant masses RG 1984; 4:331.

4. **Weinreb JC**, Maravilla K, Redman H. Nunnally R. Improved MRI of the upper abdomen with glucagon and gas. J Comput Assist Tomogr 1984; 8(5):835-838.

5. **Weinreb JC**, Maravilla K, Peschock R. Payne J. Magnetic resonance imaging: improving patient tolerance and safety. AJR 1984; 143:1285-1287.

6. **Weinreb JC**, Brateman L. Maravilla KR. Magnetic resonance imaging of hepatic lymphoma. AJR 1984; 143:1211.

7. Maravilla KR, **Weinreb JC**, Suss R, Nunnally R. Magnetic resonance demonstration of multiple sclerosis plaques in the cervical spine. AJR 1984; 5(6):658-689.

8. **Weinreb JC**, Lowe TW, Santos-Ramos R. Cunningham FG, Parkey R. The role of MRI in obstetrical diagnosis. Radiology 1985; 154:157-161.

9. Maravilla KR, Lesh P, **Weinreb JC**, Selby K. Mooney V. Magnetic resonance imaging of the lumbar spine with CT correlation. AJNR 1985; 6:237-245.

10. Babcock E. Brateman L, **Weinreb JC**, Horner S, Nunnally R. Edge Artifacts in magnetic resonance imaging: the chemical shift effect. J Comput Assist Tomogr 1985; 9(2):252-257.

11. **Weinreb JC**, Hodge S, Garcia R. Magnetic resonance imaging of patent umbilical veins. AJR 1985; 144:747-748.

12. *Cohen JM, **Weinreb JC**, Maravilla KR. Fluid collections in the intra-peritoneal and extraperitoneal spaces: comparison of MR and CT. Radiology 1985; 155:705-708

13. **Weinreb JC**, Cohen JM, Maravilla KR. Iliopsoas muscles: MR study of normal anatomy and disease. Radiology 1985; 156:435-440.

14. **Weinreb JC**, Brateman L, Babcock EE, Maravilla KR, Cohen JM, Horner SD. Chemical shift artifact in clinical magnetic resonance images at 0.35T. AJR 1985; 145:183-185.

15. *Cohen JM, Hodges S, **Weinreb JC**. Case report: MR imaging of iliopsoas bursitis and concurrent avascular necrosis of the femoral head. J Comput Tomogr 1985; 9(5):969-971.

16. Lowe TW, **Weinreb JC**, Santos-Ramos R, Cunningham FG. Magnetic resonance imaging in human pregnancy. Obstet and Gynecol 1985; 66(5):629-633.

17. **Weinreb JC**, Lowe TW, Cohen JM, Kutler M. Human fetal anatomy: MR imaging. Radiology 1985; 157:715-720.

18. Cohen JM, **Weinreb JC**, Redman HC. Arteriovenous malformations of the extremities: MR imaging. Radiology 1986; 158:475-479.

19. **Weinreb JC**, Arger P, Coleman BG, Mintz MC, Pollack HM, Arenson R. Cystic renal mass evaluation: real-time versus static imaging. J Clin Ultrasound 1986; 14:29-35.

20. Cohen JM, **Weinreb JC**, Redman HC. Postoperative assessment of splenorenal shunts with MRI: preliminary investigation. AJR 1986; 146:597-600.

21. **Weinreb JC**, Mootz A, Cohen JM. MRI evaluation of mediastinal and thoracic obstruction. AJR 1986; 146:679-684.

22. **Weinreb JC**, Brown CE, Lowe TW, Cohen JM Erdman WA. Pelvic masses in pregnant patients: MR and US imaging. Radiology 1986; 159:717-724.

23. Turner RJ, Hankins GDV, **Weinreb JC**. Magnetic resonance imaging and ultrasonography in the antenatal evaluation of conjoined twins. Am. J. Obstet and Gynec 1985;155-.645-649.

24. **Weinreb JC**, Cohen JM, Armstrong E, Smith T. Imaging the pediatric liver: MRI and CT. AJR 1986; 147:785-790.

25. Erdman WA, **Weinreb JC**, Cohen JM, Buja LM, Chaney C, Peshock RM. Venous thrombosis: clinical and experimental MR imaging. Radiology 1986; 161:233- 238.

26. Brown CEL, Lowe TW, Cunningham FG, **Weinreb JC**. Puerperal pelvic thrombophlebitis: impact on diagnosis and treatment using x-ray computed tomography and magnetic resonance imaging. Obs. and Gynec 1986; 68:789 -794.

27. **Weinreb J.C**. MRI of avascular necrosis of the hips. Current Concepts in Magnetic Resonance Imaging 1988; 2(3):15-20.

28. Rusinek H, Mourino M, Firooznia H, **Weinreb JC** and Chase NE. Volumetric rendering of magnetic resonance scans. Radiology 1989; 171:269-272.

29. **Weinreb JC**, Wolbarsht LB, Cohen LC, Brown CL, and Maravilla KR. The prevalence of lumbosacral and intervertebral disc abnormalities in pregnant and asymptomatic non-pregnant women. Radiology 1989; 170:125-128.

30. *Erdman WA, Breslau N, **Weinreb JC**, et al. Noninvasive localization of parathyroid adenomas: a comparison of x-ray computed tomography, ultrasound, scintigraphy, and MRI. Magn Reson Imaging 1989; 7:187-194.

31. *Seidenwurm D, Meng T, Kowalski J. **Weinreb JC**, Kricheff II. Intracranial hemorrhagic lesions: evaluation with spin-echo and gradient refocused MR imaging at 0.5T and 1.5T. Radiology 1989; 172:189-194.

32. Golimbu CN, Firooznia H, Melone CP, Rafii M, **Weinreb J**, Leber C. Tears of the triangular fibrocartilage of the wrist: MR imaging. Radiology 1989; 173:731- 733.

33. *Rofsky NM, Bosniak MA, **Weinreb JC**, Coppa GF. Case report: Giant renal cell carcinoma: CT and MR characteristics. J Comput Assist Tomogr 1989; 13(6):1078-1080.

34. **Weinreb JC**, Barkoff N, Megibow A, Demopolous R. The value of MR imaging to distinguish leiomyoma from other solid pelvic masses when sonography is indeterminate. AJR 1990; 154:295-299.

35. Naidich DP, **Weinreb JC**, Schinella R. MR imaging of pulmonary parenchyma: comparison with CT in evaluating cadaveric lung specimens. J Comput Assist Tomogr 1990; 14(4):595-599.

36. Birnbaum BA, **Weinreb JC**, Megibow AJ, et al. Blinded retrospective comparison of MR imaging and Te-99m-labeled red blood cell SPECT for definitive diagnosis of hepatic hemangiomas. Radiology 1990; 176:95-101.

37. Lubat E, **Weinreb JC**. MRI of the kidneys and adrenals. Topics in Mag Res Imaging 1990;2(3): I7-36.

38. *Schrem SS, Colvin SB, **Weinreb JC**, Glassman E, Kronzon I. Metastatic cardiac liposarcoma: diagnosis by transesophageal echocardiography and magnetic resonance imaging. J Am Soc Echocardiogr 1990; 3(2):149-15350.

39. **Weinreb JC**. Bone marrow imaging with MR: a map could help. Radiology 1990; 177:23-24.

40. Rafii M, Firooznia H, Sherman 0, Minkoff 0, **Weinreb J**, Golimbu C, Schinella R, Zazlav K. Rotator cuff lesions: signal patterns at MR imaging. Radiology 1990; 177:817-823.

41. Litt AW, Eidelman EM, Pinto RS, Riles TS, McLachlan SJ, Schwartzenberg S, **Weinreb JC**, Kricheff II. Diagnosis of carotid artery stenosis: comparison of 2DFT time-of-flight MR angiography with contrast angiography in 50 patients. AJNRL 990; 12:149-154.

42. **Weinreb JC**, Naidich DP. Thoracic magnetic resonance imaging. Clinics in Chest Medicine 1991; 12(1):33-54.

43. Kanzer GK, **Weinreb JC**. MRI of the liver and biliary system. Rad Clinics NA 1991; 29(6): I259-1284.

44. Snyder JR, Goldstein SR, **Weinreb JC**. Imaging of fibroids: modern diagnostic techniques. Clinical Consult Obstet and Gynecol 1991; 2(I):13-19.

45. Rofsky NM, **Weinreb JC**, Bosniak MA. Renal lesion characterization with gadolinium-enhanced MR imaging: efficacy and safety in patients with renal insufficiency. Radiology I991; 180:85-89.

46. **Weinreb JC**. MRI of the abdomen: are we there yet? (Editorial) JMRI 1991; 1:393-397.

47. Birnbaum BA, Noz ME, Chapnick J, Sanger JJ, Megibow AJ, Maguire GQ, **Weinreb JC**, Kaminer EM, Kramer EL. Hepatic hemangiomas: diagnosis with fusion of MR, CT, and Tc-99m-labeled red blood cell SPECT images. Radiology 1 991; 181:469-474.

48. Sze G, Brant-Zawadzki M, Haughton VM, Maravilla KR, McNamara MT, Kumar AJ, Aisen AM, Dreisbach JN, Bradley WG, **Weinreb JC**, Drayer BP, Tsuruda JS, Hesselink JR, Johnson CE, Zimmerman RD, Weingast GR. Multicenter study of gadodiamide injection as a contrast agent in MR imaging of the brain and spine. Radiology I991; 181:693-699.

49. Bernardino ME, Young S, Lee JKT, **Weinreb JC**. Hepatic MR Imaging with MN-DPDP: safety, image quality and sensitivity. Radiology 1992; 183:53-58.

50. White RD, Ehman RL, **Weinreb JC**. Cardiovascular MRI: current level of clinical activities. JMR11992; 2:365-370.

51. *Rofsky NM, **Weinreb JC**. Manganese (II) N,N'-Dipyroxylethylenediamine- N,N'-diacetate 5,5'-Bis(phosphate): clinical experience with a new contrast agent. Mag Res Quarterly 1992 8(3):156-168.

52. *Rofsky NM, **Weinreb JC**, Grossi E, Naidich D, Galloway AC, Libes RS, Colvin SB, Naidich DP. Aortic aneurysm and dissection: normal MR imaging and CT findings after surgical repair with the continuous-suture graft-inclusion technique. Radiology 1993; 186:195-201.

53. Rofsky NM, **Weinreb JC**, Litt AW. Quantitative analysis of gadopentetate dimeglumine excreted in breast milk. JMRI 1993; 3:131-132.

54. Rofsky NM, **Weinreb JC**, Bernardino ME, Young SW, Lee JKT, Noz ME. Hepatocellular tumors: characterization with Mn-DPDP-enhanced MR imaging. Radiology 1993; 188:53-59.

55. Rafii M, Firooznia H, Golimbu C, **Weinreb J**. Magnetic resonance imaging of glenohumeral instability. MRI Clinics of NA 1993,1(1); 87-104.

56. Galloway AC, Colvin SB, Grossi EA, Parish MA, Culliford AT, Asai T, Rofsky NM, **Weinreb JC**, Shapiro S, Baumann FG, Spencer FC. Surgical repair of type A aortic dissection by the circulatory arrest-graft inclusion technique in sixty-six patients. Jour Thorac Cardiovasc Surg 1993; 105:781-790.

57. Sze G, Brant-Zawadski M, McNamara MT, Haughton VM, Kumar AJ, Maravilla KR, Aisen AM, Dreisbach JN, Bradley WG, **Weinreb JC**, et al. Use of the magnetic resonance contrast agent gadodiamie in the cental nervous system: results of a multicenter trial. Invest Radiol 1993;28 Suppl 1:S49-55

58. Birnbaum S, **Weinreb JC**, Fernandez M, Brown J, Rofsky NM, Young SW. Comparison of Contrast-enhanced CT and MnDPDP- enhanced MR imaging for detection of focal hepatic lesions-initial findings. Clinical Imaging 1994; 18:21-27.

59. Apicella PL, Mirowitz SA, **Weinreb JC**. Extension of vessels through hepatic neoplasms: MR and CT findings. Radiology 1994; 191:135-136.

60. **Weinreb JC**, Newstead G. Controversies in Breast MRI. Mag Res Quarterly 1994; 10(2):67-83.

61. Mitchell DG, Saini S, **Weinreb J**, DeLange EE, Runge V, Kuhlman JE, Parisky Y, Johnson D, Brown JJ, Schnall M, Herfkens R, Davis PL, Gorczyca D, Sica G, Foster GS, Bernardino ME. Hepatic Metastases and Cavernous Hemangiomas: distinction with standard and triple dose gadoteridol-enhanced MR Imaging. Radiology 1994; 193:49-57.

62. Rofsky NM, Pizzarello DJ, **Weinreb JC**, Ambrosino MM, Rosenberg C. Effect on fetal mouse development of exposure to MR imaging and gadopentetate dimeglumine. JMRI 1994; 4:805-807.

63. Bernardino ME, **Weinreb JC**, Mitchell D, Small WC, Morris M. Safety and optimum concentration of a manganese chloride-based oral MR contrast agent. JMRI 1994; 4:872-876.

64. Megibow AJ, Zhou XH, Rotterdam H, Francis IR, Zerhouni EA, Balfe DM, **Weinreb JC**, Aisen A, Kuhlman J, Heiken JP, Gatsonis C, McNeil BJ. Pancreatic adenocarcinoma: CT versus MR imaging in the evaluation of resectability-report of the Radiology Diagnostic Oncology Group. Radiology 1995; 195:337-332.

65. *Haddad JL, Rofsky NM, Ambrosino MM, Naidich DP, **Weinreb JC**. T2-weighted MR imaging of the chest: comparison of electrocardiograph-triggered conventional and turbo spin-echo sequences. JMRI 1995; 5:325-329.

66. Newstead GM, **Weinreb JC**. Critical pathways for the future: magnetic resonance imaging and digital mammography. RadioGraphics 1995; 15:951-962.

67. **Weinreb JC**, Newstead G. MR imaging of the breast: state-of-the-art. Radiology 1995; 196:593-610.

68. Peterstein J, Saini S, Mitchell DG, Davis PL, Johnson CD, Kuhlman JE, Parisky YR, Runge VM, **Weinreb J**, Bernardino ME, de Lasnge EE, Gorczyca D, Herfkens RJ, Schnall M. Gadoteridol-enhanced MR imaging of malignant hepatic tumors: effects of triple versus standard doses on lesion-liver contrast. AJR 1995; 165:1157-1161.

69. Rofsky NM, Pizzarello DJ, Duhaney MO, Falick AK, **Weinreb JC**. The effect of MR combined with gadopentetate dimeglumine on chromosome morphology in animal specimens. Academic Radiology 1995; 2:492-496.

70. *Wald DS, **Weinreb JC**, Newstead G, Bose S. MR-guided fine needle aspiration of breast lesions: initial experience. J Comput Assist Tomogr 1996; 20(1):1-8.

71. *Krinsky G, Rofsky NM, **Weinreb JC**. Non-specificity of short inversion time inversion recovery (STIR) as a technique for fat-suppression: pitfalls in image interpretation. AJR 1996; 166:523-526.

72. **Weinreb JC**, Rofsky NM. Resonancia magnetica del higado. Monografias de Diagnostico por Imagen 1996; 5(17):1-16.

73. **Weinreb JC**. Resonancia magnetica de la pelvis. Monografias de Diagnostico por Imagen 1996; 5(17):65-78.

74. Rofsky N, **Weinreb JC**, Ambrosino M, Safir J, Krinsky G. Comparison between in-phase and opposed-phase T1-weighted breath-hold FLASH sequences for hepatic imaging. J Comput Assist Tomogr 1996; 20(2):230-235.

75. Krinsky G, **Weinreb JC**. Gadolinium-enhanced three-dimensional MR angiography of the thoracoabdominal aorta. Sem in US, CT, and MRI 1996; 17(4):280-303.

76. Zerhouni EA, Rutter C, Hamilton SR, Balfe DM, Megibow AJ, Francis IR, Moss AA, Heiken JP, Tempany CMC, Aisen AM, **Weinreb J**, Gatsonis C, McNeil BJ. CT and MR Imaging in the Staging of Colorectal Carcinoma: Report of the Radiologic Diagnostic Oncology Group 11. Radiology 1996; 200:443-451.

77. Earls JP, Theise ND, **Weinreb JC**, DeCorato DR, Rofsky NM, Teperman LW. Dysplastic nodules and hepatocellular carcinoma: thin section MR imaging of explanted cirrhotic livers with pathologic correlation. Radiology 1996; 201:207-214.

78. Krinsky G, Rofsky N, Flyer M, Giangola G, Maya M, DeCorato D, Earls J, **Weinreb JC**. Gadolinium-enhanced three-dimensional MR Angiography of acquired arch vessel disease. AJR. 1996; 167:981-987.

79. *Earls JP, Rofsky NM, DeCorato DR, Krinsky GA, **Weinreb JC**. Breath-hold single dose Gd-enhanced three-dimensional MR aortography; usefulness of a timing examination and MR power injector. Radiology 1996; 201:705-710.

80. *Lee VS, **Weinreb JC**, Flyer M, Krinsky G, Rofsky NM. Image subtraction in gadolinium-enhanced MR imaging. AJR 1996; 167:1427-1432.

81. Rofsky NM, Purdy D, Johnson G, DeCorato D, Earls JP, Krinsky G, **Weinreb JC**. Effective suppression of venous signal in time-of-flight MR Angiography of the lower extremities after administration of gadopentetate dimeglumine. Radiology 1997; 202:177-182.

82. Krinsky G, Rofsky NM, DeCorato DR, **Weinreb JC**, Earls JP, Flyer M, Galloway AC, Colvin SB. Thoracic Aorta: Comparison of gadolinium-enhanced three-dimensional MR angiography with conventional MR Imaging. Radiology 997; 202:183-193.

83. *Earls JP, Rofsky NM, DeCorato D, Krinsky GA, **Weinreb JC**. Hepatic arterial-phase dynamic gadolinium-enhanced MR imaging: optimization with a test examination and a power injector. Radiology 1997; 202:263-273.

84. *Lee NA, Rusinek H, **Weinreb JC**, Chandra R, Singer C, Newstead GM. Fatty and fibroglandular tissue volumes in breasts of women 20-83 years old: comparison of X-ray mammography and computer-assisted MR imaging. AJR 1997; 168:501-506.

85. Krinsky G, Johnson G, Rofsky N, Shapiro R, Yang B, **Weinreb J**. Venous aneurysms: MR diagnosis with the "layered gadolinium" sign. J Comput Assist Tomogr 1997; 21(4):623-627.

86. Krinsky G, Decorato DR, Rofsky NM, Flyer M, Earls JP, Ambrosino M, Wan L, **Weinreb JC**. Rapid T2-weighted MR imaging of uterine leiomyoma and adenomyosis. Abdom Imaging 1997; 22:531-534.

87. Rofsky NM, Johnson G, Adelman MA, Rosen RJ, Krinsky GA, **Weinreb JC**. Peripheral vascular disease evaluated with reduced-dose gadolinium-enhanced MR angiography. Radiology 1997; 205:163-169.

88. Krinsky GA, Kaminer E, Lee VS, Rofsky NM, **Weinreb JC**. The effects of apnea on timing examination for optimization of gadolinium-enhanced MRA of the thoracic aorta and arch vessels. J Comput Assist Tomogr 1998; 22(5):677-681.

89. Krinsky G, Maya M, Rofsky N, Lebowitz J, Nelson PK, Ambrosino M, Kaminer E, Earls J, Masters L, Giangola G, Litt A, **Weinreb J**. Gadolinium-enhanced three- dimensional MR angiography of the aortic arch vessels in the detection of atherosclerotic cerebrovascular occlusive disease. J Comput Assist Tomgr 1998; 22(2):I67-178.

90. Rofsky NM, Yang BM, Schlossberg P, Goldenberg A, Teperman LW, **Weinreb JC**. MR - guided aspiration biopsies of hepatic masses using a closed bore magnet. J Comput Assist Tomgr 1998; 22:633-637.

91. *Earls J, Rofsky N, DeCorato D, Krinsky G, and **Weinreb JC**. Echo-train STIR MRI of the liver: comparison of breath-hold and non-breath-hold imaging strategies. J Magn Reson Imaging 1999; 9:87-92.

92. Lee VS, Rofsky NM, Krinsky GA, Stemmerman DH, **Weinreb JC**. Single dose breath-hold gadolinium-enhanced three-dimensional MR angiography of the renal arteries. Radiology 1999; 211:69-78.

93. *Lebowitz JA, Rofsky NM, Krinsky GA, **Weinreb JC**. Gadolinium-enhanced body MR venography with subtraction technique. AJR 1997; 169:755-758.

94. Rofsky NM, Lee VS, Laub G, Pollack MA, Krinsky GA, Thomasson D, Ambrosino MM, **Weinreb JC**. Abdominal MR imaging with a volumetric interpolated breath-hold examination. Radiology 1999; 212:876-884.

95. DeCorato DR, Krinsky GA, Rofsky NM, Earls JP, Lebowitz J, **Weinreb JC**. Contrast-enhanced hepatic MRI: comparison of half-dose and standard-dose gadolinium DTPA administration in lesion characterization with T1-weighted gradient echo sequences. Clin Imaging 1999;23(5):302-310

96. Shinde TS, Lee VS, Rofsky NM, Krinsky GA, **Weinreb JC**. Three-dimensional gadolinium-enhanced venographic evaluation of central veins in the thorax: initial experience. Radiology 1999; 213:555-560.

97. Small WC, DeSimone-Macchi D, Parker JR, Sukerkar A, Hahn PF, Rubin DL, Zelch JV, Kuhlman JE, Outwater EK, **Weinreb JC**, Brown JJ, deLange EE, Woodward PJ, Arildsen R, Foster GS, Runge VM, Aisen AM, Muroff LN, Thoeni RF, Parisky YR, Tanenbaum LN, Totterman S, Herfkens RJ, Knudsen J, Laster RE, Duerinckx A, Stillman AE, Spritzer CE, Saini S, Rofsky NM, Bernardino ME. A multisite phase III study of the safety and efficacy

of a new manganese chloride-based gastrointestinal contrast agent for MRI of the abdomen and pelvis. J. Magn. Reson. Imaging 1999; 10:15-24.

98. Decorato D, Rofsky N, Earls J, Krinsky G, **Weinreb JC**. T1-weighted sequences for hepatic MRI:re-evaluation using a phased-array coil. Clinic Imaging 1999;23:26-31

99. *Stemerman D, Krinsky G, Lee VS, Johnson G, Rofsky N, **Weinreb JC**. Rapid black blood MR imaging of the thoracic aorta using half-fourier single shot Turbo spin-echo (HASTE) imaging with or without ECG triggering. Radiology 1999;213:185-191

100. Lee VS, Lavelle MT, Rofsky NM, Laub G, Thomasson DM, Krinsky GA, **Weinreb JC**. Hepatic MR imaging with a dynamic contrast-enhanced isotropic volumetric interpolated breath-hold examination: feasibility, reproducibility, and technical quality. Radiology 2000; 215:365-372.

101. Federle MP, Chezmar JL, Rubin DL, **Weinreb JC**, Freeny PC, Semelka R, Brown J, Borello J, Lee JKT, Mattrey R, Dachman AH, Saini S, Harmon B, Fenstermacher M, Pelsang RE, Harms SE, Mitchell DG, Halford HH, Anderson MW, Johnson CD, Francis IR, Bova JG, Kenney PJ, Klippenstein DL, Foster GS, Turner DA, Stillman AE, Nelson RC, Young SW, Patt RH, Rifkin M, Seltzer SE, Gay SB, Robison RO, Sherwin PF, Ballerini R. Safety and efficacy of mangafodipir trisodium (MnDPDP) injection for hepatic MRI in adults: results of the U.S. multicenter phase III clinical trials (safety). J Magn Reson Imaging 2000; 12:186-197.

102. *Lee VS, Rofsky NM, Ton AT, Johnson G, Krinsky GA, **Weinreb JC**. Angiotensin-converting enzyme inhibitor-enhanced phase-contrast MR imaging to measure renal artery velocity waveforms in patients with suspected renovascular hypertension. AJR 2000; 174:499-508.

103. Diaz Candamio MJ, Lee VS, Rofsky NM, Krinsky GA, **Weinreb J**. Pelvic arteriovenous malformations: gadolinium-enhanced three-dimensional MR angiography findings. Eur Radiol. 2000; 10:1257-60.

104. Krinsky GA, Lee VS, Nguyen MT, Rofsky NM, Theise ND, Morgan GR, Teperman LW, **Weinreb JC**. Siderotic nodules at MR imaging: regenerative or dysplastic? Jour Comput Assist Tomogr 2000;24:773

105. Federle MP, Chezmar JL, Rubin DL, **Weinreb JC**, Freeny P, Schmiedl UP, Brown JJ, Borrello JA, Lee JKT, Semelka RC, Mattrey R, Dachman AH, Saini S, Harms SE, Mitchell DG, Anderson MW, Halford HH, Bennett WF, Young SW, Rifkin M, Gay SG, Ballerini R, Sherwin PF, Robison RO. Safety and efficacy of mangafodipir trisodium (MnDPDP) injection for hepatic MRI in adults: results of the U.S. multicenter phase III clinical trials. Efficacy of early imaging. J Magn Reson. Imaging 2000; 12:689-701.

106. *Decorato D, Krinsky G, Rofsky N, Earls J, Lebowitz, **Weinreb JC**. Contrast-enhanced MRI: Comparison of half-dose and standard-dose gadolinium DTPA administration in lesion characterization with T1-weighted gradient-echo sequences. Clinical Imaging 2000;23:302-310

107. Thornbury JR, Ornstein DK, Choyke PL, Langlotz CP, **Weinreb JC**. Prostate Cancer: What is the future for imaging? AJR 2001; 176:17-22.

108. Krinsky GA, Lee VA, Nguyen MT, Rofsky NM, Theise ND, Morgan GR, Teperman LW, **Weinreb JC**. Siderotic nodules in the cirrhotic liver at MR imaging with explant correlation: no increased frequency of dysplastic nodules and hepatocellular carcinoma. Radiology 2001; 218:47-53.

109. Krinsky GA, Lee VS, Theise ND, **Weinreb JC**, Rofsky NM, Diflo T, Teperman LW. Hepatocellular carcinoma and dysplastic nodules in patients with cirrhosis: prospective diagnosis with MR imaging and explantation correlation. Radiology 2001; 219:445-454.

110. *Lavelle MT, Lee VS, Rofsky NM, Krinsky GA, **Weinreb JC**. Dynamic contrast-enhanced three-dimensional MR imaging of liver parenchyma: source images and angiographic reconstructions to define hepatic arterial anatomy. Radiology 2001; 218:389-394.

111. Lee VS, Rofsky NM, Morgan GR, Teperman LW, Krinsky GA, Berman P, **Weinreb JC**. Volumetric mangafodipir trisodium-enhanced cholangiography to define intrahepatic biliary anatomy. AJR 2001; 176:906-908.

112. Ikeda DM, Hylton NM, Kinkel K, Hochman MG, Kuhl CK, Kaiser WA, **Weinreb JC**, Smazel S, Degani H, Veihweg P, Barclay J, Schnall MD. Development, standardization, and testing of a lexicon for reporting contrast-enhanced breast magnetic resonance imaging studies. J Magn Reson Imaging 2001;13:889-895

113. Lee VS, Morgan GR, Teperman LW, John D, Diflo T, Pandharipande PV, Berman PM, Lavelle MT, Krinsky GA, Rofsky NM, **Weinreb JC**. MR imaging as the sole pre-operative imaging modality for right hepatectomy: a prospective study of living adult-to-adult transplant donor candidates. AJR 2001;176:1475-1482.

114. Harisinghani MG, Saini S, Weissleder R, Rubin D, deLange E, Harms S, **Weinreb JC**, Small W, Sukerkar A, Brown J, Zelch J, Lucas M, Morris M, Hahn PF. Splenic imaging with ultrasmall supramagnetic iron oxide ferumxtran-10 (AMI-7227): Preliminary observations. J Comput Assist Tomogr 2001;25(5):770-776

115. *Pandharipande PV, Lee VS, Morgan GR, Teperman LW, Krinsky GA, Rofsky NM, Roy M-C, **Weinreb JC**. Vascular and extravascular complications of liver transplantaton: comprehensive evaluation with three-dimensional contrast-enhanced volumetric MR imaging and MR cholangiopancreatography. AJR 2001;177:1101-1107

116. Lee VS, Rusinek H, Johnson G, Rofsky NM, Krinsky GA, **Weinreb JC**. MR renography with low-dose gadopentetate dimeglumine: feasibility. Radiology 2001;221:371-379

117. Lee VS, Resnick D, Bundy JM, Simonetti OP, Lee P, **Weinreb JC**. Cardiac function: MR evaluation in one breath hold with real-time true fast imaging with steady-state precession. Radiology 2002; 222:835-842

118. Krinsky GA, Zivin SB, Thorner KM, Lee VS, Theise ND, **Weinreb JC**. Low-grade siderotic dysplastic nodules: determination of premalignant lesions on the basis of vasculature phenotype. Acad Radiol. 2002;9:336-41

119. Israel GM, Lee VS, Edye M, Krinsky GA, Lavele MT, Diflo T, **Weinreb JC**. Comprehensive MR imaging in the preoperative evaluation of living donor candidates for laparoscopic nephrectomy: initial experience. Radiology 2002;225:427-432

120. Krinsky GA, Lee VS, Theise ND, **Weinreb JC**, Morgan GR, Diflo T, John D, Teperman LW. Transplantation for hepatocellular carcinoma and cirrhosis: sensitivity of magnetic resonance imaging. Liver Transpl 2002;8:1156-64

121. Pandharipande PV, Lee VS, Reuss PM, Charles HW, Rosen RJ, Krinsky GA, **Weinreb JC**, Rofsky NM. Two-station bolus-chase MR angiography: a simple, alternative to automated-table techniques. AJR 2002;179:1583-1589

122. Israel GM, Lee V, Resnick D, Lavelle MT, Krinsky GA, Nitti V, **Weinreb JC**. Magnetic resonance evaluation of the urethra and lower genitourinary tract in symptomatic women. J of Women's Imaging 2002;4:165-172

123. Lee VS, Morgan JN, Tan AGS, Pandharipande PV, Krinsky GA, Barker JA, Lo C, **Weinreb JC**. Celiac artery compression by the median arcuate ligament: a pitfall of end-expiratory MR imaging. Radiology 2003;228:437-442

124. Philips R, Krinsky GA, Kanzer GK, Gokhale HS, **Weinreb JC**. In vitro MR imaging of placentas from women at risk for placental insufficiency. J of Women's Imaging 2003;4:13-16

125. Lee CH, **Weinreb JC**. The use of magnetic resonance imaging in breast cancer screening. J Am Coll Radiol 2004;1:176-182

126. **Weinreb JC**. Building a team for change in an academic radiology department. Radiology 2004;232:327-330

127. **Weinreb JC,** Wilcox PA. How do training, education, and experience affect quality in radiology? J Am Coll Radiol 2004;510:510-515

128. Elefteriades JA, **Weinreb J**, Invited commentary: MRA evaluation of spinal cord blood supply. Ann Thorac Surg 2004;78:846-852

129. Hillman BJ, Amis SE, **Weinreb JC**, MD, Neiman HL. The future of imaging screening-proceedings of the fourth annual ACR forum. J Am Coll Radiol 2005;2:43-50

130. **Weinreb J**, Wilcox P, Hayden, Lewis R, Froelich J. ACR MRI accreditation: yesterday, today, and tomorrow. J Am Coll Radiol 2005;2:494-503

131. **Weinreb JC**, Larson PA, Woodard PK, Stanford W, Rubin GD, Stillman AE, Bluemke DA, Duerinckx AJ, Dunnick R, Smith GG. American College of Radiology Clinical Policy Statement on Noninvasive Cardiac Imaging. (Dual publication) Radiology 2005;235:723-727 & J Am Coll Radiol 2005;2:471-477

132. Coleman RE, Delbeke D, Guiberteau MJ, Conti PS, Royal HD, **Weinreb JC**, Siegel BA, Federle MF,Townsend DW, Berland LL. Concurrent PET/CT with an integrated imaging system: intersociety dialogue from the Joint Working Group of the American College of Radiology, the society of Nuclear Medicine, and the Society of Computed Body Tomography and Magnetic Resonance. (Dual Publication) J Nucl Med 2005;46:1225-1239 & J Am Coll Radiol 2005;2:568-584

133. *Elicker B, Cypel YS, **Weinreb J**. IV contrast administration for CT: a survey of practices for screening and prevention of contrast nephropathy. AJR 2006;186:1651-1658

134. Johnson CD, Swensen SS, Applegate K, Blackmore CC, Borgstede JP, Cardella JF, Dilling J, Dunnick R, Glenn L, Hillman B, Lau L, Lexa L, **Weinreb J**, Wilcox P. Quality improvement in radiology: white paper report of the Sun Valley Group Meeting. J Am Coll Radiol 2006;3:544-549

135. Moser JW, Wilcox PA, Bjork SS, Cushing T, Dennis M, Greissing JE, Keysor K, McKenzie K, **Weinreb JC**. Pay for performance in radiology: ACR white paper. J Am Coll Radiol 2006;3:650-664

136. Gunderman RB, **Weinreb JC**, Borgstede JP, Hillman BJ, Neiman HL. The 2006 ACR Forum: Cardiovascular Imaging: Learning from the Past, Strategies for the Future. J Am Coll Radiol 2007;4:24-31

137. Kanal E, Barkovich AJ, Bell C, Borgstede JP, Bradley WG, Froelich JW, Gilk T, Gimbel JR, Gosbee J, Kuhni-Kaminski E, Lester JW, Parag Y, Nyenhuis J, Schaefer DJ, Sebek-Soumis E, **Weinreb J**, Zaremba LA, Wilcox P, Lucey L, Sass N. ACR guidance document for MR safe practices: 2007. AJR 2007;188:1-38

138. He Q, P Shkarin, Hooley RJ, Lannin DR, **Weinreb JC**, Bossuyt VLJ. *In Vivo* MR spectroscopic imaging of polyunsaturated fatty Acids (PUFA) in healthy and cancerous breast tissues by selective multiple-quantum coherence transfer (Sel-MQC):a preliminary study. Magn Reson Med 2007;58(6):1079-1085

139. Berman L, Israel GM, McCarthy SM, **Weinreb JC**, Longo WE. Utility of magnetic resonance imaging in anorectal disease. World J Gastroenterol 2007;13(23):3153-3158

140. Cornfeld DM, **Weinreb JC**. MRI of the prostate:1.5T versus 3T. Magn Reson Imaging Clin N Amer 2007;(15):433-448

141. **Weinreb JC**. Nephrogenic systemic fibrosis and GBCAs. J Am Coll Radiol 2008;5:21-22

142. **Weinreb JC**. Nephrogenic systemic fibrosis and gadolinium contrast: impact on hospital policy: the Yale experience. J Am Coll Radiol 2008;5:53-56

143. Gunderman RB, **Weinreb JC**, Hillman BJ, Moore AV, Neiman H. Leadership in radiology: the 2007 ACR Forum. J Am Coll Radiol 2008;5:92-96

144. Cornfeld D, **Weinreb J**. Simple changes to 1.5-T abdomen and pelvis protocols to optimize results at 3T. AJR 2008;190:W140-W150

145. Cornfeld D, McCarthy S M, Israel G, **Weinreb JC**. Pelvic imaging using a T1-weighted fat suppressed three dimensional dual echo Dixon technique at 3T. J Magn Reson Imaging 2008;28:121-127

146. Galvez JA, McCarthy SM, **Weinreb J**, Zelterman D, White R, Pollak J, Tal MG. Comparison of MRI and symptom outcomes of uterine artery embolization for uterine leiomyoma using tris-acryl gelatin microspheres, poly-vinyl alcohol spheres and poly-vinyl alcohol particles. Journ Comput Assist Tomgr 2008;32(3):356-361

147. Israel G, Malguria M, McCarthey S, Copal J, **Weinreb JC**. MRI versus ultrasound for suspected appendicitis during pregnancy. J Magn Reson Imaging 2008;28:428-433

148. Gunderman RB, MD, **Weinreb JC**, Moore AV, MD, Hillman BJ, Neiman HL, Thrall JH. Radiology Practice Models: The 2008 ACR Forum. J Am Coll Radiol 2008;5:960-964

149. **Weinreb JC.** Which Study When? Is gadolinium-enhanced MR imaging safer than iodine-enhanced CT? (Editorial) Radiology 2008;249:3-8

150. Taneja C, Edelsberg J, Weycker D, Guo A, Oster G, **Weinreb J**. Cost-effectiveness of breast cancer screening with contrast-enhanced magnetic MRI in high-risk women. J Am Coll Radiol 2009;6:171-179

151. **Weinreb JC**, Blume JD, Coakley FV, Wheeler TM, Cormack, Sotto CK, Cho H, Kawashima A, Tempany-Afdhal CM, Macura KJ, Rosen M, Gerts SR, J Kurhanewicz J. Prostate cancer: sextant localization at MR imaging and MR spectroscopic imaging before prostatectomy-results of ACRIN prospective multi-institutional clinicopathological study. Radiology 2009;251:122-133

152. **Weinreb JC**, Kuo PH.Nephrogenic Systemic Fibrosis. Magn Reson Imaging Clin N Am 2009;17:159-167

153. *Moon M, Cornfeld D, **Weinreb JC**. Dynamic Contrast-Enhanced MRI of the Breast. Magn Reson Imaging Clin N Am 2009;17:351-362

154. **Weinreb JC**, Abu-Alf AK. Gadolinium Based Contrast Agents and Nephrogenic Systemic Fibrosis: Why Did It Happen and What Have We Learned? J Magn Reson Imaging 2009;30:1236-1239

155. Cornfeld D, Israel G, Martel N, **Weinreb J**, Schwartz P, McCarthey S. MRI appearance of mesenchymal tumors of the uterus. European Journal of Radiology 2010:74(1);241-249

156. Gunderman RB, Patti JA, Lexa F, **Weinreb JC**, Hillman BJ, Thrall JH, Neiman H. The 2009 ACR Forum: Health Care Payment Models. J Am Coll Radiol 2010;7:103-108

157. Carlos RJ, **Weinreb JC**, Sherry CS, Patti PA, Sunshine J, Ellenbogen PH , Hillman BJ. Managing Hospital-Radiologist Relationships: Proceedings of the Tenth Annual ACR Forum. J Am Coll Radiol 2011;8:95-98

158. *Krishnaraj A, **Weinreb JC**, Ellenbogen PH, Patti J, Hillman BJ. Impact of generational differences on the future of radiology. Proceedings of the 11th Annual ACR Forum. J Am Coll Radiol 2012 Feb;9(2):104-107

159. *Hanson JA, *Anson R, **Weinreb J**, Van Dyke A, Mitchell KN. Radiology estimates of viable tumor in hepatocellular carcinoma ablation cavities correlates poorly with pathology assessment. Arch Pathol Lab Med. 2012;136 (In Press)

160. Krishnaraj A, **Weinreb JC**, Ellenbogen PH, Patti J, Hillman BJ. Radiology in 2022: Challenges and Opportunities in the Coming Decade—Proceedings of the 12th Annual ACR Forum. J Am Coll Radiol 2013 (In Press)

161. Kanal E, Barkovish, AJ, Bell C, Borgstede JP, Bradley WG, Froelich JW, Gimbel JR, Gosbee J, Kuhni-Kaminski E, Larson P, Lester JW, Nyenhuis J, Schaefer DJ, Sebek EA, **Weinreb J**, Wilkoff BL, Woods TO, Lucey L, Hernandez D. ACR Guidance Document on MR Safety: 2012. JMRI 2013 (In Press)

162. *Davarpanah A, **Weinreb JC**. The role of imaging in hepatocellular carcinoma; the present and future. J Clin Gastroenterol 2013 (In Press)

CASE REPORTS

(* Student, Resident or Fellow working under direct supervision of Dr. Weinreb)

1. Lee WJ, **Weinreb JC**, Kumari S, Phillips G, Pochaczevsky R, Pillari G. Case report: adrenal hemangioma. J Comput Assist Tomogr 1982; 6(2):392-394.
2. **Weinreb JC**, Arger PH, Grossman R, Samuel L. Case Report: metrizamide computed tomography myelogram diagnosis of multiple bilateral meningoceles. J Comput Assist Tomogr 1983; 9(2):324-326.
3. *Wilcox DM, **Weinreb JC**, Lesh P. Case Report: MR imaging of a hemorrhagic hepatic cyst in a patient with polycystic liver disease. J Comput Assist Tomogr 1985:9(I) 193-195.
4. *Cohen JM, Hodges S, **Weinreb JC**, Lowe TW, Brown C. Case report: MR imaging of a viable full-term abdominal pregnancy. AJR 1985; 145:407.
5. *Cohen JM, **Weinreb JC**, Redman HC. Case report: magnetic resonance imaging of a congenital arteriovenous malformation of the forearm. Surgery 1986; 99(5); 623-625.
6. *Cohen JM, **Weinreb JC**, Redman HC. Case report: Preoperative and postoperative evaluation of the patient with splenorenal shunt with magnetic resonance imaging. Surgery 1986; 999(5):634-636.
7. *Brown CEL, **Weinreb JC**. Magnetic resonance appearance of growth retardation in a twin pregnancy. Obstet Gynecol 1988; 71:987.
8. Freedberg RS, **Weinreb J**, Gluck M, Kronzon I. Paraesophageal hernia may prevent cardiac imaging by transesophageal echocardiography. J Am Soc Echocardiogr 1989; 2(3):2020-2023.
9. Goldfarb A, **Weinreb J**, Daniel WG, Kronzon I. Case report: A patient with right and left atrial membranes: the role of transesophageal echocardiography and magnetic resonance imaging in diagnosis. J Am Soc Echocardiogr 1989; 2(5):350 -353.
10. Bhushan V, Gupta RR, **Weinreb JC**, Kairam R. Case report: Unusual brain MRI findings in a patient with hypomelanosis of Ito. Pedriatr Radiol 1989; 20(1- 2):104-1 06.
11. Rosenzsweig BP, Gindea AJ, Lubat E, Danilowicz D, **Weinreb J**, Kronzon I. Mirror-image dextrocardia with failure of apical pivoting ("levocardia") and situs inversus. Am Heart J 1990; 118 (4):845-848.
12. **Weinreb JC**, Davis SD, Berkmen YM, Naidich DP. Pulmonary artery sarcoma: evaluation using Gd-DTPA. J Comput Assist Tomogr 1990; 14(4):647-649.
13. Freedberg RS, Schulman IC, Naidich D, **Weinreb J**, Culliford A, Kronzon I. Constrictive pericarditis masquerading as extracardiac tumor. Amer Heart J 1 990; 120(I):227-229.
14. *Rofsky NM, Geneiser NB, Ambrosino MM, **Weinreb JC**, Roche K, Rausen AR. Diagnosis of occult primary rhabdomyosarcoma by magnetic resonance imaging. NYS Journ Med 1993; 93(2):142-3.
15. *Haddad JL, Rofsky NM, **Weinreb JC**, Galloway AC. SVC syndrome as a late complication of ascending aortic aneurysm repair: MR diagnosis. J Comput Assist Tomogr 1993; 17(6):982-985.
16. *Lebowitz JA, Rofsky NM, **Weinreb JC**, Friedmann P. Ureteral lymphoma: MRI demonstration. Abdom Imaging 1995; 20:173-175.

17. Suto Y, **Weinreb J**, Rofsky N. Segmental hyperintense area in the liver shown by delayed MR imaging with MN-DPDP. J Comput Assist Tomogr 1996; 20(4):647-649.

18. *Walsh P, Rofsky NM, Krinsky GA, **Weinreb JC**. Asymmetric signal intensity of the renal collecting systems as a sign of unilateral renal artery stenosis following administration of gadopentetate dimeglumine. J Comput Assist Tomogr 1996; 20(5); 812-813.

19. Katz ES, Applebaum RM, Earls JP, Krinsky G, **Weinreb J**, Kronzon I. Torutousity of the descending thoracic aorta simulating dissection on transesophageal echocardiography. J Am Soc Echocardiography 1997; 10(1):83-87.

20. Krinsky G, Rofsky N, **Weinreb J**. Dynamic breath-hold 3D gadolinium- enhanced MRI of intraarterial masses: findings in two patients. J Comput Assist Tomogr 1997; 21(4):631-634.

21. Krinsky G, Thiese N, Rofsky NR, Mizrachi H, Teperman L, **Weinreb JC**. Dysplastic nodules in cirrhotic liver: arterial phase enhancement at CT and MR imaging. Radiology 1998; 209:461-463.

22. *Greenberg KLZ, **Weinreb J,** Shellock FG. "MR conditional" respiratory ventilator system incident in a 3T MRI environment. Magnetic Resonance Imaging 2011;29:115-1154

TEXTBOOKS

Weinreb JC, Redman H. Magnetic Resonance Imaging of the Body. W.B. Saunders Co., Philadelphia 1987.

Firooznia H, Golimbu C, Rafii M, Rauschning W, **Weinreb JC**. MRI and CT of Musculoskeletal System. Mosby Year Book, Chicago 1992.

Mirowitz SA, Kneeland B, Mitchell DG, Siegel MJ, Tempany CMC, **Weinreb JC,** White C. Body MRI Test and Syllabus (Professional Self-Evaluation Program-No.46), American College of Radiology, Reston, VA, 2000.

Weinreb JC, Bell RA, Clarke GD, Hodges LK, Kneeland JB, Price RR. Magnetic Resonance Imaging Quality Control Manual. (American College of Radiology, Reston, VA) 2001.

BOOK CHAPTERS

1. Gadolinium - DTPA Polymers and Microspheres for Improved Enhancement of Liver, Solid Tumors, and Cardiovascular Blood Pool. Ranney DF, **Weinreb JC**, Cohen JM, et al. In: Contrast Agents in Magnetic Resonance Imaging (Eds.) Runge VM, Claussen C, Roland F. and James AE. Excerpta Media, Inc. 1986.

2. Tumor Characterization by Gadolinium-DTPA Enhanced Magnetic Resonance Imaging. Maravilla KR, Mickey B. Peshock RM, **Weinreb JC**, Riley HK and Diehl J. In: Contrast Agents in Magnetic Resonance Imaging. - (Eds.) Runge VM, Claussen C, Roland F, and James AE. Excerpta Media, Inc. 1986.

3. Obstetrics. **Weinreb JC.**In: Magnetic Resonance Imaging. (Eds.)Stark DD, Bradley WG. C.V. Mosby Company, Inc. St. Louis 1991, 1994. 1998.

4. Obstetrical MRI. **Weinreb JC**.In: Nuclear Magnetic Resonance (NMR) Imaging.(Eds.) Partain CL, Price RR, Patton JA, Kulkarni MV, and James AE. Second edition, W.B. Saunders Co., Philadelphia 1988.

5. Magnetic Resonance Imaging. **Weinreb JC** In: Assessment of Fetal Well Being. (Eds.) Eden R, Boehm F. Appleton-Century-Crofts, Norwalk 1989.

6. Obstetrical Magnetic Resonance Imaging. Birnbaum B, **Weinreb JC**. In: Magnetic Resonance Clinical Applications and Advanced Techniques. (Eds.) Edelman R, Hesselink J. Sartoris D, W.B. Saunders Co., Philadelphia 1990.

7. Hemangiomas: RBC Blood Pool Imaging. Birnbaum B, **Weinreb JC**. In: Liver Imaging: Current Trends and New Techniques (Eds.) Ferrucci JT and Stark DD. Andover Medical Publishers, Cambridge 1990.

8. Magnetic Resonance Imaging of Pituitary and Parasellar Tumors. **Weinreb JC**, Litt AW, Kricheff II. In: Proceedings of the First International MR Education Seminar JMRM, Nagoya, Japan 1991.

9. The Hip. **Weinreb JC**, Rofsky N. In: MRI and CT of the Musculoskeletal System. (Eds.) Firooznia H, Golimbu C, Rafii M, Rauschning W, **Weinreb JC**. Mosby Year Book, Chicago 1992.

10. MRI of the Body (Eds.) **Weinreb JC**. Fritzsche PJ and Stark DD, Raven Press, New York 1993. Contributor.

11. MRI Operational Safety Considerations. In: MRI and CT of the Musculoskeletal System. (Eds.) Firooznia H, Golimbu C, Rafii M, Rauschning W, **Weinreb JC**. Mosby Year Book, Chicago 1992.

12. Magnetic Resonance Imaging and Computed Tomography of the Heart and Great Vessels.**JC Weinreb**. In: Nomenclature and Criteria for Diagnosis of Diseases of the Heart and Great Vessels, 9th Edition, The Criteria Committee of the New York Heart Association. Little, Brown and Company, Boston 1993.

13. MRI of the Breast. **JC Weinreb**. In: Innovative Achievements in Cancer Imaging, Princess Takamatsu Cancer Research Fund, Tokyo 2003

14. MRI. **JC Weinreb**. In: Encyclopedia of Gastroenterology, Academic Press, San Diego 2003

15. ACR BIRADS-MRI.Ikeda D, Hylton NH, Kuhl C, **Weinreb JC**, Morris EM, Kinkel K, Hochman MG, Kaiser WA, Lewin J, DeganiH, Veihweg P, Schnall MD. In: ACR Breast Imaging and Data System, Breast Imaging Atlas. American College of Radiology, Reston VA 2003

16. Nephrogenic Systemic Fibrosis (NSF). Weinreb JC, Sirlin C. Chapter 11: ACR Manual on Contrast Media Version 8. http://www.acr.org/Quality-Safety/Resources/Contrast-Manual. July 2012.

PUBLISHED ABSTRACTS

(*Resident or Fellow working under direct supervision of Dr. Weinreb)

1. **Weinreb JC**, Kumari S. Portal vein measurements by real-time sonography, Annual Meeting of American Roentgen Ray Society, New Orleans, LA. May 1982.
2. Kumari S. Phillips G, **Weinreb JC**, Pochaczevsky R. Grey-scale sonography in the diagnosis and differential diagnosis of left upper quadrant masses. Annual meeting of American Roentgen Radiology Society, New Orleans, LA. May 1982.
3. **Weinreb JC**, Arger P, Coleman SG, Mintz MC, Pollack HM, Arenson R. Cystic renal mass evaluation: real-time versus b-scan imaging. Annual Meeting of Radiological Society of North America, Chicago, IL. November 1983.
4. Maravilla KR, **Weinreb JC**, Nunnally R. Improved NMR evaluation of the head using calculated T1, T2 estimated images. Annual Meeting of Society of Magnetic Resonance Imaging, Orlando, FL. February 1984.
5. Lowe TW, **Weinreb JC**, Santos-Ramos R, Cunningham G. Magnetic resonance imaging in human pregnancy: preliminary observations. Annual Meeting of Society of Perinatal Obstetricians, Las Vegas, NV. March 1984.
6. **Weinreb JC**, NMR in hepatic lymphoma. Annual Meeting of American Roentgen Ray Society, Las Vegas, NV. April 1984.
7. Maravilla KR, Lesh P, **Weinreb JC**, Selby DK, Mooney V, Nunnally R. Magnetic resonance imaging of the lumbar spine: comparative study with CT. Annual Meeting of American Society of Neuroradiology, Boston, MA. June 1984.
8. Babcock KR, **Weinreb JC**, Brateman L. The enhanced boundary artifact explained. Annual Meeting of the Society of Magnetic Resonance in Medicine, New York City, NY. August 1984.
9. Maravilla KR, **Weinreb JC**, Nunnally R. Magnetic Resonance imaging of multiple sclerosis plaques within the cervical spinal cord. Annual meeting of the Society of Magnetic Resonance in Medicine, New York City, NY. August 1984.
10. **Weinreb JC**, Lowe TW, Santos-Ramos R, Parkey R, Nunnally R. Magnetic resonance imaging of abnormal human pregnancies. Annual meeting of the Society of Magnetic Resonance in Medicine, New York City, NY. August 1984.
11. *Cohen JM, **Weinreb JC**. Magnetic resonance evaluation of iliopsoas disease. Annual Meeting of the Radiological Society of North America, Chicago, IL. November 1985.
12. Armstrong EA, **Weinreb JC**, Smith TH, Oshman DG, Cohen JM. Magnetic resonance imaging of pediatric liver disease. Annual Meeting of the Radiological Society of North America, Chicago, IL. November, 1985.
13. *Cohen JM, **Weinreb JC**, Redman HC. Postoperative assessment of splenorenal shunts with MRI. Annual Meeting of the Radiological Society of North America, Chicago, IL. November 1985.
14. Ranney DF, **Weinreb JC**, Cohen JM, Srikantan S. Selective MR enhancement of liver with gadolinium DTPA microspheres. Annual Meeting of the Radiological Society of North America, Chicago, IL. November 1985.
15. Sory C, Maravilla KR, Lesh P, Ross-Duggan JW, **Weinreb JC**. Updated comparison of MRI with CT of the lumbar spine. Annual Meeting of the Radiological Society of North America, Chicago, IL. November 1985.

16. Maravilla KR, Sory C, Mickey B, Suss RA, Diehl J, **Weinreb JC**, Peshock RM. Preliminary experiences using intravenous gadolinium DTPA for MR imaging: diagnostic pulse sequence considerations. Annual Meeting of the Radiological Society of North America, Chicago, IL. November 1985.

17. *Cohen JM, **Weinreb JC**. Magnetic Resonance Imaging of the Shoulder. Annual Meeting of the Radiological Society of North America, Chicago, IL. November 1985.

18. Ranney DF, **Weinreb JC**, Cohen JM, et al. Semi-synthetic macromolecular and small microsphere GD-DTPA contrast agents for improved liver and flow- perfusion enhancement. International Workshop on Contrast Agents in MRI. San Diego, CA. January 1986.

19. **Weinreb JC**, Cohen JM, Armstrong E, Erdman WA. Magnetic Resonance Imaging and Computed Tomography of pediatric livers. Annual Meeting of Society of Magnetic Resonance Imaging, Philadelphia, PA. March 1986.

20. **Weinreb JC**, Brown C, Cohen JM. A comparison of real-time ultrasound and magnetic resonance imaging for the evaluation of fetal anomalies. Annual Meeting of Society of the American Roentgen Ray Society, Washington, D.C. April 1986.

21. Armstrong EA, Smith TH, **Weinreb JC**, Cohen JM. MRI of the upper abdomen in children. Annual Meeting of the Society for Pediatric Radiology, Washington, D.C. April 1986.

22. Peshock R, Barker B, Katz J, Schaefer S, Erdman W, **Weinreb JC**. Optimizing small flip angle imaging for the evaluation of cardiovascular structure and function. Society of Magnetic Resonance in Medicine, Montreal, Canada. August 1986.

23. **Weinreb JC**, Brown C, Cohen JM, Erdman WA, Obstetrical MRI: experience with sixty-five pregnant women, Society of Magnetic Resonance in Medicine, Montreal, Canada. August 1986.

24. **Weinreb JC**, Brown C. Cohen JM, Erdman WA. Obstetric MR imaging: experience with seventy-five pregnant women. Radiolog 1986:161(P):182.

25. **Weinreb JC**, Wolbarsht LB, Brown C, Cohen JM, Erdman WA, Maravilla KR. MR imaging of the lumbosacral spine in asymtomatic pregnant and non-pregnant women. Radiology 1986; (P):23.

26. *Cohen JM, **Weinreb JC**, Muschier G., Erdman WA Avascular necrosis of the femoral heads: initial screening and postoperative evaluation with MR imaging. Radiology 1986; 161(P):23.

27. *Erdman WA, **Weinreb JC**, Barker B. Peshock R., Chaney C, Maravilla K R. Renal cortical perfusion: Correlation of radionuclide microsphere injection with contrast enhance rapid sequence MRI. Magnetic Resonance Imaging 1987; 5(P):132

28. *Cohen JM, **Weinreb JC**, Muschier G, et al. MR imaging of avascular necrosis of the femoral head. Magnetic Resonance Imaging 1987; 5(P):40.

29. *Cohen JM, Yazigi R, Weatherall P, Munoz A., **Weinreb JC**. Magnetic resonance imaging of determination of myometrial invasion in endometrial carcinoma. Magnetic Resonance Imaging 1988; 6(P):63.

30. *Erdman WA, **Weinreb J**, Weatherall P, Breslau N, Snyder W, Cohen J, Setiawan H. Prospective MR imaging at 0.35T of parathyroid adenomas in comparison with CT, ultrasound, and scintigraphy. Program for Society of Magnetic Resonance Imaging 5th Annual Meeting 1987; Mpm-ES.

31. Naidich D., **Weinreb JC**. MR imaging of the pulmonary parenchyma: comparison with CT in evaluating cadaveric lung specimens. Radiology 1988; 169(P):301.

32. Ranney DF, Cohen JM, Antich PP., Erdman WA, Kulkarni P, **Weinreb JC**, Giovanella B. Contrast-enhanced, MR imaging monitoring of acute tumor response to chemotherapy. Radiology 1987; 165(P):354.

33. **Weinreb JC**. Explanation of the MR Imaging appearance of the periprostatic and uterovaginal venous plexus. Radiology 1988; 169(P):138.

34. Rafii M, Firooznia H, Golimbu C, **Weinreb J**. Magnetic resonance imaging of rotator cuff arthropathies. Magnetic Resonance Imaging 1989; 7(P)35.

35. Bannon K, **Weinreb JC**, Martin P, Litt A. Gd-DTPA enhanced fat suppressed 3-DFT imaging of the IAC: a comparison with standard SE techniques. Annual Meeting of the Society of Magnetic Resonance in Medicine 1989; 270.

36. Birnbaum BB, **Weinreb JC**, Megibow A, et al. Blinded retrospective comparison of MR and 99mTc-labeled RSC for definitive diagnosis of hepatic hemangioma. Annual Meeting of the Society of Magnetic Resonance in Medicine 1989; 96. Radiology 1989; 173(P):270.

37. Holliday RA, **Weinreb JC**. Utility of MR imaging in post-thyroidectomy patients. Radiology 1989; 173(P):253.

38. Bannon KR, Martin P, **Weinreb JC**, Litt AW, Holliday RA, Barkoff N, Kricheff II, Gd-DTPA contrast-enhanced fat-suppressed three-dimensional fourier transform imaging of the internal auditory canal: comparison with standard spin-echo technique. Radiology 1989; 173(P):222.

39. Litt AW, Rusinek H, Simon H, Bannon KR, **Weinreb JC**. Improving MR angiography of the carotid arteries with spatial presaturation. Radiology 1989; 173(P):186.

40. Rafii M, Firooznia H, Minkoff J, Sherman 0, Schinella R, **Weinreb JC**, Golimbu C, Zazlav K. MR patterns of rotator cuff impingement lesions and histopathologic correlation of cadaver tendons. Radiology 1989; 173(P):27.

41. **Weinreb JC**, Libes R, Naidich D, et al. Evaluation of the post-operative ascending aorta: a comparison of MR and CT. Magnetic Resonance Imaging 1990; 8(I):58.

42. **Weinreb JC**. MRI of the liver. Acta Radiologica Portuguesa 1990; 2(6):43-44.

43. **Weinreb JC**. Genitourinary MRI. Acta Radiologica Portuguesa 1990; 2(6):71- 72.

44. **Weinreb JC**. Gynecological applications of MRI. Acta Radiologica Portuguesa 1990; 2(6):73-74.

45. Rusinek H, Litt A, **Weinreb J**. Volume rendering of MR images: a method for tissue classification. SMRI 1990.

46. *Rofsky NM, **Weinreb JC**, Libes R, Bosniak MA. Renal lesion characterization with Gd-DTPA-enhanced MR Imaging: Efficacy and safety in patients with renal insufficiency. Radiology 1990; 177(P):317.

47. *Rofsky NM, **Weinreb JC**, Grossi E, Naidich D, Libes R, Galloway AC, Colvin SS. Evaluation of the postoperative ascending aorta: comparison of MR imaging and CT. Radiology 1990; 177(P):201.

48. Birnbaum BA, Noz ME, Chapnick J, Sanger JJ, Megibow AJ, **Weinreb JC**, Kramer EL. Clinical evaluation of image fusion using MR imaging, CT, and SPECT-RBC images of hepatic hemangiomas. Radiology 1990; 177(P):228.

49. Litt AW, Eidelman EM, Pinto RS, Riles TS, McLachlan SJ, Schwartzenberg S, **Weinreb JC**, Kricheff II. A blinded comparison of contrast angiography, MR angiography, and duplex US in the evaluation of the carotid bifurcation. Radiology 1990; 177(P):90.

50. *Gokhale HS, Kanzer GK, **Weinreb JC**. In vitro MR imaging of placentas from patients at risk for placental insufficiency. JMRI 1991; 1(2):197.

51. **Weinreb JC**, Simon HE, Rofsky NM, Bosniak M, R Kersh. Determination of Gd-DTPA enhancement of renal masses on MR images: experimental and clinical studies. Radiology 1991; 181(P):124.

52. **Weinreb JC**, Young S, Lee J, Bernardino M. MnDPDP-enhanced MRI of primary hepatocellular tumors: specificity and patterns. Radiology 1991; 181(P):196.

53. **Weinreb JC**, Bernardino M, Lee J, Young S. Comparison of CE-CT and MnDPDP-enhanced MRI for detection of hepatic metastases. Radiology 1991; 181 (P):196.

54. Bernardino ME, Young SW, Lee J, **Weinreb J**. Contrast enhanced MR imaging of the liver with Mn-DPDP for known or suspected focal hepatic disease. Radiology 1991; 181(P):121.

55. Rafii M, Firooznia H, Sherman 0, Minkoff J, Sherman M, Golimbu C, **Weinreb J**. High resolution MR imaging of glenohumeral instability lesions. Radiology 1991; 818(P):154.

56. **Weinreb JC**, Imaging insights: understanding the chemical shift artifact in MR images, (ab), Radiology 1992; 185:622.

57. Pizzerello DJ, Rofsky NM, **Weinreb JC**. Effect of MR imaging with gadolinium dimeglumine injection on fetal mouse development. Radiology 1 992; 185(P): 129.

58. **Weinreb JC**, Haddad JL, Feinberg D, Rofsky N, Mercado C, Kiefer B. Breath-hold GRASE imaging of the liver: comparison with RARE (Turbo-SE) and FLASH. JMRI 1993; 3(P):68.

59. Rofsky NM, **Weinreb JC**, Haddad JL. T2-weighted breath-hold fat-suppressed RARE (Turbo SE) imaging of the liver with 15 mT/m gradients at 1.0T. JMRI 1993; 3(P):68.

60. *Haddad JL, **Weinreb JC**, Rofsky NM. Electrocardiogram-triggered RARE (Turbo SE) Imaging of the Chest. JMRI 1993; 3(P):102.

61. Rofsky NM, Pizzarello DJ, Duhaney MO, **Weinreb JC**. Effect of MR imaging combined with gadopentetate dimeglumine on chromosome morphology in animal specimens. Radiology 1993; 189(P):133.

62. Rofsky NM, Pizzarello DJ, Dadey EJ, Duhaney MO, **Weinreb JC**. Selective enhancement of transplanted mammary carcinoma in rat livers: first evaluation of Fe-dermatan sulfate, a new MR contrast agent. Radiology 1993; 189(P):202.

63. Bernardino ME, **Weinreb JC**, Mitchell DG. Fast MR imaging of the bowel with a manganese chloride T1/T2 contrast agent. Radiology 1993; 189(P):203.

64. Karon D, Grossi E, **Weinreb J**, Stephenson J, Porte S. The spiderweb algorithm applied in 4-D using topologically correct isosurface tracking algorithm to follow the moving surface of the heart. The Society of Nuclear Medicine Computer Instrumentation Symposium, Seattle, Washington, February 7, 1994.

65. Feinberg DA, Kiefer B, **Weinreb JC**, Rofsky N, Mercado C, Safir J, Stevenson J. High-speed T2-weighted imaging of the liver with single-shot GRASE (TGSE). JMRI 1994; 4(P):42.

66. *Goldman JP, **Weinreb JC**, Rofsky NM, Goldenberg A, Megibow A, Rosen R. Comparison of MR, CT, and angiography for the assessment of hepatocellular carcinoma treated with transcatheter arterial embolization. JMRI 1994; 4(P):65.

67. Rofsky NM, **Weinreb JC**, Safir J, Mercado C, Goldman JP, Megibow AJ. Comparison of fat-suppression techniques for hepatic MR imaging: Turbo-SE, breath-hold Turbo-SE, GRASE, and Turbo STIR. JMRI 1994; 4(P):66.

68. *Safir J, **Weinreb JC**, Rofsky N. Comparison between in-phase and opposed-phase T1-weighted breath-hold FLASH sequences for hepatic imaging. JMRI 1994; 4(P):66.

69. Safir J, Rofsky N, **Weinreb J**, Ambrosino M, Krinsky G. Comparison between in-phase and opposed-phase T1-weighted breath-hold FLASH sequences for hepatic imaging. Radiology 1994; 193 (P):133.

70. Panasci DJ, Litt AW, Shpizner BA, Holliday RA, Grossman JA, **Weinreb JC**. Evaluation of Erb palsy: MR imaging versus xylography. Radiology 1994; 193 (P):242.

71. Rofsky NM, **Weinreb JC**, Bosniak MA, Krinsky GA, Flyer MA. Gadolinium-enhanced MR imaging of unresected kidney after partial or complete nephrectomy: high resolution images with a body phased-array coil. Radiology 1995; 197(P):147.

72. *Krinsky GA, Theis N, **Weinreb JC**, Rofsky NM, Teperman L, Earls JP. MR imaging cannot reliably differentiate between malignant and nonmalignant nodules in cirrhotic livers: a correlative study of high-resolution MR imaging with pathology of explanted livers. Radiology 1995; 197(P):176.

73. Rofsky NM, Schlossberg P, **Weinreb JC**. MR imaging-guided aspiration biopsy of hepatic lesions with a conventional MR imaging unit. Radiology 1995; 197(P):177.

74. *Lee NA, Rusinek H, **Weinreb JC**, Newstead GM, Chandra R, Singer CI. Comparison of X-ray mammography and a computer-assisted MR imaging method for determination of fat-to-fibroglandular tissue ratios in the breasts of women aged 20-83 years. Radiology 1995; 197(P):311.

75. *Krinsky GA, Rofsky NM, Feinberg DA, Flyer MA, **Weinreb JC**. Fast MR imaging of the uterus: comparison of four T2-weighted sequences for diagnosis of adenomyosis leiomyoma. Radiology 1995; 197(P):322.

76. Small WC, Hahn PF, **Weinreb JC**, DeLange EE, Saini S, Bernardino ME. Safety and efficacy of an MnCl2-based gastrointestinal MR imaging contrast agent. Radiology 1995; 197(P):349.

77. *Krinsky GA, Rofsky NM, Flyer MA, **Weinreb JC**. Gadolinium-enhanced 3D MR Angiography of the thoracic aorta: optimization of technique and comparison with conventional MR imaging. Radiology 1995; 197(P):418.

78. Krinsky G, Maya M, Flyer M, Nelson K, Masters L, **Weinreb J**. Gadolinium-enhanced 3D MRA of the aortic arch and great vessels in the evaluation of cerebrovascular occlusive disease. Proceedings of the International Society for Magnetic Resonance in Medicine Fourth Scientific Meeting and Exhibition 1996; 2:698.

79. Krinsky G, Flyer M, Rofsky N, Earls J, DeCorato D, **Weinreb J**. Comparison of turbo SE with conventional SE for ECG triggered T1-weighted MRI of the thorax. Proceedings of the International Society for Magnetic Resonance in Medicine Fourth Scientific Meeting and Exhibition 1996; 2:709.

80. *Earls JP, DeCorato DR, Rofsky NM, Krinsky G, **Weinreb JC**. Comparison of a breath hold STIR with conventional non-breath hold STIR for detection of liver metastases. Proceedings of the International Society for Magnetic Resonance in Medicine Fourth Scientific Meeting and Exhibition 1996; 2:774.

81. *DeCorato DR, Earls JP, Rofsky NM, Krinsky G, **Weinreb JC**. Comparison of 3 T1- weighted sequences for detection of liver masses: SE, half-fourier SE, and FLASH (GRE). Proceedings of the International Society for Magnetic Resonance in Medicine Fourth Scientific Meeting and Exhibition 1996; 2:779.

82. Feinberg DA, Kroeker R, Earls JP, Johnson G, Rofsky N, **Weinreb JC**. Multiple breath-hold MRI of the abdomen using automated motion correction. Proceedings of the International Society for Magnetic Resonance in Medicine Fourth Scientific Meeting and Exhibition 1996; 3:1517.

83. Beatty SM, Orel SG, Schnall MD, **Weinreb JC**, Harms SE, Stomper PC. MR imaging detection of occult breast carcinoma manifesting as axillary metastases. Radiology 1996; 201(P):128.

84. *Earls JP, **Weinreb JC**, DeCorato DR, Rofsky NM, Krinsky GA. Hepatic arterial phase MR imaging: utility of timing bolus and a power injector. Radiology 1996; 201(P):350.

85. Rofsky NM, **Weinreb JC**, Krinsky GA, DeCorato DR, Earls JP, Bosniak MA. Dynamic breath-hold contrast enhanced renal MR imaging: comprehensive, time-efficient renal evaluation. Radiology 1996; 201(P):148.

86. Naik KS, Hochwald S, Marcus S, Krinsky G, Rofsky N, **Weinreb JC**. Magnetic Resonance Cholangiopancreatography (MRCP) using HASTE (half fourier single-shot turbo spin-echo) sequence: clinical evaluation in 97 cases. European Society of Gastrointestinal and Abdominal Radiology 8th Annual Meeting. Amsterdam, the Netherlands, June 26, 1997.

87. Heywang-Koebrunner SH, **Weinreb JC**. International Multicenter (12 sites) Investigation of Contrast-enhanced Breast MR Imaging (IIBM): Analysis of Diagnostic Parameters and Histopathology in 456 Patients. Radiology 1997; 205(P):539.

88. Naik KS, Hochwald S, Marcus S, Krinsky G, Rofsky N, **Weinreb JC**. Magnetic Resonance Cholangiopancreatography (MRCP) using HASTE (half fourier single- shot turbo spin-echo) sequence: clinical evaluation in 97 cases. Radiology 1997; 205(P):503.

89. Lee VS, Rofsky NM, Krinsky GA, Stemerman DH, **Weinreb JC**. Single Dose Gadolinium-enhanced 3D-MR Angiography of the Renal Arteries Optimized with a Timing Examination: Effects of Injection Rate, Patient Circulation Time, and Breath-holding. Radiology 1998; 209(P):186.

90. Lee VS, Rofsky NM, Ton AT, Krinsky GA, Johnson G, **Weinreb JC**. Complementary Roles of Phase-contrast Arterial Waveform Analysis Using an ACE-inhibitor and Gd-Enhanced 3D MRA for Evaluation of Patients with Suspected Renovascular Hypertension. Radiology 1998; 209(P):490.

91. Lee VS, Shinde TS, Rofsky NM, Krinsky GA, **Weinreb JC**. Three-Dimensional Gadolinium-Enhanced MR Venography for Evaluation of Central Vein Patency. Proceedings of the International Society for Magnetic Resonance in Medicine Seventh Scientific Meeting and Exhibition 1999.

92. Lee VS, Ton AT, Rofsky G, Krinsky GA, **Weinreb JC**. ACE-inhibitor-Enhanced Cine Phase-Contrast MR Measurements of Renal Artery Velocity Waveforms in Patients with Suspected

Renovascular Hypertension. Proceedings of the International Society for Magnetic Resonance in Medicine Seventh Scientific Meeting and Exhibition 1999.

93. Krinsky G, Theise N, Rofsky NM, Lee H, Mizrachi H, **Weinreb JC** MR Imaging of Hepatocellular Carcinoma (HCC): Prospective Evaluation with Explant Correlation. Proceedings of the International Society for Magnetic Resonance in Medicine Seventh Scientific Meeting and Exhibition 1999.

94. Lee VS, Lavelle MT, Rofsky NM, Thomasson D, Laub G, Krinsky G, **Weinreb JC**. Dynamic High-Resolution Isotropic Breathhold T1-weighted 3D Volumetric Imaging of the Abdomen: Validation and Clinical Application. Proceedings of the International Society for Magnetic Resonance in Medicine Seventh Scientific Meeting and Exhibition 1999.

95. GA Krinsky, D Stemerman, VS Lee, BM Yang, NM Rofsky, and **JC Weinreb**. Rapid "Black Blood" MR Imaging of the Thoracic Aorta Using Half-Fourier Single Shot Turbo Spin-Echo (HASTE) Imaging with or without ECG Triggering. Radiology 1999; 213(P):344.

96. GA Krinsky, ND Theise, NM Rofsky, **JC Weinreb**. Moncada Award, SCST/MRI 99: MR Imaging of hepatocellular carcinoma (HCC): Prospective Evaluation with Explant Correlation. Radiology 1999; 213(P):254.

97. DM Ikeda, NM Hylton, K Kinkel, MG Hochman, WA Kaiser, **JC Weinreb**, et al. Development, Standardization, and testing of a Lexicon for Reporting Contrast-enhanced Breast Magnetic Resonance Imaging Studies. Radiology 1999; 213(P):370.

98. *Lavelle MT, Lee VS, Krinsky GA, **Weinreb JC**, Rofsky NM. Volumetric Interpolated Isotropic 3D MR Imaging Versus Digital Subtraction Angiography in the Evaluation of Hepatic Arterial Anatomy. Proceedings of the International Society for Magnetic Resonance in Medicine Eighth Scientific Meeting and Exhibition 2000; 39 (203).

99. Krinsky GA, Lee VS, Theise ND, Rofsky NM, Morgan G, **Weinreb JC**. Siderotic Nodules in the Cirrhotic Liver at MR Imaging with Explant Correlation: Increased Frequency of Dysplastic Nodules and Hepatocellular Carcinoma. Radiology 2000; 217(P):504.

100. Lavelle MT, Lee VS, Krinsky GA, Phillips RR, Rofsky NM, **Weinreb JC**. Is MR HASTE Imaging Sufficient to Characterize Renal Cysts? Radiology 2000; 217(P):581.

101. Lee VS, Krinsky GA, Rofsky NM, Morgan GR, Teperman LW, Lavelle MT, Berman P, **Weinreb JC**. Volumetric Mangafodipir-Enhanced MR Cholangiography to Define Intrahepatic Biliary Anatomy. Proceedings of the International Society for Magnetic Resonance in Medicine Eighth Scientific Meeting and Exhibition 2001; 9(419).

102. Lee VS, Resnick D, Lee P, Bundy J, Simonetti O, Laub G, Krinsky GA, **Weinreb JC**. Cardiac Function Evaluation in a Single Breath-Hold:Real-Time True FISP Cine Imaging. Proceedings of the International Society for Magnetic Resonance in Medicine Eighth Scientific Meeting and Exhibition 2001.

103. Lee VA, Rusinek H, Lee P, Johnson G, Veneiro JC, Laub G, Krinsky GA, **Weinreb JC**. Dynamic Three-Dimensional (3D) MR Renography: Preliminary Feasibility Studies. Proceedings of the International Society for Magnetic Resonance in Medicine Eighth Scientific Meeting and Exhibition 2001.

104. Krinsky GA, Zivin SB, Thorner KM, Lee VS, **Weinreb JC**, Theise ND. Low-Grade Siderotic Dysplastic Nodules: Premalignant Leisons Based on Vascular Phenotype. Radiology 2001;221(P):574.

105. Lavelle MT, LeeVS, Krinsky GA, Tan AK, Morgan GM, **Weinreb JC**. T1-weighted, Contrast-Enhanced MR Cholangography vs T2-weighted MRCP to Define Intrahepatic Bliary Anatomy in the Nondilated System. Radiology 2001;221(P):629

106. Lee VS, Rusinek H, Lee P Kramer EL, Lavelle MT, **Weinreb JC**. Dynamic Three-dimensional MR Renography for the Mangement of Glomerlular Filtration Rate. Radiology 2001;221(P):633

107. Ikeda DM, Hylton NM, Morris EA, Lewis RS, **Weinreb JC**, Hochman MG, Kuhl CK, Kaiser WA, Lewin JM, Viehweg, Schnall MD. Refinement and Testing of a Lexicon for Reporting Contrast-enhanced Breast Magnetic Resonance (MR) Imaging Studies. ISMRM, Honolulu, HI, May 2002

108. Daftary A, **Weinreb JC**, Lee CH. Outcome of Breast Biopsies Prompted by Findings on Breast MRI. Radiological Society of North America 90th Scientific Assembly and Annual Meeting. Dec 2, 2005

109. Stewart ST, Daftary A, Philpotts L, **Weinreb JC**, Lee CH. MRI-guided Needle Localization Biopsies of the Beast: Histologic Outcome and Miss Rate. Radiological Society of North America 90th Scientific Assembly and Annual Meeting. December 3, 2005

110. Galvez J, McCarthy S, **Weinreb J**, Pollak J, White RI, Tal MG. Correlation of Incomplete infarction on MRI and Long-term Symptom Recurrence Among Three Different Embolic Agents for Uterine Artery Embolization: Polyvinyl Alcohol Particles, Polyvinyl Alcohol Spheres, Gelatin microspheres. Radiological Society of North America 91st Scientific Assembly and Annual Meeting. December 3, 2005

111. Philpotts LE, , Andrejeva L, Hooley R, Fan J , Horvath L, Tocino I, **Weinreb J**. Current Use of MRI in a Dedicated Breast Imaging Practice: Indications and Outcome Analysis. Annual Meeting of the American Reontgen Ray Society, Seatle, WA. May 7, 2006

112. Spooner SL, Stewart ST, **Weinreb JC**, Lee CH. Re-biopsy After Benign MRI-Guided Vacuum Assisted Core Needle Biopsy of the Breast: Frequency, Indications, and Outcome. Radiological Society of North America 92nd Scientific Assembly and Annual Meeting. December, 2006

113. **Weinreb JC**, Coakley F, Blume J, Wheeler T, Cormack J, Kurhanewicz J. ACRIN 6659: MRI and MRSI of Prostate Cancer Prior to Radical Prostatectomy:A Prospective Multi-Institutional Clinicopathological Study. Radiological Society of North America 92nd Scientific Assembly and Annual Meeting. December, 2006

114. *Malguria M, **Weinreb JC**, McCarthey S, Copal J. Appendicitis in Pregnant Patients: Diagnostic Efficacy of Ultrasound vs. MRI. Society of Maternal-Fetal Medicine 27th Annual Meeting. February 8, 2007

115. Taneja C, Edelsberg J, Weycker D, Guo A, Oster G, **Weinreb J**. Cost-effectiveness of breast cancer screening with contrast-enhanced MRI as an adjunct to X-ray mammography (XM) in high-risk women. Radiological Society of North America 93rd Scientific Assembly and Annual Meeting. November 25, 2007

116. Cornfeld D, Israel G, **Weinreb J**, McCarthey S. MR Imaging Findings of Uterine Stromal Neoplasms. Radiological Society of North America 93rd Scientific Assembly and Annual Meeting. November 28, 2007

117. Cornfeld D, Morin A, McCarthy S, Israel G, **Weinreb J**. Pelvic Imaging Using a T1W Fat Suppressed Three Dimensional Dual Echo Dixon Technique at 3T. Radiological Society of North America 93rd Scientific Assembly and Annual Meeting. November 29, 2007

118. Krishnan M, Thorsteinsson D, Horowitz N, **Weinreb J**, Lanin D, Lee C. The Influence of Preoperative MRI in the Timing and Type of Therapy in Women in Newly Diagnosed Breast Cancer. American Roentgen Ray Society Annual Meeting. April 15, 2008

119. Tiwari P, Rosen M, Blume J, **Weinreb** J, Madhabushi A. Automated Prostate Cancer Detection from Magnetic Resonance Spectroscopy (MRS) Using a Hierarchical Non-Linear Dimensionality Reduction Scheme. ISMRM 16th Annual Scientific Meeting and Exhibition. May 7, 2008

120. Patel J, Lee K, **Weinreb JC**, Abu-Alfa A. Screening for chronic kidney disease at the point-of-care prior to GBCA administration. 3rd Annual Scientific Symposium on Nephrogenic Systemic Fibrosis and Gadolinium-based Contrast Agents. Yale University School of Medicine, New Haven, CT. May 9, 2009

121. Geisel JL, Raghu, M, **Weinreb JC**, Cornfeld D, Varipapa BA, Philoptts LE. Analysis of biopsy recommendations from breast MRI exams: attempts to reduce false positives. Radiological Society of North America 95rd Scientific Assembly and Annual Meeting. November 29, 2009

122. Shwayhat S, Perachio M, **Weinreb J**,Goodman R, Minja R, Cushing W, LaBrec M, Mckiernan K, Dubrowski M, Hutchins L, Palmieri S. Reducing scheduling time for inpatients requiring an MRI exam. Joe A.Zaccagnino Patient Safety and Clinical Quality Conference. March 19, 2011

123. Philpotts L, Herlihy S, Lapia K, Hooley R, Geisel J, Horvath L, **Weinreb J**, Grube B, Killelea B, Lannin D. The Effect of Pre-operative MRI on Surgical Outcomes of Patients Undergoing Initial Lumpectomy for Newly Diagnosed Breast Cancer. Radiological Society of North America 97th Scientific Assembly and Annual Meeting. November 29, 2011

SCIENTIFIC EXHIBITS

1. Kumari S. Phillips G, **Weinreb JC**, Pochaczevsky R. Grey-scale sonography in the diagnosis and differential diagnosis of left upper quadrant masses. Annual Meeting of AIUM 1981.

2. Cohen JM, **Weinreb JC**, Redman HC. Magnetic Resonance Imaging in the evaluation of congenital arteriovenous malformations of the extremities. Annual Meeting of the Radiological Society of North America 1985.

3. Holliday R, **Weinreb JC**. MRI of the neck in the post-thyroidectomy patient. Annual Meeting of the Society of Magnetic Resonance in Medicine 1989.

4. Litt A, **Weinreb JC**, Simon H. Improved 3-D carotid MR angiography with presaturation of the tortular Herophili. Annual Meeting of the Society of Magnetic Resonance in Medicine 1989.

5. Rusinek H, Litt A, **Weinreb JC**. Graphic display of magnetic resonance angiography. Annual Meeting of the Society of Magnetic Resonance in Medicine 1989.

6. Chapnick J, Noz ME, Kramer E, Sanger J, Birnbaum S, Maguire GO, Megibow A, Oratz R, **Weinreb J**, Martino J. Structural, functional image fusion in cancer patients. Radiology 1990; 177(P):377.

7. Simon HE, **Weinreb JC**, Litt AW, McLachman SJ. Optimized lipid suppression by means of STIR and reduced bandwidth. JMRI 1991; 1(2):236.

8. **Weinreb JC**. MRI of the Breast. Capitol Hill Briefing on "New Frontiers in Breast Cancer Imaging and Early Detection, Washington, D.C., September 17, 1996.

9. Catanzano T, **Weinreb JC**. Imaging of the brachial plexus: A review of brachial pplexus anatomy on MR with pathologic correlation. Radiological Society of North America Sceintific Assembly and Annual Meeting 2003.

10. Malguria N, **Weinreb JC**, McCarthy SM. The utility of MR in diagnosisng appendicitis in pregnant patients with indeterminate or normal ultrasound. Radiological Society of North America Scientific Assembly and Annual Metting. Chicago, IL. Novevember 37-December 3, 2005.

11. Taneja C, Edelsberg J, Weycker D, Guo A, Oster G, **Weinreb J**. Cost-effectiveness of breast cancer (BC) screening with contrast enhanced magnetic resonance imaging (MRI) as an adjunct to x-ray mammography (XM) in high-risk women.The 30th Annual San Antonio Breast Cancer Symposium, San Antonio, TX. December 13 - 16, 2007.

12. Tiwari P, Rosen M, Blume J, **Weinreb J**, Madabhushi A. Computerized detection of prostate cancer using magnetic resonance spectroscopy (MRS). 16th Scientific Meeting and Exhibition of the International Society for Magnetic Resonance in Medicine, Toronto, ON. May 3-9, 2008

13. Patel J, Abu-Alfa A, **Weinreb JC**,* Lee K. Screening for chronic kidney disease at the point-of-care prior to GBCA administration. 3rd Annual Scientific Symposium on Nephrogenic Systemic Fibrosis and Gadolinium-based Contrast Agents. Yale University School of Medicine, New Haven, CT. May 9, 2009

14. Patel J, Lee K, **Weinreb JC**, Abu-Alfa A. Screening for CKD at Point-of-Care Prior to GBCA (Gadolinium-Based Contrast Agent) Use. ASN 2009 42nd Annual Meeting and Scientific Exposition. San Diego, CA, October 31, 2009

VISITING PROFESSOR

1. UCLA, Los Angeles, CA. November 14, 1986.
2. University of Medicine and Dentistry of New Jersey, New Brunswick, NJ. November 7, 1988.
3. New York Medical College, Valhalla, NY. April 18, 1989.
4. University of Maryland School of Medicine, Baltimore, MD. October 17, 1989.
5. University of Texas Health Science Center at Houston, Houston, TX. March 23, 1990.
6. State University of New York at Stonybrook, Stonybrook, NY. May 10, 1990.
7. North Shore University Hospital, Manhasset, NY. February 27, 1991.
8. St. Luke's/Roosevelt Hospital Center, New York, NY. March 31, 1992.
9. University of Pittsburgh School of Medicine, Pittsburgh, PA. June 16-17,1992.
10. Medical College of Virginia, Richmond, VA. November 12, 1992.

11. Thomas Jefferson University Hospital, Philadelphia, PA. December 10, 1992.
12. Lenox Hill Hospital, New York, NY. March 11, 1993.
13. Mallinckrodt Institute of Radiology, St. Louis, MO. May 10, 1993.
14. Dartmouth Hitchcock Medical Center, Hanover, NH. May 14, 1993.
15. University of Vermont Medical Center, Burlington, VT. October 29, 1993.
16. New York Medical College, Valhalla, NY. November 9, 1993.
17. Morristown Memorial Hospital, Morristown, NJ. November 17, 1993.
18. North Shore University Hospital, Manhasset, NY. November 13, 1994.
19. Beth Israel Medical Center, New York, NY. December 6, 1994.
20. Northwestern University Medical Center, Chicago, IL. February 13-14, 1995.
21. The Western Pennsylvania Hospital, Pittsburgh, PA. March 3, 1995.
22. Downstate Medical Center, Brooklyn, NY. November 17, 1995.
23. SUNY Health Science Center, Syracuse, NY. March 14-15,1996.
24. University of Medicine & Dentistry of New Jersey University Hospital, Newark, NJ, September 18, 1996.
25. North Shore University Hospital, Manhasset, NY, October 16, 1996.
26. Long Island Jewish Medical Center, New Hyde Park, NY, February 6, 1996.
27. University of Miami School of Medicine, Miami, FL, March 20, 1997.
28. Yale University School of Medicine, New Haven, CT, October 30, 1997.
29. Massachusetts General Hospital, Boston, MA, January 15, 1998.
30. Kosair Children's Hospital. Louisville, KY, October 21, 1998.
31. University of Kentucky, Lexington, KY, October 22, 1998.
32. SUNY at Stony Brook Health Sciences Center, Stony Brook, NY, February 18, 1999.
33. Vanderbilt University Medical Center, Nashville, TN, August 31, 1999.
34. University of Mississippi Medical Center, Jackson, MS, November 16, 1999.
35. Mallinckrodt Institute of Radiology, St. Louis, MO, February 21, 2000.
36. The Western Pennsylvania Hospital/Allegheny General Hospital, Pittsburgh, PA, November 16, 2000.
37. St. Louis University, St. Louis, MO April 10, 2001.
38. Yale University School of Medicine, New Haven, CT, March 8, 2002.
39. Mayo Clinic, Rochester, MN, September 19-20, 2002.
40. Brown University-Rhode Island Hospital, Providence, RI, January 6, 2003

41. North Shore University Hospital, Manhasset, NY, January 15, 2003
42. University of Maryland, Baltimore, MD, October 22, 2003
43. Columbia Presbyterian Medical Center, New York, NY, October 29, 2003.
44. University of Connecticut Health Center, Farmington, CT, February 11, 2004.
45. University of Indiana Medical Center, Indianapolis, IN, April 20, 2004
46. Baptist Hospital East, Louisville, KY. November 16, 2004
47. Columbia Presbyterian Medical Center, New York, NY, January 26, 2005
48. St. Francis Hospital, Tulsa, OK, September 7, 2006
49. University of Kansas Medical Center, Kansas City, KS, November 10, 2006
50. St. Lukes Medical Center, Kansas City, MO, November 11, 2006
51. St. Lukes/Roosevelt Hospital Center, New York, NY, November 14, 2006
52. Columbia Presbyterian Medical Center, New York, NY, November 15, 2006
53. Kent Hosptital, Warwick, RI, December 11, 2006
54. University of Minnesota Medical School, Minneapolis, MN. January 29, 2007
55. Long Island Jewish Medical Center, New Hyde Park, NY. March 15, 2007
56. Stony Brook University Medical Center, Stony Brook, NY. May 7, 2007
57. University of Alabama Hospital, Birmingham, AL, October 8, 2007
58. Wuesthoff Medical Center, Rockledge, FL, January 8, 2008
59. Lahey Clinic, Burlington, MA, February 29, 2008
60. Medical University of South Carolina, Charleston, SC, April 1, 2008
61. Brigham and Women's Hospital, Boston, MA, February 3, 2009
62. Massachusetts General Hospital, Boston, MA, February 4, 2009
63. Stony Brook University Medical Center, Stony Brook, NY. September 14, 2010
64. Cleveland Clinic, Cleveland, OH. November 8, 2010
65. University of Texas Health Science Center, Houston, TX. April 21, 2011

INVITED LECTURES

1. Glycogen Metabolism Associated with Cleft Palate Fusion. American Dental Association Research Conference. Chicago, IL. August 1983.
2. Dietary Practices of Navajo Infants in the Fort Defiance Service Unit. Navajo National Health Symposium. Tsaile, AZ. August 1975.
3. Ultrasound and CT of the Liver. Diagnostic Radiology Update Conference. Dallas, TX. May 1984.

4. Magnetic Resonance Imaging of the Abdomen. Clinical Nuclear Medicine and NMR Symposium. Dallas, TX. May 1984.

5. MR Imaging of the Female and Male Pelvis. Annual Fall Meeting of the Rheinsch - Westfalische Radiology Society. University of Bonn/Venusberg, German Federal Republic. October 1984.

6. Magnetic Resonance Image Interpretation: Pulse Sequence and Source of Contrast, UTHSCD, Montego Bay, Jamaica. February 1985.

7. Cross-sectional Imaging of the Thorax: CT and MRI. UTHSCD, Montego Bay, Jamaica. February 1985.

8. MRI of the Abdomen: Benefits and Problems. UTHSCD, Montego Bay, Jamaica. February 1985.

9. Magnetic Resonance Imaging. Centre D'imagerie Diagnostique, Lausaunne, Switzerland. June 1985.

10. MRI of Vascular Structures: Current Clinical Applications. Diagnostic Radiology Update. Dallas, TX. October 1985.

11. MRI of the Spine. Florida Physical Therapy Association. South Miami, FL. November 1985.

12. The Use of MRI in Obstetrics and Gynecology. UTHSCD OB/GYN Postgraduate Course. Dallas, TX. November 1985.

13. Magnetic Resonance Imaging: Obstetrical Risks and Applications. Union Memorial Hospital Special Lecture Series. Baltimore, MD. January 1986.

14. Magnetic Resonance Imaging of the Body - Current Clinical Applications. Dallas Fort Worth Radiological Society. Dallas, TX. January 1986.

15. Body MRI: Current Clinical Application. Medical Grand Rounds. Presbyterian Hospital, Dallas, TX. March 1986.

16. OB/GYN MRI. Maryland Obstetric Gynecologic Society. Baltimore, MD. May 1986.

17. Magnetic Resonance Imaging. Shanghai University Cancer Hospital, Shanghai, People's Republic of China. June 1986.

18. MRI of the Upper Abdomen. Cincinnati, OH. September 1986.

19. MRI of AVN. Midwest MRI Conference. Cincinnati, OH. September 1986.

20. Imaging of the Pediatric Liver. International Body Imaging Conference. Kauai, HI. October 1986.

21. Noninvasive Parathyroid Imaging. International Body Imaging Conference. Kauai, HI. October 1986.

22. MRI and US of the Maternal Pelvis and Spine. International Body Imaging Conference. Kauai, HI. October 1986.

23. Imaging of Benign Hepatic Lesions. International Body Imaging Conference. Kauai, HI. October 1986.

24. MRI of the Lower Extremities. Diagnostic Radiology Update Conference. Dallas, TX. October 1986.

25. MRI of the Female Pelvis. Diagnostic Radiology Update Conference. Dallas, TX. October 1986.

26. MRI of the Hip. A Symposium On Diseases of the Hip. Presbyterian Hospital, Dallas, TX. November 1986.

27. Will MRI Conquer the Abdomen? ? Los Angeles Radiological Society Seminar in Magnetic Resonance Imaging. Los Angeles, CA. November 1986.

28. Imaging of the Pediatric Abdomen: MRI vs CT. os Angeles Radiological Society Seminar in Magnetic Resonance Imaging. Los Angeles, CA. November 1986.

29. MRI of the Hips: How Good is it? Los Angeles Radiological Society Seminar in Magnetic Resonance Imaging. Los Angeles, CA. November 1986.

30. MRI of the Female Pelvis. International MRI and CT Conference. Orlando, FL. February 1987.

31. MRI of the Abdomen. International MRI and CT Conference. Orlando, FL. February 1987.

32. MRI: Safety Considerations. International MRI and CT Conference. Orlando, FL. February 1987.

33. MRI of the Pelvis. Educational Program of the Annual Meeting of the Society of Magnetic Resonance Imaging. San Antonio, TX. February 1987.

34. New Advances in MRI. NYU Medical Center MRI Conference. New York, NY. May 1987.

35. Body MRI. Rontgeninstitut, Basel, Switzerland. May 1987.

36. MRI of the Kidney. New York Roentgen Ray Society, New York, NY. October 1987.

37. MRI of the Female Pelvis. International MRI and CT Conference. Orlando, FL. February 1988.

38. MRI of the Knee. International MRI and CT Conference. Orlando, FL. February 1988.

39. MRI of the Hips. International MRI and CT Conference. Orlando, FL. February 1988.

40. MRI of the Hips. Magnetic Resonance Imaging Conference. Los Angeles, CA. April 1988.

41. MRI of the Pelvis. Magnetic Resonance Imaging Conference. Los Angeles, CA. April 1988.

42. Present Status of MRI in the Diagnosis and Staging of Prostatic and Bladder Tumors. New York Roentgen Ray Society Spring Meeting. New York, NY. May 1988.

43. MRI Examination of the Head, Neck, Spine, Joints and Body: Technical Considerations. University of Connecticut Health Center, Farmington, CT. August 1988.

44. MRI of the Liver. Delaware Valley MRI Society. Philadelphia, PA. November 1988.

45. MRI of the Female Pelvis. Albert Einstein College of Medicine, New York, NY. February 1989.

46. Obstetrical MRI. Society for Magnetic Resonance Imaging. Los Angeles, CA. February 1989.

47. MRI of the Lungs. University of South Florida MRI Conference. Snowmass, CO. March 1989.

48. MRI of the Female Pelvis. University of South Florida MRI Conference. Snowmass, CO. March 1989.

49. Obstetrical MRI. University of South Florida MRI Conference. Snowmass, CO. March 1989.

50. Introduction to MRI. Grand Rounds. Columbus Hospital, Newark, NJ. April 1989.

51. MRI of the Thorax. University of Michigan, Ann Arbor, MI. April 1989.

52. MRI of the Female Pelvis. University of Michigan, Ann Arbor, MI. April 1989.

53. MRI of the Liver. University of Michigan, Ann Arbor, MI. April 1989.

54. MRI of the Female Pelvis. International MRI Symposium. Orlando, FL. May 1989.

55. Practical Safety Considerations for MRI. International MRI Symposium. Orlando, FL. May 1989.

56. MRI of the Male Pelvis. International MRI Symposium. Orlando, FL. May 1989.

57. MRI of the Male Pelvis, Annual Meeting of the American Roentgen Rad Society. New Orleans, LA. May 1989.

58. MRI of the Kidneys and Adrenals. Harvard School of Medicine, Boston, MA. May 1989.

59. MRI of the Male Pelvis. Harvard School of Medicine, Boston, MA. May 1989.

60. MRI of the Female Pelvis. Colorado Radiological Society. Denver, CO. September 1989.

61. MRI of the Liver. University of Colorado School of Medicine, Denver, CO. September 1989.

62. MRI of the Female Pelvis. University of Virginia School of Medicine, Charlottesville, VA. October 1989.

63. MRI of the Liver. University of Virginia School of Medicine, Charlottesville, VA. October 1989.

64. MRI of the Thorax. University of Virginia School of Medicine, Charlottesville, VA. October 1989.

65. Practical Safety Considerations for MRI. University of Virginia School of Medicine, Charlottesville, VA. October 1989.

66. MRI of the Female Pelvis. Maryland Radiological Society, Baltimore, MD. October 1989.

67. Female pelvic imaging 1990; US, CT and MR. New York Roentgen Ray Society Spring Meeting, New York, NY. May 1990.

68. MRI of the Liver. Conferencia Norte Americana Sobre Oncologia-Diagnostica pela Imagen, Radiologia de Intervencao e Radioterapia, Organizacao de Sociadade Potugueas de Radiologia e Medicina Nuclear, Cascais, Portugal. June 1990.

69. Genitourinary MRI, Gynecological Applications of MRI. Conferencia Norte Americana Sobre Oncologia-Diagnostica pela Imagen, Radiologia de Intervencao e Radioterapia, Organizacao de Sociadade Potugueas de Radiologia e Medicina Nuclear, Cascais, Portugal. June 1990.

70. Hemangiomas: RBC Blood Pool Imaging. Liver Imaging Symposium, Harvard Medical School, Boston, MA. June 1990.

71. MRI of the Prostate. Diagnostic Imaging Symposium, Brown University and Rhode Island Hospital, Newport, RI. August 1990.

72. Gynecologic Applications of MR. Diagnostic Imaging Symposium, Brown University and Rhode Island Hospital, Newport, RI. August 1990.

73. Cardiac MR. Diagnostic Imaging Symposium, Brown University and Rhode Island Hospital, Newport, RI. August 1990.

74. Understanding the MR Image. Diagnostic Imaging Symposium, Brown University and Rhode Island Hospital, Newport, RI. August 1990.

75. MRI of Pituitary and Parasellar Tumors. JMRM/SMRI Joint Educational Symposium, Nagoya, Japan. September 1990.

76. MRI of the Pelvis. MRI Symposium, Veterans Affairs Medical Center, Bronx, NY. September 1990.

77. Understanding the MR Image: Common Misconceptions. International Body Imaging Congress, University of Colorado, Maui, HI. October 1990.

78. Useful New Techniques for MRI. International Body Imaging Congress, University of Colorado, Maui, HI. October 1990.

79. MRI of the Chest. International Body Imaging Congress, University of Colorado, Maui, HI. October 1990.

80. MRI of the Kidneys and Adrenals. International Body Imaging Congress, University of Colorado, Maui, HI. October 1990.

81. MRI of the Hips. International Body Imaging Congress, University of Colorado, Maui, HI. October 1990.

82. MRI of the Abdomen. New Jersey Academy of Medicine, New Brunswick, NJ. October 1990.

83. MRI of the Liver. Grand Rounds, Albert Einstein College of Medicine, New York, NY. October 1990.

84. MRI of the Liver. Grand Rounds, Beth Israel Medical Center, New York, NY. October 1990.

85. Biohazards of MRI. Principles and Practice of Clinical MRI, The Johns Hopkins Medical Institutions, Baltimore, MD. November 1990.

86. MRI of the Hips. Principles and Practice of Clinical MRI, The Johns Hopkins Medical Institutions, Baltimore, MD. November 1990.

87. MRI of the Liver. Principles and Practice of Clinical MRI, The Johns Hopkins Medical Institutions, Baltimore, MD. November 1990.

88. MRI of the Female Pelvis. Principles and Practice of Clinical MRI, The Johns Hopkins Medical Institutions, Baltimore, MD. November 1990.

89. MRI of the Liver: Controversy and Consensus. South Florida Radiological Society. Miami, FL. January 1990.

90. Gynecologic Applications of MRI. Ob/Gyn Grand Rounds, Mercy Hospital, Miami, FL. January 1990.

91. MRI and CT of Colorectal Carcinoma. Internationales Kernspintomographie Symposium, Munich University-National Institutes of Health-UCSF, Garmisch-Partenkirchen, Germany. January 1991.

92. MRI of the Liver, Spleen and Pancreas. Plenary Lecture. Scientific Program Society for Magnetic Resonance Imaging Annual Meeting, Chicago, IL, April 1991.

93. Understanding the MR Image: New Techniques and Common Misconceptions. Grand Rounds, Long Island Jewish Medical Center, New Hyde Park, NY. May 1991.

94. MRI of the Liver: Consensus and Controversy. Grand Rounds, Long Island Jewish Medical Center, New Hyde Park, NY. May 1991.

95. Techniques for Abdominal MRI. Johns Hopkins Medical Center, Baltimore, MD. September 1999.

96. Hepatic Lesion Characterization with MRI. New Brunswick, NJ. September 1991.

97. Practical Safety Considerations for MRI. International Body Imaging Symposium, University of Colorado, Maui, HI. October 1991.

98. MRI of the Hip. International Body Imaging Symposium, University of Colorado, Maui, HI. October 1991.

99. Techniques for Abdominal MRI. International Body Imaging Symposium, University of Colorado, Maui, HI. October 1991.

100. Hepatic Lesion Characterization with MRI. International Body Imaging Symposium, University of Colorado, Maui, HI. October 1991.

101. MRI of the Kidney and Adrenal Gland. International Body Imaging Symposium, University of Colorado, Maui, HI. October 1991.

102. Magnetic Resonance Imaging-Current and Future Applications. Medical Grand Rounds, St. Luke's-Roosevelt Medical Center, New York, NY. October 1991.

103. Intravenous Contrast Agents for MRI of the CNS. Neurosciences Grand Rounds, Humana Medical City Medical Center, Dallas, TX, November 1991.

104. Techniques for Abdominal MRI. University of Texas Southwestern Medical School, Dallas, TX. November 1991.

105. MRI of the Hip. University of Texas Southwestern Medical School, Dallas, TX. November 1991.

106. Hepatic Lesion Characterization with MRI. University of Texas Southwestern Medical School, Dallas, TX. November 1991.

107. The Future of Body MRI. **Julian Salik Lecture**. Sinai Hospital, Baltimore, MD. November 1991.

108. Practical Safety Considerations for MRI. CT/MR Head to Toe Course, NYU Medical Center, New York, NY. December 1991.

109. MRI of the Prostate. CT/MR Head to Toe Course, NYU Medical Center, New York, NY. December 1991.

110. MRI of the Female Pelvis. CT/MR Head to Toe Course, NYU Medical Center, New York, NY. December 1991.

111. Cardiovascular MRI. CT/MR Head to Toe Course, NYU Medical Center, New York, NY. December 1991.

112. Basics of Neuro MRI. CT/MR Head to Toe Course, NYU Medical Center, New York, NY. December 1991.

113. MRI Imaging Techniques and Problems. CT/MR Head to Toe Course, NYU Medical Center, New York, NY. December 1991.

114. MRI of the Prostate. North Shore University Hospital, Manhasset, NY. December 1991.

115. Techniques for Abdominal MRI. Seminars in MRI, Medical College of Wisconsin, Vail, CO. January 1992.

116. Fat Suppression and Reduced Bandwidth Techniques. Seminars in MRI, Medical College of Wisconsin, Vail, CO. January 1992.

117. MRI of the Prostate. Seminars in MRI, Medical College of Wisconsin, Vail, CO. January 1992.

118. MRI of the Hip. Seminars in MRI, Medical College of Wisconsin, Vail, CO. January 1992.

119. MRI of the Chest. Seminars in MRI, Medical College of Wisconsin, Vail, CO. January 1992.

120. MRI and CT of the Aorta. Seminars in MRI, Medical College of Wisconsin, Vail, CO. January 1992.

121. Gynecologic Applications of MRI. International Course on MRI, Societat Catalana de Radiologia, Barcelona, Spain. February 1992.

122. MRI of the Liver. International Course on MRI, Societat Catalana de Radiologia, Barcelona, Spain. February 1992.

123. Genitourinary MRI. International Course on MRI, Societat Catalana de Radiologia, Barcelona, Spain. February 1992.

124. MRI of the Thorax. International Course on MRI, Societat Catalana de Radiologia, Barcelona, Spain. February 1992.

125. Safety Considerations for MRI. Current Topics in Diagnostic Imaging, New York University School of Medicine, Cerromar, PR. February 1992.

126. Understanding the MR Image. Current Topics in Diagnostic Imaging, New York University School of Medicine, Cerromar, PR. February 1992.

127. Gynecologic Applications of MRI. Current Topics in Diagnostic Imaging, New York University School of Medicine, Cerromar, PR. February 1992.

128. MRI of the Prostate. Current Topics in Diagnostic Imaging, New York University School of Medicine, Cerromar, PR. February 1992.

129. MRI of the Liver. Current Topics in Diagnostic Imaging, New York University School of Medicine, Cerromar, PR. February 1992.

130. Gynecologic Applications of MRI. Radiology Grand Rounds, Montefiore Medical Center, Bronx, NY. March 1992.

131. MRI of the Prostate. Society of Computed Body Tomography/MR Annual Meeting, Tucson, AZ, March 1992.

132. Fat Suppression Techniques for the Liver. Society of Computed Body Tomography/MR Annual Meeting, Tucson, AZ, March 1992.

133. MRI of the Hips. Society of Computed Body Tomography/MR Annual Meeting, Tucson, AZ, March 1992.

134. CT and MR for Liver Metastases. New York Roentgen Ray Spring Meeting, New York, NY. April 1992.

135. Body Applications of MRI. Western Massachusetts Radiology Society, Holyoke, MA. May 1992.

136. Gynecologic Applications of MRI. Magnetic Resonance Imaging Update, Harvard Medical School, Boston, MA. May 1992.

137. MRI of the Male Pelvis. Magnetic Resonance Imaging Update, Harvard Medical School, Boston, MA. May 1992.

138. Gynecologic Applications of MRI. Maine Radiology Society, Rockland, ME. June 1992.

139. Techniques for Abdominal MRI. Society of Body Computed Tomography/MR Summer Practicum, Keystone, CO. August 1992.

140. Applications of MRI for Benign Gynecologic Disease. Society of Body Computed Tomography/MR Summer Practicum, Keystone, CO. August 1992.

141. Practical Safety Considerations for MRI. Society of Body Computed Tomography/MR Summer Practicum, Keystone, CO. August 1992.

142. Clinical Problems for Abdominal MRI. MR in Abdominal Pathology: State of the Art in Advanced Research, University of Ancona School of Medicine, Monte d'Ago-Ancona, Italy. September 1992.

143. Clinical Experience with MN-DPDP for Hepatic MRI. MR in Abdominal Pathology: State of the Art in Advanced Research, University of Ancona School of Medicine, Monte d'Ago-Ancona, Italy. September 1992.

144. Genitourinary MRI. XII Congreso Argentino de Radiologia Diagnostico por Imagenes y Terapia Radiante, Sociedad Argentina de Radiologia Asociacion Medica Argentina, Buenos Aires, Argentina. September 1992.

145. MRI of the Liver. XII Congreso Argentino de Radiologia Diagnostico por Imagenes y Terapia Radiante, Sociedad Argentina de Radiologia Asociacion Medica Argentina, Buenos Aires, Argentina. September 1992.

146. Gynecologic Applications of MRI. XII Congreso Argentino de Radiologia Diagnostico por Imagenes y Terapia Radiante, Sociedad Argentina de Radiologia Asociacion Medica Argentina, Buenos Aires, Argentina. September 1992.

147. Safety Considerations for MRI. XII Congreso Argentino de Radiologia Diagnostico por Imagenes y Terapia Radiante, Sociedad Argentina de Radiologia Asociacion Medica Argentina, Buenos Aires, Argentina. September 1992.

148. Fat Suppression Techniques. XII Congreso Argentino de Radiologia Diagnostico por Imagenes y Terapia Radiante, Sociedad Argentina de Radiologia Asociacion Medica Argentina, Buenos Aires, Argentina. September 1992.

149. MRI of the Hips. XII Congreso Argentino de Radiologia Diagnostico por Imagenes y Terapia Radiante, Sociedad Argentina de Radiologia Asociacion Medica Argentina, Buenos Aires, Argentina. September 1992.

150. Gynecologic Applications of MRI. Radiology Grand Rounds, University of Massachusetts Medical Center, Worcester, MA. October 1992.

151. Body MRI: Current and Future Applications. Medical Grand Rounds, Morristown Memorial Hospital, Morristown, NJ. November 1992.

152. MRI of the Prostate. Richmond Radiological Society, Richmond, VA. November 1992.

153. Fat Suppression Techniques and Applications. Philadelphia Roentgen Ray Society, Philadelphia, PA. December 1992.

154. MR Contrast Agents: Uses and Economics. Department of Radiology Grand Rounds, Maimonides Medical Center, Brooklyn, NY. January 1993.

155. Gynecologic Applications of MRI. Department of Gynecology Grand Rounds, Morristown Memorial Hospital, Morristown, NJ. February 1993.

156. Understanding the MR Image. NYU Post-Graduate Medical School, Cerromar Beach, PR. February 1993.

157. Gynecologic Applications of MRI. NYU Post-Graduate Medical School, Cerromar Beach, PR. February 1993.

158. MRI of the Prostate. NYU Post-Graduate Medical School, Cerromar Beach, PR. February 1993.

159. Characterization of Benign Liver Masses with CT/MRI. NYU Post-Graduate Medical School, Cerromar Beach, PR. February 1993.

160. MRI of the Liver. Magnetic Resonance Imaging Present and Future, The George Washington Medical Center and the University of Toronto, Naples, FL. February 1993.

161. Gynecologic Applications of MRI. Magnetic Resonance Imaging Present and Future, The George Washington Medical Center and the University of Toronto, Naples, FL. February 1993.

162. MRI of the Aorta. Magnetic Resonance Imaging Present and Future, The George Washington Medical Center and the University of Toronto, Naples, FL. February 1993.

163. MRI of the Prostate. Magnetic Resonance Imaging Present and Future, The George Washington Medical Center and the University of Toronto, Naples, FL. February 1993.

164. Gynecologic Applications of MRI. D.C. Metropolitan Area Chapter of the American College of Radiology, Washington D.C. February 1993.

165. MRI of the Hips: Workshop: Interesting Cases. Society of Computed Body Tomography and Magnetic Resonance Annual Course, Orlando, FL. March 1993.

166. MRI of the Hips. Loyola University of Chicago Stritch School of Medicine Department of Radiology, Diagnostic Radiology Conference, Maui, HI. March 1993.

167. MRI of the Aorta. Loyola University of Chicago Stritch School of Medicine Department of Radiology, Diagnostic Radiology Conference, Maui, HI. March 1993.

168. MRI of the Prostate. Loyola University of Chicago Stritch School of Medicine Department of Radiology, Diagnostic Radiology Conference, Maui, HI. March 1993.

169. Gynecologic Applications of MRI. Loyola University of Chicago Stritch School of Medicine Department of Radiology, Diagnostic Radiology Conference, Maui, HI. March 1993.

170. MRI of the Abdomen. Staten Island MRI Society, Staten Island University Hospital, Staten Island, NY. March 1993.

171. MRI Abdominal Imaging Techniques. University of Connecticut Health Center, Farmington, CT. April 1993.

172. MRI of the Prostate. University of Connecticut Health Center, Farmington, CT. April 1993.

173. New MRI Techniques for Abdominal Imaging. New Jersey MRI Club, New Brunswick, NJ. April 1993.

174. Safety Considerations for MRI. New York Roentgen Ray Society Spring Meeting, New York, NY. May 1993.

175. MRI of the Female Pelvis. City-Wide Radiology Lecture, St. Louis, MO. May 1993.

176. MRI of the Aorta. Radiology Grand Rounds, Long Island College Hospital, Brooklyn, NY. May 1993.

177. Techniques for Abdominal MRI. Curso Internacional de Resonancia Magnetica, Institute Clinica Corachan, Barcelona, Spain. May 1993.

178. Staging Prostate Cancer with MRI. Curso Internacional de Resonancia Magnetica, Institute Clinica Corachan, Barcelona, Spain. May 1993.

179. Characterization of Hepatic Disease. Curso Internacional de Resonancia Magnetica, Institute Clinica Corachan, Barcelona, Spain. May 1993.

180. Fat Suppression Techniques. Curso Internacional de Resonancia Magnetica, Institute Clinica Corachan, Barcelona, Spain. May 1993.

181. Gynecologic Applications of MRI. MRI Conference, University of Wisconsin School of Medicine, Durango, CO. July 1993.

182. MRI of the Prostate. MRI Conference, University of Wisconsin School of Medicine, Durango, CO. July 1993.

183. MRI of the Thoracic Aorta. MRI Conference, University of Wisconsin School of Medicine, Durango, CO. July 1993.

184. Hepatic Lesion Characterization with MRI. MRI Conference, University of Wisconsin School of Medicine, Durango, CO. July 1993.

185. Techniques for Abdominal MRI. MRI Conference, University of Wisconsin School of Medicine, Durango, CO. July 1993.

186. MRI Fat Suppression Techniques. MRI Conference, University of Wisconsin School of Medicine, Durango, CO. July 1993.

187. Safety Considerations for MRI. MRI Conference, University of Wisconsin School of Medicine, Durango, CO. July 1993.

188. MRI Fat Suppression Techniques. Diagnostic Radiology Review Course, Biarritz, France. September 1993.

189. Abdominal MR Imaging Techniques. Diagnostic Radiology Review Course, Biarritz, France. September 1993.

190. MRI of the Breast. Diagnostic Radiology Review Course, Biarritz, France. September 1993.

191. MRI of Prostate Cancer. Diagnostic Radiology Review Course, Biarritz, France. September 1993.

192. Gynecologic Applications of MRI. Diagnostic Radiology Review Course, Biarritz, France. September 1993.

193. MRI of the Thorax. Diagnostic Radiology Review Course, Biarritz, France. September 1993.

194. MRI of the Breast. Radiology Grand Rounds, Albert Einstein College of Medicine, Bronx, NY. October 1993.

195. MRI of the Breast. Westchester Radiological Society, Westchester, NY. November 1993.

196. MRI of the Breast. Grand Rounds, Department of Radiology, Long Island Jewish Medical Center, New Hyde Park, NY. December 1993.

197. MR Techniques for Hepatic Imaging. Dallas-Fort Worth Radiological Society, Dallas, TX. January 1994.

198. MRI of the Prostate. Department of Radiology, Parkland Hospital, Dallas, TX. January 1994.

199. Magnetic Resonance Angiography. New York Roentgen Society, New York, NY. January 1994.

200. MRI of the Breast. Abdominal Imaging Seminar, University of Colorado, Vail, CO. January - February 1994.

201. Staging of Prostate Cancer with MRI. Abdominal Imaging Seminar, University of Colorado, Vail, CO. January -February 1994.

202. Applications of MRI for Benign Gynecologic Disease. Abdominal Imaging Seminar, University of Colorado, Vail, CO. January -February 1994.

203. MR Abdominal Imaging Techniques. Abdominal Imaging Seminar, University of Colorado, Vail, CO. January -February 1994.

204. MR Imaging Techniques. Breast Cancer: New Advances in MR. Postgraduate Magnetic Resonance Imaging Course, Department of Radiology, University of California, San Diego, School of Medicine, San Diego, CA. February 1994.

205. MR for Liver Lesion Detection. Breast Cancer: New Advances in MR. Postgraduate Magnetic Resonance Imaging Course, Department of Radiology, University of California, San Diego, School of Medicine, San Diego, CA. February 1994.

206. Characterization of Hepatic Disease by MRI. MRI in Clinical Practice, Breckenridge, CO. February 1994.

207. MR of the Breast. MRI in Clinical Practice, Breckenridge, CO. February 1994.

208. Gynecological Applications of MRI. MRI in Clinical Practice, Breckenridge, CO. February 1994.

209. MR of the Thoracic Aorta. MRI in Clinical Practice, Breckenridge, CO. February 1994.

210. Safety Considerations for MRI. Grand Rounds, Department of Radiology, Long Island College Hospital, Brooklyn, NY. March 1994.

211. Will MR Imaging Replace CT for Upper Abdominal Imaging? Plenary Symposium, Annual Meeting of the Society of Magnetic Resonance, Dallas, TX. March 1994.

212. New Imaging Techniques. 46th Annual Midwest Cancer Conference, American Cancer Society Kansas Division, The University of Kansas School of Medicine-Wichita, Wichita, KS. March 1994.

213. Abdominal MR Imaging Techniques. South Central Kansas Radiological Society, Wichita, KS. March 1994.

214. MRI of the Prostate. South Central Kansas Radiological Society, Wichita, KS. March 1994.

215. Gynecologic Applications of MRI. South Central Kansas Radiological Society, Wichita, KS. March 1994.

216. Magnetic Resonance Angiography. University of Hawaii at Manoa John A. Burns School of Medicine, Laini, HI. March 1994.

217. MRI of the Prostate. University of Hawaii at Manoa John A. Burns School of Medicine, Laini, HI. March 1994.

218. Abdominal MRI. University of Hawaii at Manoa John A. Burns School of Medicine, Laini, HI. March 1994.

219. MRI of the Liver. University of Hawaii at Manoa John A. Burns School of Medicine, Laini, HI. March 1994.

220. Techniques for Abdominal MRI. University of Hawaii at Manoa John A. Burns School of Medicine, Laini, HI. March 1994.

221. MR Fat Suppression Techniques. Diagnostic Imaging Update, Department of -Radiology, Stanford University School of Medicine, Amelia Island, FL. April 1994.

222. MRI Abdominal Imaging Techniques. Diagnostic Imaging Update, Department of Radiology, Stanford University School of Medicine, Amelia Island, FL. April 1994.

223. MRI of the Thoracic Aorta. Diagnostic Imaging Update, Department of Radiology, Stanford University School of Medicine, Amelia Island, FL. April 1994.

224. MRI of the Prostate. Diagnostic Imaging Update, Department of Radiology, Stanford University School of Medicine, Amelia Island, FL. April 1994.

225. MRI of the Breast. Diagnostic Imaging Update, Department of Radiology, Stanford University School of Medicine, Amelia Island, FL. April 1994.

226. Fast MR Imaging Techniques. Midwest MRI Symposium, Kansas City, MS. April 1994.

227. MRI of the Breast. Advances in Screening, Diagnosis, and Treatment of Breast Cancer National Teleconference, Hospital of the University of Pennsylvania, Philadelphia, PA. April 1994.

228. Pelvic MR. Society of Computed Body Tomography and Magnetic Resonance Annual Course, Seattle, WA. April 1994.

229. Abdominal and Pelvic MR Workshop. Society of Computed Body Tomography and Magnetic Resonance Annual Course, Seattle, WA. April 1994.

230. MRI of the Liver. Radiology Grand Rounds, St. Luke's-Roosevelt Hospital Center, New York, NY. April 1994.

231. New Developments in MRI. Rhode Island MRI Network, Warwick, RI. April 1994.

232. MRI of the Breast. South Florida Radiological Society Annual Spring Seminar, Miami, FL. April 1994.

233. Abdominal Imaging Techniques. South Florida Radiological Society Annual Spring Seminar, Miami, FL. April 1994.

234. An Update on MRI of the Prostate. South Florida Radiological Society Annual Spring Seminar, Miami, FL. April 1994.

235. CT/MR of the Female Pelvis. Second Annual Review of Radiology, The Department of Radiology Albert Einstein College of Medicine & Montefiore Medical Center, New York, NY. May 1994.

236. Techniques for Abdominal MRI. Pitt Summer Imaging Course, University of Pittsburgh, Williamsburg, VA. June 1994.

237. MRI of the Breast. Pitt Summer Imaging Course, University of Pittsburgh, Williamsburg, VA. June 1994.

238. MRI of the Female Pelvis. Pitt Summer Imaging Course, University of Pittsburgh, Williamsburg, VA. June 1994.

239. Prostate MRI. Pitt Summer Imaging Course, University of Pittsburgh, Williamsburg, VA. June 1994.

240. MR Angiography Body Applications. Comprehensive Course in MR Imaging, The Medical College of Wisconsin, Santa Fe, NM. July 1994.

241. Current Techniques for Abdominal MR Imaging. Comprehensive Course in MR Imaging, The Medical College of Wisconsin, Santa Fe, NM. July 1994.

242. Can MR Replace CT in Abdominal Imaging. Comprehensive Course in MR Imaging, The Medical College of Wisconsin, Santa Fe, NM. July 1994.

243. Hepatic MRI. Comprehensive Course in MR Imaging, The Medical College of Wisconsin, Santa Fe, NM. July 1994.

244. MRI of the Breast. Comprehensive Course in MR Imaging, The Medical College of Wisconsin, Santa Fe, NM. July 1994.

245. Intravenous and Oral Contrast Agents for Abdominal and Pelvic MR. Comprehensive Course in MR Imaging, The Medical College of Wisconsin, Santa Fe, NM. July 1994.

246. MR of the Male and Female Pelvis. Comprehensive Course in MR Imaging, The Medical College of Wisconsin, Santa Fe, NM. July 1994.

247. MRI of the Breast. Society of Computed Body Tomography and Magnetic Resonance Summer Practicum, Napa, CA. August 1994.

248. Imaging of the Cirrhotic Liver. Society of Computed Body Tomography and Magnetic Resonance Summer Practicum, Napa, CA. August 1994.

249. Hepatic MR Imaging Techniques. Society of Computed Body Tomography and Magnetic Resonance Summer Practicum, Napa, CA. August 1994.

250. MR Evaluation of Benign Gynecologic Disease. Society of Computed Body Tomography and Magnetic Resonance Summer Practicum, Napa, CA. August 1994.

251. Guide to MR Imaging Protocols: What a Radiologist Needs to Know. Refresher Course, RSNA, Chicago, IL. November 1994, 95, 96, 97.

252. Newer Cancer Diagnostics. NYU Medical Alumni Weekend, NYU Medical Center, New York, NY. April 1995.

253. Breast MRI: Implants and Breast Cancer. MRI Symposium on Imaging of the Female Patient, Norwalk Hospital, Norwalk, CT. April 1995.

254. MRI of the Prostate. Spring Scientific Session of the New York Roentgen Society, New York, NY. April 1995.

255. MR Pulse Sequences for Liver Imaging. Society of Computed Body Tomography and Magnetic Resonance Annual Course, New York, NY. May 1995.

256. MR Characterization of Liver Lesions. Society of Computed Body Tomography and Magnetic Resonance Annual Course, New York, NY. May 1995.

257. Fundamentals of Breast MRI (Workshop). Society of Computed Body Tomography and Magnetic Resonance Annual Course, New York, NY. May 1995.

258. Page 50MRA of the Body. Society of Computed Body Tomography and Magnetic Resonance Annual Course, New York, NY. May 1995.

259. International Investigation of Breast MRI. Society for Magnetic Resonance Workshop on Breast MRI, Washington, D.C., June 24-5, 1995.

260. Stereotactic MRI Guided Fine Needle Aspiration of the Breast. Society for Magnetic Resonance Workshop on Breast MRI, Washington, D.C., June 24-5, 1995.

261. Techniques for Abdominal MRI. Society of Computed Body Tomography and Magnetic Resonance Summer Practicum, Greenbrier, WV. August 7-11, 1995.

262. MRI of the Breast and MRI-Guided Breast Biopsy. Society of Computed Body Tomography and Magnetic Resonance Summer Practicum, Greenbrier, WV. August 7-11, 1995.

263. MR Angiography and Fast Scanning Techniques. Society of Computed Body Tomography and Magnetic Resonance Summer Practicum, Greenbrier, WV. August 7-11, 1995.

264. MRI of the Breast. Roundtable of the New and Emerging Technologies for the Detection and Treatment of Breast Cancer, New York State Legislative Commission on Science and Technology, Copaigue, NY. November 16, 1995.

265. Guide to MR Imaging Protocols: What a Radiologist Needs to Know. MRI Conference, Tokyo University, Tokyo, Japan. December 28, 1995.

266. Abdominal MRI. MRI Special Interest Group of Center New Jersey, New 135.

267. MRI of the Breast. Central New York Radiological Society, Syracuse, NY. March 14, 1996.

268. Techniques for Abdominal MRI. **Clayton Hale Memorial Lecture**. Central New York Radiological Society, Syracuse, NY. March 14, 1996.

269. Abdominal MRI. MRI Special Interest Group of Center New Jersey, Brunswick, NJ. January 31, 1996.

270. MRI of Hepatic Neoplasms. Society of Computed Body Tomography and Magnetic Resonance Annual Course. Scottsdale, AZ. March 18-22, 1996.

271. MRI of the Prostate. Society of Computed Body Tomography and Magnetic Resonance Annual Course. Scottsdale, AZ. March 18-22, 1996.

272. MRA of the Aorta. Society of Computed Body Tomography and Magnetic Resonance Annual Course. Scottsdale, AZ. March 18-22, 1996.

273. Critical Overview of Breast MRI. Plenary Session. International Society of Magnetic Resonance Fourth Annual Scientific Meeting and Exhibition, New York, NY May 1, 1996.

274. Liver MR: Why and How. Clinical Categorical Course. International Society of Magnetic Resonance Fourth Annual Scientific Meeting and Exhibition, New York, NY. May 1, 1996.

275. New Developments in MRI. Medical Grand Rounds. Community Medical Center, Toms River, NJ. May 23, 1996.

276. MR of the Breast. Society of Computed Body Tomography and Magnetic Resonance Summer Practicum. Aspen, CO. August 19- 23, 1996.

277. MR Angiography of the Aorta. Society of Computed Body Tomography and Magnetic Resonance Summer Practicum. Aspen, CO. August 19- 23, 1996.

278. New Techniques for Body MRI. Society of Computed Body Tomography and Magnetic Resonance Summer Practicum. Aspen, CO. August 19- 23, 1996.

279. MR Clinical Cases with Practical Lessons. Society of Computed Body Tomography and Magnetic Resonance Summer Practicum. Aspen, CO. August 19- 23, 1996.

280. Gadolinium Enhanced MR Angiography. New Jersey Radiological Society. Newark, NJ, September 18, 1996.

281. MRA of the Thoracic Aorta. Introduction to Clinical Applications of MRA. University of Wisconsin Medical School, Newton, MA September 20, 1996.

282. MRA of the Abdominal Aorta. Introduction to Clinical Applications of MRA. University of Wisconsin Medical School, Newton, MA September 20, 1996.

283. Techniques for Abdominal MRI, University of Toronto, Toronto, Ontario, Canada. October 4,1996.

284. MRI of the Breast, University of Toronto, Toronto, Ontario, Canada. October 4,1996.

285. MRI of the Prostate. Body Imaging Update, University of Toronto, Toronto, Ontario, Canada. October 4,1996.

286. New Techniques for Abdominal MRI. MRI Society of Greater Houston. Houston, TX. October 24, 1996.

287. Recent Advances in Breast and Pelvic Magnetic Resonance Imaging. Grand Rounds. Presbyterian Hospital of Dallas, Dallas, TX. October 25, 1996.

288. Techniques for Abdominal MRI. Diagnostic Radiology Update. University of Texas Southwestern Medical School, Dallas, TX. October 27, 1996.

289. Gd-Enhanced 3D MR Aortography. Diagnostic Radiology Update. University of Texas Southwestern Medical School, Dallas, TX. October 27, 1996.

290. Controversies in Breast MRI. Diagnostic Radiology Update. University of Texas Southwestern Medical School, Dallas, TX. October 27, 1996.

291. Introduction to MRA. Rhode Island MRI Network. Providence, RI. October 30, 1996.

292. Techniques for Abdominal MRI. Rhode Island MRI Network. Providence, RI. October 30, 1996.

293. MRA of the Aorta. University of Wisconsin Medical School. Charlotte, NC. November 9, 1996.

294. Introduction to Clinical Applications of MRA. University of Wisconsin Medical School. Charlotte, NC. November 9, 1996.

295. Peripheral MRA. Introduction to Clinical Applications of MRA. University of Wisconsin Medical School, New Orleans, December 13, 1996.

296. MRA of the Aortic Arch. Introduction to Clinical Applications of MRA. University of Wisconsin Medical School, New Orleans, December 13, 1996.

297. Body MRA. Grand Rounds. Department of Radiology, Albert Einstein College of Medicine, Bronx, NY. January 14, 1996.

298. Localization of Occult Breast Cancers with MRI. International MR Symposium, Garmisch-Partenkirchen. Germany, January 24, 1997.

299. MRI of the Liver. Radiology Grand Rounds. Lenox Hill Hospital, New York, NY. February 5, 1997

300. The American College of Radiology (ACR) MR Equipment Accreditation Program. Magnetic Resonance Imaging Conference for Technologists. Northwest Imaging Forums, Las Vegas, NV, February 21, 1997

301. Body MRA. The South Florida Radiological Society. Miami, FL. March 19, 1997

302. MRI of Thoracic Aortic Dissection, Abdominal MRI: Is Gadolinium Always Necessary. Society of Computed Body Tomography and Magnetic Resonance Annual Course. Washington, DC. April 14-18, 1997.

303. Imaging of the Cirrhotic Liver by MRI. Society of Computed Body Tomography and Magnetic Resonance Annual Course. Washington, DC. April 14-18, 1997.

304. MRI of the Breast. Society of Computed Body Tomography and Magnetic Resonance Annual Course. Washington, DC. April 14-18, 1997.

305. Hepatobiliary MRI. Categorical Course, American Roentgen Ray Society Annual Meeting. Boston, MA, May 5, 1997.

306. Normal MRI of the Abdomen. International Course of Advances in Magnetic Resonance and Computed Tomography. Instituto Clinica Corachan, Barcelona, Spain. May 28-30, 1997.

307. Normal MRI of the Pelvis. International Course of Advances in Magnetic Resonance and Computed Tomography. Instituto Clinica Corachan, Barcelona, Spain. May 28-30, 1997.

308. Angio MRI of the Body. International Course of Advances in Magnetic Resonance and Computed Tomography. Instituto Clinica Corachan, Barcelona, Spain. May 28-30, 1997.

309. MRI of the Abdomen: An Update. International Course of Advances in Magnetic Resonance and Computed Tomography. Instituto Clinica Corachan, Barcelona, Spain. May 28-30, 1997.

310. MRI of the Breast. International Course of Advances in Magnetic Resonance and Computed Tomography. Instituto Clinica Corachan, Barcelona, Spain. May 28-30, 1997.

311. Breast MRI. Breast Imaging Seminar. Memorial Sloan-Kettering Cancer Center, New York, NY. June 11, 1997.

312. MRA of the Aorta. University of Wisconsin Medical School. San Diego, CA June 20, 1997.

313. Reimbursement Issues for MRA. University of Wisconsin Medical School. San Diego, CA June 20, 1997.

314. Introduction to Clinical Applications of MRA. University of Wisconsin Medical School. San Diego, CA June 20, 1997.

315. Techniques for Abdominal MRI. Abdominal Imaging Conference. University of Pennsylvania Medical Center. Jackson Hole, WY. June 30-July 4, 1997.

316. Hepatobiliary MRI. Abdominal Imaging Conference. University of Pennsylvania Medical Center. Jackson Hole, WY. June 30-July 4, 1997.

317. Gadolinium Enhanced Body MRA. Abdominal Imaging Conference. University of Pennsylvania Medical Center. Jackson Hole, WY. June 30-July 4, 1997.

318. MRI of the Prostate. Abdominal Imaging Conference. University of Pennsylvania Medical Center. Jackson Hole, WY. June 30-July 4, 1997.

319. Advances in Magnetic Resonance Imaging. U.S. Army War College Tour. New York, NY. October, 1995, 96, 97, 98, 99.

320. MRA of the Body. Delaware Valley MRI Society, Philadelphia, PA. October 9, 1997.

321. MRI of Cirrhotic Liver Nodules. New York Roentgen-Society, New York, NY. October 20, 1997.

322. Hepatobiliary MRI: How and Why. **Sandy Bluestein Memorial Lecture**. Yale University School of Medicine, New Haven, CT. October 30, 1997.

323. MRI of Hepatic Neoplasms. International Conference on Hepatic Neoplasms. New York, NY. November 13, 1997.

324. Advances in Body MR Angiography. Michigan Radiological Society. Detroit, MI. January 8, 1998.

325. Advances in Body MR. GI/GU Minicourse, Massachusetts General Hospital, Boston, MA. January 15, 1998.

326. MRI of the Thoracic Aorta. International London Annual Course in Computed Tomography and Magnetic Resonance Imaging. Auchterarder Perthshire, Scotland. March 8-12, 1998.

327. MRI of the Breast. International London Annual Course in Computed Tomography and Magnetic Resonance Imaging. Auchterarder Perthshire, Scotland. March 8-12, 1998.

328. Contrast Enhanced 3D MR Angiography. International London Annual Course in Computed Tomography and Magnetic Resonance Imaging. Auchterarder Perthshire, Scotland. March 8-12, 1998.

329. Current Techniques for MRI of the Abdomen. International London Annual Course in Computed Tomography and Magnetic Resonance Imaging. Auchterarder Perthshire, Scotland. March 8-12, 1998.

330. MR of the Breast. Radiology Update 1998. Medical College of Wisconsin, Whistler, BC, Canada. July 30 - 31, 1998.

331. Current Concepts in Hepatobiliary MR. Radiology Update 1998. Medical College of Wisconsin, Whistler, BC, Canada. July 30 - 31, 1998.

332. MR of the Aorta. Radiology Update 1998. Medical College of Wisconsin, Whistler, BC, Canada. July 30 - 31, 1998.

333. Contrast Enhanced Body MRA, PACS Implementation and Economics. Radiology Update 1998. Medical College of Wisconsin, Whistler, BC, Canada. July 30 - 31, 1998.

334. Body MRA. 17th International Cancer Congress. Rio de Janeiro, Brazil. August 28, 1998.

335. Abdominal MR Imaging. 8th Radiological Symposium. Karl-Franzens University and Medical School Graz, Graz, Austria. October 15-17, 1998.

336. Technical and Clinical Considerations for Gadolinium-Enhanced MRA. Greater Louisville Radiologist Society. Louisville, KY. October 21, 1998.

337. Technical and Clinical Considerations for Gadolinium-Enhanced MRA. Bluegrass Radiologist Society. Lexington, KY. October 22, 1998.

338. MRI of Cirrhotic Liver Nodules. International MR Symposium. Garmisch-Partenkirchen, Germany, January 29-31, 1999.

339. Dynamic Breath-hold 3D MRI. International MR Symposium. Garmisch-Partenkirchen, Germany, January 29-31, 1999.

340. Abdominal MRI Techniques and Clinical Applications. Magnetic Resonance Imaging in Oncology. The Royal Marsden NIH Trust, London, England, February 8-10, 1999.

341. MRI of the Breast. Magnetic Resonance Imaging in Oncology. The Royal Marsden NIH Trust, London, England, February 8-10, 1999.

342. Liver Tumours-Primary and Secondary. Magnetic Resonance Imaging in Oncology. The Royal Marsden NIH Trust, London, England, February 8-10, 1999.

343. Current Techniques for Abdominal MRI. Radiology Grand Rounds. SUNY at Stony Brook Health Sciences Center, Stony Brook, NY, February 18, 1999.

344. Breast MRI. Postgraduate MRI. University of California, San Diego, School of Medicine, San Diego, CA, March 11-12, 1999.

345. MR Imaging of the Liver. Postgraduate MRI. University of California, San Diego, School of Medicine, San Diego, CA, March 11-12, 1999.

346. Fundamentals of Gd-Enhanced MRA. Postgraduate MRI. University of California, San Diego, School of Medicine, San Diego, CA, March 11-12, 1999.

347. MR Angiography of the Aorta and Its Branches. Postgraduate MRI. University of California, San Diego, School of Medicine, San Diego, CA, March 11-12, 1999.

348. MR Applications of 3D Volume Imaging. Real-Time 3D Imaging and Volume Rendering Course. Johns Hopkins University School of Medicine, Orlando, FL, March 27-28, 1999.

349. Contrast Agents for Hepatic MRI: How, Which, Why? Society of Computed Tomography and Magnetic Resonance Twenty-Second Annual Course. New Orleans, LA, April 12-16, 1999.

350. Update on Breast MRI. Society of Computed Tomography and Magnetic Resonance Twenty-Second Annual Course. New Orleans, LA, April 12-16, 1999.

351. MR of the Breast. Clinical Essentials of CT & MRI. Institute for Advanced Medical Education, Atlanta, GA. April 23-25, 1999.

352. Fundamentals of Body MRA. Clinical Essentials of CT & MRI. Institute for Advanced Medical Education, Atlanta, GA. April 23-25, 1999.

353. Male and Female Pelvis. Clinical Essentials of CT & MRI. Institute for Advanced Medical Education, Atlanta, GA. April 23-25, 1999.

354. Techniques and Clinical Applications of Gadolinium-Enhanced Body MR Angiography. New York Roentgen Society Spring Conference. New York, NY, April28, 1999.

355. Contrast Agents for Hepatic MRI. International Course on Advances in Magnetic Resonance and Computed Tomography. Barcelona, Spain, May 12-14, 1999.

356. Hepatic MRI: Effective and Efficient Scanning. International Course on Advances in Magnetic Resonance and Computed Tomography. Barcelona, Spain, May 12-14, 1999.

357. Gd-Enhanced MR Angiography: A Primer for Radiologists. International Course on Advances in Magnetic Resonance and Computed Tomography. Barcelona, Spain, May 12-14, 1999.

358. MRI and MRA of the Aorta. International Course on Advances in Magnetic Resonance and Computed Tomography. Barcelona, Spain, May 12-14, 1999.

359. MRI of the Breast: An Update. International Course on Advances in Magnetic Resonance and Computed Tomography. Barcelona, Spain, May 12-14, 1999.

360. Hot Topics for Clinical Practice: MRI of the Breast and Pelvis. International Society for Magnetic Resonance in Medicine Seventh Scientific Meeting and Exhibition. Philadelphia, PA, May 24, 1999.

361. Hepatic MRI Contrast Agents: Why, Which, How, When? Essential Radiology 1999. Ithaca Center for Continuing Postgraduate Medical Education, Mackinac Island, MI, July 12 - 16, 1999.

362. Optimization of Contrast-Enhanced 3D MRA. Essential Radiology 1999. Ithaca Center for Continuing Postgraduate Medical Education, Mackinac Island, MI, July 12 - 16, 1999.

363. Current Techniques and Applications of Abdominal MRI and MRCP. Essential Radiology 1999. Ithaca Center for Continuing Postgraduate Medical Education, Mackinac Island, MI, July 12 - 16, 1999.

364. Update on Breast MRI. Essential Radiology 1999. Ithaca Center for Continuing Postgraduate Medical Education, Mackinac Island, MI, July 12 - 16, 1999.

365. Hepatic MRI: Effective and Efficient Scanning. Middle Tennessee Radiology Society, Nashville, TN, August 31, 1999.

366. An Update on Breast MRI. Middle Tennessee Radiology Society, Nashville, TN, August 31, 1999.

367. Building a Team for Change in Academic Radiology. European Working Group on Management in Radiology. European Association of Radiology. Strasbourg, France, September 9, 1999.

368. MRI of the Pancreas and Biliary System. University of California, San Francisco Clinical Magnetic Resonance Imaging Postgraduate Course, San Francisco, CA, October 4-8, 1999.

369. Techniques for Abdominal MRI. University of California, San Francisco Clinical Magnetic Resonance Imaging Postgraduate Course, San Francisco, CA, October 4-8, 1999.

370. Contrast Agents for Hepatic MRI: Why, Which, How, When? . University of California, San Francisco Clinical Magnetic Resonance Imaging Postgraduate Course, San Francisco, CA, October 4-8, 1999.

371. MRI of the Cirrhotic Liver: New Findings and Imaging Implications. University of California, San Francisco Clinical Magnetic Resonance Imaging Postgraduate Course, San Francisco, CA, October 4-8, 1999.

372. New Technologies Presentation for HCFA. American College of Radiology Economics and Health Policy Department. Reston, VA, October 19, 1999.

373. MRI of the Cirrhotic Liver: New Observations and Imaging Implications. Long Island Radiological Society, Woodbury, NY, November 9, 1999.

374. What's on the Horizon in Body Imaging. Magnetic Resonance Advocates Development, Ithaca center for Postgraduate Medical Education, Orlando, FL, January 15, 2000.

375. Radiology Reengineering: Lessons Learned. **Senturia Lecture**. Mallinckrodt Institute of Radiology, St. Louis, MO, February 21, 2000.

376. Techniques for Abdominal MRI That Really Work. MRI in Clinical Practice. Educational Symposia, Inc., Snowmass, CO, March 12 -17, 2000.

377. MR of the Cirrhotic Liver. MRI in Clinical Practice. Educational Symposia, Inc., Snowmass, CO, March 12 -17, 2000.

378. Update on Breast MRI, Techniques and Applications for Body MRA. MRI in Clinical Practice. Educational Symposia, Inc., Snowmass, CO, March 12 -17, 2000.

379. Practical Use of Body MRA. Clinical Essentials of CT & MRI. Institute for Advanced Medical Education, Las Vegas, NV, March 25, 2000.

380. MR Imaging of the Pancreas and Biliary System. Clinical Essentials of CT & MRI. Institute for Advanced Medical Education, Las Vegas, NV, March 25, 2000.

381. Techniques for Abdominal MRI. Radiology Grand Rounds. Roosevelt Hospital, New York, NY, March 28, 2000.

382. Disease Management. International Society for Magnetic Resonance in Medicine Ninth Scientific Meeting and Exhibition. Denver, CO, April 4, 2000.

383. MRI of the Pancreas and Biliary System. Magnetic Resonance Imaging National Symposium, Educational Symposia, Inc., Las Vegas, NV, May 5, 2000.

384. Techniques for Abdominal MRI That Really Work. Magnetic Resonance Imaging National Symposium, Educational Symposia, Inc., Las Vegas, NV, May 5, 2000.

385. MRI of the Cirrhotic Liver: New Observations and Imaging Implications. Magnetic Resonance Imaging National Symposium, Educational Symposia, Inc., Las Vegas, NV, May 5, 2000.

386. Update on Breast MRI. Magnetic Resonance Imaging National Symposium, Educational Symposia, Inc., Las Vegas, NV, May 5, 2000.

387. Techniques for Abdominal MRI That Really Work. Radiology Grand Rounds, St. Lukes-Roosevelt Medical Center, New York, NY, May 9, 2000.

388. Techniques for Abdominal MRI. Buffalo Radiological Society, Buffalo, NY, May 16, 2000.

389. Update on MRI of the Breast. Buffalo Radiological Society, Buffalo, NY, May 16, 2000.

390. Issues Facing Radiology Related to ACR Accreditation :MRI, Cardiovascular, and Neuroradiology. Intersociety Summer Conference, San Diego, CA, July 27, 2000.

391. Magnetic Resonance Cholangiopancreatography. 21st International Congress of Radiology, Buenos Aires, Argentina, September 4-8, 2000.

392. MRI of the Cirrhotic Liver. 21st International Congress of Radiology, Buenos Aires, Argentina, September 4-8, 2000.

393. Current Techniques for Hepatic MRI, Update on MRI of the Breast. 21st International Congress of Radiology, Buenos Aires, Argentina, September 4-8, 2000.

394. Gadolinium-Enhanced 3D MRA. The STAR Program. Jeddah, Saudi Arabia, October 2, 2000.

395. Techniques for Abdominal MRI. The STAR Program. Jeddah, Saudi Arabia, October 2, 2000.

396. An Update on MRI of the Breast. The STAR Program. Jeddah, Saudi Arabia, October 2, 2000.

397. MRI of the Pancreas and Biliary System. The STAR Program. Jeddah, Saudi Arabia, October 2, 2000.

398. Gadolinium-Enhanced 3D MRA. The STAR Program. Cairo, Egypt, October 5, 2000.

399. Techniques for Abdominal MRI. The STAR Program. Cairo, Egypt, October 5, 2000.

400. An Update on MRI of the Breast. The STAR Program. Cairo, Egypt, October 5, 2000.

401. MRI of the Pancreas and Biliary System. The STAR Program. Cairo, Egypt, October 5, 2000.

402. How I Do Abdominal MRI at NYU. Clinical Essentials of CT & MRI, Institute for Advanced Medical Education, Atlanta, GA, October 29, 2000.

403. MRI of the Cirrhotic Liver. Clinical Essentials of CT & MRI, Institute for Advanced Medical Education, Atlanta, GA, October 29, 2000.

404. Breast MRI. Clinical Essentials of CT & MRI, Institute for Advanced Medical Education, Atlanta, GA, October 29, 2000.

405. American College of Radiology Accreditation Programs: Major Issues and Update 2000. Refresher Course. Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL, November 26, 2000.

406. MRI of the Cirrhotic Liver. Radiology Grand Rounds, Jacobi Hospital Center, Bronx, NY, January 16, 2001.

407. It's Time to Re-Evaluate MRI and MR Spectroscopy of the Liver. MRI in Clinical Practice, Educational Symposia, Inc. Snowmass, CO, March 13,14, 2001.

408. Breast MRI Update 2001. MRI in Clinical Practice, Educational Symposia, Inc. Snowmass, CO, March 13,14, 2001.

409. Pearls and Pitfalls of Body MRI. MRI in Clinical Practice, Educational Symposia, Inc. Snowmass, CO, March 13,14, 2001.

410. Practical Lessons form the ACR MRI Accreditation Program. MRI in Clinical Practice, Educational Symposia, Inc. Snowmass, CO, March 13,14, 2001.

411. What's on the Horizon in Body MRI? Society of Computed Tomography and Magnetic Resonance Twenty-Fourth Annual Course, Miami Beach, FL, March 18-22, 2001.

412. Breast MRI Update. Society of Computed Tomography and Magnetic Resonance Twenty-Fourth Annual Course, Miami Beach, FL, March 18-22, 2001.

413. Lessons from the ACR MRI Accreditation Program. Society of Computed Tomography and Magnetic Resonance Twenty-Fourth Annual Course, Miami Beach, FL, March 18-22, 2001.

414. Techniques for Abdominal MRI That Really Work. **Leroy Sante Memorial Lecture**. St. Louis University, St. Louis, MO, April 10, 2001.

415. MR of the Cirrhotic Liver. New York Roentgen Society Annual Spring Meeting, New York, NY, April 20, 2001.

416. Advances in MRI of the Pancreas and Biliary System. **Thomas C. Benventano Memorial Lecture**. Montefiore Medical Center, Albert Einstein College of Medicine, Bronx, NY, May 10, 2001.

417. MRI of the Cirrhotic Liver. 6th International Course; Advances in MR & CT. Barcelona, Spain, May 16, 2001

418. Update on Prostate MRI and MR Spectroscopy. 6th International Course; Advances in MR & CT. Barcelona, Spain, May 16, 2001

419 Update on MRI of the Breast. 6th International Course; Advances in MR & CT. Barcelona, Spain, May 17, 2001

420. Techniques for Abdominal MRI That Really Work. Advances in MR & CT. Barcelona, Spain, May 18, 2001

421. MRI of the Cirrhotic Liver: New Observations and Clinical Implications. Society of Computed Tomography and Magnetic Resonance Eleventh Summer Practicum. Keystone, CO, August 20-24, 2001

422. MRI of the Breast. Society of Computed Tomography and Magnetic Resonance Eleventh Summer Practicum. Keystone, CO, August 20-24, 2001

423. Techniques for Abdominal MRI that Really Work. Society of Computed Tomography and Magnetic Resonance Eleventh Summer Practicum. Keystone, CO, August 20-24, 2001

424. Instructional Cases for Body MRI. Society of Computed Tomography and Magnetic Resonance Eleventh Summer Practicum. Keystone, CO, August 20-24, 2001

425. American College of Radiology Accreditation Programs: Updates and New Programs. Refresher Course. Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL, November 26, 2001.

426. Update on Breast MRI. MRI in Clinical Practice, Educational Symposia, Inc. Snowmass, CO, February 24-March 1, 2002.

427. MRI and MRCP of the Pancreas and Biliary System. MRI in Clinical Practice, Educational Symposia, Inc. Snowmass, CO, February 24-March 1, 2002.

428. Hepatic MRI: Lesions That Didn't Read the Book. MRI in Clinical Practice, Educational Symposia, Inc. Snowmass, CO, February 24-March 1, 2002.

429. Techniques for Hepatobiliary MRI that Really Work. Society of Computed Tomography and Magnetic Resonance Twenty-Fifth Annual Course, Charleston, SC, March 18-22, 2002.

430. Breast MRI Workshop. Society of Computed Tomography and Magnetic Resonance Twenty-Fifth Annual Course, Charleston, SC, March 18-22, 2002

431. CT and MR Accreditation Programs_American College of Radiolgy. Society of Computed Tomography and Magnetic Resonance Twenty-Fifth Annual Course, Charleston, SC, March 18-22, 2002

432. MR of the Pancreas and Biliary System. The 22nd Annual Course in Computed Tomography and Magnetic Resonance Imaging.Royal College of Radiologists, Auchterarder, Perthshire, Scotland. March 24-28,2002.

433. Abdominal MR: Techniques. The 22nd Annual Course in Computed Tomography and Magnetic Resonance Imaging.Royal College of Radiologists, Auchterarder, Perthshire, Scotland. March 24-28,2002.

434. MR Breast-Update 2002. The 22nd Annual Course in Computed Tomography and Magnetic Resonance Imaging. Royal College of Radiologists, Auchterarder, Perthshire, Scotland. March 24-28,2002.

435. Staging Prostate Cancer with MR and MRS. The 22nd Annual Course in Computed Tomography and Magnetic Resonance Imaging. Royal College of Radiologists, Auchterarder, Perthshire, Scotland. March 24-28,2002.

436. Pearls and Pitfalls of Abdominal MR. The 22nd Annual Course in Computed Tomography and Magnetic Resonance Imaging. Royal College of Radiologists, Auchterarder, Perthshire, Scotland. March 24-28,2002.

437. Breast MRI. Clinical Essentials of CT & MRI. Institute for Advanced Medical Education. Las Vegas, NV. May 4, 2002.

438. Liver MRI. Clinical Essentials of CT & MRI. Institute for Advanced Medical Education. Las Vegas, NV. May 4, 2002.

439. Body MR and MRA Interpretation Rounds. Clinical Essentials of CT & MRI. Institute for Advanced Medical Education. Las Vegas, NV. May 4, 2002.

440. MR Angiography of the Body. College of Radiology and Academy of Medicine, Malaysia. STAR Program 2002. Kual Lumpur, Malaysia. June 15, 2002.

441. MRI of the Cirrhotic Liver. College of Radiology and Academy of Medicine, Malaysia. STAR Program 2002. Kuala Lumpur, Malaysia. June 15, 2002.

442. MRI and MR Spectroscopy of the Prostate. College of Radiology and Academy of Medicine, Malaysia. STAR Program 2002. Kuala Lumpur, Malaysia. June 16, 2002.

443. Techniques for Abdominal MRI That Really Work. College of Radiology and Academy of Medicine, Malaysia. STAR Program 2002. Kuala Lumpur, Malaysia. June 16, 2002.

444. MR Angiography of the Body. Royal College of Radiology and Radiology Society of Thailand. STAR Program 2002. Bangkok, Thailand. June 18, 2002.

445. MRI of the Cirrhotic Liver. Royal College of Radiology and Radiology Society of Thailand. STAR Program 2002. Bangkok, Thailand. June 18, 2002.

446. MRI and MR Spectroscopy of the Prostate. Royal College of Radiology and Radiology Society of Thailand. STAR Program 2002. Bangkok, Thailand. June 19, 2002.

447. Techniques for Abdominal MRI. Royal College of Radiology and Radiology Society of Thailand. STAR Program 2002. Bangkok, Thailand. June 19, 2002.

448. MR Angiography of the Body.STAR Program 2002. Hangzhou, China. June 22, 2002.

449. MRI of the Cirrhotic Liver. STAR Program 2002. Hangzhou, China. June 22, 2002.

450. MRI and MR Spectroscopy of the Prostate. STAR Program 2002. Hangzhou, China. June 22, 2002.

451. Techniques for Abdominal MRI 2002. Essential Radiology 2002. Ithaca Center for Postgraduate Medical Education. Mackinac Island, MI. August 28, 2002.

452. MRI of the Cirrhotic Liver. Essential Radiology 2002. Ithaca Center for Postgraduate Medical Education. Mackinac Island, MI. August 28, 2002.

453. Breast MRI Update. Essential Radiology 2002. Ithaca Center for Postgraduate Medical Edcucation. Mackinac Island, MI. August 29, 2002.

454. Prostate MRI and MR Spectroscopy. Essential Radiology 2002. Ithaca Center for Postgraduate Medical Education. Mackinac Island, MI. August 29, 2002.

455. MRI of the Cirrhotic Liver. Grand Rounds. Mayo Clinic. Rochester, MN. September 19, 2002.

456. Prostate MRI and MRSI. Mayo Clinic. Rochester, MN. September 20, 2002.

457. Accreditation Issues. ACR 79th Annual Meeting. Miami, FL. September 29, 2002

458. Advanced Techniques for Abdominal MRI. Connecticut Radiology Society. Berlin, CT. October 9, 2002

459. Prostate MR: Born Again. MRI:Clinical State-of-the-Art. New York University School of Medicine. New York, NY. October 16, 2002.

460. Advanced Techniques for Abdominal MRI. MRI:Clinical State-of-the-Art. New York University School of Medicine. New York, NY. October 16, 2002.

461. Breast MRI: Lessons We Have Learned. MRI:Clinical State-of-the-Art. New York University School of Medicine. New York, NY. October 16, 2002.

462. Principles of MRI that Affect Breast Imaging, Made Easy. Breast MRI In Your Facility. Stanford School of Medicine. Tysons Corner, VA. October 18, 2002.

463. Technical Aspects of Image Acquisition for Breast MRI. Breast MRI In Your Facility. Stanford School of Medicine. Tysons Corner, VA. October 18, 2002.

464. MRI-Guided breast Biopsy and Needle Localizations-How We Do It, Including Billing and Coding. Breast MRI in Your Facility. Stanford School of Medicine. Tysons Corner, VA. October 19, 2002.

465. MRI of the Breast. 33rd International Symposium of the Princess Takamatsu Cancer Research Fund. Tokyo, Japan. November 12, 2002.

466. An Update on Breast MRI. Radiological Society of New Jersey. New Brunswick, NJ. November 21, 2002.

467. American College of Radiology Accreditation Programs:Updates and New Programs. Refresher Course. Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL. December 5, 2002.

468. Liver MR: Advanced Imaging. Refresher Course. Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL. December 1, 2002.

469. Advances in Body MRI: Faster, Finer, Physiologic. CT/MRI:Head to Toe. New York University School of Medicine. New York, NY. December 18, 2002.

470. Breast MRI: Practical Cases and Issues. CT/MRI:Head to Toe. New York University School of Medicine. New York, NY. December 18, 2002.

471. MRI of the Breast: Lessons Learned. Brown University-Rhode Island Hospital. Providence, RI, January 6, 2003.

472. MRI of the Cirrhotic Liver. Radiology Grand Rounds. Brown University-Rhode Island Hospital, Providence, RI, January 6, 2003.

473. MRI and MRSI of the Prostate. Radiology Grand Rounds. North Shore University Hospital, Manhasset, NY, January 15, 2003.

474. New Opportunities: Screening with MRI. MRI Consultants meeting. International Center for Postgraduate Medical Education. Dallas, TX, March 1, 2003.

475. MRI of the Breast. Society of Computed Tomography and Magnetic Resonance Twenty-Sixth Annual Course, Rancho Mirage, CA, March 24-28, 2003.

476. Prostate MRI and MRSI. Society of Computed Tomography and Magnetic Resonance Twenty-Sixth Annual Course, Rancho Mirage, CA, March 24-28, 2003.

477. MR Site Accreditation. Magnetic Resonance Imaging National Symposium. Las Vegas, NV, April 9, 2003

478. Gynecologic Applications of MRI in Routine Clinical Practice. Magnetic Resonance Imaging National Symposium. Las Vegas, NV, April 10, 2003

479. MRI of the Liver. Magnetic Resonance Imaging National Symposium. Las Vegas, NV, April 11, 2003

480. How Do Training, Education and Experience Effect Quality and Safety in Medicine? ACR Forum. Reston, VA, May 23, 2003

481. New Techniques for MRI:Faster, Finer, and Physiologic. 7th International Course:Advances in MR & CT. Barcelona, Spain. May 28-30, 2003

482. Gynecologic Applications of MRI. 7th International Course: Advances in MR & CT. Barcelona, Spain. May 28-30, 2003

483. MR Imaging and Spectroscopy of the Prostate. 7th International Course: Advances in MR & CT. Barcelona, Spain. May 28-30, 2003

484. MR of Breast Cancer: Lessons Learned. 7th International Course: Advances in MR & CT. Barcelona, Spain. May 28-30, 2003

485. Renal MR and MRA. Society of Computed Tomography and Magnetic Resonance Thirteenth Summer Practicum. Asheville, NC. July 27-31, 2003

486. MRI and MR Spectroscopy of the Prostate. Society of Computed Tomography and Magnetic Resonance Thirteenth Summer Practicum. Asheville, NC. July 27-31, 2003

487. Hepatic MRI Techniques. Society of Computed Tomography and Magnetic Resonance Thirteenth Summer Practicum. Asheville, NC. July 27-31, 2003

488. Breast MRI Update. Society of Computed Tomography and Magnetic Resonance Thirteenth Summer Practicum. Asheville, NC. July 27-31, 2003

489. Routine Gynecological Applications of MRI. Clinical Essentials of CT and MRI. Institute for Advanced Medical Education. Scottscale, AZ. October 18, 2003

490. Breast MRI Update. Clinical Essentials of CT and MRI. Institute for Advanced Medical Education. Scottscale, AZ. October 18, 2003

491. Body Imaging Rounds. Clinical Essentials of CT and MRI. Institute for Advanced Medical Education. Scottscale, AZ. October 18, 2003

492. Routine Gynecological Applications of MRI. Radiology Grand Rounds. University of Maryland. Baltimore, MD. October 22, 2003

493. MRI of the Cirrhotic Liver. University of Maryland. Baltimore, MD. October 22, 2003

494. Routine Gynecological Applications of MRI. Columbia University College for Physicians and Surgeons. New York, NY. October 29, 2003.

495. MRI of the Cirrhotic Liver. Radiology Grand Rounds. Columbia University College for Physicians and Surgeons. New York, NY. October 29, 2003.

496. Liver MR: Advanced Imaging. Refresher Course. Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL. December 1, 2003.

497. ACR MRI Orthopedic Module. D.C. Metropolitan Radiological Society. Washington, DC. January 22, 2004

498. MRI of the Cirrhotic Liver: New Observations. Department of Radiology, University of California San Francisco School of Medicine. Indian Wells, CA. February 4, 2004.

499. MRI of the Abdomen: Faster, Finer and Physiologic. Department of Radiology, University of California San Francisco School of Medicine. Indian Wells, CA. February 4, 2004.

500. Gynecologic Applications of MRI in Routine Clinical Practice. Department of Radiology, University of California San Francisco School of Medicine. Indian Wells, CA. February 4, 2004.

501. MRI of the Pancreas And Biliary System. Department of Radiology, University of California San Francisco School of Medicine. Indian Wells, CA. February 6, 2004.

502. Renal MRI/MRA. Department of Radiology, University of California San Francisco School of Medicine. Indian Wells, CA. February 6, 2004.

503. Gynecologic Applications of MRI in Routine Clinical Practice. Department of Radiology, University of Connecticut Health Center, Farmington, CT. February 11, 2004.

504. MRI of the Cirrhotic Liver, Department of Radiology Grand Rounds, University of Connecticut Health Center, Farmington, CT. February 11, 2004.

505. Current Status of Body MRA. New England Reontgen Ray Society, Boston, MA. February 27, 2004.

506. MRA Basics. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education, San Antonio, TX. April 16, 2004.

507. Body MRA. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education, San Antonio, TX. April 16, 2004.

508. Peripheral MRA. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education, San Antonio, TX. April 16, 2004.

509. Cardiac MRI. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education, San Antonio, TX. April 16, 2004.

510. MRA Basics. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education, Nashville, TN. April 17, 2004.

511. Body MRA. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education, Nashville, TN. April 17, 2004.

512. Peripheral MRA. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education, Nashville, TN. April 17, 2004.

513. Cardiac MRI. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education, Nashville, TN. April 17, 2004.

514. MRI of the Cirrhotic Liver. Radiology Grand Rounds. University of Indiana Medical Center, Indianapolis, IN. April 20, 2004.

515. How to Perform MRI of the Abdomen. University of Indiana Medical Center, Indianapolis, IN. April 20, 2004.

516. New Opportunities for MRI. MRI Summitt, International Center for Postgraduate Medical Education. Houston, TX. May 2, 2004

517. MRA Basics. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education, Chicago, IL. May 13, 2004

518. Body MRA. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education. Chicago, IL. May 13, 2004.

519. Peripheral MRA. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education, Chicago, IL. May 13, 2004.

520. Cardiac MRI. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education, Chicago, IL. May 13, 2004.

521. MRA Basics. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education, Dallas, TX. May 14, 2004.

522. Body MRA. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education, Dallas, TX. May 14, 2004.

523. Peripheral MRA. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education, Dallas, TX. May 14, 2004.

524. Cardiac MRI. Cardiovascular MR in Practice, International Center for Postgraduate Medical Education, Dallas, TX. May 14, 2004.

525. Screening Modalities and Target: Current Status. ACR Forum, Reston. VA. June16, 2004.

526. MRI of the Breast. Summer Radiology Review, Wake Forest University School of Medicine, Hilton Head, SC. June 23, 2004.

527. How to Interpret Hepatic MRI. Summer Radiology Review, Wake Forest University School of Medicine, Hilton Head, SC. June 23, 2004.

528. MRI of the Cirrhotic Liver. Summer Radiology Review, Wake Forest University School of Medicine, Hilton Head, SC. June 24, 2004.

529. Practical Gynecological Applications of MRI. Summer Radiology Review, Wake Forest University School of Medicine, Hilton Head, SC. June 24, 2004.

530. Routine Gynecological Applications of MRI. Sixty-sixth Midsummer Radiological Conference, Rocky Mountain Radiological Society, Vail, CO. June 9-11, 2004.

531. MRI of the Cirrhotic Liver. Sixty-sixth Midsummer Radiological Conference, Rocky Mountain Radiological Society, Vail, CO. June 9-11, 2004.

532. Breast MRI: Lessons Learned. Sixty-sixth Midsummer Radiological Conference, Rocky Mountain Radiological Society, Vail, CO. June 9-11, 2004.

533. Cardiac MRI. Congress on Non Invasive Vascular Imaging and MRI of the Body.University of Milan, Milan, Italy. October 1-2, 2004.

534. MRA Techniques and Applications. Congress on Non Invasive Vascular Imaging and MRI of the Body.University of Milan, Milan, Italy. October 1-2, 2004.

535. New Techniques for Body MRI. Congress on Non Invasive Vascular Imaging and MRI of the Body.University of Milan, Milan, Italy. October 1-2, 2004.

536. MRI and MR Spectroscopy of the Prostate. Congress on Non Invasive Vascular Imaging and MRI of the Body.University of Milan, Milan, Italy. October 1-2, 2004.

537. MRCP. Congress on Non Invasive Vascular Imaging and MRI of the Body. University of Milan, Milan, Italy. October 1-2, 2004

538. Breast MRI. Connecticut Radiological Society, Berlin, CT. October 13, 2004

539. How to Interpret Hepatic MRI. The University of Texas M.D. Anderson Cancer Center. Houston, TX. November 15, 2004

540. MRI of the Cirrhotic Liver. **John S. Dunn, Sr. Lectureship**, The Houston Radiological Society, Houston, TX. November 15, 2004

541. How to Interpret Hepatic MRI:The Cirrhotic Liver. Radiology Grand Rounds, Baptist Hospital East, Louisville, KY. November 16, 2004

542. Body Applications of MRI. Hospital Grand Rounds, Baptist Hospital East, Louisville, KY. November 16, 2004

543. How to Interpret Hepatic MRI: The Non-Cirrhotic Liver. Greater Louisville Radiological Society, Louisville, KY. November 17, 2004

544. Liver MR Imaging: Technique and Advanced Imaging. Refresher Course. Scientific Assembly and Annual Meeting of the Radiological Society of North America, Chicago, IL. November 29, 2004.

545. Routine Gynecologic Applications of MRI. National Diagnostic Imaging Symposium. Loma Linda University. Lake Buena Vista, FL. December 8, 2004

546. MRI/MRSI of the Prostate. National Diagnostic Imaging Symposium. Loma Linda University. Lake Buena Vista, FL. December 8, 2004

547. Teams in Academic Radiology Departments. Radiology Grand Rounds. New York Presbyterian Hospital. New York, NY. January 26, 2005

548. How to Interpret Hepatic MRI. New York Presbyterian Hospital. New York, NY. January 26, 2005

549. MRI of the Cirrhotic Liver. New Orleans Radiology Society 26th Annual MRI & CT at Mardi Gras Conference. New Orleans, LA. February 2, 2005

550. Techniques for Abdominal MRI. New Orleans Radiology Society 26th Annual MRI & CT at Mardi Gras Conference. New Orleans, LA. February 3, 2005

551. Routine Gynecologic Applications of MRI. New Orleans Radiology Society 26th Annual MRI & CT at Mardi Gras Conference. New Orleans, LA. February 3, 2005

552. Update on MRI of the Breast. New Orleans Radiology Society 26th Annual MRI & CT at Mardi Gras Conference. New Orleans, LA. February 4, 2005

553. Body MRSI: Techniques and Applications. New Orleans Radiology Society 26th Annual MRI & CT at Mardi Gras Conference. New Orleans, LA. February 5, 2005

554. Practical MRI Gynecoligal Applications. Radiology in Middle Earth. Radiology International, Inc. and Auckland City Hospital, Auckland, New Zealand. February 28, 2005

555. Update on MRI of the Breast. Radiology in Middle Earth. Radiology International, Inc. and Auckland City Hospital, Auckland, New Zealand. March 1, 2005

556. Techniques for Abdominal MRI. Radiology in Middle Earth. Radiology International, Inc. and the University of Otago, Queenstown, New Zealand. March 3, 2005

557. How to Interpret Hepatic MRI. Radiology in Middle Earth. Radiology International, Inc. and the University of Otago,Queenstown, New Zealand. March 4, 2005

558. MRI and MRSI of the Prostate. Radiology in Middle Earth. Radiology International, Inc. and the University of Otago,Queenstown, New Zealand. March 4, 2005

559. How to Interpret Hepatic MRI. Society of Computed Tomography and Magnetic Resonance Twenty-Eight Annual Course, Miami Beach, FL. March 21, 2005.

560. Quality Progress. American College of Radiology 82nd Annual Meeting and Chapter Leadership Conference, Washington, D.C. April 10, 2005

561. Cardiac CT: Point/Counterpoint. American College of Radiology 82nd Annual Meeting and Chapter Leadership Conference, Washington, D.C. April 10, 2005

562. Nodules in Cirrhotic Livers: The Role of MRI and CT. 8th International Course on Advances in CT and MRI. Barcelona, Spain. May 25-27, 2005

563. Breast MRI: An Update on Clinical Applications. 8th International Course on Advances in CT and MRI. Barcelona, Spain. May 25-27, 2005

564. Liver MRI: How to Perform and Interpret. 8th International Course on Advances in CT and MRI. Barcelona, Spain. May 25-27, 2005

565. Interactive Abdominal Workshop. 8th International Course on Advances in CT and MRI. Barcelona, Spain. May 25-27, 2005

566. 3T Body MRI. 8th International Course on Advances in CT and MRI. Barcelona, Spain. May 25-27, 2005

567. MRI and MRSI of the Prostate. 8th International Course on Advances in CT and MRI. Barcelona, Spain. May 25-27, 2005

568. MRI of the Female Pelvis. 8th International Course on Advances in CT and MRI. Barcelona, Spain. May 25-27, 2005

569. What Is and What Is Not Disruptive Technology. ACR Forum. Reston, VA. June 8-10, 2005

570. 3T Body Imaging. 3T MRI Whole Body Imaging in Clinical Practice: Basic Fundamentals-Advanced Applications. Educational Symposia, New York City, NY. June 24, 2005

571. MRI and MRSI of the Prostate. MRI Whole Body Imaging in Clinical Practice: Basic Fundamentals-Advanced Applications. Educational Symposia, New York City, NY. June 24, 2005

572. Obstetrical MRI. MRI Whole Body Imaging in Clinical Practice: Basic Fundamentals-Advanced Applications. Educational Symposia, New York City, NY. June 24, 2005

573. CT/PET: Crossing the Boundaries. Intersociety Summer Conference on Training for the Future of Radiology. Jackson Hole, WY. July 21, 2005

574. Update on Prostate MRSI. ACRIN Annual Meeting. Pentagon City, VA. September 16, 2005

575. ACR Quality Products. Sun Valley Group. Sun Valley, ID. September 24, 2005

576. Breast MRI: Current Clinical Indications. International Center for Postgraduate Medical Education. Kokomo, IN. October 6, 2005

577. Magnetic Resonance Imaging in Advanced Breast Cancer. Advanced Strategies in Breast Cancer; Exploring Options, Extending Lives. University of Cincinnati. Covington, KY. November 5, 2005

578. Body Applications of MRI. New Britain Hospital, New Britain, CT. November 16, 2005

579. Hepatobiliary Contrast Agents. Refresher Course.Radiological Society of North America Scientific Assembly and Annual Meeting. Chicago, IL. November 29, 2005

580. Liver Imaging: Technique and Advanced Imaging: Cirrhotic Liver. Refresher Course.Radiological Society of North America Scientific Assembly and Annual Meeting. Chicago, IL. November 31, 2005

581. Techniques for Breast MRI. National Diagnostic Imaging Symposium. Loma Linda University. Lake Buena Vista, FL. December 5, 2005

582. Instructive Breast MRI Cases. National Diagnostic Imaging Symposium. Loma Linda University. Lake Buena Vista, FL. December 5, 2005

583. MRI in the Setting of Pregnancy: Indications and Safety. Society of Computed Tomography and Magnetic Resonance Twenty-Ninth Annual Course. Phoenix, AZ. April 4, 2006.

584. MRI of the Breast: Update for 2006. Society of Computed Tomography and Magnetic Resonance Twenty-Ninth Annual Course. Phoenix, AZ. April 4, 2006.

585. Magnetic Resonance of the Kidneys MRI/MRA. The 26th Annual Course in Computed Tomography, Magnetic Resonance Imaging and Positron Emission Tomography. Auchterarder Perthshire, Scotland. April 9-13, 2006.

586. MRI/MRS of the Prostate. The 26th Annual Course in Computed Tomography, Magnetic Resonance Imaging and Positron Emission Tomography. Auchterarder Perthshire, Scotland. April 9-13, 2006.

587. Interesting and Informative MRI Cases. The 26th Annual Course in Computed Tomography, Magnetic Resonance Imaging and Positron Emission Tomography. Auchterarder Perthshire, Scotland. April 9-13, 2006.

588. CT/MRI in Cirrhosis of the Liver. The 26th Annual Course in Computed Tomography, Magnetic Resonance Imaging and Positron Emission Tomography. Auchterarder Perthshire, Scotland. April 9-13, 2006.

589. Practical Gynecological Applications of MRI. Magnetic Resonance Imaging 2006 National Symposium. Las Vegas, NV. April 27, 2006.

590. Obstetrical MRI. Magnetic Resonance Imaging 2006 National Symposium. Las Vegas, NV. April 27, 2006.

591. MRI and MRSI of the Prostate. Magnetic Resonance Imaging 2006 National Symposium. Las Vegas, NV. April 27, 2006.

592. How to Interpret Hepatic MRI: A Practical Approach. 60th Annual Meeting of the Pacific Northwest Radiological Society. Vancouver, BC. April 29, 2006

593. How to Interpret Hepatic MRI: MRI in the Cirrhotic Liver. 60th Annual Meeting of the Pacific Northwest Radiological Society. Vancouver, BC. April 29, 2006

594. 3T MRI of the Abdomen: Challenges and Clinical Opportunities. 3T Imaging Conference, Educational Symposia, New York, NY. June 2-4, 2006

595. Breast MRI Techniques. 3T Imaging Conference, Educational Symposia, New York, NY. June 2-4, 2006

596. Clinical Applications of Breast MRI. 3T Imaging Conference, Educational Symposia, New York, NY. June 2-4, 2006

597. ACR Quality Initiatives and Pay for Performance Activities. Connecticut Radiological Society, Berlin, CT. June 7, 2006.

598. ACR Commission on Quality and Safety. Intersociety Summer Conference, Banff, Alberta. Canada. July 21-21, 2006.

599. ACR Quality Initiatives: New Products for New Times. Pay for Performance: Translating Quality into Economic Success. Sun Valley, ID. August 24-26, 2006.

600. 3T Body MRI: Technical Challenges and Clinical Advances. San Diego Radiological Society. San Diego, CA. September 5, 2006.

601. Techniques for Breast MRI. St. Francis Hospital, Tulsa. OK. September 7, 2006.

602. Interpretation of Breast MRI. St. Francis Hospital, Tulsa. OK. September 7, 2006.

603. Clinical Applications of Breast MRI. St. Francis Hospital, Tulsa. OK. September 7, 2006.

604. Breast MRI. New Mexico Chapter ACR. Albuquerque, NM. September 9, 2006

605. Hepatic MRI. New Mexico Chapter ACR. Albuquerque, NM. September 9, 2006

606. Pelvic MRI. New Mexico Chapter ACR. Albuquerque, NM. September 9, 2006

607. 3T Body MRI: Technical Challenges and Clinical Advances. MRI Summit, International Center for Post-Graduate Medical Education. Dearborn, MI. October 21, 2006

608. 3T Body MRI: Technical Challenges and Clinical Advances. Greater Kansas City Radiological Society, Prairie Village, KS. November 10, 2006

609. P4P and ACR Quality Initiatives. Radiology Grand Rounds. St. Lukes Roosevelt Medical Center, New, York. November 14, 2006

610. Obstetrical MRI. Columbia Presbyterian Medical Center, New York, NY. November 15, 2006

611. 3T Body MRI: Technical Challenges and Clinical Advances. Radiology Grand Rounds. Columbia Presbyterian Medical Center, New York, NY. November 15, 2006

612. Diagnosing Lesions in the Cirrhotic Liver. Refresher Course. Radiological Society of North America Scientific Assembly and Annual Meeting. Chicago, IL. November 28, 2006

613. Gadolinium Chelates. Radiological Society of North America Scientific Assembly and Annual Meeting. Chicago, IL. November 28, 2006

614. 3T Imaging of the Abdomen: Challenges and Clinical Advances. Radiology Grand Rounds, University of Minnesota Medical School, Minneapolis, MN. January 29, 2007

615. How to Interpret Hepatic MRI. University of Minnesota Medical School, Minneapolis, MN. January 29, 2007

616. Basics of Breast MR. Practical Breast MRI. Institute for Advanced Medical Education. Lake Buena Vista, FL. March 2-4, 2007

617. How I Perform and Read Breast MRI. Practical Breast MRI. Institute for Advanced Medical Education. Lake Buena Vista, FL. March 2-4, 2007

618. False Positive Breast MRI Diagnosis. Practical Breast MRI. Institute for Advanced Medical Education. Lake Buena Vista, FL. March 2-4, 2007

619. 3T Body MRI: Challenges and Advances. Society of Computed Tomography and Magnetic Resonance Thirtieth Annual Course. Orlando, FL. March 4-9, 2007

620. Breast MRI Case Review. Society of Computed Tomography and Magnetic Resonance Thirtieth Annual Course. Orlando, FL. March 4-9, 2007

621. Interesting and Informative Abdominal MRI Cases. Society of Computed Tomography and Magnetic Resonance Thirtieth Annual Course. Orlando, FL. March 4-9, 2007

622. 3T Body MRI. Radiology Grand Rounds. Long Island Jewish Medical Center, New Hyde Park, NY. March 15, 2007

623. MRI/CT of the Cirrhotic Liver. Long Island Jewish Medical Center, New Hyde Park, NY. March 15, 2007

624. Advances in Prostate MR. Radiology in Sydney, Radiology International, Inc. Sydney, Australia. March 19, 2007

625. MRI and CT of the Cirrhotic Liver. Radiology in Sydney, Radiology International, Inc. Sydney, Australia. March 20, 2007

626. Renal MRI and MRA. Radiology in Sydney, Radiology International, Inc. Sydney, Australia. March 21, 2007

627. Obstetrical MRI. Radiology in Sydney, Radiology International, Inc. Sydney, Australia. March 22, 2007

628. How to Interpret Heptic MRI. Radiology in Sydney, Radiology International, Inc. Sydney, Australia. March 22, 2007

629. Techniques for MRI of the Breast. Radiology in Sydney, Radiology International, Inc. Sydney, Australia. March 22, 2007

630. 3T Imaging of the Abdomen: Challenges and Clinical Advantages. Magnetic Resonance Imaging 2007 National Symposium. Las Vegas, NV. April 20, 2007

631. Update on MRI and MRSI of the Prostate. Magnetic Resonance Imaging 2007 National Symposium. Las Vegas, NV. April 20, 2007

632. Breast MRI at 3T: Does It Matter? 3T MRI Whole Body Imaging in Clinical Practice. New Orleans, LA. April 25-28, 2007

633. 3T Body MRI Case Reviews. 3T MRI Whole Body Imaging in Clinical Practice. New Orleans, LA. April 25-28, 2007

634. MRI Techniques for the Breast at 1.5T and 3T. 3T MRI Whole Body Imaging in Clinical Practice. New Orleans, LA. April 25-28, 2007

635. Clinical Breast MRI at 1.5 and 3T. 3T MRI Whole Body Imaging in Clinical Practice. New Orleans, LA. April 25-28, 2007

636. MRI and MRSI of the Prostate at 1.5T and 3T. 3T MRI Whole Body Imaging in Clinical Practice. New Orleans, LA. April 25-28, 2007

637. Impact on Hospital Policy. 1st Annual Scientific Symposium on Nephrogenic Systemic Fibrosis and MRI Contrast. Yale School of Medicine, New Haven, CT. May 4, 2007

638. MRI and CT of the Cirrhotic Liver. Radiology Grand Rounds. Stony Brook University Medical Center, Stony Brook, NY. May 7, 2007

639. 3T Body MRI. 9th International Course in CT and MRI. Barcelona, Spain. May 9-11, 2007

640. MRI of Unusual Liver Diseases. 9th International Course in CT and MRI. Barcelona, Spain. May 9-11, 2007

641. MRI and CT of the Cirrhotic Liver. 9th International Course in CT and MRI. Barcelona, Barcelona, Spain. Spain. May 9-11, 2007

642. Update on Breast MRI. 9th International Course in CT and MRI. Barcelona, Spain. May 9-11, 2007

643. 3T Body MRI. 3T MRI Symposium. Mexico City, Mexico, May 30, 3007

644. MR Gadolinium Contrast Agents: Safety Issues and Impact on Hospital Policy. American Healthcare Radiology Administrators 35th Annual Meeting and Exposition. Orlando, FL. July 9, 2007

645. Top Issues in Imaging. Sg2 Imaging Intelligence Conference. Chicago, IL. July 19, 2007

646. Sensitivity/Specificity Reports "Extras". The Radiology Report of the Future. Intersociety Summer Conference. Annapolis, MD. July 27, 2007

647. Nephrogenic Systemic Fibrosis and Gadolinium-enhanced MR imaging. Department of Internal Medicine Medical Grand Rounds, Yale-New Haven Hospital. August 2, 2007

648. Results on ACRIN 6659 Study. ACRIN 2007 Fall Meeting. Pentagon City, Arlington, VA. September 28, 2007

649. Techniques for Breast MRI. University of Alabama Hospital, Birmingham, AL. October 8, 2007

650. Breast MRI-New Diagnosis and Cancer Follow-up: How It Makes a Difference. Department of Radiology Grand Rounds, University of Alabama Hospital, Birmingham, AL. October 8, 2007

651. 3T MRI of the Abdomen. 6th Annual Symposium on High Field MRI. Stanford School of Medicine. Las Vegas, NV. October 14, 2007

652. 3T MRI of the Pelvis. 6th Annual Symposium on High Field MRI. Stanford School of Medicine. Las Vegas, NV. October 14, 2007

653. MRI Gadolinium Issues: Understanding Safety Issues and Policy Changes. 2007 Radiology Business Management Association Imaging Center Conference. Phoenix, AZ. November 2, 2007

654. MRI Gadolinium Issues: Understanding Safety Issues and Policy Changes. Society of Interventional Radiology Symposium. Phoenix, AZ. November 2, 2007

655. MRI and CT Contrast Agent Safety Issues. American Society of Health-System Pharmacists Expert Panel on Advancing the Safe and Appropriate Use of Contrast Media Agents in the Hospital Setting. Washington, DC. November 17, 2007

656. Gadolinium Chelates. Refresher Course.Radiological Society of North America Scientific Assembly and Annual Meeting. Chicago, IL. November 25, 2007

657. Techniques for Breast MRT;Past, Current, and Future. Symposium on Advances in Breast MRI. Chicago, IL. November 26, 2007

658. Diagnosing Lesions in the Cirrhotic Liver. Refresher Course. Radiological Society of North America Scientific Assembly and Annual Meeting. Chicago, IL. November 29, 2007

659. Intravenous Contrast Agents for CT and MR Imaging: Predicting and Preventing Adverse Events. Friday Imaging Symposium. Radiological Society of North America Scientific Assembly and Annual Meeting. Chicago, IL. December 1, 2007

660. MRI of the Uterus. National Diagnostic Imaging Symposium. Lake Buena Vista, FL. December 5, 2007

661. Obstetrical MRI. National Diagnostic Imaging Symposium. Lake Buena Vista, FL. December 5, 2007

662. Clinical Applications of Breast MRI, Wuesthoff Medical Center, Rockledge, FL, January 8, 2008

663. Breast MRI. Brevard Hospice, Viera, FL. January 8, 2008

664. Techniques and Technical Considerations for Breast MRI I. Practical Breast MRI, American Roentgen Ray Society, Las Vegas, NV. February 1, 2008

665. Techniques and Technical Considerations for Breast MRI II. Practical Breast MRI, American Roentgen Ray Society, Las Vegas, NV. February 1, 2008

666. False Positives on MRI. Practical Breast MRI, American Roentgen Ray Society, Las Vegas, NV. February 2, 2008

667. Gadolinium and Other Safety Issues for Breast MRI. Practical Breast MRI, American Roentgen Ray Society, Las Vegas, NV. February 1, 2008

668. Clinical Applications of Breast MRI. 12th Annual "MRI in Clinical Practice", Vail, CO. February 15, 2008

669. Cyst or Serious. 12th Annual "MRI in Clinical Practice", Vail, CO. February 15, 2008

670. Breast MRI: Interpretation issues and False Positives. 12th Annual "MRI in Clinical Practice", Vail, CO. February 15, 2008

671. Clinical Applications of Breast MRI. Medical Grand Rounds, Lahey Clinic, Burlington, MA. February 29, 2008

672. Current Techniques for Breast MRI. Society of Computed Tomography and Magnetic Resonance Thirty-first Annual Course, Charleston, SC. March 31, 2008

673. Clinical Applications for Breast MRI. Society of Computed Tomography and Magnetic Resonance Thirty-first Annual Course, Charleston, SC. March 31, 2008

674. Impact of 3T MRI in an Academic Medical Center. 2008 Clinical 3T Today:Myths and Reality, Issues and Application, Las Vegas, NV, April 11, 2008

675. Interpretation Issues for Breast MRI. 2008 Clinical 3T Today:Myths and Reality, Issues and Application, Las Vegas, NV, April 13, 2008

676. 3T Body MRI. 2008 Clinical 3T Today:Myths and Reality, Issues and Application, Las Vegas, NV, April 13, 2008

677. Technical Advances in Breast MRI at 1.5T and 3T. 2008 Clinical 3T Today:Myths and Reality, Issues and Application, Las Vegas, NV, April 13, 2008

678. Techniques for MRI of the Breast. Magnetic Resonance Imaging 2008 National Symposium, Las Vegas, NV, May 2, 2008

679. False Positive Breast Cases with Path Correlation. Resonance Imaging 2008 National Symposium, Las Vegas, NV, May 2, 2008

680. Interpretation Issues for Breast MRI. Resonance Imaging 2008 National Symposium, Las Vegas, NV, May 2, 2008

681. MRI of Ovarian Masses. Resonance Imaging 2008 National Symposium, Las Vegas, NV, May 2, 2008

682. Safety Update on MR Contrast use in Patients with Chronic Kidney Disease: What You Need to Know. 16th Scientific Meeting and Exhibition of the International Society for Magnetic Resonance in Medicine, Toronto, Canada, May 6, 2008

683. Developing US Strategy for Screening and Risk Reduction. 2nd Annual Scientific Symposium on Nephrogenic Systemic Fibrosis and Gadolinium-Containing Contrast Agents, Yale School of Medicine, New Haven, CT, May 10, 2008

684. Future Practice Models for Radiology. ACR Resident and Fellow Section 16th Anniversary Annual Meeting, Washington, DC, May 17, 2008

685. 3T MRI of the Breast. 3T Users Meeting, Kota Kinabalu, Malaysia, May 22-3, 2008

686. 3T Body MRI. 3T Users Meeting, Kota Kinabalu, Malaysia, May 22-3, 2008

687. Advanced Body and Breast MRI. Royal North Shore Hospital. Sydney, Australia, June 5, 2008

688. Advanced Body and Breast MRI. Royal Prince Alfred Hospital. Sydney, Australia, June 6, 2008

689. Update on Nephrogenic Systemic Fibrosis and MRI/CTR Contrast Agents in the Renal Compromised Patient. Sixth Annual Sonic Imaging Conference. Royal Australian and New Zealand College for Radiologists. Surfers Paradise, Queensland, Australia, June 7, 2008

690. Clinical Applications of Breast MRI. Sixth Annual Sonic Imaging Conference. Royal Australian and New Zealand College for Radiologists. Surfers Paradise, Queensland, Australia, June 7, 2008

691. Technical Challenges and Clinical Advances –Update on MRI of the Prostate. Sixth Annual Sonic Imaging Conference. Royal Australian and New Zealand College for Radiologists. Surfers Paradise, Queensland, Australia, June 8, 2008

692. MRI of the Uterus. Sixth Annual Sonic Imaging Conference. Royal Australian and New Zealand College for Radiologists. Surfers Paradise, Queensland, Australia, June 8, 2008

693. Body MRI. Cairns Base Hospital. Cairns, Australia, June 10, 2008

694. MRI for Gynecologists. Mater Medical Centre. Brisbane, Australia, June 10, 2008

695. Update on Clinical Applications of Breast MRI. SCBT/MR 2008 Summer Practicum. Nappa Valley, CA, August 11, 2008

696. MR and CT of Hepatocellular Carcinoma. SCBT/MR 2008 Summer Practicum. Nappa Valley, CA, August 12, 2008

697. Obstetrical MRI. SCBT/MR 2008 Summer Practicum. Nappa Valley, CA, August 13, 2008

698. Clinical Experience with 3T Breast MRI. Stanford University 7th Annual Symposium on Advances in Breast MRI. Las Vegas, NV. October 16, 2008

699. 3T MRI of the Abdomen and Liver. Stanford University 7th Annual Symposium on High Field MRI-Impact on Clinical Practice. Las Vegas, NV. October 18, 2008

700. 3T MRI of the Breast. Stanford University 7th Annual Symposium on High Field MRI-Impact on Clinical Practice. Las Vegas, NV. October 18, 2008

701. MRI at 3T: Technical Challanges and Clinical Considerations. MRI/CT Update. Harvard Medical School Department of Continuing Education/Brigham and Women's Hospital Department of Radiology. Boston, MA. October 27, 2008

702. Update on Nephrogenic Systemic Fibrosis. MRI/CT Update. Harvard Medical School Department of Continuing Education/Brigham and Women's Hospital Department of Radiology. Boston, MA. October 27, 2008

703. MRI and MDCT of the Liver: Unusual Manifestations of Common Diseases. MRI/CT Update. Harvard Medical School Department of Continuing Education/Brigham and Women's Hospital Department of Radiology. Boston, MA. October 27, 2008

704. MRI in Pregnancy: Utility in Non-Obstetrical Problems. MRI/CT Update. Harvard Medical School Department of Continuing Education/Brigham and Women's Hospital Department of Radiology. Boston, MA. October 27, 2008

705. Screening Strategies to Reduce the Risk of NSF. Nephrogenic Systemic Fibrosis Symposium. Northwestern University.Chicago, IL. November 29, 2008

706. Gadolinium Chelates and NSF. Refresher Course.Radiological Society of North America Scientific Assembly and Annual Meeting. Chicago, IL. December 1, 2008

707. Update on GBCAs and NSF. Radiology Grand Rounds. Brigham and Womens' Hospital, Boston, MA, February 3, 2009

708. Update on GBCAs and NSF. Radiology Grand Rounds. Massachusetts General Hospital, Boston, MA, February 4, 2009

709. Why We Do What We Do: Basics of Breast MRI Interpretation and Technique. Practical Breast MRI. IAME. Orlando, FL February 20, 2009

710. Interactive Breast Interpretation Cases.Practical Breast MRI. IAME. Orlando, FL February 20, 2009

711. Update on Gadolinium Contrast Issues. Practical Breast MRI. IAME. Orlando, FL February 20, 2009

712. Technical Issues for Breast MRI on w Whole Body Scanner (Including 3T).Practical Breast MRI. IAME. Orlando, FL February 20, 2009

713. Screening with Breast MRI. Practical Breast MRI. IAME. Orlando, FL February 20, 2009

714. Breast MRI: Current Techniques and Pitfalls. Society of Computed Tomography and Magnetic Resonance Thirty-second Annual Course, Miami, FL. March 2, 2009

715. Breast Cancer and MR. Society of Computed Tomography and Magnetic Resonance Thirty-second Annual Course, Miami, FL. March 2, 2009

716. How to Interpret Hepatic MRI: SMRT 18th Annual Meeting. Honolulu, HW. April 18, 2009

717. Identifying and Managing Patients with Chronic Kidney Disease Referred for MR Imaging. Navigating the Brave New World: Practical Protocols for Contrast Enhanced MR Imaging.Northwest Imaging Forums. Honolulu, HW. April 21, 2009

718. GBCAs and NSF; Why Did It Happen and What Have We Learned? ISMRM 17th Scientific Meeting and Exhibition. Honolulu, HW. April 22, 2009

719. Update on Gadolinium Based Contrast Agents and NSF. ARRS 2009 Annual Meeting. Boston, MA. April 28, 2009

720. Strategies for Risk Reduction. 3rd Annual Scientific Symposium on Nephrogenic Systemic Fibrosis and Gadolinium-based Contrast Agents. Yale .May 9, 2009

721. Clinical Experience with 3T Breast MRI. 5th Annual Clinical 3T MRI Today Conference. Las Vegas, NV. June 12, 2009

722. Interesting and Informative Breast MRI Cases. 5th Annual Clinical 3T MRI Today Conference. Las Vegas, NV. June 12, 2009

723. 3T MRI: Where Does It Fit in 2009? 5th Annual Clinical 3T MRI Today Conference. Las Vegas, NV. June 12, 2009

724. Introduction to ACR Forum: Future Physician Payment Models. ACR Forum, Reston, VA. June 24, 2009

725. Update on GBCAs and NSF. Society of Computed Tomography and Magnetic Resonance Summer Practicum. Williamsburg, VA. Aug 14, 2009

726. MRI of the Uterus. Society of Computed Tomography and Magnetic Resonance Summer Practicum. Williamsburg, VA. Aug 14, 2009

727. Interesting Cases from Liver Tumor Board. Society of Computed Tomography and Magnetic Resonance Summer Practicum. Williamsburg, VA. Aug 14, 2009

728. Intravenous Contrast Agents. Liver MRI in Clinical Practice. International Center for Postgraduate Medical Education. Philadelphia, PA. October 28, 2009

729. The Cirrhotc Liver: HCC and Other Cirrhotic Nodules. International Center for Postgraduate Medical Education. Philadelphia, PA. October 28, 2009

730. MRI Monitoring of Therapy for Focal Liver Lesions. International Center for Postgraduate Medical Education. Philadelphia, PA. October 28, 2009

731. Advances in Liver MRI: Perfusion, Elastography, Iron Quantification, and Fat Quantification. International Center for Postgraduate Medical Education. Philadelphia, PA. October 28, 2009

732. Interactive Review of Liver MRI Cases. International Center for Postgraduate Medical Education. Philadelphia, PA. October 28, 2009

733. Intravenous Contrast Agents. Liver MRI in Clinical Practice. International Center for Postgraduate Medical Education. Rutherford, NJ. October 29, 2009

734. The Cirrhotc Liver: HCC and Other Cirrhotic Nodules. International Center for Postgraduate Medical Education. Rutherford, NJ. October 29, 2009

735. MRI Monitoring of Therapy for Focal Liver Lesions. . International Center for Postgraduate Medical Education. Rutherford, NJ. October 29, 2009

736. Advances in Liver MRI: Perfusion, Elastography, Iron Quantification, and Fat Quantification. International Center for Postgraduate Medical Education. Rutherford, NJ. October 29, 2009

737. Interactive Review of Liver MRI Cases. International Center for Postgraduate Medical Education. Rutherford, NJ. October 29, 2009

738. Intravenous Contrast Agents. Liver MRI in Clinical Practice. International Center for Postgraduate Medical Education. Chicago, Il. November 12, 2009

739. The Cirrhotc Liver: HCC and Other Cirrhotic Nodules. . International Center for Postgraduate Medical Education. Chicago, Il. November 12, 2009

740. MRI Monitoring of Therapy for Focal Liver Lesions. International Center for Postgraduate Medical Education. Chicago, Il. November 12, 2009

741. Advances in Liver MRI: Perfusion, Elastography, Iron Quantification, and Fat Quantification. . International Center for Postgraduate Medical Education. Chicago, Il. November 12, 2009

742. Interactive Review of Liver MRI Cases. International Center for Postgraduate Medical Education. Chicago, Il. November 12, 2009

743. Intravenous Contrast Agents. Liver MRI in Clinical Practice. International Center for Postgraduate Medical Education. Boston, MA. November 13, 2009

744. The Cirrhotc Liver: HCC and Other Cirrhotic Nodules. . International Center for Postgraduate Medical Education. Boston, MA. November 13, 2009

745. MRI Monitoring of Therapy for Focal Liver Lesions. International Center for Postgraduate Medical Education. Boston, MA. November 13, 2009

746. Advances in Liver MRI: Perfusion, Elastography, Iron Quantification, and Fat Quantification. . International Center for Postgraduate Medical Education. Boston, MA. November 13, 2009

747. Gadolinium Based Contrast Agents and Nephrogenic Systemic Fibrosis. Refresher Course. Radiological Society of North America 95rd Scientific Assembly and Annual Meeting. Chicago, Il. November 29, 2009

748. Interactive Review of Liver MRI Cases. International Center for Postgraduate Medical Education. Hot Topic Refresher Course. Radiological Society of North America 95rd Scientific Assembly and Annual Meeting. Chicago, Il. December 1, 2009

749. Use of Gadolinium Based Contrast Agents in Clinical Practice. Joint Meeting of the FDA Cardiovascular and Renal Drugs and Drug Safety and Risk Management Advisory Committee. Gaithersburg, MD. December 8, 2009

750. New Physician Pay Models and the Effect on Radiology. Society of Computed Tomography and Magnetic Resonance Thirty-third Annual Course, San Diego, CA. March 7, 2010

751. New Data About Breast MR. Society of Computed Tomography and Magnetic Resonance Thirty-third Annual Course, San Diego, CA. March 8, 2010

752. Update on NSF: Why Did It Come and Why Did It Go. Society of Computed Tomography and Magnetic Resonance Thirty-third Annual Course, San Diego, CA. March 10, 2010

753. Intravenous Contrast Agents. Liver MRI in Clinical Practice. International Center for Postgraduate Medical Education. Orlando, FL. April 8, 2010

754. The Cirrhotc Liver: HCC and Other Cirrhotic Nodules. International Center for Postgraduate Medical Education. Orlando, FL. April 8, 2010

755. Characterizing Focal Liver Lesions. International Center for Postgraduate Medical Education. Orlando, FL. April 8, 2010

756. MRI Monitoring of Therapy for Focal Liver Lesions. International Center for Postgraduate Medical Education. Orlando, FL. April 8, 2010

757. Advances in Liver MRI: Perfusion, Elastography, Iron Quantification, and Fat Quantification. International Center for Postgraduate Medical Education. Orlando, FL. April 8, 2010

758. Interactive Review of Liver MRI Cases. International Center for Postgraduate Medical Education.Orlando, FL. April 8, 2010

759. Intravenous Contrast Agents. Liver MRI in Clinical Practice. International Center for Postgraduate Medical Education. Baltimore, MD. April 9, 2010

760. The Cirrhotic Liver: HCC and Other Cirrhotic Nodules. International Center for Postgraduate Medical Education. Baltimore, MD. April 9, 2010

761. Characterizing Focal Liver Lesions. International Center for Postgraduate Medical Education. Baltimore, MD. April 9, 2010

762. MRI Monitoring of Therapy for Focal Liver Lesions. International Center for Postgraduate Medical Education. Baltimore, MD. April 9, 2010

763. Advances in Liver MRI: Perfusion, Elastography, Iron Quantification, and Fat Quantification. International Center for Postgraduate Medical Education. Baltimore, MD. April 9, 2010

764. Interactive Review of Liver MRI Cases. International Center for Postgraduate Medical Education. Baltimore, MD. April 9, 2010

765. Clinical Perspectives on Prostate Cancer. International Prostate MRI Working Group. Stockholm, Sweden, May 6, 2010

766. NSF Update and Impact on Your Practice. Hot Topics in Body MRI Course. Joint Annual Meeting ISMRM-ESMRMB. Stockholm, Sweden. May 7, 2010

767. Intravenous Contrast Agents. Liver MRI in Clinical Practice. International Center for Postgraduate Medical Education. Buffalo, NY. May 20, 2010

768. The Cirrhotic Liver: HCC and Other Cirrhotic Nodules. International Center for Postgraduate Medical Education. Buffalo, NY. May 20, 2010

769. Characterizing Focal Liver Lesions. International Center for Postgraduate Medical Education. Buffalo, NY. May 20, 2010

770. MRI Monitoring of Therapy for Focal Liver Lesions. International Center for Postgraduate Medical Education. Buffalo, NY. May 20, 2010

771. Advances in Liver MRI: Perfusion, Elastography, Iron Quantification, and Fat Quantification. International Center for Postgraduate Medical Education. Buffalo, NY. May 20, 2010

772. Interactive Review of Liver MRI Cases. International Center for Postgraduate Medical Education. Buffalo, NY. May 20, 2010

773. Intravenous Contrast Agents. Liver MRI in Clinical Practice. International Center for Postgraduate Medical Education. Garden City, NY. May 21, 2010

774. The Cirrhotic Liver: HCC and Other Cirrhotic Nodules. International Center for Postgraduate Medical Education. Garden City, NY. May 21, 2010

775. Characterizing Focal Liver Lesions. International Center for Postgraduate Medical Education. Garden City, NY. May 21, 2010

776. MRI Monitoring of Therapy for Focal Liver Lesions. International Center for Postgraduate Medical Education. Garden City, NY. May 21, 2010

777. Advances in Liver MRI: Perfusion, Elastography, Iron Quantification, and Fat Quantification. International Center for Postgraduate Medical Education. Garden City, NY. May 21, 2010

778. Interactive Review of Liver MRI Cases. International Center for Postgraduate Medical Education. Garden City, NY. May 21, 2010

779. Introduction to ACR Forum: Hospital-Radiologist Relationships. ACR Forum, Reston, VA. June 7, 2010

780. MRI of Benign Diseases of the Uterus. Radiology Grand Rounds. Stony Brook University Medical Center. Stony Brook, NY. September 14, 2010

781. Cyst or Serious? **Burton Gold Memorial Lecture**. Long Island Radiological Society. Woodbury, NY. September 14, 2010

782. New Topics in Liver MR Imaging. Radiology Grand Rounds. Cleveland Clinic, Cleveland, OH. November 8, 2010

783. Hepatobiliary MR for Clinicians. Cleveland Clinic, Cleveland, OH. November 8, 2010

784. ACRIN 6690. Liver Center Research @ Yale Workshop. New Haven, CT. November 19, 2010

785. Innovations in Imaging: impact on Clinical Care and Research. Liver Center Research @ Yale Workshop. New Haven, CT. November 19, 2010

786. Contrast Agent Issues 2010: What Do Experts Really Do About NSF. Refresher Course. Radiological Society of North America 96th Scientific Assembly and Annual Meeting. Chicago, Il. November 28, 2010

787. Practical Recommendations: How We Identify and Manage At-risk Patients in Routine Clinical Practice. Patient Management in MRI Facilities. ABC Medical Education. Washington, DC. January 30, 2011

788. CT/MRI of Unusual Liver Diseases. **John H. Harris Endowed Lecture**. University of Texas Health Science Center, Houston, TX. April 21, 2011

789. Effect of Regulatory Actions and Societal Guidance on Practice. 5th Annual Scientific Symposium on Nephrogenic Systemic Fibrosis and Gadolinium-based Contrast Agents. Yale University. May 21, 2011

790. Contrast Agent Issues. Body Imaging Boot Camp. Institute for Advanced Medical Education. Cleveland, OH. June 4, 2011

791. Diagnosing and Reporting Cirrhotic Nodules. Body Imaging Boot Camp. Institute for Advanced Medical Education. Cleveland, OH. June 4, 2011

792. Cyst or Serious. Body Imaging Boot Camp. Institute for Advanced Medical Education. Cleveland, OH. June 4, 2011

793. MRI of the Prostate. Body Imaging Boot Camp. Institute for Advanced Medical Education. Cleveland, OH. June 5, 2011

794. Introduction to ACR Forum: Generational Issues and the Impact on Radiology. ACR Forum, Reston, VA. June 6, 2011

795. Performance Measurement in Radiology. 9th Biennial International Symposium of the International Society for Strategic Studies in Radiology. Dobrovnik, Croatia. August 25, 2011

796. Who Should be Premedicated for Contrast-Enhanced Exams? Society of Computed Tomography and Magnetic Resonance Thirty-fourth Annual Course, Washington, DC. October 23, 2011

797. Screening for Patients at Risk for NSF. Society of Computed Tomography and Magnetic Resonance Thirty-fourth Annual Course, Washington, DC. October 23, 2011

798. Whole Body MRI. Society of Computed Tomography and Magnetic Resonance Thirty-fourth Annual Course, Washington, DC. October 24, 2011

799. Is Gadoxetic Acid Beneficial in Cirrhotic Patients? Society of Computed Tomography and Magnetic Resonance Thirty-fourth Annual Course, Washington, DC. October 24, 2011

800. Controversies in Breast MRI. Society of Computed Tomography and Magnetic Resonance Thirty-fourth Annual Course, Washington, DC. October 24, 2011

801. Uterine Fibroids: Not as Simple as You Think. Society of Computed Tomography and Magnetic Resonance Thirty-fourth Annual Course, Washington, DC. October 24, 2011

802. New FDA and ACR Guidelines on Use of Gadolinium Contrast Agents. Society of Computed Tomography and Magnetic Resonance Thirty-fourth Annual Course, Washington, DC. October 25, 2011

803. What You Need to Know About MRI in Patients with Cardiac Pacemakers. Society of Computed Tomography and Magnetic Resonance Thirty-fourth Annual Course, Washington, DC. October 25, 2011

804. Contrast Agent Issues 2011: What Do Experts Really Do About NSF. Refresher Course. Radiological Society of North America 97th Scientific Assembly and Annual Meeting. Chicago, Il. November 29, 2011

805. MRI in the Pregnant Patient. Obstetrics, Gynecology and Reproductive Sciences Grand Rounds, Yale-New Haven Hospital. January 5, 2012

806. Abdominal CT and MRI: Cyst or Serious? Radiology International. Siem Reap, Cambodia. January 30, 2012

807. MRI of the Benign Uterus. Radiology International. Siem Reap, Cambodia. January 31, 2012

808. Unusual Manifestations of Common Liver Diseases. Radiology International. Siem Reap, Cambodia. January 31, 2012

809. MRI of the Prostate. Radiology International. Siem Reap, Cambodia. February 1, 2012

810. CT and MRI of the Cirrhotic Liver. Radiology International. Siem Reap, Cambodia. February 2, 2012

811. MRI of the Pregnant Patient. Radiology International. Siem Reap, Cambodia. February 3, 2012

812. ACR Data Registry (NRDR). Driving Value into Your Organization through Qualilty and Safety Improvements. American College of Radiology. Scottsdale, AZ. February17, 2012

813. ACR Rad Peer. Driving Value into Your Organization through Qualilty and Safety Improvements. American College of Radiology. Scottsdale, AZ. February17, 2012

814. The Role of Radiology Present and Future. Yale School of Medicine Workshop: Hepatocellular Carcinoma in the Community. Yale CME. New Haven, CT. April 13, 2012

815. Current FDA/ACR Guidelines for Hepatobiliary Contrast Agents. Abdominal Imaging 2012: American College of Radiology Body Imaging Conference. Washington, DC. April 21, 2012

816. MRI/CT of the Cirrhotic Liver: Is It a Hepatoma? STAR Program. Delhi, India. May 15, 2012

817. MRI of the Benign Uterus. STAR Program. Delhi, India. May 15, 2012

818. MRI of the Prostate. STAR Program. Delhi, India. May 15, 2012

819. MRI/CT of the Cirrhotic Liver: Is It a Hepatoma? STAR Program. Kolkata, India. May 18, 2012

820. MRI of the Benign Uterus. STAR Program. Kolkata, India. May 18, 2012

821. MRI of the Prostate. STAR Program. Kolkata, India. May 18, 2012

822. Diagnosis of HCC: CT and MRI. Emerging Trends in Liver Imaging. American Association for the Study of Liver Diseases. Atlanta, GE. September 8, 2012

823. Contrast Agents: Safety and Administation Guidelines. Society of Computed Tomography and Magnetic Resonance Thirty-fifth Annual Course, Boston, MA. October 7, 2012

824. Hepatic Cirrhosis and HCC: Reporting Using LI-RADS. Society of Computed Tomography and Magnetic Resonance Thirty-fifth Annual Course, Boston, MA. October 8, 2012

825. Why NRDR (National Radiology Data Registry) Matters. Society of Computed Tomography and Magnetic Resonance Thirty-fifth Annual Course, Boston, MA. October 8, 2012

826. Introduction to NRDR. ACR NRDR User Group Conference, Washington, DC. October 12, 2012

827. Contrast Agent Issues 2012: What Do Experts Really Do About NSF. Refresher Course. Radiological Society of North America 98th Scientific Assembly and Annual Meeting. Chicago, Il. November 30, 2012

VIDEO/CD/DVD PRESENTATIONS

1. MR Safety Considerations. Educational Symposia, Inc. 1989
2. MRI of the Lung with CT and Pathologic Correlation. Educational Symposia, Inc. 1989
3. MRI of the Female Pelvis. Educational Symposia, Inc. 1989
4. MRI of the Male Pelvis. Educational Symposia, Inc. 1990
5. Imaging Insights: Understanding the Chemical Shift Artifact in MR imaging. RSNA Today Video 1992; 6(3)
6. Imaging Insights: Use of STIR Sequences in MR Imaging. RSNA Today Video 1992;6(6) MRI of the Prostate. CME Conference Video, Inc. 1992
7. MRI of the Chest. CME Conference Video, Inc. 1992
8. Fat Suppression and Reduced Bandwidth Techniques. CME Conference Video, Inc. 1992
9. MR and CT of the Aorta. CME Conference Video, Inc. 1992

10. Breast Cancer: Advances in Screening, Diagnosis, and Treatment. Medivision/MedEdNet. April 11, 1994
11. CT Versus MRI of the Abdomen. Center for Biomedical Communications. 1994
12. CT and MRI of the Liver. Center for Biomedical Communications. 1994
13. Guide to MR Imaging Protocols: What a Radiologist Needs to Know. RSNA Learning Center Program. 1996
14. New Concepts in Liver MRI 1996. CME Conference Video, Inc. 1996
15. How to Optimize Abdominal MRI. CME Conference Video, Inc. 1996
16. Radiology for the Year 2000. Proceedings of the 1711 International Cancer Congress MedAscend. 1998
17. How to Optimize MRI of the Abdomen. CMEinfo.com. 2000
18. Techniques for Abdominal MRI that Really Work. Educational Symposia, Inc. 2001
19. Update on Breast MRI. Educational Symposia, Inc. 2001
20. MRI of the Cirrhotic Liver: New Observations and Imaging Implications. Educational Symposia, Inc. 2001
21. Breast MRI Workshop. CMEinfo.com. 2002
22. Prostate MRI and MR Spectroscopy. CMEinfo.com. 2002
23. Pearls and Pitfalls of Body MRI. CMEinfo.com. 2002
24. CT & MRI Accreditation Programs. Educational Symposia, Inc. 2002
25. Techniques for Hepatobiliary MRI That Really Work. Educational Symposia, Inc. 2002
26. MRI of the Cirrhotic Liver. RSNA Education Center. 2003
27. Practical Gynecological Applications of MRI. Educational Symposia, Inc. 2006
28. Obstetrical MRI. Educational Symposia, Inc. 2006
29. MRI and MRSI of the Prostate. Educational Symposia, Inc. 2006
30. What Will It Take to Dominate 1.5T? Educational Symposia, Inc. 2006
31. 3T Imaging of the Abdomen: Technical Challenges and Clinical Advances. Educational Symposia, Inc. 2006
32. Breast MR Imaging Techniques. Educational Symposia, Inc. 2006
33. Clinical Applications of Breast MRI. Educational Symposia, Inc. 2006
34. Update on MRI and MRSI of the Prostate. Educational Symposia, Inc. 2007

35. 3T Body MRI Case Reviews. Educational Symposia, Inc. 2007
36. Clinical Breast MRI at 1.5 and 3T. Educational Symposia, Inc. 2007
37. MRI and MRSI of the Prostate at 1.5 and 3T. Educational Symposia, Inc. 2007
38. Update on Nephrogenic Systemic Fibrosis and Gadolinium Based Contrast Agents. International Center for Postgraduate Medical Education. 2008
39. Techniques for MRI of the Breast. Educational Symposia, Inc. 2008
40. False Positive Breast MRI Cases with Path Correlation. Educational Symposia, Inc. 2008
41. Interpretation Issues for Breast MRI. Educational Symposia, Inc. 2008
42. MRI of Ovarian Masses. Educational Symposia, Inc. 2008
43. Clinical Breast MRI at 1.5T and 3T. Educational Symposia, Inc. 2009
44. MRI Techniques for the Breast at 1.5T and 3T. Educational Symposia, Inc. 2009
45. Breast MRI at 3T: Does It Matter? Educational Symposia, Inc. 2009
46. 3T Body MRI Case Reviews. Educational Symposia, Inc. 2009
47. Interesting and Informative Breast MRI Cases. Educational Symposia, Inc. 2010
48. New Data About Breast MR. Veritas Institute for Medical Education, 2010
49. Update on NSF: Why Did It Come and Why Did It Go. Veritas Institute for Medical Education, 2010

NATIONAL AUDIO and INTERNET CONFERENCES

Breast Diseases: Advances in Treatment and Diagnosis. MEDVISION/MedEd Net. 1994

Breast Diseases: Advances in Screening. MEDVISION/MedEd Net. 1994

MRI vs CT of the Abdomen. Ithaca Center of Continuing Postgraduate Medical Education. May 26, June 27, July 29, 1994

Techniques for Abdominal MRI. Ithaca Center of Continuing Postgraduate Medical Education. April 15, May 18, June 24, 1995

CT and MRI of the Liver. November 14, 1995

Radiology Re-engineering: How PACS Fits In. Diagnostic Imaging Virtual Symposium, July 20-August 2, 1999

The American College of Radiology MRI Accreditation Program: Demystifying the Process. Ithaca Center of Continuing Postgraduate Medical. Education. November 18, December 9, 1999

MRI of the Cirrhotic Liver. RSNA InteractED, www. rsna.org 2006

How I Perform Breast MRI, iame.com, 2007

False Positive Breast MRI Exams, iame.com, 2007

Advanced Hepatic and Hepatobiliary MRI: Technologies and Techniques. Medscape CME Spotlight. October 2009. (http://cme.medscape.com/viewarticle/709016)

MRI Roundtable:Update on the Safety of Contrast Agents. Medscape CME August 2010. (http://cme.medscape.com/viewarticle/725305)

Strategies for NSF Risk Reduction. Latest Evidence of Nephrogenic Systemic Fibrosis. University of Kentucky College of Medicine January 2010 (http://www.enhancedcme.com/assets/html/welcome.html)

Intravascular Contrast Media: Optimizing Patient Safety in MRI and CT Imaging A CME/CE Certified Virtual Preceptorship. Quintiles Medical October 2010

Course Director. Immediate Adverse Events Following Contrast Administration: Prevention, Recognitions & Treatment. ABC Medical Education. January 2011 (http://www.imagingeducation.com)

Safety Considerations on the Use of Gadolinium Based Contrast Agents. Patient Management at MRI Facilities. Medical Education Resources, Inc. June 2011 (http://www.imagingeducation.com)

Practical Steps for MR Contrast Safety. Medscape CME July 2011 (http://www.medscape.org/viewarticle/745696)

Advance Liver MRI Tutorial. ICPMED July 2012. (http://courses.icpme.us/class_learn?course=266)

Diagnosis of HCC: CT and MRI. AASLD Webcast November 2012 (http://liverlearning.aasld.org)

APPENDIX V

DPH LICENSE

STATE OF CONNECTICUT

Department of Public Health

LICENSE

License No. 0044

General Hospital

In accordance with the provisions of the General Statutes of Connecticut Section 19a-493: Yale-New Haven Hospital, Inc. of New Haven, CT d/b/a Yale-New Haven Hospital, Inc. is hereby licensed to maintain and operate a General Hospital.

Yale-New Haven Hospital, Inc. is located at 20 York Street, New Haven, CT 06504.

The maximum number of beds shall not exceed at any time:
134 Bassinets
1407 General Hospital Beds

This license expires **September 30, 2013** and may be revoked for cause at any time.
Dated at Hartford, Connecticut, October 1, 2011.

SATELLITES

Hill Regional Career High School, 140 Legion Avenue, New Haven, CT
Branford High School Based Health Center, 185 East Main Street, Branford, CT
Walsh Middle School, 185 Damascus Road, Branford, CT
James Hillhouse High School Based Health Center, 480 Sherman Parkway, New Haven, CT
Weller Building, 425 George Street, New Haven, CT
Yale-New Haven Psychiatric Hospital, 184 Liberty Street, New Haven, CT
Yale-New Haven Shoreline Medical Center, 111 Goose Lane, Guilford, CT
Pediatric Dentistry Center, 860 Howard Avenue, New Haven, CT
YNHASC Temple Surgical Center, 60 Temple Street, New Haven, CT
YNHASC Women's Surgical Center, 40 Temple Street, New Haven, CT
Mauro-Sheridan School Based Health Center, 191 Fountain Street, New Haven, CT
Yale-New Haven Hospital Dental Center, 2560 Dixwell Avenue, Hamden, CT
Murphy School Based Health Center, 14 Brushy Plain Road, Branford, CT
P.T. Barnum Pediatric Center, 226 Mill Hill Avenue, Bridgeport, CT
Yale-New Haven Hospital-Saint Raphael Campus, 1450 Chapel Street, New Haven, CT
Adolescent Day Hospital, 646 George Street, New Haven, CT
Psychiatric Day Hospital, 1294 Chapel Street, New Haven, CT
Children's Psychiatric Day Hospital, 1450 Chapel Street, New Haven, CT
Elder Care Clinic, Atwater Clinic, 26 Atwater Street, New Haven, CT
Elder Care Clinic/Tower One, 18 Tower Lane, New Haven, CT
Elder Care Clinic/Casa Otonal, 135 Sylvan Avenue, New Haven, CT
Elder Care Clinic/Edith Johnson Tower, 114 Bristol Street, New Haven, CT
Evening Chemical Dependency Program, 1294 Chapel Street, New Haven, CT
Elder Care Clinic/Surfside, 200 Oak Street, West Haven, CT
Troup Magnet Academy School-Based Health Center, New Haven, CT
Adult PHP, 110 Sherman Avenue, Hamden, CT
Wheat, 674 Washington Avenue, West Haven, CT
Barnard Environmental Studies Magnet School, 170 Derby Avenue, New Haven, CT
Center for Women's Health/Midwifery & Chapel Pediatrics, 2 Ivy Brook Road, Suite 111, Shelton, CT
"Smiles 2 Go" Dental Mobile Van, 60 Commerce Street, East Haven, CT
Project Eldercare, 2080 Whitney Avenue, Suite 150, Hamden, CT
Chapel Pediatrics, 2080 Whitney Avenue, Suite 150, Hamden, CT
Shoreline Child and Adolescent Mental Health Services, 21 Business Park Drive, Branford, CT

License Revised to Reflect:
* Hospital of Saint Raphael merged with Yale-New Haven Hospital, Inc. effective 9/12/12

Jewel Mullen MD

Jewel Mullen, MD, MPH, MPA
Commissioner

APPENDIX VI

VENDOR QUOTE

SIEMENS

Siemens Medical Solutions USA, Inc.
51 Valley Stream Parkway, Malvern, PA 19355
Fax: (866) 309-6992

SIEMENS REPRESENTATIVE
Gordon Wilhelm - (610) 448-1736

PRELIMINARY PROPOSAL

Customer Number: 0000011518

Date: 5/29/2012

YALE NEW HAVEN HOSPITAL
20 YORK ST
NEW HAVEN, CT 06510

This is a CONFIDENTIAL, one-time offer which may not be shared with any third parties, buying evaluation groups or anyone not directly employed by customer. The purchase price for this quote is dependent on a multi-modality purchase to include quote 1-3V32ZS and 1-3RPTAS all being purchased on binding purchase orders by May 31, 2012.

Pricing in this proposal is contingent up Customer signing a multi-year POS Service contract on the equipment.

Order is contingent upon CON approval by the state of Connecticut.

Payment terms are 0/70/30 N60.

This proposal for a Siemens Skyra, replaces the Siemens Verio quote number 1-CPO3D0 purchased on 10/30/08 with sales order 30128019.

This agreement is to be governed by the T&C's dated 12/19/11 and signed Compliance Addendum dated 6/29/11.

Quote Nr: **1-2EZ3GC Rev. 4**

MAGNETOM Skyra

All items listed below are included for this system:

Qty	Part No.	Item Description
1	14418500	**MAGNETOM Skyra - System** MAGNETOM Skyra - 3T Tim+Dot system - the integration of the next generation Tim "Tim 4G" and Siemens unique Dot Engines (Day optimizing throughput Engines). Short and open appearance (173 cm system length with 70 cm Open Bore Design). Tim 4G with redesigned RF system and all-new coil architecture. DirectRF(tm) technology enabling Tim's new all digital-in/ digital-out design - All-new coil architecture including Dual-Density Signal Transfer Technology - Whole-body superconductive Zero Helium Boil-Off 3T magnet - TrueForm Magnet and Gradient Design - Actively shielded water-cooled Siemens gradient system - TimTX TrueForm for uniform RF distribution in all body regions - Head/Neck 20 DirectConnect, Spine 32 DirectConnect, Body 18, Flex Large/Small 4 Dot offers patient personalization, user guidance and process automation. Brain Dot Engine - personalized, guided and automated workflows - Dot Display and Dot Control Centers for efficient patient preparation. Additional features included: -Tim Application Suite including Neuro, Angio, Cardiac, Body, Onco, Breast, Ortho, Pediatric and Scientific Suite - syngo MR software including 1D/2D PACE, syngo BLADE, iPAT², Phoenix, Inline Technologies. - High performance host computer and measurement and reconstruction system The system (magnet, electronics and control room) can be installed in 31sqm space. For system cooling either the Eco Chiller options or the Separator is required.

SIEMENS
Siemens Medical Solutions USA, Inc.
51 Valley Stream Parkway, Malvern, PA 19355
Fax: (866) 309-6992

SIEMENS REPRESENTATIVE
Gordon Wilhelm - (610) 448-1736

PRELIMINARY PROPOSAL

Qty	Part No.	Item Description
1	14418502	**Tim [204x48] XQ Gradients #Sk** Tim [204x48] XQ-gradients performance level - Tim 4G's newly designed RF system and innovative coil architecture enables high resolution imaging and increased throughput. Up to 204 simultaneously connected coil elements, in combination with the standard 48 independent RF channels, allow for more flexible parallel imaging. Maximum SNR through the new Tim 4G matrix coil technolgy. XQ - gradients - The XQ - gradients - high performance and linearity to support clinical whole body imaging at 3T. The force compensated gradient system minimizes vibration levels and accoustic noise. The XQ gradients combine 45 mT/m peak amplitude with a slew rate of 200 T/m/s.
1	08464872	**PC Keyboard US english #Tim** Standard PC keyboard with 101 keys.
1	14416914	**Pure White Design #T+D** The MAGNETOM Aera / MAGNETOM Skyra design is available in different light and appealing variants which perfectly integrates into the different environments. The color of the main face plate cover of the Pure White Design Variant with the integrated Dot Control Centers and the unique Dot Display is brilliant white surrounded by a brilliant silver trim. The asymetrical deco area on the left side is colored white matte and also with a brilliant surrounding silver trim The table cover is presented also in the same color and material selection.
1	14418507	**Tim Dockable Table #Sk** The new Tim Dockable Table is designed for maximum patient comfort and smooth patient preparation. Tim Dockable Table can support up to 250 kg (550 lbs) patients without restricting the vertical or horizontal movement. The one step docking mechanism and the innovative multi-directional navigation wheel ensure easy maneuvering and handling. Critically ill or immobile patients can now be prepared outside the examination room for maximum patient care, flexibility and speed.
1	14418508	**Add. Tim Dockable Table #Sk** Additional mobile table solution with integrated removeable Spine 32 for installations that already have a Tim Dockable Table and would like to increase their throughput even more.
1	14402592	**Inline Composing syngo #Tim** Automatic anatomical or angiographic composing of multiple adjacent coronal or sagittal images for presentation and further evaluation. Composed images can be automatically loaded into Graphical Slice Positioning for scan planning purposes.
1	14402593	**Tim Planning Suite** With the Tim Planning Suite, multiple regions in the entire body can be examined in a minimum of time through measurement planning on a single FoV of any desired size.
1	14405224	**Composing syngo #Tim** This application provides dedicated evaluation software for creation of full-format images from overlapping MR volume data sets and MIPs (starting from syngo MR B13) acquired at multiple stages.
1	14416923	**Abdomen Dot Engine #T+D** The Abdomen Dot Engine: Personalized Exam Strategies - Guidance - Automatic sequence scaling - Auto Navigator - Auto-FoV - Timeline setup and monitoring - Automatic Voice Commands - Auto Bolus Detection - Inline radial range calculation for MRCP - Inline Subtraction - Inline Registration
1	14418746	**Cardiac Dot Engine, USA #T+D** Cardiac examinations: Dot Cardiac - Customized workflows that are easier to repeat. Using anatomical landmarks, standard views of the heart (such as dedicated long axis and short-axis views), are easily generated and can easily be reproduced using different scanning techniques. Scan parameters are adjusted to the patient's heart rate and automatic voice commands are given.
1	08464740	**Flow Quantification #Tim** Special sequences for quantitative assessment of flow.
1	07365419	**Argus Flow**
1	14416929	**Advanced Cardiac Package #T+D** This package contains special sequences and protocols for advanced cardiac imaging including 3D and 4D syngo BEAT functionalities. It supports advanced techniques for ventricular function imaging, dynamic imaging, tissue characterization, coronary imaging, and more.

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PRELIMINARY PROPOSAL

Qty	Part No.	Item Description
1	14401554	**Inline Perfusion #3T** Automatic real-time calculation of Global Bolus Plot (GBP), Percentage of Baseline at Peak map (PBP), and Time-to-Peak map (TTP) with Inline technology.
1	14418563	**Neuro Perfusion Evaluation,USA #T+D** Neuro Perfusion Evaluation syngo provides a task card for detailed post-processing of brain perfusion data sets. Color display of the relative Mean Transit Time (relMTT), relative Cerebral Blood Volume (relCBV), corrected rel CBV, and relative Cerebral Blood Flow (relCBF) is supported. Flexible selection of the Arterial Input Function (AIF). Furthermore a calculation of maps using the pre-selected local Arterial Input Functions (AIF) is provided. The detailed evaluation of brain perfusion data sets generates parameter maps for TTP and PBP and for the hemodynamic parameters relMTT, relCBV, rel CBVcor and relCBF.
1	14416944	**DTI Package #T+D** The DTI Package is a bundle of: - Diffusion Tensor Imaging - DTI Evaluation and - DTI Tractography syngo The bundle comprehends all acquisition and postprocessing tools for comprehensive DTI exams.
1	14402527	**SWI #Tim** Susceptibility Weighted Imaging is a high-resolution 3D imaging technique for the brain with ultra-high sensitivity for microscopic magnetic field inhomogeneities caused by deoxygenated blood, products of blood decomposition and microscopic iron deposits. Among other things, the method allows for the highly sensitive proof of cerebral hemorrhages and the high-resolution display of venous cerebral blood vessels.
1	14416941	**Spectroscopy Package #T+D** The Spectroscopy Package is a comprehensive software package which bundles Single Voxel Spectroscopy, 2D Chemical Shift Imaging, 3D Chemical Shift Imaging and syngo Spectroscopy Evaluation. Sequences and protocols for proton spectroscopy, 2D and 3D proton chemical shift imaging (2D CSI and 3D CSI) to examine metabolic changes in the brain (e.g. in tumors and degenerative diseases) and in the prostate are included. Furthermore included is the comprehensive syngo Spectroscopy Evaluation Software which enables fast evaluation of spectroscopy data on the syngo Acquisition Workplace.
1	14405328	**TWIST syngo #Tim** This package contains a Siemens unique sequence and protocols for time-resolved (4D) MR angiographic and dynamic imaging in general with high spatial and temporal resolution. syngo TWIST supports comprehensive dynamic MR angio exams in all body regions. It offers temporal information of vessel filling in addition to conventional static MR angiography, which can be beneficial in detecting or evaluating malformations such as shunts. In case of general dynamic imaging, for example an increase in spatial resolution by a factor of up to 2 at 60 seconds temporal resolution (compared to conventional dynamic imaging) is possible due to intelligent k-space sampling strategies. Alternatively, increased temporal resolution at constant spatial resolution is possible.
1	14416948	**Patient Supervision TV #T+D** The supervision solution is customizable and designed to address different site specific requirements. Up to 4 cameras can be connected for patient supervision in the examination or waiting room. This package contains a special video camera for monitoring the patient during an MR examination, conveniently mounted on the wall of the examination room. The information is displayed at an LCD monitor in the control room.
1	14416950	**Supervision Camera Controller #T+D** Additional video camera to allow for comprehensive monitoring of the patient's face independent of patient position during an MR examination. The additional camera is conveniently mounted on the opposite wall in the examination room. Together with the Wide Angle Lens option this camera can also be used wall-mounted for observing the situation in the waiting room. The supervision controller allows for easy layout switch between single views and split screen on the LCD monitor.
2	14416949	**Additional Camera #T+D** Additional video camera for monitoring the situation in the waiting room (in combination with wide angle option). The additional camera is conveniently mounted on the wall.
1	14416952	**Coil Storage Cart #T+D** Specially designed non-ferromagnetic cart for easy storage of the most commonly used coils and accessories.
1	14418521	**syngo Expert-i #T+D** This software application enables remote access to the system (connected via local area network) for planning and processing.

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PRELIMINARY PROPOSAL

Qty	Part No.	Item Description
1	14416959	**Shoulder 16 Coil Kit #Sk** The new Tim 4G coil technology with Dual Density Signal Transfer and SlideConnect Technolgy combines key imaging benefits: excellent image quality, high patient comfort, and unmatched flexibility. The Shoulder 16 Coil Kit for examinations of the left or right shoulder consists of a base plate and two different sized iPAT compatible 16 channel coils (Shoulder Large 16 and Shoulder Small 16). These will be attached and can be relocated on the base plate.The 16-element coils with 16 integrated pre-amplifiers ensure maximimum signal-to-noise ratio. Shoulder Large 16 and Shoulder Small 16 will be connected via a SlideConnect plug for fast and easy coil set-up and patient preparation.
1	14418514	**Foot/Ankle 16 #Sk** The new Tim 4G coil technology with Dual Density Signal Transfer and DirectConnect Technolgy combines key imaging benefits: excellent image quality, high patient comfort, and unmatched flexibility. Foot/Ankle 16 for examinations of the left or right foot and ankle region consists of a base plate and an iPAT compatible 16-channel coil and allows high resolution imaging of the foot and ankle within one examination. Foot/Ankle 16 is a cable-less coil and will be connected via DirectConnect for fast and easy patient preparation.
1	14418519	**Tim Coil Interface 3T** Coil adapter plug for up to 8 receive and 1 transmit channels, in order to connect existing dedicated knee and breast coils (Tx/ Rx 15-channel Knee Coil, CP Extremity Coil, 4-channel BI Breast Coil, 16-channel AI Breast Coil, 2/4/8-channel Sentinelle BreastCoil) with MAGNETOM Skyra Systems.
1	14418520	**Tx/Rx 15-channel Knee Coil 3T** New 15-channel transmitter/receiver coil for joint examinations in the area of the lower extremities. Main features : - 15-element design (3x5 coil elements) with 15 integrated preamplifiers, - iPAT-compatible
1	14418511	**Body 18 #Sk** The new Tim 4G coil technology with Dual Density Signal Transfer and SlideConnect Technolgy combines key imaging benefits: excellent image quality, high patient comfort, and unmatched flexibility: - 18 channels (inherent) or up to 30 (in combination with the Spine 32) - Dual Density Signal Transfer - Ultra light-weight - SlideConnect Technology The Body 18 is part of the standard configuration. The 18-channel coil with its 18 intergrated pre-amplifiers ensures excellent signal-to-noise ratio. The 18 coil elements provide extensive coverage in all directions. The single SlideConnect plug allows for fast and easy patient preparation. The light-weight coil ensures highest patient comfort. The Body 18 Coil features: - 18-element design with 18 integrated preamplifiers (3 clusters of 6 elements each) - Operates in an integrated fashion with the Spine 32 as an 30 channel body coil - Can be combined with further Body 18 coils for larger coverage - Can be positioned in different orientations (0°, 90°, 180°, 270°) for patient specific adaptations - No coil tuning - iPAT compatible in all directions The highly flexible design enables a wide variety of applications including: - Thorax (incl. heart) - Abdomen - Pelvis - Hip Typically combined with: - Head / Neck 20 - Spine 32 - Additional Body 18 coil(s) (optional) - Peripheral Angio 36 (optional) - Flex Large 4 - Flex Small 4 - Loop 3T coils (optional) - Endorectal coil (optional)
1	14416904	**32-channel Head Coil #Sk** The 32-channel Head Array Coil is an iPAT-compatible **"no-tune" receiver** coil for MAGNETOM Skyra.
1	14407258	**MR Workplace Table 1.2m** Table suited for syngo Acquisition Workplace and syngo MR Workplace based on syngo Hardware.
1	14407261	**MR Workplace Container, 50cm** 50 cm wide extra case for the syngo host computer with sliding front door to allow change of storage media (CD/DVD/USB).
1	14418489	**Separator 60kW** The SEP (Separation cabinet) has to be used if a central hospital chilled water supply is available or if a chiller of any brand/type is already available. The SEP is the interface between the on-site water chiller (of any brand or type) or the interface to the central hospital cooling water supply. For the above-mentioned cases the SEP is mandatory! In these cases, the primary water specifications must fulfill the requirements (i.e. 63 kW heat dissipation; 100+-10l/min flow; 6 to 12°C water temperature; pH value 6 to 8, max. working pressure 6 bar). Dimensions: 1950mm x 650mm x 650mm (height x width x depth) Weight: approx. 340kg
1	08857828	**UPS Cable #Tim** Power cable for connecting the UPS Powerware PW 9130-3000i (14413662) to the ACC of MAGNETOM Tim and MAGNETOM Tim+Dot systems for backing up the computer. Standard cable length: 9 m.

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PRELIMINARY PROPOSAL

Qty	Part No.	Item Description
1	14413662	**UPS Powerware PW9130G-3000T-XLEU** UPS system Eaton PW9130G-3000T-XLEU for MAGNETOM Tim, MAGNETOM Tim+Dot and MAGNETOM Symphony systems for safeguarding computers. Power output: 3.0 kVA / 2.7 kW Bridge time: 5 min full load / 14 min half load Input voltage: 230 VAC
1	14413663	**UPS Battery module** UPS battery module Eaton PW 9130N-3000T-EBM for all MAGNETOM Tim, MAGNETOM Tim+Dot and MAGNETOM Symphony systems for safeguarding computers. Extension for: PW9130i-3000T Battery type: Closed, maintenance-free Extension of the bridge time to: 24 minutes with a module Dimensions (H x W x D): Battery module: 346 x 214 x 412 mm incl. bracket set Weight: approx. 50 kg
1	MR_STD_RIG_INST	**MR Standard Rigging and Installation**
1	MR_BTL_INSTALL	**MR Standard Rigging & Install**
1	MR_PREINST_DOCK	**T+D Preinstall kit for dockable table**
1	MR_CRYO	**Standard Cryogens**
1	MR_PM	**MR Project Management**
1	MR_INITIAL_32	**Initial onsite training 32 hrs**
1	MR_FOLLOWUP_24	**Follow-up training 24 hrs**
1	MR_INT_SYN_BCLS	**Basic syngo MR Class**
1	MR_ADD_32	**Additional onsite training 32 hours**
1	4MR5142869	**Armrest #MR**
1	M3SSMREPICBC	**Spectris Solaris EP injector iCBC** Includes Spectris Solaris EP injector and Integrated Continuous Battery Charger (ICBC). - Optimized color touch screen with few keystrokes. - Six user-programmable phases for added flexibility. - Independent Keep Vein Open (KVO) allows more time to focus on patient. - Large 115 mL saline syringe allows for longer KVO and multiple flushes. - Design of low pressure tubing eliminates dead space in the "T" connection that can waste contrast. - The clear barrel design with molded FluidDots help detect the presence of air in a syringe. - Pressure Limit Setting control software enables user to select from one to six preset maximum pressure limits, ranging from 100-300 psi, and to view current pressure during injection next to the pre-selected maximum value on the Solaris display. Installation, applications and one year warranty provided by Medrad. Not for mobile use, refer to Siemens part number M3SSMR300EPM for the Solaris injector used in a mobile environment. This product has been tested and verified for compatibility with the following Siemens' products: MAGNETOM Trio, Espree, Essenza, Verio, Avanto, Symphony, Aera, Skyra and Biograph mMR. Compatibility with other products cannot be guaranteed and use with any other products may void service contracts and/or system warranties.
1	MR_ADDL_RIGGING	**Additional Out of Scope Rigging MR $41,148**

System Total: $2,392,690

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PRELIMINARY PROPOSAL

OPTIONS:

Qty	Part No.	Item Description	Extended Price
1	14426310	**Angio Dot Engine** The timing of contrast injection and scan is widely considered the most challenging part of an angiographic exam. Angio Dot guides the user through angiographic single or multi station examinations by providing semi-automatic detection of arterial and venous timing windows using a test bolus technique. This information is fed back into the next planning steps automatically adapting scan parameters to the individual patient and patient's condition. Where needed, AutoVoiceCommands support the communication with the patient and ensure optimal timing of breathing, scanning and contrast media. All steps of contrast injection are presented in a simple, automated graphic on the monitor. syngo Inline Composing and the Tim Planning Suite are included.	+ $31,185

FINANCING: The equipment listed above may be financed through Siemens. Ask us about our full range of financial products that can be tailored to meet your business and cash flow requirements. For further information, please contact your local Sales Representative.

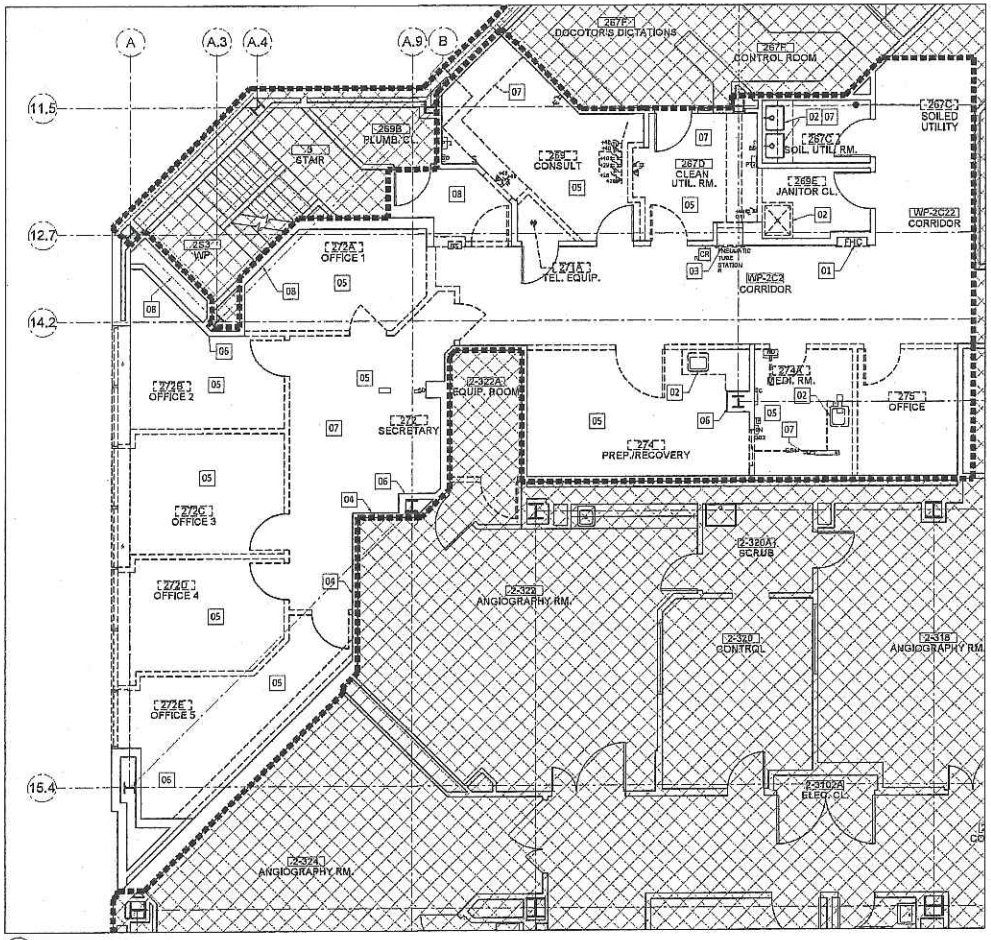
Siemens Healthcare is pleased to submit this Preliminary Pricing Proposal. To place an order for the above listed items, please notify your Siemens Healthcare Sales Representative who will submit to you a formal Siemens Healthcare Proposal, inclusive of Terms, Conditions, and Warranty coverage. Only a formal Siemens Healthcare Proposal may be used to create a binding order for this equipment.

Siemens Healthcare

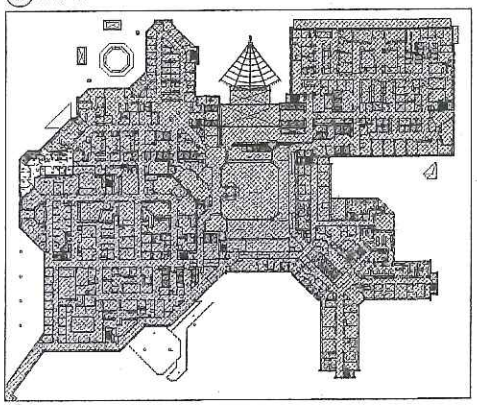
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APPENDIX VII

FLOOR PLANS



1 DEMOLITION PLAN
DM-201 SCALE: 1/4" = 1'-0"



2 SITE PLAN
DM-201 1/64" = 1'-0"

DEMOLITION GENERAL NOTES

1. FIELD VERIFY ALL EXISTING CONDITIONS AND NOTIFY ARCHITECT OF ANY DISCREPANCIES IN WRITING PRIOR TO ONSET OF DEMOLITION.
2. DEMOLITION/RESTORATION ITEMS MAY NOT BE ALL-INCLUSIVE. THE DEMOLITION CONTRACTOR IS TO REVIEW THE REQUIREMENTS OF NEW CONSTRUCTION AND IS TO COMPLETE ALL DEMOLITION/RESTORATION, CUTTING, AND PATCHING NECESSARY TO ACHIEVE INTENDED NEW CONDITION AND QUALITY.
3. SELECTIVE DEMOLITION IS NOT INDICATED IN AREAS WHERE IT MAYBE NECESSARY TO DEMOLISH ALL OR PART OF AN EXISTING BUILDING COMPONENT TO GAIN ACCESS TO AREAS FOR REVIEW TO BUILDING SYSTEMS, OR WHICH MAY BE REQUIRED TO INSTALL NEW CONSTRUCTION AS INDICATED OF THE DRAWING. DEMOLITION FOR THESE PURPOSES SHALL BE DONE AT NO ADDITIONAL COST TO THE OWNER, AND THE AREAS SHALL BE RETURNED TO THEIR ORIGINAL CONDITION PRIOR TO BEGINNING CONSTRUCTION.
4. DEMOLITION WORK SHALL BE EXECUTED IN CONFORMANCE WITH THE LOCAL BUILDING CODES.
5. EXERCISE EXTREME CAUTION IN THIS DEMOLITION. COST OF REPAIR TO ANY ADJACENT CONDITIONS WHICH ARE DAMAGED AS A RESULT OF THIS DEMOLITION SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR.
6. CERTAIN ITEMS ARE TO BE RETURNED TO THE BUILDING OWNER. COORDINATE WITH THE BUILDING OWNER WHICH ITEMS ARE TO BE RETURNED AND THE LOCATION SAID ITEMS ARE TO BE STORED.
7. ALL MATERIALS TO BE DISPOSED BY THE CONTRACTOR OFF THE PROJECT SITE IN ACCORDANCE WITH LOCAL RESTRICTIONS UNLESS NOTED OTHERWISE HEREIN.
8. ALL AREAS SHALL BE KEPT IN A BROOM CLEAN CONDITION AT ALL TIMES.
9. UNLESS SHOWN DASHED TO BE REMOVED, ALL DOORS AND FRAMES TO REMAIN. ALL HARDWARE ON DEMOLISHED DOORS TO BE REMOVED AND STORED FOR FUTURE USE BY CLIENT. SEE PARTITION PLAN.
10. ALL COLUMN ENCLOSURES TO REMAIN, UNLESS OTHERWISE NOTED.
11. EXISTING ACCESS PANELS TO REMAIN, TYP U.O.N. CLEAN, REPAIR TO LIKE NEW CONDITION AND PREPARE FOR PROPOSED FINISH.
12. EXISTING DRAINAGE TO BE REMOVED, STORED, AND REINSTALLED FOLLOWING SUBSTANTIAL COMPLETION OF WORK.

ELECTRICAL:
1. SEE ELECTRICAL DRAWINGS FOR EXTENT OF EXISTING ELECTRICAL DEVICES, RECEPTACLES, AND PANELS TO REMAIN.
2. EXISTING SECURITY DEVICES TO REMAIN, UNLESS OTHERWISE NOTED.
3. ALL ELECTRICAL DEVICES AND CONDUIT LOCATED IN A WALL TO BE DEMOLISHED MUST BE DISCONNECTED AND CUT BACK TO NEAREST JUNCTION BOX.
4. CONTRACTOR MAY NOT CUT ANY VOICE/DATA CABLING WITHOUT FIRST CONFIRMING THE CUTS WITH THE LOCAL INFORMATION TECHNOLOGY MANAGER.

MECHANICAL:
1. SEE MECHANICAL DRAWINGS FOR EXTENT OF EXISTING DUCTWORK, THERMOSTATS, AND MECHANICAL EQUIPMENT TO REMAIN.
2. EXISTING PERIMETER MECHANICAL UNITS AND BASE BUILDING METAL ENCLOSURES TO REMAIN. CLEAN, REPAIR AND PREPARE FOR FINISH. EXISTING THERMOSTATS TO BE REPLACED. SEE MECHANICAL DRAWINGS.
3. ALL ABANDONED DUCTWORK OR PIPING NOT NECESSARY FOR PROPOSED CONSTRUCTION MUST BE REMOVED FROM HUNG CEILING AREAS AND FLOOR DUCTS.

FIRE PROTECTION AND LIFE SAFETY:
1. ANY EXISTING TO REMAIN FIRE ASSEMBLIES DAMAGED DURING DEMOLITION SHALL BE REPAIRED TO MEET ORIGINAL FIRE PROTECTION REQUIREMENTS.
2. EXISTING FIRE PROTECTION AND LIFE SAFETY DEVICES, INCLUDING SPEAKERS, STROBES, EMERGENCY FIXTURES, EXIT LIGHTS AND SPRINKLERS TO REMAIN, U.O.N.
3. PATCH ALL OPENINGS LEFT IN FIRE RATED SEPARATIONS BY REMOVAL OF DUCTWORK OR PIPING. PATCH USING MATERIAL NECESSARY TO MAINTAIN FIRE RATING OF WALL OR FLOOR.

STRUCTURAL:
1. PROTECT ALL STRUCTURAL MEMBERS FROM DAMAGE.
2. DURING DEMOLITION, BRACE ALL EXISTING STRUCTURES AS NEEDED.
3. DO NOT CUT STRUCTURAL WORK IN A MANNER RESULTING IN A REDUCTION OF LOAD CARRYING CAPACITY OR LOAD/DEFLECTION RATIO. NOTIFY ARCHITECT OF ALL STRUCTURAL CUTS PRIOR TO EXECUTION TO OBTAIN APPROVAL.
4. IN ALL AREAS WHERE DEMOLITION OR EXISTING CONDITIONS CAUSE UNEVENNESS IN THE FLOOR SLAB, PERFORM THE NECESSARY WORK REQUIRED TO PROVIDE A SMOOTH SLAB PREPARED TO RECEIVE NEW FINISHES.

FINISHES:
1. PATCH AND REPAIR ALL AREAS WHERE A DEMOLISHED PARTITION INTERSECTS AN EXISTING PARTITION. PREPARE PARTITION TO RECEIVE PROPOSED FINISHES, AS SHOWN ON FINISH PLANS AND ELEVATIONS, TYP.
2. ALL CARPET, PADDING AND BASE TO BE REMOVED, UNLESS OTHERWISE NOTED. ALL TILE TO REMAIN, UNLESS LOOSE OR DAMAGED. PATCH FLOOR/PARTITION AND PREPARE FOR PROPOSED FINISH. SEE FINISH PLAN.

DEMOLITION PLAN LEGEND

	EXISTING PARTITION TO REMAIN
	EXISTING PARTITION TO BE DEMOLISHED
	EXISTING DOOR AND FRAME TO REMAIN
	EXISTING DOOR AND FRAME TO BE DEMOLISHED
	TEMPORARY WALL

DEMOLITION KEYED NOTES

01	DEMOLISH FIRE HOSE CABINET, SEE PLAN.
02	REMOVE PLUMBING & CUT BACK TO RISER, SEE PLUMBING DRAWINGS.
03	RELOCATE/RECONCILE PNEUMATIC TUBE STATION, SEE PARTITION PLAN.
04	GC TO DEMOLISH EXISTING GWB LAYER. EXISTING STUDS TO REMAIN.
05	COORDINATE DEMOLITION AND REMOVAL OF EXISTING EQUIPMENT WITH YNHH.
06	MAINTAIN EXISTING FIREPROOFING FOR COLUMNS. PATCH ANY DAMAGED FIREPROOFING.
07	DEMOLISH MILLWORK AS NECESSARY, TYP.
08	MAINTAIN FIRE RATING. SEE LIFE SAFETY PLAN AND PARTITION PLAN.

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YALE NEW HAVEN HOSPITAL
PEDIATRIC MRI

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Project No. 08-100.009

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No.	Date	Description
24	08.03.11	TEST FITS FOR REVIEW
25	08.09.11	TEST FITS FOR REVIEW
26	08.16.11	TEST FITS FOR REVIEW
27	09.23.11	TEST FITS FOR REVIEW
28	09.30.11	TEST FITS FOR REVIEW
29	10.07.11	TEST FITS FOR REVIEW
30	10.14.11	TEST FITS FOR REVIEW
31	10.21.11	TEST FITS FOR REVIEW
32	11.04.11	TEST FITS FOR REVIEW
33	11.11.11	TEST FITS FOR REVIEW
34	11.18.11	TEST FITS FOR REVIEW
35	12.07.11	FOR MEP COORDINATION
36	12.09.11	FOR CLIENT REVIEW
37	12.20.11	DD PRICING

REVISIONS
No. Date Description

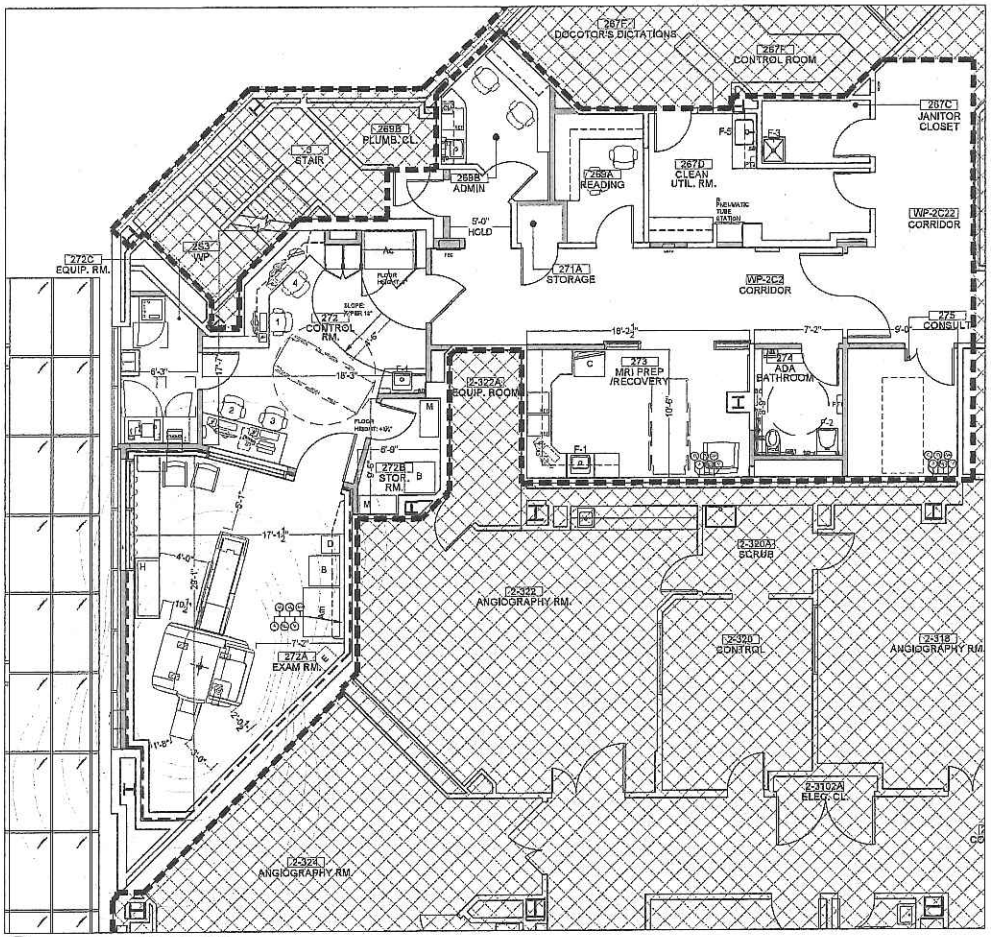
Acceptance of drawings in electronic format shall be subject to the following conditions: Drawings are prepared using AutoCAD software. Neither party hereto warrants to the other that the files created in said software will be compatible with any computer hardware or software in the other party's system regardless of any representations that the other party may have made to the contrary. Files provided hereunder shall not be considered executed versions of the drawings or specifications.

NORTH

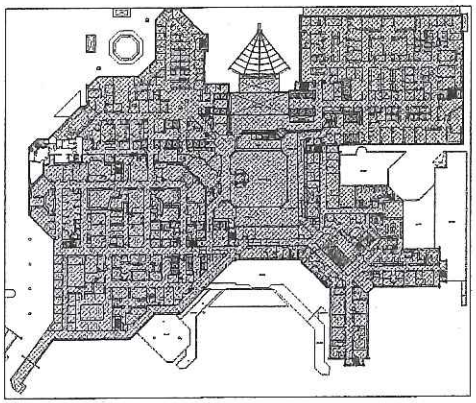
seal

2ND FLOOR
DEMOLITION PLAN

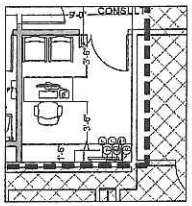
DM-201



1 FURNITURE, FIXTURE, AND EQUIPMENT PLAN
A-701.00 SCALE: 1/4" = 1'-0"



2 SITE PLAN
A-701.00 SCALE: 1/64" = 1'-0"



3 ALT CONSULT FURNITURE LAYOUT
A-701.00 SCALE: 1/4" = 1'-0"

LEGEND:
(FURNISHED AND INSTALLED BY OTHERS)

An	ANESTHESIA CART 25" X 41" - VERIFY
V	VENTILATOR 25 X 25"-VERIFY
P	PYXIS 24" X 30"-VERIFY
M	MONITOR CART 18" X 18"-VERIFY
I	INJECTOR 16" X 18"-VERIFY
F	ADULT/PEDI. DEFIB. 24" X 24"-VERIFY
C	ADULT/PEDI. CODE CART 24" X 24"-VERIFY
M	ASSORTED METRO SHELVING
	CODE CART 59"-(10" X 21"
An	ANESTHESIA MACHINE 25" X 46" - VERIFY
L	LINEN CART 24" X 60"
CPU	CPU
BED	BED
	OFFICE CHAIR
MRI	MRI

LEGEND: (FURNISHED AND INSTALLED BY GC)

FC	KOHLER CHESAPEAKE WALL-MOUNT LAVATORY #K-1721; SINGLE HOLE; SLOAN ELECTRONIC GOOSENECK HAND WASHING FAUCET #ESF-30, 30-SECOND TIME OUT, 4" TRIM PLATE, HARDWIRED, SEE TYPICAL MOUNTING HEIGHTS SHEET.
FC	KOHLER MORNINGSIDE ADA-COMPLIANT LAVATORY #K-12638; SINGLE HOLE; SLOAN ELECTRONIC GOOSENECK HAND WASHING FAUCET #ESF-30, 30-SECOND TIME OUT, 4" TRIM PLATE, HARDWIRED. SEE TYPICAL MOUNTING HEIGHTS SHEET.
SK	ELKAY FLOOR SERVICE SINK #EFS2525C; ELKAY COMMERCIAL FAUCET #LK9078997TH WALL-MOUNT 8" CENTER BUCKET HOOK ROUGH 7", MOUNT FAUCET AT 30" A.F.F. n.c.
WC	KOHLER KINGSTON ADA-COMPLIANT, WALL-MOUNTED, REAR-SPUD TOILET #K-4328; SLOAN DUAL-FLUSH FLUSHOMETER #WES-111; SEE MEP DRAWINGS. KOHLER LUCITA OPEN FRONT SEAT WITH ANTI-MICROBIAL AGENT #K-4673-CA. SEE TYPICAL MOUNTING HEIGHTS SHEET
LAV	ELKAY GOURMET UNDERMOUNT SINGLE BOWL SINK; MODEL NO: ELUH211510 ELKAY COMMERCIAL FAUCET; MODEL LMDR3451.2
GB	ELCONA STAINLESS STEEL GRAB BARS: STRAIGHT GRAB BARS WITH TWIST LOCK CONCEALED FLANGES; CATALOG NUMBER: 01-83-36-ST GC TO PROVIDE CONCEALED BLOCKING.
GB	ELCONA STAINLESS STEEL GRAB BARS: STRAIGHT GRAB BARS WITH TWIST LOCK CONCEALED FLANGES; CATALOG NUMBER: 04-22836ST; GC TO PROVIDE CONCEALED BLOCKING.
SC	SEAT-COVER DISPENSER: BOBRICK SURFACE-MOUNTED SEAT-COVER DISPENSER; CATALOG NUMBER: B-221
SV	NAPKIN DISPOSAL: BOBRICK SURFACE-MOUNTED SANITARY NAPKIN DISPOSAL; CATALOG NUMBER: B-254
PT	BOBRICK CONTURA SERIES RECESSED PAPER TOWEL DISPENSER AND WASTE RECEPTACLE; B-43944
PT	BOBRICK SURFACE MOUNTED PAPER TOWEL DISPENSER ; B-4262
TP	BOBRICK TRANSIENT SERIES SURFACE-MOUNTED NAPKIN TAMPON VENDOR; B-370039
SD	BOBRICK TOUCH FREE COUNTER MOUNT SOAP DISPENSER, B520-01.
TP	TOILET PAPER DISPENSER: BOBRICK SURFACE-MOUNTED MULTI-ROLL TOILET TISSUE DISPENSER ; CATALOG NUMBER: B-4288
M	ADA MIRROR: BOBRICK TILT MIRROR WITH STAINLESS STEEL FRAME; CATALOG NUMBER: B-293 1836 SERIES, MIRROR TO BE CENTERED ON CENTERLINE OF SINK; PROVIDE FILLER STRIP BEHIND EDGE OF MIRROR FOR BACK OF MIRROR TO BE CONTINUOUSLY FLUSH WITH PARTITION OVER FINISH TRANSITION.
AIR	AIR CONNECTION
N2O	NITROUS OXIDE CONNECTION
O2	OXYGEN CONNECTION
RF	RF SHIELDING
WV	WASTE VACUUM
VAC	VACUUM CONNECTION
MED GAS	MED GAS CONTROL VALVE; SEE MEP DRAWINGS FOR SPECIFICATIONS
FE	FIRE EXTINGUISHER CABINET; DOOR STYLE - HORIZONTAL DUO DOOR GLAZING - CLEAR TEMPERED SAFETY GLASS; TRIM STYLE PROJECTION -1/2"SQUARE TRIM SEMI RECESSED; TRIM AND DOOR MATERIAL - STEEL
REF	REFRIGERATOR

GENERAL NOTES

1. ELECTRIC AND DATA RECEPTACLES SHOWN FOR COORDINATION PURPOSES. SEE ELECTRICAL DRAWINGS FOR CIRCUITING.
2. LANDLORD SHALL PROVIDE AND INSTALL HECCO SHADES ON ALL PERIMETER WINDOWS. ARCHITECT TO CONFIRM COLOR PRIOR TO ORDER AND INSTALLATION. SEE DETAIL SHEETS FOR MOUNTING DETAILS AND POWER PLAN FOR POWER REQUIREMENTS. CONTRACTOR TO COORDINATE WITH LANDLORD'S INSTALLER.
3. ALL DIMENSIONS SHALL BE FIELD VERIFIED BY FURNITURE VENDOR AND INSTALLER PRIOR TO ORDER. CONTACT ARCHITECT PRIOR TO FURNITURE ORDER FOR ANY DISCREPANCIES. CLIENT AND ARCHITECT SHALL NOT BE RESPONSIBLE FOR ANY COSTS ASSOCIATED WITH MODIFYING FURNITURE TO FIT FIELD CONDITIONS.
4. ALL WHIP LOCATIONS TO BE CONFIRMED AND CLEARLY NOTED IN PLANS PROVIDED BY FURNITURE VENDOR. CONTACT ARCHITECT FOR ANY DISCREPANCIES.
5. ALL ELECTRICAL AND DATA LOCATIONS SHALL BE CONFIRMED IN THE FIELD BY THE FURNITURE VENDOR PRIOR TO WIRING AND INSTALLATION.
6. FURNITURE VENDOR SHALL PROVIDE SPECIFICATIONS OF THE PROPOSED WIRING CONFIGURATIONS AND COORDINATE WITH ELECTRICAL ENGINEER. CLIENT AND ARCHITECT SHALL NOT BE RESPONSIBLE FOR ANY COSTS ASSOCIATED WITH MODIFYING ELECTRICAL COMPONENTS TO FIT FIELD CONDITIONS.
7. FURNITURE VENDOR SHALL PROVIDE ARCHIMETRIC AND INSTALLATION PLAN DRAWINGS, IN .DWG AND .PDF FORMAT, WITH ALL QUOTES. ARCHITECT WILL NOT REVIEW FURNITURE QUOTE UNTIL ARCHIMETRIC AND PLAN DRAWINGS ARE RECEIVED. PROPOSAL APPROVAL IS CONTINGENT ON VENDOR PROVIDING INSTALLATION PLAN DRAWINGS.

KEYED NOTES

01	MILLWORK, GC TO PROVIDE BLOCKING. SEE PARTITION PLANS, SECTION, ELEVATION AND DETAILS.

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YALE NEW HAVEN HOSPITAL
PEDIATRIC MRI

Yale New Haven Hospital
2nd Floor
20 York Street
New Haven, CT 06504

Project No. 08-100.000

CENTEK engineering
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No.	Date	Description
24	08.02.11	TEST FITS FOR REVIEW
25	08.09.11	TEST FITS FOR REVIEW
26	08.16.11	TEST FITS FOR REVIEW
27	08.23.11	TEST FITS FOR REVIEW
28	09.30.11	TEST FITS FOR REVIEW
29	10.07.11	TEST FITS FOR REVIEW
30	10.14.11	TEST FITS FOR REVIEW
31	10.21.11	TEST FITS FOR REVIEW
32	11.04.11	TEST FITS FOR REVIEW
33	11.11.11	TEST FITS FOR REVIEW
34	11.18.11	TEST FITS FOR REVIEW
35	12.07.11	FOR MEP COORDINATION
36	12.09.11	FOR CLIENT REVIEW
37	12.20.11	DD PRICING

REVISIONS
No. Date Description

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NORTH

seal

2ND FLOOR
FURNITURE, FIXTURE
AND EQUIPMENT PLAN

A-701.00

APPENDIX VIII

FINANCIAL ATTACHMENT I

Office of Health Care Access
Financial Attachment I

Yale-New Haven Hospital
(All dollars are in thousands)

Total Facility: / Description	FY 2011 Actual Results	FY 2012 Projected W/O CON	FY 2012 Projected Incremental	FY 2012 Projected With CON	FY 2013 Projected W/O CON	FY 2013 Projected Incremental	FY 2013 Projected With CON	FY 2014 Projected W/out CON	FY 2014 Projected Incremental	FY 2014 Projected With CON	FY 2015 Projected W/out CON	FY 2015 Projected Incremental	FY 2015 Projected With CON	FY 2016 Projected W/out CON	FY 2016 Projected Incremental	FY 2016 Projected With CON
Net Patient Revenue																
Non- Government	$ 728,857	$ 927,799	$ -	$ 927,799	$ 1,164,381	$ -	$ 1,164,381	$ 1,229,971	$ 2,934	$ 1,232,905	$ 1,304,374	$ 3,052	$ 1,307,426	$ 1,379,340	$ 3,175	$ 1,382,516
Medicare	481,753	$ 521,852	-	521,852	800,034	-	800,034	822,116	484	822,600	847,043	503	847,546	880,833	523	881,356
Medicaid and Other Medical Assistance	225,122	$ 300,719	-	300,719	341,015	-	341,015	354,193	238	354,430	371,275	247	371,522	392,021	257	392,278
Other Government	6,325	13,830	-	13,830	13,844	-	13,844	13,858	-	13,858	13,872	-	13,872	13,885	-	13,885
Total Net Patient Revenue	$ 1,442,057	$ 1,764,200	$ -	$ 1,764,200	$ 2,319,274	$ -	$ 2,319,274	$ 2,420,138	$ 3,655	$ 2,423,793	$ 2,536,564	$ 3,803	$ 2,540,367	$ 2,666,079	$ 3,956	$ 2,670,035
Other Operating Revenue	$ 46,640	$ -	$ -	$ -	$ 60,727	$ -	$ 60,727	$ 60,727	$ -	$ 60,727	$ 60,727	$ -	$ 60,727	$ 60,727	$ -	$ 60,727
Revenue from Operations	$ 1,488,697	$ 1,764,200	$ -	$ 1,764,200	$ 2,380,001	$ -	$ 2,380,001	$ 2,480,865	$ 3,655	$ 2,484,520	$ 2,597,291	$ 3,803	$ 2,601,094	$ 2,726,806	$ 3,956	$ 2,730,762
Salaries and Fringe Benefits	$ 680,313	$ 770,717	$ -	$ 770,717	$ 1,053,715	$ -	$ 1,053,715	$ 1,159,251	$ 633	$ 1,159,884	$ 1,161,845	$ 652	$ 1,162,497	$ 1,222,724	$ 672	$ 1,223,396
Professional / Contracted Services	318,798	384,348	-	384,348	520,852	-	520,852	471,809	344	472,153	518,642	354	518,997	557,345	365	557,710
Supplies and Drugs	290,189	345,051	-	345,051	522,854	-	522,854	551,159	294	551,453	580,995	303	581,298	611,670	312	611,982
Bad Debts	26,390	36,129	-	36,129	35,046	-	35,046	36,097	-	36,097	37,180	-	37,180	38,295	-	38,295
Other Operating Expense	13,377	16,860	-	16,860	17,366	-	17,366	17,887	-	17,887	18,423	-	18,423	18,976	-	18,976
Subtotal	$ 1,339,067	$ 1,553,105	$ -	$ 1,553,105	$ 2,149,833	$ -	$ 2,149,833	$ 2,236,203	$ 1,272	$ 2,237,475	$ 2,337,085	$ 1,310	$ 2,338,395	$ 2,449,010	$ 1,349	$ 2,450,359
Depreciation/Amortization	67,948	$ 74,357	-	$ 74,357	$ 102,560	$ -	$ 102,560	$ 108,838	$ 355	$ 109,193	$ 113,235	$ 711	$ 113,946	$ 118,460	$ 711	$ 119,171
Interest Expense	16,867	17,759	-	17,759	42,420	-	42,420	44,111	-	44,111	43,490	-	43,490	47,848	-	47,848
Lease Expense	11,926	13,679	-	13,679	14,089	-	14,089	14,512	-	14,512	14,947	-	14,947	15,396	-	15,396
Total Operating Expense	$ 1,435,808	$ 1,658,900	$ -	$ 1,658,900	$ 2,308,902	$ -	$ 2,308,902	$ 2,403,664	$ 1,627	$ 2,405,291	$ 2,508,757	$ 2,021	$ 2,510,778	$ 2,630,714	$ 2,060	$ 2,632,774
Gain/(Loss) from Operations	$ 52,889	$ 105,300	$ -	$ 105,300	$ 71,099	$ -	$ 71,099	$ 77,201	$ 2,028	$ 79,229	$ 88,534	$ 1,782	$ 90,316	$ 96,092	$ 1,896	$ 97,988
Plus: Non-Operating Revenue	$ 14,273	$ 12,000		$ 12,000	$ 39,099	$ -	$ 39,099	$ 40,840		$ 40,840	$ 42,708		$ 42,708	$ 44,804	$ -	$ 44,804
Revenue Over/(Under) Expense	$ 67,162	$ 117,300	$ -	$ 117,300	$ 110,198	$ -	$ 110,198	$ 118,041	$ 2,028	$ 120,069	$ 131,242	$ 1,782	$ 133,024	$ 140,896	$ 1,896	$ 142,792
Number of FTE's	7,864	8,135	-	8,135	10,862		10,868	10,938	7	10,945	11,015	7	11,022	11,093	7	11,086
Inpatient Cases	57,451	60,181	-	60,181	80,208		80,208	81,650		81,950	83,680		83,680	85,458		85,458
Patient Days	30,089	316,002	-	316,002	417,201		417,201	423,031	-	423,031	428,493	-	428,493	433,777	-	433,777
Outpatient encounters	634,795	752,237	-	752,237	844,267		844,712	875,626	1,805	877,431	906,249	1,823	910,072	942,188	1,841	944,029
Inpatient MRI encounters									474			479			484	

Notes:

APPENDIX IX

FINANCIAL ATTACHMENT II

Office of Health Care Access
Financial Atttachment II

Yale-New Haven Hospital

Please provide three years of projections of incremental revenue, expense and volume statistics attributable to the proposal in the following reporting format:

Type of Service Description	MRI
Type of Unit Description:	Encounters
# of Months in Operation	12

Year 2 - 2014 FY Projected Incremental	(1)	(2) Rate	(3) Units	(4) Gross Revenue Col. 2 * Col. 3	(5) Allowances/ Deductions	(6) Charity Care	(7) Bad Debt	(8) Net Revenue Col.4 - Col.5 -Col.6 - Col.7	(9) Operating Expenses Col. 1 Total * Col. 4 / Col. 4 Total	(10) Gain/(Loss) from Operations Col. 8 - Col. 9
Total Incremental Expenses:	**$1,627,123**									
Total Facility by Payer Category:										
Medicare		$6,110	239	$1,460,290	$976,712			$483,578	$215,447	$268,131
Medicaid		$6,110	124	$757,640	$520,035			$237,605	$111,780	$125,825
CHAMPUS/TriCare		$6,110	-	$0	$0			$0	$0	$0
Total Governmental			363	$2,217,930	$1,496,747	$0	$0	$721,183	$327,227	$393,956
Commercial Insurers		$6,110	1,415	$8,645,650	$5,767,815			$2,877,835	$1,275,556	$1,602,279
Uninsured		$6,110	27	$164,970		$103,831	$4,949	$56,190	$24,339	$31,851
Total NonGovernment		$6,110	1,442	$8,810,620	$5,767,815	$103,831	$4,949	$2,934,025	$1,299,895	$1,634,130
Total IP All Payers		$6,110	1,805	$11,028,550	$7,264,562	$103,831	$4,949	$3,655,208	$1,627,123	$2,028,085
		5% inflation								

Office of Health Care Access
Financial Atttachment II

Yale-New Haven Hospital

Please provide three years of projections of incremental revenue, expense and volume statistics attributable to the proposal in the following reporting format:

Type of Service Description	MRI									
Type of Unit Description:	Encounters									
# of Months in Operation	12									
Year 3 - 2015	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
FY Projected Incremental		Rate	Units	Gross Revenue Col. 2 * Col. 3	Allowances/ Deductions	Charity Care	Bad Debt	Net Revenue Col.4 - Col.5 -Col.6 - Col.7	Operating Expenses Col. 1 Total * Col. 4 / Col. 4 Total	Gain/(Loss) from Operations Col. 8 - Col. 9
Total Incremental Expenses:	**$2,020,902**									
Total Facility by Payer Category:										
Medicare		$6,416	241	$1,546,136	$1,043,070			$503,066	$267,163	$235,903
Medicaid		$6,416	125	$801,938	$554,758			$247,180	$138,570	$108,610
CHAMPUS/TriCare		$6,416	-	$0	$0			$0	$0	$0
Total Governmental			366	$2,348,073	$1,597,827	$0	$0	$750,246	$405,732	$344,514
Commercial Insurers		$6,416	1,430	$9,174,165	$6,179,775			$2,994,390	$1,585,239	$1,409,151
Uninsured		$6,416	27	$173,219	$0	$110,146	$5,197	$57,876	$29,931	$27,945
Total NonGovernment		$6,416	1,457	$9,347,384	$6,179,775	$110,146	$5,197	$3,052,266	$1,615,170	$1,437,096
Total All Payers		$6,416	1,823	$11,695,457	$7,777,602	$110,146	$5,197	$3,802,512	$2,020,902	$1,781,610
		5% inflation								

Office of Health Care Access
Financial Atttachment II

Yale-New Haven Hospital

Please provide three years of projections of incremental revenue, expense and volume statistics attributable to the proposal in the following reporting format:

Type of Service Description	MRI									
Type of Unit Description:	Encounters									
# of Months in Operation	12									
Year 3 - 2016	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
FY Projected Incremental		Rate	Units	Gross Revenue Col. 2 * Col. 3	Allowances/ Deductions	Charity Care	Bad Debt	Net Revenue Col.4 - Col.5 -Col.6 - Col.7	Operating Expenses Col. 1 Total * Col. 4 / Col. 4 Total	Gain/(Loss) from Operations Col. 8 - Col. 9
Total Incremental Expenses:	**$2,060,199**									
Total Facility by Payer Category:										
Medicare		$6,736	243	$1,636,915	$1,113,575			$523,340	$271,933	$251,407
Medicaid		$6,736	127	$855,507	$598,366			$257,141	$142,121	$115,020
CHAMPUS/TriCare		$6,736	-	$0	$0			$0	$0	$0
Total Governmental			370	$2,492,422	$1,711,941	$0	$0	$780,481	$414,054	$366,427
Commercial Insurers		$6,736	1,444	$9,727,181	$6,609,785			$3,117,396	$1,615,930	$1,501,466
Uninsured		$6,736	27	$181,879	$0	$118,547	$5,456	$57,876	$30,215	$27,661
Total NonGovernment		$6,736	1,471	$9,909,061	$6,609,785	$118,547	$5,456	$3,175,272	$1,646,145	$1,529,127
Total All Payers		$6,736	1,841	$12,401,482	$8,321,726	$118,547	$5,456	$3,955,753	$2,060,199	$1,895,554
		5% inflation								

APPENDIX X

FINANCIAL ASSUMPTIONS

YALE-NEW HAVEN HOSPITAL
Proposal for the Pedi MRI

Assumptions

Net Revenue Rate Increases	FY 2013	FY 2014	FY 2015	FY 2016
1) Government	0.0 - 2.8%	0.0 - 2.8%	0.0 - 2.8%	0.0 - 2.8%
2) Non-Government	5.0 - 8.0%	5.0 - 6.0%	4.5 - 6.0%	4.0 - 6.0%

	FY 2013	FY 2014	FY 2015	0	FY 2016
EXPENSES					
A. Salaries and Fringe Benefits	5.0%	5.0%	5.0%		5.0%
B. Non-Salary					
1) Medical and Surgical Supplies	3.5%	3.5%	3.5%		3.5%
2) Pharmacy and Solutions	6.0%	6.0%	6.0%		6.0%
3) Malpractice Insurance	3.0%	3.0%	3.0%		3.0%
4) Professional and Contracted Services	2.5%	2.5%	2.5%		2.5%
5) All Other Expenses	3 - 4%	3 - 4%	3 - 4%		3 - 4%

	FY 2013	FY 2014	FY 2015	FY 2016
FTEs				
1) Total estimated FTEs	10,861.5	10,937.5	11,014.5	11,092.6

Notes - The above increase projections reflect all changes relating to Medicare and Medicaid reimbursement regulations.

Incremental MRI encounters are based on the following assumptions:
Pediatric MRI volume will increase 1% per year FY 2014- FY 2016
Shifted pediatric volume from adult scanners will be backfilled with incremental adult scan volume and will increase 1% per year FY 2014-FY 2016.

Greer, Leslie

From:	Greci, Laurie
Sent:	Friday, January 11, 2013 3:51 PM
To:	nancy.rosenthal@greenwichhospital.org
Cc:	Riggott, Kaila; Armah, Olga; Greer, Leslie
Subject:	Completeness Letter for CON Application to Acquire a 3.0T MRI for Yale Children's Hospital - Docket 12-31810-CON
Attachments:	12-31810-Yale Ped MRI completeness letter.docx; 12-31810-Yale Ped MRI completeness letter.pdf; Hospital of Saint Raphael.pdf; Yale New Haven Hospital.pdf

Dear Nancy,

Attached is the completeness letter in .pdf format for the above CON application that OHCA received on December 14, 2012. Included is a MS Word document version as well as the two attachments referred to in the letter.

Any questions, just contact one of us.

Thank you,

Laurie K. Greci
Associate Research Analyst
Department of Public Health
Health Care Access
laurie.greci@ct.gov
860 418-7032
860 418-7053

STATE OF CONNECTICUT

DEPARTMENT OF PUBLIC HEALTH

Office of Health Care Access

January 11, 2013

VIA ELECTRONIC MAIL ONLY

Ms. Nancy Rosenthal
Senior Vice President
Health Systems Development
Department of Planning & Business Development
Yale-New Haven Hospital
2 Howe St
New Haven, CT 06519

RE: Certificate of Need Application; Docket Number: 12-31810-CON
Yale-New Haven Hospital
Proposal to Acquire 3.0 Tesla Magnetic Resonance Imaging Scanner for the Yale-New Haven Children's Hospital Located in the City of New Haven

Dear Ms. Rosenthal:

On December 14, 2012, the Office of Health Care Access ("OHCA") received your initial Certificate of Need ("CON") application filing on behalf of Yale New Haven Hospital ("YNHH"), for the acquisition and installation of a 3.0 Tesla magnetic resonance imaging ("MRI") scanner in the Yale-New Haven Children's Hospital ("YNHCH") currently located in the city of New Haven. The total capital expenditure related to this proposal is approximately $5,875,828.

OHCA has reviewed the CON application and requests the following additional information pursuant to Connecticut General Statutes §19a-639a(c):

Page 14

1. Provide a comprehensive discussion on the options that YNHH considered concerning the pediatric MRI scanner proposal, including the following:
    a. Extending hours of operation of existing MRI scanners;
    b. Moving an existing MRI scanner to the YNHCH; and
    c. Upgrading to a 3.0T MRI scanner by replacing an existing MRI scanner and dedicating the new MRI scanner to the YNHCH.

2. Please provide a discussion on the preference for the use of MRI over Computed Tomography ("CT") as an imaging modality for children. Reference information in the articles submitted in Exhibit 3 of the CON application to support your discussion.

Page 15

3. Provide a discussion concerning each of the following:
    a. The capabilities of the proposed MRI scanner as compared to YNHH's existing scanners;
    b. The effect of the additional MRI scanning availability on providers within the service area with the proposal;

4. Will the centralization of pediatric MRI scans to a single location enable YNHH to perform 100% of these scans on the proposed 3.0T MRI scanner? Provide additional discussion. If existing MRI scanners are to be used for children, please report the conditions under which that would occur.

Pages 16 – 18

5. For "clear public need", YNHH describes the growing need for MRI scanners for pediatric patients as partly driven by Y-Access Transfer Line transfers from other physicians.
    a. Report the actual annual volumes of FYs 2010-2012 pediatric MRI transfers from non-YNHH physicians.
    b. Explain how meaningful use of electronic health records ("EHR") will affect the hospital's adult and pediatric MRI volumes, separately, due to these transfers. Include in your discussion the percentage of pediatric patients that come to YNHH with EHR that require additional scans.

6. In response to the OHCA 2011 Imaging Questionnaire ("Imaging Questionnaire") YNHH reported that every MRI scanner located at 20 York Street was in operation Sunday through Saturday, 24 hours each day. In Table B on page 18 of the initial CON application, varying hours of operation were reported in conflict with the Imaging Questionnaire. In Table 1 on page 21, the hours of operation for the Shoreline Medical Center at 111 Goose Lane again do not agree with the Imaging Questionnaire. Also, in Table 1 there are only three MRI scanners reported for the Temple Street location but in the response to the Imaging Questionnaire YNHH reported four MRI scanners; the hours of operations also do not agree. Please discuss and provide a current and accurate equipment list with operating hours for each MRI scanner at the three locations. For your convenience, a copy of the Imaging Questionnaire submitted by YNHH is attached.

7. According to the Imaging Questionnaire, the Saint Raphael Magnetic Resonance Center has four MRI scanners at 330 Orchard Street, New Haven. Report the operating hours and utilization of these four MRI scanners using the same format as Table 1 on page 21. For your convenience, a copy of the Imaging Questionnaire submitted by Saint Raphael Magnetic Resonance Center is attached.

Page 19

8. The MRI Center is listed as having 85 scheduled hours per week. However, on page 18 the reported hours total 84 hours. Please review Table C and revise as needed.

9. Discuss the use of MRI scanners for 51 weeks per year as reported in Table C.

10. Report the utilization of the two MRI scanners at the Saint Raphael campus using the same formats as Table C on page 19 and Table 1 on page 21.

11. How was it determined that there is a two to three week backlog for elective pediatric MRI exams? How many MRI scans and pediatric patients are counted in the backlog? Discuss the backlog for

elective exams in relation to the normal amount of time it takes for a pediatric patient and an adult patient to be scheduled for and receive a scan. What are the factors that contribute to the backlog?

12. Please complete the following table using utilization levels for all MRI patients and include any MRI scanners from Temple Radiology and Saint Raphael campus that are not listed as reported in response to Questions 5 and 6 above:

Scanners	Location	FY 2010	FY 2011	FY 2012	FY 2013 (Oct 1 to -)	FY 2013 Annual-ized	Acquisi-tion Date	Slice/ Strength	New/ Refur-bished
MRI Center 1	20 York St.			3,645				3.0T closed	
MRI Center 2	20 York St.			3,899				1.5T closed	
MRI Center 3	20 York St.			3,565				1.5T closed	
MRI Smilow 1 (breast only)	20 York St.			3,640				3.0T closed	
MRI Smilow 2	20 York St.			6,290				3.0T closed	
MRI Smilow 3	20 York St.			5,766				1.5T closed	
MRI Smilow 4	20 York St.			5,661				3.0T closed	
Operating Room Intraop. only	20 York St.								
Temple Radiology (outpatient only)	111 Goose Ln, Guilford			4,092				1.5T closed	
Temple Radiology (outpatient only)	60 Temple St, New Haven			1,131				0.6T Stand-up Unit	
Temple Radiology	60 Temple St., New Haven			3,101				1.5T	
St. Raphael's Campus 1									
St. Raphael's Campus 2									

Page 20

13. Explain the role of the child life specialist when performing a pediatric MRI scan.

Page 26 and 27

14. Please report the information provided in Tables 2a, 2b and 2c by age groups, i.e., 0-4 years, 5-12, and 13-17. In addition report subtotals within the age group of the number that required anesthesia and/or sedation.

15. The reported projected volume for FYs 2014, 2015, and 2016 are 4,734, 4,782 and 4,829 pediatric MRI scans, respectively. There are no scans listed for the "Proposed Pediatric MRI". Please complete the table for the projected volume that includes the number that will be performed on the proposed pediatric MRI scanner as well as those that may be performed on existing scanners.

16. Report the days and hours of operation for the MRI scanner that will be located in the YNHCH.

In responding to the questions contained in this letter, please repeat each question before providing your response. **Paginate and date** your response, i.e., each page in its entirety. Information filed after the initial CON application submission (i.e. completeness response letter, prefile testimony, late file submissions and the like) must be numbered sequentially from the Applicant's document preceding it. Please begin your submission using Page 292 and reference "Docket Number: 12-31810-CON." Submit one (1) original and four (4) hard copies of your response. In addition, please submit a scanned copy of your response, in an Adobe format (.pdf) including all attachments on CD. If available, a copy of the response in MS Word should also be copied to the CD.

Pursuant to Section 19a-639a(c) 0f the Connecticut General Statutes, you must submit your response to this request for additional information not later than sixty days after the date that this request was transmitted. Therefore, please provide your written responses to OHCA no later than March 10, 2013. If you have any questions concerning this letter, please feel free to contact me by email or at (860) 418-7070 or Laurie Greci at (860) 418 7032.

Sincerely,

Olga Armah

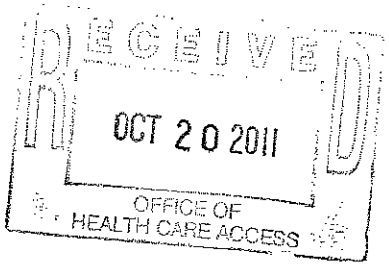
Olga Armah
Associate Research Analyst

Laurie Greci

Laurie Greci
Associate Research Analyst

Attachments

DEPARTMENT OF PUBLIC HEALTH
OFFICE OF HEALTH CARE ACCESS



IMAGING QUESTIONNAIRE

(MRI, CT, PET or PET/CT imaging equipment only)

Reporting Period: (*Please provide data for* **Calendar Year 2010**)

(Imaging equipment, utilization and health care services provided are for this physical location only – if another campus or satellite imaging office is owned and/or operated by the same provider in a different location, complete an additional questionnaire for that location – e.g., Helen and Harry Gray Cancer Center in Avon should be completed on a separate questionnaire from Hartford Hospital.)

1) Provider Name: Yale New Haven Hospital

2) Address: 20 York Street

3) City: New Haven **CT** **4) Zip Code:** 06504

5) Town/City where service is provided: New Haven

(Please list only the official town name – 1 of 169 official CT towns)

6) Zip Code where service is provided: 06504

7) Date Completed: 10/18/2011

8) Contact Name: Sahel Shwayhat

9) Contact Title: Manager, Finance and Quality, Diagnostic Radiology

10) Contact Phone: 203-688-7432

11) Contact Fax: 203-688-6228

12) Contact Email: sahel.shwayhat@ynhh.org

(Please list name and contact information for provider)

13) Provider Type: Hospital [X] Imaging Center [ ] Physician's Office [ ]

Other:

(Check appropriate box or list in "Other" the provider type where MRI, CT, PET or PET/CT is used)

14) Hours of Operation:

Day(s): 24X7 From: To:

Day(s): From: To:

Day(s): From: To:

Day(s): From: To:

Day(s): From: To:

(Please list hours of operation for provider – e.g., M-F 8am to 5pm)

15) Equipment/Volumes: *Please list the individual imaging equipment (MRI, CT, PET/CT or PET only) owned and/or operated at this location as of 12/31/10. Provide the following information for each machine: brand and model, fixed or mobile, open or closed, age (in years), # of slices, tesla, and department if applicable. In addition, provide the number of patient visits (e.g., one patient imaged on 3 separate visits should be reported as 3 visits) and the number of scans (one scan = one single CPT coded procedure) performed during calendar year 2010. See next page for specific instructions on the CPT/HCPCS codes to utilize in this survey. Visits and scans should be reported as aggregate counts by individual imaging unit. If it is not possible to report utilization by individual imaging unit, provide a description of the individual imaging unit and indicate that the utilization numbers have been combined for more than one unit.*

CT SCANNERS **Brand and Model**	**Fixed or Mobile**	**# of Slices**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.	**# of Patient Visits CY 10**	**# of Scans CY 10**
GE Light Speed VCT XT	FIXED	64	2	Radiology: CT-ED	17,386	32,863
GE VCT 64	FIXED	64	1	Radiology: CT-SMILOW 2506	2,210	4,332
GE HD 750	FIXED	64	1	Radiology: CT-SMILOW 2508	2,952	6,751
GE Light Speed 16	FIXED	16	7	Radiology: CT-SP 2115	7,634	13,526
GE VCT 64	FIXED	64	4	Radiology: CT-SP 2117	7,567	12,726
GE Light Speed Widebore 16	FIXED	16	1	Radiology: CT-SP BIOPSY	765	962

MRI SCANNERS **Brand and Model**	**Fixed or Mobile**	**Open or Closed**	**Tesla**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.)	**# of Patient Visits CY 10**	**# of Scans CY 10**
Siemens Espree	FIXED	Closed	1.5	1	Rad: MR CENTER 1	3,154	3,581
Siemens Avanto	FIXED	Closed	1.5	1	Rad: MR CENTER 2	2,663	3,466
Siemens Verio	FIXED	Closed	3.0	1	Rad: MR CENTER 3	2,679	3,003
Siemens Verio	FIXED	Closed	3.0	1	Rad: MR SMLW 1-BI	1,824	1,998
Siemens Verio	FIXED	Closed	3.0	1	Rad: MR SMILOW 2	3,630	5,225
Siemens Avanto	FIXED	Closed	1.5	1	Rad: MR SMILOW 3	3,568	5,286
Siemens Verio	FIXED	Closed	3.0	1	Rad: MR SMILOW 4	3,948	5,157

PET/CT SCANNERS **Brand and Model**	**Fixed or Mobile**	**# of Slices**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.)	**# of Patient Visits CY 10**	**# of Scans CY 10**
GE Discovery D690	FIXED	64	1	Radiology: NM1	1,407	1,419
GE Discovery DRX16	FIXED	16	1	Radiology: NM7	912	915

PET SCANNERS **Brand and Model**	**Fixed or Mobile**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.)	**# of Patient Visits CY 10**	**# of Scans CY 10**
Same equipment as PET/CT	[redacted]	[redacted]	[redacted]	58	58
Same equipment as PET/CT				16	16

If you have any questions, please contact: **Karen Roberts** Phone: 860-418-7001 Email: karen.roberts@ct.gov

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IMAGING QUESTIONNAIRE

(MRI, CT, PET or PET/CT imaging equipment only)

Reporting Period: (*Please provide data for* **Calendar Year 2010**)

(Imaging equipment, utilization and health care services provided are for this physical location only – if another campus or satellite imaging office is owned and/or operated by the same provider in a different location, complete an additional questionnaire for that location – e.g., Helen and Harry Gray Cancer Center in Avon should be completed on a separate questionnaire from Hartford Hospital.)

1) Provider Name: Yale New Haven Hospital

2) Address: 20 York Street

3) City: New Haven **CT** **4) Zip Code:** 06510

5) Town/City where service is provided: Guilford

(Please list only the official town name – 1 of 169 official CT towns)

6) Zip Code where service is provided: 06437

7) Date Completed: 10/18/2011

8) Contact Name: Sahel Shwayhat

9) Contact Title: Manager, Finance and Quality, Diagnostic Radiology

10) Contact Phone: 203-688-7432

11) Contact Fax: 203-688-6228

12) Contact Email: sahel.shwayhat@ynhh.org

(Please list name and contact information for provider)

13) Provider Type: Hospital [X] Imaging Center [ ] Physician's Office [ ]

Other:

(Check appropriate box or list in "Other" the provider type where MRI, CT, PET or PET/CT is used)

14) Hours of Operation:

Day(s): 24X7	From:	To:
Day(s):	From:	To:
Day(s):	From:	To:
Day(s):	From:	To:
Day(s):	From:	To:

(Please list hours of operation for provider – e.g., M-F 8am to 5pm)

15) Equipment/Volumes: *Please list the individual imaging equipment (MRI, CT, PET/CT or PET only) owned and/or operated at this location as of 12/31/10. Provide the following information for each machine: brand and model, fixed or mobile, open or closed, age (in years), # of slices, tesla, and department if applicable. In addition, provide the number of patient visits (e.g., one patient imaged on 3 separate visits should be reported as 3 visits) and the number of scans (one scan = one single CPT coded procedure) performed during calendar year 2010. See next page for specific instructions on the CPT/HCPCS codes to utilize in this survey. Visits and scans should be reported as aggregate counts by individual imaging unit. If it is not possible to report utilization by individual imaging unit, provide a description of the individual imaging unit and indicate that the utilization numbers have been combined for more than one unit.*

CT SCANNERS **Brand and Model**	**Fixed or Mobile**	**# of Slices**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.	**# of Patient Visits CY 10**	**# of Scans CY 10**
GE Light Speed H 16	FIXED	16	6	Radiology: Shoreline	5,770	9,513
GE Light Speed H 16	FIXED	16	6	Radiology: Simulator	650	945

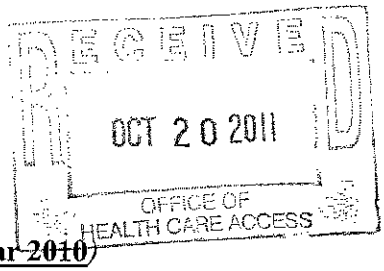
MRI SCANNERS **Brand and Model**	**Fixed or Mobile**	**Open or Closed**	**Tesla**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.)	**# of Patient Visits CY 10**	**# of Scans CY 10**
GE LX Horizon 1.5 T	FIXED	Closed	1.5	6	Radiology:Shoreline	3,330	3,631

PET/CT SCANNERS **Brand and Model**	**Fixed or Mobile**	**# of Slices**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.)	**# of Patient Visits CY 10**	**# of Scans CY 10**

PET SCANNERS **Brand and Model**	**Fixed or Mobile**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.)	**# of Patient Visits CY 10**	**# of Scans CY 10**

If you have any questions, please contact: **Karen Roberts**
Phone: 860-418-7001 Email: karen.roberts@ct.gov

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IMAGING QUESTIONNAIRE

(MRI, CT, PET or PET/CT imaging equipment only)

Reporting Period: (*Please provide data for* **Calendar Year 2010**)

(Imaging equipment, utilization and health care services provided are for this physical location only – if another campus or satellite imaging office is owned and/or operated by the same provider in a different location, complete an additional questionnaire for that location – e.g., Helen and Harry Gray Cancer Center in Avon should be completed on a separate questionnaire from Hartford Hospital.)

1) Provider Name: Yale New Haven Hospital

2) Address: 20 York Street

3) City: New Haven **CT** **4) Zip Code:** 06510

5) Town/City where service is provided: New Haven

(Please list only the official town name – 1 of 169 official CT towns)

6) Zip Code where service is provided: 06510

7) Date Completed: 10/18/2011

8) Contact Name: Sahel Shwayhat

9) Contact Title: Manager, Finance and Quality, Diagnostic Radiology

10) Contact Phone: 203-688-7432

11) Contact Fax: 203-688-6228

12) Contact Email: sahel.shwayhat@ynhh.org

(Please list name and contact information for provider)

13) Provider Type: Hospital [X] Imaging Center [ ] Physician's Office [ ]

Other:

(Check appropriate box or list in "Other" the provider type where MRI, CT, PET or PET/CT is used)

14) Hours of Operation:

Day(s): Mon, Fri	From: 6:30 AM	To: 10 PM
Day(s): Tue,Wed, Th	From: 6:30 AM	To: 5 PM
Day(s):	From:	To:
Day(s):	From:	To:
Day(s):	From:	To:

(Please list hours of operation for provider – e.g., M-F 8am to 5pm)

15) Equipment/Volumes: *Please list the individual imaging equipment (MRI, CT, PET/CT or PET only) owned and/or operated at this location as of 12/31/10. Provide the following information for each machine: brand and model, fixed or mobile, open or closed, age (in years), # of slices, tesla, and department if applicable. In addition, provide the number of patient visits (e.g., one patient imaged on 3 separate visits should be reported as 3 visits) and the number of scans (one scan = one single CPT coded procedure) performed during calendar year 2010. See next page for specific instructions on the CPT/HCPCS codes to utilize in this survey. Visits and scans should be reported as aggregate counts by individual imaging unit. If it is not possible to report utilization by individual imaging unit, provide a description of the individual imaging unit and indicate that the utilization numbers have been combined for more than one unit.*

CT SCANNERS **Brand and Model**	**Fixed or Mobile**	**# of Slices**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.	**# of Patient Visits CY 10**	**# of Scans CY 10**
GE Bright Speed H 16	FIXED	16	2	Radiology: Temple	2,266	3,215

MRI SCANNERS **Brand and Model**	**Fixed or Mobile**	**Open or Closed**	**Tesla**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.)	**# of Patient Visits CY 10**	**# of Scans CY 10**
GE Lightning LX 1.5T	FIXED	Closed	1.5	4	Radiology	3,107	3,425
GE FONAR INDOMITABLE	FIXED	Open	0.7	6	Radiology: FONAR	1,063	1,145

PET/CT SCANNERS **Brand and Model**	**Fixed or Mobile**	**# of Slices**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.)	**# of Patient Visits CY 10**	**# of Scans CY 10**

PET SCANNERS **Brand and Model**	**Fixed or Mobile**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.)	**# of Patient Visits CY 10**	**# of Scans CY 10**

If you have any questions, please contact: **Karen Roberts**
Phone: 860-418-7001 Email: karen.roberts@ct.gov

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IMAGING QUESTIONNAIRE

(MRI, CT, PET or PET/CT imaging equipment only)

Reporting Period: (*Please provide data for* **Calendar Year 2010**)

(Imaging equipment, utilization and health care services provided are for this physical location only – if another campus or satellite imaging office is owned and/or operated by the same provider in a different location, complete an additional questionnaire for that location – e.g., Helen and Harry Gray Cancer Center in Avon should be completed on a separate questionnaire from Hartford Hospital.)

1) Provider Name: Yale New Haven Hospital

2) Address: 20 York Street

3) City: New Haven **CT** **4) Zip Code:** 06510

5) Town/City where service is provided: Hamden

(Please list only the official town name – 1 of 169 official CT towns)

6) Zip Code where service is provided: 06518

7) Date Completed: 10/18/2011

8) Contact Name: Sahel Shwayhat

9) Contact Title: Manager, Finance and Quality, Diagnostic Radiology

10) Contact Phone: 203-688-7432

11) Contact Fax: 203-688-6228

12) Contact Email: sahel.shwayhat@ynhh.org

(Please list name and contact information for provider)

13) Provider Type: Hospital [X] Imaging Center [ ] Physician's Office [ ]

Other:

(Check appropriate box or list in "Other" the provider type where MRI, CT, PET or PET/CT is used)

14) Hours of Operation:

Day(s): M-F	From: 8 AM	To: 5 PM
Day(s):	From:	To:
Day(s):	From:	To:
Day(s):	From:	To:
Day(s):	From:	To:

(Please list hours of operation for provider – e.g., M-F 8am to 5pm)

15) Equipment/Volumes: *Please list the individual imaging equipment (MRI, CT, PET/CT or PET only) owned and/or operated at this location as of 12/31/10. Provide the following information for each machine: brand and model, fixed or mobile, open or closed, age (in years), # of slices, tesla, and department if applicable. In addition, provide the number of patient visits (e.g., one patient imaged on 3 separate visits should be reported as 3 visits) and the number of scans (one scan = one single CPT coded procedure) performed during calendar year 2010. See next page for specific instructions on the CPT/HCPCS codes to utilize in this survey. Visits and scans should be reported as aggregate counts by individual imaging unit. If it is not possible to report utilization by individual imaging unit, provide a description of the individual imaging unit and indicate that the utilization numbers have been combined for more than one unit.*

CT SCANNERS **Brand and Model**	**Fixed or Mobile**	**# of Slices**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.	**# of Patient Visits CY 10**	**# of Scans CY 10**
GE Light Speed VCT 64	FIXED	64	1	Radiology: Hamden	1,378	1,509

MRI SCANNERS **Brand and Model**	**Fixed or Mobile**	**Open or Closed**	**Tesla**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.)	**# of Patient Visits CY 10**	**# of Scans CY 10**

PET/CT SCANNERS **Brand and Model**	**Fixed or Mobile**	**# of Slices**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.)	**# of Patient Visits CY 10**	**# of Scans CY 10**

PET SCANNERS **Brand and Model**	**Fixed or Mobile**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.)	**# of Patient Visits CY 10**	**# of Scans CY 10**

If you have any questions, please contact: **Karen Roberts**
Phone: 860-418-7001 Email: karen.roberts@ct.gov

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IMAGING QUESTIONNAIRE

(MRI, CT, PET or PET/CT imaging equipment only)

Reporting Period: (*Please provide data for* **Calendar Year 2010**)

(Imaging equipment, utilization and health care services provided are for this physical location only – if another campus or satellite imaging office is owned and/or operated by the same provider in a different location, complete an additional questionnaire for that location – e.g., Helen and Harry Gray Cancer Center in Avon should be completed on a separate questionnaire from Hartford Hospital.)

1) Provider Name: Hospital of Saint Raphael PET/CT Department

2) Address: 1450 Chapel Street

3) City: New Haven **CT** **4) Zip Code:** 06511

5) Town/City where service is provided: _____

(Please list only the official town name – 1 of 169 official CT towns)

6) Zip Code where service is provided: New Haven

7) Date Completed: 6/21/11

8) Contact Name: Jamie Sheehan

9) Contact Title: Manager of Nuclear Medicine & PET/CT

10) Contact Phone: 203-789-5110

11) Contact Fax: 203-789-3664

12) Contact Email: Jsheehan@srhs.org

(Please list name and contact information for provider)

13) Provider Type: Hospital [X] Imaging Center [ ] Physician's Office [ ]

Other: _____

(Check appropriate box or list in "Other" the provider type where MRI, CT, PET or PET/CT is used)

14) Hours of Operation:

Day(s): Sat-Sun	From: 7:00 am	To: 5:00 pm
Day(s):	From:	To:
Day(s):	From:	To:
Day(s):	From:	To:
Day(s):	From:	To:

(Please list hours of operation for provider – e.g., M-F 8am to 5pm)

15) Equipment/Volumes: *Please list the individual imaging equipment (MRI, CT, PET/CT or PET only) owned and/or operated at this location as of 12/31/10. Provide the following information for each machine: brand and model, fixed or mobile, open or closed, age (in years), # of slices, tesla, and department if applicable. In addition, provide the number of patient visits (e.g., one patient imaged on 3 separate visits should be reported as 3 visits) and the number of scans (one scan = one single CPT coded procedure) performed during calendar year 2010. See next page for specific instructions on the CPT/HCPCS codes to utilize in this survey. Visits and scans should be reported as aggregate counts by individual imaging unit. If it is not possible to report utilization by individual imaging unit, provide a description of the individual imaging unit and indicate that the utilization numbers have been combined for more than one unit.*

CT SCANNERS **Brand and Model**	**Fixed or Mobile**	**# of Slices**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.	**# of Patient Visits CY 10**	**# of Scans CY 10**
Siemens SOMATOM Sensation 64 / Cardiac 64	Fixed	64	3	Radiology	18,900	18,900
Siemens SOMATOM Volume Zoom	Fixed	4	11	Radiology	3,491	3,991

PET/CT SCANNERS **Brand and Model**	**Fixed or Mobile**	**# of Slices**	**Age** (years)	**Department (if applicable)** (ED, Radiology, etc.)	**# of Patient Visits CY 10**	**# of Scans CY 10**
Siemens Biograph / Sensation 16	Fixed	16	7	Radiology	1,239	1,374

If you have any questions, please contact: **Karen Roberts**
Phone: 860-418-7001 Email: karen.roberts@ct.gov

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IMAGING QUESTIONNAIRE

(MRI, CT, PET or PET/CT imaging equipment only)

Reporting Period: (*Please provide data for* **Calendar Year 2010**)

(Imaging equipment, utilization and health care services provided are for this physical location only – if another campus or satellite imaging office is owned and/or operated by the same provider in a different location, complete an additional questionnaire for that location – e.g., Helen and Harry Gray Cancer Center in Avon should be completed on a separate questionnaire from Hartford Hospital.)

1) Provider Name: Saint Raphael Magnetic Resonance Center

2) Address: 330 Orchard Street

3) City: New Haven **CT** **4) Zip Code:** 06511

5) Town/City where service is provided: New Haven

(Please list only the official town name – 1 of 169 official CT towns)

6) Zip Code where service is provided: 06511

7) Date Completed: June 8, 2011

8) Contact Name: Annamarie Rose

9) Contact Title: Manager, SRMRC

10) Contact Phone: 203-789-4120

11) Contact Fax: 203-789-5183

12) Contact Email: arose@srhs.org

(Please list name and contact information for provider)

13) Provider Type: Hospital [ ] Imaging Center [X] Physician's Office [ ]

Other: _____

(Check appropriate box or list in "Other" the provider type where MRI, CT, PET or PET/CT is used)

14) Hours of Operation: Day(s): Monday-Friday From: 6:30am To: 10:30pm

Day(s): Saturday From: 7:00am To: 3:00pm

Saturday 3:00pm to Monday 6:30am: On Call emergency coverage

(Please list hours of operation for provider – e.g., M-F 8am to 5pm)

15) Equipment/Volumes: *Please list the individual imaging equipment (MRI, CT, PET/CT or PET only) owned and/or operated at this location as of 12/31/10. Provide the following information for each machine: brand and model, fixed or mobile, open or closed, age (in years), # of slices, tesla, and department if applicable. In addition, provide the number of patient visits (e.g., one patient imaged on 3 separate visits should be reported as 3 visits) and the number of scans (one scan = one single CPT coded procedure) performed during calendar year 2010. See next page for specific instructions on the CPT/HCPCS codes to utilize in this survey. Visits and scans should be reported as aggregate counts by individual imaging unit. If it is not possible to report utilization by individual imaging unit, provide a description of the individual imaging unit and indicate that the utilization numbers have been combined for more than one unit.*

CT SCANNERS Brand and Model	Fixed or Mobile	# of Slices	Age (years)	Department (if applicable) (ED, Radiology, etc.	# of Patient Visits CY 10	# of Scans CY 10

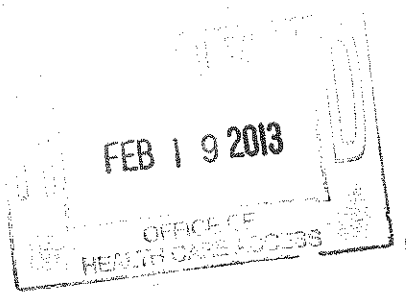
MRI SCANNERS Brand and Model	Fixed or Mobile	Open or Closed	Tesla	Age (years)	Department (if applicable) (ED, Radiology, etc.)	# of Patient Visits CY 10	# of Scans CY 10
Siemens: 1.5T Symphony	Fixed	Closed	1.5T	11 yrs	MRI Department	4339	5075
Siemens: 3T Trio	Fixed	Closed	3.oT	6 yrs	MRI Department	3802	4241

PET/CT SCANNERS Brand and Model	Fixed or Mobile	# of Slices	Age (years)	Department (if applicable) (ED, Radiology, etc.)	# of Patient Visits CY 10	# of Scans CY 10

PET SCANNERS Brand and Model	Fixed or Mobile	Age (years)	Department (if applicable) (ED, Radiology, etc.)	# of Patient Visits CY 10	# of Scans CY 10

If you have any questions, please contact: **Karen Roberts**
Phone: 860-418-7001 Email: karen.roberts@ct.gov

YALE NEW HAVEN HEALTH



February 19, 2013

Ms. OlgaArmah
Ms. Laurie Greci
Associate Research Analysts
Office of Healthcare Access
410 Capitol Avenue
MS #13HCA
P.O. Box 340308
Hartford, CT 06106

Re: Docket Number 12-31810-CON
Yale-New Haven Hospital (YNHH)
Acquisition of a Dedicated 3 Tesla MRI for the Children's Hospital

Dear Ms. Armah and Ms. Greci:

Enclosed please find the original, five (5) hard copies and an electronic copy on CD of YNHH's responses to OHCA's January 11, 2013 completeness questions for the above referenced CON application.

Please do not hesitate to contact me with any questions or concerns. I can be reached at (203) 863-3908.

Thank you for your time and support of this important project.

Sincerely,

Nancy Rosenthal

Nancy Rosenthal
Senior Vice President – Health Systems Development

Enclosures

789 Howard Avenue
New Haven, CT 06519

Yale-New Haven Hospital

Proposal to Acquire 3.0 Tesla Magnetic Resonance Imaging Scanner for the Yale-New Haven Children's Hospital Located in the City of New Haven

Docket Number: 12-31810-CON

Responses to Completeness Questions

February 19, 2013

Certificate of Need Application; Docket Number: 12-31810-CON
Yale-New Haven Hospital

Proposal to Acquire 3.0 Tesla Magnetic Resonance Imaging Scanner for the Yale-New Haven Children's Hospital Located in the City of New Haven

Completeness Questions and Responses

Page 14

1. Provide a comprehensive discussion on the options that YNHH considered concerning the pediatric MRI scanner proposal, including the following:
   a. Extending hours of operation of existing MRI scanners;
   b. Moving an existing MRI scanner to the YNHCH; and
   c. Upgrading to a 3.0T MRI scanner by replacing an existing MRI scanner and dedicating the new MRI scanner to the YNHCH.

YNHH MRI scan volume has increased from a total of 33,026 scans in 2009 to 41,821 projected scans for FY 2013 based on the first quarter's volume. This represents an average annual increase of 6% between 2009 and 2013 annualized as shown in the table below.

YNHH MRI Scan Volumes						
	2009	2010	2011	2012	2013*	
ED MRI	501	663	858	1,162	1,092	
IP MRI	6,901	7,316	8,082	8,520	10,000	
OP MRI	25,624	28,058	29,924	31,272	30,729	
TOTAL	**33,026**	**36,037**	**38,864**	**40,954**	**41,821**	
% Change						Avg Annual
ED		32%	29%	35%	-6%	23%
IP		6%	10%	5%	17%	10%
OP		9%	7%	5%	-2%	5%
TOTAL		9%	8%	5%	2%	6%
* 2013 is annualized based on first quarter = 24% of annual total						
* (as per 2009-2012 historical trends)						

In FY 2012, YNHH along with SRMRC performed almost 49,000 MRI scans (excluding 755 scans done between 11pm and 7am). SRMRC performed a total of 8,578 scans in FY 2012. Based on hours of operation and average scan time, capacity for all of the existing scanners (12 scanners) during FY 2012 was 53,652 scans which equates to combined MRI utilization of 91% as shown in the table below.

YNHH MRI: OVERALL SUMMARY (FY '12)	
100% Capacity/Yr	53,652
2012 Total Volume	48,777
% Utilization (@100%)	91%

This high utilization level exceeds OHCA's 85% utilization guideline and 4,000 scans/MRI scanner as described in the recently released *Statewide Health Care Facilities and Services Plan – Imaging Standards and Guidelines.*

Each MRI area is described in more detail below including FY 12 utilization, extending hours of operation and the reasons why an existing scanner cannot be moved or upgraded and moved to the Children's Hospital.

A. <u>MRI CENTER – Outpatient Center Only</u>

The MRI Center offers three MRI scanners (one 3.0 T and two 1.5 T scanners). Each of these three scanners was operated from 7am until 11 pm Monday through Thursday, 7 am until 7pm on Friday and 7am until 3pm on Saturday (total of 252 hours weekly) in FY 2012. These scanners serve scheduled outpatients and some emergency department patients. Patients have expressed concern about having to obtain an outpatient MRI as late as 10pm at night. This is not desirable but has been necessary to accommodate the demand.

Previously YNHH offered scheduled outpatient scans on Sunday but found that patients would not schedule their scans on Sundays due to conflicts with religious observances and family commitments. These hours were therefore discontinued as it was not financially feasible to keep the center open for very few patients willing to take advantage of the Sunday hours. The same holds true for Friday night hours. Patients were not interested in scheduling scans for Friday late evening or night.

Based on these extensive hours of operation and the actual MRI scan volume (FY '12) performed on these three scanners, this area was operating at <u>86%</u> utilization. The table below summarizes these calculations.

YNHH MR Center - 3 MRIs for Outpatients	
	MR CTR
Scheduled Hours/Week (see below)	252
Weeks/Year	51
Time (hrs)/Scan	1.00
100% Capacity: Scans/Week	252
100% Capacity: Scans/Year	12,852
2012 Actual Volume	11,109
% Utilization (@100%)	86%

As these three scanners were operating above 85% utilization, they are highly utilized and unavailable for use in the Children's Hospital. If one of these three scanners was moved to the Children's Hospital, the remaining two scanners would be unable to accommodate the volume from the third scanner.

Volume is distributed among the three scanners based on clinical needs, availability of the scanners and the patient's needs. Volume was fairly equally distributed, but does vary somewhat due to specialized functionality offered on one scanner and not the others. Below is a brief description of each scanner in this area.

MR Center 1 (3T)
The 3T MRI, known as the Verio, is primarily utilized for orthopedic imaging and is coordinated with x-ray for arthrograms. 3T imaging is preferred by many referring physicians for joints and this particular scanner has special coil technology to image sports related injuries and find subtle conditions that are not readily visible on other scanners. This scanner also provides functional brain imaging as a result of special equipment hard wired to the scanner. This scanner also has a wide bore and can accommodate large patients. Additional special features of this scanner include its capabilities to perform MRA body imaging of the heart and vessels in the abdomen and MR Spectroscopy for brain tumor patients. Brain tumor patients require mapping of brain functionality prior to surgery to identify motor functions that may be affected from the surgery. This is also the primary scanner for prostate imaging, a patient population that is expected to continue to grow at YNHH.

As a result of the special capabilities of this scanner, much of the historical volume performed on this machine cannot be done elsewhere.

MR Center 2 (1.5T)
This Espree scanner is the only true bariatric imaging MRI scanner at YNHH and can accommodate people up to 550 pounds. With the increasing prevalence of obesity in the United States and Connecticut, there has been a growing population of individuals requiring this scanner due to their size. This scanner is generally used for more routine MRI scanning.

MR Center 3 (1.5 T)
This Aera scanner has the latest imaging capabilities, in particular for cardiac and body imaging patients. The scanner is equipped with DOT engine software which provides specialized functionality for body scanning. YNHH has a large liver transplant program and this scanner is utilized for this population due to the DOT engine software which permits the specialized imaging required for ongoing follow-up of the liver transplant patients. The DOT technology ensures more consistent imaging on follow-up exams which is extremely important to monitor progression of disease or growth of pathology.

B. SMILOW MRIs (one Breast (3T), two 3Ts and one 1.5T) – Inpatient & Outpatient

Breast MRI
The Smilow Breast MRI is located in the Breast Center in the Smilow Cancer Hospital. This is a discrete area where women requiring breast exams, procedures, and imaging come for care. This scanner is used for breast imaging with or without an accompanying biopsy. Routine hours of operation are Monday through Thursday from 7am – 7pm, Friday from

7am to 3pm and Saturday from 9am until noon. Due to the high volume of MRI volume at the other three Smilow MRI scanners, there are times when non-breast patients must come to this area for their MRI scan. This requires the hours of operation to be extended when necessary and explains why this scanner was utilized more than 100% of the time in FY 2012 (see below).

YNHH Smilow - Breast MRI	
	BREAST
Scheduled Hours/Week (see below)	60
Weeks/Year	51
Time (hrs)/Scan	1.00
100% Capacity: Scans/Week	60
100% Capacity: Scans/Year	3,060
2012 Actual Volume*	3,640
% Utilization (@100%)	119%

Ideally, this scanner would only be used for breast MRIs and if additional capacity were available on the other Smilow MRI scanners, utilization of this scanner could be reduced. Breast MRIs have ranged between 2,500 and 3,100 per year over the past three years. The current hours of operation permit a maximum of 3,060 breast MRI scans to be done and these hours would be extended if breast MRI demand required additional capacity.

This scanner is dedicated to breast MRI and is an integral part of the breast center at YNHH and is therefore unavailable for use in the Children's Hospital.

Other Smilow MRIs

The three other MRIs located in the Smilow Cancer Center serve inpatients, outpatients, and emergency department patients. The majority of outpatients utilizing these scanners are cancer patients being treated at Smilow. These three scanners were operated from 7am until 11pm seven days per week. One scanner is routinely staffed from 11pm until 7am and can scan emergency and inpatients during the middle of the night. Excluding the 11pm - 7am hours, these three scanners are operating 336 hours per week. Hours of operation cannot be expanded since all the scanners run until 11 pm seven days per week. The one scanner which is staffed during the night can accommodate the inpatient and emergency volume which must be done during those hours. Outpatients are not willing to come to YNHH after 11pm for an outpatient scan and would be an unreasonable expectation.

Despite these extensive hours of operation, these scanners operated at almost 100% utilization in FY 12 as shown in the table below.

YNHH Smilow - 3 MRIs for Inpt/Outpt	
	SMILOW
Scheduled Hours/Week (see below)	336
Weeks/Year	51
Time (hrs)/Scan	1.00
100% Capacity: Scans/Week	336
100% Capacity: Scans/Year	17,136
2012 Actual Volume*	16,962
% Utilization (@100%)	99%
* Excludes volume on Smilow Scanner 2 between 11pm and 7am	

It is important to note that there are certain patients who cannot have their MRI scan on a 3T scanner due to the fact that they may have some type of implanted hardware or implant that would not be compatible with the strength of the3T magnet. These patients must be scanned on the 1.5 T.

As these three scanners were operating at 99% utilization, they are fully utilized and unavailable for use in the Children's Hospital.

C. <u>SRMRC – Saint Raphael Campus</u>

As OHCA is aware, SRMRC is currently a joint venture between Yale New Haven Ambulatory Services Corporation (YNHASC) and Medical Imaging Associates (MIA). SRMRC operates a 3T and a 1.5T MRI and serves inpatients and outpatients at the Saint Raphael campus. A Certificate of Need application was submitted on Friday January 25, 2013 to permit YNHASC/YNHH to purchase MIA's ownership share and operate these two MRI scanners as YNHH-based MRIs.

In FY 2012, these two scanners operated a total of 176 hours per week. Hours of operation were Monday through Friday from 6:30am until 10:30 pm and Saturday from 7am until 3pm.

As shown in the table below, FY12 scan volume was 8,578 and despite these extensive hours of operation, the scanners were operating at 96% utilization.

SRMRC - 2 MRIs at SR Campus	
	SRMRC
Scheduled Hours/Week (see below)	176
Weeks/Year	51
Time (hrs)/Scan	1.00
100% Capacity: Scans/Week	176
100% Capacity: Scans/Year	8,976
2012 Actual Volume*	8,578
% Utilization (@100%)	96%

As these two scanners were operating at 96% utilization, they are fully utilized and are required to provide MRI services to patients at the Saint Raphael campus. It is anticipated that the MRI volume on the Saint Raphael campus will increase as YNHH opens additional beds and establishes certain clinical programs/services on this campus. These scanners must remain at this campus to support the hospital's clinical operations and could not be relocated to the Children's Hospital.

D. COMMUNITY BASED MRI SCANNERS

YNHH operates an MRI at its Shoreline Medical Center in Guilford, a temporary mobile MRI in Hamden which will be permanently located in North Haven, and an MRI at 60 Temple Street in New Haven. Each of these scanners serves only outpatients who live close to these locations and can access MRI services at the locations.

Shoreline MRI

As shown in the table below, the Shoreline MRI operated at 102% utilization in FY 2012. In addition to serving scheduled outpatients, this scanner is also utilized by the free-standing emergency department located at the Shoreline Medical Center. Hours of operation are based on the outpatient population's needs and at times must be extended to meet the needs of emergency department patients. The scanner was operating from 7am to 5pm on Mondays and Fridays and 7am – 8pm Tuesday, Wednesday and Thursday. Weekend hours historically were not provided but will likely be added due to the high utilization.

This scanner serves those residents of the Shoreline and the YNHH Shoreline facility, is highly utilized and is therefore unavailable for relocation to the Children's Hospital.

YNHH Shoreline (Guilford)	
	Shoreline
Scheduled Hours/Week (see below)	59
Weeks/Year	51
Time (hrs)/Scan	0.75
100% Capacity: Scans/Week	79
100% Capacity: Scans/Year	4,012
2012 Actual Volume*	4,092
% Utilization (@100%)	102%

Mobile MRI in Hamden

This is a temporary location for the future North Haven MRI. YNHH operated a Fonar MRI for many years at 60 Temple Street. The technology was outdated and the scanner was discontinued and will be upgraded to a 3T and located in North Haven to provide MRI services for YNHH's Multiple Sclerosis (MS) Center and Smilow's satellite cancer center, which are both going to be located in the same building at 6 Devine Street and offer MRI imaging for residents of North Haven and surrounding towns.

FY 2012 was a transition year as the Fonar was discontinued in August of 2012 and the temporary mobile MRI is in use just until the North Haven site is ready. The North Haven site's MRI scanner will be performing specialized MRI scans on MS patients who will be coming to that site for their MS care. This patient population requires specialized MRI protocols and average scan time is one and a half hours. Each MS patient receives at least one annual MRI and the program treats approximately 1,200 patients. Projected volumes as described later in this response will occupy that scanner 83% of the time in FY 2014. Based on the need for this scanner for the MS population at this location and its projected utilization, it cannot be relocated to the Children's Hospital.

60 Temple Street MRI

The scanner located at 60 Temple Street is the oldest scanner owned by YNHH and primarily serves patients visiting physicians in the 60 Temple Street building. This is an outpatient scanner only and currently provides routine MRI scanning. The scanner was fairly well utilized in FY 12 at 81% utilization and operated Monday and Friday from 7am until 8pm and Tuesday through Thursday from 7am – 5pm. Physicians in the building do not see patients on the weekends and therefore there is no demand for weekend hours.

Although there is a small amount of capacity on this scanner, it still provided more than 3,000 MRI scans which cannot be relocated to other scanners as there is no available capacity (as described above).

YNHH 60 Temple	
	Temple
Scheduled Hours/Week (see below)	56
Weeks/Year	51
Time (hrs)/Scan	0.75
100% Capacity: Scans/Week	75
100% Capacity: Scans/Year	3,808
2012 Actual Volume*	3,101
% Utilization (@100%)	81%

PROJECTED MRI VOLUME (FY 2014)

The discussion above is based on actual scan volume from FY 2012. As MRI volume overall at YNHH has been growing at an average annual rate of 6%, by FY 2014, the first year the proposed YNHCH MRI would be operational, there will be more MRI volume to accommodate. For the purposes of this CON application, the projected MRI volume for 2014 has been conservatively projected to increase 3% between FY 2012 and 2013 and 3% between 2013 and 2014. This represents 50% of the historical average annual rate of growth. Continued growth in MRI services for the pediatric population has already been addressed in the CON application. Growth in MRI services for the adult population is going to be driven by several factors including:

- **Population growth and aging.**
- **Additional ED growth at YNHH. Currently due to limited access, ED patients cannot always receive an MRI during their ED visit. With the addition of the Children's Hospital MRI scanner, it will be easier for ED patients to receive an MRI during their visit to the ED.**
- **Prostate MRI volume will grow substantially. As discussed in the attached medical journal articles (see Attachment I), prostate MRI has been shown to be an effective and safer method of staging and monitoring prostate lesions and will reduce the need for invasive biopsies. Prostate cancer is the most commonly diagnosed cancer in the male population and the second leading cause of cancer-related deaths in men. As the male population ages, the prevalence of prostate cancer increases substantially with up to 70% of men 80 years of age and older having evidence of prostate cancer. The recent recruitment of a new Chief of Urology to YNHH is expected to result in continued strong volume in this area.**

As shown in the tables below, despite the addition of the proposed MRI scanner for the Children's Hospital, projected FY 2014 overall MRI utilization would continue to be high (~91%) with most scanners still operating well above 85% utilization and a few just below 85% utilization. The community based scanners would have a small amount of additional capacity for continued future growth. The utilization below was modeled using the current

hours of operation at the MR Center, Smilow, Breast MRI, SRMRC, and Temple Street. Hours at the Shoreline site will be expanded to better meet the demand at that location and planned hours of operation for North Haven are 42.5 hours/week which will allow it to operate at 83% utilization based on a projected 1,200 scans.

YNHH MR Center - 3 MRIs for Outpatients	
	MR CTR
Scheduled Hours/Week (see below)	252
Weeks/Year	51
Time (hrs)/Scan	1.00
100% Capacity: Scans/Week	252
100% Capacity: Scans/Year	12,852
2012 Vol-Peds	9,895
2014 Proj Vol (6% Inc)	10,489
Plus 10% Peds	473
2014 Proj Vol	10,962
% Utilization (@100%)	85%

YNHH Smilow Breast	
	BREAST
Scheduled Hours/Week (see below)	60
Weeks/Year	51
Time (hrs)/Scan	1.00
100% Capacity: Scans/Week	60
100% Capacity: Scans/Year	3,060
2012 Vol-Peds	3,576
2014 Proj Vol (6% Inc)	3,791
Shift to other	758
2014 Proj Vol	3,032
% Utilization (@100%)	99%

YNHH Smilow - 3 MRIs for Inpt/Outpt	
	SMILOW
Scheduled Hours/Week (see below)	336
Weeks/Year	51
Time (hrs)/Scan	1.00
100% Capacity: Scans/Week	336
100% Capacity: Scans/Year	17,136
2012 Vol-Peds	13,956
2014 Proj Vol (6% Inc)	14,794
Plus shift from Breast	758
2014 Proj Vol	15,552
% Utilization (@100%)	91%
* Excludes volume on Smilow Scanner 2 between 11pm and 7am	

SRMRC - 2 MRIs at SR Campus	
	SRMRC
Scheduled Hours/Week (see below)	176
Weeks/Year	51
Time (hrs)/Scan	1.00
100% Capacity: Scans/Week	176
100% Capacity: Scans/Year	8,976
2012 Vol-Peds	8,578
2014 Proj Vol (per BP)	8,896
% Utilization (@100%)	99%

YNHCH 3T	
	Childrens
Scheduled Hours/Week (see below)	80
Weeks/Year	51
Time (hrs)/Scan	1.00
100% Capacity: Scans/Week	80
100% Capacity: Scans/Year	4,080
2014 Proj Volume (90% of Peds Vol)	4,261
% Utilization (@100%)	104%

YNHH Shoreline (Guilford)	
	Shoreline
Scheduled Hours/Week (see below)	73
Weeks/Year	51
Time (hrs)/Scan	0.75
100% Capacity: Scans/Week	97
100% Capacity: Scans/Year	4,964
2012 Vol-Peds	3,876
2014 Proj Vol (6% Inc)	4,109
% Utilization (@100%)	83%

YNHH 60 Temple	
	Temple
Scheduled Hours/Week (see below)	56
Weeks/Year	51
Time (hrs)/Scan	0.75
100% Capacity: Scans/Week	75
100% Capacity: Scans/Year	3,808
2012 Vol - Peds	2,960
2014 Proj Vol (6% Inc)	3,138
% Utilization (@100%)	82%

No Haven	
	No Haven
Scheduled Hours/Week (see below)	42.5
Weeks/Year	51
Time (hrs)/Scan	1.50
100% Capacity: Scans/Week	28
100% Capacity: Scans/Year	1,445
2014 Proj Volume	1,200
% Utilization (@100%)	83%

YNHH MRI: OVERALL SUMMARY (Proj	
100% Capacity FY '14	56,321
2014 Proj Volume	51,149
% Utilization (@100%)	91%

The addition of the proposed Children's Hospital MRI will permit a number of enhancements to the MRI services offered by YNHH as noted below:

- **The proposed pediatric MRI which will be located in the Children's Hospital, a child friendly environment, will eliminate the need for pediatric staff to travel to other areas of the campus with pediatric patients for MRI scans. It will eliminate the need for young children to obtain MRIs in adult oriented areas and will enhance both the patient/family experience and patient satisfaction. The Children's Hospital MRI is expected to serve ~90% of the pediatric projected volume, including all inpatients. The projected hours of operation extend from 7am until 9pm Monday through Friday and 7am until 5 pm on Saturday. Children cannot be scanned any**

later than 9pm. These hours will permit 90% of the projected pediatric volume to be accommodated. These planned hours have been updated since the initial CON filing. It is assumed that 10% of the pediatric volume (older children who do not require sedation) will receive their MRI scans in the MR Center.

- **Capacity would be expanded some at the Smilow scanners with pediatric volume shifted to the Children's Center. Non-breast MRIs that have had to be done on the Breast MRI could be shifted to the Smilow scanners and the Breast MRI would just serve the breast patients, as it was intended.**

YNHH has instituted Enterprise-wide scheduling for MRI services. It is the hope that through this centralized scheduling service, some of the outpatient scan volume that is shown above at the Smilow scanners might be able to be scheduled at one of the community based sites in order to more evenly distribute the volume.

2. Please provide a discussion on the preference for the use of MRI over Computed Tomography ("CT") as an imaging modality for children. Reference information in the articles submitted in Exhibit 3 of the CON application to support your discussion.

As noted in the CON application, due to a number of technology enhancements and increasing concerns over ionizing radiation exposure, MRI imaging has become more appropriate for imaging children in a number of areas. The articles included in Exhibit 3 address a number of these clinical areas. The table below summarizes each of articles included in Exhibit 3 of the CON application and their relevance to the discussion on the preference for the use of MRI over CT as an imaging modality for children.

Author(s) and Date	Article Title	Key Points re: MRI vs. CT
Shenoy-Bhangle, A., Nimkin, K. & Gee, MS (2010)	Pediatric imaging: Current and emergency techniques	• Children are known to be more sensitive to the effects of radiation. • Recent studies have focused on radiation risk and there is growing concern that children may be placed at risk for future malignancies due to radiation exposure. • MRI uses no ionizing radiation and with recent technology improvements has increased uses in pediatric patients.
National Cancer Institute (2012)	Radiation risks and pediatric Computed Tomography (CT): A guide for health care providers	• Pediatric CT is a valuable tool and use has been increasing however, potential for radiation exposure to children is a growing public health concern. • Children have unique concerns regarding

Author(s) and Date	Article Title	Key Points re: MRI vs. CT
		radiation exposure include their bodies/tissues are more sensitive, they have longer life expectancies than adults and may receive higher doses if the CT settings are not adjusted for their small size. • Risk for developing radiation-related cancer can be several times higher for children than adults. • Recommendations include: perform CT only when necessary, adjust exposure parameters and resolution. • Carefully assess whether CT is the best examination or can another imaging modality be utilized.
Wyers, M (2010)	Evaluation of pediatric bone lesions	• CT may be helpful in imaging bone lesions, but benefits must be weighed against unnecessary radiation exposure. • MRI is modality of choice when a malignant bone tumor is suspected. • MRI has best contrast resolution. • MR in children may require sedation in young children. • Both CT and MRI have a role in evaluation of bone following tumor resection. • MRI is the best imaging modality for evaluation of marrow edema. • Bone lesions in children are common and determining which are malignant is the most important goal.
Toma, P., Granata, C., Magnano, G. & Barabino, A. (2007)	CT and MRI of paediatric Crohn disease	• The high radiation exposure is a limitation to the use of CT in imaging children with Crohn's

Author(s) and Date	Article Title	Key Points re: MRI vs. CT
		disease. • Lack of ionizing radiation, multiplanar imaging and superior soft-tissue contrast make MR an ideal technique of imaging inflammatory bowel disease patients. • Although CT has unparalleled sensitivity and specificity detecting abnormalities of Crohn's disease, the substantial radiation dose makes it unsuitable for repeated studies in children. • Increasing evidence shows that MRI can reliably and accurately show most Crohn's disease lesions with better accuracy than barium radiographic studies. • Lack of ionizing radiation of MRI makes it an excellent modality for children who require repeated studies for disease monitoring.
Cahoon, G. (2011)	Techniques in pediatric MRI – Tips for imaging children	• Children require special considerations for MRI imaging due to their size, need for sedation, physiology, and development stage. • Simulation, special preparation, age appropriate communication, and distraction/relaxation strategies are critically important to successful image children. • Children require specialized coils to ensure high quality imaging. • 3T offers improve resolution for small patients. • Emerging uses for MRI in

Author(s) and Date	Article Title	Key Points re: MRI vs. CT
		pediatric patients include: susceptibility-weighted imaging for trauma and vascular disease, parallel transmit technology, diffusion tensor imaging for developing brain imaging and epilepsy, arterial spin labeling for blood perfusion and MR urography for kidney and urological issues.
Gaillard, W., Chiron, C., Cross, J., Harvey, A., Kyzniecky, R., Hertz-Pannier, L. & Vezina, L. (2009)	Guidelines for imaging infants and children with recent-onset epilepsy	• Structural neuroimaging plays and essential role in diagnosis and treatment of children with epilepsy. • Neuroimaging detects underlying cerebral lesion(s) that may be cause of seizures or a neurodevelopmental impairment. • MRI is considered the imaging modality of choice – due to superior anatomic resolution. • MRI identifies more abnormalities than CT.
Hiorns, M. (2010)	Imaging of the urinary tract: the role of CT and MRI	• Although imaging of the urinary tract relies heavily on ultrasound (US), MRI has an invaluable role with CT playing a lesser role. • MRI is the modality of choice for imaging tumors and congenital anomalies when US not clear. • Functional MRI has some applications which are becoming relevant for children.
Medina, L., Kuntz, K., & Pomery, S. (2001)	Children with headache suspected of having brain tumor: A cost-effective analysis of diagnostic strategies	• MRI the most effective imaging strategy for high-risk children with headache of less than 6 months duration and other clinical predictors of brain tumor. • MRI maximizes quality-adjusted life year gained at

Author(s) and Date	Article Title	Key Points re: MRI vs. CT
		a reasonable cost-effectiveness ratio in children with headache at risk of having a brain tumor.
Pienaar, M., Andronikou, S. & vanToorn, R. (2008)	**MRI to demonstrate diagnostic features and complications of TBM not seen with CT**	• **MRI is superior to CT for diagnosing Tuberculous meningitis (TBM) and its complications.** • **MRI is more sensitive to detecting basal meningeal enhancement, granulomata and infarcts for diagnosis and prognosis in pediatric TBM cases.**

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3. Provide a discussion concerning each of the following:
   a. The capabilities of the proposed MRI scanner as compared to YNHH's existing scanners;

      The capabilities of the proposed MRI as compared to YNHH's existing scanners include the following special features:
      - **Undockable table which in the event of an adverse reaction to anesthesia or other emergency during the exam, staff can "undock" or detach the table and move the patient quickly out of the room. The Hospital's current MRI units do not feature undockable tables.**
      - **Advanced cardiac software for pediatrics which allows imaging of children with congenital cardiac disease.**
      - **DOT Engine Technology – which as previously described ensures more consistent imaging on follow-up exams which is extremely important to monitor progression of disease or growth of pathology.**

   b. The effect of the additional MRI scanning availability on providers within the service area with the proposal;

      The additional MRI scanning availability is being requested due to YNHH's current high utilization levels and increasing demand for its routine and specialized MRI capabilities. The additional scanner capacity is necessary to meet patient needs who are already presenting to YNHH. Therefore, the additional MRI scanning availability is not expected to have any significant impact on other providers within the core service area. Additionally there are no other MRI providers in the service area with pediatric anesthesia or sedation capabilities.

4. Will the centralization of pediatric MRI scans to a single location enable YNHH to perform 100% of these scans on the proposed 3.0T MRI scanner? Provide additional discussion. If existing MRI scanners are to be used for children, please report the conditions under which that would occur.

As previously discussed, the proposed 3T MRI scanner for the YNHCH is expected to provide scans for 90% of the projected pediatric scan volume. Children with any type of metallic implant or internal hardware would have to be scanned on a 1.5T MRI. In additional, older adolescents who do not require sedation can be accommodated in the MRI Center should a slot not be available on the YNHCH scanner. Also as previously discussed, with Enterprise-wide scheduling, if an older adolescent requires an outpatient MRI and lives closer to Guilford or North Haven, it is possible one of these scanners could be used.

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5. For "clear public need", YNHH describes the growing need for MRI scanners for pediatric patients as partly driven by Y-Access Transfer Line transfers from other physicians.
    a. Report the actual annual volumes of FYs 2010-2012 pediatric MRI transfers from non-YNHH physicians.

    Pediatric transfer cases through the Y-Access line were:
    2010 – 431 transfers
    2011 - 759 transfers
    2012 – 1,018 transfers

    These transfers represent patients who were hospitalized elsewhere and a transfer was arranged to YNHH. These figures do not represent MRI statistics. Approximately 18% of the transfers in FY 2011 and 2012 required an MRI scan at YNHH.

    b. Explain how meaningful use of electronic health records ("EHR") will affect the hospital's adult and pediatric MRI volumes, separately, due to these transfers. Include in your discussion the percentage of pediatric patients that come to YNHH with EHR that require additional scans.

    In the case of transfer patients, YNHH currently utilizes software tools that allow for the transmission of images from referring institutions that have the available technology. In those cases where MRI images cannot be transmitted to YNHH, patients may bring a CD with a copy of the image. This has been a long standing practice, even before the increase in EHR implementation.

    The current and future practice is not to repeat scans unless absolutely necessary. In the case of pediatric scans, it is not uncommon that previously obtained scans may not offer the degree of image quality and specificity that can be obtained with YNHH's current MRI scanners and in particular with the proposed 3T MRI. In these situations, the scan will be repeated so that physicians have the best diagnostic information to develop the patient's plan of care. A scan will also be repeated if for some reason the previous image cannot be obtained. As EHR implementation continues to advance, there may be fewer cases where previous images cannot be obtained and therefore may eliminate the need to repeat a scan, assuming the previous image is of appropriate/adequate quality. However, this will have a minimal impact on YNHH's overall demand for MRI services.

6. In response to the OHCA 2011 Imaging Questionnaire ("Imaging Questionnaire") YNHH reported that every MRI scanner located at 20 York Street was in operation Sunday through Saturday, 24 hours

each day. In Table B on page 18 of the initial CON application, varying hours of operation were reported in conflict with the Imaging Questionnaire. In Table 1 on page 21, the hours of operation for the Shoreline Medical Center at 111 Goose Lane again do not agree with the Imaging Questionnaire. Also, in Table 1 there are only three MRI scanners reported for the Temple Street location but in the response to the Imaging Questionnaire YNHH reported four MRI scanners; the hours of operations also do not agree. Please discuss and provide a current and accurate equipment list with operating hours for each MRI scanner at the three locations. For your convenience, a copy of the Imaging Questionnaire submitted by YNHH is attached.

Some of the differences reported in the 2011 Imaging Questionnaire and on page 18 of the initial CON application are due to changes in hours of operation between the two time periods. Additionally, the response to the Imaging Questionnaire regarding the MRI scanners at 20 York Street being open 24/7 was incorrect. There is only one scanner that offers 24/7 service. Please refer to the hours of operation in this CON application for the most current information.

7. According to the Imaging Questionnaire, the Saint Raphael Magnetic Resonance Center has four MRI scanners at 330 Orchard Street, New Haven. Report the operating hours and utilization of these four MRI scanners using the same format as Table 1 on page 21. For your convenience, a copy of the Imaging Questionnaire submitted by Saint Raphael Magnetic Resonance Center is attached.

   Based on the Applicant's review of the Imaging Questionnaire for SRMRC provided by OHCA (see page 4), only two scanners are listed; a Siemens 1.5T Symphony and a Siemens 3T Trio. SRMRC has only two MRI scanners

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8. The MRI Center is listed as having 85 scheduled hours per week. However, on page 18 the reported hours total 84 hours. Please review Table C and revise as needed.

   Page 18 contained a typographical error. The MRI center hours are 84 per week. Table C has been revised and is provided below. Hours of operation for Smilow 2 scanner have also been shown for 7am – 11pm since only emergency patients and inpatients can be accommodated after these hours on the one scanner which is staffed. The hours between 7am – 11pm better reflect the scanner's utilization in this context.

Table C - Revised

YNHH							
MRI Utilization - York Street MRIs (2012 Utilization) - Updated							
	MR Center 1	MR Center	MR Center	Smilow 1	Smilow 2	Smilow 3	Smilow 4
	2012						
					Open 24/7		
					7a-11p below (88%)		
Equipment	**3.0 T**	**1.5 T**	**1.5T**	**3.0 T-Breast**	**3.0 T**	**1.5 T**	**3.0 T**
Scheduled Hours/Week (see below)	84	84	84	60	112	112	112
Weeks/Year	51	51	51	51	51	51	51
Time (hrs)/Scan	1.00	1.00	1.00	1.00	1.00	1.00	1.00
100% Capacity: Scans/Week	84	84	84	60	112	112	112
100% Capacity: Scans/Year	4,284	4,284	4,284	3,060	5,712	5,712	5,712
Actual Volume*	3,645	3,899	3,565	3,640	5,535	5,766	5,661
% Utilization (@100%)	85%	91%	83%	119%	97%	101%	99%

9. Discuss the use of MRI scanners for 51 weeks per year as reported in Table C.

There are 7 holidays when non- emergency MRI scans are not scheduled. These days are also used for routine maintenance and other quality control activities. Every quarter, each machine requires at least 4-8 hours for maintenance. Therefore, 51 weeks has been utilized as the number of weeks per year that each MRI scanner is available for scheduling exams.

10. Report the utilization of the two MRI scanners at the Saint Raphael campus using the same formats as Table C on page 19 and Table 1 on page 21.

Utilization of the two MRI scanners at the Saint Raphael campus using the same format as Table C on page 19 and Table 1 on page 21 is shown below. Please note that SRMRC does not track MRI volume by scanner and therefore volumes for both scanners have been listed.

Provide Name Street Address Town, Zip	Description of Service	Hours/Days of Operation	Utilization FY 12	Pediatric Utilization FY 12
Saint Raphael Magnetic Resonance Center 330 Orchard Street New Haven, CT 06511	**MRI – 3.0T Closed** **MRI – 1.5T Closed**	**Monday – Friday: 6:30am – 10:30 pm** **Saturday: 7am – 3pm**	**8,578**	**68**

SRMRC - 2 MRIs at SR Campus	
	SRMRC
Scheduled Hours/Week (see below)	176
Weeks/Year	51
Time (hrs)/Scan	1.00
100% Capacity: Scans/Week	176
100% Capacity: Scans/Year	8,976
2012 Actual Volume*	8,578
% Utilization (@100%)	96%

11. How was it determined that there is a two to three week backlog for elective pediatric MRI exams? How many MRI scans and pediatric patients are counted in the backlog? Discuss the backlog for elective exams in relation to the normal amount of time it takes for a pediatric patient and an adult patient to be scheduled for and receive a scan. What are the factors that contribute to the backlog?

Pediatric sedation/anesthesia cases require the participation of a pediatric anesthesiologist or nurse anesthetist. These specialized clinicians are also providing anesthesia in the operating rooms and therefore have limited availability. The backlog is primarily for pediatric sedation/anesthesia exams. The backlog is also a factor of what type of exam is required. It is not uncommon for pediatric patients to require more than one scan during their MRI visit. In these situations, two consecutive MRI slots must be scheduled and this can be difficult to find on the schedule due to high volume of scans. Once a week, the MRI scheduling office identifies the time span between patient requests and available appointments. Although this time frame can fluctuate, it is generally 2-3 weeks. It has been as long as 4 weeks at certain points in the year. The timeframe between requests and scheduled appointments is how the backlog is quantified.

Sedation for adults is required less often, however there are times when it is necessary. Some adults can be given oral sedation and that is found to be sufficient. If not, anesthesia staff will have to administer intravenous sedation. Scheduling adult MRI scans requiring anesthesia staff is also challenging due to limited anesthesia resources for MRI and it is not uncommon for adults to have to wait 2-3 weeks as well.

12. Please complete the following table using utilization levels for all MRI patients and include any MRI scanners from Temple Radiology and Saint Raphael campus that are not listed as reported in response to Questions 5 and 6 above:

Scanners	Location	FY 2010	FY 2011	FY 2012	FY 2013 (Oct 1 to – Dec 31)	FY 2013 Annual-ized	Acquisi-tion Date	Slice/ Strength	New/ Refur-bished
MRI Center 1	20 York St.	3,993	3,645	3,645	956	3.983	3/2009	3.0T closed	New
MRI Center 2	20 York St.	3,786	3,392	3,899	1,099	4,579	3/2009	1.5T closed	New
MRI Center 3	20 York St.	3,301	3,612	3,565	941	3,921	9/2011	1.5T closed	New
MRI Smilow 1 (breast only)	20 York St.	2,234	3,602	3,640	884	3,683	12/2009	3.0T closed	New
MRI Smilow 2	20 York St.	4,838	5,628	6,290	1,517	6,321	12/2009	3.0T closed	New
MRI Smilow 3	20 York St.	5,317	5,434	5,766	1,368	5,700	12/2009	1.5T closed	New
MRI Smilow 4	20 York St.	4,210	5,253	5,661	1,379	5,746	12/2009	3.0T closed	New
Operating Room Intraop. only	20 York St.	21	167	191	35	146	6/2010		New
Temple Radiology (outpatient only)	111 Goose Ln, Guilford	3,713	3,722	4,092	987	4,113	2004	1.5T closed	New
Temple Radiology (outpatient only)	60 Temple St, New Haven	1,149	1,170	1,131	Dis-continued	N/A	2004	0.6T Stand-up Unit	New
Temple Radiology	60 Temple St., New Haven	3,496	3,406	3,101	607	2,529	1995	1.5T	New
St. Raphael's Campus 1		9,390	9,122	8,578	1,973	8,221	1/2000 & 8/2003	1.5T & 3T	New
St. Raphael's Campus 2	See above – volume not tracked by scanner								

*Annualized volume based on first quarter = 24% of total as per historical trends (2010-2012)

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13. Explain the role of the child life specialist when performing a pediatric MRI scan.

The Child Life specialist is a certified individual who works with medical professionals and pediatric patients to provide:

- **Medical play which allows children to learn about tests, procedures, surgeries and correct any misconceptions.**
- **Distraction techniques which significantly reduce anxiety levels during a procedure or diagnostic test.**
- **Expressive activities that help children express their thoughts or feelings about their hospital experience either verbally, through art or other methods.**
- **Providing developmentally appropriate material to children which explains what they will experience and why.**
- **Overall support for the pediatric patient and the family during procedures and examinations.**

The Child Life specialist accompanies the pediatric patient to the MRI scanner area, has helped to prepare the child for what they will experience often escorts the child into the MRI room, depending on the child's age.

Page 26 and 27

14. Please report the information provided in Tables 2a, 2b and 2c by age groups, i.e., 0-4 years, 5-12, and 13-17. In addition report subtotals within the age group of the number that required anesthesia and/or sedation.

Tables 2a, 2b and 2c have been completed by pediatric age cohorts. In addition anesthesia/sedation volumes have also been provided. Please refer to Attachment II.

15. The reported projected volume for FYs 2014, 2015, and 2016 are 4,734, 4,782 and 4,829 pediatric MRI scans, respectively. There are no scans listed for the "Proposed Pediatric MRI". Please complete the table for the projected volume that includes the number that will be performed on the proposed pediatric MRI scanner as well as those that may be performed on existing scanners.

A Revised Table 2a is provided below.

Equipment Unit	***Actual Volume (Last 4 Completed FYs)***				**Current FY* (1 Month)**	***Projected Volume***		
	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014[1]	FY 2015	FY 2016
MRI Center 1	**543**	**515**	**483**	**389**	**24**			
MRI Center 2	**426**	**388**	**353**	**426**	**36**	**473**	**478**	**483**
MRI Center 3	**594**	**519**	**428**	**399**	**35**			
MRI Smilow 1 *(breast MRI, opened 12/2009)*	**0**	**21**	**37**	**64**	**7**			
MRI Smilow 2	**1,247**	**1,297**	**1,534**	**1,618**	**122**			
MRI Smilow 3	**486**	**619**	**557**	**550**	**50**			
MRI Smilow 4 *(opened 12/2009)*	**0**	**601**	**727**	**838**	**68**			
Temple MRIs	**448**	**377**	**338**	**357**	**34**			

Equipment Unit	*Actual Volume (Last 4 Completed FYs)*				Current FY* (1 Month)	*Projected Volume*		
	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014[1]	FY 2015	FY 2016
Proposed Pediatric MRI	**0**	**0**	**0**	**0**		**4,261**	**4,304**	**4,346**
Total MRI	**3,744**	**4,337**	**4,457**	**4,641**	**376**	**4,734**	**4,782**	**4,829**

Note: 10% of the pediatric projected volume is shown on MR Center 2 scanner however, this volume could be completed on any of the MR scanners.

16. Report the days and hours of operation for the MRI scanner that will be located in the YNHCH.

Based on the projected volumes and assuming 90% will be completed on the proposed MRI at the YNHCH, the planned hours of operation are:

- **Monday through Friday 7am – 9pm**
- **Saturday: 7am – 5pm**

These hours may be adjusted over time based on patient demand and staff availability.

ATTACHMENT I

MRI AND PROSTATE CANCER ARTICLES

Magnetic Resonance Imaging for Predicting Prostate Biopsy Findings in Patients Considered for Active Surveillance of Clinically Low Risk Prostate Cancer

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Abbreviations and Acronyms

AS = active surveillance
ECE = extracapsular extension
MP = multiparametric
MRI = magnetic resonance imaging
PSA = prostate specific antigen
SVI = seminal vesicle invasion

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† Supported by the Peter Michael Foundation.
‡ Equal study contribution.

See Editorial on page 1658.

For another article on a related topic see page 1957.

Purpose: A barrier to the acceptance of active surveillance for men with prostate cancer is the risk of underestimating the cancer burden on initial biopsy. We assessed the value of endorectal magnetic resonance imaging in predicting upgrading on confirmatory biopsy in men with low risk prostate cancer.

Materials and Methods: A total of 388 consecutive men (mean age 60.6 years, range 33 to 89) with clinically low risk prostate cancer (initial biopsy Gleason score 6 or less, prostate specific antigen less than 10 ng/ml, clinical stage T2a or less) underwent endorectal magnetic resonance imaging before confirmatory biopsy. Three radiologists independently and retrospectively scored tumor visibility on endorectal magnetic resonance imaging using a 5-point scale (1—definitely no tumor to 5—definitely tumor). Inter-reader agreement was assessed with weighted kappa statistics. Associations between magnetic resonance imaging scores and confirmatory biopsy findings were evaluated using measures of diagnostic performance and multivariate logistic regression.

Results: On confirmatory biopsy, Gleason score was upgraded in 79 of 388 (20%) patients. Magnetic resonance imaging scores of 2 or less had a high negative predictive value (0.96–1.0) and specificity (0.95–1.0) for upgrading on confirmatory biopsy. A magnetic resonance imaging score of 5 was highly sensitive for upgrading on confirmatory biopsy (0.87–0.98). At multivariate analysis patients with higher magnetic resonance imaging scores were more likely to have disease upgraded on confirmatory biopsy (odds ratio 2.16–3.97). Inter-reader agreement and diagnostic performance were higher for the more experienced readers (kappa 0.41–0.61, AUC 0.76–0.79) than for the least experienced reader (kappa 0.15–0.39, AUC 0.61–0.69). Magnetic resonance imaging performed similarly in predicting low risk and very low risk (Gleason score 6, less than 3 positive cores, less than 50% involvement in all cores) prostate cancer.

Conclusions: Adding endorectal magnetic resonance imaging to the initial clinical evaluation of men with clinically low risk prostate cancer helps predict findings on confirmatory biopsy and assess eligibility for active surveillance.

Key Words: magnetic resonance imaging, prostatic neoplasms, watchful waiting

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EARLY diagnosis of prostate cancer during the PSA era has resulted in a downward trend in cancer stage at presentation and improved overall survival.[1,2] Nevertheless, the high rate of diagnosis of clinically low risk, localized prostate cancer, coupled with the minimal incidence of death from such disease, has raised concerns about overtreatment.[3,4] In the quest to prevent overtreatment, active surveillance has emerged as a plausible option. AS has proven extremely effective, with disease specific survival rates reported at 97% to 100% after 3 to 10 years.[5–9] However, appropriate criteria for selecting patients for AS are continuously debated. In 2010 the NCCN (National Comprehensive Cancer Network) recommended the use of active surveillance as the sole initial management strategy, not just an option, for patients with low risk prostate cancer and a life expectancy of less of than 10 years, as well as for patients with very low risk prostate cancer and a life expectancy of less than 20 years.[10,11]

A potential pitfall of basing AS decisions on biopsy findings is in the fact that high grade or large volume tumors may be missed by the biopsy needle, and the resulting delays in treatment may negatively affect outcomes. Even the most stringent criteria misclassify 16% to 42% of cases which, despite low risk features on initial biopsy, have unfavorable pathological features at radical prostatectomy.[12] To improve the detection of large or high grade cancers, some centers recommend a second (confirmatory) prostate biopsy before the start of AS. Berglund et al found that up to 27% of patients with very low risk features on initial biopsy had disease upgraded or up staged at confirmatory biopsy, and that patients who had upgraded and/or up staged disease on confirmatory biopsy were more likely to show an increase in stage and grade at radical prostatectomy than those whose did not.[13]

MRI alone or combined with clinical parameters may be useful in the prediction of insignificant prostate cancer, particularly in the context of clinically nonpalpable tumors.[14–16] Furthermore, on MRI, less aggressive tumor foci (ie Gleason score 6 or less) are more difficult to detect than more aggressive tumors.[17,18] However, to our knowledge the capacity of T2-weighted MRI to predict confirmatory prostate biopsy findings has not been explored. Therefore, we evaluated T2-weighted MRI as a tool to predict pathological upgrading on confirmatory prostate biopsy in men with clinically low risk prostate cancer being considered for AS.

MATERIALS AND METHODS

The institutional review board approved our retrospective study and waived the informed consent requirement. Our study was compliant with the Health Insurance Portability and Accountability Act of 1996.

Eligibility Criteria and Patient Characteristics

Using computerized searches of our institutional database, we identified 573 patients satisfying the inclusion criteria of Gleason score 6 or less prostate cancer on initial transrectal prostate biopsy performed between January 1, 1999 and September 30, 2010, PSA less than 10 ng/ml, clinical stage T2a or less and confirmatory prostate biopsy performed within 6 months of the initial prostate biopsy. We excluded patients with no prostate MRI performed between the initial and confirmatory biopsies (173 patients), prostate MRI performed without an endorectal coil (11 patients) and MRI performed elsewhere (1 patient). Thus, our final study population consisted of 388 patients.

MRI Acquisition

All MRI studies were performed using whole-body units (GE Healthcare, Waukesha, Wisconsin). A body coil was used for excitation, and a pelvic phased array coil and an expandable endorectal coil were used for signal reception. Due to the length of the study period (10 years), the MRI parameters varied slightly as per the standard clinical protocols in place at our institution at the time of each examination. However, all MRI studies involved the sequences and acquisition parameters of transverse T1-weighted images (repetition time/echo time 400 to 750/10 to 14 ms, section thickness 5 mm, intersection gap 1 mm, field of view 28 to 36 cm, matrix 256 × 192); transverse, coronal and sagittal T2-weighted fast spin-echo images (repetition time/effective echo time 3,500 to 6,000/120 ms, section thickness 3 mm, no intersection gap, field of view 12 to 14 cm, matrix 256 × 192). MRI studies were performed at 1.5 T (312 patients) and 3 T (76 patients).

MRI Interpretation

Three radiologists retrospectively and independently interpreted the MRI studies, which were archived in a picture archiving and communication system (Centricity®). Reader 1 was a fellowship trained body radiologist who had read only about 50 prostate MRI examinations before this study. Reader 2 was a body imaging fellow with a special interest and dedicated training in prostate imaging, who had read approximately 500 prostate MRI examinations. Reader 3 was a fellowship trained genitourinary radiologist who had interpreted more than 5,000 prostate MRI examinations. Readers were aware that the patients had low risk features on initial clinical evaluation and biopsy but were unaware of their PSA levels, the number(s) or location(s) of initial positive biopsies and the confirmatory biopsy findings. For each patient, each reader independently assigned a score for the presence of tumor on MRI on a 1 to 5 index scale (1—definitely no tumor, 2—probably no tumor, 3—indeterminate, 4—probably tumor, 5—definitely tumor) using previously published criteria (figs. 1 to 3).[19] If a score of 4 or greater was assigned, the reader also recorded the number of lesions per patient, the maximum diameter of the largest lesion and lesion laterality (unilateral or bilateral), as well as the likelihood of ECE and SVI (using the same 5-point scale).

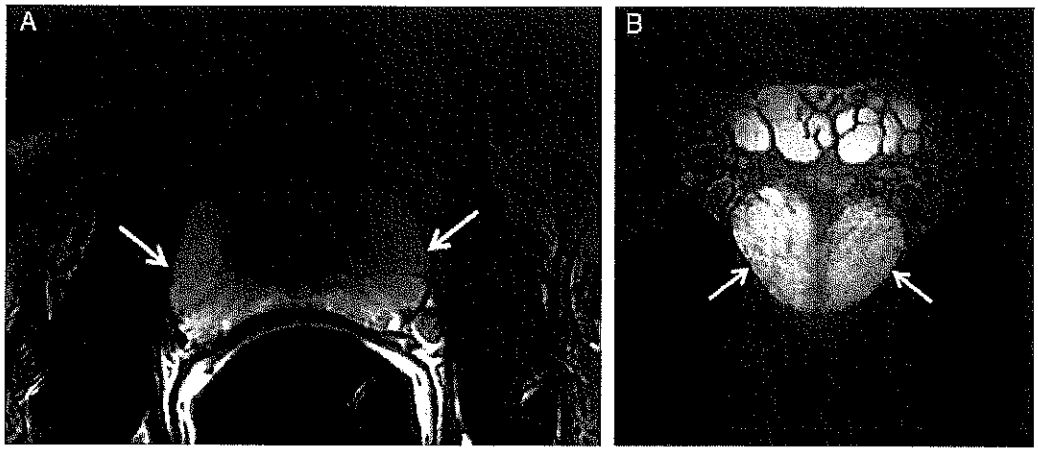


Figure 1. Imaging in 50-year-old patient with clinical stage T1c prostate cancer, PSA 4.5 ng/ml. Axial (*A*) and coronal (*B*) T2-weighted MRI demonstrated normal high signal intensity of peripheral zone (arrows). Study was interpreted as probably no tumor (MRI suspicion score 2) by all 3 readers. Confirmatory prostate biopsy demonstrated 2 of 12 cores positive for cancer, 2% to 12% cancer involvement in each core and Gleason score 3 + 3, thus fulfilling NCCN criteria for very low risk disease.

Histopathological Analysis and Image Correlation

For all patients initial biopsy was performed at a referring institution and confirmatory biopsy was performed at our institution within the following 6 months. There were 55 patients (14%) who had more than 1 prostate biopsy before the confirmatory biopsy, and of these patients 3 had more than 1 positive biopsy before confirmatory biopsy. The confirmatory biopsy included a standard 12-core biopsy, in which samples were obtained from the medial and lateral aspects of the base, middle and apical portions of the prostate bilaterally. In addition, 2 biopsy samples were obtained from the transition zone for a total of 14 cores. At the discretion of the urologist performing the procedure, samples were also obtained from suspicious lesions identified on digital rectal examination, transrectal ultrasound or MRI. All biopsy specimens were reviewed at our institution by a dedicated genitourinary pathologist. In the patients who underwent radical prostatectomy within 6 months of prostate MRI, pathology findings were compared with those from confirmatory biopsy.

Reference Standards

Confirmatory prostate biopsy was used as the reference standard to identify patients for whom the NCCN Prostate Cancer Guidelines recommended active surveillance.[11] The NCCN low risk category included patients with no cores showing Gleason score 7 or greater cancer in the confirmatory biopsy (regardless of the number of pos-

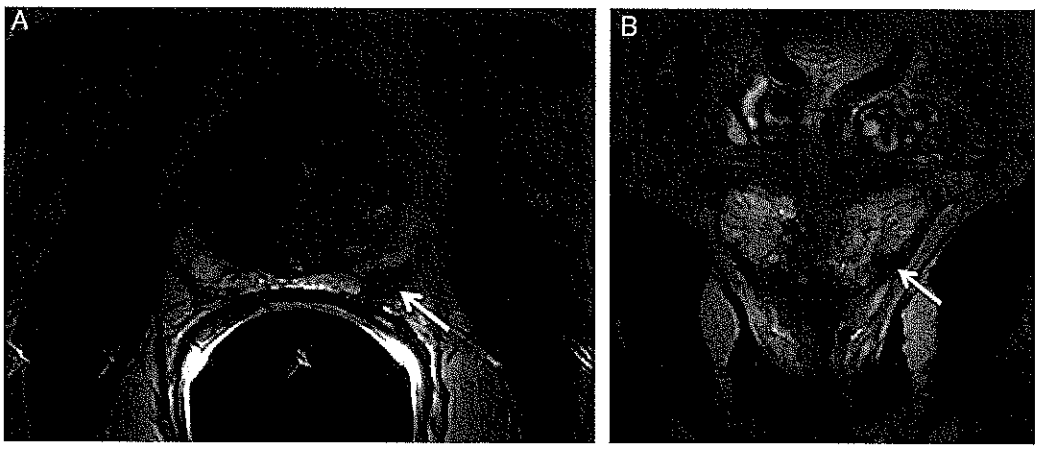


Figure 2. Imaging in 69-year-old patient with clinical stage T1c prostate cancer, PSA 5.1 ng/ml. Axial (*A*) and coronal (*B*) T2-weighted MRI demonstrated nodular area of decreased signal intensity in left posterolateral peripheral zone suspicious for tumor (arrows), which was interpreted as definitely tumor (MRI suspicion score 5) by all 3 readers. Confirmatory prostate biopsy demonstrated 4 of 12 cores positive for cancer, 20% to 50% cancer involvement in each core and Gleason score 3 + 4. Therefore, case did not fulfill NCCN low risk or very low risk criteria and, therefore, was deemed ineligible for active surveillance. Radical prostatectomy specimen revealed Gleason 3 + 4 prostate cancer, dominant tumor in left peripheral zone (concordant with MRI finding), invading into but not beyond prostatic capsule.

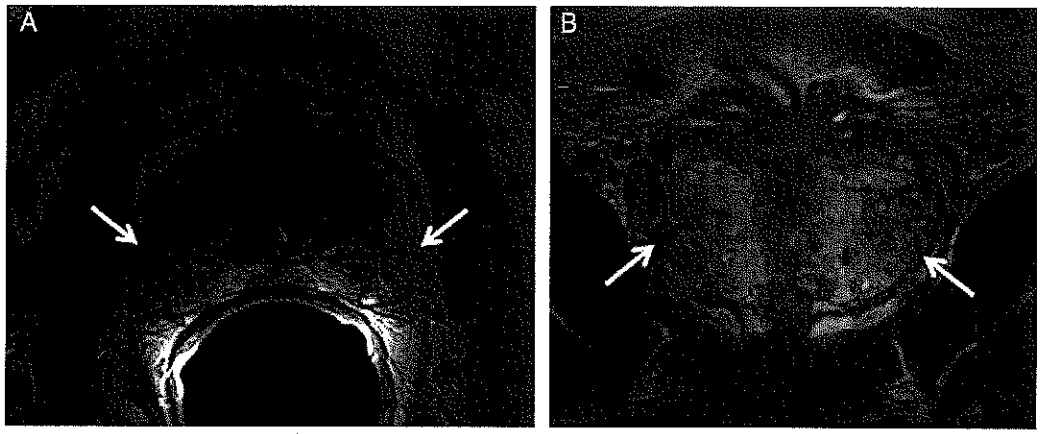


Figure 3. Imaging in 62-year-old patient with clinical stage T1c prostate cancer, PSA 5.8 ng/ml. Axial (*A*) and coronal (*B*) T2-weighted MRI demonstrated heterogeneous appearance of peripheral zone with areas of decreased signal intensity interspersed among areas of normal high signal intensity (arrows). This was interpreted as indeterminate (MRI suspicion score 3) by 2 more experienced readers and probably tumor (MRI suspicion score 4) by least experienced reader. Confirmatory prostate biopsy demonstrated 4 of 12 cores positive for cancer, 10% to 20% cancer involvement in each core and Gleason score 3 + 3.

itive cores), and the NCCN very low risk category included patients with no Gleason score 7 or greater cancer in the confirmatory biopsy, no more than 3 cores involved by cancer and no single core with 50% or more involvement by cancer.

Statistical Analysis

Clinical and demographic data were summarized using descriptive statistics. Inter-reader agreement was assessed using weighted kappa statistics with Fleiss-Cohen (quadratic) weights and interpreted based on the table provided by Landis and Koch.[19,20] Measures of diagnostic accuracy for predicting confirmatory biopsy findings, including sensitivity, specificity, positive predictive value and negative predictive value, were estimated at a per patient level at every possible cutoff of the 1 to 5 suspicion scale. Performance was also evaluated using the empirical ROC and AUC. AUCs for reader performance were calculated separately for 1.5 and 3 T MRI studies, and for MRI studies obtained before January 1, 2007 and on or after that date (which coincided with the last major software upgrade at our institution).

Multivariate logistic regression was used to evaluate associations between MRI features and confirmatory biopsy findings using odds ratios with $p \leq 0.05$ considered significant. All statistical analyses were performed with SAS® 9.2 software.

RESULTS

Pathological Findings

Confirmatory biopsy findings fit the NCCN criteria for low risk disease in 309 of 388 patients (80%) and the NCCN criteria for very low risk disease in 239 of 388 patients (62%). In 124 patients (32%) no cancer was identified on confirmatory biopsy. In 79 patients disease was upgraded on confirmatory biopsy (ie there was at least 1 core with Gleason score 7 or greater cancer). Confirmatory biopsy included targeted cores of lesions detected by transrectal ultrasound, MRI or digital rectal examination in 70 of 388 patients (18%). Prostatectomy was done within 6 months of MRI in 129 patients (33%). In 84 of these 129 patients (65%) prostatectomy showed higher grade disease than did initial biopsy, and for 51 of the 84 patients (61%) confirmatory biopsy also showed higher grade disease than did initial biopsy.

MRI Score

An MRI score of 2 or less was associated with a high negative predictive value (0.96–1.0) for upgrading on confirmatory biopsy and a high negative predictive value (0.77–0.98) for non-very low risk features on confirmatory biopsy. For all readers an MRI score of 5 was associated with high sensitivity (0.87–0.98) for upgrading on confirmatory biopsy and high sensitivity (0.88–0.99) for non-very low risk features on confirmatory biopsy. Table 1 summarizes the measurements of diagnostic accuracy for predicting confirmatory biopsy findings at different cutoff points. AUCs did not differ significantly between 1.5 and 3 T MRI studies ($p = 0.16$–0.30) or between MRI studies obtained before January 1, 2007 and those obtained on or after that date ($p = 0.26$–0.73).

Other MRI Findings

The readers detected at least 1 lesion in 27% to 52% of patients. In the majority of cases, the lesions were unilateral according to readers 1 and 3 and bilateral according to reader 2. All readers suspected ECE in approximately 4% of patients and SVI in less than 1%.

Multivariate Analysis

Multivariate logistic regressions showed that for all readers, MRI scores were significantly associated

Table 1. *Measurements of accuracy of MRI for predicting confirmatory biopsy features consistent with NCCN risk categories*

Cutoff	Specificity Value (95% CI)	Sensitivity Value (95% CI)	Pos Predictive Value Value (95% CI)	Neg Predictive Value Value (95% CI)	AUC Value (95% CI)
		Prediction of NCCN low risk features on confirmatory biopsy			
Reader 1:					
2 or Less	1.00 (0.95, 1.00)	0.06 (0.03, 0.09)	0.21 (0.17, 0.26)	1.00 (0.81, 1.00)	0.69 (0.63, 0.75)
3 or Less	0.65 (0.53, 0.75)	0.67 (0.61, 0.72)	0.33 (0.26, 0.41)	0.88 (0.83, 0.92)	
4 or Less	0.37 (0.26, 0.48)	0.87 (0.83, 0.91)	0.43 (0.31, 0.55)	0.84 (0.80, 0.88)	
Reader 2:					
2 or Less	1.00 (0.95, 1.00)	0.20 (0.16, 0.25)	0.24 (0.20, 0.29)	1.00 (0.94, 1.00)	0.79 (0.74, 0.84)
3 or Less	0.89 (0.80, 0.95)	0.56 (0.51, 0.62)	0.34 (0.28, 0.41)	0.95 (0.91, 0.98)	
4 or Less	0.44 (0.33, 0.56)	0.90 (0.86, 0.93)	0.54 (0.41, 0.66)	0.86 (0.82, 0.90)	
Reader 3:					
2 or Less	0.95 (0.88, 0.99)	0.32 (0.27, 0.37)	0.26 (0.21, 0.32)	0.96 (0.90, 0.99)	0.76 (0.70, 0.81)
3 or Less	0.57 (0.45, 0.68)	0.82 (0.77, 0.86)	0.44 (0.34, 0.54)	0.88 (0.84, 0.92)	
4 or Less	0.22 (0.13, 0.32)	0.98 (0.96, 0.99)	0.74 (0.52, 0.90)	0.83 (0.79, 0.87)	
		Prediction of NCCN very low risk features on confirmatory biopsy			
Reader 1:					
2 or Less	0.97 (0.93, 0.99)	0.05 (0.03, 0.09)	0.37 (0.32, 0.42)	0.77 (0.50, 0.93)	0.61 (0.56, 0.67)
3 or Less	0.52 (0.43, 0.60)	0.68 (0.61, 0.73)	0.48 (0.40, 0.56)	0.71 (0.65, 0.77)	
4 or Less	0.28 (0.21, 0.36)	0.88 (0.84, 0.92)	0.57 (0.45, 0.69)	0.68 (0.63, 0.73)	
Reader 2:					
2 or Less	0.99 (0.96, 1.00)	0.25 (0.19, 0.31)	0.43 (0.38, 0.49)	0.98 (0.91, 1.00)	0.79 (0.75, 0.83)
3 or Less	0.81 (0.73, 0.87)	0.63 (0.57, 0.69)	0.56 (0.49, 0.63)	0.85 (0.79, 0.90)	
4 or Less	0.37 (0.29, 0.45)	0.95 (0.91, 0.97)	0.80 (0.68, 0.89)	0.72 (0.67, 0.77)	
Reader 3:					
2 or Less	0.94 (0.89, 0.98)	0.38 (0.32, 0.44)	0.47 (0.41, 0.53)	0.92 (0.85, 0.97)	0.76 (0.71, 0.80)
3 or Less	0.49 (0.40, 0.56)	0.87 (0.82, 0.91)	0.68 (0.58, 0.77)	0.75 (0.69, 0.80)	
4 or Less	0.15 (0.10, 0.22)	0.99 (0.97, 1.00)	0.91 (0.72, 0.99)	0.67 (0.62, 0.72)	

with confirmatory biopsy findings (table 2). For reader 1, lesion size was associated with the NCCN low risk category (OR 0.92, 95% CI 0.85–0.99, p = 0.03). No other MRI features were associated with confirmatory biopsy findings for any readers.

Inter-reader Agreement

Agreement on MRI score was fair between reader 1 (least experienced) and reader 2 (intermediate experience) (weighted kappa 0.31), and between reader 1 and reader 3 (most experienced) (weighted kappa 0.38). Agreement was substantial between readers 2 and 3 (weighted kappa 0.61).

DISCUSSION

Among patients initially diagnosed with clinically low risk prostate cancer, those with tumors not clearly visualized on MRI were significantly more likely to demonstrate low risk features on confirmatory biopsy, while patients with tumors clearly visualized on MRI were significantly more likely to have

Table 2. *Multivariate analysis*

	Reader 1		Reader 2		Reader 3	
	OR (95% CI)	p Value	OR (95% CI)	p Value	OR (95% CI)	p Value
Confirmatory biopsy findings consistent with NCCN low risk criteria:						
MRI score	3.97 (2.11, 7.46)	<0.001	2.16 (1.15, 4.06)	0.017	3.22 (2.06, 5.05)	<0.001
No. lesions	1.18 (0.64, 2.16)	0.603	1.30 (0.80, 2.10)	0.287	1.38 (0.81, 2.37)	0.237
Lesion size	0.92 (0.85, 0.99)	0.030	1.07 (0.97, 1.19)	0.161	1.01 (0.93, 1.09)	0.850
SVI*	1.35 (0.44, 4.12)	0.596	0.62 (0.26, 1.50)	0.291	—	—
ECE	0.97 (0.69, 1.38)	0.869	1.06 (0.79, 1.43)	0.687	0.81 (0.49, 1.35)	0.421
Confirmatory biopsy findings consistent with NCCN very low risk criteria:						
MRI score	1.92 (1.13, 3.27)	0.016	3.71 (2.02, 6.79)	<0.001	3.49 (2.40, 5.07)	<0.001
No. lesions	1.32 (0.75, 2.32)	0.343	1.32 (0.83, 2.10)	0.243	1.22 (0.68, 2.18)	0.510
Lesion size	0.95 (0.89, 1.01)	0.105	0.96 (0.87, 1.06)	0.397	1.03 (0.95, 1.11)	0.489
SVI*	1.33 (0.50, 3.55)	0.565	0.61 (0.27, 1.35)	0.221	—	—
ECE	1.29 (0.95, 1.76)	0.102	1.19 (0.88, 1.63)	0.262	0.74 (0.44, 1.26)	0.265

* Reader 3 did not identify SVI in any of the patients.

disease upgraded on confirmatory biopsy. In addition, our results confirm the importance of confirmatory biopsy in patients being evaluated for AS. Among the patients who underwent prostatectomy within 6 months of MRI, the surgicopathological Gleason score was higher than that of the initial biopsy in 65%, but was higher than that of the confirmatory biopsy in only 26%, suggesting that confirmatory biopsy provided a better estimate of the total tumor burden than did the initial biopsy. The clinical and demographic characteristics of our study population are similar to those of patients undergoing AS in all the largest published series.[5–7,9,21,22] This suggests that by predicting the findings of confirmatory biopsy, MRI could aid the identification of suitable candidates for AS. Our results also confirm prior reports on the importance of training and experience for accurate interpretation of prostate MRI.[23] Measurements of diagnostic performance were consistently lowest for the least experienced reader, while agreement was moderate to substantial between the 2 more experienced readers, although only slight to fair between the least experienced reader and either of the other readers. These results suggest that MRI of the prostate, if read by radiologists with appropriate training and experience, could help determine AS eligibility and obviate the need for confirmatory biopsy in substantial numbers of patients.

In the only published study we found that evaluated the use of T2-weighted MRI to select patients for AS, Ploussard et al reported on 96 patients who decided to pursue definitive treatment, although they were deemed eligible for AS based on stringent criteria from a single 21-core biopsy scheme (Gleason score 6 or less, fewer than 3 cores involved by cancer and tumor length per core less than 3 mm).[24] The authors concluded that MRI findings (dichotomized as organ confined vs nonorgan confined disease) did not improve the prediction of unfavorable features at prostatectomy in the population studied. Our results are concordant with theirs, as we did not find an association between ECE or SVI (ie nonorgan confined disease) on MRI and upgrading from the NCCN low and very low risk categories at confirmatory biopsy. However, we did find an association between tumor visibility on MRI and confirmatory biopsy findings, meaning that in this clinical setting, the most important MRI finding is not whether the cancer appears organ confined, but whether it is clearly visualized.

Our study has several limitations. It is retrospective, and we chose confirmatory biopsy rather than long-term outcomes as our reference standard. However, our results could provide the foundation for a prospective study incorporating outcome data. In addition, NCCN classifications and all other predictive tools intended to define clinically significant prostate cancer are controversial. Nevertheless, many of these tools are routinely used in clinical practice (such as the D'Amico risk stratification system[25] and the Epstein criteria[26]). Despite subtle differences between the tools and guidelines used to classify risk level and select patients for AS, no substantial differences in AS outcomes associated with their use have been reported. Furthermore, the NCCN risk assessment criteria used here, which are the only ones that include specific recommendations about suitability for AS, are part of established management guidelines.[11] It should also be noted that 18% of confirmatory biopsies in our study included samples from lesions targeted based on clinical or imaging findings. Theoretically this could have improved tumor burden detection on confirmatory biopsies, although whether the initial biopsies also included targeted samples is unknown.

Another limitation of our study was the inclusion of 1.5 and 3 T MRI examinations performed during a period of 10 years. This allowed us to maximize the number of eligible patients but also introduced potential diagnostic heterogeneity. However, we found no differences in diagnostic performance between 1.5 and 3 T MRI studies, or between MRI studies obtained before or after the last major software upgrade at our institution. This suggests that technological improvements in the last decade may not have significantly affected conventional sequences such as T2-weighted imaging, which still represents the mainstay of prostate MRI. To date, the theoretical advantages of 3 T MRI for prostate cancer diagnosis have not been comprehensively validated.[27] While there is currently great interest in the use of MP MRI sequences such as diffusion weighted imaging and dynamic contrast enhanced MRI, such sequences have only been clinically available for a few years. Thus, the largest published study to our knowledge of MP MRI in patients considering AS includes only 60 patients.[28] We hope our study of T2-weighted MRI will serve as a basis for future studies assessing the incremental value of MP MRI in larger cohorts.

In summary, the success of active surveillance as a management strategy for prostate cancer relies primarily on the accurate identification of patients with low risk disease unlikely to progress. The fact that clear tumor visualization on MRI was predictive of upgrading on confirmatory prostate biopsy suggests that prostate MRI may contribute to the complex process of assessing patient eligibility for AS.

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REFERENCES

1. Siegel R, Ward E, Brawley O et al: Cancer statistics, 2011: the impact of eliminating socioeconomic and racial disparities on premature cancer deaths. CA Cancer J Clin 2011; **61:** 212.
2. Jemal A, Ward E and Thun M: Declining death rates reflect progress against cancer. PLoS One 2010; **5:** e9584.
3. Draisma G, Etzioni R, Tsodikov A et al: Lead time and overdiagnosis in prostate-specific antigen screening: importance of methods and context. J Natl Cancer Inst 2009; **101:** 374.
4. Thompson IM and Klotz L: Active surveillance for prostate cancer. JAMA 2010; **304:** 2411.
5. Klotz L, Zhang L, Lam A et al: Clinical results of long-term follow-up of a large, active surveillance cohort with localized prostate cancer. J Clin Oncol 2010; **28:** 126.
6. van den Bergh RC, Roemeling S, Roobol MJ et al: Outcomes of men with screen-detected prostate cancer eligible for active surveillance who were managed expectantly. Eur Urol 2009; **55:** 1.
7. Dall'Era MA, Konety BR, Cowan JE et al: Active surveillance for the management of prostate cancer in a contemporary cohort. Cancer 2008; **112:** 2664.
8. Roemeling S, Roobol MJ, de Vries SH et al: Active surveillance for prostate cancers detected in three subsequent rounds of a screening trial: characteristics, PSA doubling times, and outcome. Eur Urol 2007; **51:** 1244.
9. Soloway MS, Soloway CT, Eldefrawy A et al: Careful selection and close monitoring of low-risk prostate cancer patients on active surveillance minimizes the need for treatment. Eur Urol 2010; **58:** 831.
10. Mohler JL, Armstrong AJ, Bahnson RR et al: NCCN Clinical Practice Guidelines in Oncology for Prostate Cancer, v2.2010. Available at http://www.nccn.org/professionals/physician_gls/pdf/prostate.pdf. Accessed June 6, 2010.
11. Mohler JL, Armstrong AJ, Bahnson RR et al: NCCN Clinical Practice Guidelines in Oncology for Prostate Cancer, v3.2011. Available at http://www.nccn.org/professionals/physician_gls/pdf/prostate.pdf. Accessed May 25, 2011.
12. Ploussard G, Epstein JI, Montironi R et al: The contemporary concept of significant versus insignificant prostate cancer. Eur Urol 2011; **60:** 291.
13. Berglund RK, Masterson TA, Vora KC et al: Pathological upgrading and up staging with immediate repeat biopsy in patients eligible for active surveillance. J Urol 2008; **180:** 1964.
14. Zhang J, Hricak H, Shukla-Dave A et al: Clinical stage T1c prostate cancer: evaluation with endorectal MR imaging and MR spectroscopic imaging. Radiology 2009; **253:** 425.
15. Shukla-Dave A, Hricak H, Kattan MW et al: The utility of magnetic resonance imaging and spectroscopy for predicting insignificant prostate cancer: an initial analysis. BJU Int 2007; **99:** 786.
16. Delongchamps NB, Beuvon F, Eiss D et al: Multiparametric MRI is helpful to predict tumor focality, stage, and size in patients diagnosed with unilateral low-risk prostate cancer. Prostate Cancer Prostatic Dis 2011; **14:** 232.
17. Vargas HA, Akin O, Franiel T et al: Diffusion-weighted endorectal MR imaging at 3 T for prostate cancer: tumor detection and assessment of aggressiveness. Radiology 2011; **259:** 775.
18. Langer DL, van der Kwast TH, Evans AJ et al: Intermixed normal tissue within prostate cancer: effect on MR imaging measurements of apparent diffusion coefficient and T2–sparse versus dense cancers. Radiology 2008; **249:** 900.
19. Fleiss JL, Cohen J and Everitt BS: Large-sample standard errors of kappa and weighted kappa. Psychol Bull 1969; **72:** 323.
20. Landis JR and Koch GG: The measurement of observer agreement for categorical data. Biometrics 1977; **33:** 159.
21. Carter HB, Kettermann A, Warlick C et al: Expectant management of prostate cancer with curative intent: an update of the Johns Hopkins experience. J Urol 2007; **178:** 2359.
22. Kakehi Y, Kamoto T, Shiraishi T et al: Prospective evaluation of selection criteria for active surveillance in Japanese patients with stage T1cN0M0 prostate cancer. Jpn J Clin Oncol 2008; **38:** 122.
23. Mullerad M, Hricak H, Wang L et al: Prostate cancer: detection of extracapsular extension by genitourinary and general body radiologists at MR imaging. Radiology 2004; **232:** 140.
24. Ploussard G, Xylinas E, Durand X et al: Magnetic resonance imaging does not improve the prediction of misclassification of prostate cancer patients eligible for active surveillance when the most stringent selection criteria are based on the saturation biopsy scheme. BJU Int 2011; **108:** 513.
25. D'Amico AV, Whittington R, Malkowicz SB et al: Biochemical outcome after radical prostatectomy, external beam radiation therapy, or interstitial radiation therapy for clinically localized prostate cancer. JAMA 1998; **280:** 969.
26. Epstein JI, Walsh PC, Carmichael M et al: Pathologic and clinical findings to predict tumor extent of nonpalpable (stage T1c) prostate cancer. JAMA 1994; **271:** 368.
27. Park BK, Kim B, Kim CK et al: Comparison of phased-array 3.0-T and endorectal 1.5-T magnetic resonance imaging in the evaluation of local staging accuracy for prostate cancer. J Comput Assist Tomogr 2007; **31:** 534.
28. Margel D, Yap SA, Lawrentschuk N et al: Impact of multiparametric endorectal coil prostate magnetic resonance imaging on disease reclassification among active surveillance candidates: a prospective cohort study. J Urol 2012; **187:** 1247.

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RadioGraphics

Advancements in MR Imaging of the Prostate: From Diagnosis to Interventions[1]

TEACHING POINTS
See last page

CME FEATURE
See www.rsna.org/education/rg_cme.html

LEARNING OBJECTIVES FOR TEST 2
After reading this article and taking the test, the reader will be able to:

- Describe the clinical background, prognosis, and current screening of prostate cancer.
- List the findings of prostate cancer at T1- and T2-weighted MR imaging and multiparametric MR imaging.
- Discuss the rationale for and technique of MR imaging–guided prostate biopsy.

INVITED COMMENTARY
See discussion on this article by Oto (pp 704–706).

David Bonekamp, MD, PhD • Michael A. Jacobs, PhD • Riham El-Khouli, MD • Dan Stoianovici, PhD • Katarzyna J. Macura, MD, PhD

Prostate cancer is the most frequently diagnosed cancer in males and the second leading cause of cancer-related death in men. Assessment of prostate cancer can be divided into detection, localization, and staging; accurate assessment is a prerequisite for optimal clinical management and therapy selection. Magnetic resonance (MR) imaging has been shown to be of particular help in localization and staging of prostate cancer. Traditional prostate MR imaging has been based on morphologic imaging with standard T1-weighted and T2-weighted sequences, which has limited accuracy. Recent advances include additional functional and physiologic MR imaging techniques (diffusion-weighted imaging, MR spectroscopy, and perfusion imaging), which allow extension of the obtainable information beyond anatomic assessment. Multiparametric MR imaging provides the highest accuracy in diagnosis and staging of prostate cancer. In addition, improvements in MR imaging hardware and software (3-T vs 1.5-T imaging) continue to improve spatial and temporal resolution and the signal-to-noise ratio of MR imaging examinations. Another recent advancement in the field is MR imaging guidance for targeted prostate biopsy, which is an alternative to the current standard of transrectal ultrasonography–guided systematic biopsy.

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Abbreviations: ADC = apparent diffusion coefficient, BPH = benign prostatic hyperplasia, DCE = dynamic contrast-enhanced, DRE = digital rectal examination, EES = extracellular-extravascular space, PSA = prostate-specific antigen, ROI = region of interest, SNR = signal-to-noise ratio, TKCM = tracer kinetic compartmental model

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Introduction

Prostate cancer is the most frequently diagnosed cancer in males, accounting for 25% of all cancers in males (192,280 of 766,130 newly diagnosed cancers in males in 2009), compared with 15% for lung cancer. It is the second leading cause of cancer-related death in men, making up 9% of cancer deaths in males (27,360 of 292,540 cancer-related deaths in males in 2009), a value exceeded only by the death rate from lung cancer in males (30%). Sixteen percent of males (one in six) will develop prostate cancer during their lifetime (1).

The prevalence of prostate cancer increases with age; 34% of men in the 5th decade of life and up to 70% aged 80 years or older have histologic evidence of prostate cancer. The anticipated demographic change in an aging population is expected to increase the incidence of prostate cancer. Over the past 25 years, the 5-year survival rate for all stages of prostate cancer combined has increased from 69% to almost 99%. The corresponding 10-year survival rate is 93%, and the 15-year survival rate is 79%. The notable improvements in survival, particularly at 5 years, are commonly attributed to earlier diagnosis and improvements in treatment.

Radical treatment options for patients with prostate cancer include prostatectomy (for organ-confined T1 and T2 disease) and hormone ablation and radiation therapy (for advanced extraprostatic T3 and T4 disease). Local and minimally invasive therapy choices for organ-confined prostate cancer include cryoablation, radiofrequency ablation, brachytherapy, photodynamic therapy, and high-intensity focused ultrasonography (US); however, these therapies require exact localization of the cancer. In certain situations, expectant management (watchful waiting) is a legitimate choice for patients with small-volume, low-grade, low-risk disease without any additional morbidity.

With accurate staging and localization of prostate cancer, minimally invasive therapies can provide uncompromised oncologic outcome with significantly less comorbidity. However, patient selection for such treatments remains a challenge, since the tumor biology of prostate cancer still remains poorly understood. Most patients in whom prostate cancer is diagnosed die *with* the disease rather than *of* the disease.

Although several methods have been developed to predict patients' outcome (2), it is still difficult to project which patients will experience progression of the disease. The most important predictors of prognosis in prostate cancer are the Gleason score and the clinical stage at the time of diagnosis. Prostate-specific antigen (PSA) screening has led to earlier diagnosis of tumors at lower clinical stages and with lower Gleason scores (3).

Despite PSA screening, there remains a major medical and socioeconomic impact due to morbidity and mortality from prostate cancer. The three dimensions in the accurate assessment of prostate cancer are detection, localization, and staging. Improvements in all three of these dimensions are prerequisites for optimal clinical management and therapy selection.

Magnetic resonance (MR) imaging continues to evolve as a powerful modality for localization and staging of prostate cancer. Recent advances employ functional and physiologic MR imaging techniques, in addition to the established morphologic imaging with T1-weighted and T2-weighted sequences. Often, these new techniques are used together in a multiparametric approach.

Diffusion-weighted imaging interrogates the tissue microstructure at the microscopic scale of water self-diffusion (Brownian motion). MR spectroscopy probes the concentration of biochemical disease markers in tissues. Dynamic contrast material–enhanced (DCE) MR imaging dynamically captures the distribution of intravenously administered gadolinium-based contrast agents between tissue and the blood pool, allowing characterization of alterations in the microvascular environment resulting from tumor angiogenesis. All of these techniques benefit from continuing improvements in imaging unit hardware and software. MR-compatible devices have been developed for diagnostic and therapeutic interventions and for minimally invasive procedures.

In this article, we review the currently available MR methodologies for the evaluation of prostate cancer in a practical and integrated clinical context and discuss and illustrate the recent advancements in the field, including MR imaging guidance for targeted prostate biopsy as an alternative to transrectal US–guided systematic biopsy, which is the current standard. We also discuss the advantages and limitations of current diagnostic MR imaging of the prostate. In addition, we provide a comparison of prostate MR imaging at 3 T and 1.5 T. Finally, development of an imaging algorithm for MR imaging of the prostate is described.

Clinical Background and Specific MR Imaging Considerations

Prostate Cancer Screening

Teaching Point

Currently, prostate cancer screening is based on assessment of the level of PSA elevation and results of digital rectal examination (DRE). Both markers have suboptimal accuracy for the diagnosis of prostate cancer. DRE is affected by interexaminer variability, irrespective of experience, and is limited to assessment of peripheral zone tumors. DRE remains a fundamental part of screening owing to its being part of the clinical examination without additional cost, its ubiquitous availability, and its ability to allow identification of the tumor in 14% of men with prostate cancer (4).

PSA screening was recognized as a screening tool in 1991 after its initial description in 1979. Its introduction has led to a significant decrease in stage at diagnosis and to detection of tumors of very small volume (often <0.5 cm^3) and of low Gleason score (≤6). Despite a diagnosis of prostate cancer, patients with such small and low-grade cancers may not be subject to decreased life expectancy. This is also suggested by the discrepancy between a patient's lifetime risk of a prostate cancer diagnosis (16.7%) and the risk of death from the disease (3%–4%). Therefore, clinically significant prostate cancer has been defined as a tumor with a volume greater than 0.5 cm^3 and a Gleason score greater than or equal to 7 (5).

Despite its significant impact, PSA screening is not optimal. PSA screening has been criticized due to its relatively poor sensitivity and specificity. For PSA levels under 10 ng/mL, elevation above the threshold of 4 ng/mL (values above this threshold are commonly regarded as abnormal) has low specificity for prostate cancer. In 70%–80% of patients with mild elevation of PSA level, the increased PSA level is in fact caused by benign conditions such as benign prostatic hyperplasia (BPH) or prostatitis, resulting in a false-positive PSA test result and subsequently in an unnecessary biopsy.

At least 15% and up to 44% of biopsy-proved prostate cancers occur in patients with PSA levels in the accepted normal range below 4 ng/mL (3). In 15.2% of prostate cancer patients with a normal PSA level, the tumor is not palpable and therefore is clinically silent (3). Nevertheless, these clinically silent tumors may significantly affect the patients' life expectancy, since 15.6% of these cancers are found to be high grade (Gleason score of 7–9) (3). At PSA levels of 2–10 ng/mL, more than one-third of prostate cancers occur at very low total PSA levels of 2–3.9 ng/mL (6). These low PSA level cancers were found in younger patients and at lower stages with a smaller prostate volume.

In addition to the total PSA level, several additional PSA level–based indexes are clinically used today due to their ability to stratify patients into different risk groups. PSA velocity is the increase in total PSA level over time, which can also be expressed as the PSA doubling time. A PSA velocity of greater than 0.4–0.75 ng/mL/y is commonly considered suspicious for the presence of prostate cancer.

Different molecular forms of total PSA have been identified, for example, free PSA and PSA bound to α_1-antichymotrypsin. PSA in serum is predominantly complexed to protease inhibitors; however, in the form of free PSA it is not bound to these proteins. Use of the percentage of free PSA—that is, the ratio of free PSA to total PSA—has been found to improve the specificity of an elevated total PSA level. In benign processes of the prostate, the percentage of free PSA tends to be higher in comparison to the total PSA. Use of the percentage of free PSA for screening is often recommended in the setting of a normal DRE result together with a total PSA level of 4.0–10 ng/mL. At times, screening with the percentage of free PSA is initiated when a high normal PSA level is found.

In the setting of a high normal total PSA level of 2.0–3.9 ng/mL or in the intermediate range of 4.0–10 ng/mL, data suggest that a free PSA level above 18% of the total PSA is associated with a risk of less than 10% for prostate cancer; conversely, a free PSA level below 10% is associated with a 30% risk for prostate cancer (7). Accordingly, in the setting of a low to intermediate total PSA level, the clinical decision to perform a prostate biopsy is often made if the free PSA level is found to be below 20%–25%. Additional free PSA subforms exist, including precursor PSA, "benign" PSA, and intact PSA, which may help increase the specificity of the percentage of free PSA; however, these subforms are beyond the scope of this article.

The PSA density is defined as the total PSA level divided by the prostate volume in cubic centimeters (classically as measured at transrectal

US). PSA density is based on the concept that prostate cancer produces more PSA per gram of tissue than does normal or benign tissue. Its clinical usefulness is controversial due to limitations in specificity and sensitivity. Although a PSA density greater than or equal to 0.15 was proposed as the threshold for biopsy in men with PSA levels of 4–10 ng/mL, approximately 40% of prostate cancers were missed with this approach. However, the most significant barrier to its widespread use is the unwillingness of patients and physicians to have transrectal US performed without a biopsy.

Transrectal US and Guided Biopsy

US is widely used in the form of transrectal US, nearly always with the primary intent for transrectal biopsy to be performed in the same session.

Transrectal US alone is not recommended for initial screening (eg, according to the current screening guidelines of the American Cancer Society and the Centers for Disease Control and Prevention) owing to *(a)* lack of supportive data on sufficient specificity or ability to significantly increase the detection rate of prostate cancer and *(b)* its significant cost when used as a screening tool. Transrectal US is mainly used to provide visual guidance for biopsy.

At transrectal US, most prostate cancers (60%–70%) are hypoechoic to the normal peripheral zone, whereas up to 40% of lesions are not distinguished from the background normal parenchyma owing to its isoechogenicity (8). Evaluation of the transition zone with transrectal US is very limited. In a large study, transrectal US was found to have only a 15.2% positive predictive value in detection of cancers versus 28% for DRE; therefore, both techniques are unable to allow differentiation of an abundance of benign processes mimicking prostate cancer from true-positive cases. Transrectal US used in the absence of palpable findings has a low sensitivity of 30%–45%, meaning that less than one-half of the ultimately diagnosed cancers can be visualized with transrectal US, even if the improved systematic sextant approach is used (9).

If no abnormality is visualized at US, transrectal US provides anatomic landmarks for systematic biopsy (eg, with the sextant or octant sampling scheme). Transrectal US–guided prostate needle biopsy is performed in men with an abnormal DRE result, an elevated PSA level (>4.0 ng/mL), and a PSA velocity greater than 0.4–0.75 ng/mL/y, as well as in men in whom a previous biopsy showed high-grade prostatic intraepithelial neoplasia or atypia (repeat biopsy is usually performed 3–12 months after the initial biopsy). Some centers perform transrectal US–guided biopsy in the setting of age-specific elevation of PSA level, a low percentage of free PSA (eg, <22%–25%), or a PSA density greater than 0.15. The estimated number of prostate biopsies performed yearly in the United States is 1,300,000. In 2007, these resulted in detection of 186,320 new cases of prostate cancer (10).

As a confirmatory test for patients suspected of having prostate cancer on the basis of DRE result and PSA level, transrectal US–guided biopsy provides a sufficiently high specificity for diagnosis; however, it has limited sensitivity. With prostate biopsy, cancer is missed in up to 10%–38% of men eventually found to have prostate cancer (11), and not uncommonly patients require repeat biopsies until a diagnosis is made. In some instances, failure rates may be as high as 73%. For example, the prostatic apex is difficult to access during biopsy, and lateral as well as anterior cancers are not well evaluated with standard sextant biopsies (11).

The management of cases in which a first set of biopsies was negative for cancer is a known problem and creates uncertainty and emotional stress for the patients, who may be facing a series of repeat biopsies, with cancer detection rates of 34%, 25%, 24%, and 21% for the first, second, third, and fourth biopsies, respectively, as shown in a recent study of 10,429 biopsies (12). Moreover, with the current stage migration, the smaller tumors are becoming ever more difficult to sample. The total volume of the cores extracted in a biopsy session is very small in comparison with the gland volume, less than 1%. Therefore, the overall probability of sampling a minute cancer in the early stage is low and is even lower for larger prostate volumes.

Options in patients with prior negative biopsy results and a high suspicion for prostate cancer

include saturation biopsy and transperineal biopsy. During a saturation biopsy, a much larger number of cores (not uncommonly 40–80) is obtained. Different sampling schemes including saturation biopsy may be performed transperineally, allowing better access to the prostatic apex; however, decreased access to the prostatic base has been described. Transperineal biopsy has been found to be associated with no significant increased risk for complications when compared with transrectal biopsy (13). Although transperineal and transrectal biopsies have been found to have comparable sensitivity, transrectal biopsy remains markedly more popular at this time, an outcome attributed to the increased technical difficulty and the need for at least local anesthesia with transperineal biopsy.

Intraglandular anatomic localization of prostate cancer with transrectal US–guided biopsy has been found to often be inaccurate when compared with the final prostatectomy results; this outcome is likely caused by difficulty in sampling the correct anatomic location for each needle pass. Without accurate intraglandular tumor localization, the patient may not be able to consider minimally invasive local therapies that can improve the quality of life with a good oncologic outcome.

Role of MR Imaging in Screening, Localization, and Biopsy

Because of the limitations of DRE, transrectal US, and transrectal US–guided biopsy, there is a need for further imaging, with MR imaging being an attractive modality owing to its high resolution and soft-tissue contrast. As cases in which MR imaging will be the only modality to demonstrate a suspicious focus are unavoidable, biopsy guidance with MR imaging continues to be developed.

As for localization of prostate cancer, PSA screening provides no spatial information and DRE essentially involves a surface assessment of the prostate. DRE and transrectal US are also operator dependent. Prostate cancer is multifocal in 85% of cases, and this property can be assessed only with imaging or biopsy, not with PSA screening; DRE has only very limited capability for this purpose. MR imaging is currently best suited for detection of multiple foci and for localization of prostate cancer, which is becoming increasingly important.

Staging of Prostate Cancer

Results of clinical staging with DRE, serum PSA levels, and biopsy-derived Gleason score are of limited use in guiding treatment decisions. With clinical staging, prostate cancer stage is underestimated in 30%–60% of cases; however, this is an inexpensive and specific technique in clearly advanced disease, in that once clinical staging suggests inoperability, the risk for inappropriate exclusion of patients from indicated surgery is relatively low. However, patients with clinically understaged disease may undergo unnecessary surgery.

Therefore, MR imaging and other imaging modalities have been evaluated for their ability to improve staging accuracy. The most important aspect of local staging is differentiation between organ-confined disease (stage T1 or T2) and early advanced disease in the form of extracapsular extension or seminal vesicle invasion (stage T3). Advanced MR imaging techniques have been repeatedly shown to be more accurate in differentiation between stage T2 and T3 prostate cancer than other imaging modalities and are preferred for local staging, despite the lack of clearly specified clinical protocols for integration of MR imaging at this time.

Of all noninvasive anatomic imaging modalities, MR imaging is most suited for evaluation of the prostate, as it has unparalleled ability to depict detail of the prostate owing to its exquisite soft-tissue contrast. Computed tomography (CT) does not provide sufficient soft-tissue contrast beyond size assessment of the prostate. Although CT is valuable in the evaluation of pelvic lymphadenopathy and bone metastases, MR imaging and bone scanning have been found superior in their assessment (14).

Currently experimental or reserved to few institutions is use of fluorine 18 (^{18}F)–labeled radiotracers (eg, ^{18}F fluoroethylcholine) for positron emission tomography for staging prostate cancer. Use of ultrasmall paramagnetic iron oxide particles with MR imaging has been found to allow detection of nearly 100% of pathologically involved lymph nodes (15). Single photon emission computed tomography (SPECT) with indium 111 (^{111}In)–labeled murine monoclonal antibody to prostate-specific membrane antigen (capromab pendetide) is hampered by limited image resolution and limited specificity (16).

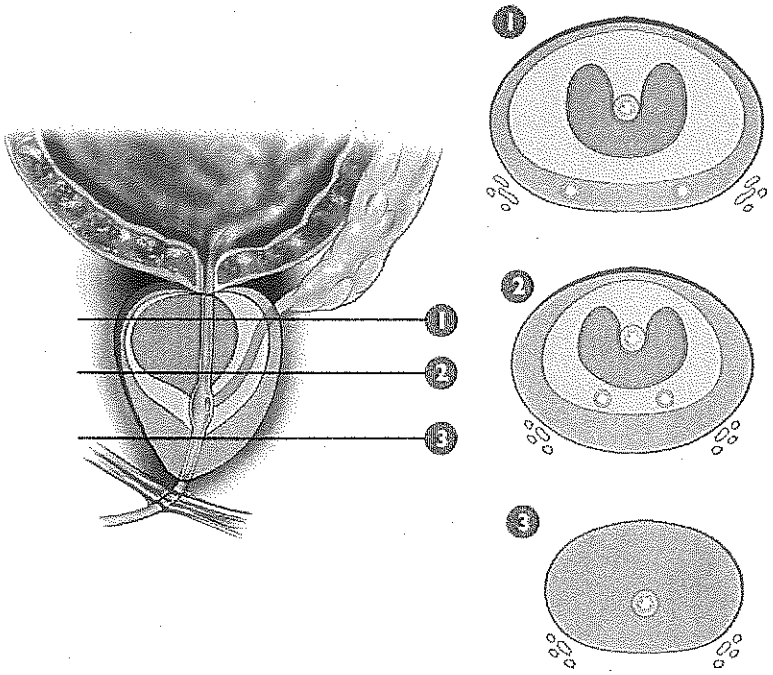


Figure 1. Distribution and proportions of the tissue layers composing the prostate. Diagram of the prostate shows its zonal anatomy in the sagittal plane and corresponding axial sections from the base *(1)*, midgland *(2)*, and apex *(3)*. Note the anterior fibromuscular stroma (red), peripheral zone (pink), central zone (yellow), and transition zone (blue).

Anatomy, Histologic Features, and Morphologic Imaging of the Prostate

Imaging Anatomy of the Prostate

Anatomically, the prostate is divided from superior to inferior into the base (just below the urinary bladder), the midgland, and the apex (Figs 1, 2). In the axial plane, the prostate is divided into four zones: *(a)* the anterior fibromuscular stroma, which contains no glandular tissue; *(b)* the transition zone surrounding the urethra, which contains 5% of the glandular tissue; *(c)* the central zone, which contains 20% of the glandular tissue; and *(d)* the outer peripheral zone, which contains 70%–80% of the glandular tissue (17). The volume of the peripheral zone increases from the base to the apex of the gland.

Teaching Point

Ninety-five percent of prostate cancers are adenocarcinomas that develop from the acini of the prostatic ducts. Thus, prostate cancers arise in the glandular tissue, with about 70% originating in the peripheral zone, 25% in the transition zone, and 5% in the central zone. At imaging, the transition zone cannot be separated from the central zone; therefore, these two zones are often referred to together as the central gland (Fig 2).

The prostate does not have a true capsule, only an outer band of concentric fibromuscular tissue that is an inseparable component of the prostatic stroma (18). The outer-layer "capsule" is most apparent posteriorly and posterolaterally; it is seen at MR imaging as a thin layer of tissue that is dark on T2-weighted images. The capsule is an important landmark for assessment of extraprostatic tumor extension, since irregularities, bulges, and disruptions of the capsule are signs of tumor invasion or spread outside the confines of the prostate.

The periprostatic neurovascular bundles course posterolateral to the prostate bilaterally. They are well seen at imaging at the 5-o'clock and 7-o'clock positions in reference to the prostate (Fig 2). At the apex and base, the nerve bundles send penetrating branches through the capsule, which provide a route for extraprostatic tumor extension.

Grading of Prostate Cancer with the Gleason System

Histologic evaluation of the prostate is performed by using the Gleason grading system (19). Tumors are assigned a primary grade, which is based on the predominant pattern of tissue differentiation, and a secondary grade, which based on the second most common pattern of tissue differentiation. The two numbers (primary grade and secondary grade) are added to produce the final Gleason score.

A tumor with a Gleason score of 6 will have components of Gleason grade 3 + Gleason grade 3. A tumor with a Gleason score of 7 can have components of Gleason grade 3 + Gleason grade 4 or of Gleason grade 4 + Gleason grade 3. The biologic behavior of a tumor with a Gleason score

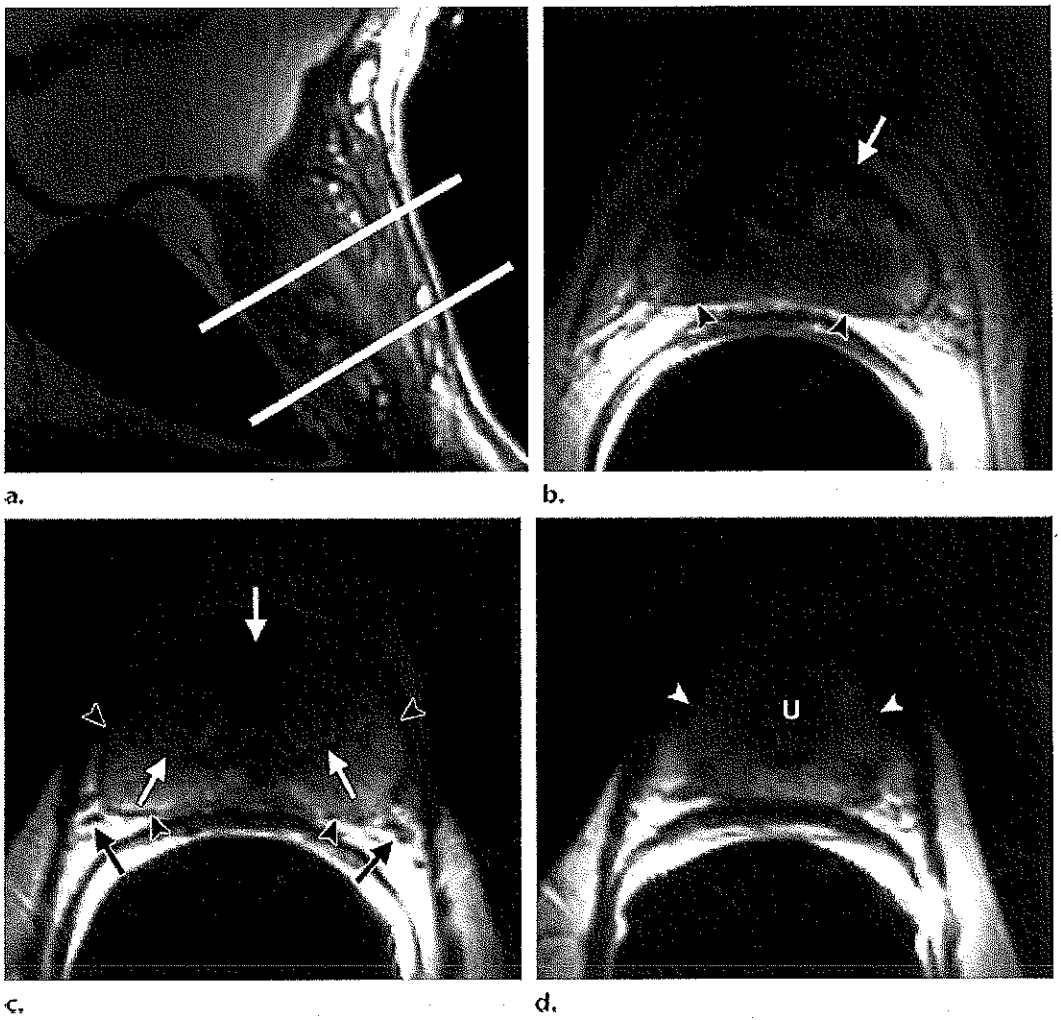


Figure 2. Anatomy of the prostate on endorectal MR images obtained at 1.5 T. **(a)** Sagittal T2-weighted image (repetition time msec/echo time msec = 3350/92) shows division of the prostate into three sections in the craniocaudal direction. The superior one-third of the prostate below the bladder is the base. The middle one-third is the midgland. The distal one-third is the apex. **(b)** Axial T2-weighted image (6000/92) shows the base of the prostate. The anterior fibromuscular stroma (arrow) consists of nonglandular tissue and appears dark. Note the symmetric homogeneous muscular stroma layer (arrowheads) in the posterior prostate base. **(c)** Axial T2-weighted image of the midprostate shows the homogeneously bright peripheral zone (arrowheads) surrounding the central gland (white arrows). The central gland is composed of the transition zone and central zone, which cannot be resolved at imaging. Therefore, they are referred to jointly as the *central gland*. Note the neurovascular bundles at the 5-o'clock and 7-o'clock positions (black arrows). **(d)** Axial T2-weighted image of the prostatic apex shows the homogeneous peripheral zone (arrowheads) surrounding the urethra *(U)*. Note that the volume of the peripheral zone increases from the base to the apex.

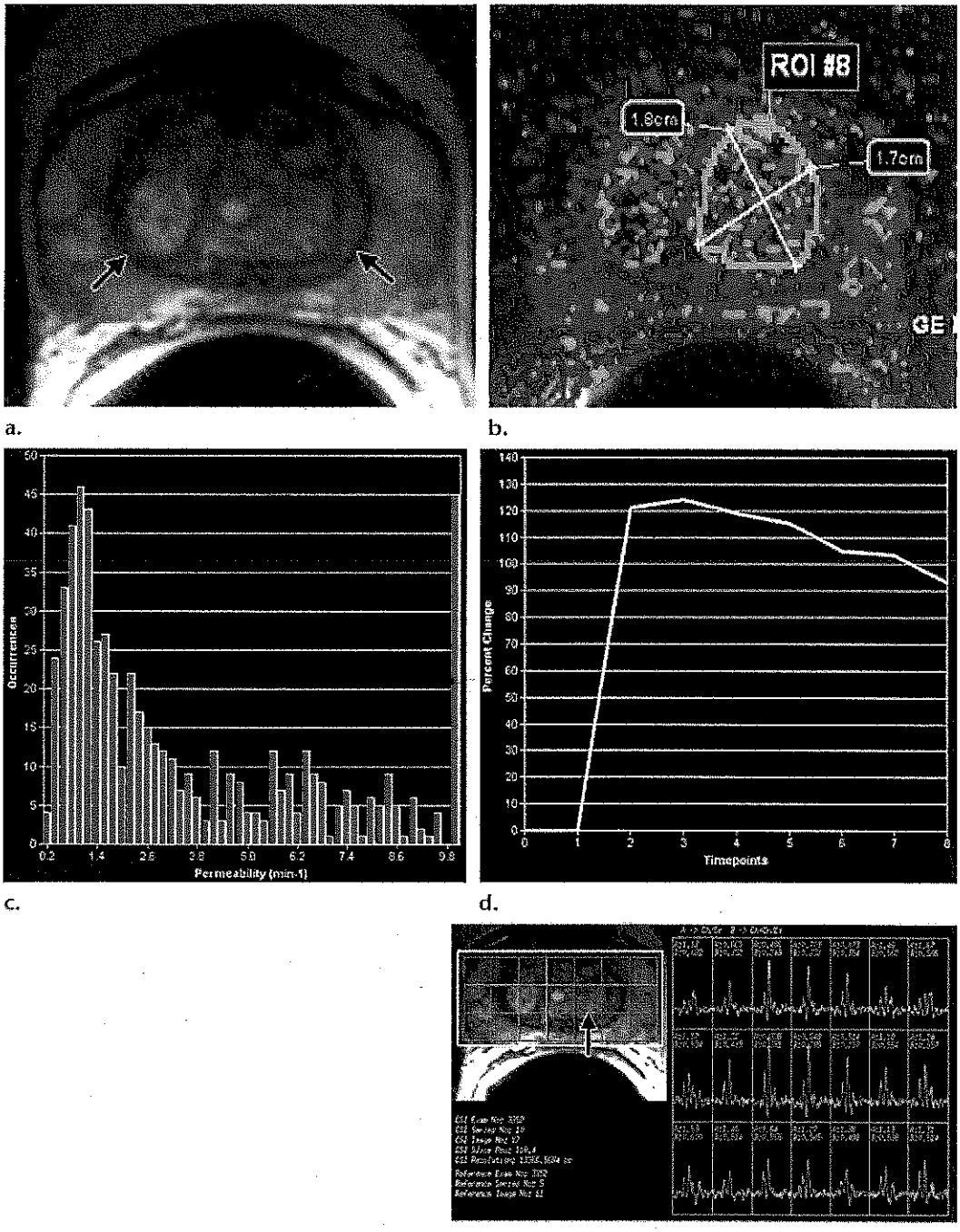
of 4 + 3 would be more aggressive than that of one with a Gleason score of 3 + 4 (20,21).

In the United States, the lowest Gleason score for cancer is a Gleason score of 6; such a tumor is considered well differentiated and has a good prognosis. Tumors with Gleason scores of 8–10 have the worst prognosis and the highest risk for recurrence. Tumors with a Gleason score of 7 have a variable prognosis and an intermediate risk of recurrence (21).

Morphologic Imaging with T2-weighted and T1-weighted Sequences

On T2-weighted images, the normal peripheral zone has homogeneous high signal intensity and the central gland has variable amounts of intermediate signal intensity, which is often replaced by well-circumscribed hyperplastic nodules of BPH (Fig 3).

Figure 3. BPH on endorectal MR images obtained at 1.5 T. **(a)** Axial T2-weighted image (6000/92) shows well-defined heterogeneously bright hyperplastic nodules in the central prostate. Note the discrete dark margins of the junction of the central gland and the peripheral zone pseudocapsule (arrows). **(b)** Color map from computer-assisted diagnosis analysis of DCE MR imaging data shows a region of interest (ROI) marking the left hyperplastic nodule of BPH. **(c)** Permeability histogram shows a wide range of permeability values for tissue in the ROI. **(d)** Kinetic curve (percentage of enhancement over time) from DCE MR imaging data shows a washout pattern of enhancement in the BPH tissue included in the ROI. In this case, the morphologic features at T2-weighted imaging are more specific for the diagnosis of BPH than are the results of kinetic curve analysis, which may suggest malignancy. **(e)** Image from MR spectroscopy shows a voxel grid overlay over the T2-weighted image (left); the spectral display (right) shows normal spectra in the region of BPH. For example, the spectrum for the selected voxel (arrow) shows a high citrate *(Ci)* peak and a low choline *(Ch)* peak in the benign tissue of BPH. Ch + Cr/Ci = 0.297, where *Cr* = creatine.



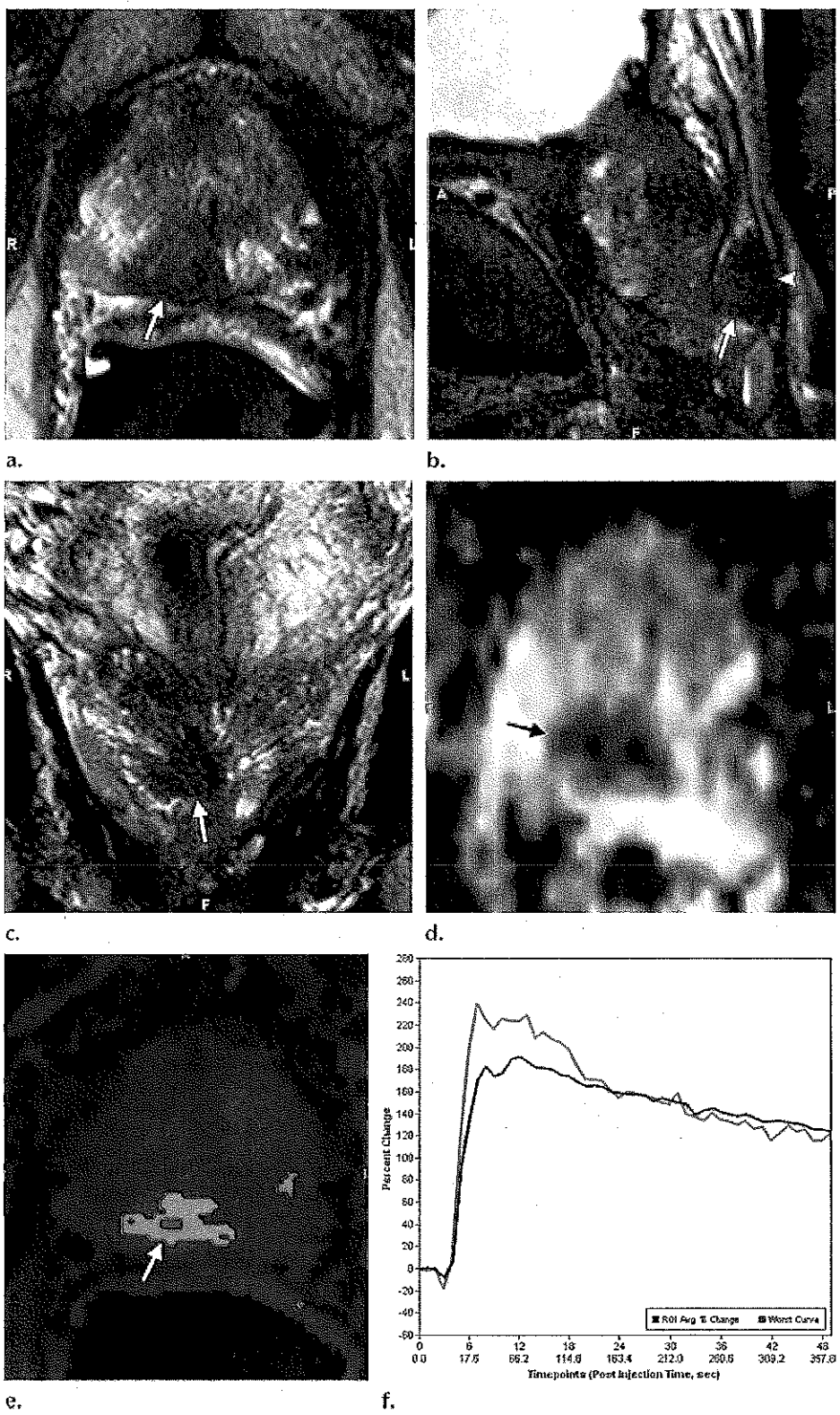


Figure 4. Prostate cancer in a 72-year-old man with a Gleason score of 4 + 3 and a PSA level of 7.2 ng/mL. Endorectal MR imaging of the prostate was performed at 3.0 T. **(a)** Axial T2-weighted image (5000/123) of the prostatic apex shows a hypointense nodule (arrow) in the right side of the apex. **(b)** Sagittal T2-weighted image (5000/153) shows the dark nodule in the prostatic apex (arrow). Note the intact, well-defined, thin, dark prostatic capsule (arrowhead). **(c)** Coronal T2-weighted image (3360/153) shows the hypointense spiculated nodule (arrow). This is a typical morphology for prostate cancer. **(d)** Axial apparent diffusion coefficient (ADC) map from diffusion-weighted imaging shows restricted diffusion (ADC = 0.7 × 10^{-3} mm^2/sec) in the region of malignancy (arrow). **(e)** Color map from DCE MR imaging shows that the area of highest permeability (arrow) is in the region of prostate cancer, a finding that corresponds to the findings on the T2-weighted images and the ADC map. **(f)** Kinetic curve (percentage of enhancement over time) from DCE MR imaging shows a washout pattern of enhancement, typical of malignancy, in the prostatic apex nodule.

A series of studies in the late 1980s established that prostate cancer is characterized by low T2 signal intensity replacing the normally high T2 signal intensity in the peripheral zone (Fig 4) (22). However, the presence of decreased T2 signal intensity in the peripheral zone is of limited sensitivity because some prostate tumors are isointense (Fig 5). This finding is also of limited

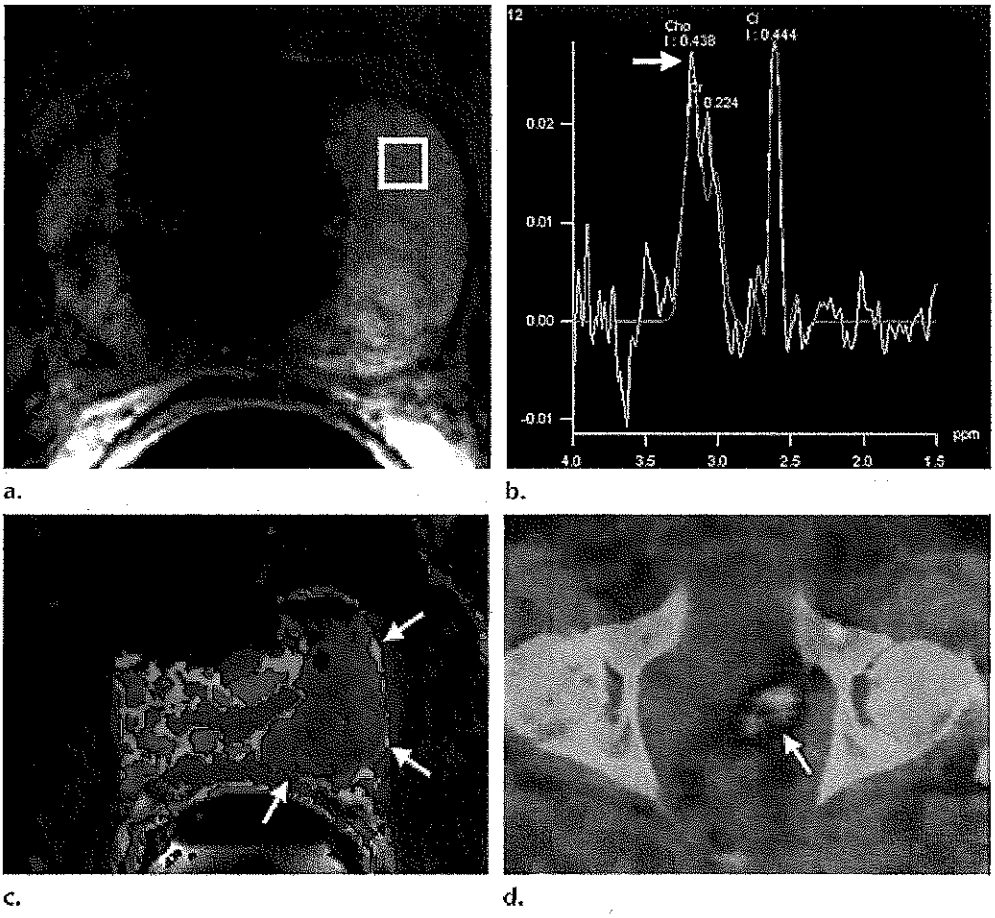


Figure 5. Prostate cancer in a 43-year-old man with a Gleason score of 4 + 3 and a PSA level of 90.5 ng/mL. Endorectal MR imaging was performed at 3.0 T. **(a)** T2-weighted image (4860/109) shows a voxel of interest (square) in the left peripheral zone. Although the left peripheral zone is enlarged compared with the right peripheral zone, it has no focal dark areas. There are patchy dark abnormalities in the right peripheral zone. **(b)** MR spectroscopic spectrum from the voxel of interest shows a markedly elevated level of choline *(Cho)* (arrow) that is almost equal to the citrate *(Ci)* peak. Elevation of choline level with a decrease in citrate level is the spectral signature of prostate cancer. *Cr* = creatine. **(c)** Color DCE MR map shows a large area of high permeability (K^{trans}) occupying the entire left peripheral zone (arrows). **(d)** Axial image from a SPECT study with ^{111}In-labeled prostate monoclonal antibody (capromab pendetide [ProstaScint; Cytogen, Princeton, NJ]) shows avid uptake in the entire left prostate (arrow), a finding compatible with a large-volume prostate cancer. As seen in this case, some aggressive prostate cancers, even of large volume, may appear isointense on T2-weighted images; thus, morphologic imaging alone may not be able to show these tumors. Functional MR imaging—MR spectroscopy and DCE MR imaging—as well as antibody imaging accurately depicted this large prostate cancer.

specificity because there are other possible causes of low T2 signal intensity in the peripheral zone, including hemorrhage, prostatitis, scarring, atrophy, and effects of radiation therapy, cryosurgery, or hormonal therapy.

Prostate cancer arising in the transition zone poses additional imaging difficulties because of the heterogeneity of signal intensity in the central gland. Although there are several findings supporting the diagnosis of a transition zone tumor (23), such as a region of homogeneous low T2 signal intensity in the transition zone (Fig 6) and lack

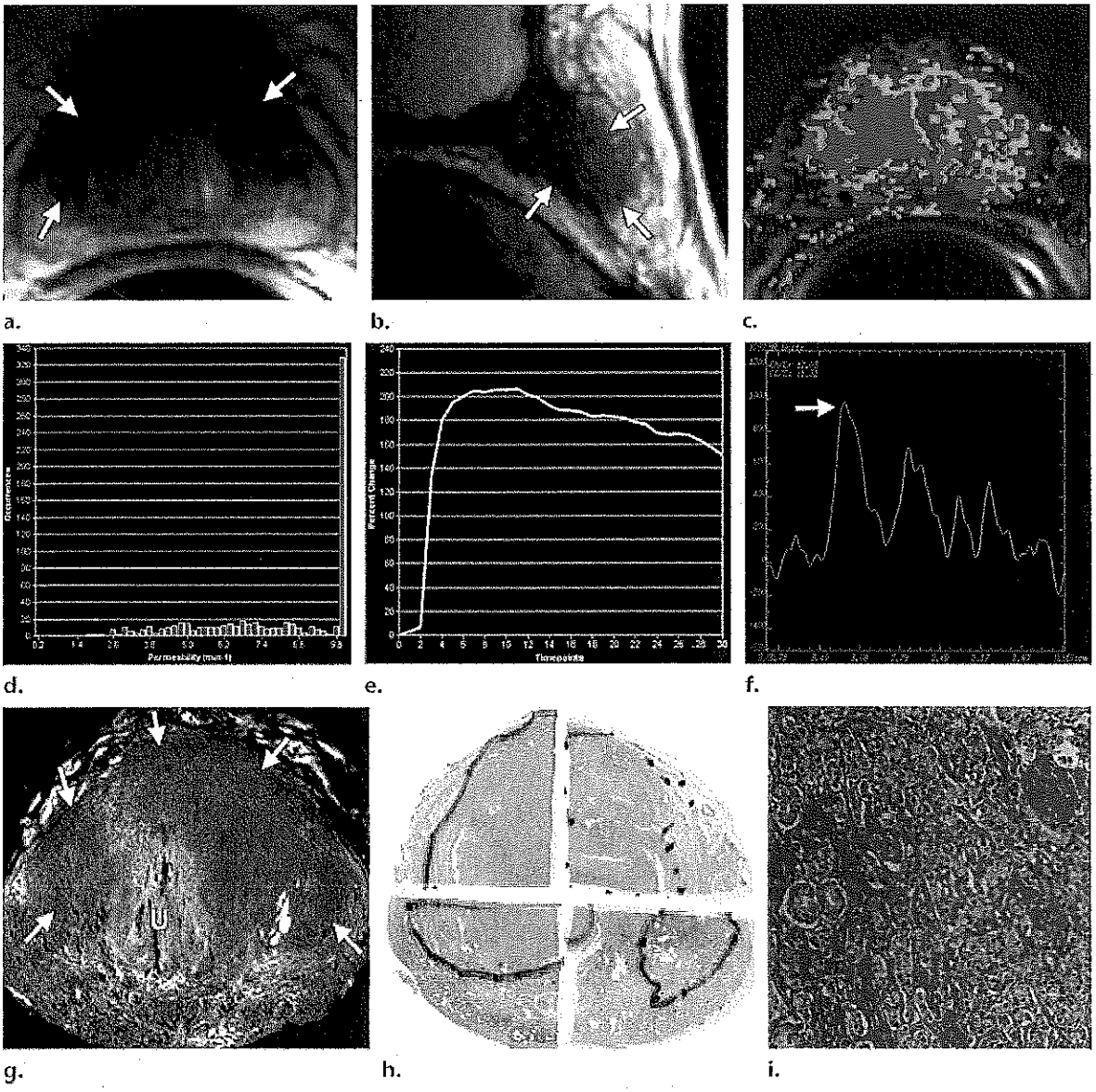
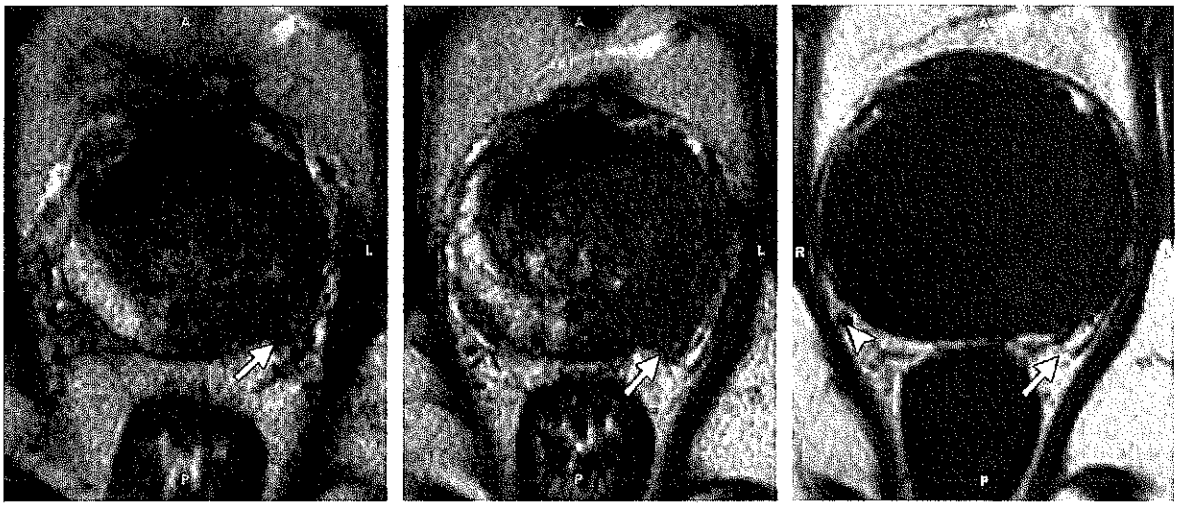


Figure 6. Prostate cancer of the transition zone in a 52-year-old man with a Gleason score of 3 + 4 and a PSA level of 19 ng/mL. Endorectal MR imaging was performed at 1.5 T. **(a)** Axial T2-weighted image (6000/92) shows ill-defined homogeneous dark infiltration of the central gland (arrows). **(b)** Sagittal T2-weighted image (3350/92) shows homogeneous dark tissue replacing the central gland (arrows). **(c)** Axial color DCE MR map shows a large area of high permeability (K^{trans}) (red areas) in the transition zone. **(d)** Permeability histogram shows a shift toward high permeability values, a finding characteristic of cancer. **(e)** Kinetic curve (percentage of enhancement over time) shows typical washout pattern in the transition zone tumor. **(f)** MR spectroscopic spectrum from the transition zone tumor shows a high choline *(Cho)* peak (arrow) at 3.2 ppm that is above that of citrate *(Ci)* at 2.64 ppm. Cho + Cr/Ci = 1.31, where *Cr* = creatine; this value is typical of prostate cancer. **(g)** Ex vivo T2-weighted image (4700/42) of the specimen, obtained at 9.4 T, shows highly cellular, compact dark tissue in the central gland (arrows) surrounding the urethra *(U)*. **(h)** Photograph of a whole-mount reconstructed histologic section (original magnification, ×2; hematoxylin-eosin [H-E] stain) of the midgland shows a large volume of tumor in the transition zone (outlined in green). Note the excellent correlation with the ex vivo image in **g** and the in vivo image in **c**, which show cancer of high cellular density in the transition zone. **(i)** Photomicrograph of a histologic section (original magnification, ×40; H-E stain) from the transition zone tumor shows loss of gland units and sheets of cancer cells with randomly scattered lumina. Note the muscular stroma component between the tumor cells.



a. b. c.

Figure 7. Prostate cancer in a 51-year-old man with a Gleason score of 3 + 3 and a PSA level of 36.4 ng/mL. MR imaging of the prostate was performed at 3.0 T with a body matrix coil. **(a)** Axial T2-weighted image (4000/109) at the level of the prostate base shows confluent dark signal intensity replacing a large volume of the left peripheral zone, with extraprostatic tumor extension (arrow) involving the left neurovascular bundle. **(b)** Axial T2-weighted image at the level of the midgland shows the extracapsular extension of the tumor, with encasement of the left neurovascular bundle (arrow). **(c)** Axial T1-weighted image (600/11) shows good definition of the prostatic contour and the extracapsular tumor extension on the left into the bright periprostatic fat. Note the obliterated left neurovascular bundle (arrow) in comparison with the intact right neurovascular bundle (arrowhead).

of the low-signal-intensity rim commonly seen in association with BPH (Fig 3), low signal intensity is also normally seen in the anterior fibromuscular stroma (Fig 2) as well as in the stromal type of BPH. Several studies that investigated the accuracy of MR imaging in detection of prostate cancer reported low sensitivity, low specificity, and high interobserver variability, even when high-resolution endorectal MR imaging was used.

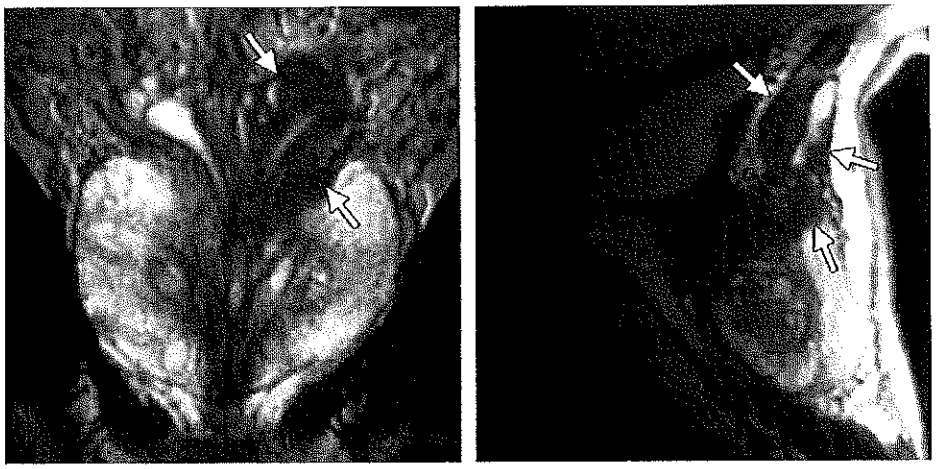
T1-weighted imaging of the prostate is of limited use for assessment of prostate morphology, as detail of the prostate is not well seen. T1-weighted sequences are mainly used *(a)* for detection of postbiopsy hemorrhage; *(b)* for evaluation of the contour of the prostate and the status of the neurovascular bundles, which are well seen in the bright periprostatic fat (Fig 7); and *(c)* as a baseline sequence for calculation of precontrast T1-weighted and DCE images for purposes of subtraction.

Staging of Prostate Cancer with Morphologic Imaging

MR imaging criteria for organ-confined versus extraglandular tumor invasion, in the form of extracapsular tumor extension and seminal vesicle invasion, have been established. At endorectal MR imaging, criteria for extracapsular extension include asymmetry of the neurovascular bundle, tumor encasement of the neurovascular bundle, a bulging prostatic contour, an irregular or spiculated margin, obliteration of the rectoprostatic angle, capsular retraction, a tumor-capsule interface of greater than 1 cm, and a breach of the capsule with evidence of direct tumor extension (Fig 7) (23).

At multivariate feature analysis, the following MR imaging criteria were most predictive of extracapsular extension: a focal irregular capsular bulge, asymmetry or invasion of the neurovascular bundles, and obliteration of the rectoprostatic angle (24). The features of seminal vesicle invasion at endorectal MR imaging include focal low signal intensity within and along the seminal vesicle (Fig 8), an enlarged low-signal-intensity seminal vesicle, enlarged low-signal-intensity ejaculatory ducts, obliteration of the angle between the prostate and the seminal vesicle, and demonstration of direct tumor extension from the base of the prostate into and around the seminal vesicle (Fig 8) (23).

MR imaging has been reported to have a wide range of sensitivities (13%–95%) and specificities (49%–97%) for detection of extracapsular extension, with a similarly wide range of sensitivities



a. b.

Figure 8. Prostate cancer in a 64-year-old man with a prostatectomy Gleason score of 4 + 3 (tertiary pattern 5) (the presurgical biopsy score from a single fragmented 30% core was 3 + 3) and a PSA level of 3.4 ng/mL. The final histopathologic analysis showed a dominant nodule in the left posterolateral prostate at the base and midgland, with substantial extraprostatic tumor extension and seminal vesicle invasion at the left base. Endorectal MR imaging was performed at 1.5 T. **(a)** Coronal T2-weighted image (5000/93) shows concentric wall thickening of the left seminal vesicle (arrows) and dark tumor extending along the left seminal vesicle, findings compatible with seminal vesicle invasion. **(b)** Sagittal T2-weighted image (2900/92) shows continuity of the dark tumor, which extends from the left base into the left seminal vesicle (arrows).

(23%–80%) and specificities (81%–99%) for detection of seminal vesicle invasion (23,25). Limitations of conventional morphologic MR imaging of the prostate highlight the need for a combined anatomic and functional imaging approach.

Diffusion-weighted Imaging and ADC Mapping

Diffusion-weighted imaging can add valuable information about tissue at the cellular level to the information from conventional T1-weighted and T2-weighted imaging (26). Because diffusion-weighted imaging measures the Brownian motion of water molecules, it provides important information about the functional environment of water in tissue and reflects the cellular status of normal and pathologic tissue.

Furthermore, diffusion-weighted imaging is sensitive to changes in the microdiffusion of water within the intracellular space and extracellular space and cytotoxic edema due to alterations in the adenosine triphosphate–dependent sodium-potassium pumps. Reduced diffusion of water in prostate cancer has been attributed to the increased cellularity of malignant lesions, with reduction of the extracellular space and restriction of the motion of a larger portion of water molecules to the intracellular space. Therefore, diffusion-weighted imaging provides an important quantitative biophysical parameter that can be used to differentiate benign from malignant prostate tissue (27).

Teaching Point

The amount of diffusion in tissue is determined by the diffusion coefficient *D*, which usually varies on subvoxel scales. The MR imaging–measurable spatially averaged biomarker of diffusion-weighted imaging is the ADC. The ADC quantifies the combined effects of both diffusion and capillary perfusion. A decreased ADC is interpreted as reduced motion of water molecules or diffusion, whereas in tissue with an increased ADC there is less restriction of water molecule motion.

The ADC has been related to the state of tissue during the growth of tumors or progression of cancer. With proliferating cells, there is an increase in cellular density and a decrease in the amount of intracellular space or extracellular space available, leading to a reduction in the ADC (Fig 4). Thus, diffusion-weighted imaging and ADC have become powerful indicators for characterization of prostate tissue, particularly in differentiation between benign and malignant lesions (27).

In general, regional ADC map values differ depending on location and tissue composition. Malignant lesions have lower ADC values (about

20%–40%) than benign or normal prostatic tissue. Also, there are regional variations in the normal tissue values for different zones of the prostate. Although in theory the ADC represents tissue properties only, in practice ADC measurements depend on the details of imaging unit hardware and imaging protocols. Therefore, comparison necessitates knowledge of the normal ranges for a specific system.

Some authors have stratified ADC values into benign and malignant and demonstrated that diffusion-weighted imaging and ADC mapping can increase the sensitivity (54%–98%) and specificity (58%–100%) of MR imaging in detection of prostate cancer when diffusion-weighted imaging is used in conjunction with T2-weighted imaging (28). Preliminary results suggest that diffusion-weighted imaging has the potential to increase the specificity of prostate cancer detection and to support prediction of tumor aggressiveness (29).

Acquisition parameters for diffusion-weighted imaging should be optimized according to the imaging unit and magnetic field strength used. The acquisition of different *b* values allows creation of matrix trace ADC maps on a pixel-by-pixel basis for quantitative analysis according to the following equation (30):

$$\mathrm{ADC} = \frac{-1}{n}\sum_{i=1}^{n}\frac{\ln\left(S_i / S_0\right)}{b_i},$$

where b_i = the diffusion gradient values, S_0 = first image ($b = 0$), and S_i = i'th image.

$$b = \gamma^2 G^2 \delta^2 (\Delta - \delta/3),$$

where γ = gyromagnetic ratio, G = gradient strength, δ = diffusion gradient duration, and Δ = time between diffusion gradient pulses.

The *b* value specifies the sensitivity of diffusion. Correctly assigning the *b* value for diffusion-weighted imaging is critical because it directly affects the ability to detect water molecule diffusion. As the *b* value increases, the amount of diffusion weighting increases and the sensitivity to diffusion increases. At high *b* value, diffusion-weighted imaging represents the molecular diffusion of water almost exclusively. However, as the *b* value increases, the gradient radiofrequency pulse is prolonged, thus increasing the echo time and reducing the quality of the diffusion-weighted images and the signal-to-noise ratio (SNR).

The smaller the *b* value, the higher the quality and SNR of the diffusion-weighted images; however, at the same time the T2 shine-through effect and tissue perfusion effects increase their influence on diffusion-weighted imaging. With lower *b* values, the ADC value also reflects the perfusion of the microcirculation, while the ability to reflect water molecule diffusion is worse than at higher *b* values (31). Traditionally, a set of images with a *b* value of 0 and another set with a *b* value of up to 1000 sec/mm² are acquired. The diffusion sensitivity can be varied to control the image contrast.

The approach to clinical interpretation of diffusion-weighted images in the diagnosis of prostate cancer must take into account several limitations of the technique, as outlined in the remainder of this section. In general, these limitations result in better performance in peripheral zone prostate cancer than in transition zone prostate cancer.

It has been reported that postbiopsy hemorrhage lowers the ADC of benign peripheral zone tissue and therefore limits the usefulness of diffusion-weighted imaging in this setting (31). However, more recent data demonstrated excellent ability of the ADC in differentiation of prostate cancer from hemorrhage in the peripheral zone, and it was suggested that delayed imaging after biopsy may not be necessary (32).

The location of prostate cancer affects the sensitivity of diffusion-weighted imaging. Noncancerous peripheral zone tissue has been found to have higher average ADC (less overlap with cancerous tissue) than the transition zone and prostate base. Overlap limits the ability to differentiate prostate cancer from noncancerous tissue (33). The high prevalence of BPH in elderly men significantly contributes to this difficulty. The stromal form of BPH in particular exhibits lower ADC and low T2 signal intensity, mimicking prostate cancer, whereas glandular BPH and prostatic intraepithelial neoplasia can be more readily distinguished because of their higher average ADC and higher T2 signal intensity (34).

Higher Gleason score has repeatedly been shown to be associated with decreased ADC, likely due to the dedifferentiated infiltrative growth of these tumors, as opposed to the glandular organization of more well-differentiated prostate cancer, which more closely resembles normal prostatic tissue (31,32).

Studies have found that ADC values in the central gland increase with age, in association

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with the development of BPH (31). Therefore, diagnosis of prostate cancer with ADC measurements, especially in the central gland, may be less sensitive in younger patients.

Recently, high *b*-value diffusion-weighted imaging has been reported to increase diagnostic performance, sensitivity, and specificity in detection of prostate cancer (35), although other reports did not find significant increases in these parameters (36). The signal of diffusion-weighted imaging is dominated by the fast component of diffusion at standard *b* values; however, at least biexponential modeling is suggested for high *b*-value situations to take into account the slow diffusion component. Otherwise, deviation from the expected decrease in ADC with higher *b* values may result (36). High *b*-value imaging is hampered by further loss of the available signal owing to increased spin dephasing resulting from proton diffusion. To avoid prohibitive SNR loss, 3-T and endorectal coil techniques are favorable to compensate for these effects.

The advantages of diffusion-weighted imaging are short acquisition time and high contrast resolution between tumors and normal tissues. The shortcomings of diffusion-weighted imaging include susceptibility-induced distortions. These distortions are caused by susceptibility effects from the air-filled rectum or endorectal coil balloon, bone-tissue interfaces, poor local magnetic field homogeneity, and chemical shift artifacts caused by periprostatic fat. The susceptibility effects can be minimized by using rigid endorectal coils with no balloon or by filling the balloon with liquid perfluorocarbon or barium suspension.

MR Spectroscopy

MR spectroscopy is also known as chemical shift imaging. The chemical shift is the physical phenomenon in which the electron cloud surrounding the imaged nucleus (in prostate MR spectroscopy, hydrogen nuclei = protons) shields the nucleus partially from the external field. Therefore, the nucleus exhibits a slightly different Larmor frequency. With ω_0 being the Larmor frequency, γ being the gyromagnetic ratio, and B_0 being the static magnetic field, the Larmor equation can be rewritten as follows:

$$\omega_0 = -\gamma B_0(1-\sigma),$$

where σ, the chemical shift, quantifies this electronic shielding and is highly dependent on the chemical environment (chemical bond, adjacent molecules or atoms) and the molecule the proton is located in.

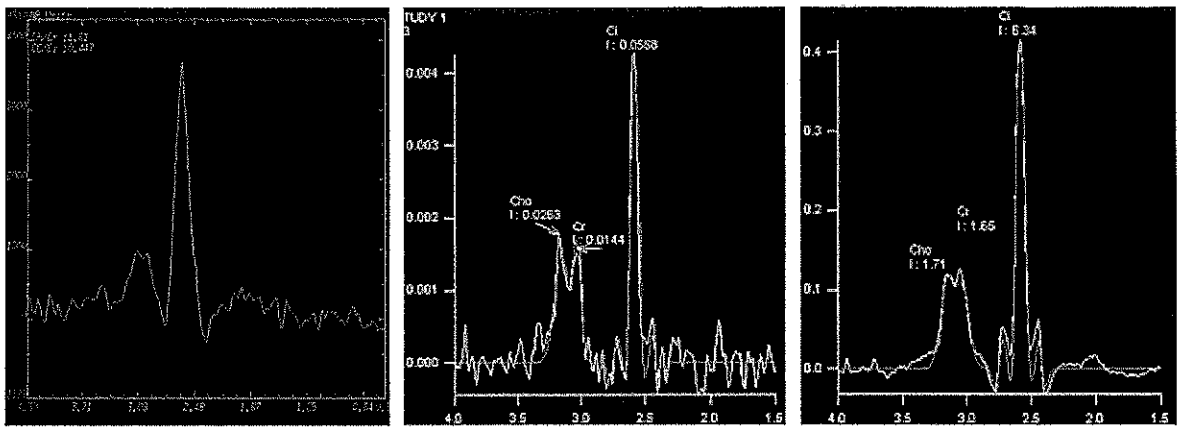
Highly specific fingerprints of chemical compounds are the result in the form of MR spectra, which are made even more distinct by additional phenomena such as J coupling or chemical exchange (which are beyond the scope of this article). Some chemical compounds have simple spectra (a singlet or single spectral peak) while others possess highly coupled spectra with multiple spectral main peaks, each of which may be composed of multiplets (doublet, triplet, etc).

Little of this intricate physicochemical interplay can in fact be discerned with in vivo human MR spectra. This is because the effects of low SNR (due to use of lower field strength than achievable in tissue extracts and cell cultures), motion (arterial pulsations and bowel, bladder, or patient motion), imaging at the relatively high body temperature, and the need for localization of the MR spectroscopic signal to the prostate lead to spectral line broadening, which blurs many peaks into each other so that only compound peaks can be measured.

As can be seen from the preceding formula, the chemical shift σ is a constant fraction of the reference Larmor frequency. Chemical shift is usually expressed in parts per million, a unit that means millionth parts of the reference Larmor frequency (commonly that of water). For example, at 1.5 T water protons precess at a Larmor frequency of approximately 64 MHz. Choline, with a chemical shift of 3.2 ppm, is therefore shifted by 3.2 ppm × 64 MHz = 205 Hz from the null point.

The null point is defined in MR spectroscopy as the MR resonance of tetramethylsilane in heavy water. It is known that by this standard, water resonates at 4.7 ppm; therefore, in vivo experiments are commonly calibrated to the water peak, with the scale set to 4.7 at the water resonance. Because MR spectroscopy provides important information about the biochemical and metabolic environment of the tissue, it is increasingly being used as a biomarker for detection of cancers, including prostate cancer (37).

Normal in vivo prostate spectra at different field strengths are shown in Figure 9. Citrate is found in fairly high concentrations (>60 mM) in healthy prostate epithelium and prostatic fluid; it is found in low concentrations elsewhere in tissue (38). The normal prostate has an MR spectrum with a prominent citrate peak at 2.6 ppm, which is usually seen as a doublet with occasional



a. b. c.

Figure 9. Comparison of MR spectroscopic spectra obtained in the peripheral zone of the normal prostate in different patients. **(a)** MR spectroscopic spectrum, obtained at 1.5 T with an endorectal coil, shows a high citrate *(Ci)* peak (resonance at 2.6 ppm) and a low choline *(Ch)* peak (resonance at 3.2 ppm), characteristics of benign tissue. The choline and creatine *(Cr)* peaks are overlapping. Ch + Cr/Ci = 0.447. **(b)** MR spectroscopic spectrum, obtained at 3 T with a body matrix coil, shows good separation of the choline *(Cho)* and creatine *(Cr)* peaks at higher magnetic field strength. The spectrum is normal, with a high concentration of citrate *(Ci)* and low concentration of choline. A diagnostic high-quality spectrum could be obtained with a noninvasive MR procedure without use of an endorectal coil. **(c)** MR spectroscopic spectrum, obtained at 3 T with an endorectal coil, shows a normal spectrum with a high citrate *(Ci)* peak and low choline *(Cho)* peak. Note the excellent spectral resolution of the citrate, choline, and creatine *(Cr)* metabolites, with only minimal baseline noise and detailed morphology of the citrate peak, which shows the effect of increased spectral resolution at 3 T, leading to a dominant central peak at 2.6 ppm with symmetric side peaks.

visualization of small additional side peaks. A decreased citrate level is found in prostate cancer, as well as in prostatitis and hemorrhage.

Choline is represented by its distinct methyl proton resonance, which forms a composite peak of phospholipid cell membrane components (eg, phosphocholine, glycerophosphocholine, and free choline) at 3.2 ppm. Owing to increased cell membrane turnover (phospholipid synthesis and degradation) and increased cell surface compared with cell volume in cellular tumors, choline concentrations are increased in prostate cancer. Increased choline signal or concentration is considered the spectroscopic hallmark of cancer (39); however, it has also been found in benign conditions of the prostate such as prostatitis (40).

Creatine resonates at 3.0 ppm and is related to energy metabolism. Normal prostatic tissue contains high polyamine levels, of which spermine is a predominant component. Polyamines are represented by a relatively broad spectral beak between creatine and choline (3.1 ppm) that shows significant overlap with creatine and choline. Polyamine levels are reduced in prostate cancer.

Lipids cause signal in a broad range at the lower end of the citrate peak (typically 1.3 ppm). Adequate placement of saturation bands around the prostate is important to avoid contamination of the spectra by inclusion of extraprostatic fat, which causes large lipid signals.

MR spectroscopy of the prostate requires use of multivoxel volume selection techniques. The most commonly used MR spectroscopic method is the point-resolved spectroscopy sequence (PRESS) (41). When applied to prostate imaging, PRESS provides increased SNR in comparison with that of alternative localization techniques, such as the stimulated-echo acquisition method (STEAM). After localization, single-voxel spectra can be obtained. However, more commonly, the PRESS volume is further subsectioned by using two- or three-dimensional phase-encoding gradients to perform MR spectroscopic imaging. In this fashion, a grid of multiple spectroscopic voxels can be collected at the same time, allowing coverage of the entire prostate.

In summary, the classic spectral signature of prostate cancer consists of increased choline and decreased citrate (Figs 5, 6). Because the spectra do not provide absolute metabolite concentrations in a straightforward fashion and calibration is complex, common approaches to MR spectroscopy take advantage of metabolite ratios, which allow comparison of changes in the relative quantities of metabolites present. Because citrate and choline vary in opposite directions in prostate

Teaching Point

RadioGraphics

cancer, formulation of a ratio between them accentuates the change. An increase in the choline-to-citrate ratio or the (choline + creatine)/citrate ratio is often used as a marker of malignancy in prostate cancer and increases the specificity of diagnosis; however, it is most reliable in the peripheral zone.

Definition of spectra suspicious for prostate cancer can be performed in various ways, all of which set the measured spectral metabolites in relation to normal values. For example, a commonly used five-point MR spectroscopic scale scheme has been established (42). This scale is based on the known mean normal (choline + creatine)/citrate ratio, which is commonly given as 0.22 ± 0.013 (mean ± standard deviation [SD]) at 1.5 T (42). A score of 1 is assigned to ratios less than 1 SD above the mean. Subsequent scores are based on similar constructs (a score of 2 is <2 SDs above the mean, a score of 3 is <3 SDs above the mean, a score of 4 is <4 SDs above the mean, and a score of 5 is ≥4 SDs above the mean). Scores of 3 or more are commonly interpreted as suspicious, with individual scores interpreted as equivocal for cancer (score of 3), probably malignant (score of 4), and likely malignant (score of 5) (Fig 6).

Although MR spectroscopy shows promise as a problem-solving modality with high specificity, it is limited by low sensitivity. Partial volume effects may obscure the presence of prostate cancer, especially small or infiltrative lesions, which are obscured by strong signals from glandular BPH or surrounding normal tissue present in the MR spectroscopic voxels. By shifting the MR spectroscopic voxels to a position centered on the area of suspected abnormality, a voxel containing the highest possible partition of abnormal tissue can be generated; with this method, some of the lost information can occasionally be recovered. The extracellular lakes of mucin in the rare (0.4% of all prostate adenocarcinomas) and aggressive mucinous subtype of prostate cancer often make this cancer undetectable at both T2-weighted imaging and MR spectroscopy (43).

Despite the relatively high specificity of MR spectroscopy, false-positive MR spectroscopic interpretations can result from inclusion of signal from the seminal vesicles, stromal BPH, prostatitis, and focal prostatic atrophy (44). Although the (choline + creatine)/citrate ratio can be low or normal in BPH (Fig 3), this is the case predominantly in glandular BPH, which has high levels of citrate and polyamines as a result of the histologic composition of hyperplastic glandular tissue. In stromal BPH, however, citrate and polyamine levels can be strongly suppressed and there may be elevation of choline due to the presence of proliferative elements, leading to significant overlap with the findings of prostate cancer. In addition, prostatitis has previously been found to be able to mimic prostate cancer (45). This leads to possible significant difficulty in distinguishing prostate cancer from prostatitis and stromal BPH, especially in the transition zone.

When combined with anatomic imaging, MR spectroscopy has been found to increase the accuracy of tumor volume estimation in prostate cancer (46), although other data have shown lack of an additional advantage. More recent data have shown significantly increased choline-to-citrate ratios and larger tumor volumes in stage T2b or higher tumors than in stage T2a or lower tumors, further suggesting a potential of MR spectroscopy for tumor volume estimation and staging (47). However, currently data are too sparse to determine if MR spectroscopy can surpass other modalities for this purpose.

Multiple MR spectroscopy software packages are commercially available, allowing performance of routine clinical prostate MR imaging. Several challenges remain in the clinical application of MR spectroscopy. Complex postprocessing of the prostatic spectra requires significant operator skill to achieve reproducible data. To achieve high-quality data, adequate saturation band placement is needed to suppress signals from periprostatic tissues. Optimal shimming must be performed to achieve optimal magnetic field homogeneity over the MR spectroscopic volume, a process that can be time-consuming.

Susceptibility effects from endorectal balloon air, air in the rectum, or motion artifacts may decrease spectral quality and limit the ability to acquire high-quality data. The lower resolution of MR spectroscopy demands minimization of diagnostically decisive partial volume effects. A significant number of spectral voxels acquired may contain nondiagnostic levels of metabolites owing to poor SNR related to suboptimal shimming and motion artifacts. Postbiopsy hemorrhage is known to degrade MR spectra (48). However, it was shown that MR spectroscopy may improve diagnostic accuracy for cancer in the presence of postbiopsy hemorrhage, when findings on T2-weighted images are nondiagnostic (49).

Dynamic Contrast-enhanced MR Imaging

DCE MR imaging is an advanced prostate imaging modality that allows derivation of parameters that are closely related to microvascular properties and angiogenesis in tissues. Tumor hypoxia and the expression of angiogenesis-inducing factors, such as vascular endothelial growth factor, induce budding of new blood vessels from existing blood vessels (angiogenesis) or de novo formation of blood vessels (vasculogenesis). Tumor neovessels are in general more permeable than normal vessels, more heterogeneous in size and branching pattern, and disorganized.

Teaching Point

In prostate cancer, increased tumor vascularity leads to early hyperenhancement (higher and earlier peak enhancement than in normal tissue) and to rapid washout of contrast material from the tumor, in comparison with normal prostate tissue (Fig 4). Microvascular alterations and neovascularity are in general most severe in prostate cancer, in comparison with other processes in the prostate such as BPH or prostatic intraepithelial neoplasia (50). DCE MR imaging uses a pharmacokinetic tracer kinetic compartmental model (TKCM) to describe the microscopic processes leading to the distribution of molecules of contrast agent (most commonly a gadolinium chelate, which is referred to as *the tracer*) between the vascular and extravascular spaces over time.

The TKCM is mathematically complex, and the reader is referred to the literature for more detail (25,51). Different TKCMs can be employed, which vary in their complexity. The more compartments are included to model the intravoxel signal behavior, the more data are needed to achieve reasonable convergence of the model parameters.

Classically, a four-compartment Tofts model (52) is used, which models the intravoxel signal by using a intravascular blood plasma compartment and an extracellular-extravascular space (EES) compartment. It also includes the whole-body vascular and extracellular space and a kidney excretory pathway to model the behavior of contrast agent dilution, recirculation, and excretion. In kinetic modeling, the transfer constant K^{trans}, which describes microvascular permeability and blood flow, and the EES volume fraction or leakage space v_e in the tissue represent the two main differentiating parameters of cancer. These parameters are derived as follows:

The known variables in the TKCM are the time variation of the tracer concentration in the artery supplying the tissue of interest (the input artery) and the tissue tracer concentration (Fig 10). In fact, only the signal intensity change between the unenhanced and enhanced phases is known, and assumptions are made to convert this signal intensity change into absolute concentrations. Input artery and tissue tracer concentrations are zero at the beginning of the examination. After intravenous injection of the tracer, the tracer concentration first rises in the input artery and subsequently the tissue is observed to enhance, meaning that the signal intensity in the tissue voxels is caused to change by the presence of the tracer.

Ideally, one measures the input artery concentration as close to the tissue of interest as possible. In practice, this is limited by the identification of a large enough artery from which to derive a reliable ROI for assessment of tracer concentration. Commonly, the external iliac artery is chosen. The concentration-time course observed in the input artery is called the arterial input function. Although the input arterial lumen is large in comparison with the voxel size, the processes underlying the observed tissue enhancement are below the resolution of MR imaging.

In a small MR imaging voxel, tissue arterioles, venules, capillaries, and neovessels follow the blood pool tracer concentration, in that their contrast agent concentration is similar to the arterial input function, although it is delayed by the time it takes the bolus to travel from the input artery ROI to the tissue voxel and altered by hematocrit changes in the microvasculature. The tracer does not stay intravascular only, because the vascular endothelium and the microvascular boundaries allow the tracer to diffuse into the EES according to the concentration gradient between the intravascular space and the EES. Once the vascular contrast agent bolus has passed the capillaries, the tissue concentration will be higher in the EES, and back-diffusion of the tracer into the intravascular space will occur, leading to washout of contrast agent from the tissue.

Therefore, tissue enhancement provides information about the microvascular properties, the extravascular space, and the exchange rate between these compartments. Enhancement will be strong and fast if many tumor vessels exist, occupying a relatively large fraction of the voxel. Enhancement will also be strong and reasonably fast if the surface area of the microvessels is large and their walls are highly permeable, allowing fast exchange between the intravascular space and EES. In both cases, washout from the tissue will be fast for the same reasons.

TKCM is a concept well known from the fields of pharmacology and nuclear medicine, where many of the mathematical foundations were first derived. The unknown parameters in the TKCM

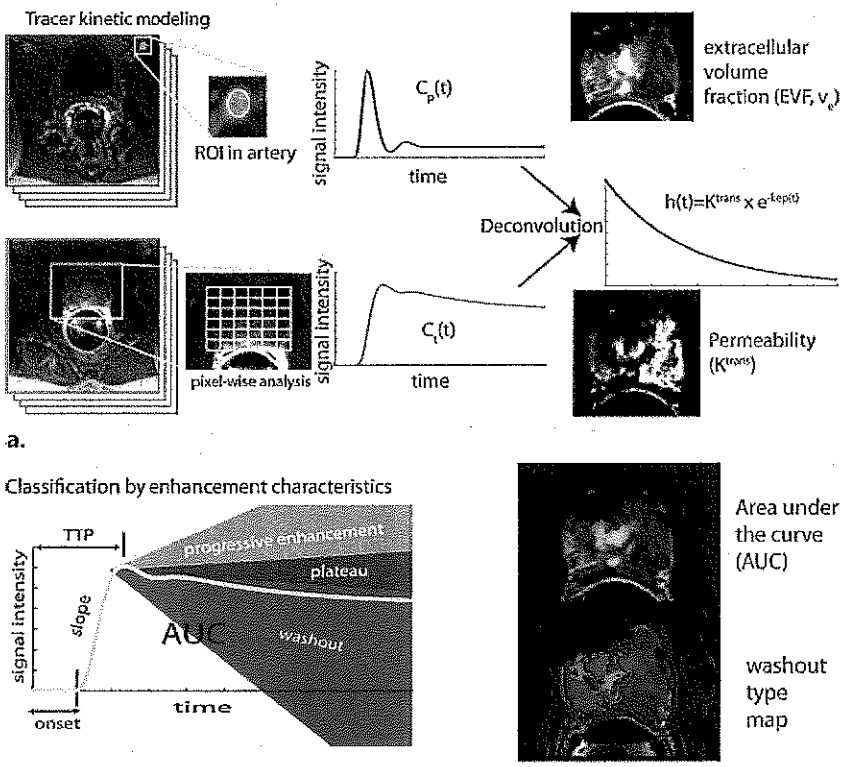


Figure 10. Synopsis of DCE MR imaging. **(a)** Use of the TKCM. Repeated imaging before and after administration of contrast material is performed. ROI analysis of the input artery (top) and voxel-wise analysis of the prostate (bottom) yield the arterial input function and voxel-wise time-concentration curves. Mathematical deconvolution is used to recover the tissue response *h(t)*, from which the TKCM parameters can be estimated. Parametric maps are generated by color-coding ranges of TKCM parameters according to nomograms. *kep* = efflux rate constant, K^{trans} = influx transfer constant, v_e = leakage space. **(b)** Heuristic parameters are illustrated for a tissue time–signal intensity curve. These include onset time, slope, time to peak *(TTP)*, washout characteristics (progressive enhancement, plateau, and washout), and area under the curve *(AUC)*. Parametric maps are pseudocolored to facilitate recognition of suspicious parameter values.

are commonly called the leakage space (v_e), efflux rate constant (k_{ep}), and influx transfer constant (K^{trans}). These parameters are connected by the following equation: $v_e = K^{trans}/k_{ep}$. The leakage space is the EES volume fraction, which is the percentage of volume in the MR imaging voxel that is occupied by the EES. K^{trans} determines the flux from the intravascular space into the EES; it may represent the blood flow into the tissue in a flow-limited situation (high permeability relative to flow), or it may predominantly represent the vascular permeability in a permeability-limited situation (high flow relative to permeability) (51).

It is important to be aware that K^{trans} does not directly represent permeability or blood flow alone. However, in many tumors, flow and permeability are higher than in normal tissue and therefore K^{trans} will be elevated, due to a mixed effect of increased flow and permeability. It is an advantage that the parameters influencing K^{trans}—permeability, microvascular surface area, microvascular fractional volume, and microvascular blood flow—are commonly altered in concert in such a way that K^{trans} is synergistically elevated in tumor neoangioneogenesis. This may explain why K^{trans} has been identified as one of the most useful parameters in DCE MR imaging to date.

The EES fractional volume (v_e) commonly decreases in tumors when the neovessels occupy a higher fraction of the voxel volume than in normal tissue. However, a v_e decrease has been found to be less specific for prostate cancer than is K^{trans}. v_e can be similar in BPH, the normal transition zone, and prostate cancer (53,54).

The TKCM has an enormous and currently largely unused potential in its application to DCE MR imaging. In fact, the most established parameters in DCE MR imaging are not based on the TKCM but are heuristic parameters, which are descriptive and empirically derived and do not directly represent an underlying pathophysiologic correlate, as opposed to the TKCM parameters, which reflect microvascular properties. Heuristic parameters are also known as time–signal intensity parameters, as they describe the important features of the tissue enhancement curve. These include the onset time, mean gradient, time to peak enhancement, magnitude of peak enhancement, and washout characteristics (Fig 10).

The onset time is defined as the time delay between the onset of bolus injection of the tracer and the time point of signal intensity increase above 10% of the peak enhancement. The mean gradient is the average rate of change of the relative signal intensity between the points of 10% and 90% peak enhancement. Maximum signal intensity or peak enhancement is defined as the highest signal intensity during the dynamic acquisition period. Washout characteristics are usually grouped into the three observations of washout, plateau enhancement, and progressive enhancement. They are dependent on whether there is significant signal intensity decrease after peak enhancement, no significant change, or no maximum reached during the first minutes, respectively.

To some degree, heuristic parameters can be related to TKCM parameters. The rate of enhancement is thought to be reflective of the vascular volume and the permeability of the vessels, while the magnitude of enhancement likely reflects the extravascular-extracellular leakage space (55).

In prostate cancer, there is early, rapid, and intense enhancement with quick washout of contrast material (Fig 4). The presence of washout is highly indicative of prostate cancer (56), even in the absence of low T2 signal intensity (Fig 5). In prostate cancer, onset time and time to peak enhancement are lower and peak enhancement is higher than in high-grade prostatic intraepithelial neoplasia and chronic inflammation, and abnormalities are more distinct in high-grade prostate cancer (57). All DCE MR imaging parameters can be converted into pseudocolor parametric maps and overlaid on the anatomic T1- and T2-weighted images for interpretation (Figs 3–6).

Criteria for extracapsular extension or seminal vesicle invasion at DCE MR imaging include abnormally high or asymmetric peak enhancement, contrast agent washout, and short onset time and time to peak enhancement. In the case of extracapsular extension, these findings are detected near the neurovascular bundle or rectoprostatic angle, broadly abutting the capsule, or in an extracapsular location. In seminal vesicle invasion, these abnormalities are found in the lumen of the ejaculatory ducts or in the seminal vesicles themselves and are associated with wall thickening of the ejaculatory ducts.

DCE MR imaging can improve the staging accuracy of less-experienced readers for detection of capsular penetration and seminal vesicle invasion and can allow detection of cancers that are not apparent on T2-weighted images. In addition, in multifocal cancers, DCE MR imaging may demonstrate additional foci of higher stage than the known lesions, leading to adequate upstaging of tumors (58).

DCE MR imaging forms part of the current advanced multiparametric MR imaging approach for evaluation of prostate cancer. DCE MR imaging in combination with MR spectroscopy allows detection of prostate cancer in 46% of patients with prior negative transrectal US–guided biopsy results and a persistently elevated PSA level (4–10 ng/mL), versus a prostate cancer detection rate of 24% with repeat transrectal US–guided biopsy in these patients (59). A parametric model using the diffusion-weighted imaging parameter ADC, results of quantitative T2-weighted imaging, and K^{trans} was found to have the best performance in a logistic regression analysis (53).

Although much progress has been made, challenges for DCE MR imaging remain. Current DCE MR imaging techniques may not allow differentiation of prostatitis from cancer in the peripheral zone or distinction between BPH and transition zone tumors, but differences in the initial enhancement amplitude and washout patterns have been reported (50). Figure 6 depicts a case of transition zone prostate cancer, whereas Figure 3 shows findings in BPH; the comparison illustrates use of histogram analysis of K^{trans} for the differentiation.

Prostatic intraepithelial neoplasia and well-differentiated prostate cancer demonstrate less neovascularity and permeability changes than does higher-grade prostate cancer and therefore represent a source of false-negative results at DCE MR imaging. Differentiation of chronic prostatitis from low-grade prostate cancer may not be possible, while differences were found in DCE MR imaging parameters between high-grade prostate cancer and chronic prostatitis (60). In addition, low tumor volumes and infiltrative prostate cancer are affected by partial volume effects and are more difficult to detect.

Although heuristic parameters are generally quite useful clinically and generally show good agreement with TKCM parameters, they are limited by their qualitative or semiquantitative nature. The advantage of TKCM parameters is their direct relationship to pathophysiologic properties of the examined tissue. In practice, this advantage is limited by dependence on accurate estimation of the arterial input function and sequence parameters; however, use of TKCM parameters is superior in the settings of interindividual quantitative comparisons and posttherapy follow-up. BPH may demonstrate washout characteristics suggestive of malignancy, and histogram analysis of TKCM parameters may be helpful in differentiation from prostate cancer (Figs 3, 6).

Prostate MR Imaging at 3 T versus 1.5 T

Prostate MR imaging at 1.5 T has been well established, and use of an endorectal coil with a 1.5-T MR imaging system is considered indispensable for diagnostic quality imaging. With the growing availability of 3-T whole-body MR imaging units, new opportunities arise for clinical and research applications in prostate imaging.

The fundamental impetus for the migration to higher static magnetic field strengths lies in an increased SNR (which increases linearly with the static magnetic field B_0) and increased spectral resolution. The SNR gain at 3 T can be used in multiple ways. In comparison with 1.5-T imaging, improvements in spatial or temporal resolution and in patient comfort—when no endorectal coil is used—are possible. At 3 T, the spatial resolution can reach 0.18 mm with use of an endorectal coil, while it is near 0.55 mm at 1.5 T. Imaging voxel sizes can be reduced to 0.13 mm^2 at 3 T, while the smallest voxel sizes are about 1.21 mm^2 at 1.5 T (61). Both conventional T1- and T2-weighted imaging techniques and the new multiparametric MR imaging protocols benefit significantly from imaging at higher field strength, when the potential sources of increased image distortion or signal loss and the specific challenges of higher-field-strength imaging are considered.

In comparison with 1.5-T imaging, the power deposition by radiofrequency pulses increases fourfold, if the same imaging sequences are used. Prostate imaging benefits from lower specific absorption rate sequences, many of which have been developed initially for 3-T applications in other body regions. Power deposition can be reduced by using a lower number of phase-encoding steps with parallel imaging techniques, increased repetition time or decreased flip angle, or modified radiofrequency pulses, which may be of longer duration. Shorter T2 and longer T1 relaxation times at 3 T, increased susceptibility and dielectric effects, and signal heterogeneity from larger magnetic field variations can be addressed by using thinner sections, higher spatial resolution, or higher bandwidth. Radiofrequency penetration effects can compromise radiofrequency field homogeneity. Most of these compensatory techniques imply an inherent SNR reduction, which has to be controlled and optimized in 3-T–specific imaging protocols.

Imaging without endorectal coils is feasible at 3 T and helps decrease patients' reluctance to undergo an uncomfortable and invasive examination, while allowing simpler patient preparation for the study. Although essential at 1.5 T, use of endorectal coils is itself accompanied by technical challenges, which reach beyond the patient comfort factors. The inhomogeneous endorectal coil receive field has its highest sensitivity directly adjacent to the coil surface and spans a relatively small area, mandating optimal anatomic positioning to take most advantage of the addition of the coil. At 3 T, image quality comparable with that at 1.5 T can be achieved without use of endorectal coils (62). However, if endorectal coils are used, significant improvements in localization and staging of prostate cancer have been reported in comparison with use of phased-array surface coils only (63).

Endorectal coils are prone to introducing strong susceptibility gradients, especially if air is used to inflate the coil balloon. Although common practice at 1.5 T, use of air inflation at 3 T often causes prohibitive artifacts; therefore, balloon distention is often achieved by using substances that are more similar to the tissue susceptibility (eg, liquid perfluorocarbon or barium) (64). Rigid coils that avoid the need for inflatable balloons have been developed for use at 1.5 T and were found to provide approximately 2.5-fold higher SNR near the peripheral zone midline than did inflatable coils, while being devoid of the strong susceptibility gradients asociated with endorectal inflatable balloon coils.

The novel functional and physiologic MR imaging techniques (MR spectroscopy, diffusion-weighted imaging, and DCE imaging) specifically benefit from the migration to 3 T for prostate imaging, as discussed in the remainder of this section.

MR spectroscopy inherently benefits from higher field strengths as a result of the inability to increase the spectral resolution with other methods. Spectral line broadening is introduced by physiologic and thermal effects, and only

transition to higher field strengths will reduce the line width in relation to the constant chemical shift of the coupled and uncoupled metabolite protons of interest, thus making them better discernible (Fig 9). At 1.5 T, the spectral quality may prohibit routine separation of closely adjacent peaks such as the choline, polyamine, and creatine peaks, which are therefore often combined into a single parameter (eg, the [choline + creatine]/citrate ratio) for analysis.

In addition, the SNR gain benefits MR spectroscopy, which is a low-SNR technique, in that faster data acquisition and imaging at smaller voxel sizes (at higher resolution) become feasible. Voxel sizes for 3-T MR spectroscopy of 0.15 cm^3 can be achieved with use of an endorectal coil, while the voxel size for 1.5-T MR spectroscopy has been found to be limited near 0.30 cm^3 (65). Smaller voxel sizes are desirable to reduce volume averaging of tumors with periprostatic fat, the seminal vesicles, postbiopsy hemorrhage, or periurethral tissues. Both better spatial resolution and better spectral resolution improve the ability to detect and characterize tumors with MR spectroscopy.

Diffusion-weighted imaging is another low-SNR technique that benefits from higher field strengths, allowing higher-quality imaging and higher spatial resolution (66). Technical challenges at higher field strength include increased susceptibility artifacts and greater chemical shifts. However, use of parallel imaging (67) can reduce some of these artifacts by reducing the number of phase-encoding steps for a full acquisition, thus allowing adjustment of other parameters (echo spacing and echo train length), and by use of multiple shots during an echo-planar imaging readout. Diffusion-weighted imaging benefits from the concurrent use of endorectal coils with 3-T magnets, as the signal gain can be fully deployed for higher resolution or better image quality.

ADC measurements depend on both field strength and sequence parameters, so that results from 1.5-T and 3-T imaging systems may be different despite examination of the same underlying physiologic processes. Separation of tumor from healthy parenchyma is improved with 3-T diffusion-weighted imaging in comparison with 1.5-T diffusion-weighted imaging, and the ADC has been found to be significantly lower in prostate cancer than in normal tissue (68). Because the sensitivity of diffusion-weighted imaging to susceptibility artifacts and distortions is increased at 3 T, significant motion artifacts need to be avoided by limiting gross motion of the patient and suppressing rectal peristalsis (eg, by intravenous administration of glucagon before the examination).

Because DCE MR imaging is a demanding technique that requires high temporal resolution, high spatial resolution, and adequate volume coverage of the prostate at the same time, it is limited by the performance of imaging equipment at 1.5 T. In DCE MR imaging at 1.5 T, the temporal resolution is often a limiting factor to preserve spatial resolution. Increased spatial resolution reduces volume averaging and allows detection of smaller tumor foci and more precise tumor volume assessment. However, adequate temporal sampling is necessary for estimation of pharmacokinetic parameters with higher fidelity to reduce overlap between malignant and benign tissue.

Both spatial and temporal resolution must be sufficiently high at the same time to permit a useful DCE MR imaging protocol, and DCE MR imaging will best achieve its potential at higher field strengths such as 3 T. In an experimental animal model, it has been shown that decreased temporal resolution (15–85 seconds) leads to underestimation of the transfer constant K^{trans} (4%–25%) and to overestimation of the fractional EES volume v_e (1%–10%) (69). This underlines the importance of high-temporal-resolution imaging (preferably <10 seconds per phase). The temporal resolution increase relies on fast pulse sequences and benefits from the increased SNR at higher field strengths.

In summary, detection, localization, and staging of prostate cancer benefit from the higher achievable spatial resolution and increased SNR at 3 T, as tissue interfaces are better visualized and lower-contrast structures are better identified. Combination of functional techniques with anatomic imaging has been reevaluated at 3 T. Although DCE MR imaging and MR spectroscopy alone had lower sensitivity than T2-weighted imaging, combination of both had higher specificity (97%–99% for MR spectroscopy, 96%–97% for DCE MR imaging) than did T2-weighted imaging (83%–89%), and their addition increased the overall accuracy and predictive value of conventional T2-weighted imaging for accurate localization of prostate cancer (70).

In the experience of the authors, the concurrent use of endorectal coils allows one to take full advantage of the increased SNR for more detailed imaging of the prostate, and this approach is best able to answer new research and clinical questions. On the other hand, the ability to perform high-quality imaging without the use of endorectal coils is a significant factor that makes prostate MR imaging attractive to patients who would otherwise hesitate to undergo the examination, and this technique should be offered to such patients.

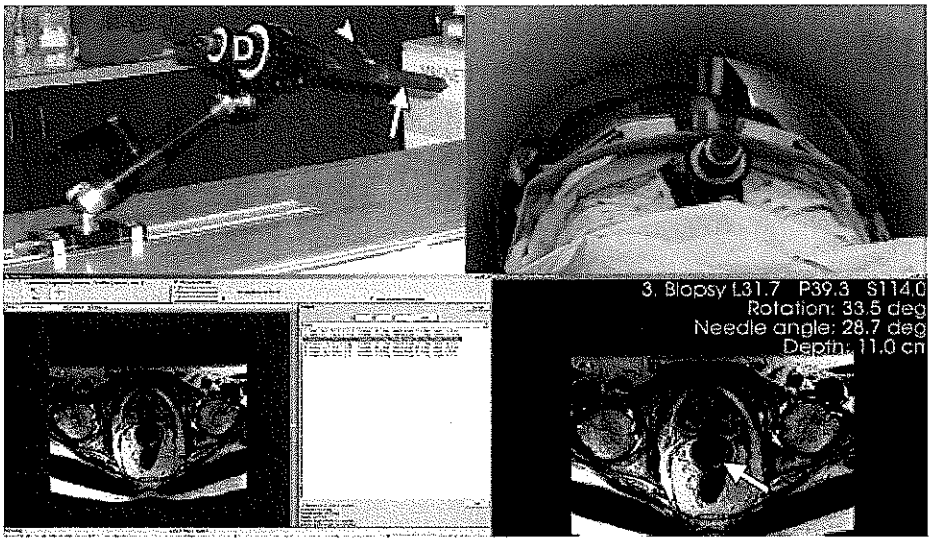


Figure 11. MR imaging–guided prostate biopsy. Photographs (top) and computer screens (bottom) show use of an MR imaging–compatible biopsy device (72). The device (top left) has an endorectal probe (arrow), a needle guide (arrowhead), and a set of dials *(D)*, which allow the needle to be directed to the target on the basis of input from the targeting software (bottom left). The software provides the necessary angles for probe rotation, needle angulation, and needle depth (bottom right). The dials are adjusted manually by the operator on the basis of software calculations derived from prebiopsy targeting MR images. The patient is placed in the prone position (top right) with endorectal placement of the biopsy probe (arrow at bottom right).

MR Imaging–guided Biopsy

The limitations of transrectal US with biopsy were outlined earlier. New instruments for image-guided interventions are needed to increase the accuracy and repeatability with which needles are placed in the prostate. Because MR imaging provides more detailed anatomic images of the prostate than does transrectal US and because it has been shown to be the most accurate imaging modality for localization of prostate cancer, MR imaging–based guidance offers the possibility of more precise targeting, which may be crucial to the success of modern diagnostic and local therapeutic interventions in the prostate.

Real-time virtual sonography is a technique in which the MR imaging dataset is coregistered to landmarks during the US examination, so that a needle can be placed sonographically. However, experience with this technique is currently limited (71). The advantage of MR imaging–guided needle placement appears to be the temporal proximity of imaging and needle placement with the option of real-time visualization of the target, while the patient remains in the same position (Fig 11), thus reducing the effects of differing position and distention of pelvic structures (bladder, rectum, areas of peristalsis) on the location and shape of the prostate.

The usefulness of MR imaging–guided biopsy has been recognized. Transrectal MR imaging–guided prostate biopsies and brachytherapy have been performed in a closed-bore 1.5-T imaging unit (72). Preliminary evidence suggests that MR imaging–guided biopsy may improve cancer detection (73).

Providing guidance with MR imaging poses several challenges. Access within the MR imaging unit is limited for manual instrument handling, and development of new instrumentation for use in the MR imaging environment is demanding. MR imaging–compatible robots are being purposely designed to operate in the space and environmental restrictions inside the MR imaging unit, allowing real-time interventions. Material restrictions (nonferromagnetic components) apply, and actuators and sensors without electric currents are preferred.

Robotic prostate biopsy promises high accuracy and is a topic of intense research. Prototypes of MR imaging–compatible robots are being developed at several institutions (74). At the authors' institution, a fully automated MR imaging–compatible "stealth" robot has been developed (Fig 12) (75), which is currently designed for

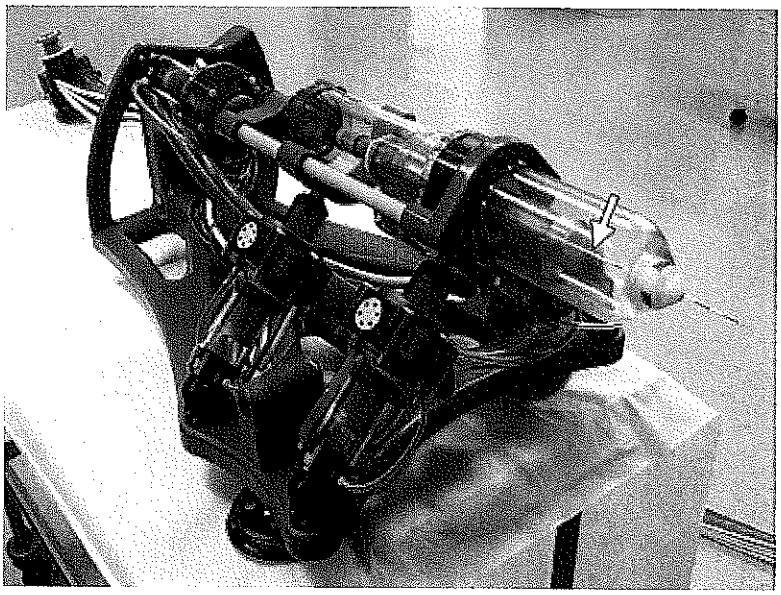


Figure 12. Photograph of an MR imaging–compatible stealth prostate intervention robotic device (currently an investigational device). Note the needle driver (arrow), which is automatically manipulated with a pneumatic motor. The device can operate in the gantry of an MR imaging unit alongside the patient in the decubitus position and can be actuated remotely.

transperineal needle access to the prostate. This robot can perform biopsies and automatically place brachytherapy seeds in the prostate. It possesses six degrees of freedom: five for positioning and orienting the injector and one for setting the depth of needle insertion. High accuracy of registration with targeting errors due to registration as low as 0.3 mm have been achieved. The robot was tested on a canine model and is currently being tested for human use.

As technology matures, precise image guidance for prostate interventions performed or assisted by specialized MR imaging–compatible robotic devices may provide a uniquely accurate solution for directly guiding the intervention on the basis of MR imaging findings and feedback. Such an instrument would become a valuable clinical tool for biopsies, directly targeting imaged tumor foci and delivering tumor-centered focal therapy. Further research is needed to define the indications for MR imaging–guided procedures (eg, persistently elevated PSA level in the setting of a prior transrectal US–guided prostate biopsy with negative results or identification of larger than expected tumor foci in patients undergoing active surveillance who may need curative intervention) and to define the patient populations who could benefit most from these procedures.

Development of an Imaging Algorithm

After reviewing the complexity of multimodality prostate MR imaging, the question arises how to select the appropriate technique for an individual patient. The general trend in the existing literature is that addition of functional imaging to anatomic imaging increases the accuracy of prostate cancer assessment with MR imaging. In general, the more imaging modalities are combined, the better the accuracy seems to be. For example, recent data have shown that T2-weighted imaging, MR spectroscopy, and DCE MR imaging show synergy in reaching a high probability of tumor detection (70).

Given the variability in technical parameters, a prerequisite to take advantage of multimodality imaging is institutional optimization of each sequence to achieve optimal performance. This includes optimal shimming and saturation band placement for MR spectroscopy, standardized injection of contrast material and determination of arterial input function for DCE MR imaging, and standardized *b* value use for diffusion-weighted imaging. Quality control should be performed regularly to assure that all parts of the protocol are optimized. After these prerequisites are met, protocol adjustment can be performed according to the individual situation.

For example, in the presence of hemorrhage, data suggest that diffusion-weighted imaging should be included (32). Posthemorrhage detection of prostate cancer has been found to benefit from inclusion of MR spectroscopy and DCE MR imaging as well (49). Use of an endorectal coil and 3-T imaging should be preferred in general, with the option to offer 3-T imaging without use of an endorectal coil to attract patients who would otherwise elect not to undergo MR imaging. In

patients with contraindications to administration of gadolinium contrast agents, such as low glomerular filtration rate, DCE MR imaging will have to be avoided. In the setting of prior pelvic surgery, susceptibility artifacts from surgical slips or hardware may impede achievement of high-quality diffusion-weighted imaging and MR spectroscopy.

Assessment of transition zone cancer is thought to benefit more from use of diffusion-weighted imaging in patients of more advanced age (31). Differentiation of peripheral zone cancer from prostatitis and of BPH from transition zone cancer may benefit from use of DCE MR imaging with the TKCM. At the authors' institution, anatomic imaging, diffusion-weighted imaging, and DCE MR imaging are part of the standard MR imaging protocol for prostate cancer. MR spectroscopy is performed regularly; however, it requires dedicated protocol selection by the radiologist reviewing the order and is used when deemed appropriate for problem-solving purposes.

Summary

Much advancement has recently been made in the evaluation of prostate cancer with MR imaging. The result is an integrated concept of multimodality imaging of the prostate, in which classic anatomic imaging with T1- and T2-weighted imaging is combined with novel functional techniques including diffusion-weighted imaging, DCE MR imaging, and MR spectroscopy. Significant improvements have been made in the accuracy of MR imaging in diagnosis, localization, and staging of prostate cancer. Owing to the morbidity associated with prostate cancer treatments, increased diagnostic and staging accuracy is of high importance for accurate treatment selection. In addition, existing MR imaging protocols have benefited from improvements in imaging unit hardware and postprocessing techniques, such as higher field strength, parallel imaging, faster imaging, and use of multiparametric maps.

Owing to its exquisite soft-tissue contrast, MR imaging is well suited for assessment of the prostate. New developments in robotics and interventional MR imaging techniques benefit from the advantages of MR imaging in guiding biopsies, enabling excellent adjustment and confirmation of needle position during the procedure. MR imaging is a rapidly evolving field, and the application of many new techniques to the evaluation of prostate cancer will continue to improve the diagnostic accuracy of prostate cancer assessment with MR imaging and is expected to continue to significantly improve patient care.

References

1. American Cancer Society. Prostate cancer facts. In: Cancer facts & figures 2009. Atlanta, Ga: American Cancer Society, 2009; 19–20.
2. Slawin KM, Diblasio CJ, Kattan MW. Minimally invasive therapy for prostate cancer: use of nomograms to counsel patients about the choice and probable outcome of therapy. Rev Urol 2004;6 (suppl 4):S3–S8.
3. Thompson IM, Pauler DK, Goodman PJ, et al. Prevalence of prostate cancer among men with a prostate-specific antigen level < or =4.0 ng per milliliter. N Engl J Med 2004;350(22):2239–2246.
4. Okotie OT, Roehl KA, Han M, Loeb S, Gashti SN, Catalona WJ. Characteristics of prostate cancer detected by digital rectal examination only. Urology 2007;70(6):1117–1120.
5. Stamey TA, Freiha FS, McNeal JE, Redwine EA, Whittemore AS, Schmid HP. Localized prostate cancer: relationship of tumor volume to clinical significance for treatment of prostate cancer. Cancer 1993;71(3 suppl):933–938.
6. Pelzer AE, Tewari A, Bektic J, et al. Detection rates and biologic significance of prostate cancer with PSA less than 4.0 ng/mL: observation and clinical implications from Tyrol screening project. Urology 2005;66(5):1029–1033.
7. Basso D, Fogar P, Piva MG, et al. Total PSA, free PSA/total PSA ratio, and molecular PSA detection in prostate cancer: which is clinically effective and when? Urology 2000;55(5):710–715.
8. Spajic B, Eupic H, Tomas D, Stimac G, Kruslin B, Kraus O. The incidence of hyperechoic prostate cancer in transrectal ultrasound-guided biopsy specimens. Urology 2007;70(4):734–737.
9. Svetec D, McCabe K, Peretsman S, et al. Prostate rebiopsy is a poor surrogate of treatment efficacy in localized prostate cancer. J Urol 1998;159(5): 1606–1608.
10. Jemal A, Siegel R, Ward E, et al. Cancer statistics, 2008. CA Cancer J Clin 2008;58(2):71–96.
11. Patel AR, Jones JS, Rabets J, DeOreo G, Zippe CD. Parasagittal biopsies add minimal information in repeat saturation prostate biopsy. Urology 2004;63(1): 87–89.
12. Presti J Jr. Does the yield of prostate cancer biopsy and repeat biopsy justify the frequency of their use? Nat Clin Pract Urol 2008;5(5):246–247.
13. Webb JA, Shanmuganathan K, McLean A. Complications of ultrasound-guided transperineal prostate biopsy: a prospective study. Br J Urol 1993;72(5 Pt 2):775–777.
14. Dotan ZA. Bone imaging in prostate cancer. Nat Clin Pract Urol 2008;5(8):434–444.
15. Weidner A, Michaely HJ, Pelzer A, et al. Imaging of prostate cancer by diagnostic radiology and nuclear medicine. Aktuelle Urol 2010;41(1):35–42.
16. Lacy GL 2nd, Soderdahl DW, Hernandez J. Optimal cost-effective staging evaluations in prostate cancer. Curr Urol Rep 2007;8(3):190–196.
17. McNeal JE, Redwine EA, Freiha FS, Stamey TA. Zonal distribution of prostatic adenocarcinoma: correlation with histologic pattern and direction of spread. Am J Surg Pathol 1988;12(12):897–906.

18. Ayala AG, Ro JY, Babaian R, Troncoso P, Grignon DJ. The prostatic capsule: does it exist? Its importance in the staging and treatment of prostatic carcinoma. Am J Surg Pathol 1989;13(1):21–27.
19. Epstein JI. An update of the Gleason grading system. J Urol 2010;183(2):433–440.
20. Makarov DV, Sanderson H, Partin AW, Epstein JI. Gleason score 7 prostate cancer on needle biopsy: is the prognostic difference in Gleason scores 4 + 3 and 3 + 4 independent of the number of involved cores? J Urol 2002;167(6):2440–2442.
21. Kang DE, Fitzsimons NJ, Presti JC Jr, et al. Risk stratification of men with Gleason score 7 to 10 tumors by primary and secondary Gleason score: results from the SEARCH database. Urology 2007;70 (2):277–282.
22. Bezzi M, Kressel HY, Allen KS, et al. Prostatic carcinoma: staging with MR imaging at 1.5 T. Radiology 1988;169(2):339–346.
23. Hricak H, Choyke PL, Eberhardt SC, Leibel SA, Scardino PT. Imaging prostate cancer: a multidisciplinary perspective. Radiology 2007;243(1):28–53.
24. Yu KK, Hricak H, Alagappan R, Chernoff DM, Bacchetti P, Zaloudek CJ. Detection of extracapsular extension of prostate carcinoma with endorectal and phased-array coil MR imaging: multivariate feature analysis. Radiology 1997;202(3):697–702.
25. Bonekamp D, Macura KJ. Dynamic contrast-enhanced magnetic resonance imaging in the evaluation of the prostate. Top Magn Reson Imaging 2008;19 (6):273–284.
26. Moseley ME, Kucharczyk J, Mintorovitch J, et al. Diffusion-weighted MR imaging of acute stroke: correlation with T2-weighted and magnetic susceptibility-enhanced MR imaging in cats. AJNR Am J Neuroradiol 1990;11(3):423–429.
27. Hosseinzadeh K, Schwarz SD. Endorectal diffusion-weighted imaging in prostate cancer to differentiate malignant and benign peripheral zone tissue. J Magn Reson Imaging 2004;20(4):654–661.
28. Haider MA, van der Kwast TH, Tanguay J, et al. Combined T2-weighted and diffusion-weighted MRI for localization of prostate cancer. AJR Am J Roentgenol 2007;189(2):323–328.
29. desouza NM, Reinsberg SA, Scurr ED, Brewster JM, Payne GS. Magnetic resonance imaging in prostate cancer: the value of apparent diffusion coefficients for identifying malignant nodules. Br J Radiol 2007;80(950):90–95.
30. Le Bihan D, Breton E, Lallemand D, Grenier P, Cabanis E, Laval-Jeantet M. MR imaging of intravoxel incoherent motions: application to diffusion and perfusion in neurologic disorders. Radiology 1986;161(2):401–407.
31. Tamada T, Sone T, Jo Y, et al. Apparent diffusion coefficient values in peripheral and transition zones of the prostate: comparison between normal and malignant prostatic tissues and correlation with histologic grade. J Magn Reson Imaging 2008;28(3): 720–726.
32. Rosenkrantz AB, Kopec M, Kong X, et al. Prostate cancer vs. post-biopsy hemorrhage: diagnosis with T2- and diffusion-weighted imaging. J Magn Reson Imaging 2010;31(6):1387–1394.
33. Kim JH, Kim JK, Park BW, Kim N, Cho KS. Apparent diffusion coefficient: prostate cancer versus noncancerous tissue according to anatomical region. J Magn Reson Imaging 2008;28(5):1173–1179.
34. Noworolski SM, Vigneron DB, Chen AP, Kurhanewicz J. Dynamic contrast-enhanced MRI and MR diffusion imaging to distinguish between glandular and stromal prostatic tissues. Magn Reson Imaging 2008;26(8):1071–1080.
35. Katahira K, Takahara T, Kwee TC, et al. Ultra-high-b-value diffusion-weighted MR imaging for the detection of prostate cancer: evaluation in 201 cases with histopathological correlation. Eur Radiol 2011; 21(1):188–196.
36. Kim CK, Park BK, Kim B. High-b-value diffusion-weighted imaging at 3 T to detect prostate cancer: comparisons between b values of 1,000 and 2,000 s/mm2. AJR Am J Roentgenol 2010;194(1): W33–W37.
37. Heerschap A, Jager GJ, van der Graaf M, Barentsz JO, Ruijs SHJ. Proton MR spectroscopy of the normal human prostate with an endorectal coil and a double spin-echo pulse sequence. Magn Reson Med 1997;37(2):204–213.
38. Yacoe ME, Sommer G, Peehl D. In vitro proton spectroscopy of normal and abnormal prostate. Magn Reson Med 1991;19(2):429–438.
39. Podo F. Tumour phospholipid metabolism. NMR Biomed 1999;12(7):413–439.
40. Shukla-Dave A, Hricak H, Eberhardt SC, et al. Chronic prostatitis: MR imaging and 1H MR spectroscopic imaging findings—initial observations. Radiology 2004;231(3):717–724.
41. Bottomley PA. Spatial localization in NMR spectroscopy in vivo. Ann NY Acad Sci 1987;508: 333–348.
42. Jung JA, Coakley FV, Vigneron DB, et al. Prostate depiction at endorectal MR spectroscopic imaging: investigation of a standardized evaluation system. Radiology 2004;233(3):701–708.
43. Westphalen AC, Coakley FV, Kurhanewicz J, Reed G, Wang ZJ, Simko JP. Mucinous adenocarcinoma of the prostate: MRI and MR spectroscopy features. AJR Am J Roentgenol 2009;193(3):W238–W243.
44. Prando A, Billis A. Focal prostatic atrophy: mimicry of prostatic cancer on TRUS and 3D-MRSI studies. Abdom Imaging 2009;34(2):271–275.
45. van Dorsten FA, van der Graaf M, Engelbrecht MR, et al. Combined quantitative dynamic contrast-enhanced MR imaging and (1)H MR spectroscopic imaging of human prostate cancer. J Magn Reson Imaging 2004;20(2):279–287.
46. Coakley FV, Kurhanewicz J, Lu Y, et al. Prostate cancer tumor volume: measurement with endorectal MR and MR spectroscopic imaging. Radiology 2002;223(1):91–97.
47. Crehange G, Parfait S, Liegard M, et al. Tumor volume and metabolism of prostate cancer determined by proton magnetic resonance spectroscopic imaging at 3T without endorectal coil reveal poten-

tial clinical implications in the context of radiation oncology. Int J Radiat Oncol Biol Phys 2010 Jul 7. [Epub ahead of print]
48. Qayyum A, Coakley FV, Lu Y, et al. Organ-confined prostate cancer: effect of prior transrectal biopsy on endorectal MRI and MR spectroscopic imaging. AJR Am J Roentgenol 2004;183(4):1079–1083.
49. Kaji Y, Kurhanewicz J, Hricak H, et al. Localizing prostate cancer in the presence of postbiopsy changes on MR images: role of proton MR spectroscopic imaging. Radiology 1998;206(3):785–790.
50. Padhani AR, Harvey CJ, Cosgrove DO. Angiogenesis imaging in the management of prostate cancer. Nat Clin Pract Urol 2005;2(12):596–607.
51. Tofts PS, Brix G, Buckley DL, et al. Estimating kinetic parameters from dynamic contrast-enhanced T(1)-weighted MRI of a diffusable tracer: standardized quantities and symbols. J Magn Reson Imaging 1999;10(3):223–232.
52. Tofts PS. Modeling tracer kinetics in dynamic Gd-DTPA MR imaging. J Magn Reson Imaging 1997;7 (1):91–101.
53. Langer DL, van der Kwast TH, Evans AJ, Trachtenberg J, Wilson BC, Haider MA. Prostate cancer detection with multi-parametric MRI: logistic regression analysis of quantitative T2, diffusion-weighted imaging, and dynamic contrast-enhanced MRI. J Magn Reson Imaging 2009;30(2):327–334.
54. Kozlowski P, Chang SD, Jones EC, Berean KW, Chen H, Goldenberg SL. Combined diffusion-weighted and dynamic contrast-enhanced MRI for prostate cancer diagnosis: correlation with biopsy and histopathology. J Magn Reson Imaging 2006;24 (1):108–113.
55. Kurhanewicz J, Vigneron D, Carroll P, Coakley F. Multiparametric magnetic resonance imaging in prostate cancer: present and future. Curr Opin Urol 2008;18(1):71–77.
56. Alonzi R, Padhani AR, Allen C. Dynamic contrast enhanced MRI in prostate cancer. Eur J Radiol 2007;63(3):335–350.
57. Sciarra A, Panebianco V, Ciccariello M, et al. Magnetic resonance spectroscopic imaging (1H-MRSI) and dynamic contrast-enhanced magnetic resonance (DCE-MRI): pattern changes from inflammation to prostate cancer. Cancer Invest 2010;28(4):424–432.
58. Fütterer JJ, Engelbrecht MR, Huisman HJ, et al. Staging prostate cancer with dynamic contrast-enhanced endorectal MR imaging prior to radical prostatectomy: experienced versus less experienced readers. Radiology 2005;237(2):541–549.
59. Sciarra A, Panebianco V, Ciccariello M, et al. Value of magnetic resonance spectroscopy imaging and dynamic contrast-enhanced imaging for detecting prostate cancer foci in men with prior negative biopsy. Clin Cancer Res 2010;16(6):1875–1883.
60. Franiel T, Lüdemann L, Rudolph B, et al. Evaluation of normal prostate tissue, chronic prostatitis, and prostate cancer by quantitative perfusion analysis using a dynamic contrast-enhanced inversion-prepared dual-contrast gradient echo sequence. Invest Radiol 2008;43(7):481–487.
61. Fütterer JJ, Scheenen TW, Huisman HJ, et al. Initial experience of 3 tesla endorectal coil magnetic resonance imaging and 1H-spectroscopic imaging of the prostate. Invest Radiol 2004;39(11):671–680.
62. Sosna J, Pedrosa I, Dewolf WC, Mahallati H, Lenkinski RE, Rofsky NM. MR imaging of the prostate at 3 Tesla: comparison of an external phased-array coil to imaging with an endorectal coil at 1.5 Tesla. Acad Radiol 2004;11(8):857–862.
63. Heijmink SW, Fütterer JJ, Hambrock T, et al. Prostate cancer: body-array versus endorectal coil MR imaging at 3 T—comparison of image quality, localization, and staging performance. Radiology 2007; 244(1):184–195.
64. Hamilton G, Middleton MS, Choi SH, Salibi N, Mattrey RF. Improved MR spectral analysis for a PFC-filled endorectal prostate surface coil compared to an air-filled coil [abstr]. In: Proceedings of the 15th Meeting of the International Society for Magnetic Resonance in Medicine. Berkeley, Calif: International Society for Magnetic Resonance in Medicine, 2007; 293.
65. Chen AP, Xu D, Sotto C, Coakley FV, Kurhanewicz J, Vigneron DB. High resolution MRSI and DTI of prostate cancer at 3T [abstr]. In: Proceedings of the 15th Meeting of the International Society for Magnetic Resonance in Medicine. Berkeley, Calif: International Society for Magnetic Resonance in Medicine, 2007; 558.
66. Barker PB, Hearshen DO, Boska MD. Single-voxel proton MRS of the human brain at 1.5T and 3.0T. Magn Reson Med 2001;45(5):765–769.
67. Sodickson DK, Manning WJ. Simultaneous acquisition of spatial harmonics (SMASH): fast imaging with radiofrequency coil arrays. Magn Reson Med 1997;38(4):591–603.
68. Gibbs P, Pickles MD, Turnbull LW. Diffusion imaging of the prostate at 3.0 tesla. Invest Radiol 2006; 41(2):185–188.
69. Heisen M, Fan X, Buurman J, van Riel NA, Karczmar GS, ter Haar Romeny BM. The influence of temporal resolution in determining pharmacokinetic parameters from DCE-MRI data. Magn Reson Med 2010;63(3):811–816.
70. Turkbey B, Pinto PA, Mani H, et al. Prostate cancer: value of multiparametric MR imaging at 3 T for detection—histopathologic correlation. Radiology 2010;255(1):89–99.
71. Ukimura O, Gill IS. Image-fusion, augmented reality, and predictive surgical navigation. Urol Clin North Am 2009;36(2):115–123.
72. Susil RC, Ménard C, Krieger A, et al. Transrectal prostate biopsy and fiducial marker placement in a standard 1.5T magnetic resonance imaging scanner. J Urol 2006;175(1):113–120.
73. Lattouf JB, Grubb RL 3rd, Lee SJ, et al. Magnetic resonance imaging–directed transrectal ultrasonography-guided biopsies in patients at risk of prostate cancer. BJU Int 2007;99(5):1041–1046.
74. Futterer JJ, Schouten M, Scheenen TW, Barentsz J. MR-compatible transrectal prostate biopsy robot: a feasibility study [abstr]. In: Proceedings of the 18th Meeting of the International Society for Magnetic Resonance in Medicine. Berkeley, Calif: International Society for Magnetic Resonance in Medicine, 2010.
75. Stoianovici D, Song D, Petrisor D, et al. "MRI Stealth" robot for prostate interventions. Minim Invasive Ther Allied Technol 2007;16(4):241–248.

RadioGraphics

Advancements in MR Imaging of the Prostate: From Diagnosis to Interventions

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Currently, prostate cancer screening is based on assessment of the level of PSA elevation and results of digital rectal examination (DRE). Both markers have suboptimal accuracy for the diagnosis of prostate cancer.

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In the axial plane, the prostate is divided into four zones: *(a)* the anterior fibromuscular stroma, which contains no glandular tissue; *(b)* the transition zone surrounding the urethra, which contains 5% of the glandular tissue; *(c)* the central zone, which contains 20% of the glandular tissue; and *(d)* the outer peripheral zone, which contains 70%–80% of the glandular tissue (17).

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Reduced diffusion of water in prostate cancer has been attributed to the increased cellularity of malignant lesions, with reduction of the extracellular space and restriction of the motion of a larger portion of water molecules to the intracellular space. Therefore, diffusion-weighted imaging provides an important quantitative biophysical parameter that can be used to differentiate benign from malignant prostate tissue (27).

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An increase in the choline-to-citrate ratio or the (choline + creatine)/citrate ratio is often used as a marker of malignancy in prostate cancer and increases the specificity of diagnosis; however, it is most reliable in the peripheral zone.

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In prostate cancer, increased tumor vascularity leads to early hyperenhancement (higher and earlier peak enhancement than in normal tissue) and to rapid washout of contrast material from the tumor, in comparison with normal prostate tissue (Fig 4). Microvascular alterations and neovascularity are in general most severe in prostate cancer, in comparison with other processes in the prostate such as BPH or prostatic intraepithelial neoplasia (50).

Oncology: Prostate/Testis/Penis/Urethra

Multiparametric Magnetic Resonance Imaging and Ultrasound Fusion Biopsy Detect Prostate Cancer in Patients with Prior Negative Transrectal Ultrasound Biopsies

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Abbreviations and Acronyms

DRE = digital rectal examination
GS = Gleason score
mpMRI = multiparametric magnetic resonance imaging
MRI = magnetic resonance imaging
PSA = prostate specific antigen
PSAD = prostate specific antigen density
TRUS = transrectal ultrasound
US = ultrasound

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Purpose: Patients with negative transrectal ultrasound biopsies and a persistent clinical suspicion are at risk for occult but significant prostate cancer. The ability of multiparametric magnetic resonance imaging/ultrasound fusion biopsy to detect these occult prostate lesions may make it an effective tool in this challenging scenario.

Materials and Methods: Between March 2007 and November 2011 all men underwent prostate 3 T endorectal coil magnetic resonance imaging. All concerning lesions were targeted with magnetic resonance imaging/ultrasound fusion biopsy. In addition, all patients underwent standard 12-core transrectal ultrasound biopsy. Men with 1 or more negative systematic prostate biopsies were included in our cohort.

Results: Of the 195 men with previous negative biopsies, 73 (37%) were found to have cancer using the magnetic resonance imaging/ultrasound fusion biopsy combined with 12-core transrectal ultrasound biopsy. High grade cancer (Gleason score 8+) was discovered in 21 men (11%), all of whom had disease detected with magnetic resonance imaging/ultrasound fusion biopsy. However, standard transrectal ultrasound biopsy missed 12 of these high grade cancers (55%). Pathological upgrading occurred in 28 men (38.9%) as a result of magnetic resonance imaging/ultrasound fusion targeting vs standard transrectal ultrasound biopsy. The diagnostic yield of combined magnetic resonance imaging/ultrasound fusion platform was unrelated to the number of previous negative biopsies and persisted despite increasing the number of previous biopsy sessions. On multivariate analysis only prostate specific antigen density and magnetic resonance imaging suspicion level remained significant predictors of cancer.

Conclusions: Multiparametric magnetic resonance imaging with a magnetic resonance imaging/ultrasound fusion biopsy platform is a novel diagnostic tool for detecting prostate cancer and may be ideally suited for patients with negative transrectal ultrasound biopsies in the face of a persistent clinical suspicion for cancer.

Key Words: prostatic neoplasms, biopsy

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SINCE the advent of PSA screening, the pathological diagnosis of prostate cancer has been based on the use of systematic transrectal ultrasound guided biopsies. It is now well understood that systematic 12-core TRUS biopsies can under sample apical and anterior areas of the prostate, particularly in large glands.[1] As a result, prostate cancer biopsy diagnosis has traditionally been fraught with poor sensitivity (as low as 53% in autopsy studies),[2] raising diagnostic concerns of missed prostate cancers.

A particular challenge is presented by the patient with continued clinical suspicion of prostate cancer (whether based on PSA, PSA velocity, PSAD or DRE) after repeated negative biopsies. Different strategies have been used in this setting to minimize false-negative biopsy results including repeat biopsy,[3–5] the addition of anterior directed biopsy cores,[6] saturation biopsy templates[7,8] and transperineal template guided biopsy.[9] While all of these strategies add some diagnostic usefulness, they ultimately remain dependent on random sampling.

Recent advances in mpMRI have allowed high quality visualization of the prostate and are aiding in identification of prostate cancer lesions.[10] We previously reported on the use of a novel MRI/US fusion biopsy system for the targeted detection of lesions detected on MRI.[10] In this series we present our experience in patients with no prior prostate cancer diagnosis with at least 1 previous negative TRUS biopsy and a continued clinical suspicion of cancer. We show the diagnostic usefulness of mpMRI and this novel MRI/US fusion biopsy platform in this challenging clinical scenario.

METHODS AND MATERIALS

This study was approved by the institutional review board of the National Cancer Institute of the National Institutes of Health. Patients eligible for this study were consented and informed appropriately of the potential harms and benefits. Study enrollment began in March 2007 and continued through November 2011.

All patients initially underwent mpMRI using a 3.0 T MRI scanner (Achieva, Philips Healthcare, Best, The Netherlands) in addition to a 16-channel cardiac surface coil (SENSE, Philips Healthcare) placed over the pelvis with an endorectal coil (BPX-30, Medrad, Pittsburgh, Pennsylvania) as previously described.[10] MRI sequences were also routinely obtained, including tri-planar T2-weighted imaging, axial diffusion weighted imaging with apparent diffusion coefficient mapping, 3-dimensional point resolved spatially localized spectroscopy and axial dynamic contrast enhanced MRI. Details of these imaging sequences have been described previously.[11,12] All imaging underwent blinded centralized radiological evaluation.[10] MRI lesions were graded by suspicion based on the number of positive imaging sequences (low—fewer than 2, moderate—3 and high suspicion—4).

Patients with lesions suspicious for cancer on MRI were enrolled in a prostate biopsy protocol. All patients undergoing prostate biopsy were given antibiotic prophylaxis and a cleansing Fleet® enema. Biopsies were performed with the patient under local anesthesia with lidocaine jelly and injectable lidocaine for analgesia. All patients first underwent a standard 12-core transrectal ultrasound biopsy. For this biopsy the operator was blinded to the location of suspicious lesions detected on the MRI. Following TRUS biopsy the patients subsequently underwent MRI/US fusion guided biopsy of suspicious lesions found on MRI. An electromagnetic field generator was placed above the pelvis to track the rectal probe in real time during the biopsy and sensors were placed on the transrectal ultrasound probe. After a 2-dimensional sweep of the ultrasound probe through the prostate, the real-time US image was manually registered to the magnetic resonance image, allowing the operator to guide the ultrasound probe to biopsy previously identified suspicious lesions. A full description of this procedure was published recently.[10] A minimum of 2 biopsy cores were obtained from each lesion (1 in the axial plane, 1 in the sagittal plane). All biopsies underwent blinded centralized pathological evaluation by a genitourinary pathologist. For this retrospective study all consecutive patients were included in the analysis if they had undergone at least 1 prior biopsy which did not reveal cancer. All patients with a previous biopsy confirmed diagnosis of prostate cancer were excluded from analysis. Patients with a prior diagnosis of prostatic intraepithelial neoplasia or atypia were included in the analysis.

Descriptive statistics were used to describe patient demographics. Univariate analysis was performed using a t test for continuous variables, and chi-square and Fisher's exact tests for nominal variables. For patients with multiple lesions, MRI suspicion was assigned by the lesion with the highest MRI suspicion level and Gleason score was assigned based on the cancer with the highest Gleason score. Multivariate analysis was performed using regression models and tests were considered significant if $p < 0.05$. All tests were 2-tailed.

RESULTS

Demographics

A total of 195 patients were eligible for this case series. The median number of prior biopsies was 2 (range 1 to 9). A median of 2 lesions per patient (range 1 to 7) were identified on MRI. A median of 5 (range 2 to 14) MRI guided cores was taken during MRI/US fusion guided biopsy (table 1).

Diagnostic Yield of MRI Fusion Platform

Cancer was detected on biopsy (combined standard 12-core TRUS guided and MRI targeted) in 73 of the 195 men (37.4%). High grade cancer (GS 8 or greater) was found in 21 men (10.8%). MRI targeting detected cancer in 56 of the 73 men and found all 21 cases of high grade cancer. Furthermore, MRI targeted biopsies upgraded tumors detected on stan-

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Table 1. *Patient demographics*

Median pt age (range)	62	(37–80)
Median ng/ml PSA (range)	9.13	(0.3–103)
Median ml prostate vol (range)	56	(16–187)
Median ng/ml/ml PSAD (range)	0.156	(0.019–1.675)
No. race (%):		
Caucasian	148	(75.9)
Black	36	(18.5)
Hispanic	3	(1.5)
Asian	8	(4.1)

dard TRUS biopsies in 28 men (38.4%). Systematic TRUS biopsy missed 11 of the 21 men with high grade disease (52.3%, table 2). A characterization of Gleason score stratification by modality of diagnosis is presented in table 3. Using MRI targeting 33 patients were found to have anterior lesions, 12 of whom were found to have high grade disease (36.3%). These patients had a median of 2 additional lesions on MRI (range 0 to 5) and only 8 (24.2%) had cancer detected in MRI suspicious lesions in other nonanterior locations.

The diagnostic yield of fusion biopsy as stratified by the number of prior biopsies and MRI suspicion is presented in table 4 and figure 1. The increased number of prior negative biopsies did not influence the diagnostic yield, especially in the detection of high grade disease. Increasing MRI suspicion was associated with greater diagnostic yield for all cancers (detection rate of 15.22% for low, 38.14% for moderate and 67.14% for high suspicion lesions). Similarly, MRI suspicion was associated with greater diagnostic yield of high grade disease (high grade cancer detected in 0% of low, 9.32% of moderate and 32.26% of those with high suspicion lesions).

Prediction of Biopsy Outcome

Results of univariate analysis are presented in table 5. Race, number of prior negative biopsies or DRE findings were not statistically associated with a positive biopsy result on fusion MRI biopsy (all cancers or high grade cancers). Age was not found to be higher in those with cancer overall but was higher in those with a diagnosis of high grade disease (67.71 vs 61.11 years old, $p = 0.0001$). In those men with a diagnosis of cancer, prostate volume was significantly smaller (54.51 vs 71.64 ml, $p = 0.0006$), PSA was significantly higher (18.73 vs 11.28 ng/ml, $p = 0.0005$) and PSAD was significantly greater (0.3843 vs 0.1639 ng/ml/ml, $p < 0.0001$). This association was consistent in those men with a diagnosis of high grade disease, with smaller prostate volume (46.43 vs 67.49 ml, $p < 0.0001$), higher PSA (27.37 vs 12.46 ng/ml, $p = 0.0071$) and greater PSAD (0.6342 vs 0.1985 ng/ml/ml). MRI suspicion level was significantly correlated with biopsy detection of all cancers and high grade cancers. Those with cancer detected on biopsy had significantly greater MRI suspicion ($p = 0.0004$). This was also noted in those diagnosed with high grade cancers ($p = 0.0048$). A multivariate logistic regression model including age, race, number of previous negative biopsies, MRI suspicion level, PSA, prostate volume and PSAD was constructed to predict biopsy outcome. In this analysis only PSAD ($p = 0.0026$) and MRI suspicion level ($p = 0.0334$) remained significant predictors of biopsy outcome of cancer.

Table 3. *Characterization of Gleason score stratification by modality of diagnosis*

	No. Low Grade (%)	No. Intermediate Grade (%)	No. High Grade (%)	Totals
Standard 12-core biopsy only	12 (85.71)	2 (14.29)	0 (0)	14
MRI guided biopsy only	5 (26.32)	7 (36.84)	7 (36.84)	19
Standard + MRI guided biopsy	11 (27.5)	15 (37.5)	14 (35)	40
Total No.	28	24	21	73

PSAD and MRI Suspicion Level as Threshold for Biopsy

In figure 2 we present PSAD stratified by biopsy result. When we applied the threshold PSAD of

Table 2. *Diagnostic yield stratified by standard TRUS vs targeted MRI/US fusion platform*

	All Ca	Low Grade (GS 6)	Intermediate Grade (GS 7)	High Grade (GS 8+)
No. either modality detected Ca	73	28	24	21
No. MRI targeting detected Ca (%)	56 (76.7)	16 (57.1)	19 (79.2)	21 (100)
No. US only guidance detected Ca (%)	45 (61.6)	23 (82.1)	12 (50)	10 (47.6)
No. both methods detected Ca (%)	28 (35.9)	11 (39.3)	7 (29.2)	10 (47.6)
No. MRI targeting upgraded risk (%)	28 (38.4)	5 (17.9)	12 (50)	11 (52.3)

Table 4. *The diagnostic yield of fusion biopsy*

	Totals	No. Biopsies with Ca (%)	No. Low Grade (%)	No. Intermediate Grade (%)	No. High Grade (%)
Previous neg biopsy sessions:					
1	73	21 (28.8)	10 (13.7)	8 (11.0)	3 (4.1)
2	52	25 (48.1)	8 (15.4)	10 (19.2)	7 (13.5)
3	40	16 (40)	7 (17.5)	3 (7.5)	6 (15.0)
4+	30	11 (36.7)	3 (10.0)	3 (10.0)	5 (16.7)
MRI levels of suspicion:					
Low	46	7 (15.22)	5 (10.87)	2 (4.35)	0 (0)
Moderate	118	45 (38.14)	21 (17.8)	13 (11.02)	11 (9.32)
High	31	21 (67.14)	2 (6.45)	9 (29.03)	10 (32.26)

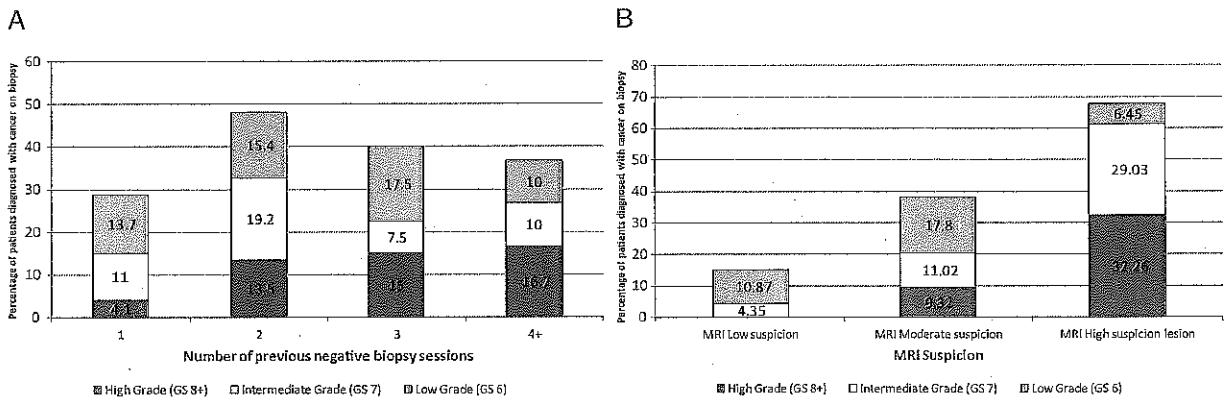


Figure 1. Diagnostic yield stratified by number of previous negative biopsies (*A*) and by MRI suspicion level (*B*). Diagnostic yield is further broken down into Gleason grade (low grade GS 6, intermediate grade GS 7 and high grade GS 8–10).

0.15 ng/ml/ml, the reported threshold for very low risk cancer in NCCN Guidelines® (National Comprehensive Cancer Network prostate cancer guidelines, version 4.2011), no high grade cancers were found in cases below this value. Specifically, the minimum PSAD in those with high grade cancer was 0.1851 ng/ml/ml. In addition, no high grade cancers were noted in patients with low suspicion lesions on MRI. If we applied this 0.15 ng/ml/ml PSAD threshold and chose not to biopsy those below this level, we could potentially prevent unnecessary biopsies without impacting cancer detection. Applying this PSAD threshold, 94 men would have avoided biopsy. In this setting the diagnostic yield for high grade disease would have improved from 10.82% to 21.0% while not missing any high grade cancers (ie 100% sensitivity for high grade cancers). Regarding the detection of all cancers, 21 of those 94 men would not have had their cancer detected (15 men with GS 6 and 6 men with GS 7).

Repeat MRI Fusion Biopsy with Prior Negative Result

Of the 122 men with negative results on MRI/US fusion biopsy 10 underwent subsequent fusion biopsy. Of these men 7 had negative results on subsequent biopsy. The other 3 men had disease detected on second fusion biopsy, none of whom had low suspicion disease on MRI. High grade disease was noted in 1 of these 3 patients. We previously reported that MRI/US fusion has a known spatial accuracy of 2.4 mm as assessed in phantom models.[13] As such, it is possible to miss targets, especially those that are small.

Table 5. *Univariate analysis of biopsy outcome*

	All Ca			High Risk Disease (GS 8+)		
	Neg	Pos	p Value	Neg	Pos	p Value
Mean age	61.15	62.96	0.1086	61.11	67.71	0.0001
Black race (%)	15.57	23.29	0.1875	18.39	19.05	1.0000
Abnormal DRE (%)	10.66	15.07	0.3759	10.92	23.81	0.1487
Mean No. prior biopsies	2.15	2.34	0.3119	2.17	2.67	0.0958
Mean PSA (ng/ml)	11.28	18.73	0.0005	12.46	27.37	<0.0001
Mean prostate vol (ml)	71.64	54.51	0.0006	67.49	46.43	0.0071
Mean PSAD (ng/ml/ml)	0.1639	0.3843	<0.0001	0.1985	0.6342	<0.0001
MRI low suspicion (%)	31.97	9.59	0.0004	26.44	0	0.0048

DISCUSSION

This series of patients demonstrates the well understood limitations of traditional random TRUS biopsy sampling strategies, namely missed clinically significant prostate cancers. In this group of highly screened men we demonstrated that mpMRI fusion biopsy was able to identify 37.5% who harbored cancer, nearly a third of whom harbored high grade clinically significant lesions.

This study suggests that MRI will be particularly useful in identifying lesions harboring high grade tumors in men with previous negative biopsies. Several studies on the usefulness of MRI for the detection of cancer in men with prior negative biopsies have been previously reported. Hoeks et al recently published similar favorable diagnostic results using MRI guided biopsies in patients with 1 or more prior negative biopsies with a cancer detection rate of 41%.[14] While our fusion platform has some similarity to the technique described by this group, substantial differences exist. Our fusion guided biopsy was conducted in an outpatient setting, building on the common urological skill set of TRUS biopsy. In contrast, Hoeks et al used an in-gantry MRI biopsy platform.[14] While our overall detection rates are similar, we believe the convenience of an outpatient biopsy platform will ultimately be more feasible for the application of MRI in prostate cancer detection.

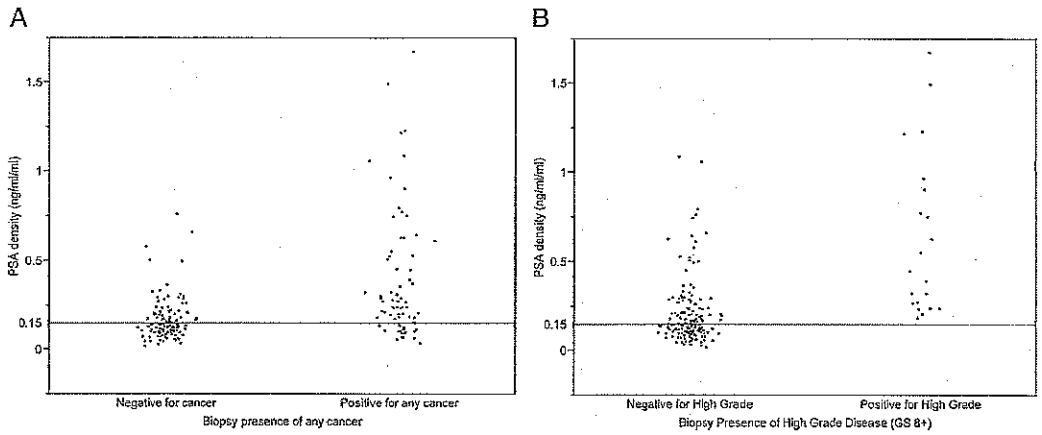


Figure 2. Scatter plots representing PSAD stratified by MRI/US fusion biopsy results for all cancers (*A*) and high grade cancers (*B*). No high grade cancers were found below 0.15 ng/ml/ml threshold used in 2011 NCCN guidelines for very low risk cancer.

Interestingly, the diagnostic yield of MRI in this study was not dependent on the number of prior biopsies, in stark contrast to the results seen with repeat random biopsy[3,4,15] as well as repeat saturation templates.[16] Zaytoun et al described their experience with a repeat saturation template but noted that due to the previously reported decreased diagnostic usefulness for biopsy after multiple negative biopsies, decided only to include patients with 1 prior negative biopsy in their study.[7] On the contrary, we believe that the maintenance of diagnostic yield in detecting cancer after multiple prior negative biopsies on our platform confirms that the localization of tumor with MRI and subsequent targeting of tumor with MRI/US fusion are true departures from the stochastic processes seen in repeated random biopsy strategies. This is especially evident in lesions in the anterior prostate which are more likely missed by the standard random template, as evident by the fact that nearly half of the patients in our series were found to have cancer localized anteriorly (33 of 73 men). Nontargeted strategies to reach these anterior lesions have been less fruitful, with Chon et al reporting on a series of 111 men with a previous negative biopsy in whom repeat extended template biopsy was supplemented with 6 additional anteriorly directed cores.[6] This nontargeted strategy to sample the anterior gland uniquely discovered only 2 cancers (2%).

Another technique used to overcome the under sampling of nontargeted TRUS prostate biopsy is transperineal template based prostate biopsy. This has been reported to have an excellent diagnostic yield and results in thorough sampling of areas of the anterior prostate.[9,17] However, this technique requires general anesthesia and, thus, is associated with a higher rate of complications (approximately a 10% rate of urinary retention) as well as increased costs. On the other hand, MRI/US fusion biopsy uses a urologist's existing skill sets, avoids general anesthesia and can be delivered comfortably using local anesthesia in an awake patient in an outpatient, office based setting.

As prostate cancer diagnostic techniques advance, concerns increase that an additional diagnostic yield may be associated with the discovery of additional small, low grade and clinically insignificant lesions. This series emphasizes that previous negative nontargeted biopsy does not rule out the absence of high grade, clinically significant lesions, especially in those with continued clinical suspicion (increasing PSA and elevated PSAD). We previously reported that mpMRI was most sensitive in detecting tumors larger than 5 mm in diameter as well as those GS 8 or greater.[18] With this performance, MRI targeting tends to focus on clinically relevant lesions, a fact emphasized by the relatively high diagnostic yield of high grade lesions in this group (11%). Indeed the primary predictive factor indicating the detection of cancer was PSAD and MRI suspicion, and was unrelated to previous sampling. Thus, PSAD and MRI suspicion could be incorporated into future trials to further improve performance characteristics, preventing unnecessary biopsies while maintaining sensitivity in the detection of cancer.

There are several weaknesses in the analysis of this series. As our center is a specialty referral center, the very act of primary urologist referral in the face of negative biopsy suggests some clinical suspicion of cancer, resulting in selection bias. The true denominator of those men with negative results and those who were not referred cannot be assessed. It is likely that several factors contribute to this clinical suspicion (including PSA, PSA velocity, PSAD, DRE, age specific PSA thresholds and patient anxiety). The applicability of these data to the larger screen-

ing population will require more testing. A formal randomized prospective trial, as always, is the best methodology to clarify this issue.

CONCLUSIONS

MRI/US fusion biopsy specifically targets clinically suspicious cancers throughout the prostate, including the anterior gland. This biopsy technique delivers a significant diagnostic yield in patients with prior negative TRUS biopsies and is not degraded by the number of previous biopsy sessions. Therefore, in contrast to nontargeted diagnostic strategies, we believe that MRI/US fusion biopsy is ideally suited for those men with persistent clinical suspicion of cancer but negative biopsy.

REFERENCES

1. Presti JC Jr: Repeat prostate biopsy–when, where, and how. Urol Oncol 2009; **27:** 312.
2. Haas GP, Delongchamps N, Brawley OW et al: The worldwide epidemiology of prostate cancer: perspectives from autopsy studies. Can J Urol 2008; **15:** 3866.
3. Roehl KA, Antenor JA and Catalona WJ: Serial biopsy results in prostate cancer screening study. J Urol 2002; **167:** 2435.
4. Yanke B, Gonen M, Scardino P et al: Validation of a nomogram for predicting positive repeat biopsy for prostate cancer. J Urol 2005; **173:** 421.
5. Keetch DW, McMurtry JM, Smith DS et al: Prostate specific antigen density versus prostate specific antigen slope as predictors of prostate cancer in men with initially negative prostatic biopsies. J Urol 1996; **156:** 428.
6. Chon CH, Lai FC, McNeal JE et al: Use of extended systematic sampling in patients with a prior negative prostate needle biopsy. J Urol 2002; **167:** 2457.
7. Zaytoun OM, Moussa AS, Gao T et al: Office based transrectal saturation biopsy improves prostate cancer detection compared to extended biopsy in the repeat biopsy population. J Urol 2011; **186:** 850.
8. Stewart CS, Leibovich BC, Weaver AL et al: Prostate cancer diagnosis using a saturation needle biopsy technique after previous negative sextant biopsies. J Urol 2001; **166:** 86.
9. Pinkstaff DM, Igel TC, Petrou SP et al: Systematic transperineal ultrasound-guided template biopsy of the prostate: three-year experience. Urology 2005; **65:** 735.
10. Pinto PA, Chung PH, Rastinehad AR et al: Magnetic resonance imaging/ultrasound fusion guided prostate biopsy improves cancer detection following transrectal ultrasound biopsy and correlates with multiparametric magnetic resonance imaging. J Urol 2011; **186:** 1281.
11. Turkbey B, Pinto PA, Mani H et al: Prostate cancer: value of multiparametric MR imaging at 3 T for detection–histopathologic correlation. Radiology 2010; **255:** 89.
12. Turkbey B, Shah VP, Pang Y et al: Is apparent diffusion coefficient associated with clinical risk scores for prostate cancers that are visible on 3-T MR images? Radiology 2011; **258:** 488.
13. Xu S, Kruecker J, Turkbey B et al: Real-time MRI-TRUS fusion for guidance of targeted prostate biopsies. Comput Aided Surg 2008; **13:** 255.
14. Hoeks CM, Schouten MG, Bomers JG et al: Three-Tesla magnetic resonance-guided prostate biopsy in men with increased prostate-specific antigen and repeated, negative, random, systematic, transrectal ultrasound biopsies: detection of clinically significant prostate cancers. Eur Urol, Epub ahead of print February 1, 2012.
15. Keetch DW, Catalona WJ and Smith DS: Serial prostatic biopsies in men with persistently elevated serum prostate specific antigen values. J Urol 1994; **151:** 1571.
16. Rabets JC, Jones JS, Patel A et al: Prostate cancer detection with office based saturation biopsy in a repeat biopsy population. J Urol 2004; **172:** 94.
17. Bott SR, Henderson A, Halls JE et al: Extensive transperineal template biopsies of prostate: modified technique and results. Urology 2006; **68:** 1037.
18. Turkbey B, Mani H, Shah V et al: Multiparametric 3T prostate magnetic resonance imaging to detect cancer: histopathological correlation using prostatectomy specimens processed in customized magnetic resonance imaging based molds. J Urol 2011; **186:** 1818.

ATTACHMENT II

MRI VOLUMES BY AGE GROUP AND SEDATION STATUS

Pedi Billable Fee Code Volume by Equipment Unit- Age Groups & Anesthesia/Sedation added

Equipment Unit	Pedi Age Group (years)	Anesthesia/ Sedation	Actual Volume (Last 4 Completed FYs)				CFY Volume
			FY 2009	FY 2010	FY 2011	FY 2012	Dec YTD FY 2013
Main Campus - New Haven							
Center 1	0-4	Anesthesia	5	32	0	0	0
		Sedation	28	2	0	0	0
		No Anes./Sed.	123	144	110	104	29
		Subtotal	*156*	*178*	*110*	*104*	*29*
	5-12	Anesthesia	6	41	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	151	115	172	115	22
		Subtotal	*157*	*156*	*172*	*115*	*22*
	13-17	Anesthesia	0	7	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	230	174	201	170	40
		Subtotal	*230*	*181*	*201*	*170*	*40*
		Anesthesia	***11***	***80***	***0***	***0***	***0***
		Sedation	***28***	***2***	***0***	***0***	***0***
		No Anes./Sed.	***504***	***433***	***483***	***389***	***91***
	Total		***543***	***515***	***483***	***389***	***91***
MR Center 2	0-4	Anesthesia	0	2	0	0	0
		Sedation	14	1	0	0	0
		No Anes./Sed.	91	35	25	34	4
		Subtotal	*105*	*38*	*25*	*34*	*4*
	5-12	Anesthesia	1	9	0	3	0
		Sedation	2	0	0	0	0
		No Anes./Sed.	142	135	121	155	29
		Subtotal	*145*	*144*	*121*	*158*	*29*
	13-17	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	176	206	207	234	72
		Subtotal	*176*	*206*	*207*	*234*	*72*
		Anesthesia	***1***	***11***	***0***	***3***	***0***
		Sedation	***16***	***1***	***0***	***0***	***0***
		No Anes./Sed.	***409***	***376***	***353***	***423***	***105***
	Total		***426***	***388***	***353***	***426***	***105***
MR Center 3	0-4	Anesthesia	4	21	0	0	0
		Sedation	46	63	0	2	0
		No Anes./Sed.	65	7	5	6	6
		Subtotal	*115*	*91*	*5*	*8*	*6*
	5-12	Anesthesia	1	45	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	227	142	142	133	28
		Subtotal	*228*	*187*	*142*	*133*	*28*
	13-17	Anesthesia	0	4	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	251	237	281	258	53
		Subtotal	*251*	*241*	*281*	*258*	*53*
		Anesthesia	***5***	***70***	***0***	***0***	***0***
		Sedation	***46***	***63***	***0***	***2***	***0***
		No Anes./Sed.	***543***	***386***	***428***	***397***	***87***
	Total		***594***	***519***	***428***	***399***	***87***

Equipment Unit	Pedi Age Group (years)	Anesthesia/ Sedation	Actual Volume (Last 4 Completed FYs)				CFY Volume
			FY 2009	FY 2010	FY 2011	FY 2012	Dec YTD FY 2013
MR Smilow 1	0-4	Anesthesia	0	0	0	0	0
(breast MR		Sedation	0	0	0	0	0
opened 12/2009)		No Anes./Sed.	0	0	0	0	0
		Subtotal	*0*	*0*	*0*	*0*	*0*
	5-12	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	0	6	15	23	1
		Subtotal	*0*	*6*	*15*	*23*	*1*
	13-17	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	0	15	22	41	15
		Subtotal	*0*	*15*	*22*	*41*	*15*
		Anesthesia	***0***	***0***	***0***	***0***	***0***
		Sedation	***0***	***0***	***0***	***0***	***0***
		No Anes./Sed.	***0***	***21***	***37***	***64***	***16***
	Total		*0*	*21*	*37*	*64*	*16*
MR Smilow 2	0-4	Anesthesia	3	248	306	272	66
		Sedation	222	228	325	297	76
		No Anes./Sed.	328	115	126	221	37
		Subtotal	*553*	*591*	*757*	*790*	*179*
	5-12	Anesthesia	2	282	360	322	67
		Sedation	0	0	1	0	0
		No Anes./Sed.	429	166	157	201	61
		Subtotal	*431*	*448*	*518*	*523*	*128*
	13-17	Anesthesia	0	33	72	44	15
		Sedation	0	0	0	0	0
		No Anes./Sed.	263	225	187	261	62
		Subtotal	*263*	*258*	*259*	*305*	*77*
		Anesthesia	***5***	***563***	***738***	***638***	***148***
		Sedation	***222***	***228***	***326***	***297***	***76***
		No Anes./Sed.	***1,020***	***506***	***470***	***683***	***160***
	Total		*1,247*	*1,297*	*1,534*	*1,618*	*384*
'milow 3	0-4	Anesthesia	0	38	51	33	12
		Sedation	0	11	17	14	0
		No Anes./Sed.	114	157	93	101	25
		Subtotal	*114*	*206*	*161*	*148*	*37*
	5-12	Anesthesia	0	39	39	33	9
		Sedation	0	0	1	0	0
		No Anes./Sed.	145	129	115	118	32
		Subtotal	*145*	*168*	*155*	*151*	*41*
	13-17	Anesthesia	0	3	15	2	2
		Sedation	0	0	0	0	0
		No Anes./Sed.	227	242	226	249	54
		Subtotal	*227*	*245*	*241*	*251*	*56*
		Anesthesia	***0***	***80***	***105***	***68***	***23***
		Sedation	***0***	***11***	***18***	***14***	***0***
		No Anes./Sed.	***486***	***528***	***434***	***468***	***111***
	Total		*486*	*619*	*557*	*550*	*134*
MR Smilow 4	0-4	Anesthesia	0	70	70	117	20
		Sedation	0	25	38	27	2
		No Anes./Sed.	0	70	71	92	40
		Subtotal	*0*	*165*	*179*	*236*	*62*
	5-12	Anesthesia	0	73	101	109	37
		Sedation	0	0	0	0	0
		No Anes./Sed.	0	146	176	190	28
		Subtotal	*0*	*219*	*277*	*299*	*65*
	13-17	Anesthesia	0	3	11	25	4
		Sedation	0	0	0	0	0
		No Anes./Sed.	0	214	260	278	54
		Subtotal	*0*	*217*	*271*	*303*	*58*
		Anesthesia	***0***	***146***	***182***	***251***	***61***
		Sedation	***0***	***25***	***38***	***27***	***2***
		No Anes./Sed.	***0***	***430***	***507***	***560***	***122***
	Total		*0*	*601*	*727*	*838*	*185*

Equipment Unit	Pedi Age Group (years)	Anesthesia/ Sedation	Actual Volume (Last 4 Completed FYs)				CFY Volume
			FY 2009	FY 2010	FY 2011	FY 2012	Dec YTD FY 2013
Temple Radiology - Guilford							
MR	0-4	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	0	0	0	0	0
		Subtotal	*0*	*0*	*0*	*0*	*0*
	5-12	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	81	65	42	50	6
		Subtotal	*81*	*65*	*42*	*50*	*6*
	13-17	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	179	180	156	166	54
		Subtotal	*179*	*180*	*156*	*166*	*54*
		Anesthesia	***0***	***0***	***0***	***0***	***0***
		Sedation	***0***	***0***	***0***	***0***	***0***
		No Anes./Sed.	***260***	***245***	***198***	***216***	***60***
	Total		*260*	*245*	*198*	*216*	*60*

Equipment Unit	Pedi Age Group (years)	Anesthesia/ Sedation	Actual Volume (Last 4 Completed FYs) FY 2009	FY 2010	FY 2011	FY 2012	CFV Volume Dec YTD FY 2013
Temple Radiology - New Haven							
MR	0-4	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	0	1	0	0	0
		Subtotal	*0*	*1*	*0*	*0*	*0*
	5-12	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	30	29	23	29	5
		Subtotal	*30*	*29*	*23*	*29*	*5*
	13-17	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	149	98	111	99	20
		Subtotal	*149*	*98*	*111*	*99*	*20*
		Anesthesia	***0***	***0***	***0***	***0***	***0***
		Sedation	***0***	***0***	***0***	***0***	***0***
		No Anes./Sed.	***179***	***128***	***134***	***128***	***25***
	Total		*179*	*128*	*134*	*128*	*25*
MR *(FONAR)*	0-4	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	0	0	0	0	0
		Subtotal	*0*	*0*	*0*	*0*	*0*
	5-12	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	3	0	3	1	0
		Subtotal	*3*	*0*	*3*	*1*	*0*
	13-17	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	6	4	3	12	0
		Subtotal	*6*	*4*	*3*	*12*	*0*
		Anesthesia	***0***	***0***	***0***	***0***	***0***
		Sedation	***0***	***0***	***0***	***0***	***0***
		No Anes./Sed.	***9***	***4***	***6***	***13***	***0***
	Total		*9*	*4*	*6*	*13*	*0*
ple Radiology - Hamden							
MR *(Hamden van replaced FONAR 8/2012)*	0-4	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	0	0	0	0	0
		Subtotal	*0*	*0*	*0*	*0*	*0*
	5-12	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	0	0	0	0	0
		Subtotal	*0*	*0*	*0*	*0*	*0*
	13-17	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	0	0	0	9	13
		Subtotal	*0*	*0*	*0*	*9*	*13*
		Anesthesia	***0***	***0***	***0***	***0***	***0***
		Sedation	***0***	***0***	***0***	***0***	***0***
		No Anes./Sed.	***0***	***0***	***0***	***9***	***13***
	Total		*0*	*0*	*0*	*9*	*13*

Equipment Unit	Pedi Age Group (years)	Anesthesia/ Sedation	Actual Volume (Last 4 Completed FYs)				CFY Volume
			FY 2009	FY 2010	FY 2011	FY 2012	Dec YTD FY 2013
Total MR	0-4	Anesthesia	12	411	427	422	98
		Sedation	310	330	380	340	78
		No Anes./Sed.	721	529	430	558	141
		Subtotal	*1,043*	*1,270*	*1,237*	*1,320*	*317*
	5-12	Anesthesia	10	489	500	467	113
		Sedation	2	0	2	0	0
		No Anes./Sed.	1,208	933	966	1,015	212
		Subtotal	*1,220*	*1,422*	*1,468*	*1,482*	*325*
	13-17	Anesthesia	0	50	98	71	21
		Sedation	0	0	0	0	0
		No Anes./Sed.	1,481	1,595	1,654	1,777	437
		Subtotal	*1,481*	*1,645*	*1,752*	*1,848*	*458*
		Anesthesia	***22***	***950***	***1,025***	***960***	***232***
		Sedation	***312***	***330***	***382***	***340***	***78***
		No Anes./Sed.	***3,410***	***3,057***	***3,050***	***3,350***	***790***
	Total		***3,744***	*4,337*	*4,457*	*4,650*	***1,100***

Pedi Billable Fee Code Volume by Patient Status- Age Groups & Anesthesia/Sedation added

Patient Status	Pedi Age Group (years)	Anesthesia/ Sedation	Actual Volume (Last 4 Completed FYs)				CFY Volume
			FY 2009	FY 2010	FY 2011	FY 2012	Dec YTD FY 2013
ED	0-4	Anesthesia	0	0	1	4	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	2	10	12	25	9
		Subtotal	*2*	*10*	*13*	*29*	*9*
	5-12	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	10	16	39	80	19
		Subtotal	*10*	*16*	*39*	*80*	*19*
	13-17	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	35	31	78	85	24
		Subtotal	*35*	*31*	*78*	*85*	*24*
		Anesthesia	***0***	***0***	***1***	***4***	***0***
		Sedation	***0***	***0***	***0***	***0***	***0***
		No Anes./Sed.	***47***	***57***	***129***	***190***	***52***
	Total		*47*	*57*	*130*	*194*	*52*
IP	0-4	Anesthesia	4	65	75	93	16
		Sedation	43	34	32	35	8
		No Anes./Sed.	310	361	294	389	92
		Subtotal	*357*	*460*	*401*	*517*	*116*
	5-12	Anesthesia	2	47	68	52	6
		Sedation	1	0	1	0	0
		No Anes./Sed.	169	225	181	175	51
		Subtotal	*172*	*272*	*250*	*227*	*57*
	13-17	Anesthesia	0	11	26	12	3
		Sedation	0	0	0	0	0
		No Anes./Sed.	231	291	262	321	86
		Subtotal	*231*	*302*	*288*	*333*	*89*
		Anesthesia	***6***	***123***	***169***	***157***	***25***
		Sedation	***44***	***34***	***33***	***35***	***8***
		No Anes./Sed.	***710***	***877***	***737***	***885***	***229***
	Total		*760*	*1,034*	*939*	*1,077*	*262*
OP	0-4	Anesthesia	8	346	351	325	82
		Sedation	267	296	348	305	70
		No Anes./Sed.	409	158	124	144	40
		Subtotal	*684*	*800*	*823*	*774*	*192*
	5-12	Anesthesia	8	442	432	415	107
		Sedation	1	0	1	0	0
		No Anes./Sed.	1,029	692	746	760	142
		Subtotal	*1,038*	*1,134*	*1,179*	*1,175*	*249*
	13-17	Anesthesia	0	39	72	59	18
		Sedation	0	0	0	0	0
		No Anes./Sed.	1,215	1,273	1,314	1,371	327
		Subtotal	*1,215*	*1,312*	*1,386*	*1,430*	*345*
		Anesthesia	***16***	***827***	***855***	***799***	***207***
		Sedation	***268***	***296***	***349***	***305***	***70***
		No Anes./Sed.	***2,653***	***2,123***	***2,184***	***2,275***	***509***
	Total		*2,937*	*3,246*	*3,388*	*3,379*	*786*
Total MR	0-4	Anesthesia	12	411	427	422	98
		Sedation	310	330	380	340	78
		No Anes./Sed.	721	529	430	558	141
		Subtotal	*1,043*	*1,270*	*1,237*	*1,320*	*317*
	5-12	Anesthesia	10	489	500	467	113
		Sedation	2	0	2	0	0
		No Anes./Sed.	1,208	933	966	1,015	212
		Subtotal	*1,220*	*1,422*	*1,468*	*1,482*	*325*
	13-17	Anesthesia	0	50	98	71	21
		Sedation	0	0	0	0	0
		No Anes./Sed.	1,481	1,595	1,654	1,777	437
		Subtotal	*1,481*	*1,645*	*1,752*	*1,848*	*458*
		Anesthesia	***22***	***950***	***1,025***	***960***	***232***
		Sedation	***312***	***330***	***382***	***340***	***78***
		No Anes./Sed.	***3,410***	***3,057***	***3,050***	***3,350***	***790***
	Total		*3,744*	*4,337*	*4,457*	*4,650*	*1,100*

Pedi Billable Fee Code Volume by Scan/Exam Type- Age Groups & Anesthesia/Sedation added

Scan/Exam Type	Pedi Age Group (years)	Anesthesia/ Sedation	Actual Volume (Last 4 Completed FYs)				CFY Volume
			FY 2009	FY 2010	FY 2011	FY 2012	Dec YTD FY 2013
MR - Neurologic	0-4	Anesthesia	8	362	358	355	77
		Sedation	258	262	312	262	58
		No Anes./Sed.	652	502	402	519	133
		Subtotal	*918*	*1,126*	*1,072*	*1,136*	*268*
	5-12	Anesthesia	7	437	443	399	97
		Sedation	0	0	0	0	0
		No Anes./Sed.	976	721	678	722	163
		Subtotal	*983*	*1,158*	*1,121*	*1,121*	*260*
	13-17	Anesthesia	0	46	82	62	19
		Sedation	0	0	0	0	0
		No Anes./Sed.	894	982	1,036	1,128	249
		Subtotal	*894*	*1,028*	*1,118*	*1,190*	*268*
		Anesthesia	***15***	***845***	***883***	***816***	***193***
		Sedation	***258***	***262***	***312***	***262***	***58***
		No Anes./Sed.	***2,522***	***2,205***	***2,116***	***2,369***	***545***
	Total		***2,795***	***3,312***	***3,311***	***3,447***	***796***
MR - Musculoskeletal	0-4	Anesthesia	2	9	9	13	3
		Sedation	13	13	6	14	5
		No Anes./Sed.	17	2	1	9	1
		Subtotal	*32*	*24*	*16*	*36*	*9*
	5-12	Anesthesia	0	15	12	16	1
		Sedation	1	0	2	0	0
		No Anes./Sed.	146	131	150	164	26
		Subtotal	*147*	*146*	*164*	*180*	*27*
	13-17	Anesthesia	0	3	12	8	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	465	436	417	411	106
		Subtotal	*465*	*439*	*429*	*419*	*106*
		Anesthesia	***2***	***27***	***33***	***37***	***4***
		Sedation	***14***	***13***	***8***	***14***	***5***
		No Anes./Sed.	***628***	***569***	***568***	***584***	***133***
	Total		***644***	***609***	***609***	***635***	***142***
MR - Body	0-4	Anesthesia	2	29	41	35	10
		Sedation	39	54	62	64	15
		No Anes./Sed.	42	21	19	20	5
		Subtotal	*83*	*104*	*122*	*119*	*30*
	5-12	Anesthesia	2	21	34	42	9
		Sedation	1	0	0	0	0
		No Anes./Sed.	52	62	105	96	22
		Subtotal	*55*	*83*	*139*	*138*	*31*
	13-17	Anesthesia	0	0	1	1	1
		Sedation	0	0	0	0	0
		No Anes./Sed.	72	136	162	193	77
		Subtotal	*72*	*136*	*163*	*194*	*78*
		Anesthesia	***4***	***50***	***76***	***78***	***20***
		Sedation	***40***	***54***	***62***	***64***	***15***
		No Anes./Sed.	***166***	***219***	***286***	***309***	***104***
	Total		***210***	***323***	***424***	***451***	***139***
MR - Breast	0-4	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	0	0	0	0	0
		Subtotal	*0*	*0*	*0*	*0*	*0*
	5-12	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	0	0	0	0	0
		Subtotal	*0*	*0*	*0*	*0*	*0*
	13-17	Anesthesia	0	0	0	0	0
		Sedation	0	0	0	0	0
		No Anes./Sed.	0	0	0	2	0
		Subtotal	*0*	*0*	*0*	*2*	*0*
		Anesthesia	***0***	***0***	***0***	***0***	***0***
		Sedation	***0***	***0***	***0***	***0***	***0***
		No Anes./Sed.	***0***	***0***	***0***	***2***	***0***
	Total		***0***	***0***	***0***	*2*	***0***

Pedi Billable Fee Code Volume by Scan/Exam Type- Age Groups & Anesthesia/Sedation added

Scan/Exam Type	Pedi Age Group (years)	Anesthesia/ Sedation	Actual Volume (Last 4 Completed FYs)				CFY Volume
			FY 2009	FY 2010	FY 2011	FY 2012	Dec YTD FY 2013
MR - Cardiovascular	0-4	Anesthesia	0	11	19	19	8
		Sedation	0	1	0	0	0
		No Anes./Sed.	10	4	8	10	2
		Subtotal	*10*	*16*	*27*	*29*	*10*
	5-12	Anesthesia	1	16	11	10	6
		Sedation	0	0	0	0	0
		No Anes./Sed.	34	19	33	33	1
		Subtotal	*35*	*35*	*44*	*43*	*7*
	13-17	Anesthesia	0	1	3	0	1
		Sedation	0	0	0	0	0
		No Anes./Sed.	50	41	39	43	5
		Subtotal	*50*	*42*	*42*	*43*	*6*
		Anesthesia	***1***	***28***	***33***	***29***	***15***
		Sedation	***0***	***1***	***0***	***0***	***0***
		No Anes./Sed.	***94***	***64***	***80***	***86***	***8***
	Total		*95*	*93*	*113*	*115*	*23*
Total MR	0-4	Anesthesia	12	411	427	422	98
		Sedation	310	330	380	340	78
		No Anes./Sed.	721	529	430	558	141
		Subtotal	*1,043*	*1,270*	*1,237*	*1,320*	*317*
	5-12	Anesthesia	10	489	500	467	113
		Sedation	2	0	2	0	0
		No Anes./Sed.	1,208	933	966	1,015	212
		Subtotal	*1,220*	*1,422*	*1,468*	*1,482*	*325*
	13-17	Anesthesia	0	50	98	71	21
		Sedation	0	0	0	0	0
		No Anes./Sed.	1,481	1,595	1,654	1,777	437
		Subtotal	*1,481*	*1,645*	*1,752*	*1,848*	*458*
		Anesthesia	***22***	***950***	***1,025***	***960***	***232***
		Sedation	***312***	***330***	***382***	***340***	***78***
		No Anes./Sed.	***3,410***	***3,057***	***3,050***	***3,350***	***790***
	Total		*3,744*	*4,337*	*4,457*	*4,650*	*1,100*