SHIPMAN & GOODWIN LLP®
COUNSELORS AT LAW

Vincenzo Carannante
Phone: (860) 251-5096
Fax: (860) 251-5311
vcarannante@goodwin.com
Admitted in Massachusetts, Connecticut and Rhode Island

January 15, 2016

VIA HAND DELIVERY

Kimberly R. Martone
Director of Operations
Office of Health Care Access
Department of Public Health
410 Capitol Avenue, MS#13 CMN
Hartford, CT 06134

Re: **Hartford Hospital CON Application**

Dear Ms. Martone:

On behalf of Hartford Hospital, enclosed please find a Certificate of Need Application for the acquisition of a CT and MRI scanner.

As requested, I have included 1 original and a USB flash drive containing a scanned copy of the Application in its entirety as a .pdf (Adobe) and a copy of the completed Main and Supplemental Forms in MS Word and the Financial Workbook in MS Excel. Also attached to this letter is a check for the $500.00 filing fee.

Please do not hesitate to contact me at 860-251-5096 if you have any questions.

Sincerely,

Vincenzo Carannante

VZC/kad

Enclosures

Application Checklist

Instructions:

1. Complete the following checklist and **submit** as the first page of the CON application:

☒ Attached is a paginated hard copy of the CON application (all social security numbers must be redacted), including a completed affidavit, signed and notarized by the appropriate individuals.

☒ (**New**). A completed supplemental application form specific to the proposal type, available on OHCA's website under OHCA Forms (see previous page for the list of supplemental forms).

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

☒ 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) 418-7053, at the time of the publication)*

☒ Attached is a completed Financial Worksheet (A, B or C) available at OHCA's website under OHCA Forms.

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

☒ 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; and
2. An electronic copy of the completed application forms in **MS Word** (the applications) and **MS Excel** (Financial Worksheet)

For OHCA Use Only:

Docket No.: 16-32062-CON **Check No.:** 02 1647
OHCA Verified by: SC **Date:** 1/19/16

General Information

Name of Applicant:	Name of Co-Applicant:
Hartford Hospital	

Connecticut Statute Reference:
C.G.S. 19a-638

Main Site

MAIN SITE	MEDICAID PROVIDER ID	TYPE OF FACILITY	MAIN SITE NAME
N/A	4041869	Acute Care Hospital	Hartford Hospital
STREET & NUMBER			
80 Seymour Street			
TOWN			ZIP CODE
Hartford, Connecticut			06115

Project Site

PROJECT SITE	MEDICAID PROVIDER ID	TYPE OF FACILITY	PROJECT SITE NAME
N/A	4041869	Acute Care Hospital	Hartford Hospital
STREET & NUMBER			
80 Seymour Street			
TOWN			ZIP CODE
Hartford, Connecticut			06115

Operator

OPERATING CERTIFICATE NUMBER	TYPE OF FACILITY	LEGAL ENTITY THAT WILL OPERATE OF THE FACILITY (or proposed operator)
	Acute Care Hospital	Hartford Hospital
STREET & NUMBER		
80 Seymour Street		
TOWN		ZIP CODE
Hartford, Connecticut		06115

Chief Executive

NAME		TITLE	
Stuart Markowitz		Sr. VP Hartford HealthCare and President of the Harford Region	
STREET & NUMBER			
80 Seymour Street			
TOWN		STATE	ZIP CODE
Harford		**Connecticut**	**06115**
TELEPHONE	FAX	E-MAIL ADDRESS	
860-545-2349	860-545-3622	stuart.markowitz@hhchealth.org	

		Title of Attachment:
Is the applicant an existing facility? If yes, attach a copy of the resolution of partners, corporate directors, or LLC managers, as the case may be, authorizing the project.	YES X NO ☐	N/A HHC Board approval is not required for acquisition of Equipment
Does the Applicant have non-profit status? If yes, attach documentation.	YES X NO ☐	See Exhibit 1
Identify the Applicant's ownership type.	PC ☐ LLC ☐ Corporation X	Other: _____
Applicant's Fiscal Year (mm/dd)	Start 10/01	End 09/30

Contact:

Identify a single person that will act as the contact between OHCA and the Applicant.

Contact Information			
NAME		TITLE	
Barbara A. Durdy		Director, Strategic Planning	
STREET & NUMBER			
181 Patricia Genova Boulevard			
TOWN	STATE		ZIP CODE
Newington	CT		06111
TELEPHONE	FAX		E-MAIL ADDRESS
860-972-4231	860-972-9025		barbara.durdy@hhchealth.org
RELATIONSHIP TO APPLICANT	Employee; Director, Strategic Planning		

Identify the person primarily responsible for preparation of the application (optional):

Prepared by			
NAME		TITLE	
Barbara A. Durdy		Director, Strategic Planning	
STREET & NUMBER			
181 Patricia Genova Boulevard			
TOWN	STATE		ZIP CODE
Newington	**Connecticut**		**06111**
TELEPHONE	FAX		E-MAIL ADDRESS
860-972-4231	860-972-9025		barbara.durdy@hhchealth.org
RELATIONSHIP TO APPLICANT	Employee; Director, Strategic Planning		

COPY

HARTFORD HEALTHCARE
ATTN: ACCOUNTS PAYABLE
PO BOX 5037
HARTFORD, CT 06102-5037

51-57
119

Check Number
021647
Bank of America

THE FACE OF THIS DOCUMENT HAS A COLORED BACKGROUND ON WHITE PAPER

Five hundred and 00/100 Dollars

Pay to the order of

TREASURER, STATE OF CONNECTICUT
DEPARTMENT OF PUBLIC HEALTH
DIVISION OF HEALTH SYSTEMS REGULATI
P.O. BOX 1080
HARTFORD, CT 06143--108

Date: 01/13/2016

Payment Amount: *******$500.00

VOID AFTER 90 DAYS

THE BACK OF THIS DOCUMENT CONTAINS LAID LINES AND AN ARTIFICIAL WATERMARK. HOLD AT AN ANGLE TO VIEW.

⑈021647⑈ ⑆011201539⑆ 00222026926O⑈

TREASURER, STATE OF CONNECTICUT
DEPARTMENT OF PUBLIC HEALTH
DIVISION OF HEALTH SYSTEMS REGULATI
P.O. BOX 1080
HARTFORD, CT 06143--108

Entity	Vendor ID / Location	Check Number
30100	1000071485	021647

HARTFORD HEALTHCARE

Invoice Number	Invoice Date	Gross Amount	Discount Amount	Withholding Amount	Net Amount
C100007148550000HH HH CON APPLICATION	12/17/2015	500.00			500.00

0004 (01/15/16)

HH571485 1/03	**TOTALS**	$500.00	0.00	0.00	$500.00

Affidavit

Applicant: Hartford Hospital

Project Title: Acquisition of CT Scanner and 3T MRI Scanner

I, Stuart Markowitz, Sr. VP Hartford HealthCare and President of the Hartford Region of Hartford Hospital being duly sworn, depose and state that Hartford Hospital complies with the appropriate and applicable criteria as set forth in the Sections 19a-630, 19a-637, 19a-638, 19a-639, 19a-486 and/or 4-181 of the Connecticut General Statutes.

Signature

1-13-16
Date

Subscribed and sworn to before me on 1·13·16

Martha Santilli

Notary Public/Commissioner of Superior Court

My commission expires:

MARTHA SANTILLI
NOTARY PUBLIC OF CONNECTICUT
My Commission Expires 5/31/2019

The Hartford Courant.
A TRIBUNE PUBLISHING COMPANY

Affidavit of Publication

State of Connecticut

Wednesday, December 16, 2015

County of Hartford

I, Sterling O'Keefe, do solemnly swear that I am Sales Assistant of the Hartford Courant, printed and published daily, in the state of Connecticut and that from my own personal knowledge and reference to the files of said publication the advertisement of Public Notice was inserted in the regular edition.

On date as follows: 12/14/2015, 12/15/2016, 12/16/2015

In the amount of $298.39

Mintz & Hoke

Sales Assistant
Sterling O'Keefe

Subscribed and sworn to before me on December 16, 2015

Notary Public

RENEE N. JANES
NOTARY PUBLIC
MY COMMISSION EXPIRES MAR. 31, 2018

3820094

0006 (01/15/16)

Hartford Courant media group

Publication Date: 12/14/2015

This E-Sheet confirms that the ad appeared in The Hartford Courant on the date and page indicated. You may not create derivative works, or in any way exploit or repurpose any content displayed or contained on the e-tearsheet.

Ad Number:	3820094-1	Client Name:	/ PO# Order No. 023466
Insertion Number:		Advertiser:	Mintz & Hoke (HTF)
Size:	1 x 1.33	Section/Page/Zone:	CLA/C008/MONCLA
Color Type:	B&W	Description:	Order No. 023466

CT Shops Here

Buy. Sell. Save.

To advertise, call 860-525-2525 or placeanad.courant.com

Stuff

Antiques/ Collectibles

Stuff

Wanted To Buy

ANTIQUES & OLD STUFF WANTED

Real Estate

Rentals

WEST HARTFORD

Wheels

Antiques/ Classics

HONDA PILOT EX-L SUV 2004

LEXUS LS 460 2010

AT YOUR SERVICE

At Your Service

CNA TRAINING

MAKE A CONNECTION. REAL PEOPLE, FLIRTY CHAT

MR. ROOTER PLUMBING

EXCELLENT HARDWOOD FLOORS

CITY RECYCLING

Announcements

Lost/Found

Business

Business Opportunities

Independent Auditor

Business Opportunities are available

860-241-3223

MINI COOPER S CLUBMAN 2009

MERCEDES-BENZ 380SL 1982

www.courant.com/pets

pets POWERED BY gadzoo.com

Adoption • News • Advice • More

Cats

Dogs

MIXED BREED

Auto / Truck Wanted

WE BUY CARS WE OFFER IMMEDIATE CASH PAYMENT 860-989-7600

CITY RECYCLING

Auto & SUV's

CADILLAC SRX Luxury 2011

Trucks & Vans

GMC ENVOY XL SLT 2003

HONDA CR-V SE 4WD 2011

PUBLIC NOTICES

Connecticut

Request for Information
2016 Home Energy Solutions-Income Eligible Program – Appliance Voucher Initiative Energy Efficiency Programs in Connecticut

NOTICE OF PUBLIC SALE: The following self-storage Cube contents containing household and other goods will be sold for cash by CubeSmart [167-3 Elm Street] to satisfy a lien on [December 28, 2015] at approx. 10:30am] at [www.storagetreasures.com]

Public Notice Filing for Hartford Hospital Acquisition of a CT Scanner and a 3T MRI Scanner

Statutory Reference: Connecticut General Statutes §19a-638
Applicant: Hartford Hospital
Project Address: 80 Seymour Street Hartford, Connecticut 06115
Proposal: the Applicant intends to file a Certificate of Need application with the State of Connecticut Office of Health Care Access for approval to acquire a CT scanner and a 3T MR scanner.
Capital Expenditure: $ 2,787,520

LEGAL NOTICE

Request For Quotation #03-1506

STATE OF CONNECTICUT SUPERIOR COURT JUVENILE MATTERS

ORDER OF NOTICE

INVITATION TO BID – SECURITY SYSTEM UPGRADES

Courant HomeFinder

Real estate transactions and local properties on the market.

Every Friday.

HEALTH Wednesday in LIVING.

IS YOUR JOB WORKING AGAINST YOU?

START BUILDING careerbuilder.com

0007 (01/15/16)

PUBLIC NOTICES

Connecticut

Request for Proposals
Connecticut State Department of Education
Evaluate PreService Performance Assessment & Validate Teacher and Employer Feedback Survey
1342600SGWP
Date Issued: 12/08/15 - Due Date 12/31/15

PURPOSE: To conduct an external, multi-method study of the Connecticut State Department of Education's exploratory pilot of a new in-depth preservice performance assessment and to validate two survey instruments, the New Teacher Feedback Survey and the Employer Feedback Survey. The Connecticut State Department of Education (SDE) is seeking submissions in written proposals as a competitive basis from qualified organizations to partner with the SDE in the formative evaluation of 2015-2016 implementation pilot of a preservice teacher performance assessment, as well as the validation of a feedback survey instrument for new teachers and their employers.
Font 407 at: http://www.ctdhr.ct.gov/opm/RFP_Search_Redirect.asp?RID=16148 or SDE Website: http://www.sde.ct.gov/sde/cwp/view.asp?a=2626&q=324914&sdeNav_GID=1

IMPORTANT DATES: Release December 08, 2015. Receipt of Questions: December 16, Answers to questions will be an addendum to RFP at SDE web address above. Deadline for Questions must be emailed to Amanda Turner, CEDE Talent Development E-mail: Proposal due: December 31, 2015 by 4 PM.

Proposals must be received at the address below by 4:00 p.m., Thursday, December 31, 2015.
The mailing and delivery address is:
Connecticut State Department of Education
165 Capitol Avenue, Room 231
Hartford, CT 06106
Attn: Amanda B. Turner

* Expedited services (FedEx, DHL, UPS, etc.) are acceptable providing a signed receipt identifies the delivery time prior to the above noted deadline and any other delivery for delivery is sent in accordance with this specified RFP.

Barker Mechanical, a solidly top sub-contractor and standing by support our bid for the Plumbing and Fire Protection work on the Town Hall of Connecticut New Engineering & Science Building Project #A12-0-1000 / MSC 14002-00), interested who are not already notified by the State of Connecticut Department of Administrative Services are encouraged to bid. Bid Date: Friday, December 18, 2015 at 12 PM. For more information, please contact us via email at Barker_Mechanical@hotmail.com.

NOTICE OF DISSOLUTION AND NOTICE TO CREDITORS OF OUSTOM BOTTLE, LLC

Notice is hereby given pursuant to Sections 34-212 and 34-213 of the Connecticut General Statutes, as amended, that Custom Bottle, LLC, a Connecticut limited liability company with a principal place of business in Wethersfield, Connecticut has been dissolved by resolution of its Members. Articles of Dissolution have been filed with the Secretary of the State of Connecticut as required by law.

All creditors are warned to present their claims against Custom Bottle, LLC or be barred as provided by Sections 34-212 and 34-213 of the Connecticut General Statutes. Any such claims should be presented to Robert S. Joy, Esq., Updike, Kelly & Spellacy, One Century Tower, 265 Church Street, New Haven, Connecticut 06510. Any claim shall include the amount of the claim, facts on the claim and supporting evidence. In accordance with Section 34-213 of the Connecticut General Statutes, any claim against Custom Bottle, LLC will be barred unless a proceeding to enforce the claim is commenced within three years of the publication of this notice.

LEGAL NOTICE

SUPERIOR COURT
J.D. OF NEW HAVEN
at New Haven
DOCKET NO.: NNH-CV15-6059211-S
FEBRUARY 2015
VS.
CORTHEN, MARGARET, ET AL

STATE OF CONNECTICUT
NOTICE TO MARGARET CORHEN, HER WIDOWER, HEIRS, REPRESENTATIVES AND CREDITORS, AND ALL UNKNOWN PERSONS, CLAIMING OR WHO MAY CLAIM ANY RIGHTS, TITLE, INTEREST OR ESTATE IN OR LIEN OR ENCUMBRANCE UPON THE REAL PROPERTY DESCRIBED IN THIS COMPLAINT, ADVERSE TO THE PLAINTIFF, WHETHER SUCH CLAIM OR POSSIBLE CLAIM BE VESTED OR CONTINGENT,

The Plaintiff Carlson Legacy, Inc. has named Margaret Corhen, if living or not living, and her widower, heirs, representatives and creditors, as parties defendant in the complaint which it is bringing to this above-named court seeking a foreclosure of the mortgage upon premises known as 1289 North Colony Road, Meriden, CT. The complaint is returnable to said court on September 22, 2015 and will be pursuing them in that date.

The above-named defendants think that the residence of the above-named Defendant, if living, and the identity and whereabouts of her widower and heirs, if not living, is unknown to the Plaintiff after reasonable efforts have been made to ascertain the same and have failed.

LEGAL NOTICES
CONNECTICUT LOTTERY CORPORATION
NOTICE OF START OF SCRATCH GAME

The Connecticut Lottery hereby gives notice that sales of the scratch game "Supreme Pay" (game #1430) will begin on or about 12/15/15 and continue until the game ends.

The Official Procedures for All Scratch Games will apply to this new game. These Official Procedures are available at Lottery.org. Under the "Games & Winning Numbers" tabs and from the Lottery Game Desk, 777 Brook St., Rocky Hill, CT 06067.

LEGAL NOTICE

Sealed proposals for the performance of Aerial Photogrammetric Survey and other work incidental thereto as per and in the general quantity of the proposal State-Aid Project No. 201-343 Resurfacing, Bridge Rehabilitation and Safety Improvements for Route 5 in Wethersfield and 5.0 in the town of Rocky Hill, CT, will be received at the Office of Construction, 2800 Berlin Turnpike, Newington, CT 06131-7546 until 11:00 a.m. Eastern Standard Time, December 18, 2015.

Map showing limits of aerial survey, specific control, proposal form and form of contract may be downloaded at https://ct.marylandsurveying.com/bidrooms/CT/CTDOT/45-95R

Proposals must be made upon the form furnished. No data appears in the form may be filled in or noted, and no change in the wording of the phraseology of the proposal or in the form mentioned must. Proposals that contain unauthorized additions, deletions, or qualifications will be rejected.

The Department reserves the right to reject any or all bids.

Public Notice

Notice: Parsons Brinckerhoff Inc. (PB) is releasing notice for bid invitations and bid pkg for the New Haven Rail Maintenance Facility Complex in New Haven, Connecticut. Proposal bid documents may be obtained by email inquiry to John Allen at jallen@pbworld.com. Bonding, Small, Disadvantaged, CT DOT's Small Contractor Mentor Protégé program apply. Bids are due on December 22, 2015 at 12:00 PM. All bids that were previously received based on the original bid documents and a bid due date of November 12, 2015 have been rejected.

Re: RFQ for a Design-Build Team for the Nelson Elementary School Photovoltaic Project

You are hereby invited to submit a Qualifications Statement for the above referenced project located at:

Nelson Elementary School
90 Church Street
Nelson, CT 06224

Project Description: A two photovoltaic solar panel systems to be designed and installed on the rooftops of the (2) The project site is an elementary school with a new (2014) asphalt shingle roof. Any firm submitting a proposal must meet the minimum qualifications as expressed in the RFQ.

The RFQ is available at the following link: http://www.cga.ct.gov/asp/cgabidnet.asp?pid=3400 or may be picked up at the office of Richard Hunt at the address listed below.

Qualification Statements for this project will be due on January 5, 2016 at 2:00 pm. Board of Education Offices located at 1480 Silver St. Nelson, CT 06224 Attention: Richard A. Hunt, Director of Finance & Operations.

Sealed bids must be labeled and clearly marked with the project name and to the attention of Richard Hunt.

Nelson Board of Education reserves the right to accept or reject any qualifications statements that it deems is in the best interest of Nelson Public Schools.
Nelson Public Schools is an Equal Opportunity Employer

Public Notice Filing for Hartford Hospital Acquisition of a CT Scanner and a 1T MRI Scanner

Statutory Reference: notice per section 19a-638-1(b)(2)
Applicant: Hartford Hospital
Project Address: 80 Seymour Street
Hartford, Connecticut 06115
Proposal: The applicant intends to acquire one of their mobile units with the State of Connecticut Office of Health Care Access for use and to operate a CT scanner and a 1T MRI scanner.
Capital Expenditure: $ - 0 -

courant.com NEWS UPDATES 24/7

Stuff

Antiques/ Collectibles

ART American & European based oil paintings & watercolors. Many pieces of Japanese art & artifacts. Starting at $100. 860-567-2167

Stuff

AMANA WASHER Wht. Top Load M-Size Drum $125 860.990.7414

BICYCLE GIRLS SCHWINN 17 in. like new $75 (860) 463-2179

CARPET CLEANER Rug Doctor Deep Reach Pro Pwd Feather/Bis $75 (860) 216-0888

ENTERTAINMENT UNIT solid wood 67"Hx54"Lx15"D $65 860-463-2708

GRANDFATHER CLOCK Seth Thomas, like New, Rhine Cabnt, $650 (860) Andrew 860-620-7283

ICE BUCKET Champagne & Wine w/ stand $45 860-657-3070

KEROSENE HEATER DR 660 (860) 216-0888

KEY PENDANT 18K, Tiffany $40.0, Chain 20" 27G, 860 553 2415

MICHAEL KORS GRAYSON BAG exc. cond Blk 860-736-1481

MICROWAVE Sanyo white model White $30 860 216-0888

POOL TABLE $150. 860-216-0888.

PRIBRE Louis Vuitton Bucket, $550. Mint w/box. 860-703-4143

QUEEN AIR MATTRESS w/ Fabric Frame. $45. 860-871-0655

SHED Build on site. Milford/Bethel. Free estimate. Includes base preparation. 239-3705 mainlinemaintenance.com

TREE WORK Tree take down, sterling. Tree trim, prune, stump removal. Free written estimates. 860-833-6812

TREE WORK Full tree service. Free written estimates. 860-620-0617

Wanted To Buy

1 BUY VINTAGE ELECTRONICS OLD TOYS, MILITARY, JEWELRY ADVERTISING, WEATHER, SPORTS MEMORABILIA OLD STUFF ANTIQUES, ARMY, AMPS, TUBES, HI-FI, RECEIVERS, AUDIO EQ, RADIOS, RAM, GE, SANSUI/SONY & MANY OTHER ITEMS! CALL 860-707-0500

ANTIQUES & OLD STUFF WANTED
Pottery Glass Lighting Old Toys Tools Hunting Military Tools Jewelry Watches Bi-Cars Bi-planes & many other items. "Always Analyzed" 860-614-6206

BUYING 1900'S - 1960'S. Vintage sports - Autographs - Collectibles - Costume jewelry - old pocket knives - gas signs - baseball - Football - Hockey - old equipment & Attic! 860-467-4389

BUYING MACHINIST TOOLBOXES Tools & tooling, contents of machine shops, carbide inserts and machinist tools. Call anytime 860-985-6741

BUYING OLD MAHJONG SETS Incomplete sets OK. Chinese symbol sets. 860-233-4466

CITY RECYCLING
Will buy your scrap steel, copper, aluminum cans and trucks. 30 Ferry St. Hartford. Call 860-522-9273

Announcements

Lost/Found

IMPOUND - #265 Tomcat F. Bikejerry, #266 short hair kitten F. blk, #267 short hair kitten F. tiger, #268 Lhasa X, M. black. Call 860-860-527-6300

LOST ARMY ARROWHEAD 101ST JACKET - Fort Campbell Ky. Camouflaged metal. Black name badge, can be replaced 860-567-7487 or 860-388-7412

Real Estate

Rentals

EAST GRANBY 1 & 2 BR Apartments available. Call 677-1381

HANTORD Room $120. 1bth $565 2BR $840. Well-kept, safe building, all the amenities. Parking available. No Pets. 860-549-3181

SIMSBURY 1 & 2 BR apts. Twnhses Apts. some w/ garages. Call 860-677-1381

courant.com NEWS UPDATES 24/7

WEST HARTFORD
1 large, sunny quiet apts avail in the Oakwood Ave area. Spacious floorplans and hardwood floors. Building has hot water, Laundry and storage area available. Ass good off-street parking. Starting at $495.00 rent up.
860-223-8866

Wheels

Antiques/ Classics

CADILLAC DEVILLE 1970 - $12K in convertible red with black leather interior, PW, PS, older restoration runs well, looks great. Must Sell, Garage kept, Asks $8500 860-643-7250

CHEVROLET CORVETTE 1981 $3500/0 OBO Finish on restoration 283/V-8, Manual, 860-671-0694

FORD COUPE Model A 1931 $21500 LMH Int. Exc Cond Paint & Chrome 860-930-7600

FORD DELUXE Sedan 1936 Straight six, Runs, Drives, Nice Tires, 860-836-7695

FORD MODEL A 1928 - $16500 obo, modified, mint cond, orange, runs great, Vehicle 860-644-4076

MERCEDES-BENZ 380SL 1982 $14,700.00 70,440 miles, Diamond blue, 2 tops, Always garaged, Excellent condition, Must be seen, 860-614-7788

MG MGA 1962 - $13,000 OBO Red Many spare parts, 860-428-1004

Auto / Truck Wanted

WE BUY CARS WE OFFER IMMEDIATE CASH PAYMENT
860-989-7600
ANY CONDITION!!!
$$$ Top Dollar Paid $$$

CITY RECYCLING
Will buy your scrap steel, copper, aluminum cans and trucks. 30 Ferry St. Hartford. Call 860-522-9273

Auto & SUV's

BUICK LESABRE 2002 - $3500 110,000 miles 1 owner Plainfield. 860-564-0437

CADILLAC SRX Luxury 2011 $23,995 California Car, Silver with Navy, sleep packed, excellent condition! Black with Grey Leather interior. Fully loaded, Navigation, Very clean interior. Will not last! Low miles. No accidents. One owner! 714-310-7984

CHEVROLET BLAZER 4x4 1994 - $1,900 130,000 miles 1 owner Thomaston 860-946-0971

CHRYSLER TOWN & COUNTRY 2005 - $1,400 Call Neal 860-559-0637

FORD ESCORT 1996 - $1,000 Auto, 4 cylinder. 860-559-3809

FORD EXPLORER SPORT 2002 - $3800 / 75,715 mi. 6L w. has oil loaded, 3 seats! AM/FM CD class, very good cond. 860-965-1585

FORD MUSTANG Convertible 2012 - $17,995 White, V6, AT, 19,641 mi. Ford 3 year warranty, Woman owned, Garaged, Wash, 860-573-9362

FORD MUSTANG GT 2001 - 32,000 4.6 V8 w/ Roush Charger & Mach-1 tunes! In charger pckg, car Maroon. Call James 860-613-2511

FORD TAURUS 2002 - $3000 OBO Royal Blue. New brakes, passed ez emission mar. 09 sensor. 81,000 miles, new tires, Bonne 860-482-1407 Call 860-482-5412

GMC ENVOY XL SLT 2003 $4000 Exc Cond. Heated, New Front, power window, remote start, 4wd with grey leather seats, 7, 860-214-2120

GMC SUBURBAN 1997 - 2250 New Front & Rr. 860-828-7100

HONDA ACCORD 2008 - $8900 Auto, Power Excellent condition, 4 door, 860-463-4348

HONDA CIVIC 2013 - $12939 Al. Ac., power, rear camera, bck, excellent cond., 860-647-7087

HONDA CIVIC LX 2012 - $10500 4dr Sedan, 26,xx, 30k 860-250-5153

HONDA CIVIC 2012 - $10999 Al. Ac. Pwr sdn mi. Lx, Cond. 4 door 860-463-2418

HONDA CR-V SE 4WD 2011 $14450 Excellent condition! 73K Pioneer stereo/nav. Apple/Android ready! Extra wheels/tires. 860-729-0647

Trucks & Vans

CHEVROLET ASTRO VAN 1999 - $2500 (bal). Runs good work ready extra wheels, white 860-242-8677

CHEVROLET VENTURA 2001 - $1500 OBO. Grey, will maintenance, 140,000 miles. 860-846-1169

FORD E250 Van 2000 - $6,000.0 Black with interior seats, 143K miles. 860-875-2476 ext. 103

FORD F350 2003 - $15000 0.0 diesel dually 4x4 1 owner, red behind tow mileage, excell-t with warranty 213-447-1154

HONDA PILOT EX-L SUV 2004 $9,500.00 Original owner, great mileage, 89K Exc. cond. 4 wheels drive, Engine 3.5L 347SOL V6 860-490-8179

LEXUS LS 430 2005 - $9995 126k miles, Inspected, 1 owner clean Carfax, In for power everything, green, 860-966-7122

LEXUS LS 460 2010 $39900 44K miles,brand every option, Loaded, one owner 860-210-3179

MAZDA MAZDA 3 4 Door sedan 2010 $8750 Very good condition. 860-930-1159

MAZDA MAZDA3 SI 2005 $4400.00 Hatchback, Silver, 6k Leather, Auto, A/C, Power Windows/Steering/Locks, 80K, Very Good Condition, 860-742-8436

MERCEDES-BENZ E-CLASS 350 Coupe 2012 - $31,000 Black/tan, 13Mmiles, hot, seat/sunroof/ blind, voice control, very fast and responsive, ass wired garage kept, Friends, 405-833-0464

MERCEDES-BENZ GL-CLASS 320 CDI 2008 - $23500 DIR, Mint cond, 29 in area, Fully tox, 3yr warranty, Garage kept 860-315-8455

MERCEDES-BENZ SL-CLASS 550 1986 - $18,000 49k mi, Black and burgundy/leather int, sun roof w/defroster, alarm system, fully equipped, garage kept, Fine owner, Beautiful, Well kept! 860-918-3427

MINI COOPER S CLUBMAN 2009 $10,511 / 77,055 mi, All maintenance UTD by MINI dealer, Carfx available, 860-985-4218

NISSAN ALTIMA 2014 - $19,900 4 door, 5 person, white, 4x mi, AC, pwr, abs, cond, 860-348-1101

OLDSMOBILE AURORA 1998 - $3500 V8, fast, Great performance car, Must Sell! 203-245-4531

OLDSMOBILE CALAIS 1987 - $2500 OBO, 6 cyl, cpe, very low mileage (91K) red interior, estate car, Fine notarial. This other work! Inspected, Must Sell! 203-245-4531

SUBARU OUTBACK 2.5I 2012 - $16900 OBO 31k mi, white, auto heated seats, etc., 860-830-4144

TOYOTA AVALON XLS 2006 - $4200 obo, Fully loaded, Alwhel gard, 4 new tires, 130k mi, 860-965-6141

TOYOTA CAMRY 2000 - $3900 140K mi, Runs like new, Mechanics #244

TOYOTA COROLLA LE 2003 - $3800 AT/AC, Power, 70K mi, 860-847-9242

TOYOTA TACOMA 2015 - $24500 2.1k-mi, 6 sp, man, Nav, 4x4 Limited, White, 860-575-9362, 4.0 L engine. 860-886-7122

Wednesday in LIVING.

COMMERCIAL REAL ESTATE & BUSINESS OPPORTUNITIES

Business Opportunities

★★★★★★★
Independent Auditor
Business Opportunities are available
Start or expand your current business by contracting for audits of newspapers and related products with the Hartford Courant in Central and Eastern CT. We are looking for business minded people who are ready to assume auditing responsibilities several days a week at deliveries to homes and wholesale outlets. The Courant is looking for people who can demonstrate a strong commitment to provide accurate auditing results on a consistent basis.
Auditors will need to have updated cell phone technology (Android or iPhone) that can accommodate our auditing applications.
If interested please call us at 860-241-3223

IS YOUR JOB WORKING AGAINST YOU?
START BUILDING careerbuilder.com
©2015 CareerBuilder, LLC All rights reserved.

To advertise under this banner please contact Michele Tingley at (860) 647-5401

Client Name: / PO# Order No. 023466
Advertiser: Mintz & Hoke (HTF)
Section/Page/Zone: Legals FR/C006/WEDCLA
Description: Order No. 023466
Ad Number: 3820094-1
Insertion Number:
Size: 1 x 1.33
Color Type: B&W

Hartford Courant media group
Publication Date: 12/16/2015

CTShopsHere

Buy. Sell. Save.

To advertise, call 860-525-2525
or placeanad.courant.com

Stuff

Antiques/ Collectibles

ART American & European framed oil paintings & watercolors, Many pieces of Japanese art & artifacts. Starting at $100. 860-667-2167

XMAS ILLUM. HOUSES 80+ pcs. $150. 860-871-9555

Stuff

AMANA WASHER Wht Top Load St. Steel drum $295 860.990.7949

BICYCLE GIRL'S SCHWINN 13 in. Like new $75 (860) 563-0259

CARPET CLEANER Dirt Devil Featherlite $25 (860) 216-0988.

DUNLOP WINTER TIRES 4/17" Porsche. $380 860.990.7949

ENTERTAINMENT UNIT solid wood 63x54x24 $75 860-461-2050

GRANDFATHER CLOCK Seth Thomas. Like New. Brown Color. $400 OBO. Andrew 860-224-7283

ICE BUCKET Champagne & Wine w/ stand $45 860-657-9070

KEROSENE HEATER $85 OBO (860) 216-0988

MICHAEL KORS GRAYSON BAG exc. cond Blk 860-796-3481

MICROWAVE over stove model White $70 860 216-0988.

POOL TABLE $350. 860-216-0988.

PRIUS O.E. CARGO COVER Lt Gray never used. $100 860.990.7949

QUEEN AIR MATTRESS w/ Folding Frame. $15. 860-871-9555

SAAB RIMS 4/5 spoke, size 6.5/1 Jx16" $380 860.990.7949

SHED Built on site Milled Lumber Free estimate. Includes base prep.860-228-2003 ctshedsbuilt onsite.com

TREE WORK Full tree service. Free written estimates. 860-633-6612

WANTED: JAZZ RECORD ALBUMS Mike @ 860-346-2003

courant.com
NEWS UPDATES 24/7

HEALTH
Wednesday in LIVING.

Wanted To Buy

1 BUY VINTAGE ELECTRONICS OLD TOYS MILITARY JEWELRY ADVERTISING WATCHES SPORTS MEMORABILIA, OLD STUFF ANTIQUES, GUITARS, AMPS, TUBE HI-FI, RECEIVERS, AUDIO EQ RADIOS, HAM, CB, SAXOPHONES & MANY OTHER OLD ITEMS! CALL 860-707-9350

ANTIQUES & OLD STUFF WANTED
Pottery Glass Lighting Old Toys Fishing Hunting Military Tools Jewelry Watches Bottles Bicycles & many other items. "Always Antiques" 860-874-8098

BUYING 1900'S - 1960'S: Vintage sports • Toys • Antiques • Costume jewelry • oil/gas/beer cans/signs • Postcards • Political • Holiday • etc • Basement & Attic • 860-817-4350

BUYING MACHINIST TOOLBOXES Tools & tooling contents of machinist shops, carbide inserts and mechanic tools, Call anytime 860-985-5780

BUYING OLD MAHJONG SETS Incomplete sets okay. Greater Hartford area. 860-231-8466

CITY RECYCLING
Will buy your scrap steel, copper, aluminum, cars and trucks. 30 Fenfry St., Hartford. Call 860-522-9273

Announcements

Lost/Found

IMPOUND - #269 Pit Mix F, wht/tan; #270 Chih. X M, blk/tan; #271 Terrier Mix M, tan/wht. Call Hartford PD 860-527-6300

IMPOUND - Chihuahua. Call Suffield ACO at 860-668-3861.

Courant HomeFinder
Real estate transactions and local properties on the market.
Every Friday.

Business

Business Opportunities

★★★★★★★

Independent Verifier Opportunities are available

Start or expand your current business by contracting to provide verification of delivery for newspapers and related products with the Hartford Courant in Central and Eastern CT. We are looking for business minded people who are ready to assume auditing responsibilities several days a week of deliveries to homes and wholesale outlets. The Courant is looking for people who can demonstrate a strong commitment to provide accurate auditing results on a consistent basis.

Auditors will need to have updated cell phone technology (Android or iPhone) that can accommodate our auditing applications, a reliable vehicle and a valid driver's license in good standing.

If interested please call us at
860-241-3223

Real Estate

Rentals

EAST GRANBY 1 & 2 BR apartments available. Call 677-1381

HARTFORD Studio $550, 1BR $685, 2BR $850. Well-kept elev building ht/hw included parking available. No Pets. 860-549-3181

SIMSBURY 1 & 2 BR apts. twnhses. flats, some w/ garages. Call 860-677-1381

WEST HARTFORD
Large sunny quiet apts lived in the Oakwood Ave area. Spacious floorplans and hardwood floors. Includes heat, hot water. Laundry and storage area available. Assigned off street parking. Starting at $895.00 and up. 860-223-8866

Auto & SUV's

BUICK LESABRE 2002 - $1500 160,000 miles, 1 owner Plantsville 860-940-9332

CADILLAC SRX Luxury 2011
$23,995 California Car, never seen snow, always garaged, excellent condition! Black with Grey Leather interior. Fully loaded. Non-smoker. Very clean interior. Well maintained. Low miles. No accidents. One owner 714-330-7088

CHEVROLET BLAZER 4x4 1994 - $1500 130,000 miles, 1 owner, Plantsville 860-940-9332

CHRYSLER TOWN & COUNTRY 2005 - $1400 Call Peter 860-599-6443

FORD ESCORT 1990 - $1500 Auto, 4 cylinder. 860-459-3800

FORD EXPLORER SPORT 2002 - $3950 LO 71K mi. Blk w/ tan int. loaded, sunroof, AM/FM CD, mass, very good cond. 860-485-1585

FORD MUSTANG GT 2001 - $2795 4.6 V8 w/ super charger & tranny tuned to charger, parts car. Manson. Call James 860-649-2031

FORD TAURUS 2002 - $3000 OBO Royal Blue, New brakes, passed emissions test, O2 sensor, 81,000 miles, new tires. Hurry 860-895-1497 Cell 860-402-5832

GMC ENVOY XL SLT 2003
$5000 Exc cond. Loaded. New trans. dealer service records avail. Red with grey leather seats 7. 860-714-2320

GMC SUBURBAN 1997 - $2250 New Plates & Int. 860-828-7600

HONDA ACCORD 2008 - $8995 Auto, Power, Excellent condition. 4 door, 860-883-6048

HONDA CIVIC 2013 - $12999 At, Ac, power, four cylinders. 30K, excellent cond., 860-647-0787

HONDA CIVIC LX 2012 - $10500 4dr sedan, at/ac, 20K 860-299-5153

HONDA CIVIC 2012 - $10999 At, AC, Pwr, 35k mi. Exc. Cond. 4 door. 860-883-6048

HONDA CR-V SE 4WD 2011
$14750 Excellent condition! 73K, Pioneer stereo/nav. Apple/Android connectivity, ext warranty available. 860-725-2860

HONDA PILOT EX-L SUV 2004
$5,500.00 Original owner great condition. 5DR EX-L gray. 4 wheels drive. Engine 3.5L 3475CC V6 857-636-8170

LEXUS LS 430 2006 - $9995 126k miles loaded, 1 owner, clean Carfax, FL car, power everything, green. 860-886-7122

LEXUS LS 460 2010
$13900 44K mi,loaded every option, pristine,one owner 860-258-5574

MAZDA MAZDA3 4 Door sedan 2010
$8750 Very good condition. 860-930-1155

MAZDA MAZDA3 SL 2005
$4400.00 Hatchback, Silver, blk Leather, Auto, A/C, Power Windows/ Steering Sunroof, 85K, Very Good Condition 860-677-0836

MERCEDES-BENZ SL-CLASS 560 1988 - $18,000 48K mi. Black ext. burgundy/leather int. sun roof, automatic, alarm system, fully equipped, garage kept. One owner. Beautiful. Well kept! 860-918-3427

MERCEDES-BENZ E-CLASS 350 Coupe 2012 - $31000 Black/ tan, 31800K mi, fwd, auto/paddle shift, voice control, very fast and responsive, exc. cond. garage kept. Franklin 860-633-4468

MERCEDES-BENZ GL-CLASS 320 CDI 2008 - $22500 OBO. Mint cond., 29 in mm. Fully ldd. 2yr. wrnty. Garage kept 860-310-8530

MINI COOPER S CLUBMAN 2009
$10335 / or BO, Fully loaded cream puff, 53,255 mi. All maintenance UTD thru MINI dealer, Cash discount, 860-989-4678

NISSAN ALTIMA 2014 - $15,300 4 door, S option, white, 8k mi, AC, pwr exc. cond. 860-349-1051

OLDSMOBILE AURORA 1998 - $1300 V-8, Tan, Great car! Reduced price. Must Sell! 203-245-4530

OLDSMOBILE CALAIS 1987 - $2590 OBO 6 cyl. cpe. very low milage (83K), red interior, estate car. Price reduced, this offer won't last long. Must Sell! 203-245-4530

SUBARU OUTBACK 2.5I 2012 - $10200 OBO 73K mi. white, auto heated seats, exc., 860-930-4898

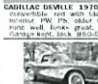
TOYOTA CAMRY 2000 - $2900 140K mi. Runs like new. 860-890-8494

TOYOTA COROLLA LE 2003 - $4999 AT/AC Power, 70K mi, 860-647-0787

TOYOTA TACOMA 2016 - $24995 5,140mi, 6 sp. man, trans. 4x4 backup camera, touch screen radio, 4.0 L engine. 860-886-7122

Antiques/ Classics

CADILLAC DEVILLE 1970 - $12500 convertible, red with black leather interior, PW, PS, older restoration, runs well, looks great. Must Sell. Garage kept. Jack 860-543-2050



CHEVROLET CORVETTE 1961 - $59000 OBO, frame off restoration. 283/245, Manson, 860-621-0694

FORD COUPE Model A 1931 - $21500 L&B int. Exc. Cond. Paint & Chrome. 860.828.7600

FORD DELUXE Sedan 1936 - $19500 New Ext. Runs Great. New Tires. 860-828-7600

FORD MODEL A 1928 - $16500 obo. modified, mint cond. orange, runs great. Vernon 860-649-4076

MERCEDES-BENZ 380SL 1982
$18,700.00 50,440 miles. Diamond blue, 2 tops. Always garaged. Excellent condition. Must be seen. 860-463-7798

MG MGA 1962 - $13000 OBO, red. Many spare parts. 860-739-1004

Trucks & Vans

CHEVROLET ASTRO VAN 1999 - $2500 (firm). Runs good, work ready racks, white. 860-262-8677

CHEVROLET VENTURE 2001 - $1850 OBO Grey, well maintained 141,000 miles. 860-384-1163

FORD E250 Van 2006 - $6,000.00 Black, with interior racks. 165K miles. 860-875-2876 ext. 101

FORD F350 2003 - $15600 6.0 diesel dually, 4x4, 1 owner red loaded, low mileage, excellent with warrantee 203-441-6154

FORD VAN Conversion 1994 - $2900 Reduced price. Great mechanic special.110K mi. 203-245-4530

Auto / Truck Wanted

WE BUY CARS
WE OFFER IMMEDIATE CASH PAYMENT
860-989-7600
ANY CONDITION!!!!!
$$$ Top Dollar Paid $$$

CITY RECYCLING
Will buy your scrap steel, copper aluminum, cars and trucks. 30 Fenfry St. Hartford. Call 860-522-9273

PUBLIC NOTICES

Connecticut

INVITATION TO BID
THE TOWN OF VERNON
FORMER AMERBELLE MILL – PHASE 1
INVITATION TO BID # 1081-01-06-16

Sealed bids for the **FORMER AMERBELLE MILL – PHASE 1** will be received by the Town of Vernon at the office of the Town Administrator, Memorial Building, 14 Park Place, 3rd Floor, Vernon, CT 06066 until **11:00 a.m. on Wednesday, January 6, 2016** and at that time and place will be publicly opened and read aloud. No emailed, faxed or bids received after 11:00 a.m. will be accepted.

The Work consists of: Complete removal of interior hazardous materials and asbestos containing building materials in preparation for demolition and renovation of abandoned buildings. The project is located at 104 East Main Street and 5 Brooklyn Street, Vernon, Connecticut and is completely described and depicted in the Contract Bid Documents. Complete sets of the Contract Bid Documents may be examined at the Town of Vernon, Office of the Town Administrator, 14 Park Place, Vernon, Connecticut 06066. Copies will be made available at a non-refundable cost of $143.51 each from Minuteman Press located at 352 Hartford Turnpike, Vernon, Connecticut. An electronic copy of the Contract Bid Documents will also be made available for viewing and/or for download at http://www.vernon-ct.gov/legal-notices, IFB#1081 and at www.DAS.CT.GOV. Bids must be enclosed in an opaque sealed envelope and plainly marked with the Project Title, **FORMER AMERBELLE MILL – PHASE 1** and shall contain the name and address of the Bidder on the envelope. Each bid shall be submitted in accordance with the Instructions to Bidders and be accompanied by a Bid Security in the amount of 5 percent of the Total Bid Price.

An Affirmative Action Plan must be filed with and approved by the CHRO prior to the commencement of construction. For construction contracts valued over $50,000, the contractor should be required to make good faith efforts to place a minimum of 25% of the subcontracts awarded by the general contractor with eligible contractors holding current certification from the DAS under the provisions of CGS 4a-60g as amended. (25% of the work with DAS certified Small and Minority owned businesses and 25% of that work with DAS certified Minority, Women and/or Disabled owned businesses.)

A mandatory pre-bid conference will be held at 104 East Main Street, Vernon, Connecticut at 10:00 a.m. on Wednesday, December 23, 2015. Attendance at the pre-bid conference by a representative of each Bidder is mandatory.

This Contract is subject to state set-aside and contract compliance requirements. The Project is subject to Prevailing Wage Rates established by the Connecticut Department of Labor.

Contact: Stephen Raymond, G2A at (603) 232-8749 for further information.

An Affirmative Action/Equal Opportunity Employer. Minority/Women's Businesses Enterprises are encouraged to apply.

Tucker Mechanical is soliciting subcontractors and vendors to support our bid for the Plumbing and Fire Protection work on the University of Connecticut New Engineering & Science Building Project #901276. WBE/MBE/DBE/SBE businesses who are currently certified by the State of Connecticut Department of Administrative Services are encouraged to bid. Bid Date: Friday, December 18, 2015 @ 12 PM. For more information please contact us via email at tucker_estimating@emcorgroup.com.
AA/EOE

LEGAL NOTICE
TOWN OF FARMINGTON, CT
ADVERTISEMENT FOR BIDS
BID # 233
UNIONVILLE SIDEWALK REPLACEMENT PROJECT

Sealed BIDS for the "Unionville Sidewalk Replacement" project will be accepted by the Finance Department at Farmington Town Hall, 1 Monteith Drive, Farmington, Connecticut 06032, until 11:00 A.M. on Wednesday January 27, 2016 at which time they will be publicly opened and read aloud.

BID documents may be examined at the Farmington Town Hall, Department of Public Works Office, 1 Monteith Dr, Farmington, CT Monday through Friday excluding holidays between the hours of 8:30 a.m. and 4:30 p.m. BID documents may be obtained at the Farmington Town Finance Office, 1 Monteith Dr, Farmington, CT, Monday through Friday excluding holidays, between the hours of 8:30 a.m. and 4:30 p.m. upon payment of $50.00 per set. Refunds will not be issued for returned sets. Bidders must obtain bid documents directly from the Finance Department in order to be eligible to bid on this project.

A mandatory pre-bid meeting for all prospective bidders is scheduled for Thursday January 7, 2016 at 1:00 PM. in the Town Council Chambers at the Farmington Town Hall.

The contract consists of providing all labor, equipment, and materials necessary for the replacement of the sidewalks on Plainville Avenue (CT Rt177) from Depot Place to West District Road. As part of an alternate this contract also may include sidewalk installation along Perry/School Street. Construction will involve the removal and installation of new concrete sidewalks and handicap ramps, and the removal and reinstallation of traffic signs.

The Town reserves the right to reject any or all BIDS, in whole or in part, to award any item, group of items or the total BID, and to waive any or all informalities or technical defects, if it is deemed by the Town to be in its best interest to do so.

This contract is subject to State of Connecticut set-aside and contract compliance requirements. The successful BIDDER is required to comply with the provisions of the Civil Rights Act of 1964, the Equal Employment Opportunity Act of 1972, Executive Orders 3, 17, 11246, 11375, 11474, State of Connecticut Set Aside Requirements and, if applicable, the Connecticut Fair Employment Practices Law.

No BIDDER may withdraw his BID within sixty (60) days from the actual date of BID opening. If for some reason the CONTRACT cannot be awarded within the specified period, the time may be extended by mutual agreement between the Town of Farmington and the designated qualified low BIDDER.

Facsimile and e-mail BIDS will not be accepted.

Public Notice Filing for Hartford Hospital Acquisition of a CT Scanner and a 3T MRI Scanner

Statutory Reference: Connecticut General Statutes §19a-638
Applicant: Hartford Hospital
Project Address: 80 Seymour Street, Hartford, Connecticut 06115
Proposal: The Applicant intends to file a Certificate of Need application with the State of Connecticut Office of Health Care Access for approval to acquire a CT scanner and a 3T MRI scanner.
Capital Expenditure: $ 7,287,[illegible]

NOTICE OF TENTATIVE DETERMINATION

The Department of Energy and Environmental Protection ("DEEP") hereby gives notice that a tentative determination has been reached to approve the following application submitted under Section 22a-208a of the Connecticut General Statutes. Subsequently, the existing Permit to Construct and Operate No. [illegible] issued on December 1, 2008 will expire upon issuance of the proposed permit.

Application No.: 201303645
Applicant's Name and Address: Murphy Road Recycling, LLC.
Contact Name and Phone No.: Jonathan Murray, Director of Operations 860-741-5027
Type of Permit: Renewal
Type of Facility: Intermediate Processing Facility
Facility Location: [illegible] Christian Lane, Berlin, CT 06037
Facility design capacity: 1,000 tons per day
Hours of operation: Monday – Saturday 5:30 a.m. – 11:00 p.m.

The facility consists of a main building with a tipping floor for receipt of source separated fiber, single stream processing area and processing equipment; a document shredding building with a tipping floor for the overflow of single stream recyclables and source separated fibers; consumer electronics storage area and a recyclables bunker; off load a vehicle equipment and maintenance building; a rail spur; a truck scale; loading docks for trucks; a concrete block wall and bunkers and an outdoor canopy structure attached to the main building to be used for the tipping of source separated fiber.

The facility may accept source separated paper and cardboard; source separated containers and single stream recyclables; plastic film; universal waste lamps and used electronics. The facility's maximum storage capacity is 10,950 cubic yards.

INFORMATION REQUESTS/PUBLIC COMMENT
Interested persons may obtain copies of the application from the applicant at the above address. The application and supporting documentation are available for inspection at the Department of Energy and Environmental Protection, Waste Engineering and Enforcement Division, Bureau of Materials Management and Compliance Assurance, 79 Elm Street, Hartford, CT from 8:30 a.m. to 4:30 p.m. Monday through Friday and at other times by appointment. All interested persons are invited to express their views on the tentative determination concerning this application. Written comments on the application should be directed to Brent Madho, Waste Engineering and Enforcement Division, Bureau of Materials Management and Compliance Assurance, Department of Energy and Environmental Protection, 79 Elm Street, Hartford, CT 06106-5127 no later than thirty (30) days from the publication date of this notice. Comments regarding this application may be submitted via electronic mail to: Brent.Madho@ct.gov.

PETITIONS FOR HEARING
The Commissioner will hold a hearing if a petition signed by no less than twenty-five (25) persons is submitted no later than thirty (30) days from the publication date of this notice. Petitions for a hearing should include the application number noted above and also identify a contact person to receive notifications. Petitions may also identify a person who is authorized to engage in discussions regarding the application and, if resolution is reached, withdraw the petition. Original petitions must be mailed or delivered within the comment period noted above to: DEEP Office of Adjudications, 79 Elm Street, 3rd floor, Hartford, CT 06106-5127. Petitions cannot be sent by fax or email. For additional information go to www.ct.gov/deep/adjudications.

The Connecticut Department of Energy and Environmental Protection is an Affirmative Action and Equal Opportunity Employer that is committed to complying with the Americans with Disabilities Act. To request an accommodation contact us at (860) 418-5910 or deep.accommodations@ct.gov.

/s/ Robert C. Isner
Robert C. Isner, Director
Waste Engineering and Enforcement Division
Bureau of Materials Management and Compliance Assurance

RETURN DATE: JANUARY 19, 2016
SUPERIOR COURT
NATIONSTAR MORTGAGE LLC F/K/A CHAMPION MORTGAGE COMPANY J.D. OF HARTFORD
VS. AT HARTFORD
WIDOWER, HEIRS, BENEFICIARIES, REPRESENTATIVES AND CREDITORS OF C.B. KELLY A/K/A CAROLE B. KELLY, DECEASED
DECEMBER 3, 2015

STATE OF CONNECTICUT
NOTICE TO WIDOWER, HEIRS, BENEFICIARIES, REPRESENTATIVES AND CREDITORS OF C.B. KELLY A/K/A CAROLE B. KELLY, DECEASED AND ALL UNKNOWN PERSON CLAIMING OR WHO MAY CLAIM ANY RIGHTS, TITLE, INTEREST OR ESTATE IN OR LIEN OR ENCUMBRANCE UPON THE REAL PROPERTY DESCRIBED IN THIS COMPLAINT, ADVERSE TO THE PLAINTIFF, WHETHER SUCH CLAIM OR POSSIBLE CLAIM BE VESTED OR CONTINGENT.

The Plaintiff has named Widower, Heirs, Beneficiaries, Representatives and Creditors of C.B. Kelly a/k/a Carole B. Kelly deceased, as parties defendant in the complaint which it is bringing to the above named court seeking a foreclosure of its mortgage upon premises known as 35 Foxcroft Drive, East Hartford, Connecticut. This complaint is returnable to court on January 19, 2016 and will be pending therein after that date.

The plaintiff has represented to said court, by means of an affidavit annexed to the said complaint, that despite all reasonable efforts to ascertain such information, it has been unable to determine the residence of the said Widower, Heirs, Beneficiaries, Representatives and Creditors of C.B. Kelly a/k/a Carole B. Kelly, deceased.

Now therefore, it is hereby ordered that notice of the institution of the action be given to each such defendant by some proper officer causing a true and attested copy of this order to be published in the HARTFORD COURANT once a week for two weeks, commencing on or before December 17, 2015 and that return of service be made to the Court.

Adam Bolowich
Assistant Clerk, Superior Court
Judicial District of HARTFORD

PROPERTY AUCTION

The Town of Newington auctioned the following properties in Newington to satisfy delinquent taxes and charges on December 8, 2015.

144 Churchill Drive owned by Hollie and Horace Henderson was sold to A127 LLC of 494 Bridgeport Avenue, Suite 101-308, Shelton CT 06484 for $84,330.00.

5 Horizon Hill Road owned by Beth A. Rohrbaugh was sold to A127, LLC of 494 Bridgeport Avenue, Suite 101-308, Shelton CT 06484 for $78,900.00.

211 Harding Avenue owned by Martin Swaim was sold to A127 LLC of 494 Bridgeport Avenue, Suite 101-308, Shelton CT 06484 for $125,000.00.

38 Summit Street owned by Antonio Tavernet, Jr. was sold to A127, LLC of 494 Bridgeport Avenue, Suite 101-308, Shelton CT 06484 for $122,000.00.

17 Brick Walk Lane owned by Richard M. Zacher was sold to Kevin Zaleski of 22 Lynn Avenue, Greenwich CT 06830 for $122,000.00.

The redemption period expires on June 8, 2016. If redemption does not take place by the date stated and in the manner provided by law, the delinquent taxpayers, and all mortgagees, lienholders and other encumbrancers who have received actual or constructive notice of such sale as provided by law, are hereby notified that their respective titles, mortgages, liens, restraints on alienation and other encumbrances in such properties shall be extinguished.

LEGAL NOTICE

Sealed proposals for the performance of Aerial Photogrammetric Survey and other work incidental thereto on and in the general vicinity of the proposed State Project No. 96-200 I-84 Resurfacing, Bridge Rehabilitation and Safety Improvements between Interchanges 9 and 10 in the town of Newtown, Connecticut, will be received by GL Companies, 355 Research Parkway, Meriden, CT 06450 Consulting Engineer, until 12:00 noon Eastern Standard Time, December 18, 2015.

Map showing limits of aerial survey, specifications, proposal form and form of contract can be downloaded at: https://lcompanies.sharefile.com/d-[illegible]

Proposals must be made upon the form provided. The blank places in the form must be filled in as noted, and no change shall be made in the phraseology of the proposal or in the items mentioned therein. Proposals that contain any omissions, alterations, additions, or items not called for in the itemized proposal, or that contain irregularities of any kind, may be rejected as non-responsive.

GL Companies reserves the right to reject any or all bids.

THE UNIVERSITY OF CONNECTICUT
REQUEST FOR STATEMENTS OF QUALIFICATION
For
ON-CALL TRADE SEWER/WATER LINE CONTRACTORS
PROJECT NUMBER 121415AA

RELEASED December 14, 2015
PROPOSALS DUE January 6, 2016 by 2:00 PM

THE UNIVERSITY OF CONNECTICUT IS AUTHORIZED TO SOLICIT EXPERIENCED FIRMS TO PROVIDE ON-CALL TRADE SEWER/WATER LINE SERVICES ON THE STORRS, HCH AND REGIONAL CAMPUSES.

TO FIND OUT MORE ABOUT THIS RFQ AND THE REQUIREMENTS FOR SUBMISSION, PLEASE VISIT OUR WEBSITE: www.cpca.uconn.edu OR www.das.ct.gov/cr1.aspx?page=12

NOTICE

RETURNED DATE: JANUARY 5, 2016

SUPERIOR COURT

J.D. OF HARTFORD

AT HARTFORD

CHRISTIANA TRUST A DIVISION OF WILMINGTON SAVINGS FUND SOCIETY, FSB, NOT IN ITS INDIVIDUAL CAPACITY BUT AS TRUSTEE OF ARLP TRUST 5

VS

THE WIDOW, HEIRS, BENEFICIARIES, DEVISEES, REPRESENTATIVES AND/OR CREDITORS OF THE ESTATE OF WILLARD L. GORTON A/K/A WILLARD GORTON A/K/A WILLARD LIVERMORE GORTON III A/K/A BILL GORTON, ET AL

STATE OF CONNECTICUT

NOTICE TO THE HEIRS, BENEFICIARIES, DEVISEES, REPRESENTATIVES AND/OR CREDITORS OF THE ESTATE OF WILLARD L. GORTON A/K/A WILLARD GORTON A/K/A LIVERMORE GORTON III A/K/A BILL GORTON

The plaintiff has named **THE WIDOW, HEIRS, BENEFICIARIES, DEVISEES, REPRESENTATIVES AND/OR CREDITORS OF THE ESTATE OF WILLARD L. GORTON A/K/A WILLARD GORTON A/K/A WILLARD LIVERMORE GORTON, III A/K/A BILL GORTON**, as parties defendant in the complaint which it is bringing to the above named court seeking a foreclosure of its mortgage upon premises known as 6 WOODS LANE, SIMSBURY, Connecticut. This complaint is returnable to court on January 5, 2016 and will be pending therein after that date.

The plaintiff has represented to said court, by means of an affidavit annexed to the said complaint, that despite all reasonable efforts to ascertain such information, it has been unable to determine the residence of the said **THE WIDOW, HEIRS, BENEFICIARIES, DEVISEES, REPRESENTATIVES AND/OR CREDITORS OF THE ESTATE OF WILLARD L. GORTON A/K/A WILLARD GORTON A/K/A WILLARD LIVERMORE GORTON, III A/K/A BILL GORTON**

Now, therefore, it is hereby ordered under C.G.S. § 52-69 that notice of the institution of this action be given to each such defendant by some proper officer causing a true and attested copy of this order to be published in **THE HARTFORD COURANT** once a week for two weeks, commencing on or before December 9, 2015 and that return of service be made to the Court.

Adam Bolowich, AC
(Please Print)
Assistant Clerk, Superior Court
Judicial District of HARTFORD

A TRUE COPY
ATTEST:

/s/ John J. Fiorillo
Connecticut State Marshal

TOWN OF SOUTHINGTON CONNECTICUT
ADVERTISEMENT FOR BIDS

Sealed Bids for the Phosphorus Removal System Equipment to be supplied as part of the "Town of Southington CT Water Pollution Control Plant Upgrade" will be received at the Office of the Town Manager, 75 Main Street, Southington, CT 06489 until 2:00 p.m. local time on January 14, 2016 at which time the Bids received will be publicly opened and read. Sealed Bids must have outer envelope marked as "Town of Southington CT Water Pollution Control Plant Upgrade Phosphorus Removal System - Town Bid No. 2015-15."

The Town will select an equipment manufacturer to provide the Phosphorus Removal System equipment to be installed as part a construction project to upgrade the Southington Water Pollution Control Plant. The selected Phosphorus Removal System will be used as the basis of design and named in the final bid documents for the Water Pollution Control Plant Upgrade Project. The successful bidder will be required to provide information requested by the Engineer to assist in preparation of the detailed design of the system for the Construction Contract Documents. The Construction Contractor selected for the future project will be required to use the successful bidder's equipment as a sole source at the fixed price given in this bid documents. The successful bidder shall be required to deliver the specified equipment for the prices quoted in this bid. If the upgrade construction contract is not awarded, the Town will have no obligation to the successful bidder.

Bidding Documents may be obtained online from the Tighe & Bond website located at http://www.tighebond.com/Projects_Out_to_Bid.php. Prospective Bidders are required to register on the Tighe & Bond website to download Bidding Documents. Sets may also be obtained at the Town of Southington's website at www.southington.org and on the State of Connecticut DAS Contracting Portal website.

Bidding Documents may be examined at the office of Tighe & Bond, Inc., 213 Court Street, Suite 1100, Middletown, Connecticut between the hours of 8:00 a.m. and 5:00 p.m., Monday through Friday, legal holidays excluded. Bidding Documents may also be examined at the office of the Town Engineer, Municipal Center, 196 North Main Street, Southington, CT 06489 between the hours of 8:30 a.m. and 4:30 p.m. Monday through Friday, legal holidays excluded.

No bid may be withdrawn until October 31, 2018.

The Town reserves the right to waive any informality in or to reject any or all bids, or to accept any Bid which in their opinion is in the public interest to do so.

TOWN OF SOUTHINGTON, CT

Executive Summary

The purpose of the Executive Summary is to give the reviewer a conceptual understanding of the proposal. In the space below, provide a succinct overview of your proposal (this may be done in bullet format). Summarize the key elements of the proposed project. Details should be provided in the appropriate sections of the application that follow.

Hartford Hospital is seeking approval from the State of Connecticut Office of Health Care Access to acquire a new CT Scanner and a 3T MRI Scanner to be located within the new Hartford Hospital Bone & Joint Institute which is currently under construction. Both scanners will provide needed imaging capability for inpatients and outpatients of the Bone & Joint Institute. The total capital cost for this project is $2,787,020.

Pursuant to Section 19a-639 of the Connecticut General Statutes, the Office of Health Care Access is required to consider specific criteria and principles when reviewing a Certificate of Need application. Text marked with a "§" indicates it is actual text from the statute and may be helpful when responding to prompts.

Project Description

1. **Provide a detailed narrative describing the proposal. Explain how the Applicant(s) determined the necessity for the proposal and discuss the benefits for each Applicant separately (if multiple Applicants). Include all key elements, including the parties involved, what the proposal will entail, the equipment/service location(s), the geographic area the proposal will serve, the implementation timeline and why the proposal is needed in the community.**

General Background: Hartford Hospital (the "Hospital" or the "Applicant") is an 867 bed acute care hospital located in Hartford, CT and is a member of Hartford HealthCare, an integrated health care delivery system. Hartford Hospital provides primary, secondary, and tertiary acute care services to the Greater Hartford region. To advance the delivery of the highest quality orthopedic services, Hartford Hospital is currently constructing a new and world-class Bone & Joint Institute on its main campus in Hartford, Connecticut (the "Bone & Joint Institute"). The Bone & Joint Institute will encompass 135,000 square feet of space dedicated to providing diagnostic, treatment, research and educational services relating to musculoskeletal disorders, including radiology services, laboratory and other diagnostic services, research laboratories, simulation laboratories, motion laboratory teaching space, approximately 75 inpatient rooms, dedicated inpatient operating rooms, physical medicine and rehabilitation space, medical office space and an outpatient ambulatory surgery center.

Most importantly, all Bone & Joint Institute clinical services will be clinically integrated within one central location so that the patient can physically navigate within the Bone & Joint Institute with ease and convenience. Essentially, there will be no reason for the patient to leave the premises of the Bone & Joint Institute to receive any of their services. This is particularly advantageous for patients who by virtue of their musculoskeletal problems often have moderate to severe mobility limitations. For example, a patient who is seen for an orthopedics consultation, may immediately proceed to have a scan or undergo diagnostic laboratory tests, proceed to a rheumatology consult, return for infusion therapy, or have inpatient or outpatient surgery, and then return for rehabilitation, all of which will be proximately located in one central location. The objective of a centralized location is to improve the patient experience so that a visit to the Bone & Joint Institute neither stresses nor exhausts the patient, especially the elderly and those in pain.

As reflected above, one of the main goals and benefits of the Bone & Joint Institute is to offer patients an unparalleled network of coordinated services for those with musculoskeletal disorders and orthopedic injuries. In furtherance of the aforementioned objectives, the Bone & Joint Institute will have and offer, as a critical component, the latest MRI and CT imaging services. Accordingly, the Hospital is seeking CON authorization to acquire a CT Scanner (the "CT Scanner") and a 3T MRI Scanner (the "MRI Scanner") (collectively, the

"Scanners") for installation and operation at the Bone & Joint Institute as described in this application (this "Proposal" or "Application").

Support for the Bone & Joint Institute:

- CT Scanner: The CT Scanner will provide needed imaging capability for inpatients and outpatients of the Bone & Joint Institute, including standard orthopedic imaging, surgical planning scans as well as computed tomography angiography ("CTA") for post-surgical follow-up of potential embolisms.

- MRI Scanner: The MRI Scanner will provide needed imaging capability for patients of the Bone & Joint Institute, including standard orthopedic imaging as well as pre-discharge and post-discharge follow-up assessment of post-surgical patients with potential complications.

Higher Quality Imaging:

- CT Scanner: As the number of people needing joint replacements keeps increasing, so does the number of people who undergo imaging procedures that have metal implants. The artifacts from metal implants can seriously degrade the quality of CT images. The CT Scanner will be capable of providing dual energy scans, which is the best method to alleviate severe artifacts associated with scans of anatomic areas containing metal. This will substantially improve the ability to evaluate joints in those patients.

- MRI Scanner: The MRI Scanner will be optimized for orthopedic exams and also include advanced techniques to reduce image degradation due to the presence of metal.

Better Patient Access, Scheduling and Overall Experience:

- CT Scanner: It is also expected that many CT scan outpatients from the Hospital's main campus will be scheduled on the new CT Scanner. Currently, Hospital outpatients requiring CTs are scanned on the Hospital's heavily scheduled inpatient scanner. Delays caused by inpatient transport, handling and medical care frequently disrupt the schedule, leading to often substantial delays in outpatient scans. The availability of the new CT Scanner will provide an easier scheduling and a better overall outpatient experience for our patient population.

- MRI Scanner: It is also expected that many MRI outpatients from the Hospital's main campus will be scheduled on the new MRI Scanner. Currently, Hospital outpatients requiring MRI services are scanned on the Hospital's two existing, heavily scheduled MRI scanners. Delays caused by inpatient transport, handling and medical care frequently disrupt the schedule, leading to often substantial delays in outpatient scans. The availability of the new MRI Scanner will provide a better scheduling and a better overall outpatient experience for our patient population.

2. **Provide the history and timeline of the proposal (i.e., When did discussions begin internally or between Applicant(s)? What have the Applicant(s) accomplished so far?).**

- In FY 2013, planning began for the establishment of the Bone & Joint Institute on the main campus of Hartford Hospital. At that time, it was anticipated that the Hospital would need to acquire the Scanners in order to accommodate MRI and CT scans for inpatients and outpatients of the Bone & Joint Institute, to alleviate the demand on the usage of other MRI and CT scanners on the Hospital's main campus, and further implement its plan to create a state of the art, all-inclusive musculoskeletal treatment center.

- On July 15, 2013, the Applicant filed a CON Application for the establishment of an ambulatory surgery center ("ASC") for the Bone & Joint Institute.

- On June 11, 2014, OHCA approved the CON Application for the establishment of the ASC. Please see Docket Number: 13-81851-CON.

- The Applicant commenced construction on the Bone & Joint Institute on January 7, 2015.

- The Applicant expects that construction of the Bone & Joint Institute will be completed and the opening of the Institute will occur in October of 2016.

3. **Provide the following information:**

   a. **utilizing OHCA Table 1, list all services to be added, terminated or modified, their physical location (street address, town and zip code), the population to be served and the existing/proposed days/hours of operation;**

      Not applicable. The Proposal is for the acquisition of equipment. The Applicant is not adding, terminating or modifying services.

   b. **identify in OHCA Table 2 the service area towns and the reason for their inclusion (e.g., provider availability, increased/decreased patient demand for service, market share);**

      Not applicable. The Proposal is for the acquisition of equipment. The Applicant is not adding, terminating or modifying services.

4. **List the health care facility license(s) that will be needed to implement the proposal;**

   Not applicable. There will be no change in licensure or the need for additional licenses as a result of this Proposal.

5. **Submit the following information as attachments to the application:**

   a. **a copy of all State of Connecticut, Department of Public Health license(s) currently held by the Applicant(s);**

      Please see Exhibit 2 attached hereto for a copy of Hartford Hospital's license issued by the State of Connecticut Department of Public Health.

   b. **a list of all key professional, administrative, clinical and direct service personnel related to the proposal and attach a copy of their Curriculum Vitae;**

      List of Key Personnel:

      - Stuart K. Markowitz, M.D., FACR (Sr. VP Hartford HealthCare and President of the Hartford Region)
      - Gerald J. Boisvert (Vice President & CFO of Hartford Hospital)
      - Michael T. O'Loughlin, M.D. (Medical Director of Computed Tomography and Magnetic Resonance Imaging at Hartford Hospital)
      - Thomas H. Farquhar, M.D., PhD (Chief of Radiology)
      - Ryan W. Kaliney, M.D. (Orthopedic Radiologist)

      Please see Exhibit 3 for their related CVs.

   c. **copies of any scholarly articles, studies or reports that support the need to establish the proposed service, along with a brief explanation regarding the relevance of the selected articles;**

      - **"Detection of Pulmonary Embolism in the Postoperative Orthopedic Patient Using Spiral CT Scans":** This article reflects the significant risk of post-operative pulmonary embolisms that are associated with orthopedic surgeries. Rapid assessment of post-surgical patients with suspected lung and other emboli through the use of the CT scanner will aid in preventing readmissions and complications post-surgery.

      - **"Value of 3D CT in Defining Skeletal Complications of Orthopedic Hardware in the Postoperative Patient":** Conventional CT scanning such as the type of CT scanning performed on the Hospital's main campus with its current CT scanner is sometimes limited for post-operative patients with metal hardware. With the progress of the three dimensional scanners, such as the CT Scanner the Applicant plans to purchase and install at the Bone & Joint Institute, CT scanning is an increasingly effective means of examining post-surgical patients for the integrity of their hardware and the course of the patient's healing.

      - **"Virtual Monochromatic Spectral Imaging with Fast Kilovoltage Switching: Reduction of Metal Artifacts at CT":** As the number of people needing joint replacements keeps increasing, so does the number of people who undergo imaging procedures that have metal implants. The artifacts from metal implants can seriously

degrade the quality of CT images. The dual energy CT Scanner proposed by the Applicant will reduce the effect/impact of these artifacts and, thus, result in better images and higher quality care.

- **"Imaging of non-osteochondral tissues in osteoarthritis":** Proper evaluation of osteoarthritis ("OA") is essential for musculo-skeletal medical care. This article reviews the literature and state-of-the-art in imaging of non-osteochandral (non-cartilage) tissues in OA. MRIs and ultrasounds are demonstrated to be the most valuable imaging techniques, with MRI particularly useful for meniscal damage and synovitis, associated with OA pain, is best assessed with contrast-enhanced MRI.

- **"MRI Evaluation of Lumbar Disc Degenerative Disease":** Lower back pain is a common orthopedic condition secondary to degenerative disc disease that affects young to middle-aged persons (peak incidence at approximately 40 years of age). MRI is the standard imaging modality for detecting disc pathology due to its advantage of lack of radiation, multiplanar imaging capability, excellent spinal soft-tissue contrast and precise localization of intervertebral discs changes.

- **"MR Imaging Tools to Assess Cartilage and Joint Structures":** MRIs provide objective data in OA and other cartilage conditions to assess not only cartilage morphology but also cartilage biochemistry and collagen orientation. This type of MRI data also provides important insight into the appropriate timing of surgical treatments aimed at delaying progression and provides noninvasive and objective assessment of cartilage repair techniques.

Please see Exhibit 4 for copies of the aforementioned articles.

d. letters of support for the proposal;

Please see Exhibit 5 attached hereto for letters in support of the Proposal.

e. the protocols or the Standard of Practice Guidelines that will be utilized in relation to the proposal. Attach copies of relevant sections and briefly describe how the Applicant proposes to meet the protocols or guidelines.

Not applicable. There are no new Standard of Practice Guidelines that will be utilized in relation to this Proposal.

f. copies of agreements (e.g., memorandum of understanding, transfer agreement, operating agreement) related to the proposal. If a final signed version is not available, provide a draft with an estimated date by which the final agreement will be available.

Please see Exhibit 6 for the proposed equipment offers/quotes from the vendor.

Public Need and Access to Care

§ *"Whether the proposed project is consistent with any applicable policies and standards adopted in regulations by the Department of Public Health;" (Conn.Gen.Stat. § 19a-639(a)(1))*

6. Describe how the proposed project is consistent with any applicable policies and standards in regulations adopted by the Connecticut Department of Public Health.

This proposal is consistent with policies and standards set forth in Connecticut General Statute Section 19a-639(a)(1) because the proposed acquisition of the Scanners will be subject to OHCA's prior approval and the Scanners will provide higher quality imaging and greater population health outcomes for the Applicant's patients.

§ *"The relationship of the proposed project to the statewide health care facilities and services plan;" (Conn.Gen.Stat. § 19a-639(a)(2))*

7. Describe how the proposed project aligns with the Connecticut Department of Public Health Statewide Health Care Facilities and Services Plan, available on OHCA's website.

This project aligns with the Statewide Health Care Facilities and Services Plan by ensuring that cost-effective and efficient imaging services are available to support the needs of all the members of the greater Hartford community and to support the advancement of high quality, well-coordinated orthopedic care.

§ *"Whether there is a clear public need for the health care facility or services proposed by the applicant;" (Conn.Gen.Stat. § 19a-639(a)(3))*

8. With respect to the proposal, provide evidence and documentation to support clear public need:

a. identify the target patient population to be served;

The population to be served is the same population currently served by the existing Hospital CT and MRI scanners. This includes patients residing within the Applicant's primary service area as well as patients referred from outside of the Applicant's primary and secondary service areas.

In the past three fiscal years, patients have undergone an average of 43,688 CT exams/scans per year on the Applicant's three current CT scanners. Excluding the older technology QX/i scanner, whose schedule is mostly filled by lengthy CT-guided interventional procedures, the Hospital's two existing CT scanners in the main department and emergency department or "ED" averaged 14,000 and 25,000 exams/year, respectively. Those volumes have increased by 8-10% per year mostly due to increased needs for inpatient and ED CT scans.

In the past three fiscal years, patients have undergone an average of 10,212 MRI exams/scans per year on the Applicant's two general purpose MRI scanners. The Hospital's two existing MRI scanners in the Radiology MRI center averaged 6,355 and 3,857exams per year, respectively. Those volumes have increased by 8-10% per year.

In addition, with the aging of Connecticut's population (See Connecticut State Health Assessment: Preliminary Findings, published by the Connecticut Department of Public Health, January 2013 http://www.ct.gov/dph/lib/dph/state_health_planning/sha-ship/coalition_kickoff/ct_sha_prelim_rev020413.pdf) and the fact that there are proportionately more residents over the age of 65 in 2010 than in 2000, the Applicant expects that the need for orthopedic scans in particular will continue to increase.

b. discuss how the target patient population is currently being served;

CT Scanning: The Hospital currently operates three CT scanners on the main campus, all of which are operating at or near capacity. Depending on the circumstance, patients requiring CT scans are scheduled on one of the Hospital's three main campus scanners. Hospital outpatients requiring CTs are scanned on the Hospital's primary, heavily scheduled inpatient scanner. Delays caused by inpatient transport, handling and medical care along with urgent scanning requests frequently disrupt the schedule and cause long delays for routine outpatient scans.

MRI Scanning: The patient population is currently being served in the Radiology MRI Center located at 85 Jefferson Street (attached to Hartford Hospital), Hartford CT, 06012. The patient population will be the same as those currently imaged with the Hospital's two existing MRI scanners, which are operating at or near capacity.

c. document the need for the equipment and/or service in the community;

CT Scanner: There is a clear public need for the proposed CT scanner for the following reasons:

- The CT Scanner will provide medically necessary imaging services to the new Bone & Joint Institute, including standard orthopedic imaging, surgical planning scans as well as CTA for post-surgical follow-up of potential embolisms.
- CTA provided by the new CT Scanner will allow rapid assessment of post-surgical patients with suspected lung and other emboli. Otherwise, such post-surgical patients would need to be transferred to the main Hospital for angiography or CTA.
- The volume of and difficulty of patients currently handled by the main Hospital's current CT scanners are such that outpatient scans are more difficult to schedule and are subject to frequent delays to transport, handling and medical care of inpatients being scanned. By augmenting existing Hospital scanning capacity, outpatients will be better served in a facility more conducive for managing outpatients.

MRI Scanner: There is clear public need for the MRI Scanner for the following reasons:

- Medically necessary orthopedic imaging services will be provided to the Bone & Joint Institute using a state-of-the-art MRI Scanner optimized for orthopedic imaging.
- As a key diagnostic tool for orthopedics, this MRI will allow for appropriate follow-up assessment without scheduling delays of both pre-discharge and post-discharge post-surgical patients exhibiting symptoms of complications.
- The MRI Scanner will provide appropriate and more timely imaging of other Hospital outpatients requiring MRI imaging. The volume of and difficulty of patients currently handled by the Hospital's existing MRI scanners are such that outpatients are difficult to schedule in a timely manner, and are subject to frequent delays due to transport, handling and medical care of inpatients needed MRI. By augmenting existing Hospital scanning capacity, outpatient will be better served in a facility more conducive for managing outpatients.

d. explain why the location of the facility or service was chosen;

The CT Scanner will allow medically necessary imaging services to be provided at the new Bone & Joint Institute, including standard orthopedic imaging and surgical planning scans. In addition, CTA for post-surgical follow-up of potential embolisms provided by the new CT Scanner will allow rapid assessment of post-surgical patients with suspected lung and other emboli. Otherwise, such post-surgical patients would need to be transferred to the main Hospital for angiography or CTA. The MRI Scanner will allow medically necessary imaging services to be provided at the new Bone & Joint Institute, including timely and appropriate follow-up of post-surgical assessment of patients returning with potential complications.

In addition, because even ambulatory orthopedic patients often have limited mobility, proximity of the needed services such as MRI or CT to the offices of patients' physicians, who will be located within/at the Bone & Joint Institute, is critical to proper patient care. Also, as a facility designed for outpatient care, availability of MRI and CT services in the Bone & Joint Institute will allow for a timelier and better experience for other Hospital outpatients requiring MRI and CT imaging.

e. provide incidence, prevalence or other demographic data that demonstrates community need;

With the aging of Connecticut's population (See Connecticut State Health Assessment: Preliminary Findings, published by the Connecticut Department of Public Health, January 2013 http://www.ct.gov/dph/lib/dph/state_health_planning/sha-ship/coalition_kickoff/ct_sha_prelim_rev020413.pdf) and the fact that there are proportionately more residents over the age of 65 in 2010 than in 2000, the Applicant expects that the need for orthopedic scans in particular will continue to increase.

f. discuss how low income persons, racial and ethnic minorities, disabled persons and other underserved groups will benefit from this proposal;

Underserved patient populations including low income persons, racial and ethnic minorities, and disabled persons will benefit by having medically necessary imaging services available in a location proximate to where they receive their orthopedic or muscular skeletal medical care.

g. list any changes to the clinical services offered by the Applicant(s) and explain why the change was necessary;

Not applicable. The Applicant currently provides MRI and CT scanning services and this will not change as a result of the Proposal.

h. explain how access to care will be affected;

The Hospital currently operates three CT scanners and two MRI scanners on the main campus, all of which are operating at or near capacity. Depending on the circumstance, patients requiring CT and/or MRI scans are scheduled on one of the Hospital's main campus scanners. Hospital outpatients requiring CTs and MRIs are scanned on the Hospital's primary, heavily scheduled inpatient scanners. Delays caused by inpatient transport, handling and medical care along with urgent scanning requests frequently disrupt the schedule and cause long delays for routine outpatient scans. Overall, access to imaging services for persons requiring CT and MRI scans will be vastly improved as the Hospital's other CT and MRI scanners are operating at or near capacity.

i. discuss any alternative proposals that were considered.

Not applicable. The Hospital has always contemplated the acquisition of a new CT and MRI Scanner as part of the Bone & Joint Institute.

§ "Whether the applicant has satisfactorily demonstrated how the proposal will improve quality, accessibility and cost effectiveness of health care delivery in the region, including, but not limited to, (A) provision of or any change in the access to services for Medicaid recipients and indigent persons; (Conn.Gen.Stat. § 19a-639(a)(5))

9. Describe how the proposal will:

a. improve the quality of health care in the region;

The quality of health care in the region will be improved as the proposed Scanners bring advanced imaging technology to the Hospital and its patients. Moreover, access for patients requiring imaging as part of an orthopedic or musculoskeletal episode of care will be greatly enhanced by having conveniently located, proximate imaging within the physical location of the Bone & Joint Institute.

The new CT Scanner will allow higher quality imaging for patients with metal implants and prostheses as the new CT Scanner will be capable of providing dual energy scans, which is the best method to alleviate severe artifacts associated with scans of anatomic areas containing metal. This will substantially improve the ability to evaluate joints in patients with implanted devices. CTA capability provided by the proposed new CT Scanner will allow rapid assessment of post-surgical patients with suspected lung and other emboli. Otherwise, such post-surgical patients would need to be transferred to the main Hospital for angiography or CTA. In addition, the Hospital's outpatients requiring CT scans will also be provided with improved care via more timely exams without delays associated with scheduling and performance of scans on existing CT scanners used predominantly for inpatient care.

In addition to standard orthopedic imaging, MRI, as a key orthopedic diagnostic tool with advanced imaging capability even near metal, will provide and allow for the appropriate follow-up assessment of post-surgical patients with potential complications. Also, by providing needed capacity, other Hospital outpatients requiring MRI scans will also be provided with improved care via more timely exams in an environment more conducive to outpatient care.

b. improve accessibility of health care in the region; and

Access to imaging services for persons requiring CT and/or MRI scans will be improved as the Hospital's existing MRI and CT scanners are operating at or near capacity. As previously stated, Hospital outpatients often experience significant scheduling delays as a result of sharing the main Hospital scanners with inpatients. In particular, access for patients requiring imaging as part of an orthopedic or musculoskeletal episode of care will be greatly enhanced by having conveniently located, proximate imaging within the physical location of the Bone & Joint Institute.

c. improve the cost effectiveness of health care delivery in the region.

To the extent that imaging will be better coordinated and integrated into the care plan for patients at the Bone & Joint Institute, the care provided will be more cost effective. Rapid assessment of post-surgical patients with suspected lung and other emboli will aid in preventing readmissions and complications post-surgery.

By providing necessary imaging services to patients of the new Bone & Joint Institute, the proposed CT Scanner will improve the financial health of the State's health care delivery system by eliminating or reducing the following costs:

- personnel costs to transport inpatients requiring imaging to the main Hospital;
- Medical costs associated with delays in evaluating post-surgical patients for potential emboli and other possible complications; and
- Retests associated with sub-optimal and/or artifact-corrupted CT images of patients with metal implants and orthopedic prostheses, by using dual energy imaging.

By providing necessary imaging services to patients of the new Bone & Joint Institute, the proposed MRI Scanner will improve the financial health of the State's health care delivery system by eliminating or reducing the following costs:

- personnel costs to transport inpatients requiring MRI imaging to the main Hospital;
- Medical costs associated with delays in evaluating both pre-discharge and post-discharge post-surgical patients for potential complications;
- Retests associated with sub-optimal and/or artifact-corrupted MRI images of patients with MRI conditional metallic implants and orthopedic prostheses by using the MAVRIC technology, which improves imaging near such metal devices.

10. How will this proposal help improve the coordination of patient care (explain in detail regardless of whether your answer is in the negative or affirmative)?

Please see response to question 9c above.

11. Describe how this proposal will impact access to care for Medicaid recipients and indigent persons.

The Bone & Joint Institute is a department of the Hospital and, thus, patients including Medicaid patients, will be subject to the Hospital's Charity Care Policy, which provides for the provision of services to patients covered by Medicare and Medicaid, as well as providing free or reduced charge services to the poor or indigent on the basis of ability to pay. Please see Exhibit 7 for a copy of the Hospital's charity care policy. Moreover, access for all patients, including Medicaid patients, requiring CT and MRI scans will be positively impacted as a result of fewer scheduling delays and more proximate access for patients receiving care at the Bone & Joint Institute.

§ "Whether an applicant, who has failed to provide or reduced access to services by Medicaid recipients or indigent persons, has demonstrated good cause for doing so, which shall not be demonstrated solely on the basis of differences in reimbursement rates between Medicaid and other health care payers;" (Conn.Gen.Stat. § 19a-639(a)(10))

12. If the proposal fails to provide or reduces access to services by Medicaid recipients or indigent persons, provide explanation of good cause for doing so.

Not applicable. This Proposal will not reduce access to services for Medicaid patients.

§ "Whether the applicant has satisfactorily demonstrated that any consolidation resulting from the proposal will not adversely affect health care costs or accessibility to care." (Conn.Gen.Stat. § 19a-639(a)(12))

13. Will the proposal adversely affect patient health care costs in any way? Quantify and provide the rationale for any changes in price structure that will result from this proposal, including, but not limited to, the addition of any imposed facility fees.

Not applicable. There will be no changes to the Hospital's price structure for imaging services as a result of this Proposal.

Financial Information

§ "Whether the applicant has satisfactorily demonstrated how the proposal will impact the financial strength of the health care system in the state or that the proposal is financially feasible for the applicant;" (Conn.Gen.Stat. § 19a-639(a)(4))

14. Describe the impact of this proposal on the financial strength of the state's health care system or demonstrate that the proposal is financially feasible for the applicant.

The proposed acquisition of the Scanners will improve the financial strength of the State's health care system by eliminating or reducing the following costs:

- Personnel costs to transport patients requiring imaging to the main Hospital campus;
- Medical costs associated with delays in evaluating post-surgical patients for potential emboli and other possible complications;
- Retests associated with sub-optimal and/or artifact-corrupted CT images of patients with metal implants and orthopedic prostheses, by using dual energy imaging;
- Medical costs associated with delays in evaluating both pre-discharge and post-discharge post-surgical patients for potential complications; and
- Retests associated with sub-optimal and/or artifact-corrupted MRI images of patients with MRI conditional metallic implants and orthopedic prostheses by using the MAVRIC technology, which improves imaging near such metal devices.

15. Provide a final version of all capital expenditure/costs for the proposal using OHCA Table 3.

Please see OHCA Table 3. In addition, please note the following:

	Equipment Cost	Construction/Renovation Costs	Total Costs
CT Scanner	$454,313.98	$149,444.00	$603,757.98
MRI Scanner	$1,745,864.80	$437,398.00	$2,183,162.80
Totals	$2,200,178.78	$586,842.00	**$2,787,020.78**

16. **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.**

The Hospital intends to fund the purchase of the proposed Scanner from operations.

17. **Include as an attachment:**

    a. **audited financial statements for the most recently completed fiscal year. If audited financial statements do not exist, provide other financial documentation (e.g., unaudited balance sheet, statement of operations, tax return, or other set of books). Connecticut hospitals required to submit annual audited financial statements may reference that filing, if current;**

The Hospital's most recent audited financial statements are on file with OHCA.

    b. **completed Financial Worksheet A (non-profit entity), B (for-profit entity) or C (§19a-486a sale), available on OHCA's website under OHCA Forms, providing a summary of revenue, expense, and volume statistics, "without the CON project," "incremental to the CON project," and "with the CON project." Note: the actual results reported in the Financial Worksheet must match the audited financial statement that was submitted or referenced.**

Please see Exhibit 8 for Financial Worksheet A.

18. **Complete OHCA Table 4 utilizing the information reported in the attached Financial Worksheet.**

Please see OHCA Table 4.

19. **Explain all assumptions used in developing the financial projections reported in the Financial Worksheet.**

Hartford Hospital operations (before CON Proposal) were calculated by using actual FY16 budget, as well as the Hartford Hospital 5-Year Forecast for FY17-FY19. It is anticipated that the Bone & Joint Institute will open in October 2016, therefore financial projections begin in FY 2017. For the CON Proposal impact, average net patient revenue per scan was determined for both CT and MRI by using actual Hartford Hospital data. Average net patient revenue was determined based on payer category by reviewing actual FY15 payments for Hartford Hospital inpatient CTs and MRIs. Once average net patient revenue numbers were ascertained by payer, the averages were applied to the associated volume presented in OHCA Table 7. Provision for bad debt was then determined by looking at bad debt averages associated with FY15 CTs and MRIs.

Annual depreciation for the Proposal's equipment (CT and MRI) was calculated by dividing the total equipment cost of $2,200,179 by a useful life of 10 years. Annual depreciation for

expected space renovation was calculated by dividing the total estimated renovation cost of $586,842 by a useful life of 10 years. Additional variable costs were considered and determined based on each incremental MRI and CT scan, using actual FY14 Hartford Hospital cost data for inpatient MRIs & CTs (latest available cost information). Variable costs considered per exam include allocations for supplies and PACS (digital image management, viewing, and storage). Starting year 2 (FY18), an annual equipment service maintenance contract was quoted at $304k for both the CT and MRI, as both pieces of equipment will be covered by warranty in year 1. Lastly, the Proposal will require 2 CT techs, 2 MRI techs, and 1 registration/receptionist earning competitive salaries and benefits.

20. Explain any projected incremental losses from operations resulting from the implementation of the CON proposal.

Not applicable as the Applicant does not project any losses from operations resulting from the implementation of this Proposal.

21. Indicate the minimum number of units required to show an incremental gain from operations for each projected fiscal year.

Breakeven Analysis

Exams Needed for Breakeven	FY17	FY18	FY19
CT	991	1,324	1,336
MRI	326	552	559

**Indicates number of exams/scans necessary to show incremental gain from operations*

Utilization

§ "The applicant's past and proposed provision of health care services to relevant patient populations and payer mix, including, but not limited to, access to services by Medicaid recipients and indigent persons;" (Conn.Gen.Stat. § 19a-639(a)(6))

22. Complete OHCA Table 5 and OHCA Table 6 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/or proposed services. Report the units by service, service type or service level.

Please see OHCA Table 5 and Table 6 for historical and projected volumes.

23. Provide a detailed explanation of all assumptions used in the derivation/ calculation of the projected service volume; explain any increases and/or decreases in volume reported in OHCA Table 5 and 6.

Prior and current volumes are taken directly from Hospital Information System. Projected volumes were estimated from actual FY15 volumes by using the volume growth observed from FY14 to FY 15. The increase in aggregate volume assumed a volume growth the same as that observed between that last two full fiscal years (FY14 and FY15). The reduction in projected volumes for all existing CT and MRI scanners (except for the emergency department CT scanner) reflects outpatient and inpatient volumes and orthopedic and spine volumes that are expected to move to the new Scanners if this Proposal is approved. Those volumes expected to move include all current non-ED CT outpatient scans, all orthopedic CT and MRI inpatient scans, 50% of existing inpatient CT spine scans, and all current MRI outpatient head scans.

24. Provide the current and projected patient population mix (number and percentage of patients by payer) for the proposal using OHCA Table 7 and provide all assumptions. Note: payer mix should be calculated from patient volumes, not patient revenues.

Please see Table 7.

> *§ "Whether the applicant has satisfactorily identified the population to be served by the proposed project and satisfactorily demonstrated that the identified population has a need for the proposed services;" (Conn.Gen.Stat. § 19a-639(a)(7))*

25. Describe the population (as identified in question 8(a)) by gender, age groups or persons with a specific condition or disorder and provide evidence (i.e., incidence, prevalence or other demographic data) that demonstrates a need for the proposed service or proposal. Please note: if population estimates or other demographic data are submitted, provide only publicly available and verifiable information (e.g., U.S. Census Bureau, Department of Public Health, CT State Data Center) and document the source.

Not applicable. This Proposal is for the acquisition of equipment and not for the addition of a new service.

26. Using OHCA Table 8, provide a breakdown of utilization by town for the most recently completed fiscal year. Utilization may be reported as number of persons, visits, scans or other unit appropriate for the information being reported.

Please see Table 8.

§ "The utilization of existing health care facilities and health care services in the service area of the applicant;" (Conn.Gen.Stat. § 19a-639(a)(8))

27. Using OHCA Table 9, identify all existing providers in the service area and, as available, list the services provided, population served, facility ID (see table footnote), address, hours/days of operation and current utilization of the facility. Include providers in the towns served or proposed to be served by the Applicant, as well as providers in towns contiguous to the service area.

Please see Table 9.

28. Describe the effect of the proposal on these existing providers.

There will be no impact on existing providers as the Hospital will be using the proposed Scanners to serve its existing patient population.

29. Describe the existing referral patterns in the area served by the proposal.

Outpatients who require imaging as part of their episode of care are referred by their attending physician.

30. Explain how current referral patterns will be affected by the proposal.

There will be no change in existing referral patterns as a result of this Proposal.

§ "Whether the applicant has satisfactorily demonstrated that the proposed project shall not result in an unnecessary duplication of existing or approved health care services or facilities;" (Conn.Gen.Stat. § 19a-639(a)(9))

31. If applicable, explain why approval of the proposal will not result in an unnecessary duplication of services.

§ "Whether the applicant has satisfactorily demonstrated that the proposal will not negatively impact the diversity of health care providers and patient choice in the geographic region;" (Conn.Gen.Stat. § 19a-639(a)(11))

Not applicable. The Hospital will be using the proposed Scanners to serve its existing patient population to alleviate capacity and scheduling issues and to provide higher quality care at the Bone & Joint Institute.

The primary purpose of the new CT Scanner is to provide needed imaging services to inpatients and outpatients of the new Bone & Joint Institute. Although the Bone & Joint Institute is on the campus of Hartford Hospital, there is not easy access to facilities of the Hospital for imaging purposes, especially for inpatients requiring post-surgical scans. The new CT Scanner also provides dual energy imaging, which alleviates severe artifacts associated with metal within the CT-scanned field of view, a frequent occurrence among

orthopedic patients. In addition, the two fully capable Hospital CT scanners are at or near capacity, making it difficult to schedule outpatients in a timely fashion and to image those patients without delays. The additional capacity that the new CT Scanner will provide will allow for a better scheduling, scanning and overall better experience for the Hospital's outpatient CT patients.

The primary purpose of the new MRI Scanner is to provide needed imaging services to inpatients and outpatients of the new Bone & Joint Institute. Although the Bone & Joint Institute is on the campus of Hartford Hospital, there is not easy access to facilities of the Hospital for imaging purposes, especially for inpatients requiring post-surgical scans. The new MRI Scanner also provides advanced technology to allow better imaging for patients with MRI-conditional metallic implants and prostheses. In addition, the two fully capable Hospital MRI scanners are at or near capacity, making it difficult to schedule outpatients in a timely fashion and to image those patients without delays. The additional capacity that the new MRI Scanner will provide will allow for a better scheduling, scanning and overall better experience for the Hospital's outpatient MRI patients.

32. How will the proposal impact the diversity of health care providers and patient choice or reduce competition in the geographic region.

Not applicable. The proposed Scanners are for the purpose of providing higher quality imaging services and better access/scheduling to said imaging services.

Tables

TABLE 1
APPLICANT'S SERVICES AND SERVICE LOCATIONS

Service	Street Address, Town	Population Served	Days/Hours of Operation	New Service or Proposed Termination
*****				

*****Not applicable. The Proposal is for the acquisition of equipment. The Applicant is not adding, terminating or modifying services.

TABLE 2
SERVICE AREA TOWNS

List the official name of town* and provide the reason for inclusion.

Town*	Reason for Inclusion
****	

* Village or place names are not acceptable.

*****Not applicable. The Proposal is for the acquisition of equipment. The Applicant is not adding, terminating or modifying services.

TABLE 3
TOTAL PROPOSAL CAPITAL EXPENDITURE

Purchase/Lease	Cost
Equipment (Medical, Non-medical, Imaging)	$2,200,178
Land/Building Purchase*	
Construction/Renovation**	$586,842
Other (specify)	
Total Capital Expenditure (TCE)	$2,787,020
Lease (Medical, Non-medical, Imaging)***	
Total Lease Cost (TLC)	
Total Project Cost (TCE+TLC)	$2,787,020

* 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.

TABLE 4
PROJECTED INCREMENTAL REVENUES AND EXPENSES

High Level Summary	FY17	FY18	FY19
Revenue from Operations (after bad debt)	$ 4,985,765	$ 5,376,344	$ 5,796,921
Total Operating Expenses	829,750	1,157,038	1,180,581
Gain/Loss from Operations	**$ 4,156,015**	**$ 4,219,306**	**$ 4,616,340**

**Fill in years using those reported in the Financial Worksheet attached.*

TABLE 5
HISTORICAL UTILIZATION BY SERVICE

Service**	Actual Volume (Last 3 Completed FYs)			CFY Volume*
	FY 2013	FY 2014	FY 2015	FY 2016****
CT Scanners:				
GE VCT- Radiology Dept	12,017	13,990	16,030	2663
GE QX/i- Radiology Dept	3856	4318	4928	831
GE VCT – ED Dept	23,196	25,929	26,803	5064
CT Total:	**39,069**	**44,237**	**47,761**	**8558**
MRI Scanners				
GE Signa Echospeed 1.5T	5993	6269	6802	1114
GE Signa Twinspeed 1.5T	3619	3854	4097	676
MRI Total:	**9613**	**10,123**	**10,899**	**1790**

* 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 6 months, report actual volume and identify the period covered.

** Identify each service type and level adding lines as necessary. Provide the number of visits or discharges as appropriate for each service type and level listed.

*** Fill in years. If the time period reported is not *identical* to the fiscal year reported in Table 4 of the application, provide the date range using the mm/dd format as a footnote to the table.

**** 09/30/2015 - 11/30/15

Table 6
Projected Utilization by Service

Service*	Projected Volume FY 2017	Projected Volume FY 2018	Projected Volume FY 2019
1. CT SCANNERS			
a. GE VCT-Radiology Dept	14,144	15,275	16,496
b. GE QX/i-Radiology Dept	4340	4697	5072
c. GE VCT – ED Dept	31,262	33,763	36,464
d. GE CT750HD 64-slice CT	5951	6427	6941
Totals	**55,697**	**60,162**	**64,973**
2. MRI SCANNERS			
a. GE Signa Echospeed 1.5T	6002	6464	6958
b. GE Signa Twinspeed 1.5T	3615	3893	4190
c. GE SIGNA Pioneer MRI	3013	3244	3492
Totals	**12,632**	**13,601**	**14,640**

* Identify each service type by location and add lines as necessary. Provide the number of visits/discharges as appropriate for each service listed.

** 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. If the time period reported is not *identical* to the fiscal year reported in Table 4 of the application, provide the date range using the mm/dd format as a footnote to the table.

Please note that the QX/i CT (scanner b. in table 6) is 15 year old scanner used primarily for CT guided procedures (biopsies, aspirations, etc), scheduled for 90 to 120 minutes each. Three to five of these procedures are scheduled per weekday. This type of utilization, along with its higher radiation doses and limited, older technology constrains the type of conventional CT exams that can be performed on this scanner.

TABLE 7
APPLICANT'S CURRENT & PROJECTED PAYER MIX

CT PAYOR MIX

	Current** FY 2016	Year 1*** FY 2017	Year 2*** FY 2018	Year 3*** FY 2019
Medicare*	44%	45%	45%	45%
Medicaid*	23%	24%	24%	24%
Other Government	1%	1%	1%	1%
Total Government	**68%**	**70%**	**70%**	**70%**
Commercial Insurers*	26%	26%	26%	26%
Uninsured/Selfpay	6%	4%	4%	4%
Workers Compensation	<1%	<1%	<1%	<1%
Total Non-Government	**32%**	**30%**	**30%**	**30%**
Total Payer Mix	**100%**	**100%**	**100%**	**100%**

MRI PAYOR MIX

	Current** FY 2016	Year 1 FY 2017	Year 2 FY 2018	Year 3 FY 2019
Medicare*	39%	38%	38%	38%
Medicaid*	21%	22%	22%	22%
Other Government	1%	1%	1%	1%
Total Government	**61%**	**61%**	**61%**	**61%**
Commercial Insurers*	33%	38%	38%	38%
Uninsured/Selfpay	6%	1%	1%	1%
Workers Compensation	<1%	<1%	<1%	<1%
Total Non-Government	**39%**	**39%**	**39%**	**39%**
Total Payer Mix	**100%**	**100%**	**100%**	**100%**

* Includes managed care activity.
** Fill in years. Ensure the period covered by this table corresponds to the period covered in the projections provided. New programs may leave the "current" column blank.
*** Based on Last Full Fiscal Year Distribution (FY 2015)

TABLE 8
UTILIZATION BY TOWN

CT EXAMS BY TOWN- FY 2015

CITY	CT EXAMS	CITY	CT EXAMS	CITY	CT EXAMS
HARTFORD	11332	EAST GRANBY	131	NORTH GRANBY	42
EAST HARTFORD	3228	STORRS MANSFIELD	130	LITCHFIELD	42
WEST HARTFORD	2236	UNIONVILLE	130	DEEP RIVER	40
WETHERSFIELD	1979	LEBANON	129	HAMPTON	39
MANCHESTER	1658	BURLINGTON	127	KENSINGTON	39
GLASTONBURY	1478	BOLTON	122	TARIFFVILLE	38
WINDSOR	1465	SOMERS	121	WOODSTOCK	38
NEWINGTON	1442	WILLINGTON	114	TAFTVILLE	38
ROCKY HILL	1346	DANIELSON	104	SALEM	37
NEW BRITAIN	1003	UNCASVILLE	100	LEDYARD	37
BLOOMFIELD	989	HIGGANUM	93	GROTON	37
SOUTH WINDSOR	959	PLAINFIELD	92	BOZRAH	37
ENFIELD	896	CHESHIRE	92	MOODUS	35
MERIDEN	892	COLUMBIA	84	PROSPECT	34
MIDDLETOWN	888	ANDOVER	82	NEW HAVEN	34
VERNON ROCKVILLE	583	MANSFIELD	81	WEST GRANBY	34
WINDSOR LOCKS	513	AMSTON	81	WATERFORD	34
BRISTOL	499	BROOKLYN	79	HAMDEN	34
TORRINGTON	468	DAYVILLE	77	CANAAN	32
COLCHESTER	371	PLANTSVILLE	73	SALISBURY	30
NORWICH	367	NORTH WINDHAM	73	STERLING	30
FARMINGTON	344	WEST SIMSBURY	72	BALTIC	29
AVON	337	SPRINGFIELD	69	FALLS VILLAGE	29
WILLIMANTIC	323	WINDHAM	66	POMFRET CENTER	28
SOUTHINGTON	321	MOOSUP	65	OAKVILLE	27
BERLIN	317	DURHAM	65	MYSTIC	27
SIMSBURY	305	MIDDLEFIELD	64	VOLUNTOWN	27
CROMWELL	287	HARWINTON	64	MILFORD	27
SUFFIELD	283	EAST HADDAM	62	EAST BERLIN	27
COVENTRY	273	OLD SAYBROOK	59	NEW MILFORD	26
WATERBURY	271	PUTNAM	58	NEW YORK	26
EAST HAMPTON	271	WEATOGUE	57	GALES FERRY	26
GRANBY	266	EAST HARTLAND	56	EASTFORD	26
WALLINGFORD	263	TERRYVILLE	55	CHAPLIN	25
TOLLAND	257	ASHFORD	55	WORCESTER	24
EAST WINDSOR	249	NAUGATUCK	54	WEST HAVEN	24
ELLINGTON	229	OLD LYME	52	MORRIS	23
SOUTH GLASTONBURY	215	HADDAM	50	THOMASTON	23
STAFFORD SPRINGS	215	OAKDALE	49	CHICOPEE	23
PLAINVILLE	206	BRIDGEPORT	48	HOLYOKE	23
PORTLAND	199	CLINTON	47	WEST CORNWALL	22
BROAD BROOK	194	NIANTIC	45	WOLCOTT	21
CANTON	187	CANTERBURY	45	SOUTHBURY	21
WINSTED	167	WEST SUFFIELD	44	WESTFIELD	21
HEBRON	157	PRESTON	43	MIDDLEBURY	20
JEWETT CITY	150	CHESTER	43	WESTBROOK	19
MARLBOROUGH	140	WATERTOWN	42	ALL OTHERS:	1886
NEW HARTFORD	136				

MRI EXAMS BY TOWN: FY 2015:

CITY	MRI Exams	CITY	MRI Exams	CITY	MRI Exams
HARTFORD	1961	CANTON	39	VOLUNTOWN	10
EAST HARTFORD	589	PORTLAND	37	WEATOGUE	10
WEST HARTFORD	437	EAST GRANBY	37	FEEDING HILLS	10
WETHERSFIELD	391	CHESHIRE	36	WEST SUFFIELD	10
MANCHESTER	389	DANIELSON	34	IVORYTON	10
WINDSOR	337	WILLINGTON	33	MADISON	10
GLASTONBURY	336	UNCASVILLE	31	NAUGATUCK	9
NEWINGTON	300	PLANTSVILLE	29	CANAAN	9
NEW BRITAIN	240	ANDOVER	27	POMFRET	9
ROCKY HILL	236	OAKDALE	27	POMFRET CENTER	9
MIDDLETOWN	224	TERRYVILLE	27	STERLING	9
SOUTH WINDSOR	213	PUTNAM	26	WESTFIELD	9
BLOOMFIELD	198	ASHFORD	26	MIDDLEFIELD	8
BRISTOL	174	NORTH WINDHAM	26	BETHLEHEM	8
MERIDEN	171	BROOKLYN	24	NORTH FRANKLIN	8
ENFIELD	165	OLD LYME	24	TARIFFVILLE	8
TORRINGTON	153	MANSFIELD	23	CLINTON	8
VERNON ROCKVILLE	141	WEST SIMSBURY	23	PROSPECT	8
NORWICH	139	PLAINFIELD	22	CHAPLIN	8
WINDSOR LOCKS	135	WINDHAM	22	RIVERTON	8
WILLIMANTIC	115	OLD SAYBROOK	21	SOUTH WINDHAM	7
COLCHESTER	113	AMSTON	21	LONGMEADOW	7
FARMINGTON	92	HARWINTON	21	BRIDGEPORT	7
AVON	91	MOOSUP	21	LUDLOW	7
SOUTHINGTON	91	DURHAM	19	WESTBROOK	7
CROMWELL	90	HIGGANUM	19	WATERFORD	7
ELLINGTON	86	HAMDEN	19	MIDDLEBURY	7
SIMSBURY	84	NEW LONDON	19	WOODSTOCK	7
COVENTRY	83	SPRINGFIELD	18	NEW HAVEN	7
JEWETT CITY	74	DAYVILLE	17	EAST BERLIN	7
BERLIN	73	BOZRAH	16	OAKVILLE	7
WATERBURY	72	PRESTON	16	NORFOLK	6
TOLLAND	71	WOLCOTT	16	HADDAM	6
EAST HAMPTON	69	CANTERBURY	15	ESSEX	6
MARLBOROUGH	69	BALTIC	15	WOODBURY	6
PLAINVILLE	66	GROTON	15	GALES FERRY	6
WALLINGFORD	62	SALEM	15	NEW MILFORD	6
GRANBY	60	TAFTVILLE	14	CENTRAL VILLAGE	5
LEBANON	57	HAMPTON	14	KENSINGTON	5
SOUTH GLASTONBURY	56	EAST HADDAM	13	TRUMBULL	5
HEBRON	56	LEDYARD	13	FAIRFIELD	5
WINSTED	52	EAST HARTLAND	13	SPRINGFIELD GARDEN:	4
BURLINGTON	46	THOMASTON	13	DANBURY	4
STAFFORD SPRINGS	44	MOODUS	12	BRATTLEBORO	4
UNIONVILLE	44	MYSTIC	12	SOUTHWICK	4
SUFFIELD	44	NORTH GRANBY	12	WEST GRANBY	4
STORRS MANSFIELD	43	GOSHEN	11	PLEASANT VALLEY	4
COLUMBIA	43	WATERTOWN	11	OXON HILL	4
BROAD BROOK	42	MORRIS	11	BRIDGEWATER	4
SOMERS	42	GRANVILLE	11	NORTHFORD	4
EAST WINDSOR	41	CHESTER	11	EAST KILLINGLY	4
BOLTON	41	LITCHFIELD	10	AGAWAM	4
NEW HARTFORD	40	SOUTHBURY	10	ALL OTHERS:	393

TABLE 9
SERVICES AND SERVICE LOCATIONS OF EXISTING PROVIDERS

Service or Program Name	Population Served	Facility ID*	Facility's Provider Name, Street Address and Town	Hours/Days of Operation	Current Utilization
See note & table below	See note & table below	See note & table below	See note & table below	See note & table below	See note & table below

* Provide the Medicare, Connecticut Department of Social Services (DSS), or National Provider Identifier (NPI) facility identifier and label column with the identifier used.

Note: Saint Francis Hospital and Medical Center, Hartford CT, the University of Connecticut Health Center, Farmington CT and Manchester Memorial Hospital, Manchester, CT have CT and MRI scanners. Other private practice imaging centers also provide CT and MRI services in the service area, but this information is not publically available.

CT Scanner*

Hospital	Inpatient	Outpatient
Saint Francis Hospital and Medical Center	18,942	24,006
University of Connecticut Health Center	3,238	9,963
Manchester Memorial Hospital	4,252	12,799

Data obtained from Patient Census Report data from the Connecticut Hospital Association (September 2015 vs. 2014 - CT Scans YTD)

MRI Scanner*

Hospital	Inpatient	Outpatient
Saint Francis Hospital and Medical Center	4,923	8,660
University of Connecticut Health Center	656	5,747
Manchester Memorial Hospital	1,173	2,638

Data obtained from Patient Census Report data from the Connecticut Hospital Association (September 2015 vs. 2014 - CT Scans YTD)

EXHIBIT

1

U. S. TREASURY DEPARTMENT
INTERNAL REVENUE SERVICE
WASHINGTON 25, D. C.

Vault

IN REPLY REFER TO
T:R:E:C:4
VCJ

JAN 6 1960

Hartford Hospital
Hartford 15, Connecticut

Gentlemen:

This refers to your letter of November 13, 1959 in which you state that you received a ruling from this office dated August 11, 1953, exempting you from Federal income tax under the provisions of section 101(6) of the Internal Revenue Code. This ruling also had the effect of affirming prior rulings dated August 28, 1934, September 19, 1938 and January 27, 1941. You are now requesting that your status be brought up to date to conform with the 1954 Code, section 501(c)(3).

Treasury Regulations prescribed under the Internal Revenue Code of 1954 provide at section 1.501(a)-1(a)(2), as amended by Treasury Decision 6391, published June 26, 1959, for situations such as yours and read, in part, as follows:

> "Subject only to the Commissioner's inherent power to revoke rulings because of a change in the law or regulations or for other good cause, an organization that has been determined by the Commissioner or the district director to be exempt under section 501(a) or the corresponding provision of prior law may rely upon such determination so long as there are no substantial changes in the organization's character, purposes, or methods of operation. An organization which has been determined to be exempt under the provisions of the Internal Revenue Code of 1939 or prior law is not required to secure a new determination of exemption merely because of the enactment of the Internal Revenue Code of 1954 unless affected by substantive changes in law made by such Code."

In view of the present Regulations you are not required to have your existing exempt status affirmed under the 1954 Code in the absence of basic changes in your organization and/or operations. If you prefer, as a matter of convenience, to have a current ruling on your

status it will be necessary for you to file a new exemption application, Form 1023, with your District Director at Hartford, Connecticut, together with all supporting documents required by the application, as well as a statement in some detail concerning your activities subsequent to 1953. Inasmuch as we have on file the copies of your charter and by-laws submitted with your prior application, further copies of these documents need not be furnished, but any amendments subsequent to July 1953 should be supplied. For your use in this connection, there are enclosed three copies of Form 1023, two executed copies of which may be filed and the third may be retained for your use.

A cursory examination of your charter shows that it does not specify that you are organized as a nonprofit charitable hospital, contains no provision requiring you to be operated to the extent of your financial ability for those not able to pay for the services rendered, and other requirements of Revenue Ruling 56-185, published in Internal Revenue Bulletin 1956-1, page 202, which establishes the criteria to be met in determining whether a hospital qualifies for exemption as an organization described in section 501(c)(3) of the 1954 Code. Further, your charter does not contain any provision impressing your assets with a trust by providing that in the event of dissolution your assets are required to be distributed for one or more of the purposes described in section 501(c)(3). In this connection your attention is invited to section 1.501(c)(3)-1(b)(6) of the Regulations which reads, in part, as follows:

> "Applicability of the organizational test. A determination by the Commissioner or a district director that an organization is described in section 501(c)(3) and exempt under section 501(a) will not be granted after July 26, 1959 (regardless of when the application is filed), unless such organization meets the organizational test prescribed by this paragraph. If, before July 27, 1959, an organization has been determined by the Commissioner or district director to be exempt as an organization described in section 501(c)(3) or in a corresponding provision of prior law and such determination has not been revoked before such date, the fact that such organization does not meet the organizational test prescribed by this paragraph shall not be a basis for revoking such determination. Accordingly, an organization which has been determined to be exempt before July 27, 1959, and which does not seek a new determination of exemption is not required to amend its articles of organiza-

tion to conform to the rules of this paragraph, but any organization which seeks a determination of exemption after July 26, 1959, must have articles of organization which meet the rules of this paragraph.
* * *"

This office is also in receipt of a communication, dated April 16, 1959, from Shipmen & Goodwin, Counselors at law, Hartford, Connecticut, submitting in your behalf a request for a ruling on certain proposed transaction contemplated by you with respect to their effect on your exempt status. You are advised that our reply to this request will be held in abeyance pending receipt of advice from you as to what further action you intend to take with regard to having your status affirmed under the Internal Revenue Code of 1954.

Your reply should also contain information concerning any implementing action which you may have taken subsequent to April 1959 with regard to the proposed transactions.

Your reply should be directed to the attention of T:R:EO:4-VCS.

Very truly yours,

G. F. Worley

Chief, Exempt Organizations Branch

Enclosure:
Form 1023 (3)

EXHIBIT

2

STATE OF CONNECTICUT

Department of Public Health

LICENSE

License No. 0046

General Hospital

In accordance with the provisions of the General Statutes of Connecticut Section 19a-493:

Hartford Hospital of Hartford, CT d/b/a Hartford Hospital is hereby licensed to maintain and operate a General Hospital.

Hartford Hospital is located at 80 Seymour Street, Hartford, CT 06106.

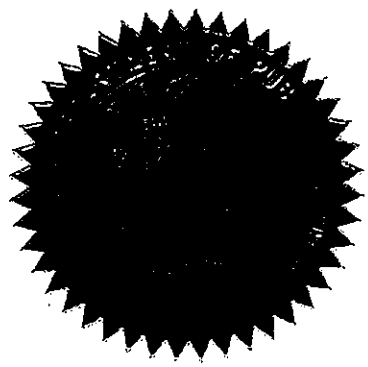
The maximum number of beds shall not exceed at any time:

48 Bassinets
819 General Hospital Beds

This license expires **December 31, 2015** and may be revoked for cause at any time.
Dated at Hartford, Connecticut, January 1, 2014.

Satellites:
West Hartford Surgery Center, 65 Memorial Road, Suite 500, West Hartford
Hartford Hospital, 505 Willard Avenue, Bldg. 3, Newington
Duncaster Primary Care Satellite, 40 Loeffler Road, Bloomfield

License revised to reflect:
*Removed (3) Satellites for Hartford Marathon effective 10/11/15.



Jewel Mullen, MD, MPH, MPA
Commissioner

EXHIBIT

3

Stuart K Markowitz, MD, FACR

66 Berwyn Road
West Hartford, CT 06107
860.313.1121
smarkow@harthosp.org

Education

Yale University and University of Pennsylvania: Visiting Fellowships in Gastrointestinal Radiology	July-October 1985
Hartford Hospital: Diagnostic Radiology Residency	1982-1985
Hartford Hospital: Flexible Internship	1981-1982
University of Health Sciences – The Chicago Medical School Degree: M.D.	1977-1981
University of Pennsylvania – Degree: B.A.	1973-1977

Professional Work Experience

Hartford Hospital: President, Hartford Hospital & Hartford Region	2013 - present
Hartford Hospital: Chief Medical Officer and Vice President	2012-2013
Jefferson Radiology: Radiologist	1985-2011

Administrative and Professional Activities

Board of Directors, VNA Healthcare	2012-present
Board of Directors, HPA and HPHO, Hartford Hospital	2012-present
Hartford Healthcare Board Quality and Safety Committee	2010-present
Hartford Hospital Board Credentialing and Quality Committee	2010-present
Board of Directors, Hartford Hospital	2010-2011
Vice President, Medical Staff, Hartford Hospital	2010-2011
Chairman, Department of Radiology, Hartford Hospital	1995-2011
Vice Chair, Department of Radiology, Hartford Hospital	1992-1995
Medical Director, Radiology Technology Program, Hartford Hospital	1990-2011
Section Chief, Gastrointestinal Radiology, Hartford Hospital	1985-2011
Section Chief, Emergency Radiology, Hartford Hospital	1992-2007
Full Time Instructor in the Diagnostic Radiology Residency Program at Hartford Hospital	1985-present

	Partner, Jefferson Radiology (Jefferson X-Ray Group)	1986-2011
	Board of Directors, Jefferson Radiology	1988-2011
	President, 937-941 Farmington Avenue Limited Partnership	1991-2011
	American College of Radiology Practice Certification Reviewer	1985-1990
	Statewide Healthcare Facilities Planning Advisory Body, Department of Public Health, CT	2010-present
	Office of Healthcare Access CON Task Force	2009-present
	Connecticut State Radiology Society Legislative Committee	2005-2009
	Hospital Committee Experience : Medical Staff Council, Executive Committee of the Medical Staff, Joint Conference Committee, Mead Fund Committee, Library Committee, Credentials Committee, Radiation Safety Committee, Radiology Management Committee, Radiology Quality Council, Risk Management Committee, Claims Review Committee, Radiology/IT Steering Committee, Reimbursement Committee, Technology Advisory Group, Endovascular Credentialing Committee, OR Committee, EMR Committee, IS Physician Advisory Committee, Tumor Board	
	Hartford Hospital CEO Advisory Body	2009-present

Certifications	Medical License – State of Massachusetts	2011
	Fellowship in the American College of Radiology: FACR	2009
	American Board of Radiology	1985
	Medical License – State of Connecticut	1983
	National Board of Medical Examiners	1982

Hospital Appointments	Hartford Hospital, Senior Attending Staff – Hartford, Connecticut
	Connecticut Children's Medical Center, Attending Staff – Hartford, Connecticut
	University of Connecticut Health Center, Assistant Clinical Professor – Farmington, Connecticut
	Johnson Memorial Hospital, Attending Staff – Stafford Springs, Connecticut
	Windham Hospital, Attending Staff – Willimantic, Connecticut
	Day Kimball Hospital, Attending Staff – Putnam, Connecticut
	Noble Hospital, Attending Staff – Westfield, Massachusetts

Current Memberships

Society of Chairman of Academic Radiology Departments
American College of Radiology
American Society of Emergency Radiology – Fellow
Radiologic Society of North America
American Roentgen Ray Society
Connecticut State Radiology Society
Society of Breast Imaging – Fellow
American College of Physician Executives

Publications

ZITER FMH, MARKOWITZ SK, ZAMSTEIN J. LARGE RENAL PELVIC DEFECTS CAUSED BY SOUGHED PAPILLA. APPLIED RADIOLOGY, NOV. 1987.

PISTOIA F AND MARKOWITZ S. SPLENIC LYMPHANGIOMATOSIS: CT DIAGNOSIS. AJR 150: 121-22, JANUARY 1988.

MARKOWITZ S AND ZITER F. THE LATERAL CHEST FILM AND PNEUMOPERITONEUM. ANNALS OF EMERGENCY MEDICINE 15:4 APRIL 1986.

JACOBS J AND MARKOWITZ S. CT DIAGNOSIS OF UTERINE LIPOMA. AJR 150:1335-1336, JUNE 1988.

WOLF S AND MARKOWITZ S. SPONTANEOUS GAS FORMATION IN A STERILE RENAL CELL CARCINOMA. UROLOGIC RADIOLOGY 9:222-224, 1988.

PISTOIA F, MARKOWITZ S, SUSSMAN S. CONTRAST MATERIAL IN POSTERIOR VAGINAL FORNIX MIMICKING BLADDER RUPTURE: CT FEATURES. JCAT 13(1):153-155 JAN/FEB 1989.

MILICI L AND MARKOWITZ S. INTRAMURAL GASTRIC PSEUDOCYST: CT DIAGNOSIS. GASTROINTESTINAL RADIOLOGY, VOL 14:113-114, 1989.

TREEM WR, MARKOWITZ SK, SULLIVAN BM, HYAMS JS. DEFECOGRAPHY IN CHILDREN WITH PROLONGED CONSTIPATION. ABSTRACT SUBMITTED AT THE NORTH AMERICAN SOCIETY FOR PEDIATRIC GASTROENTEROLOGY AND NUTRITION, 1990.

MARKOWITZ SK, ZITER FMH. RADIOLOGIC DIAGNOSIS OF BOWEL OBSTRUCTION. IN: BOWEL OBSTRUCTION, CLINICAL DIAGNOSIS AND MANAGEMENT. J. WELCH, ED. SAUNDERS, 1990.

SAWHNEY R, REES JH, MARKOWITZ SK. CLOSTRIDIAL GAS GANGRENE COMPLICATING LEUKEMIA. ABDOMINAL IMAGING 19:45102, 1994.

SCAPPATICCI F AND MARKOWITZ SK. INTRAHEPATIC PSEUDOCYST COMPLICATING ACUTE PANCREATITIS: IMAGING FINDINGS. AJR, 1995; 165:873-4.

MARKOWITZ SK. DELAYED RUPTURE OF THE GALLBLADDER: DIAGNOSIS BY ERCP. SUBMITTED FOR PUBLICATION.

MARKOWITZ SK. BILIARY OBSTRUCTION DUE TO DUODENAL DIVERTICULUM: DIAGNOSIS BY CT AND ERCP. SUBMITTED FOR PUBLICATION.

MARKOWITZ SK. LONG TERM ALIMENTATION: COMPARISON

OF INTRAVENOUS AND NASOENTERIC ALIMENTATION. WORK IN PROGRESS.

ALLMENDINGER N, HALLISEY MJ, MARKOWITZ SK, ET AL. BALLOON DILATION OF ESOPHAGEAL STRICTURES IN CHILDREN. J. OF PEDIATRIC SURGERY, VOL 31, NO 3, P334-6, MARCH 1996.

CIRAULO DL, NIKKANEN HE, PALTER M, MARKOWITZ S, ET AL. CLINICAL ANALYSIS OF THE UTILITY OF REPEAT COMPUTED TOMOGRAPHIC SCAN BEFORE DISCHARGE IN BLUNT HEPATIC INJURY. JOURNAL OF TRAUMA 41(5):821-824, NOVEMBER 1996.

MARKOWITZ SK, KIRECZYK W. RADIOLOGIC EVALUATION OF DIVERTICULAR DISEASE OF THE SMALL AND LARGE INTESTINES. IN DIVERTICULAR DISEASE: MANAGEMENT OF THE DIFFICULT SURGICAL CASE. J. WELCH, ED. WILLIAMS AND WILKINS, 1997.

Recognitions Awards

Best Doctors in Hartford, Hartford Magazine	2004-2012
Best Doctors in Connecticut, Connecticut Magazine	2010-2012

Current Work Contact Information

Stuart K Markowitz, MD, FACR
Chief Medical Officer and Vice President
Hartford Hospital
80 Seymour Street
Hartford, CT 06102

860-545-5110
smarkow@harthosp.org

Personal

Born: April 22, 1955 – Brooklyn, New York

Wife: Debra Markowitz

Children: Melissa, Jessica, Nicole, Zachary
Stepson: Devin

GERALD J. BOISVERT, CPA, FHFMA
18 Alexander Place
South Windsor, CT 06074
860-644-6491 (Home)
860-545-0585 (Work)

Work Experience

April 2013 To present	Vice President & Chief Financial Officer Harford Hospital, Hartford, Connecticut

Chief Financial Officer for 867 bed tertiary care academic medical center.

May 1997 To April 2013	Executive Vice President & Chief Financial Officer Connecticut Children's Medical Center, Hartford, Connecticut

Executive Vice President & Chief Financial Officer for Connecticut's only independent Children's Hospital, and related entities (Faculty Practice Plan, School, and Foundation). Significant operational experience includes active financial oversight of 100 plus physician practice plan. Current responsibilities include Finance and Accounting, Revenue Cycle, Strategic Planning/Project Management/Process Improvement, Purchasing/Materials Management, Environmental Services, Facilities, Food Service, and Safety/Security. Previous responsibilities included oversight of IS, Community Relations, Rehabilitation Services, Pharmacy, Radiology and other ancillary services.

April 1996 To May 1997	Vice President, Finance and Chief Financial Officer US HomeCare Corp., Hartford, Connecticut

Chief Financial Officer, reporting directly to the Chairman of the Board for publicly traded home care company. Responsibilities included direct supervision of accounting department, MIS department, and human resources department. Also responsible for investor relations, corporate secretary functions, SEC reporting, Medicare cost reporting, treasury and banking relationships. Worked in a turnaround/restructuring mode with crises management team and banks to stabilize and prepare company for sale.

August 1992 To April 1996	Senior Vice President, Finance Windham Community Memorial Hospital Willimantic, Connecticut

Chief Financial Officer of 130-bed, acute care hospital, reporting to the President & CEO. Responsible for the following functions: Finance, Billing, Admitting/Registration, MIS, Medical Records, Personnel and Purchasing departments. Significant focus and

involvement with third party reimbursement, regulatory issues, banking/financing matters and union negotiations.

April 1988 To August 1992 — **Executive Vice President – Finance and Administration, Alden Design, Inc., Glastonbury, Connecticut**

Chief Financial and Administrative Officer of multi-location, full service communications company providing communications, consulting and production services to Fortune 1000 companies. Specific areas of responsibility included cash management, accounting, strategic planning, budgeting, human resources administration and company marketing/advertising.

September 1980 To April 1988 — **Senior Manager, Ernst & Whinney, Hartford, Connecticut**

Certified Public Accountant. Responsible for audit and special project consulting engagements for companies involved in manufacturing, banking, health care, education and non-profit services.

July 1979 To September 1980 — **Advanced Staff Accountant, Wolf & Company, Boston, Massachusetts**

Staff accountant for regional accounting firm located in Massachusetts. Served as staff accountant and in-charge accountant on savings bank, construction and small business audit engagements.

Education

Boston University School of Management
B.S. in Business Administration

Professional

Certified Public Accountant
Fellow, Health Care Financial Management Association

Member: American Institute of Certified Public Accountants; Connecticut Society of Certified Public Accountants; Health Care Financial Management Association; American College of Healthcare Executives

Community Service

Former Board Member and Finance Committee Chair of University of St. Joseph; Treasurer and member of the Board of Directors of the Capital Area Health Consortium; member of Committee of Hospital Finance for The Connecticut Hospital Association;

18 Alexander Place · South Windsor, Connecticut 06074
Home: 860-644-6491 · Work: 860-545-8557

Community Service - continued

Former President and former Treasurer of Southside Institution Neighborhood Alliance (SINA) and former Chairman of the Board of The Learning Corridor Corporation; former Finance Chairman and Personnel Chairman of Canon Greater Hartford Open (PGA Tournament); former member of Vernon, Connecticut Economic Development Commission; and former Treasurer and Director of Sunshine Project, Inc. (a non-profit organization involved in housing and support services for the psychiatrically disabled).

Recognized as CFO of the year by Hartford Business Journal - 2011

Other Interests: Enjoy sailing, skiing, running, tennis and golf.

18 Alexander Place · South Windsor, Connecticut 06074
Home: 860-644-6491 · Work: 860-545-8557

Michael Thomas O'Loughlin, M.D.

155 Stoner Drive
West Hartford, CT 06107
(860) 246-6589
Pager/voicemail (860) 825-0733
MTO@Jeffersonradiology.com

OBJECTIVE

A long term career in an intellectually challenging environment with a strong, growing, and collegial radiology practice

EDUCATION

University of Connecticut School of Medicine, Farmington, CT
M.D. May 1995

Colby College, Waterville, ME
B.A. May 1990, *cum laude*, Distinction in the Major
Bio-Chemistry Major

PROFESSIONAL EXPERIENCE

Jefferson Radiology Group, Hartford, CT, 7/01 to present
Partner Radiologist, Board Member
Director of MRI
Director of CT

Hartford Hospital Department of Radiology, 7/01 to present
Department Vice Chair
Section Chief - MR Imaging
Radiology Residency Program Director, 7/10 to present

University of Connecticut School of Medicine, Department of Diagnostic Imaging and Therapeutics, Farmington, CT
Clinical Instructor, 9/02 to present

Mayo Clinic Graduate School of Medicine, Rochester, MN
Cross Sectional Imaging Fellowship, 7/00 to 6/01

Hartford Hospital Diagnostic Radiology Residency Program, Hartford, CT
Resident in Radiology, 7/96 to 6/00
Chief Resident, 1999/2000

University of Connecticut Internal Medicine Residency Program, Farmington, CT
Internship in Internal Medicine, 7/95 to 6/96

HONORS

Certificate of Achievement, Academy of Radiology Leadership and Management 2013
Fred Ziter Teacher of the Year Award, Hartford Hospital Radiology Residency 2007
Fred Ziter Teacher of the Year Award, Hartford Hospital Radiology Residency 2004
Honors in Internal Medicine and Surgery Clerkships, UCONN
Deans List for Five Semesters, Colby College
Senior Scholar, Colby College
Senior Class Award in Chemistry, Colby College
Junior Class Award in Chemistry, Colby College

ACTIVITIES

Hartford Hospital

Member at Large, Hartford Hospital Medical Executive Committee, 2015 to present
Graduate, Hartford Healthcare Physician Leadership Development Institute, 2015
Chairman, Professionalism in Graduate Medical Education Committee, 2013 to present
Member, Genitourinary Disease Management Team Hartford Healthcare, 2013-present
Member, Gynecologic Oncology Disease Management Team, Hartford Healthcare 2013-present
Member, Esophageal Cancer Work Group, 2012 to present
Member, Mead Fund Committee, 2012 to present
Member, Hepato-Oncology Program Work Group Committee, 2011 to present
Member, Hartford Hospital Multidisciplinary Care Committee, 2010 to present
Member, Genital Urinary Workgroup, MDC Committee, 2010 to present
Member, Gynecologic Oncology Workgroup, MDC committee, 2010 to present
Member, Hartford Hospital Research Committee, 2010 to present
Chief Resident, 1999/00
Member, Hospital Graduate Medical Education Committee, 1999/00 and 7/10 to present
Member, Radiology Residency Education Committee, 1999/00 and 7/01 to present
Member, Quality Assurance Committee 1999/00
Resident Coordinator, Visiting Professor Staff Lecture Series 1997/98
Resident Coordinator, Interdepartmental Staff Lecture Series 1996/97

UCONN

Laboratory Instructor for the General Pathology, Respiratory, Cardiovascular, and Renal-Urinary Subject Committees
Member, First and Second Year Pre-Clinical Operating Committees
Member, Peer Support (Stress relief/emotional support group for students)
Volunteer, South Park Inn Medical Clinic (a clinic for homeless in Hartford)
Volunteer, Hartford Area Habitat for Humanity
Tutor, First and Second Year Medical and Dental Students

Colby

Director, Colby Emergency Response (our college based EMT service)
President, Colby Outing Club

U.S.M.L.E.

Part I	June 1992	82nd percentile
Part II	Sept. 1994	87th percentile
Part III	May 1996	91st percentile

LICENSURE

Massachusetts 2010 to present
Connecticut 1998 to present
Minnesota 2000 to 2001

BOARD CERTIFICATION

American Board of Radiology, May 17, 2000
Magnetic Resonance Medical Director/Physician (MRMD), Oct. 21, 2015

PATENTS RECEIVED

Fixed Anterior Gantry CT Shielding for Dose Reduction,
United States Patent 9,101,272

GRANTS RECEIVED

Hyundai Hope on Wheels $250,000 Research Grant 2012
"Early Onset Occult Asymptomatic Cardiotoxicity in Childhood Cancer Survivors Exposed to Anthracycline Therapy: A Cardiac Magnetic Resonance and Biomarker Imaging and Serological Biomarker Study". Olga Salzar, Eileen Gillan, Kerry Moss, Michael O'Loughlin, Bruce Liang

Saint Baldericks Foundation $100,000 Research Grant, 2011
"Defining Late Onset Occult Asymptomatic Cardiotoxicity in Childhood Cancer Survivors Exposed to Anthracycline Therapy: A Cardiac Magnetic Resonance and Biomarker Imaging and Serological Biomarker Study". Olga Salzar, Eileen Gillan, Kerry Moss, Michael O'Loughlin, Bruce Liang

Medtronic $81,000 Research Grant, 2011
"Use of a Screening Questionaire to Decide whether a Pacing System with the Revo-MRI Pacemaker is Warranted (the "Ready MRI" trial)". Steven Zweibel, Michael O'Loughlin, David O'Sullivan

Connecticut Breast Health Initiative $50,000 Research Grant, 2004
Principal Investigator - "Prospective Analysis of Breast MRI Outcomes in a Large Hospital Population", Hartford Hospital, Received 12/09/04

RESEARCH

Site Principal Investigator – American College of Radiology Imaging Network (ACRIN), Hartford Hospital 2003
Study 6667, Site Principal Investigator for multicenter trial assessing contralateral breast disease in patients with recent diagnosis of breast cancer.

Site Principal Investigator - International Breast MRI Consortium, Hartford Hospital 2001-2002
Study 6884, Arm 1B and Arm 1C. Site Principal Investigator for multicenter trials assessing breast MRI in high risk subjects.

Post Sophomore Medical Student Fellowship in Anatomic Pathology, University of Connecticut Health Center 1992-1993
Functioned as a Junior Resident in the Department of Anatomic Pathology. Dissected surgical specimens, prepared microscopic slides, and then jointly worked of diagnoses with an attending Pathologist. Performed over thirty postmortem examinations form initial incision to signature on final dictated report. Presented cases at Radiology, Internal Medicine, and Orthopedic conferences. Participated in month long electives in Neuropathology and Renal Pathology. Attended bi-weekly brain dissections.

University of Connecticut School of Medicine Summer Research Fellowship 1991
"Lymphocyte Glucocorticoid Receptors in PTSD, Major Depression, Panic and Schizophrenia" with Dr. Earl Giller in the Department of Psychiaty

Senior Scholars Project, Colby College 1989-1990
"Two-Dimensional Gel Electrophoretic Analysis of Cellular Proteins from E. coli in the Presence of Mutated and Homologous Genes for 4.5s RNA" with Dr. David Bourgaize in the Department of Chemistry

University of Connecticut School of Medicine Summer Research Fellowship 1989
"Characterization of the B. Malayi 70 Kilodalton Heat Shock Protein Gene Family" with Dr. T.V. Rajan in the Department of Pathology

PROFESSIONAL MEMBERSHIPS

American Roentgen Ray Society 1996 to present
Radiological Society of North America 1996 to present
American College of Radiology 1996 to present
Wilderness Medical Society 1994 to 2004
European Society of Radiology 2004 to present
International Society of Magnetic Resonance in Medicine 2004 to present
Society of Cardiovascular Magnetic Resonance Imaging 2004 to present
Society of Cardiovascular Computed Tomography 2010 to present
Association of Program Directors in Radiology 2010 to present

RESIDENT LECTURES

The Radiology of Wilderness Medicine, Not Necessarily a Contradiction in Terms
May 1997
Magnetic Resonance Angiography, Understanding the Flow
May 1998
The Radiology of Renal Transplantation
March 1999

PAPERS and PRESENTATIONS

"Introduction to Cardiac MRI", Department of Cardiology Grand Rounds. Hartford Hospital, Sept 22, 2015.

"Radiation Doses in Modern Imaging." M O'Loughlin. Presented at the Day Kimball Hospital Quarterly Medical Staff Meeting. Sept. 8, 2015. Putman, CT

"Comparative Assessment of Gleason Scoring of Prostate Biopsies Obtained by Standard US and MRI-TRUS at Follow-up in Active Surveillance Patients." M Jackson, Haddock, I Staff, R Dorin, S Kesler, M O'Loughlin, A Meraney, J Wagner. Presented at the AUA Annual Meeting. New Orleans, May 2015

"Serial Lung Magnetic Resonance Imaging to Monitor Disease Progression in a Child with a Diffuse Alveolar Hemorrhage Syndrome" Kaleel M, Schramm C, Pascal M, O'Loughlin M, Collins MS. J Clin Med Res 2015 Apr; 7 (4):267-9

"The Impact of Enteric Contrast on Radiologist Confidence in Intravenously Enhances MDCT of the Abdomen and Pelvis: A Randomized Controlled Trial". C. Garcia, S. Boe, B. Coughlin, D. O'Sullvan, D. Moote, MT O'Loughlin, D. Jajoo, S Lee. Advances in Computed Tomography, 2014:3, 18-23

"Expected and Unexpected Findings in Diffusion Weighted Imaging MRI in Pediatric Patients with IBD." M. Froicu, D Moote, M O'Loughlin. Presented at the Society of Abdominal Radiology SAR 2014 Meeting. Boca Raton FL, March 23, 2014

"Occult Cardiotoxicity in Childhood Survivors Exposed to Anthracycline Therapy" OH Toro-Salazar, E Gillan, M O'Loughlin, et al. Circulation Cardivascular Imaging. 2013;6:873-880

"MRI for the Non-MRIologists" M O'Loughlin Presented at the 27th Annual Northeast Regional Meeting of the Society of Nuclear Medicine and Molecular Imaging. Mystic CT. October 26, 2013

"Right Atrial Pseudomass on Imaging" M Khalil, S Boe, M O'Loughlin. Presented at the 2013 North American Society for Cardiovascular Imaging 2013 Meeting. Reston VA. Sept. 29, 2013, *Honorable Mention* awarded.

"Case Based Review Categorical Course: Non-Invasive Arterial Imaging" B Stein, B Spillane, M O'Loughlin. Society of Interventional Radiology Annual Meeting, New Orleans April 2013

"Current Concepts in the Imaging of Cystic Pancreatic Lesions" MT O'Loughlin

Presented at the Hartford Hospital Pancreatic Cancer Symposium 2013, Farmington, CT. March 8, 2013

"Defining Late Onset Occult Asymptomatic Cardiotoxicity in Childhood Cancer Survivors Exposed to Anthracycline Therapy: A Cardiac Magnetic Resonance Study" OH Toro-Salazar, M Taylor, M O'Loughlin, G Burke, J Stainsby, E Gillan, B Liang, KN Hor. Presented at the Society of Cardiovascular Magnetic Resonance Annual Meeting 2013, San Franscisco, CA

"Dose of reduced *z*-axis length of computed tomography angiography (CTA) of the chest for pulmonary embolism using 64-detector rows and adaptive iterative reconstruction techniques. Martillotti, et al. Emergency Radiology. 2013 Jan; 20(1): 39-44

"Transient Osteoporosis of Pregnancy in a 34 year old female" Patel V, Temkin S, O'Loughlin MT." *Radiology Case Reports*. (Online) 2011;7:646. http://radiology.casereports.net/index.php/rcr/article/viewArticle/646/978

"Turner Syndrome: An Evaluation of Vascular Anomalies and Incidental Findings" A Kanfi, S Lang, MT O'Loughlin, and O Toto-Salazar. Presented at the 2012 Society of Cardiovascular MRI Annual Meeting, Orlando FL

"Myocardial Fatty Focus in a Patient with Tuberous Sclerosis" Society for Cardiovascular Magnetic Resonance Case of the Week Number 11-24. T Herbst, O Toro-Salazar, MT O'Loughlin http://www.scmr.org/caseofthe week/2011/2689.html

"Utilization of Catheter Directed CT and MR Venography for Superior Visualization of Complex Venous Anatomy", Suchecki B, Stein B, O'Loughlin MT, Sussman, SK. Presented at the RSNA 97th Scientific Assembly and Annual Meeting 2011. *Cum Laude* Award Received

"Evaluating the Effectiveness of Anterior Gonadal Shielding in CT". Hynecek R, Temkin S, O'Loughlin MT, presented at the 2011 Hartford Hospital Practice Quality Improvement Symposium. Third Place Award Received

"Evaluation of CT Scan Radiation Dose in the Outpatient Setting Before and After Implementation of Dose-Reducing Techniques – Correlation of Radiologist Image-Quality Satisfaction", Kanfi A, O'Loughlin MT, Presented at the American Roentgen Ray Society Annual Meeting May 2, 2011

"Practical CT Dose Reduction Strategies", General Electric CT Trends National Webinar Presentation, March 23,2011. http://webcast.streamlogics.com/audience/index.asp?eventid=94570558

"Magnetic Resonance Imaging of the Pelvic Floor", Connecticut Society of Radiologic Technologists 68th Annual Conference, Waterbury, CT October 9, 2010

"Prostate MRI: Tips, Techniques, and Tricks of the Trade". Urology Grand Rounds, University of Connecticut Department of Urology. February 25, 2010.

"Prospective Outcome of BIRADS Category 3 "Probably Benign" Breast MRI Lesions". O'Loughlin MT, McLaughlin TL, Staff I, and Cronin EB. Presented at RSNA 95th Scientific Assembly and Annual Meeting 2009

"Reduced Z-Axis Coverage CTA vs Standard Z-Axis Coverage CTA for Pulmonary Embolism" Kallen J, Coughlin BF, O'Loughlin MT, and Stein B. Presented at RSNA 95th Scientific Assembly and Annual Meeting 2009

"Reduced Z-axis coverage multidetector CT Angiography for Suspected Acute Pulmonary Embolism Could Decrease Dose and Maintain Diagnostic Accuracy". J Kallen; B F Coughlin, MT O'Loughlin, B Stein. Emerg Radiol. 2010 17(1) 31-35

MRI Contrast Reactions and Nephrogenic Systemic Fibrosis", Spring Contrast Safety Conference, Jefferson Radiology. Farmington Educational Center, April 4, 2009

"R/O Foreign Body": Looking for Embedded Glass Fragments with Digital Imaging" Chang J, Tubbs D, O'Loughlin MT. Presented at RSNA 94th Scientific Assembly and Annual Meeting 2008

"Urologic MRI – Part One, Male and Gender Neutral Pathology", University of Connecticut Urology Residency Lecture Series. August 28 2008

"Radiation Dose Issues in Modern Imaging", Dept. of Emergency Medicine Grand Rounds, Hartford Hospital August 21, 2008

"MRI Evaluation of the Contralateral Breast in Women with Recently Diagnosed Breast Cancer" Lehman,CD et al, N Engl J Med 2007; 356: 13 pp 1-9. *Summation of the ACRIN 6667 Research Project*

"Incidental Non-cardiac Findings on Cardiac CTA's." Zink, S., O'Loughlin, M., Stein, B. and Primiano, C. Presented at RSNA 92nd Scientific Assembly and Annual Meeting 2006

"Issues in Imaging the Pregnant Patient - the do's, the don'ts, the doses, and the alternatives". Dept. of OB-GYN Grand Rounds, Hartford Hospital October 6, 2005

"Added Cancer Yield of MRI in Screening Women at High Risk for Breast Cancer", C. Lehman, et al, J Surg Oncol. 2005 Oct 1;92(1):9-15

"Bladder exstrophy and phenotypic gender determination on fetal magnetic resonance imaging" K. Hsieh, M. O'Loughlin, F. Ferrer. *Urology*, Volume 65, Issue 5, May 2005. 998-999

"Cross Sectional Imaging of Supernumerary Kidneys", Ryan, M. and O'Loughlin, MT presented at RSNA 90th Scientific Assembly and Annual Meeting 2004

"Cardiac CT and MRI – State of the Art", presented at the 18th Annual Northeast Regional Scientific Meeting of the Society of Nuclear Medicine, October 24, 2004

"Fetal MRI". Presented at the University of Connecticut Department of Genetics. October 30, 2003

"Radiologic and Pathologic Correlation of Mammographically Occult Breast Lesions Identified by MRI and Excised Using MRI-Guided Needle Localization", presented at RSNA 88th Scientific Assembly and Annual Meeting. Dec. 4, 2002

"Giant Right Coronary Artery Aneurysm: Identification by Cardiovascular Magnetic Resonance Imaging" Ford, L., O'Loughlin, M., Stein, B., and Primiano, C. (submitted for publication)

"Sonographically Guided Percutaneous Radiofrequency Ablation of a Renal Cell Carcinoma in a Transplanted Kidney" Charboneau, JW., O'Loughlin, MT., Milliner, DS., and Engen, DE. Journal of Ultrasound in Medicine 2002 Nov. 21(11):1299-1302

"Hepatic Metastases: Imaging for Case Selection". Presented at the New England Cancer Society Meeting. November 2001

"The Radiology of Wilderness Medicine: Not Necessarily a Contradiction on Terms". Presented at University of Connecticut Second Annual Medical Student Symposium in Emergency Medicine. Jan. 15, 2000

"Bayesian Analysis of Lumbar Spine MR Imaging" Glickstein, M., and O'Loughlin, M. Presented at RSNA 85th Scientific Assemble and Annual Meeting. Dec 1, 1999

INTERESTS Canoeing, Canoe Poling (ACA National Champion 2010), Carpentry, Traditional Archery

REFERENCES Available on Request

THOMAS H. FARQUHAR, MD, PHD

Contact Information
Jefferson Radiology
111 Founders Plaza, Suite 400
East Hartford, CT 06108
(860) 289-3375
tfarquhar@jeffersonradiology.com

Professional Experience:

Chief, Department of Radiology, Hartford Hospital, Hartford, CT, 11/2014 – present.

Radiation Safety Officer, Noble Hospital, 115 West Silver Street, Westfield, MA, 7/2013 – present.

Radiologist, Jefferson Radiology, East Hartford, CT, 1/2012 – present.

Chair, Department of Radiology, Mills-Peninsula Health Services, Burlingame, California, 6/2010 – 12/2011.

Radiation Safety Officer, Mills Peninsula Health Services, 1501 Trousdale Drive, Burlingame, California, 7/2009 – 12/2011.

Radiologist, California Advanced Imaging Medical Associates, Inc., Novato, California, 7/2006 – 1/2012.

Hospital Affiliations

Hartford Hospital, 80 Seymour Street, Hartford, CT, 1/2012 – present.

Connecticut Children's Medical Center, 282 Washington Street, Hartford, CT, 1/2012 – present.

Windham Memorial Community Hospital, 112 Mansfield Avenue, Willimantic, CT, 1/2012 – present.

Day Kimball Hospital, 320 Pomfret Street, Putnam, CT, 1/2012 – present.

Johnson Memorial Medical Center, 201 Chestnut Hill Road, Stafford Springs, CT, 1/2012 – present.

Noble Hospital, 115 West Silver Street, Westfield, MA, 1/2012 – present.

Holyoke Medical Center, 575 Beech Street, Holyoke, MA, 1/2012 – present.

Griffin Hospital, 130 Division Street, Derby, CT, 7/2014 – present.

Mills Peninsula Health Services, 1501 Trousdale Drive, Burlingame, California, 10/2006 – 1/2012.

San Mateo Medical Center, 222 West 39th Avenue, San Mateo, California, 7/2006 – 1/2012.

Academic Appointments:

Clinical Instructor, UCSD Medical Center, 200 West Arbor Drive, San Diego, CA and VA San Diego Healthcare System, 3350 La Jolla Village Drive, La Jolla, CA, 7/2005 – 6/2006.

Education

MRI Fellow, UCSD Medical Center, 200 West Arbor Drive, San Diego, CA and VA San Diego Healthcare System, 3350 La Jolla Village Drive, La Jolla, CA, 7/2005 – 6/2006.

Radiology Resident, UCSF Radiology Residency Program, 505 Parnassus Avenue, San Francisco, California, 7/2001 – 6/2005.

Medicine Intern, UCLA-San Fernando Valley Internal Medicine Residency Program (now known as UCLA-Olive View Internal Medicine Residency), 14445 Olive View Drive, Sylmar, California, 6/2000 – 6/2001.

Doctor of Medicine, UCLA School of Medicine (now David Geffen School of Medicine at UCLA), 12-159 CHS, Box 951720, Los Angeles, California, 8/1992 – 6/2000.

Doctor of Philosophy, UCLA Graduate Program in Biomedical Physics, UCLA School of Medicine, 10833 LeConte Avenue, Los Angeles, California, 8/1994 – 8/1998.

Master of Science, Department of Electrical Engineering, Stanford University, 459 Lagunita Drive, Suite 7, Stanford, California, 9/1991 – 6/1992.

Bachelor of Science, Department of Electrical Engineering, Stanford University, 459 Lagunita Drive, Suite 7, Stanford, California, 9/1988 – 6/1992.

Licensure and Certification

American Board of Radiology, 6/8/05 – present.

Connecticut Medical License, 7/1/2011 – present.

Massachusetts Medical License, 8/3/2011 – present.

California Medical License, 12/7/2001 – present (retired status).

Honors and Awards

Teacher of the Year, Hartford Hospital Diagnostic Radiology Residency Program, 2013.

Roentgen Resident/Fellow Research Award, Radiological Society of North America, 2003.

Leo G. Rigler Award in Radiological Sciences, UCLA School of Medicine, 2000.

Emil Brogen Research Prize, UCLA School of Medicine, 2000.

Alpha Omega Alpha, UCLA School of Medicine, 1999.

Young Investigators' Award, Society of Nuclear Medicine, 1999.

Sylvia Sorkin Greenfield Award, UCLA Graduate Program in Biomedical Physics, 1998.

Young Investigators' Award finalist, Society of Nuclear Medicine, 1998.

Norman A. Bailey Award, American Association of Physicists in Medicine, 1997.

Phi Beta Kappa, Stanford University, 1992.

Frederick E. Terman Award for Excellence in Engineering, Stanford University, 1992.

Tau Beta Pi, Stanford University, 1991.

Wallace A. Davis Graduate Fellowship in Engineering, Stanford University, 1991.

Professional Activities

Member, Hartford Hospital Radiology Residency Committee, 7/2013 – present.
Interviewer, Hartford Hospital Radiology Residency Admissions Committee, 10/2013 – present.
Member, Society of Nuclear Medicine, 1994-2001 and 2009 – present.
Member, American Roentgen Ray Society, 2006 – present.
Member, American College of Radiology, 2001 – present.
Member, Radiological Society of North America, 2001 – present.
Member, San Mateo County Medical Association, 2007 – 2012.
Reviewer, Journal of the National Cancer Institute, 2001 - 2002.
Reviewer, Journal of Nuclear Medicine, 2000 - 2002.
Reviewer, IEEE Transactions of Nuclear Science, 1997 - 2001.
Member, Institute of Electrical and Electronics Engineers, 1994 – 2001.
Member, American Association of Physicists in Medicine, 1994 - 2001.
Member, UCLA MSTP Admissions Committee, 1995 - 1997.
Interviewer, UCLA MSTP Admissions Committee, 1993 - 1998.

Research Experience

Graduate Student Researcher, Division of Nuclear Medicine and Biophysics, UCLA School of Medicine, Los Angeles, California, 1993 - 1998.
Research Assistant, Radiological Sciences Laboratory, Stanford University Medical Center, Stanford, California, 1991 - 1992.
Research Assistant, Westinghouse Science & Technology Center, Pittsburgh, Pennsylvania, 1988 & 1989.

Teaching Experience

Teaching Assistant, Department of Computer Science, Stanford University, Stanford, California, 1989 - 1991.
Instructor of Physics, Columbia MCAT Review, Los Angeles, California, 1994 - 1998.
Instructor of Physics, Columbia MCAT Review, Los Angeles, California, 1994 - 1998.

Invited Presentations

"Risk of Radiation from Medical Imaging." *The Leadership Institute*, Ritz-Carlton Hotel, Boston, MA. September 2012.
"Risk of Radiation from Medical Imaging." *The Leadership Institute*, Ritz-Carlton Hotel, San Francisco, CA. February 2011.
"PET/CT in Oncology." Carson Tahoe Regional Healthcare, Carson City, NV, October 2008.

Peer Reviewed Journal Articles

1. Holdsworth CH, Levin CS, Farquhar TH, Dahlbom M, and Hoffman EJ. Investigation of Accelerated Monte Carlo Techniques for PET Simulation and 3D PET Scatter Correction. *IEEE Transactions on Nuclear Science* 2001, vol 48:1, pp 74-81.
2. Chatziioannou A, Silverman RW, Meadors K, Farquhar TH, and Cherry SR. Techniques to Improve the Spatial Sampling of microPET - a High Resolution Animal PET Tomograph. *IEEE Transactions on Nuclear Science* 2000, vol 47:3, 422-427.
3. Farquhar TH, Llacer J, Hoh CK, Czernin J, Gambhir SS, Seltzer MA, Silverman DHS, Hsu C, Qi J, and Hoffman EJ. ROC and LROC Analyses of Lesion Detection in Whole Body FDG PET: Effects of Acquisition Mode, Attenuation Correction, and Reconstruction Algorithm. *Journal of Nuclear Medicine* 1999 40:12, 2043-2052.
4. Farquhar TH, Llacer J, Sayre J, Tai Y-C, and Hoffman EJ. ROC and LROC Analyses of the Effects of Lesion Contrast, Size, and Signal-to-noise Ratio on Detectability in PET Images. *Journal of Nuclear Medicine* 2000, vol. 41:4, pp. 745-754.
5. Chatziioannou AF, Cherry SR, Shao Y, Silverman RW, Meadors K, Farquhar TH, Pedarsani M, and Phelps ME. Performance Evaluation of microPET: A High-Resolution Lutetium Oxyorthosilicate PET Scanner for Animal Imaging. *Journal of Nuclear Medicine* 1999, vol. 40:7, pp. 1164-1175.
6. Farquhar TH, Chatziioannou A, and Cherry SR. An Evaluation of Exact and Approximate 3D Reconstruction Algorithms for a High-Resolution, Small Animal PET Scanner. *IEEE Transactions on Medical Imaging* 1998, vol 17:6, pp. 1073-1080.
7. Farquhar TH, Chinn G, Hoh CK, Huang S-C, and Hoffman EJ. A Nonlinear, Image Domain Filtering Method for Cardiac PET Images. *IEEE Transactions on Nuclear Science* 1998, vol. 45:4, pp. 2073-2079.
8. Qi J, Leahy RM, Farquhar TH, and Cherry SR. Fully 3D Bayesian Image Reconstruction for ECAT EXACT HR+. *IEEE Transactions on Nuclear Science* 1998, vol 45:3, pp 1096-1103.
9. Farquhar TH, Chatziioannou A, Chinn G, Dahlbom M, and Hoffman EJ. An Investigation of Filter Choice for Filtered Back-Projection Reconstruction in PET. *IEEE Transactions on Nuclear Science* 1998, vol 45:3, pp. 1133-1137.
10. Qi J, Leahy RM, Cherry SR, Chatziioannou A, and Farquhar TH. High Resolution 3D Bayesian Image Reconstruction using the microPET Small Animal Scanner. *Physics in Medicine and Biology* 1998, vol 43:4, 1001-1013.
11. Cherry SR, Shao Y, Silverman RW, Meadors K, Siegel S, Chatziioannou A, Young JW, Jones WF, Moyers JC, Newport D, Boutefnouchet A, Farquhar TH, Andreaco M, Paulus MJ, Binkley DM, Nutt R, and Phelps ME. MicroPET: A High Resolution PET Scanner for Imaging Small Animals. *IEEE Transactions on Nuclear Science* 1997, vol 44:3, pp. 1161-1166.

Peer Reviewed Research Abstracts and Oral Presentations

1. Farquhar TH, Mankin L, and Yee EF. All That Wheezes is not Asthma. Society of General Internal Medicine Annual Meeting, San Diego, CA, June 2001.
2. Holdsworth CH, Levin CS, Dahlbom M, and Farquhar TH, and Hoffman EJ. Accelerated Monte Carlo Scatter Correction for 3D PET. *Journal of Nuclear Medicine* 41:5 Supp. The Society of Nuclear Medicine 47th Annual Meeting, St. Louis, MO, June 2000.
3. Farquhar TH, Llacer J, Hoh CK, Sayre J, Tai Y-C, Czernin J, Gambhir SS, Seltzer MA, Silverman DHS, Leahy RM, Hsu C, Qi J, and Hoffman EJ. ROC/LROC Analyses of Lesion Detection in Whole Body FDG PET: Effects of Acquisition Mode, Attenuation Correction, and Reconstruction Algorithm. *Journal of Nuclear Medicine* 40:5P. The Society of Nuclear Medicine 46th Annual Meeting, Toronto, Canada, June 1999.
4. Farquhar TH, Llacer J, Sayre J, Tai Y-C, Chatziioannou A, Czernin J, Dahlbom M, Gambhir SS, Hoh CK, Huang S-C, Levin CS, MacDonald LR, and Hoffman EJ. Effect of Size, Contrast, and Signal-to-Noise Ration on Tumor Detection in Position Emission Tomography. *Journal of Investigative Medicine* 47:2. Western Regional Meeting of the American Federation for Medical Research, Carmel, CA, January 1999.
5. Cherry SR, Chatziioannou A, Shao Y, Farquhar TH, Meadors K, and Phelps M. MicroPET: A High Resolution PET Scanner for Animal Studies. *National Institute for Drug Abuse Research Monograph.* Proceedings of the 60th Annual Scientific Meeting, College of Problems of Drug Dependence, Richmond, VA, July 1998.
6. Farquhar TH, Llacer J, Sayre J, Tai Y-C, Chatziioannou A, Cherry SR, Czernin J, Dahlbom M, Gambhir SS, Hoh CK, Huang S-C, Levin CS, MacDonald LR, Schelbert HR, Seltzer MA, Silverman DHS, and Hoffman EJ. Effect of Lesion Contrast, Size, and SNR on Detectability in PET as Measured by ROC Analysis. *Journal of Nuclear Medicine* 39:5P. The Society of Nuclear Medicine 45th Annual Meeting, Toronto, Canada, June 1998.
7. Chatziioannou A, Cherry SR, Silverman RW, Meadors K, Farquhar TH, and Phelps ME. Techniques to Improve Spatial Sampling of a High Resolution Animal Tomograph. *Journal of Nuclear Medicine* 39:5P. The Society of Nuclear Medicine 45th Annual Meeting, Toronto, Canada, June 1998.
8. Farquhar TH, Chinn G, Hoh CK, Huang S-C, and Hoffman EJ. A Nonlinear, Image Domain Filtering Method for PET Images. *1997 IEEE Nuclear Science Symposium Conference Record.* IEEE Nuclear Science Symposium and Medical Imaging Conference, Albuquerque, NM, November 1997.
9. Farquhar TH, Chatziioannou A, Chinn G, Dahlbom M, and Hoffman EJ. An Investigation of Filter Choice for FBP Reconstruction in PET. *1997 IEEE Nuclear Science Symposium Conference Record.* IEEE Nuclear Science Symposium and Medical Imaging Conference, Albuquerque, NM, November 1997.
10. Qi J, Leahy RM, Farquhar TH and Cherry SR. Fully 3D Bayesian Image Reconstruction for ECAT EXACT HR+. *1997 IEEE Nuclear Science Symposium Conference Record.* IEEE Nuclear Science Symposium and Medical Imaging Conference, Albuquerque, NM, November 1997.

11. Qi J, Leahy RM, Mumcuoglu EU, Cherry SR, Chatziioannou A, and Farquhar TH. High Resolution 3D Bayesian Image Reconstruction for microPET. International Meeting on Fully 3D Image Reconstruction in Radiology and Nuclear Medicine, Nemacolin Woods, PA, June 1997.
12. Chatziioannou A, Cherry SR, Shao Y, Silverman RW, Meadors K, Farquhar TH, and Phelps ME. MicroPET I: Performance Evaluation of a Very High Resolution PET Scanner for Imaging Small Animals. *Journal of Nuclear Medicine* 38:5P. The Society of Nuclear Medicine 44th Annual Meeting, San Antonio, TX, June 1997.
13. Farquhar TH, Chinn G, Hoh CK, Huang S-C, and Hoffman EJ. A Novel Method for the Removal of Streak Artifacts from PET Images. *Journal of Nuclear Medicine* 38:5P. The Society of Nuclear Medicine 44th Annual Meeting, San Antonio, TX, June 1997.
14. Chinn G, Farquhar TH, and Huang S-C. The Effect of Spacelimiting Constraints on Statistical Reconstruction for PET. *1996 IEEE Nuclear Science Symposium Conference Record.* IEEE Nuclear Science Symposium and Medical Imaging Conference, Anaheim, CA, November 1996.
15. Cherry SR, Shao Y, Siegel S, Silverman RW, Meadors K, Young J, Jones WF, Newport D, Moyers JC, Mumcuoglu EU, Chatziioannou A, Farquhar TH, Andreaco M, Paulus M, Binkley D, Nutt R, and Phelps ME. MicroPET: A High Resolution PET Scanner for Imaging Small Animals. *1996 IEEE Nuclear Science Symposium Conference Record.* IEEE Nuclear Science Symposium and Medical Imaging Conference, Anaheim, CA, November 1996.
16. Farquhar TH, Tai Y-C, Hoffman EJ, Dahlbom M, and Cherry SR. Investigation of Resolution and Artifacts in 3-D PET due to Data Set Reduction Techniques. *Journal of Nuclear Medicine* 37:5P. The Society of Nuclear Medicine 43rd Annual Meeting, Denver, CO, June 1996.
17. Levin CS, Tai Y-C, Hoffman EJ, Dahlbom M, and Farquhar TH. Removal of the Effect of Compton Scattering in 3-D Whole Body Positron Emission Tomography by Monte Carlo. *1995 IEEE Nuclear Science Symposium Conference Record.* IEEE Nuclear Science Symposium and Medical Imaging Conference, San Francisco, CA, November 1995.

30 High St. • Farmington, CT 06032
860.990.5429 • rkaliney@jeffersonradiology.com

RYAN W. KALINEY, MD

Work Experience

Jefferson Radiology, PC

- July 2011 – Present; Hartford, CT
- Radiologist, musculoskeletal division
- Partner, 2014 - present
- Expertise: Musculoskeletal radiology, general radiology, musculoskeletal and spine procedures
- Chairman of the IT Committee, 2015
- IT Committee Member, 2012 - present
- Finance Committee Member, 2013 - present

University of Virginia Teleradiology

- April 2009 – April 2011; Charlottesville, VA
- Weeknight and weekend moonlighting coverage of emergent CT and US from the following regional centers
  - Bath Community Hospital
  - Buchanan General Hospital
  - VAMC Salem, Virginia

Training

Fellowship: Musculoskeletal Radiology, University of Virginia Health System

- July 2010 – June 2011; Charlottesville, VA
- Modalities: plain film, CT, MRI, US
- Extensive musculoskeletal procedure training including spine

Residency: Radiology, University of Virginia Health System

- June 2006 – 2010; Charlottesville, VA
- Academic Chief Resident, 2008-2009
- Housestaff Council Representative, 2007-2008
- Dept. of Radiology Education Committee Member, 2008-2010

Internship: Transitional Year, Tufts-New England Medical Center/Brockton Hospital

- June 2005 – June 2006; Brockton Hospital, Brockton, MA

Education

M.D., Northwestern University Feinberg School of Medicine

- 2001-2005; Chicago, IL
- Jonathan Philip Reder Award for outstanding leadership and academic performance

B.S., Biomedical Engineering, Northwestern University

- 1998-2001; Evanston, IL
- Honors Program in Medical Education – 7 year combined BS/MD program
- Magna Cum Laude

Licensure & Certification

States:

- Connecticut
- Massachusetts

USMLE

- Step 1: Passed, 2003
- Step 2 CK: Passed, 2005
- Step 2 CS: Passed, 2005
- Step 3: Passed, 2006

ABR

- Physics: Passed, 2007
- Writtens: Passed, 2008
- Orals: Passed, 2010

Presentations & Publications

Kaliney R, Fox M, Arlet V, Mason J, Gaskin C, Shen F. Does the Use of Recombinant Bone Morphogenetic Protein-2 (rhBMP-2) Affect the Imaging Appearance Following Transforaminal Lumbar Interbody Fusion (TLIF) Utilizing Allograft? 96th Meeting of the Radiological Society of North America, November, 2010.

Kaliney R. Book Review. Radcases Musculoskeletal Imaging. JVIR. Vol 21(12), 1606. December, 2010

Fox, M; Kaliney, R; Bean, D; Rak, K. "Noninvasive Gastrointestinal Imaging: Ultrasound, computed tomography, and magnetic resonance scanning" in GI/Liver Secrets Plus, 4th edition. McNally, P. Chapter 70, 508-26; 2010.

Kaliney R, Kreitel KD, Alford B. Intrinsic Pediatric Bone Lesions: Sorting out the bad actors in a sea of do-not-touch lesions. Educational exhibit. 94th Meeting of the Radiological Society of North America, November, 2008.

Choudhri A, Hawk H, Kaliney R, Barr M. Needles in the Back: How and when to perform percutaneous spine interventions. Educational exhibit. 94th Meeting of the Radiological Society of North America, November, 2008.

Kaliney R, Choudhri A, Stay R, Whitehead M, Phillips CD, Shah L. Neuroradiology Plain Film Emergencies: What every radiologist must know. Educational exhibit. 93rd Meeting of the Radiological Society of North America, November, 2007.

Collins J, Pereles FS, Bello D, Betts T, Zachariah A, Kaliney R, Song GK, Shors SM, Carr JC, Finn JP. Pre-ablative high resolution MRA facilitates electrophysiologic pulmonary vein ablation and reduces fluoroscopy time in patients with paroxysmal atrial fibrillation. Medical Imaging Convention of the International Society for Optical Engineering (SPIE), February, 2003.

Zachariah A, Pereles FS, Kaliney R, Carr JC, Collins JD, Wood C, Finn JP. Subsecond magnetic resonance angiography and the evaluation of arteriovenous communications. Medical Imaging Convention of the International Society for Optical Engineering (SPIE), February, 2003.

Research Experience

Dept. of Radiology, University of Virginia Health System, Charlottesville, VA — *2010-2011*

- Preceptor – Michael G. Fox, MD
  Evaluated the prevalence of vertebral endplate osteolysis and associated complications in the setting of bone morphogenetic protein use with transforaminal lumbar interbody fusion.

Dept. of Radiology, Northwestern University Feinberg School of Medicine, Chicago, IL — *2002-2004*

- Preceptor – Stephen Futterer, MD
  Assisted in coordinating an inter-observer variability study comparing carotid artery stenoses on MRA as measured with maximal intensity projections vs. 3-D volume rendering.
- Preceptor – F. Scott Pereles, MD
  Assisted in a study exploring the utility of subsecond MRA in diagnosing abdominal arteriovenous malformations.

Northwestern University, Dept. of Biochemical Engineering, Evanston, IL — *January – August 2001*

- Preceptor – Eleftherios T. Papoutsakis, PhD.
  Assisted in the study of stem cell hematopoiesis by maintaining cell colonies and performing assays including flow cytometry and RNA arrays.

Professional Organizations

Radiological Society of North America

Radiological Society of Connecticut

American Roentgen Ray Society

Healthcare Information Management Systems Society

Formerly - American Alliance of Academic Chief Residence in Radiology (A^3CR^2)

- Steering Committee Member, 2008-2009
- Representative to the Society for Imaging Informatics in Medicine (SIIM), 2008-2009

EXHIBIT

4

Detection of Pulmonary Embolism in the Postoperative Orthopedic Patient Using Spiral CT Scans.

ARTICLE *in* HSS JOURNAL · SEPTEMBER 2009

DOI: 10.1007/s11420-009-9128-5 · Source: PubMed

7 AUTHORS, INCLUDING:

Han Jo Kim
Hospital for Special Surgery
135 PUBLICATIONS 367 CITATIONS
SEE PROFILE

Ronald Adler
NYU Langone Medical Center
201 PUBLICATIONS 4,134 CITATIONS
SEE PROFILE

Helene Pavlov
Hospital for Special Surgery
140 PUBLICATIONS 3,202 CITATIONS
SEE PROFILE

Geoffrey Westrich
Hospital for Special Surgery
136 PUBLICATIONS 1,467 CITATIONS
SEE PROFILE

HSSJ (2010) 6: 95–98
DOI 10.1007/s11420-009-9128-5

ORIGINAL ARTICLE

Detection of Pulmonary Embolism in the Postoperative Orthopedic Patient Using Spiral CT Scans

Han Jo Kim, MD · Sarah Walcott-Sapp, BA · Kristi Leggett, AA · Anne Bass, MD · Ronald S. Adler, PhD, MD · Helene Pavlov, MD · Geoffrey H. Westrich, MD

Received: 2 March 2009/Accepted: 14 July 2009/Published online: 23 September 2009

Abstract Orthopedic surgery is associated with a significant risk of postoperative pulmonary embolism (PE) and/or deep vein thrombosis (DVT). This study was performed to compare the clinical presentations of a suspected versus a documented PE/DVT and to determine the actual incidence of PE/DVT in the post-operative orthopedic patient in whom CT was ordered. All 695 patients at our institution who had a postoperative spiral CT to rule out PE/DVT from March 2004 to February 2006 were evaluated and information regarding their surgical procedure, risk factors, presenting symptoms, location of PE/DVT, and anticoagulation were assessed. Statistical analysis was performed using an independent samples t test with a two-tailed p value to examine significant associations between the patient variables and CT scans positive for PE. Logistic regression models were used to determine which variables appeared to be significant predictors of a positive chest CT. Of 32,854 patients admitted for same day surgery across all services, 695 (2.1%) had a postoperative spiral CT based on specific clinical guidelines. The incidence of a positive scan was 27.8% (193/695). Of these, 155 (22.3%) scans were positive for PE only, 24 (3.5%) for PE and DVT, and 14 (2.0%) for DVT only. The most common presenting symptoms were tachycardia (56%, 393/695), low oxygen saturation (48%, 336/695), and shortness of breath (19.6%, 136/695). Symptoms significantly associated with DVT were syncope and chest pain. A past medical history of PE/DVT was the only significant predictor of a positive scan. Patients who have a history of thromboembolic disease should be carefully monitored in the postoperative setting.

Keywords spiral CT · orthopedic surgery · thromboembolic complications

Each author certifies that his or her institution has approved the reporting of these cases and that all investigations were conducted in conformity with ethical principles of research.

Each author certifies that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

A. Bass, MD
Department of Rheumatology,
Hospital for Special Surgery,
535 East 70th Street, New York, NY 10021, USA

H. J. Kim, MD · S. Walcott-Sapp, BA · G. H. Westrich, MD (✉)
Department of Orthopedic Surgery,
Hospital for Special Surgery,
535 East 70th Street, New York, NY 10021, USA
e-mail: westrichg@hss.edu

K. Leggett, AA · R. S. Adler, PhD, MD · H. Pavlov, MD
Department of Radiology,
Hospital for Special Surgery,
535 East 70th Street, New York, NY 10021, USA

Introduction

Orthopedic surgery patients are at a high risk for thromboembolic complications including deep vein thrombosis (DVT), pulmonary embolism (PE), and, as a consequence, death. Hip and knee arthroplasty traditionally carry the highest risk of thromboembolic disease of all orthopedic procedures. The incidence of DVT in patients without prophylaxis is 40–84% for total knee replacement [1] and 39–74% for total hip replacement [2]. The incidence of fatal PE following total joint replacement has ranged from 0.19% to 3.4% [2–4], and the incidence of asymptomatic PE has been reported to be as high as 12% [1]. Trauma patients also have notoriously high rates of DVT, although these clots are often detected prior to any fracture fixation procedures. Geerts et al. [5] found a 69% rate of DVT in patients with lower extremity fractures, a 62% rate in patients with spine fractures, and a 54% rate of DVT in patients with major head injuries. Research has shown that

the rate of DVT in spine surgery patients ranges from 0.8% to 15.5% [6–9]. A recent study found an incidence of DVT of 0.5% and an incidence of PE of 0.23% in total shoulder arthroplasty patients [10]. The rate of DVT following foot and ankle procedures is typically between 0.2% and 3.5%, and the rate of symptomatic PE is even lower, ranging from 0% to 0.2% [11–12].

Because clinical presentation is unreliable for diagnosis of thromboembolic complications, imaging modalities have become the most effective way to diagnose PE. In the past, ventilation–perfusion (VQ) scans were used to determine the probability of PE. The VQ lung scan involves the inhalation of xenon gas and is advantageous because of low radiation exposure to the patient undergoing the exam (<2.5 mSv) and relatively low cost when compared to spiral CT. However, VQ scans have serious limitations as the results are based on the indirect visualization of the clot, and diagnosis is, therefore, restricted to "high, intermediate, or low probability". The study also takes approximately 1 h to complete. Spiral CT is currently the most popular test to aid in the diagnosis of pulmonary emboli [13] as it provides high specificity (81% to 100%) with direct visualization of the pulmonary vasculature, can reliably detect compounding or additional pulmonary conditions, and can be completed in less than 30 s. Reports validating the clinical significance of this sensitive and specific imaging for PE/DVT and identifying the potential for identifying clinically insignificant PE do not currently exist.

The symptoms of PE can range from nonexistent to mild to severe and are strongly related to a patient's underlying pulmonary reserve [14–16]. Pulmonary emboli pose a diagnostic challenge because of their lack of consistent, specific presentation. The goal of this study was to determine the overall incidence of positive spiral CT scans in a postoperative orthopedic surgical patient population who underwent the scans for suspected PE/DVT and to determine the relationship between the type of procedure and a positive scan. Another aim was to determine which symptoms were associated with positive spiral CT scans in this patient population. The final goal was to determine which risk factors were associated with a positive spiral CT scan in this patient population.

Materials and methods

All orthopedic surgery patients who underwent spiral CT scans of the chest, pelvis, or lower extremities at our institution during the 2-year period from March 2004 to February 2006 were screened for inclusion. Of these 771 patients, 76 were excluded immediately because they were non-surgical patients (43), had medical records that were missing documentation of the scan (18), or had preoperative instead of postoperative scans (15). After this initial review, there were 695 patients who had the designated spiral CT scans following an orthopedic surgical procedure and were included in this retrospective case series.

The hospital medical records and spiral CT scan reports of these 695 patients were reviewed to collect demographic and surgical data. Risk factors for the development of PE were defined as including a history of previous PE or DVT, smoking, current hormone replacement therapy or oral contraceptives, and current malignancy The clinical signs, symptoms and abnormal test results which prompted the ordering of the scans were noted. The anticoagulation prophylaxis, size and location of identified PEs, and treatment of PE and/or DVT in patients with positive scans were also recorded. The spiral CT scans included the chest, pelvis, and lower extremities, so only DVT proximal to the popliteal vein was detected and recorded.

The location of the PE/DVT was stratified into left and/or right main, lobar, segmental, and subsegmental arteries and peripherally into pelvic and lower extremity clots. Only the largest vessel order clot was noted for each side.

All of the hip, knee, shoulder, trauma, and spine patients had pneumatic compression sleeves placed. All patients undergoing total hip and total knee replacement also received pharmacological anti-coagulation with warfarin, low-molecular-weight heparin, or aspirin in accordance with the standard protocol for DVT prophylaxis at our institution. Arthroscopy, foot, ankle, and hand patients were not given anticoagulation therapy.

Statistical analysis was performed by a medical statistician using an independent samples t test with a two-tailed p value. Significance was defined as a p value less than 0.05. Logistic regression models were used to determine which variables appeared to be significant predictors of a positive chest CT in this patient population.

Results

One hundred ninety-three of the 695 scans were interpreted as indicating the presence of DVT and PE. The overall incidence of PE/DVT was 27.8% (193/695). One hundred fifty-five scans (22.3%) were positive for PE only, 24 (3.5%) for PE and proximal DVT, and 14 (2.0%) for proximal DVT only. A total of 179 patients had a scan positive for PE, comprising 0.5% of the total surgical population (155/32,854). The location of the identified PE and/or DVT was as follows: 3 main-single, 7 main-multiple, 28 lobar-single, 42 lobar-multiple, 29 segmental-single, 35 segmental-multiple, 30 subsegmental-single, 24 subsegmental-multiple, 15 pelvic clots, and 26 lower extremity clots.

Total joint arthroplasty and spine procedures were observed to have the highest incidence of positive scans in this sample of patients that underwent scans for suspected PE/DVT. The incidence of positive findings for total shoulder arthroplasty was 8 of 11 or 72%, for total knee arthroplasty 84 of 244 or 34.4%, for total hip arthroplasty 52 of 188 or 27.7%, for revision total knee arthroplasty 8 of 29 or 27.6%, and for spine procedures 33 of 136 or 24.3%. The highest incidence of positive scans for PE only were in total shoulder arthroplasty (63.6%, 7/11), primary total knee arthroplasty (32.4%, 79/244), primary total hip arthroplasty (25%, 47/188), and spine patients (22.8%, 31/136).

The symptoms that prompted the ordering of a scan included tachycardia, fever, syncope, chest pain, shortness

of breath, low oxygen saturation defined as <90% on pulse oximetry, atrial fibrillation, confusion, nausea, and dizziness. Tachycardia (54.4%, 105/193), low oxygen saturation (49.7%, 96/193), and shortness of breath (23.3%, 45/193) were the symptoms most commonly associated with positive scans. Atrial fibrillation (p=0.057, 15/78, 19.2%), confusion (p=0.058, 5/35, 14.3%), and nausea (p=0.075, 13/14, 92.9%) were not predictive of a positive scan. Patients with low oxygen saturation were significantly (p=0.0001) more likely to have scans positive for PE. Using a logistic regression model, oxygen saturation (p=0.003) and a history of PE/DVT (p=0.008) were found to be significant predictors of PE. Atrial fibrillation and estrogen use were not significant predictors (p=0.09).

Of the risk factors analyzed as predictive of a positive scan, a history of PE and/or DVT was significantly associated with a scan positive for PE (p=0.004, 21/48, 43.8%). In addition, patients with a higher BMI (BMI>30) were more likely to have scans positive for PE (p=0.048, mean 28.98 negative vs. mean 30.10 positive) than those with a lower BMI. When patient demographic variables were entered into a logistic regression model, a history of previous PE/DVT was found to be a significant predictor (p=0.006) of having a positive scan for PE, while BMI and estrogen use were found to be marginally significant predictors (p=0.06 and p=0.07, respectively). The odds of having a positive chest CT scan were 2.3 times higher if patients had a history of PE/DVT than if they did not (95% CI, 1.3–4.3). Smoking was not found to be a positive predictor of a positive scan. There was no detectable relationship between patient risk factors or presenting symptoms with respect to the detection of proximal (pelvic) DVTs. Syncope and age were found to have a trend towards significance with pelvic clots (p=0.075, p=0.103). Positive lower extremity CT scans were significantly related to previous PE/DVT (p=0.03, 5/48, 10.4%), syncope (p=0.005, 4/20, 20%), and chest pain (p=0.04, 8/109, 7.3%).

Discussion

The purpose of the study was to examine those post-operative orthopedic surgical patients with documented positive spiral CT for detecting PE/DVT as related to the clinical symptoms at presentation, medical history, and risk factors. We hoped to use this information to determine appropriate and optimal utilization of this sensitive but costly diagnostic imaging evaluation, which exposes patients to both ionizing radiation and potential contrast reaction.

In our study, patients with low oxygen saturation were significantly more likely to have a spiral CT scan positive for PE than those with normal saturation values. In addition, when all risk factors were considered (previous history of PE or DVT, smoking, current hormone replacement therapy or oral contraceptive use, and current malignancy), patients with a history of prior DVT and/or PE were more likely to have a positive CT scan, which suggests that a patient's propensity for developing DVT and/or PE may depend on individual factors (i.e., variation in coagulation factors, genetics, etc.).

Parvizi et al. [18] suggested that sensitive imaging studies like spiral CT result in an increase in detection of pulmonary emboli and may lead to the unnecessary treatment of single, isolated subsegmental clots. Over the 5-year study period, the incidence of PE increased from 0.21% with VQ scans to 0.98% with spiral CT without changes in mortality rates [18]. The patients whose clots were not detected with the less sensitive VQ scans did not seem to suffer a greater risk of death and were spared the risk of complications associated with the prolonged anticoagulation therapy which is the accepted treatment for pulmonary emboli. Furthermore, as the technology continues to improve, the resolution and ability to observe smaller subsegmental PE will undoubtedly increase along with the required anticoagulation. Further research is needed to determine the risk/benefit profile for the treatment of small and/or isolated subsegmental clots and determine if patients diagnosed with only small tertiary pulmonary emboli would benefit from not being treated. In our study, the overall incidence of detected PE was approximately 0.5%, which is an incidence consistent with that reported in the literature [2–4].

Because of the low overall incidence of PE [1–4], it is unreasonable to perform postoperative CT scans on all orthopedic patients or even all patients who have undergone higher risk procedures like total joint arthroplasty. Such an approach would increase the risk of unnecessary radiation exposure to patients and would be imprudent from a cost–benefit analysis of health care. In the outpatient setting, D-dimer measurement may be useful in stratifying patients into groups with high or low suspicion of venous thromboembolism [17]; however, D-dimers are almost universally positive in the postoperative setting and are therefore unhelpful in this setting [19].

In our study, total joint arthroplasty and spine procedures were observed to have the highest incidence of positive scans. Common symptoms at presentation prompting a scan to rule out PE were tachycardia, shortness of breath, and a low O_2 saturation (<90%), and although not all of these symptoms were positive predictors of a scan, it is possible that a combination of symptoms with certain demographics can lead to highly specific presentations for PE. When analyzing risk factors, a past medical history of PE/DVT and BMI>30 were significantly associated with a positive scan. Larger clinical trails need to be done to integrate sensitive and specific risk factors for deterring life-threatening PE/DVT with clinical presentation in order to develop the most appropriate algorithm for ordering a spiral CT to rule out PE/DVT in the postoperative orthopedic setting.

Acknowledgment The authors would like to acknowledge Lindsey Bornstein for her assistance in the preparation of this manuscript.

References

1. Freedman KB, Brookenthal KR, Fitzgerald RH et al, A meta-analysis of thromboembolic prophylaxis following elective total hip arthroplasty. J. Bone Jt. Surg. Am. 2000; 82-A: 929–938

2. Westrich GH, Haas SB, Mosca P, et al, Meta-analysis of thromboembolic prophylaxis after total knee arthroplasty. J. Bone Jt. Surg. Br. 2000; 82: 795–800
3. Kim YH, Oh SH, Kim JS, Incidence and natural history of deep-vein thrombosis after total hip arthroplasty. A prospective and randomized clinical study. J. Bone Jt. Surg. Br. 2003; 85: 661–665
4. Lawton RL, Morrey BF, Narr BJ, Validity of index of suspicion for pulmonary embolism after hip arthroplasty. Clin. Orthop. Relat. Res. 2003; 415: 180–192
5. Geerts WH, Code KI, Jay RM, A prospective study of venous thromboembolism after major trauma. N. Engl. J. Med. 1994; 331: 1601–1606
6. Brambilla S, Ruosi C, LaMaida GA, et al, Prevention of venous thromboembolism in spinal surgery. Eur. Spine J. 2004; 13: 1–8
7. Catre MG Anticoagulation in spinal surgery. A critical review of the literature. Can. J. Surg. 1997; 40: 413–419
8. Dearborn JT, Hu SS, Tribus CB, et al, Thromboembolic complications after major thoracolumbar spine surgery. Spine. 1999; 24: 1471–1476
9. Oda T, Fuji T, Kato Y, et al, Deep venous thrombosis after posterior spinal surgery. Spine 2000; 25: 2962–2967
10. Lyman S, Sherman S, Carter TI, et al, Prevalence and risk factors for symptomatic thromboembolic events after shoulder arthroplasty. Clin. Orthop. Relat. Res. 2006; 448: 152–156
11. Hanslow SS, Grujic L, Slater HK, et al, Thromboembolic disease after foot and ankle surgery. Foot Ankle Int. 2006; 27: 693–695
12. Mizel MS, Temple HT, Michelson JD, et al Thromboembolism after foot and ankle surgery. Clin. Orthop. Relat. Res. 1998; 348: 180–185
13. Ghaye B, Ghuysen A, Bruyere PJ, et al, Can CT pulmonary angiography allow assessment of severity and prognosis in patients presenting with pulmonary embolism? What the radiologist needs to know. Radiographics. 2006; 26: 23–39
14. Kokturk N, Oguzulgen IK, Demir N, et al, Differences in clinical presentation of pulmonary embolism in older vs. younger patients. Circ. J. 2005; 69:981–986
15. Miniati M, Prediletto R, Formichi B, et al, Accuracy of clinical assessment in the diagnosis of pulmonary embolism. Am. J. Respir. Crit. Care Med. 1999;159:864–871
16. Stein PD, Henry JW Clinical characteristics of patients with acute pulmonary embolism stratified according to their presenting syndromes. Chest 1997; 112:974–979
17. Wells PS, Ginsberg JS, Anderson DR, et al, Use of a clinical model for safe management of patients with suspected pulmonary embolism. Ann. Intern. Med. 2005; 129: 997–1005
18. Parvizi J, Smith EB, Pulido L, et al, The rise in the incidence of pulmonary embolus after joint arthroplasty: is modern imaging to blame? Clin. Orthop. Relat. Res. 2007; 463: 107–113
19. Douketis JD, The clinical utility of a rapid beside d-dimer assay for screening of deep vein thrombosis following orthopaedic surgery. Thrombosis Haemost. 1997; 78: 1300
20. Douketis JD, The clinical utility of a rapid beside d-dimer assay for screening of deep vein thrombosis following orthopaedic surgery. Thrombosis Haemost. 1997; 78: 1300

Value of 3D CT in Defining Skeletal Complications of Orthopedic Hardware in the Postoperative Patient

Laura M. Fayad[1]
Ajanta Patra
Elliot K. Fishman

OBJECTIVE. Conventional CT of the postoperative patient with metal hardware is frequently limited by beam-hardening artifacts. With the evolution of 3D CT, CT is an increasingly effective means of examining the postsurgical patient for the integrity of their hardware and the course of their healing.

CONCLUSION. Potential postsurgical complications such as nonunion, osteolysis, infection, and heterotopic ossification are all well assessed by 3D CT.

Keywords: CT, nonunion, orthopedic hardware, osteolysis, postoperative complications

DOI:10.2214/AJR.09.2610

Received February 19, 2009; accepted after revision March 23, 2009.

[1]All authors: The Russell H. Morgan Department of Radiology and Radiological Science, 601 N Caroline St., Baltimore, MD 21287. Address correspondence to L. M. Fayad (lfayad1@jhmi.edu).

CME
This article is available for CME credit.
See www.arrs.org for more information.

AJR 2009; 193:1155–1163

0361–803X/09/1934–1155

Because of severe beam-hardening artifacts, evaluating the skeleton of a postsurgical patient with metal hardware is challenging with conventional CT. Metals, which have high Hounsfield unit values (usually 1,000–4,000 HU), result in the attenuation of x-rays, producing gaps in CT projection data and significant starburst artifacts or streaking [1]. The degree of artifact is related to several factors, including the composition of the metal, the orientation and shape of the hardware, the thickness of the metal, and the intrinsic scanning parameters [1–4]. With the optimization of CT parameters and the evolution of 3D CT, metal-related artifacts can be diminished, allowing diagnostic examinations in most clinical scenarios [5–8]. In this article, the technical aspects and benefits of generating 3D CT images in the postoperative setting will be reviewed, highlighting the role of 3D CT in diagnosing postoperative complications of the skeleton.

Optimal CT Technique and Reconstruction Algorithms

The CT technique must be optimized in the setting of metal. Modifications to standard CT protocols include using a lower pitch setting, a higher tube current (250–350 mAs), and higher peak kilovoltage (140 kVp) during acquisition. Soft-tissue image reconstruction filters, rather than edge-enhancing algorithms, are used to reduce the appearance of metal artifacts. Finally, at the time of display, the use of wide window settings (width, 3,000–4,000 HU; level, 800 HU) is advocated [1–8].

Many of the modified acquisition parameters will increase radiation dose to the patient. However, as was the case with the introduction of the 16-MDCT, the use of 64-MDCT with volume visualization and postprocessing (3D CT) limits radiation exposure by offering single-plane acquisitions with isotropic data sets. These data sets may be subsequently manipulated to view the imaged body part in any perspective of choice at the same resolution as the initial acquisition. After the axial acquisition, the data sets are reconstructed at 3-mm thickness for axial viewing and at the thinnest possible thickness (0.75 mm on a 16-MDCT) for reconstruction into multiplanar (MPR) and 3D CT views. In general, 3D CT images provide a comprehensive view of the postoperative site, displaying the relationship of the hardware to the skeleton and soft tissues, while drastically minimizing artifacts associated with the metal hardware observed on traditional axial and MPR views (Figs. 1–4). Using the volume-rendering technique, the data sets can be reconstructed to show the skeleton alone, the soft tissues alone, or their relationship, a decided advantage over MPR views [6, 7] (Figs. 4 and 5).

Postoperative Complications of the Skeleton

Nonunion

Evaluation of fracture healing is generally assessed by evaluating the amount of osseous

bridging present [3]. Signs of nonhealing on CT include the lack of bony bridging, persistent cortical defects, and bone sclerosis. Early bridging may be subtle because immature osteoid is not as dense as mature bone, thereby making detection easier on CT than on radiography. Predisposing factors to nonunion include the displacement of fragments, open fractures, and inadequate immobilization. The treatment of nonunion includes open reduction and internal fixation using plates and screws, with the option for bone grafting across the fracture site in some cases [9, 10] (Figs. 6 and 7).

Loosening and Particle Disease (Osteolysis)

Loosening is a general term that describes aseptic hardware relaxation manifested on CT as greater than 2 mm of radiolucency surrounding the hardware [3]. Such features overlap with those of infection; typically, the entities must be differentiated by clinical means or other tests. In implants, the polyethylene liner can erode, with debris causing a granulomatous reaction in the nearby bone that is termed "particle disease," a specific cause of aseptic loosening. Imaging may show lobulated expansile radiolucencies in the bone and a periosteal reaction [2, 11, 12] (Fig. 8). Occasionally, CT may also show associated soft-tissue masses that can mimic malignancy [11]. Treatments for osteolysis include surgical revision with cement, bone graft, or metallic augmentation.

Infection

When areas of focal erosions or regions of periosteal reaction are identified on CT, infection should be ruled out (Fig. 9). Other signs of infection include joint effusions and fluid collections surrounding the hardware [4]. In later stages, sclerosis of the bone may occur. Acute infection is generally managed aggressively with débridement and replacement of the hardware [13].

New Fracture

Secondary fracture may occur in postoperative patients from weakened bone or altered weight-bearing. These are easily recognized on postoperative 3D CT that show reduced metal artifact (Fig. 10).

Malplacement

Malplacement is the postoperative scenario in which the hardware is not positioned in the expected location or when the hardware impinges on an adjacent vital structure such as a nerve or vessel. In these cases, IV contrast material with CT angiography may be useful for the detection of vascular complications (Figs. 11–13).

Hardware Fracture

Hardware fracture occurs when the hardware experiences abnormal stresses because of malpositioning or migration or as a result of nonhealing at the original fracture site. This scenario is well evaluated by 3D CT (Fig. 14) because 3D CT images are superior to axial and MPR views for the detection of hardware fracture [1].

Heterotopic Ossification

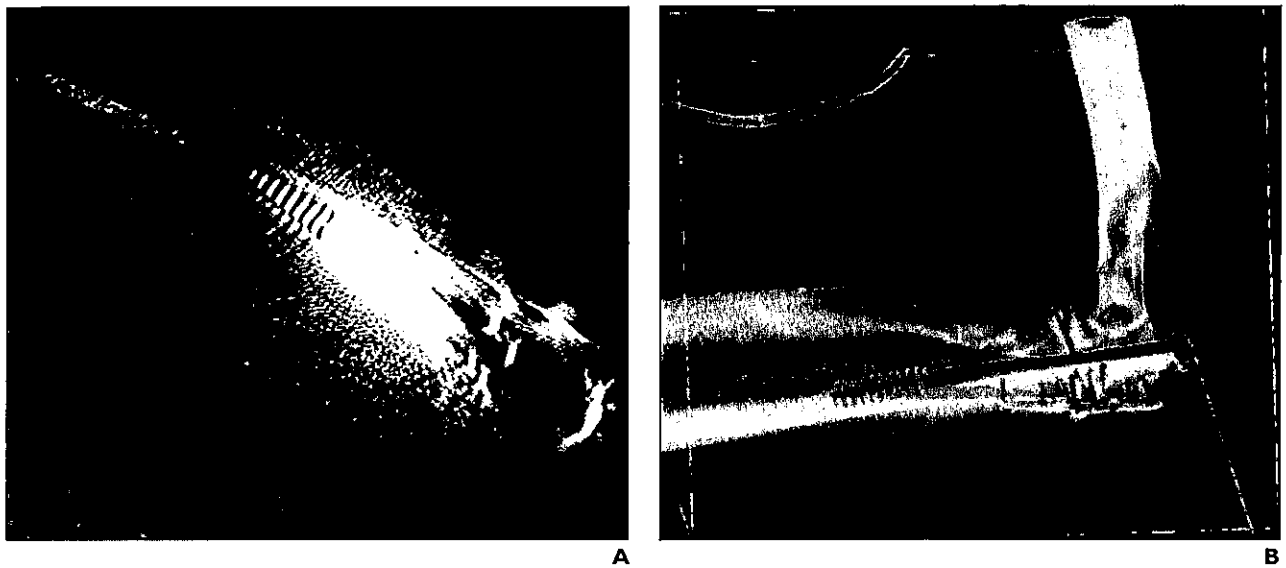
Heterotopic bone formation may develop around hardware and limits movement around the joint. The presence of heterotopic ossification is easily detected on CT. Heterotopic ossification after joint replacement in the lower limb occurs in 3–90% of cases [2]. Prophylaxis options for patients at high risk for the development of heterotopic ossification include radiotherapy and treatment with indomethacin [14] (Fig. 15).

Conclusion

For the evaluation of the postoperative skeleton, 3D CT carries an advantage over traditional axial and MPR views by markedly diminishing artifact associated with the presence of hardware.

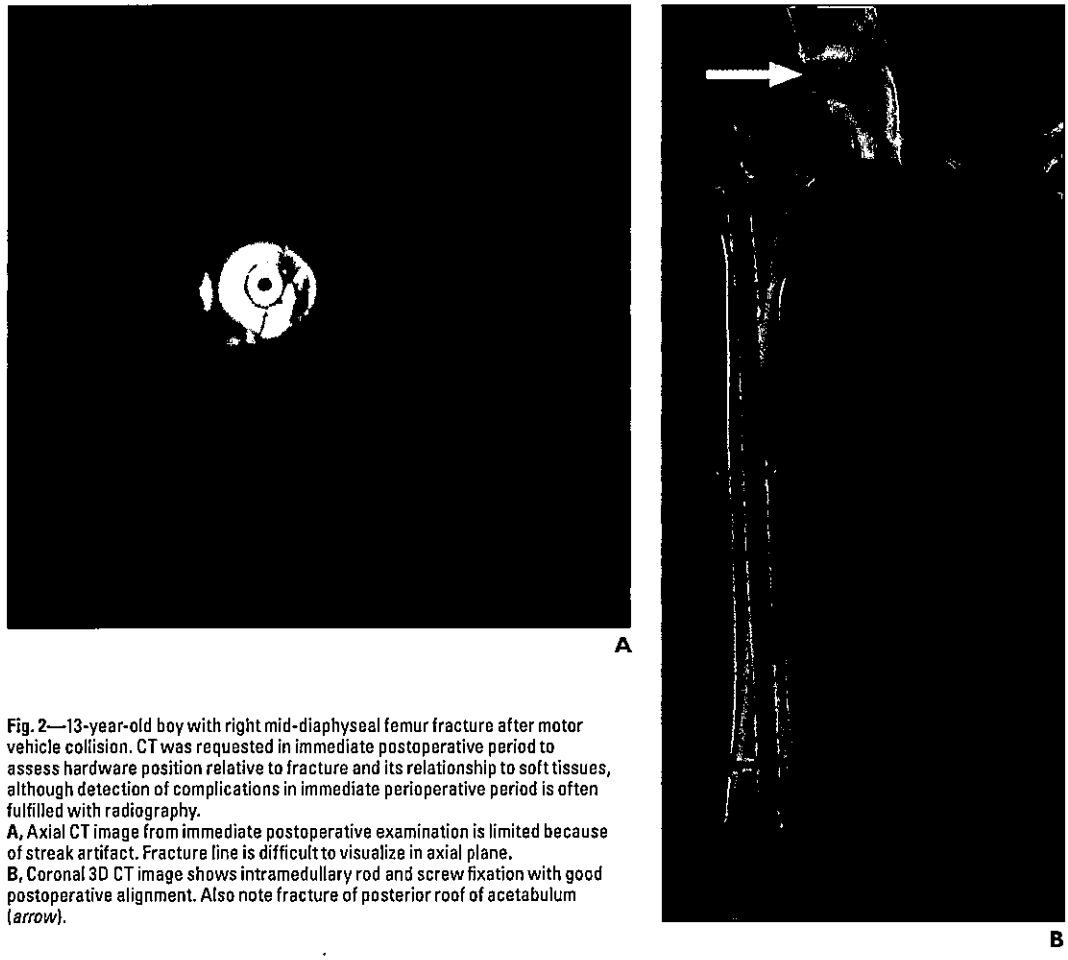
References

1. White LM, Buckwalter KA. Technical considerations: CT and MR imaging in the postoperative orthopedic patient. *Semin Musculoskelet Radiol* 2002; 6:5–17
2. Sofka CM, Potter HG, Adler RS, Pavlov H. Musculoskeletal imaging update: current applications of advanced imaging techniques to evaluate the early and long-term complications of patients with orthopedic implants. *HSS J* 2006; 2:73–77
3. Buckwalter KA, Parr JA, Choplin RH, Capello WN. Multichannel CT imaging of orthopedic hardware and implants. *Semin Musculoskelet Radiol* 2006; 10:86–97
4. Berg BV, Malghem J, Maldague B, Lecouvet F. Multi-detector CT imaging in the postoperative orthopedic patient with metal hardware. *Eur J Radiol* 2006; 60:470–479
5. Robertson DD, Magid D, Poss R, Fishman EK, Brooker AF, Sledge CB. Enhanced computed tomographic techniques for the evaluation of total hip arthroplasty. *J Arthroplasty* 1989; 4:271–276
6. Neyman EG, Corl FS, Fishman EK. 3D-CT evaluation of metallic implants: principles, techniques, and applications. *Crit Rev Computed Tomogr* 2002; 43:419–452
7. Pretorius ES, Fishman EK. Volume-rendered three-dimensional spiral CT: musculoskeletal applications. *RadioGraphics* 1999; 19:1143–1160
8. Douglas-Akinwande AC, Buckwalter KA, Rydberg J, Rankin JL, Choplin RH, Multichannel CT: evaluating the spine in postoperative patients with orthopedic hardware. *RadioGraphics* 2006[suppl 1]; 26:S97–S110
9. Lorenzen M, Wedegärtner U, Weber C, Petersen JP, Adam G, Lorenzen J. Clinical relevance of multislice CT of the spine after osteosynthesis [in German]. *Rofo* 2005; 177:1540–1544
10. Ebraheim NA, Mekhail AO, Ortho MS, Darwich M. Open reduction and internal fixation with bone grafting of clavicular nonunion. *J Trauma* 1997; 42:701–704
11. Park JS, Ryu KN, Hong HP, Park YK, Chun YS, Yoo MC. Focal osteolysis in total hip replacement: CT findings. *Skeletal Radiol* 2004; 33:632–640
12. Maloney W, Rosenberg A. What is the outcome of treatment for osteolysis?; Impant Wear Symposium 2007 Clinical Work Group. *J Am Acad Orthop Surg* 2008; 16[suppl 1]:S26–S32
13. Haddad FS, Bridgens A. Infection following hip replacement: solution options. *Orthopedics* 2008; 31:907–908
14. Board TN, Karva A, Board RE, Gambhir AK, Porter ML. The prophylaxis and treatment of heterotopic ossification following lower limb arthroplasty. *J Bone Joint Surg Br* 2007; 89-B:434–440



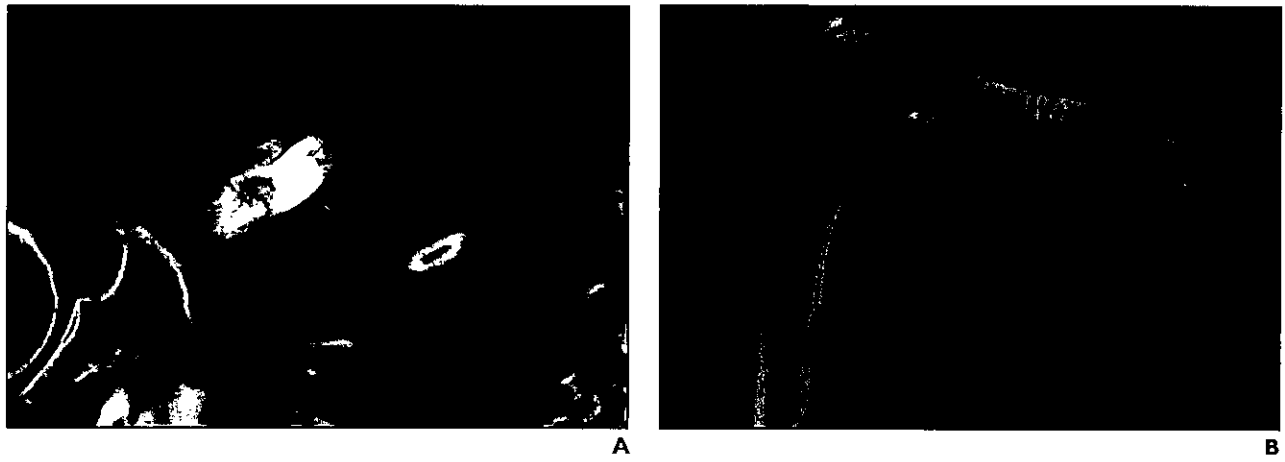
A B

Fig. 1—41-year-old woman with transolecranon fracture–dislocation of left elbow after motor vehicle collision requiring open reduction and internal fixation.
A, Coronal multiplanar reformatted image provides limited evaluation because of streak artifact.
B, Sagittal 3D CT image shows satisfactory alignment of fracture fragments and hardware.



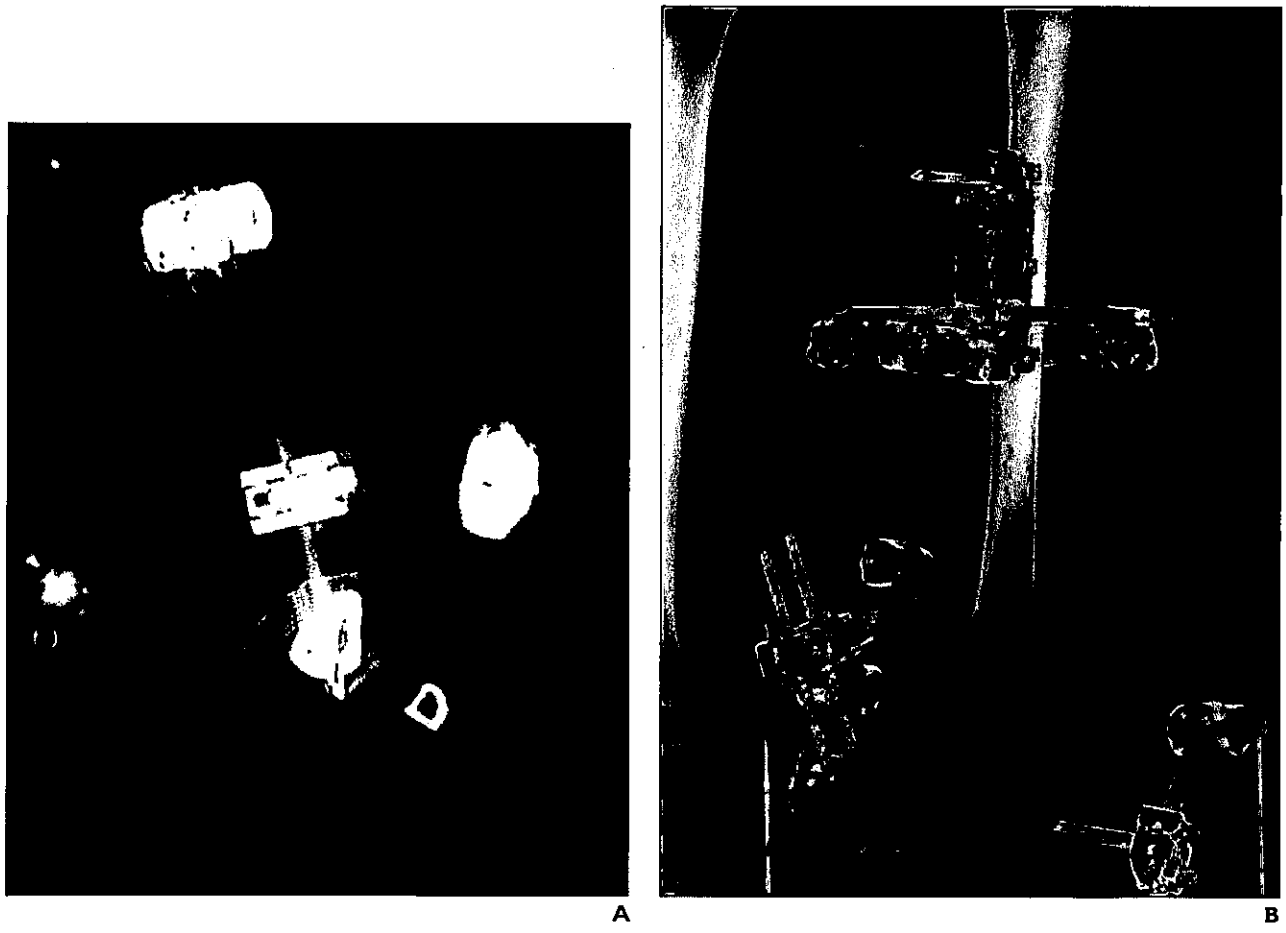
A B

Fig. 2—13-year-old boy with right mid-diaphyseal femur fracture after motor vehicle collision. CT was requested in immediate postoperative period to assess hardware position relative to fracture and its relationship to soft tissues, although detection of complications in immediate perioperative period is often fulfilled with radiography.
A, Axial CT image from immediate postoperative examination is limited because of streak artifact. Fracture line is difficult to visualize in axial plane.
B, Coronal 3D CT image shows intramedullary rod and screw fixation with good postoperative alignment. Also note fracture of posterior roof of acetabulum (*arrow*).



A B

Fig. 3—48-year-old woman with right distal clavicle fracture several months previously after open reduction and internal fixation. CT examination was performed to evaluate for nonunion.
A, Axial CT image is limited by streak artifact.
B, Coronal 3D CT image shows bony bridging across fracture site with no evidence of nonunion.



A B

Fig. 4—40-year-old man with comminuted fracture of distal left tibia after trauma who subsequently underwent placement of external fixation hardware.
A, Full assessment of hardware placement is difficult on axial CT image alone.
B, Coronal 3D CT image comprehensively depicts external fixation hardware alignment and its relationship to skeleton.

Fig. 5—75-year-old man with history of bladder cancer and right hip pain.
A–C, Coronal volume-rendered 3D CT images: rendered to show right hip prosthesis (**A**), rendered to show relationship of prosthesis screws to skeleton and adjacent iliac arteries (**B**), and rendered to show relationship of prosthesis screws to skeleton and right ureter (**C**). Note bladder mass, patient's known bladder cancer (*arrow*). Although surgical screws traversed cortex and extended into adjacent pelvic soft tissues, no symptoms were directly attributable to this abnormality.

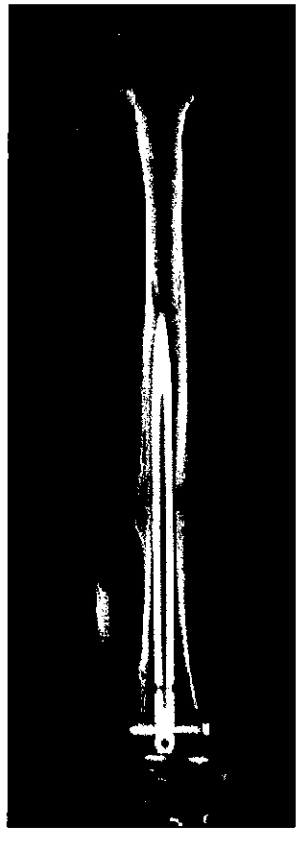


Fig. 6—56-year-old man who sustained traumatic tibial fracture. Coronal 3D CT image taken 8 months after fracture shows fracture in mid-distal tibia with intramedullary rod in place. Note evidence of nonunion with no evidence of bony bridging across fracture line and sclerotic fracture margins.

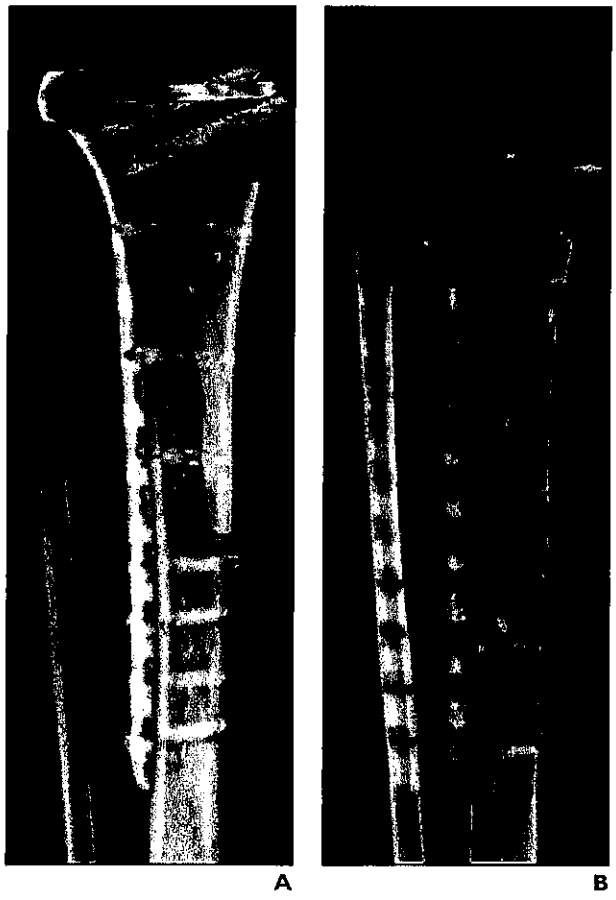


Fig. 7—23-year-old man with history of osteosarcoma of mid left tibia after resection and allograft placement. Plate and screw fixation was performed to augment healing. Three-dimensional CT was performed 6 months later to assess healing.
A and **B**, Coronal 3D CT images show no evidence of bony bridging at allograft–host junction.

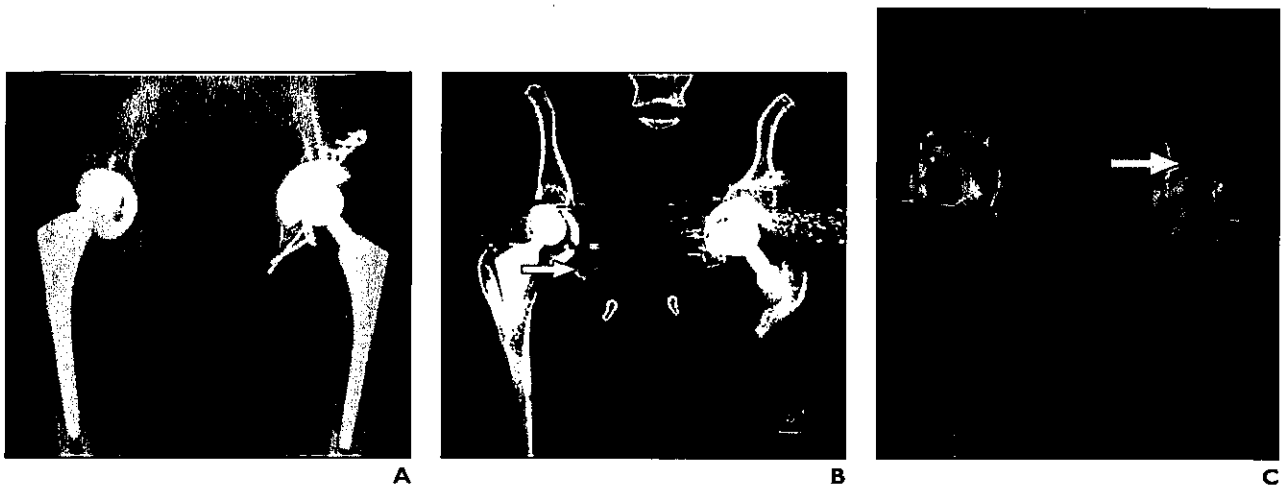


Fig. 8—Two patients with osteolysis demonstrated by 3D CT imaging.
A, 43-year-old woman with history of bilateral hip replacement and increasing right hip pain. Anteroposterior radiograph of pelvis shows hip prostheses bilaterally. Note radiolucency about right hip prosthesis.
B, However, degree of osteolysis in patient shown in **A** is better appreciated on CT. Coronal multiplanar reformatted CT image shows large lytic component (*arrow*) in inferior right acetabulum representing osteolysis or particle disease. Note asymmetry of right femoral head component in acetabular component, consistent with polyethylene wear. Note also that acetabular component is rotated clockwise from its expected position.
C, 62-year-old man with volume-rendered 3D depiction of osteolysis in left hip (*arrow*).

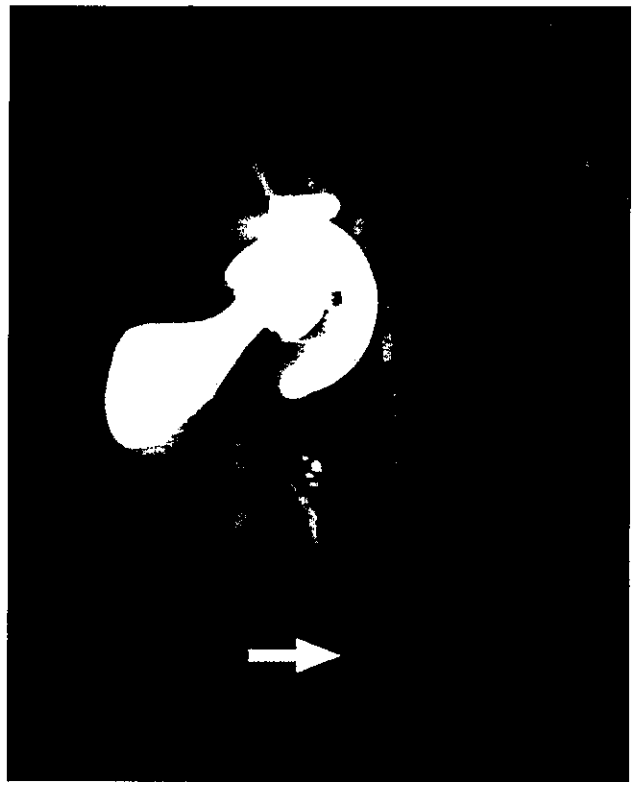
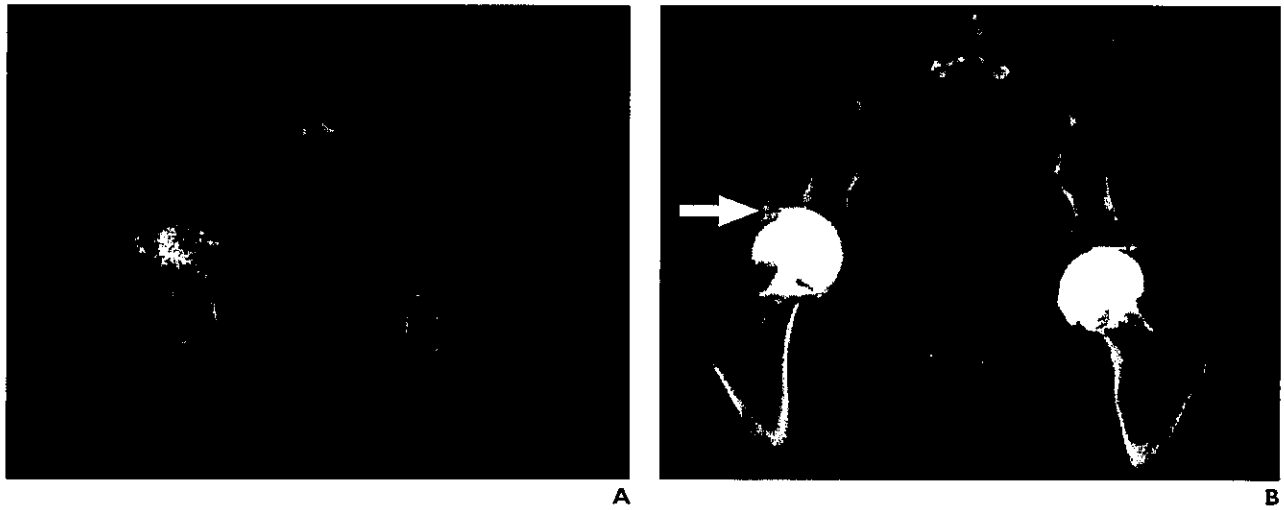


Fig. 9—46-year-old man after hip replacement who has history of right femur fracture after motor vehicle collision 20 years earlier. Patient presented with draining ulcer near right hip (*arrow*). Coronal 3D CT image shows cortical irregularity and lytic area in right ischium adjacent to ulceration, suggestive of osteomyelitis, which was subsequently proven at biopsy.



A **B**

Fig. 10—8-year-old boy with history of bilateral hip resurfacing for avascular necrosis who presented with right hip pain after motor vehicle collision. **A** and **B**, Coronal 3D CT images show fracture of right ischium (**A**) and acetabulum (**B**) with displacement (*arrow*, **B**).

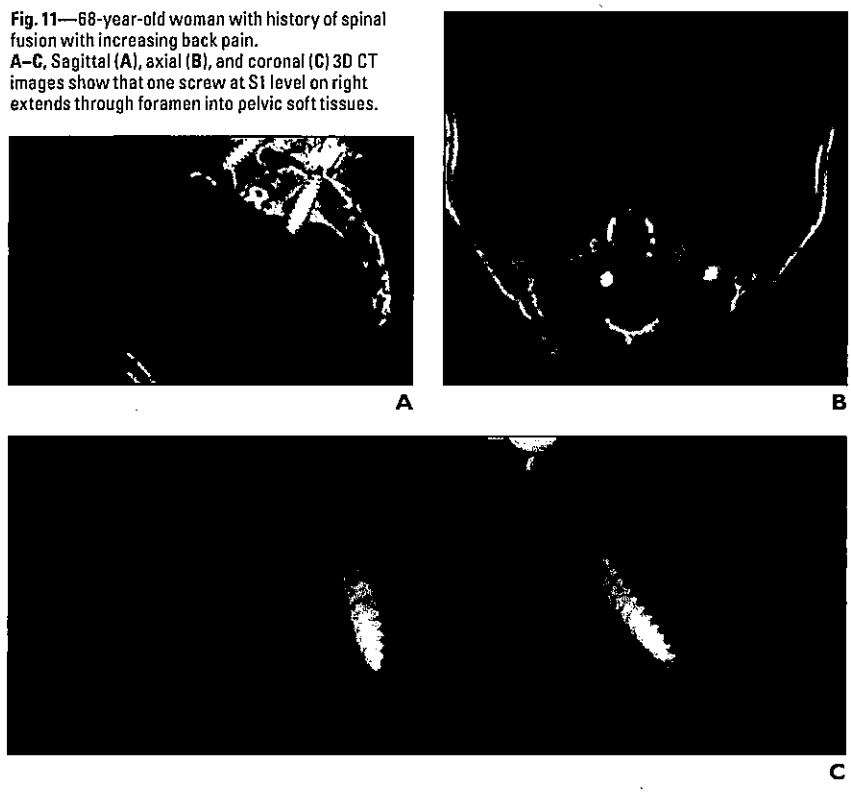


Fig. 11—68-year-old woman with history of spinal fusion with increasing back pain.
A–C, Sagittal (**A**), axial (**B**), and coronal (**C**) 3D CT images show that one screw at S1 level on right extends through foramen into pelvic soft tissues.

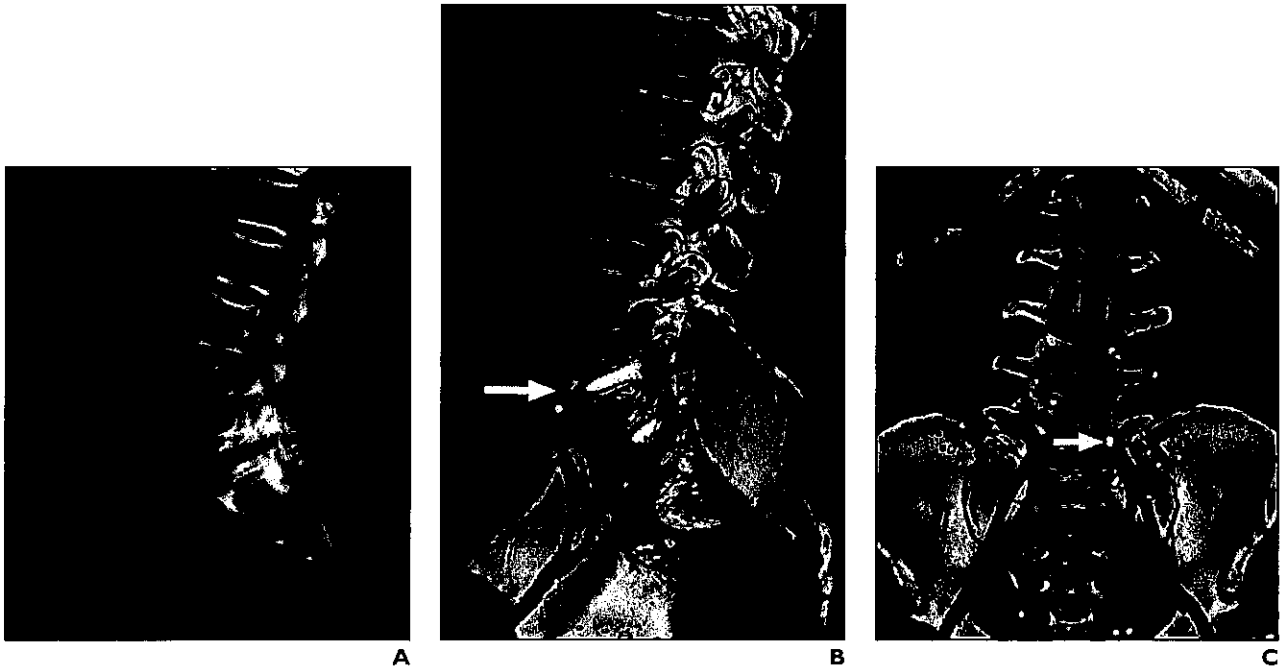


Fig. 12—45-year-old woman who underwent posterior fusion of L5–S1 vertebrae with laminectomy at L5.
A, Sagittal 3D CT image provides comprehensive view of hardware in spine.
B and **C,** Sagittal oblique (**B**) and coronal (**C**) 3D CT images show that L5 pedicle screw tip protrudes anterior to L5 vertebral body, with tip contacting left common iliac artery (*arrows,* **B** and **C**).

A

B

Fig. 13—86-year-old woman after left hip hemiarthroplasty performed for fracture, who presented with left hip pain.
A, Coronal 3D CT image shows superior dislocation of left hip prosthesis.
B, Axial multiplanar reformatted CT image, shown for comparison, does not provide comprehensive view of regional anatomy and is limited by streak artifact.

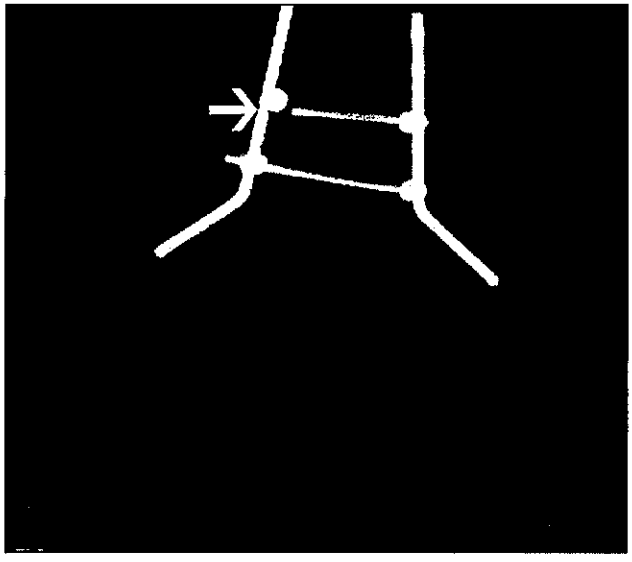


Fig. 14—12-year-old girl with Marfan syndrome who underwent surgical treatment of scoliosis. Coronal 3D CT image shows disconnection of horizontal bar and surgical screw (*arrow*). Note that for detection of hardware fracture, 3D CT retains particular advantage over axial and multiplanar reformatted CT.

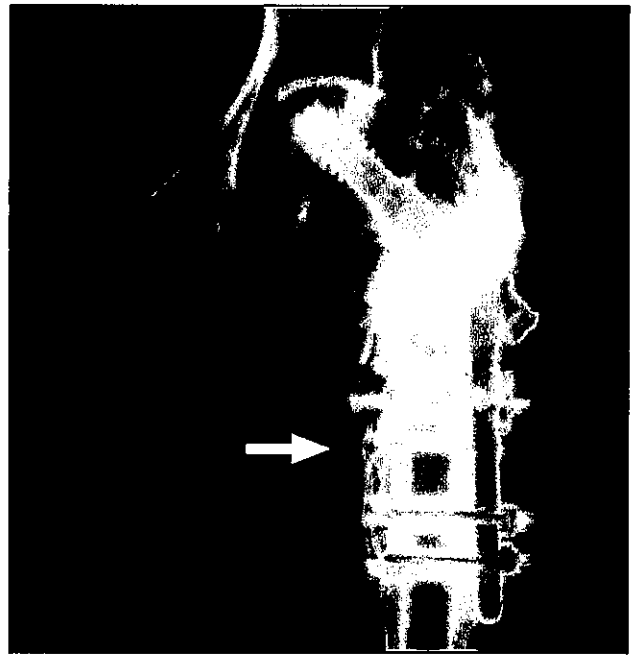


Fig. 15—56-year-old woman with left intertrochanteric femur fracture who underwent open reduction and internal fixation. Coronal 3D CT image shows dynamic hip screw traversing femoral neck. At medial aspect of femoral diaphysis, note development of heterotopic ossification (*arrow*). As ossification increases, range of motion of hip may become compromised.

FOR YOUR INFORMATION

This article is available for CME credit. See www.arrs.org for more information.

RadioGraphics

Virtual Monochromatic Spectral Imaging with Fast Kilovoltage Switching: Reduction of Metal Artifacts at CT[1]

TEACHING POINTS
See last page

Eric Pessis, MD • Raphaël Campagna, MD • Jean-Michel Sverzut, MD
Fabienne Bach, MD • Mathieu Rodallec, MD • Henri Guerini, MD
Antoine Feydy, MD, PhD • Jean-Luc Drapé, MD, PhD

With arthroplasty being increasingly used to relieve joint pain, imaging of patients with metal implants can represent a significant part of the clinical work load in the radiologist's daily practice. Computed tomography (CT) plays an important role in the postoperative evaluation of patients who are suspected of having metal prosthesis–related problems such as aseptic loosening, bone resorption or osteolysis, infection, dislocation, metal hardware failure, or periprosthetic bone fracture. Despite advances in detector technology and computer software, artifacts from metal implants can seriously degrade the quality of CT images, sometimes to the point of making them diagnostically unusable. Several factors may help reduce the number and severity of artifacts at multidetector CT, including decreasing the detector collimation and pitch, increasing the kilovolt peak and tube charge, and using appropriate reconstruction algorithms and section thickness. More recently, dual-energy CT has been proposed as a means of reducing beam-hardening artifacts. The use of dual-energy CT scanners allows the synthesis of virtual monochromatic spectral (VMS) images. Monochromatic images depict how the imaged object would look if the x-ray source produced x-ray photons at only a single energy level. For this reason, VMS imaging is expected to provide improved image quality by reducing beam-hardening artifacts.

Introduction

Conventional computed tomography (CT) of patients with large metal implants is difficult at best. Beam hardening, photon starvation (ie, noise from low photon counts), and scatter artifact normally obscure the immediate surrounding bone, making it impossible to evaluate the metal-to-bone interfaces for loosening, granulomatous particle disease, and fractures. In addition, at CT of patients with hip prostheses, the loss of soft-tissue detail due to streak artifact both near and farther away from the implant can cause concern by making evaluation of intrapelvic anatomy and adenopathy difficult (1). Current CT systems correct this

Abbreviations: MARS = metal artifact reduction software, VMS = virtual monochromatic spectral

RadioGraphics 2013; 33:573–583 • Published online 10.1148/rg.332125124 • Content Codes: CT MK PH

[1]From the Department of Radiology, Centre Cardiologique du Nord, Saint-Denis, 32-36 rue des Moulins Gémeaux, 93200 Saint-Denis, France (E.P., J.M.S., F.B., M.R.); Department of Radiology, Imagerie de l'Orangerie, Le Perreux-sur-Marne, France (R.C.); and Department of Radiology B, Hôpital Cochin, Université Paris Descartes, Paris, France (E.P., R.C., F.B., H.G., A.F., J.L.D.). Presented as an education exhibit at the 2011 RSNA Annual Meeting. Received May 22, 2012; revision requested July 12 and received September 23; accepted October 19. All authors have no financial relationships to disclose. **Address correspondence to** E.P. (e-mail: *eric.pessis@gmail.com*).

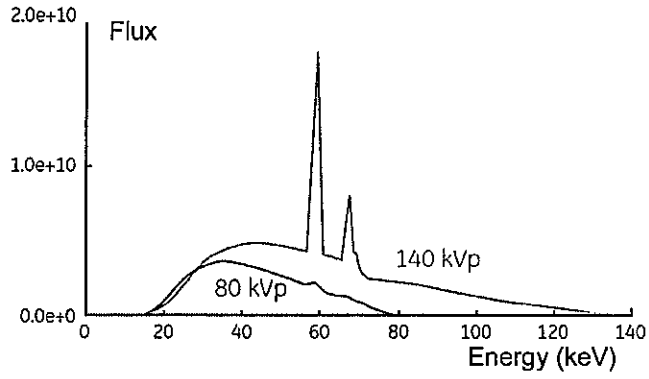


Figure 1. Graph illustrates polychromatic x-ray spectra for 80 and 140 kVp. Conventional CT makes use of a polychromatic x-ray beam composed of photons with a range of energies, with maximum energy expressed as peak voltage (kilovolt peak), which defines the upper-limit x-ray for a polychromatic x-ray beam. *keV* = kiloelectron volts, which is the unit of measure for one x-ray photon and specifies the photon energy for a monochromatic x-ray source. The y-axis represents the number of photons, which is relative; consequently, the y-axis is unitless. (Used with permission of Paul Ayestaran, GE Medical Systems, Buc, France.)

phenomenon, called beam-hardening effective energy shift, with use of calibration data measured in specific phantoms and calculated with the relevant function during the image reconstruction process (2). Other factors may diminish the production of artifacts at multidetector CT. During image acquisition, the use of a high peak voltage (kilovolt peak), high tube charge (in milliampere-seconds), narrow collimation, and thin sections helps reduce metal-related artifacts. During image reconstruction, the use of thick sections, lower kernel values (similar to the standard reconstruction algorithm), and the extended CT scale helps reduce these artifacts (3). However, use of these techniques may not be sufficient. For instance, if the tube charge is increased, the problem of photon starvation is overcome and artifacts are reduced, but the patient receives a higher radiation dose if the beam passes through a region with lower attenuation (2). Despite advances in detector technology and computer software, artifacts from metal implants remain a problem. More recently, the use of virtual monochromatic spectral (VMS) imaging has been proposed as a means of reducing beam-hardening metal artifacts (4,5). VMS images are reconstructed from a pair of accurate material-density images and mass-attenuation coefficients. For a given kiloelectronvoltage, the object is depicted as if it were being imaged with a monochromatic beam at the same voltage.

In this article, we review the theory of VMS imaging and describe our clinical experience with a single-source dual-energy scanner with fast kilovoltage switching (ie, rapid alternation between high- and low-kilovoltage settings) to reduce beam-hardening artifact, using optimized protocols to improve diagnostic performance in patients with metal implants.

Polychromatic X-ray Spectra and Beam-hardening Artifact

At conventional CT, the attenuation of the x-ray beam passing through an object is measured. The x-ray beam quality is commonly defined in terms of kilovolt peak (ie, maximum photon energy [6]), since the x-ray beam consists of a mixture of photon energies (2,5). The polychromatic spectra for 80 and 140 kVp are shown in Figure 1. A polychromatic image is an image generated at conventional single-energy CT due to the full spectrum of photon energies with the kilovolt peak defined by the user (eg, 80, 100, 120, or 140 kVp) (Fig 1). As the beam passes through an object, it becomes "harder"; that is to say, the mean photon energy increases, because the lower-energy photons are absorbed more rapidly than the higher-energy photons (2). The detected x-ray beam contains the higher-energy portion of the spectrum, resulting in dark streaks between metal structures (Fig 2). These streaks occur because the portion of the beam that passes through one of the objects at certain tube positions is hardened less than when it passes through both objects at other tube positions. Because monochromatic dual-energy CT images are generated from projection-space data, they are less affected by beam-hardening artifact and provide more accurate data than do standard single-energy CT images. In addition, because monochromatic dual-energy CT images can be generated for any photon energy level between 40 and 140 keV, a set of images can be created that optimizes contrast differences between two adjacent structures (7). For this reason, VMS imaging has the potential to reduce beam-hardening artifacts.

Teaching Point

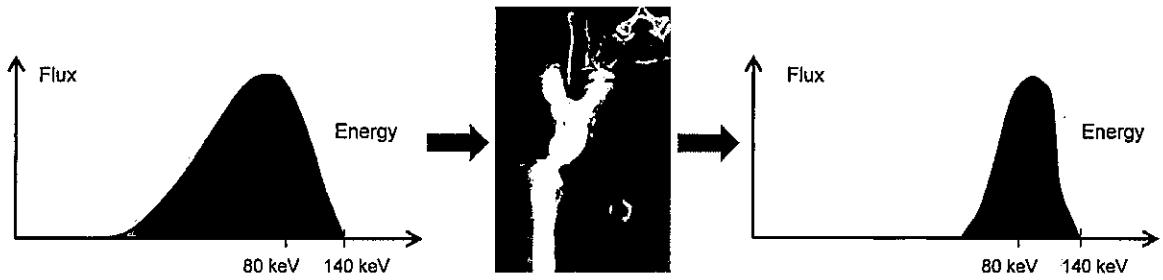


Figure 2. Graphs and image illustrate beam-hardening artifact. As an x-ray beam passes through metal, low-energy x-ray photons are absorbed first, and the remaining high-energy photons are not attenuated as easily. The detected x-ray beam contains the higher-energy portion of the spectrum, resulting in dark streaks between metal structures.

Advantages and Disadvantages of Three Types of Dual-Energy CT Scanners

Type of Scanner	Advantages	Disadvantages
Dual-source	Good spectral separation between high- and low-energy scans, ease of equalizing dose and noise between high and low-energy scans by modulating tube current for each tube, ability to measure attenuation (in Hounsfield units) on virtual unenhanced images	Limited temporal and spatial registration because two separate image datasets are acquired, maximum field of view of 33 cm for dual-energy acquisition, limited flexibility caused by image-domain dual-energy decomposition
Single-source with dual detector layers	Perfect temporal and spatial registration, projection-space dual-energy decomposition can be used	Limited energy separation with substantial spectral overlap
Single-source with fast kilovoltage switching	Good temporal registration between high- and low-energy datasets, which are obtained nearly simultaneously; availability of the full 50-cm field of view for use in image analysis	Limited spectral separation between high- and low-energy scans, higher noise levels on images obtained at a lower peak voltage

Source.—Reference 7.

Principles of Dual-Energy CT and VMS Imaging

Teaching Point

The basic principle of dual-energy CT is the acquisition of two datasets from the same anatomic location with use of different kilovolt peaks (usually 80 and 140 kVp). The two datasets must be acquired together to "freeze" patient and gantry motion. Dual-energy CT allows the analysis of energy-dependent changes in the attenuation of different materials. Three types of dual-energy CT scanners are available: a dual-source dual-energy scanner, a single-source dual-energy scanner with dual detector layers, and a single-source dual-energy scanner with fast kilovoltage switching (7). These scanners differ in the way high- and low-energy CT datasets are acquired, with each scanner having certain advantages and disadvantages (Table).

The single-source CT scanner with a single detector layer (Discovery CT 750HD; GE Healthcare, Milwaukee, Wis) relies on a single x-ray source with fast switching between two kilovoltage settings (80 and 140 kVp) at intervals of 0.5 msec during a single gantry rotation to generate high- and low-energy x-ray spectra. A detector with a fast response and a data acquisition system with a fast sampling capability are used to capture the alternating high- and low-energy data. If the x-ray attenuation of an object is measured at two different (low- and high-kilovolt-peak) spectra, alternating quickly from one view to the next, it is possible to mathematically transform the attenuation measurements into the density (or amount) of two materials that would be needed

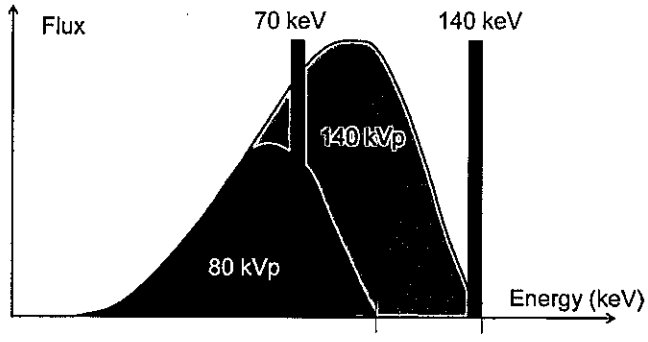


Figure 3. Graph illustrates VMS imaging versus polychromatic spectral imaging. A polychromatic x-ray beam is composed of photons with a range of energies, with maximum energy expressed as the kilovolt peak. A monochromatic x-ray beam is composed of photons with a single, constant energy expressed in kiloelectronvolts, the unit of measure for one x-ray photon, which specifies the photon energy for a monochromatic x-ray source. The VMS image shows how the imaged object would look if the x-ray source produced x-ray photons at only one energy level (eg, 70 or 140 keV).

to produce the measured attenuation. This process is referred to as material decomposition or material separation. It is important to note that material decomposition does not help identify materials. Rather, given two selected basis materials, material decomposition helps determine how much of each material would be needed to produce the observed low- and high-kilovolt-peak measurements (Fig 3). Generally, low- and high-attenuation materials are selected as the basis pair. For medical diagnostic imaging, water and iodine are often used, since they span the range of atomic numbers of materials generally found in medical imaging and thus approximate soft tissue and iodinated contrast material, resulting in material-density images that are intuitive to interpret.

Monochromatic images may be synthesized from the mass-attenuation coefficient values and density images of the two basis materials with a normalization process that makes use of a water-attenuation coefficient for the intended x-ray energy level. The monochromatic image depicts how the imaged object would look if the x-ray source produced x-ray photons at only a single energy level (Fig 3). The unit of measurement for one x-ray photon is kiloelectronvolts and specifies the photon energy for a monochromatic x-ray source (6). Calculation of the monochromatic image is a linear operation performed on the basis material images. Once a spectral acquisition is completed, postprocessing is applied to generate conventional low- and high-kilovolt-peak attenuation, material density, and synthesized monochromatic 40–140-keV images with use of dedicated software (Gemstone Spectral Imaging [GSI] Viewer 2.00 and GE Volume Share 4—AW 4.4, GE Healthcare). This postprocessing usually takes less than 20 seconds. The GSI Viewer allows the radiologist to efficiently obtain the desired clinical information and adjust the energy level (eg, to 70, 80, 90, 110, and 140 keV) to optimally reduce beam-hardening artifacts. Once the optimal energy level is chosen, the reformatted images are sent to the picture archiving and communication system and can be viewed on all commercially available viewers.

Teaching Point

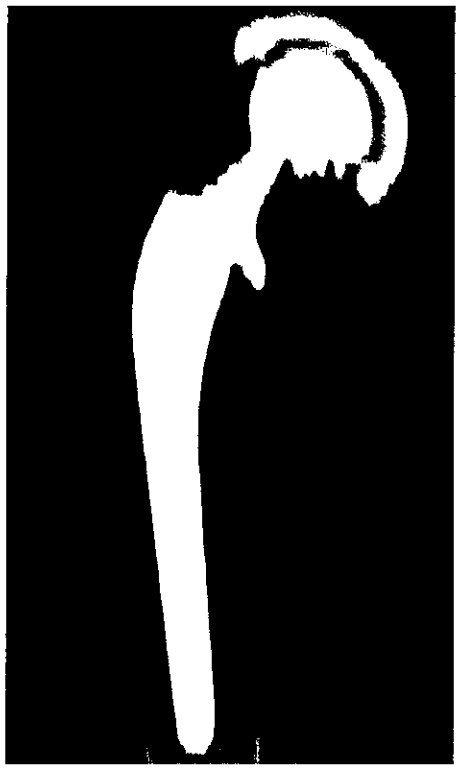
Beam-hardening Correction

A zone of nonfocal or focal periprosthetic lucency is a common complication of nonseptic hip arthroplasty (8). To improve the visualization of periprosthetic lucency or metal-to-bone or cement-to-bone interfaces, a higher energy (ie, 140 keV) should be used (Figs 4, 5). However, higher energies yield less contrast between materials, and lower energies are needed to visualize soft tissue.

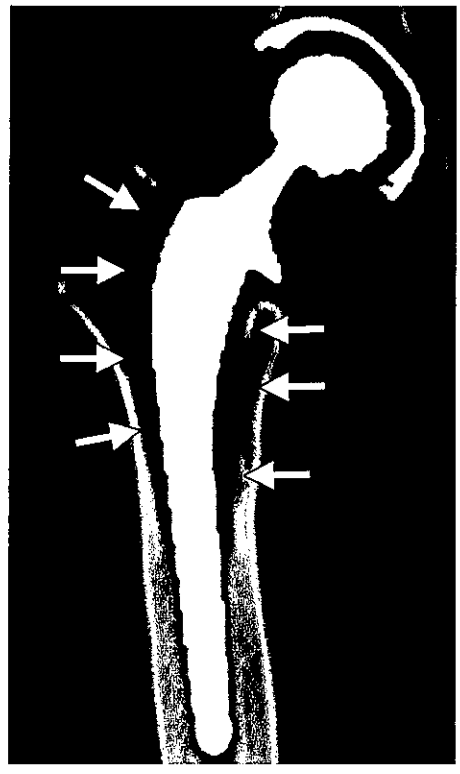
Teaching Point

CT is accurate in the detection of painful infection at the site of a hip prosthesis on the basis of soft-tissue findings, rather than bone periprosthetic abnormalities as seen at CT or conventional radiography. Infected hips show evidence of joint distention or fluid collections around the prosthesis (8). To improve the visualization of soft tissue both near and farther away from the implant, it is necessary to improve contrast between materials. Monochromatic images can provide the superior contrast resolution afforded by lower-energy acquisition (ie, 70 or 80 keV), but with less noise. The image noise on VMS images is lowest at approximately 70 keV. Consequently, for a given radiation dose, VMS images that are reconstructed at approximately 70 keV from split 80- and 140-kVp datasets have a lower noise level and a higher contrast-to-noise ratio than do 120-kVp CT images (5). At a lower energy level (eg, 80 keV), VMS imaging is more suitable for soft-tissue detail and easily demonstrates joint distention and fluid collections in infected hips (Fig 6).

Teaching Point

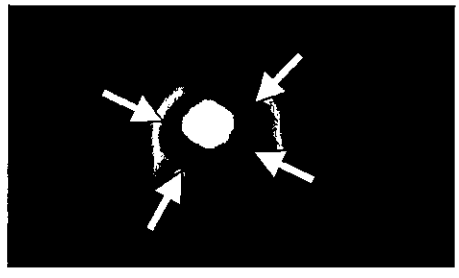


4a.

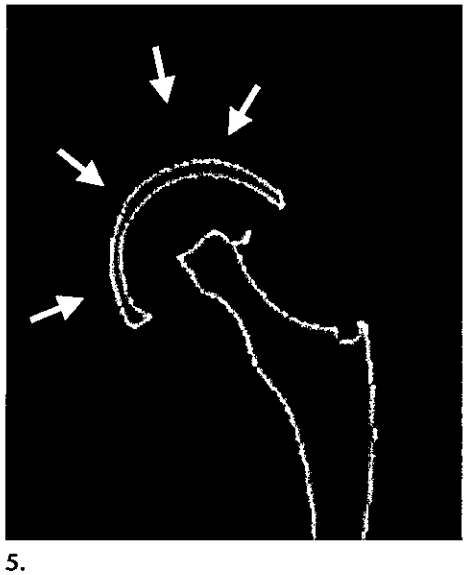


4c.

4b.



4d.



5.

Figures 4, 5. Aseptic prosthetic loosening. (4) On coronal reformatted (a) and axial (b) conventional (polychromatic) CT images, regions of bone around metal implants are obscured by beam-hardening artifacts. (c, d) Corresponding VMS CT images (140 keV) clearly depict a nonfocal low-attenuation line (arrows) at the bone-stem interface. Note the undersampling artifact around the metal implant in c. (5) Coronal reformatted VMS CT image (140 keV) clearly depicts a nonfocal low-attenuation line (arrows) at the acetabular cement-bone interface.

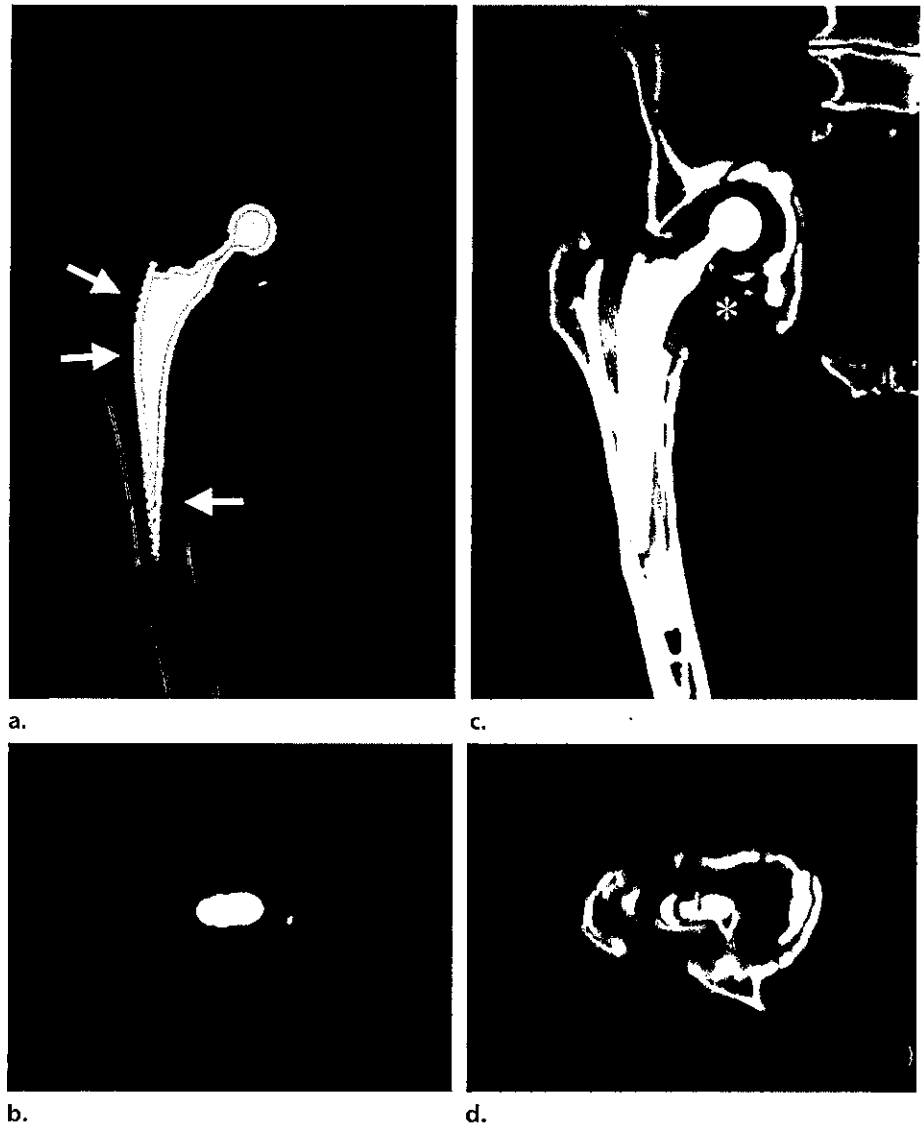
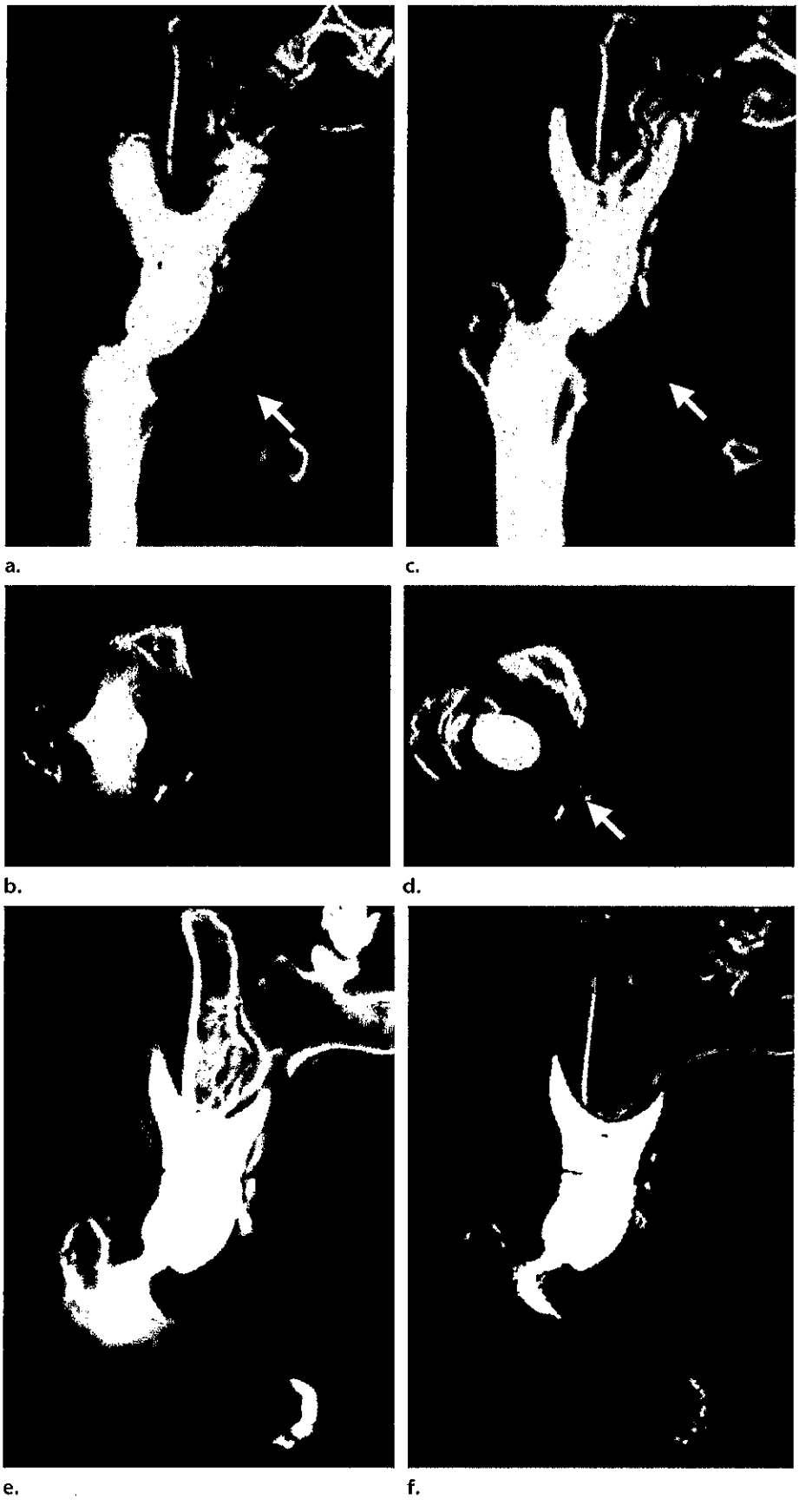
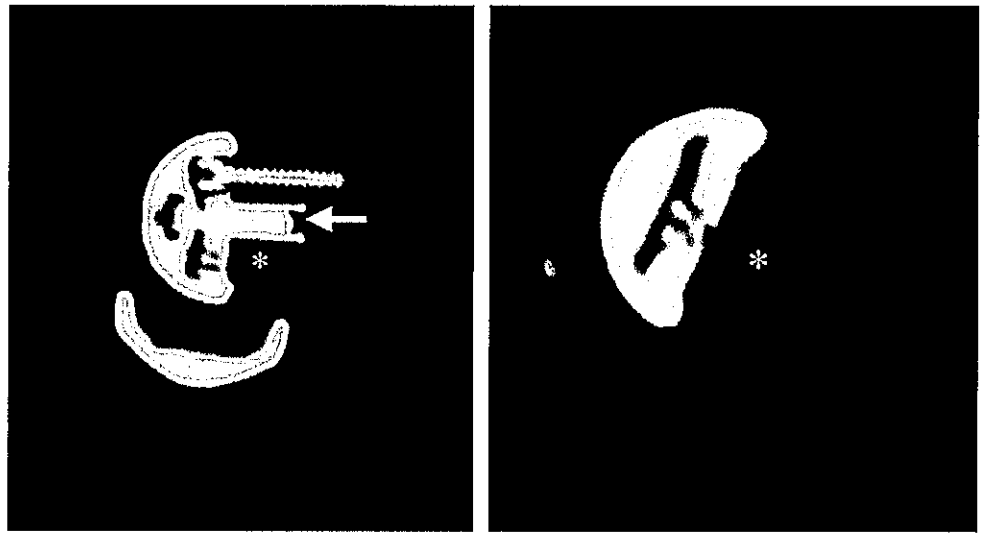


Figure 6. Septic hip prosthesis (*Staphylococcus aureus* infection). **(a, b)** Coronal reformatted **(a)** and axial **(b)** VMS images (140 keV) show large areas of low attenuation around the prosthesis (arrows in **a**), thereby helping visualize the bone-metal interface. **(c, d)** Corresponding VMS images obtained at 80 keV with MARS show joint distention (* in **c**) and allow better visualization of the soft tissues close to the prosthesis.

However, low-energy VMS imaging is less efficient in reducing beam-hardening artifact. To improve the visualization of soft tissue near (and not so near) the implant at lower energy, we use a vendor-specific metal artifact reduction software (MARS). With the GSI-MARS method, a metal prosthesis can be segmented on a conventionally reconstructed image based on a CT number threshold. By means of forward projection, the metal artifact–corrected image is then overlaid on the original image. GSI-MARS can also replace the photon-starved regions with information derived from accurate projection measurements by using material decomposition on the corrected projections and monochromatic images (9,10). Therefore, the GSI-MARS technology has the capacity to improve image quality in patients with prostheses (Figs 6, 7). However, the composition of the prosthesis can

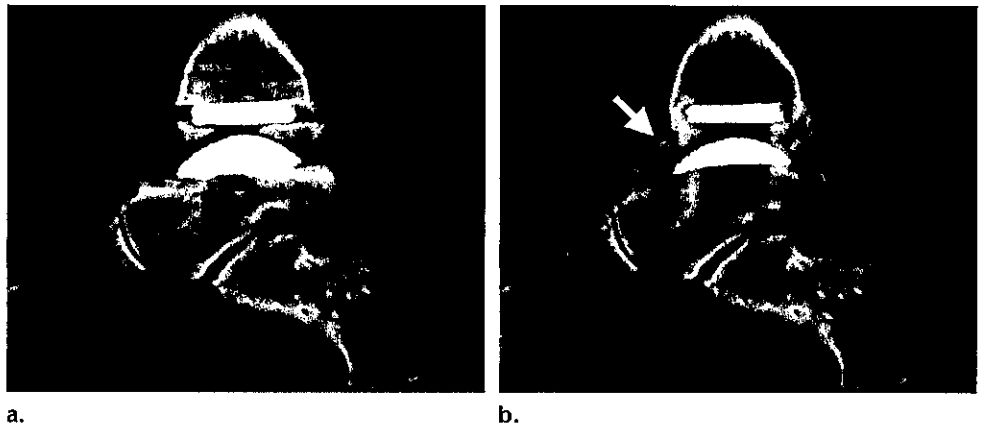
Figure 7. Relapse of bone metastasis next to a saddle prosthesis that had been used for reconstruction following excision of metastatic periacetabular tumors from a thyroid neoplasm. **(a, b)** On coronal reformatted **(a)** and axial **(b)** conventional (polychromatic) CT images, the regions of bone around the prosthesis are obscured by beam-hardening artifacts (arrow in **a**). **(c, d)** Corresponding VMS CT images (80 keV) obtained with MARS allow better visualization of the soft tissues near the prosthesis. Arrow = metastasis. **(e, f)** Follow-up coronal reformatted VMS CT images (80 keV) obtained 7 months later with soft-tissue windowing **(e)** and bone windowing **(f)** with MARS show an interval increase in tumor size. ▶


a.
c.
b.
d.
e.
f.



a. b.

Figure 8. Scapular notch in reverse total shoulder arthroplasty. A scapular notch is a defect of the bone in the inferior part of the glenoid component and corresponds to impingement of the superomedial part of the humeral implant against the pillar of the scapula. Coronal reformatted **(a)** and axial **(b)** VMS CT images (80 keV) obtained with MARS clearly depict the extent of the scapular notch (grade 4 in this case) (*), which obscures the lower screw and extends under the baseplate (arrow in **a**).



a. b.

Figure 9. Beam-hardening artifacts in total ankle arthroplasty. **(a)** On a conventional (polychromatic) CT image, the regions of bone around the metal implant are obscured by beam-hardening artifacts. **(b)** Corresponding VMS CT image (80 keV) obtained with MARS more clearly depicts a loose body in the anterior tibiotalar recess (arrow).

influence image quality. GSI-MARS CT is effective for the visualization of stainless steel prostheses (10). Dense metal alloys such as cobalt-chrome and stainless steel significantly attenuate the x-ray beam and produce more severe artifacts than do less dense metals such as titanium. For this reason, GSI-MARS reconstruction is more effective with dense metal prostheses than with titanium prostheses (10,11).

This technology can be used to reduce metal-related artifacts from a variety of causes: sinuses or facial bones compromised by dental fillings, a pelvic cavity compromised by a hip prosthesis, reverse total shoulder arthroplasty (Fig 8), total ankle arthroplasty (Fig 9), intervertebral fusion devices (Fig 10), lumbar disk arthroplasty (Fig 11), or

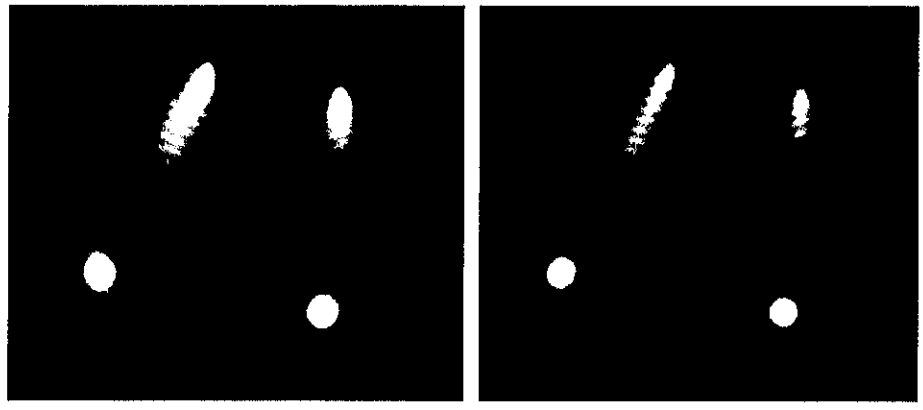


Figure 10. Beam-hardening correction in vertebral fusion. Axial VMS CT images of the lumbar spine obtained at 70 keV **(a)** and 140 keV **(b)** show fixation hardware at L4-L5.

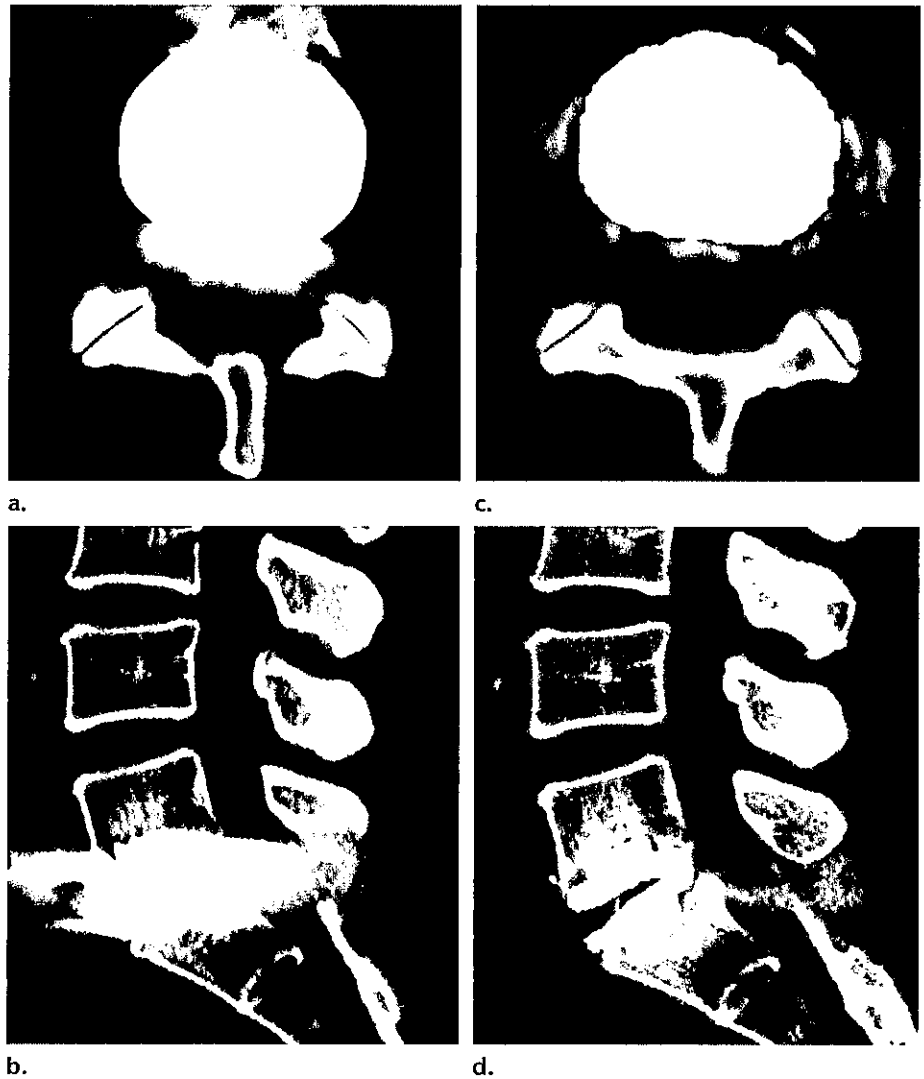


Figure 11. Beam-hardening correction in lumbar disk arthroplasty at the L5-S1 level. **(a, b)** Axial **(a)** and sagittal reformatted **(b)** conventional (polychromatic) CT images of the lumbar spine (soft-tissue windowing) show severe beam-hardening artifacts from orthopedic hardware that obscure the anatomy and limit evaluation of the spine. **(c, d)** Corresponding VMS CT images (80 keV) obtained with MARS show significant but incomplete reduction of beam-hardening artifact around the disk replacement **(c)** and in the spinal canal **(d)**.

Figure 12. Mechanical failure with bone resorption and osteolysis after total knee arthroplasty. **(a)** Coronal reformatted conventional (polychromatic) CT scan shows severe beam-hardening artifacts from orthopedic hardware that obscure the anatomy and limit evaluation of the bone. **(b)** Corresponding VMS CT image (110 keV) obtained with MARS shows reduction of the artifacts and allows better visualization of osteolysis (*).

total knee arthroplasty (Fig 12). In most of these cases, the artifacts are not completely eliminated but are substantially reduced (Figs 11, 12), allowing better visualization of the interfaces between the implant, bone, and surrounding tissue. In a study of 31 patients who underwent dual-energy CT of the area around a metal implant, Bamberg et al (4) found that image quality improved by 49% and diagnostic value by about 44%. In clinical practice, the optimal energy level for VMS imaging is variable. To improve image quality, the user needs to select an energy value for VMS imaging that is appropriate given the circumstances surrounding the imaged object.

Radiation Dose Considerations

More recent studies of dual-energy CT performed with fast kilovoltage switching have shown radiation dose levels similar to those with conventional CT. Li et al (12) found that the weighted CT dose index from dual-energy abdominal CT performed with fast kilovoltage switching was 14% higher than that from conventional CT. In a study comparing abdominal examinations performed with dual-energy CT with fast kilovoltage switching and those performed with conventional CT with a similar volume CT dose index (26.27 mGy), Zhang et al (13) found that diagnostic performance based on interpretation of 65-keV monochromatic dual-energy CT images was equivalent to that based

on interpretation of conventional images. To the best of our knowledge, however, there are no currently available data on radiation dose levels at dual-energy scanning compared with those at conventional single-energy CT for the evaluation of joints with metal implants (nonabdominal imaging). Further development of dual-energy CT noise-reduction algorithms may allow greater reductions in radiation dose levels (7).

Conclusion

The ability to obtain VMS images gives dual-energy CT potential advantages over conventional CT in reducing metal artifacts and improving image quality and diagnostic value. Evaluation of metal implants and adjacent bone or tissue is enhanced with VMS images reconstructed from dual-energy CT datasets. However, understanding principles of dual-energy CT data processing and image generation is necessary to derive maximum benefit from the dual-energy CT datasets.

References

1. Liu PT, Pavlicek WP, Peter MB, Spangehl MJ, Roberts CC, Paden RG. Metal artifact reduction image reconstruction algorithm for CT of implanted metal orthopedic devices: a work in progress. Skeletal Radiol 2009;38(8):797–802.
2. Barrett JF, Keat N. Artifacts in CT: recognition and avoidance. RadioGraphics 2004;24(6):1679–1691.
3. Lee MJ, Kim S, Lee SA, et al. Overcoming artifacts from metallic orthopedic implants at high-field-strength MR imaging and multidetector CT. RadioGraphics 2007;27(3):791–803.
4. Bamberg F, Dierks A, Nikolaou K, Reiser MF, Becker CR, Johnson TR. Metal artifact reduction by dual energy computed tomography using monoenergetic extrapolation. Eur Radiol 2011;21(7):1424–1429.
5. Matsumoto K, Jinzaki M, Tanami Y, Ueno A, Yamada M, Kuribayashi S. Virtual monochromatic spectral imaging with fast kilovoltage switching: improved image quality as compared with that obtained with conventional 120-kVp CT. Radiology 2011;259(1):257–262.
6. Silva AC, Morse BG, Hara AK, Paden RG, Hongo N, Pavlicek W. Dual-energy (spectral) CT: applications in abdominal imaging. RadioGraphics 2011;31(4):1031–1046; discussion 1047–1050.
7. Kaza RK, Platt JF, Cohan RH, Caoili EM, Al-Hawary MM, Wasnik A. Dual-energy CT with single- and dual-source scanners: current applications in evaluating the genitourinary tract. RadioGraphics 2012;32(2):353–369.
8. Cyteval C, Hamm V, Sarrabère MP, Lopez FM, Maury P, Taourel P. Painful infection at the site of hip prosthesis: CT imaging. Radiology 2002;224(2):477–483.
9. Brook OR, Gourtsoyianni S, Brook A, Mahadevan A, Wilcox C, Raptopoulos V. Spectral CT with metal artifacts reduction software for improvement of tumor visibility in the vicinity of gold fiducial markers. Radiology 2012;263(3):696–705.
10. Lee YH, Park KK, Song HT, Kim S, Suh JS. Metal artefact reduction in gemstone spectral imaging dual-energy CT with and without metal artefact reduction software. Eur Radiol 2012;22(6):1331–1340.
11. Douglas-Akinwande AC, Buckwalter KA, Rydberg J, Rankin JL, Choplin RH. Multichannel CT: evaluating the spine in postoperative patients with orthopedic hardware. RadioGraphics 2006;26(suppl 1):S97–S110.
12. Li B, Yadava G, Hsieh J. Quantification of head and body CTDI(VOL) of dual-energy x-ray CT with fast-kVp switching. Med Phys 2011;38(5):2595–2601.
13. Zhang D, Li X, Liu B. Objective characterization of GE discovery CT750 HD scanner: gemstone spectral imaging mode. Med Phys 2011;38(3):1178–1188.

Virtual Monochromatic Spectral Imaging with Fast Kilovoltage Switching: Reduction of Metal Artifacts at CT

Eric Pessis, MD • Raphaël Campagna, MD • Jean-Michel Sverzut, MD • Fabienne Bach, MD • Mathieu Rodallec, MD • Henri Guerini, MD • Antoine Feydy, MD, PhD • Jean-Luc Drapé, MD, PhD

RadioGraphics 2013; 33:573–583 • **Published online** 10.1148/rg.332125124 • **Content Codes:** CT MK PH

Page 574
A polychromatic image is an image generated at conventional single-energy CT due to the full spectrum of photon energies with the kilovolt peak defined by the user (eg, 80, 100, 120, or 140 kVp) (Fig 1).

Page 575
The basic principle of dual-energy CT is the acquisition of two datasets from the same anatomic location with use of different kilovolt peaks (usually 80 and 140 kVp).

Page 576
The monochromatic image depicts how the imaged object would look if the x-ray source produced x-ray photons at only a single energy level (Fig 3).

Page 576
To improve the visualization of periprosthetic lucency or metal-to-bone or cement-to-bone interfaces, a higher energy (ie, 140 keV) should be used (Figs 4, 5).

Page 576
At a lower energy level (eg, 80 keV), VMS imaging is more suitable for soft-tissue detail and easily demonstrates joint distention and fluid collections in infected hips (Fig 6).

Osteoarthritis and Cartilage 22 (2014) 1590–1605

Osteoarthritis and Cartilage

OARSI OSTEOARTHRITIS RESEARCH SOCIETY INTERNATIONAL

Review

Imaging of non-osteochondral tissues in osteoarthritis

A. Guermazi † *, F.W. Roemer † ‡, M.D. Crema † §, M. Englund ‖ ¶, D. Hayashi † #

† *Department of Radiology, Boston University School of Medicine, Boston, MA, USA*
‡ *Department of Radiology, University of Erlangen-Nuremberg, Erlangen, Germany*
§ *Department of Radiology, Hospital do Coração (HCor) and Teleimagem, São Paulo, SP, Brazil*
‖ *Department of Orthopedics, Clinical Sciences Lund, Lund University, Lund, Sweden*
¶ *Clinical Epidemiology Research and Training Unit, Boston University School of Medicine, Boston, MA, USA*
# *Department of Radiology, Bridgeport Hospital, Yale University School of Medicine, Bridgeport, CT, USA*

ARTICLE INFO

Article history:
Received 5 February 2014
Received in revised form
1 May 2014
Accepted 1 May 2014

Keywords:
Osteoarthritis
Synovitis
Meniscus
Ligaments
MRI
Ultrasound

SUMMARY

Objective: The aim of this review is to describe imaging techniques for evaluation of non-osteochondral structures such as the synovium, menisci in the knee, labrum in the hip, ligaments and muscles and to review the literature from recent clinical and epidemiological studies of OA.
Methods: This is a non-systematic narrative review of published literature on imaging of non-osteochondral tissues in OA. PubMed and MEDLINE search for articles published up to 2014, using the keywords osteoarthritis, synovitis, meniscus, labrum, ligaments, plica, muscles, magnetic resonance imaging (MRI), ultrasound, computed tomography (CT), scintigraphy, and positron emission tomography (PET).
Results: Published literature showed imaging of non-osteochondral tissues in OA relies primarily on MRI and ultrasound. The use of semiquantitative and quantitative imaging biomarkers of non-osteochondral tissues in clinical and epidemiological OA studies is reported. We highlight studies that have compared both imaging methodologies directly, and those that have established a relationship between imaging biomarkers and clinical outcomes. We provide recommendations as to which imaging protocols should be used to assess disease-specific changes regarding synovium, meniscus in the knee, labrum in the hip, and ligaments, and highlight potential pitfalls in their usage.
Conclusion: MRI and ultrasound are currently the most useful imaging modalities for evaluation of non-osteochondral tissues in OA. MRI evaluation of any tissue needs to be performed using appropriate MR pulse sequences. Ultrasound may be particularly useful for evaluation of small joints of the hand. Nuclear medicine and CT play a limited role in imaging of non-osteochondral tissues in OA.

Introduction

Thanks to modern imaging techniques and our improved understanding of the osteoarthritis (OA) disease process, it is now widely accepted that OA is a disease of the whole joint. The joint includes the non-osteochondral tissues such as fibrocartilage, synovium, and ligaments, although deterioration of the articular cartilage and osteophyte formation are still considered the hallmark features of OA. For decades, conventional radiography has been the main imaging tool to evaluate OA[1,2]. However, radiography cannot depict any of the aforementioned non-osteochondral structures (i.e., fibrocartilage, synovium and ligaments), which may be sources of pain and functional limitations in OA[3]. With the current wide availability of magnetic resonance imaging (MRI), importance of tissues other than bone has been increasingly recognized in OA research[4,5]. MRI is uniquely able to directly depict all anatomic structures of the joint, and is particularly suited for evaluation of non-osteochondral structures due to its inherent high soft tissue contrast. MRI allows evaluation of the joint as a whole organ and provides a more detailed picture of the changes associated with OA than is possible with any other imaging modality[6]. For MRI evaluation of OA features, one needs to be aware of the paramount importance of using the appropriate MR pulse sequences to visualize each particular feature (Table I). Ultrasound can also be used to assess synovium and meniscus affected in OA[7]. Other imaging modalities such as nuclear medicine and computed tomography (CT) play a limited role in evaluation of non-osteochondral tissues in OA studies[8]. This article reviews the role of MRI, ultrasound, CT and nuclear medicine imaging in the assessment of the

* Address correspondence and reprint requests to: A. Guermazi, Department of Radiology, Boston University School of Medicine, 820 Harrison Avenue, FGH Building, Boston, MA 02118, USA. Tel: 1-617-414-3893; Fax: 1-617-638-6616.
E-mail address: guermazi@bu.edu (A. Guermazi).

http://dx.doi.org/10.1016/j.joca.2014.05.001
1063-4584/

synovium, fibrocartilage (including the menisci and the acetabular labrum), ligaments and other non-osteochondral tissues including muscles and synovial plica, focusing on the available literature regarding imaging-based assessment of pathology of these tissues. The role of these pathological features in predicting pain and structural progression related to OA is also reviewed.

Methods

A PubMed and MEDLINE search for articles published up to September 2014 was performed, using the keywords "osteoarthritis" and "imaging". This search strategy yielded 4274 abstracts. Additional keywords, synovitis, meniscus, labrum, ligaments, plica and muscles were then added to narrow the search, yielding 959 abstracts, which were screened for relevance. In particular, authors focused on recently published articles written in English. Of those, 146 were included in the current review. Reference lists of all articles cited in this review article were also assessed to complete the literature search. Initial literature search was performed by AG and DH, and screening for relevance was performed by all authors. Evaluation was based upon the authors' own clinical and research experience in the field.

Imaging of synovitis

Overview

Imaging of synovitis has been reported using MRI, ultrasound, CT and nuclear medicine imaging in the literature. An advantage of MRI over ultrasound is that it can visualize synovial changes located deep within the large joints without being obscured by bony structures. MRI assessment of synovitis in knee OA is well-documented in the literature[9]. However, studies focusing on synovitis in hand OA are limited and those on other joints such as shoulder, ankle and spine are scarce[9]. Publications using CT and nuclear medicine imaging for imaging of synovitis in any joints are also limited[9].

MRI evaluation of synovitis

Prevalence of MRI-detected synovitis in knee OA

Data from Framingham OA Study showed the prevalence of synovitis, detected by non-contrast-enhanced (CE)-MRI, to be as high as 37% in 710 middle-aged and elderly persons without radiographic knee OA[10]. Various studies report the frequency of synovitis, detected using CE-MRI, to be high in persons with or at risk of knee OA (50.9–89.2%)[11–14].

Scoring methods for MRI evaluation of synovitis in knee OA

Several methods are available for semiquantitative or quantitative assessment of synovitis in OA using non-CE and CE-MRI[11,15–23]. MRI signs of synovitis are related to increased thickness/volume, increased signal intensity after intravenous gadolinium injection ("enhancement"), and increased water content, alone or in combination[24]. The importance of deploying CE-MRI for assessment of synovitis in OA has recently been recognized[9]. However large epidemiological OA studies published thus far have usually utilized non-CE-MRI for synovitis assessment. Semi-quantitative whole-organ scoring systems of knee OA that involve synovitis assessment as well as synovitis-specific scoring systems are summarized in Table II.

Non-CE-MRI evaluation of synovitis in knee OA

Using non-CE-MRI, synovitis can be assessed indirectly using a surrogate marker, i.e., hyperintense signal changes within Hoffa's fat pad on fat-suppressed (FS) proton density (PD)- or T2-weighted fast spin-echo sequences[25,26] ("Hoffa synovitis"[19]). Alternatively, synovitis can be evaluated in combination with effusion on these sequences but distinguishing inflamed synovium from joint fluid filling the joint cavity surrounded by synovium is not possible because both usually demonstrate equivalent high signal intensities[16,19]. Because of this, the phrase "effusion synovitis" has recently been introduced in the literature[19].

Differentiation between effusion and synovitis in knee OA

Studies have shown that effusion and synovitis often coexist in OA-affected joints[13,25] but they seem to be two distinct entities. A study has shown effusion volume is correlated with microscopic synovial inflammation but not macroscopic inflammation[27]. A recent CE-MRI-based study showed definite synovitis may be present with or without effusion[13]. Also, in a cohort without radiographic OA, baseline joint effusion—but not synovitis—predicted development of tibiofemoral cartilage loss[28]. Thus, inflamed synovium and effusion should probably be treated as two separate entities.

Considerations for imaging acquisition for non-CE-MRI evaluation of synovitis in knee OA

With non-CE-MRI, suggested pulse sequences to evaluate regions for Hoffa synovitis and effusion synovitis are T2-weighted, intermediate-weighted or PD-weighted fat-saturated images[19]. T1-weighted gradient echo type sequences are less suited for evaluation of synovitis on non-CE-MRI. These sequences are prone to chemical shift artifacts that hinder accurate assessment of synovial thickness and differentiation from other peripatellar structures

Table I
Suggested MRI sequences for optimum semiquantitative assessment of knee osteoarthritis features

Feature to be assessed	Suggested sequences	Planes	Reference
Synovitis (knee)	If CE-MRI is available:		Guermazi (2011)[23]
	Pre- and post-contrast T1-weighted fat saturated	Axial/sagittal	
	If CE-MRI is not available:		
	Hoffa synovitis: T2, intermediate or PD-weighted fat saturated	Mid-slices of the sagittal plane	
	Effusion synovitis: T2, intermediate or PD-weighted fat saturated or non-fat saturated	Axial	
Synovitis (hand)	Pre- and post-contrast T1-weighted fat saturated	Axial/sagittal/coronal	Haugen (2011)[48]
Synovitis (hip)	Pre- and post-contrast T1-weighted fat saturated	Axial/coronal	Roemer (2011)[51]
Meniscus (knee)	T1, T2 or PD-weighted fat saturated	Sagittal/coronal	Hunter (2011)[19]
Labrum (hip)	PD-weighted fat saturated	Sagittal/coronal	Roemer (2011)[51]
	Pre- and post-contrast T1-weighted fat saturated	Axial/coronal	
Ligaments (knee)	Intermediate or PD-weighted fat saturated	Axial/sagittal/coronal	Hunter (2011)[19]
Ligaments (hand)	T1-weighted fat saturated	Coronal	Haugen (2011)[48]

Table II
Summary of semiquantitative MRI scoring system for evaluation of synovitis, meniscal, labral and ligamentous lesions in knee, hip and hand osteoarthritis

Evaluation	Publication	Acronym	Joint	Scores	CE-MRI
Whole organ	Peterfy (2004)[16]	WORMS	Knee	Effusion/synovitis: 0–3 Meniscal tear: 0–4 Cruciate and collateral ligaments: 0–1	No
	Kornaat (2005)[18]	KOSS	Knee	Meniscal tear and extrusion: 0–3 Synovial thickening: 0–1	No
	Hunter (2008)[17]	BLOKS	Knee	Synovitis: size of signal changes in Hoffa's fat pad 0–3; five additional sites 0–1 Meniscal extrusion: 0–3 Meniscal status: evaluated 0–1 for: intrameniscal signal, tears, maceration, meniscal cyst Ligaments: 0–1	No
	Hunter (2011)[19]	MOAKS	Knee	Effusion-synovitis, Hoffa synovitis: 0–3 Meniscal extrusion: 0–3 Meniscal status: evaluated 0–1 for: intrameniscal signal, tears, maceration, meniscal cyst, hypertrophy Ligaments: 0–1	No
	Meredith (2009)[22]	–	Knee	Effusion and synovitis: 0–3	No
	Roemer (2011)[51]	HOAMS	Hip	Labrum: 0–3 Labral hypertrophy: 0–1	Yes
	Lambert (2011)[52]	HIMRIS	Hip	Combined synovitis and effusion: 0–2	
	Haugen (2011)[48]	OHOA-MRI	Hand	Synovitis: 0–3 Collateral ligament: 0–1	Yes
	Haugen (2013)[50]	HOAMRIS	Hand	Synovitis 0–3	Yes
Synovitis only	Rhodes (2005)[20]	–	Knee	Synovitis: 0–3	Yes
	Pelletier (2008)[31]	–	Knee	Synovitis: 0–3	No
	Baker (2010)[11]	–	Knee	Synovitis: 0–3	Yes
	Guermazi (2011)[23]	–	Knee	Synovitis: 0–2	Yes
	Wenham (2012)[54]	–	Hand	Synovitis: 0–2	No
Ligaments only	Bergin (2002)[131]	–	Knee	Ligaments: 0–4	No
	Stein (2011)[127]	–	Knee	Ligaments: 0–2	No
	Crema (2011)[128]	–	Knee	Ligaments: 0–3	No
Meniscus only	Berthiaume (2005)[100]	–	Knee	Meniscal tear: 0–3 Meniscal extrusion: 0–2	No

Abbreviations: KOSS = Knee Osteoarthritis Scoring Systems; BLOKS = Boston Leeds Osteoarthritis Knee Score; HOAMS = Hip Osteoarthritis MRI Scoring system.

such as the medial and lateral retinaculae and the surrounding fat[29].

Non-CE-MRI evaluation of synovitis in knee OA and associations with pain

There is conflicting evidence regarding association of pain with the severity of synovitis as determined on non-CE-MRI[26,30–35]. Possible reasons for such discrepancies may include the use of different scoring methods for synovitis and pain, the use of different pulse sequences in different studies, small sample size and no adjustment for potential confounders in some studies, and the limited specificity of signal alterations in Hoffa's fat pad for detection of synovitis[36].

CE-MRI evaluation of synovitis in knee OA and associations with pain

Although non-CE-MRI is still the most commonly used modality to assess synovitis in OA clinical studies[24,25,37,38], findings from CE-MRI studies have demonstrated the limitations of non-CE-MRI for evaluation of synovitis[11–13,20,23,36,39–43]. One clear advantage of CE-MRI over non-CE-MRI is its ability to differentiate inflamed synovium from joint effusion. Only synovium with inflammatory activity will show enhancement, while effusion will remain hypointense on T1-weighted sequences when imaged at the appropriate time after contrast administration (Fig. 1). Two recent studies reported that signal alterations in Hoffa's fat pad seen on non-CE sequences were a sensitive (71–97%) but not a specific (10–55%) sign of peripatellar synovitis, compared with CE sequences[14,36]. A histological correlation study compared three scoring systems for evaluating synovitis and joint effusion on MRI found that only the scoring from CE images correlated with microscopically proven synovitis[43].

Rhodes *et al.*[20] demonstrated that semiquantitative scoring of OA synovitis using CE T1-weighted images correlated well with quantitative synovial volume assessments. This scoring method was subsequently modified and was used in another study which demonstrated that synovitis in the peripatellar region has a strong relation with knee pain severity[11]. In these studies, however, evaluation was limited to synovitis of the peripatellar region. To enable evaluation of whole-knee synovitis, a new scoring system was published by Guermazi *et al.* based on a CE T1-weighted sequence to assess synovitis at 11 sites in subjects with knee OA[23]. Synovitis is graded from 0 to 2 at each of 11 locations in the knee joint: medial and lateral parapatellar recess; suprapatellar, infrapatellar, intercondylar, medial and lateral perimeniscus; and adjacent to posterior and anterior cruciate ligaments (PCL and ACL), loose bodies and Baker's cysts. This scoring system showed good to excellent inter-reader and intra-reader reliability. Additionally, moderate to severe synovitis showed a significant association with the maximum Western Ontario and McMaster Osteoarthritis Index (WOMAC) pain score compared to knees with no or equivocal synovitis. Using this scoring method, a recent study reported that synovitis was strongly associated with tibiofemoral radiographic OA and widespread MRI-detected cartilage damage[12]. Another study by Roemer *et al.* demonstrated an association between meniscal damage of the posterior horns and localized posterior synovitis[44]. Moreover, synovitis severity evaluated using this scoring method was validated by arthroscopic and synovial biopsy findings in knee OA patients[45]

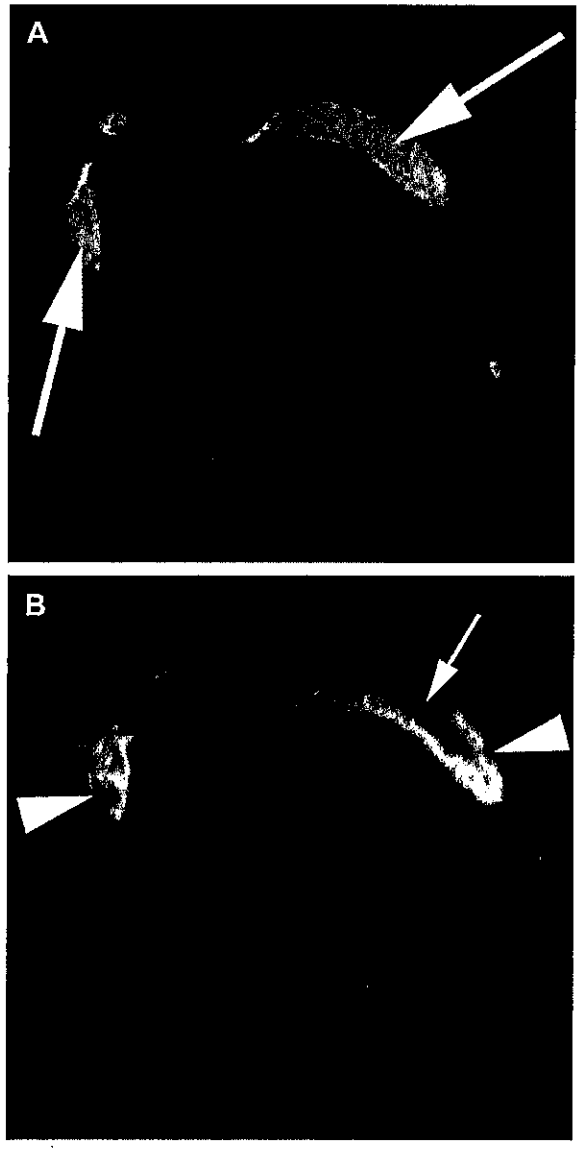


Fig. 1. Synovitis assessed on non-enhanced and contrast-enhanced sequences. (A) Axial PD-weighted fat-suppressed MRI shows severe patellofemoral OA of the knee with cartilage loss, subchondral bone marrow alterations and diffuse hyperintensity in the joint cavity representing a composite of joint effusion and synovial thickening. (B) Axial CE T1-weighted fat-suppressed MRI of the same knee clearly shows that most of this represents synovial thickening (arrowheads). There is only a little joint fluid seen in the left peripatellar recess (arrow), which is visualized as linear hypointensity.

Need for longitudinal knee OA studies using CE-MRI

There is a lack of longitudinal studies using CE-MRI to evaluate changes in synovitis severity before and after treatment. So far, only one study has been published, which is a randomized controlled study using CE-MRI to monitor the efficacy of a bradykinin receptor 2 antagonist in painful knee OA[40]. Despite significant improvement in the visual analogue scale (VAS) pain score after therapy, there was no significant change in the severity of synovitis as detected on CE-MRI in 36 subjects. Moreover, a paucity of histopathologic correlation studies is noted. Such studies are needed to establish a better cutoff between normal and pathologic enhancement, since discrete enhancement of synovial tissue may be physiologic[46,47]. To date, only three such studies have been published[39,42,43]. Moreover, there is a lack of longitudinal studies using CE-MRI to assess synovitis in knee OA and its relationship with progression of structural damage, such as progression of joint space narrowing or progression of cartilage loss. This important question, whether synovitis in knee OA predicts progression of structural disease, is of the utmost importance since the synovium would be a potential target in clinical practice and clinical research.

Scoring methods for MRI evaluation of synovitis in hand OA

Synovitis in hand OA can be semiquantitatively assessed using an MRI scoring system for hand osteoarthritis, called the Oslo Hand Osteoarthritis MRI Score (OHOA-MRI)[48]. Pathological features are assessed at eight locations (distal and proximal interphalangeal joints of the second, third, fourth and fifth fingers) of the dominant hand. This study demonstrated reliable assessment of synovitis in hand OA is possible. Using this system, one study showed that MRI-assessed moderate/severe synovitis was associated with joint tenderness[49]. These studies demonstrated that synovitis of hand OA may be a target for therapeutic interventions. Using the OHOA-MRI as a template, the Outcome Measures in Rheumatology (OMERACT) Hand Osteoarthritis Magnetic Resonance Imaging Scoring System (HOAMRIS) was iteratively developed. Modifications to the original OHOA-MRI included exclusion of flexor tenosynovitis and collateral ligament scoring, as well as combining the scoring of distal and proximal parts of distal interphalangeal joint (DIP) and proximal interphalangeal joint (PIP) joints and half-grade scoring for some of the features. The HOAMRIS includes semiquantitative assessment of synovitis in the interphalangeal joints and was shown to be a reliable tool[50]. However, longitudinal studies are needed to assess both semiquantitative methods for their sensitivity to detect change in synovitis over time.

Scoring methods for MRI evaluation of synovitis in hip OA

To date, two semiquantitative scoring systems are available for MRI evaluation of synovitis in hip OA. One is the Hip OA MRI Score (HOAMS), in which synovitis is one of 14 features of hip OA, and CE T1-weighted sequences are used whenever available[51]. Synovitis is graded 0–2 at four locations (anterior/posterior/lateral/medial femoral head–neck junction). If CE-MRI is not available, non-CE-MRI can be used to evaluate joint effusion (which is in fact a combination of effusion and synovitis, i.e., "effusion synovitis") as an indirect marker of synovitis. The other is the Hip Inflammation MRI Scoring System (HIMRISS), in which synovitis is graded 0–2 in combination with effusion, once in 15 slices, giving a maximum score of 30 per hip[52]. Recently performed validation exercises demonstrated that these two scoring systems are feasible and reliable for the purpose of synovitis assessment in hip OA[53], although these scoring systems have not yet been applied in observational studies or clinical trials and require further validation.

Association of pain with MRI-detected synovitis in hand and hip OA

One randomized, double-blind, placebo-controlled trial of low-dose oral prednisolone for treating painful hand OA used 0.2 T MRI for semiquantitative assessment of synovitis/effusion using short tau inversion recovery (STIR) sequence[54]. They showed a high prevalence of MRI-detected synovitis/effusion in painful hand OA, but little change was observed in the severity of synovitis/effusion between baseline and follow-up in both treatment and placebo groups. However, short-term low-dose oral prednisolone was found not to be an effective analgesic treatment for hand OA. A trend of an increased risk of pain with increasing severity of MRI-detected synovitis in hip OA was shown, albeit statistically non-

significant[51], in a study using 1.5 T MRI and CE-MRI-based semi-quantitative assessment of synovitis.

Advantages of dynamic CE-MRI over static CE-MRI

There are few studies using dynamic CE-MRI, in which early enhancement (i.e., initial distribution of gadolinium) accurately reflects the inflammatory activity of the joint[24,55,56]. With static CE-MRI, the extent of "synovial enhancement" may be misinterpreted if the assessment is performed on images acquired at a late phase, because the signal intensity of joint effusions also increases with time, starting in the periphery and gradually approaching the central parts, as gadolinium passes into the joint space by diffusion of fluid from synovial capillaries[27]. Thus, dynamic CE-MRI seems to be a useful tool for assessing synovitis in rheumatoid arthritis (RA) patients[24]. One study showed that dynamic CE-MRI with derived pharmacokinetic parameters can provide useful information in differentiating synovitis in hand OA from that in RA[57]. Thus, there might also be added clinical value in using dynamic CE T1-weighted MRI assessment of synovitis in OA.

Two recent studies[40,41] used dynamic CE-MRI and directly compared ultrasound and MRI (with or without contrast) for detection of synovitis in painful knee OA. Although they found that CE-ultrasound was more sensitive than CE-MRI for detecting synovitis in painful knee OA, the work was done with a 0.2 T magnet. Unfortunately, direct comparison with other studies using 1.5 T or 3 T magnets is difficult since there is no published evidence regarding the equivalence of diagnostic performance between 0.2 T and 1.5 T/3 T magnets for synovitis assessment using dynamic CE-MRI. One dynamic CE-MRI-based study that used a 3 T magnet found that quantitative synovial volume strongly correlated with total volume of bone marrow lesions in knee OA patients[21].

Ultrasound evaluation of synovitis

Advantages and disadvantages

Thanks largely to recent technological advance, ultrasound is increasingly used for imaging of OA patients. Advantages include the multiplanar nature of the modality, high-resolution imaging, and dynamic imaging in real time[58]. Its usefulness as a guidance tool for interventional procedures has been demonstrated[59–61]. It is also cost efficient and does not require contrast agents to visualize synovium[6]. Major limitations include its relatively limited anatomical field-of-view compared to MRI and its highly operator-dependent nature, as well as potential difficulty in reproducibility and scoring of synovitis, especially in terms of tracking the same location within the synovium[58].

With current generation ultrasound technology, one can detect synovial pathologies including hypertrophy, increased vascularity and the presence of synovial fluid in joints affected by arthritis[6,62]. It has been demonstrated that ultrasound detects synovial pathology more readily than clinical examination[63,64] and has been validated against the findings based on MRI, arthroscopy and histopathology[64–68]. Moreover, ultrasound can detect synovitis in joints which are thought to be clinically quiescent[62]. In addition to morphologic changes, Doppler techniques enable evaluation of synovial vascularity, a surrogate of inflammatory activity[65,66]. A recent study demonstrated that ultrasound-detected synovial thickening and power Doppler signals were more frequently found in erosive hand OA compared to non-erosive hand OA[69]. It should be noted that, while color Doppler ultrasound is a useful technique for the detection of synovitis, it cannot differentiate between synovitis in OA and other arthritides based on the findings of color Doppler signals alone[70].

Scoring methods for ultrasound evaluation of synovitis in hand OA

Numerous reports on the validity of ultrasound in inflammatory arthritis are available[71,72]. Recently, a preliminary ultrasound-based scoring system for features of hand OA was published[73]. This scoring system included evaluation of grey-scale synovitis and power Doppler signal in 15 joints of the hand. These features were assessed for their presence/absence and if present were scored semiquantitatively using 1–3 scale. Overall, the reliability exercise demonstrated moderately good intra- and inter-reader reliability without extensive standardization. This study has demonstrated that an ultrasound-based outcome measure suitable for multicenter trials is feasible and likely to be reliable, and has provided a foundation for further development[73]. Currently, a clinical trial to determine effectiveness of hydroxychloroquine in reducing symptoms and providing long-term structural benefit in hand OA patients is in progress[74]. A substudy of this trial will address whether baseline synovitis is a predictor of therapeutic response.

Ultrasound evaluation of synovitis in hand OA and association with pain

A recent study with 55 hand OA patients evaluated the association of ultrasound-detected features including synovial thickening and power Doppler signal with symptoms, and found that these features were associated with pain on palpation of the affected joints[75]. In contrast, a study involving 36 subjects showed that a reduction in symptoms following intra-muscular corticosteroid injection was not associated with a statistically significant reduction in grey-scale synovitis or power Doppler signal[76]. There was, however, little synovitis in the patients with hand OA in this study and it may have been insufficient to show detectable change. Likewise, in a small study involving 16 subjects, there was a decrease in VAS score for pain 24 weeks after intra-articular high molecular weight hyaluronic acid treatment, and yet there was no significant decrease in the synovial hypertrophy score or power Doppler signal during the same follow-up period[61]. The small sample size also limits the statistical power of this study.

Ultrasound evaluation of synovitis in knee OA and association with pain

Evaluation of synovitis in knee OA using ultrasound has also been documented[63,70,77–80]. A cross-sectional, multicenter European study supported by the European League against Rheumatism (EULAR)[63] analyzed 600 patients with painful knee OA, and found that ultrasound-detected synovitis was correlated with advanced radiographic OA and clinical signs and symptoms suggestive of an inflammatory "flare". A longitudinal study based on the same cohort showed ultrasound-detected synovitis was not a predictor of subsequent joint replacement[77]. Additionally, ultrasound signs of synovitis were found to be reflected metabolically by markers of joint tissue metabolism[79]. In a study involving 56 knee OA patients, medial compartment synovitis detected by grey-scale ultrasound was positively linearly associated with VAS scores on motion, as well as VAS scores at rest, WOMAC pain subscale, and the presence of medial knee pain[80].

An attempt was recently made to utilize a novel technique of digital synovial vascularization quantification by using ultrasound with CE[41] for detection of synovitis in 41 patients with knee OA. CE-ultrasound showed higher sensitivity (95%) for synovitis detection than CE-MRI (82%), power Doppler ultrasound (64%) or grey-scale ultrasound (58%). It is a little surprising that ultrasound shows higher sensitivity than the CE-MRI used as the reference standard. Without histological proof, these results should be viewed with some skepticism.

Ultrasound evaluation of synovitis in hip OA and association with pain

There is mixed evidence regarding the association between the severity of OA-related symptoms and ultrasound-detected synovial hypertrophy. Recently, a study of synovitis in 40 patients with hip OA demonstrated a statistically significant reduction of synovial hypertrophy together with reduced pain on walking (measured by VAS) following intra-articular corticosteroid injection[59].

Nuclear medicine imaging of synovitis in OA

Scintigraphy

Scintigraphic techniques to visualize synovitis target cells such as macrophages or lymphocytes which are involved in the inflammatory process of the synovium, as the intravenously injected radiopharmaceuticals bind to the activated macrophages[81]. Scintigraphy with ^{99m}Technetium (Tc)-labelled J001 detected synovitis in experimental OA in a rodent model[81]. However, scintigraphic studies to evaluate synovitis in OA patients have been limited to date. One study showed positive localization of ^{99m}Tc-hexamethylpropyleneamine-oxime-labelled white blood cells[82] in the synovium, suggesting that low-grade synovitis was occurring in some OA patients. Another study showed that ^{99m}Tc-labelled polyclonal human immunoglobulin G (IgG), compared to ^{99m}Tc-labelled hydroxymethylene-diphosphonate, was more specific when detecting synovitis in RA and OA patients[83]. In this study, ^{99m}Tc-IgG scintigraphy demonstrated higher disease activity in RA than in OA patients.

Positron emission tomography (PET)

PET uses ^{18}F-fluoro-2-deoxy-D-glucose (FDG) and demonstrates metabolic changes in target tissues and can detect foci of inflammation. One study evaluated shoulder OA using FDG-PET[84]. In this study, the FDG uptake in the shoulder joint showed a circumferential and diffuse pattern in patients with clinically diagnosed shoulder OA. A recent pilot study in knees with medial OA showed a periarticular pattern of increased FDG uptake[85]. The standard uptake values in OA patients were significantly higher than those in healthy controls. Another study compared FDG uptake in the hand and wrist of patients with OA[86]. FDG uptake was observed in a few OA joints. These findings were thought to reflect the presence of synovitis in OA-affected joints.

Limitations of nuclear medicine imaging techniques

Limitations of scintigraphy and PET include poor anatomical resolution and radiation exposure. Because of the wide availability of ultrasound and MRI, scintigraphy has little current clinical application in routine practice. However, to overcome the poor anatomical resolution of PET, an attempt has been made to register PET images with MRI which offer high anatomical resolution[87]. Additional drawbacks of PET are its limited availability and high costs. PET permits molecular imaging and may have potential for studying OA synovitis because of both the high resolution of commercially available scanners and the possibility of new PET tracers that specifically target molecular pathways associated with synovitis in OA[86,88]. At this time, however, the value of PET for the assessment of OA in clinical and research settings remains to be shown.

CT imaging of synovitis in OA

CT without contrast enhancement (CE) is unsuitable for synovitis evaluation because of low soft tissue contrast. The role of CE-CT has not been well studied for assessment of synovitis in OA. However, a recent study showed that CE-CT with digital bone masking could be used to demonstrate synovial enhancement in RA patients[89]. Moderate to high agreement between CE-CT and CE-MRI findings for synovitis and tenosynovitis was demonstrated. Due to a much shorter examination time (average 3.5 min) compared to CE-MRI (average 55 min), all participants preferred CE-CT to CE-MRI. Additional advantages of CT are its wide-spread availability and cost-efficiency compared to MRI. Evaluation of CE-CT in OA patients may be a worthwhile exercise when access to MRI facilities is limited, or when MRI is contraindicated, but further evaluation is needed to determine its potential role in research or clinical practice.

Summary of imaging of synovitis in OA

At present, CE-MRI and ultrasound appear to be the two most useful imaging modalities for evaluation of synovitis in OA. Recent studies have shown a potential for ultrasound to become a powerful tool for synovial assessment in OA of the hand and the knee, including monitoring of disease progression and therapeutic effects, such as assessment of response to corticosteroid and hydroxychloroquine. An important question that remains to be determined is whether ultrasound-detected synovitis in OA predicts those who respond to corticosteroid or hydroxychloroquine therapies. Data from ongoing clinical studies are awaited. Non-CE-MRI is currently the most common technique to evaluate synovitis in knee OA clinical studies. It may still be used where CE-MRI is unavailable or contraindicated, but one should note that the choice of pulse sequences needs to be appropriate for a meaningful interpretation of results. Although there is conflicting evidence, recent studies suggest synovitis may be a source of pain in OA. CE-MRI-detected synovitis seems to correlate with histology and is more sensitive and more specific than non-CE-MRI. Overall, studies based on CE-MRI showed associations of synovitis with pain more consistently than those based on non-CE-MRI. While pitfalls do exist for CE-MRI (e.g., discrete enhancement of synovial tissue from CE-MRI can be physiologic and it is unknown if CE-MRI-assessed synovitis can predict the disease progression of OA), CE-MRI would be recommended for comprehensive assessment of synovitis in OA whenever synovitis is the focus of interest as a surrogate outcome measure or as a predictor of subsequent clinical or structural changes.

Imaging of meniscal pathology in the knee

Overview

Although meniscal tears can occur in persons with or without radiographic knee OA[10,90], meniscal pathologies are strongly linked to the knee OA disease process (Fig. 2), since structural changes (i.e., meniscal tear, maceration, or extrusion) can lead to a loss of the normal function of buffering the mechanical load at the tibiofemoral joint[91]. Loss of meniscal function is strongly associated with increased risk of development of radiographic OA[92–94]. The loss may be the result of the meniscal tear or meniscal root tear, meniscal extrusion and/or potential ensuing surgical resection of meniscal tissue (partial or total meniscectomy), and severe medial meniscal tears and medial meniscal extrusion at baseline are long-term predictors of total knee arthroplasty[95]. Imaging of meniscal pathology in OA is mainly done using MRI, but the use of ultrasound has also been reported.

Prevalence of meniscal pathology in knee OA

The prevalence of meniscal tears in the knees of middle-aged or elderly persons ranges from about 19% to 56% and increases with

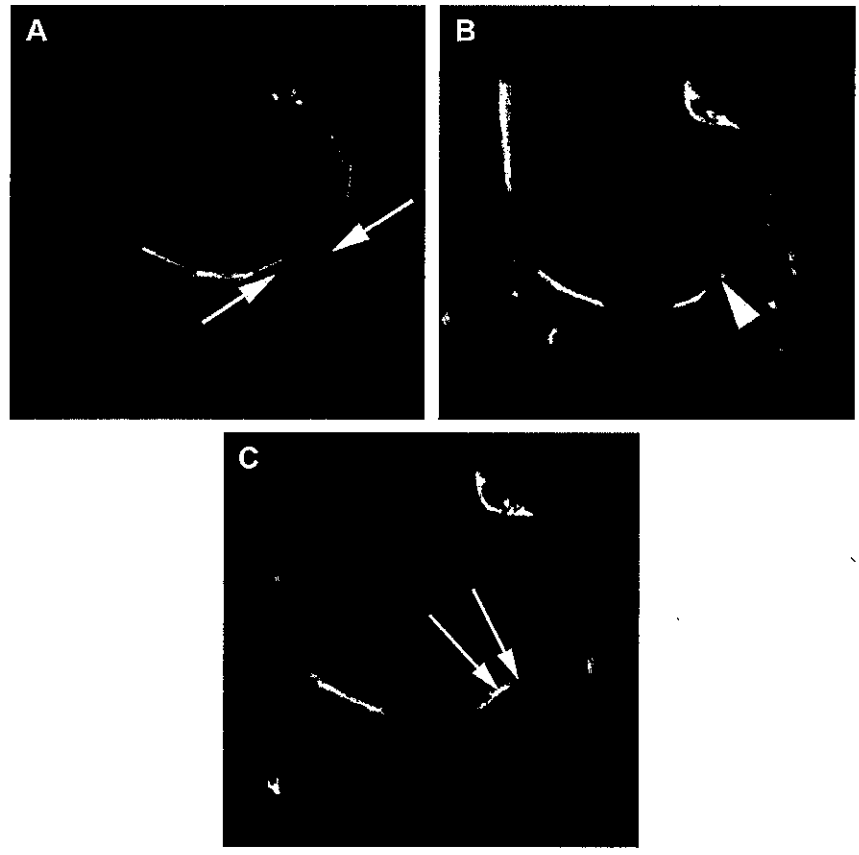


Fig. 2. Meniscal damage preceding cartilage loss. (A) Baseline sagittal intermediate-weighted fat-suppressed MRI shows a horizontal oblique degenerative meniscal tear of the medial-posterior horn (arrows). (B) Twelve months later, focal cartilage damage is seen at the central part of the medial femur directly adjacent to the meniscal lesion (arrowhead). (C) At 24-month follow-up increasing cartilage loss is observed locally, directly adjacent to the meniscus. This example illustrates how the meniscal function is paramount for physiological load transmission and protection of the articular surface integrity.

age. If meniscal maceration/destruction is included in the definition of a tear, the prevalence is even higher, particularly in elderly women[90]. A Korean population-based study reported the frequency of meniscal damage in elderly persons to be 49.7% in men and 71.2% in women[96].

MRI evaluation of meniscal pathology in knee OA

Technical considerations

To achieve imaging of the menisci and its pathologies with high spatial resolution and a high signal-to-noise ratio, the use of a dedicated knee coil is essential. To visualize menisci and detect pathology, slice thickness should be no more than 3 mm, and both sagittal and coronal images are required[97]. Also, axial MRI had demonstrated usefulness in the detection and characterization of meniscal pathology[98]. T1, T2 and PD-weighted fat-saturated fast or turbo spin-echo sequences are useful for diagnosis of meniscal pathology[14]. The sensitivity and specificity of detecting a meniscal tear by MRI are reported to range 82–96%, and the utilization of the "two-slice touch" rule, in routine bi-dimensional techniques, i.e., requiring the tear to be seen on at least two adjacent slices, yields high specificity[99]. Available whole-organ semiquantitative scoring systems of the knee joint include scoring for meniscal pathology[16–19,22]. A grading scheme dedicated to meniscal tear and extrusion alone has also been published[100].

Meniscal tear

Using the data from the Multicenter Osteoarthritis Study (MOST) study, Englund *et al.* demonstrated that knee trauma, varus malalignment, and bony enlargement of finger joints were risk factors for development of MRI-detected medial meniscal pathology in knees with normal medial meniscus at baseline[101]. Degenerative tears are by far the most typical tears[90], and this fact has important treatment implications. The Meniscal Tear in Osteoarthritis Research (MeTeOR) trial is a multicenter, randomized, controlled trial involving symptomatic patients 45 years of age or older with an MRI-detected meniscal tear and evidence of mild-to-moderate OA[102]. Investigators randomly assigned 351 patients to surgery and postoperative physical therapy or to a standardized physical-therapy regimen (with the option to cross over to surgery at the discretion of the patient and surgeon). In the intention-to-treat analysis, no significant differences were found between the study groups in functional improvement 6 months after randomization. In a more recent Finnish trial, using a placebo-controlled design, of symptomatic patients with MRI-verified degenerative meniscal tear and no radiographic OA, the authors found that outcomes after arthroscopic partial meniscectomy were no better than those after a sham surgical procedure[103]. These two high quality trials together with prior evidence from other randomized controlled trials of arthroscopy in OA[104,105] strongly highlight that arthroscopic surgery should be avoided in patients in these categories. Symptoms are more likely to be caused by other features or

processes in the knee related to OA or incipient OA such as bone marrow lesions or synovitis rather than the damaged meniscal tissue itself[106,107]. Authors of a cross-sectional study involving 294 subjects reported the presence of meniscal tear was associated with higher age, body mass index, female gender, and family history of OA[108].

Meniscal extrusion

Meniscal position is also of great importance in imaging of soft tissue. Using MRI, Crema *et al.* found that medial meniscal extrusion is associated with medial meniscal tears, medial cartilage damage, and varus alignment; and that lateral meniscal extrusion is associated with lateral meniscal tears, lateral cartilage damage and valgus alignment[109]. In a study by Stehling *et al.*, subjects with degenerative knee abnormalities showed significantly increased meniscal extrusion compared to normal subjects when the knee was subjected to an axial mechanical load[110]. In a 2-year longitudinal study the authors found meniscal extrusion at baseline to be associated with greater loss of knee cartilage over 2 years[111]. This study further suggested that increasing body mass index and bone size, past knee injury, and osteophytes might be causally related to meniscal extrusion, and that meniscal extrusion might represent one pathway between bone expansion and cartilage loss.

Meniscal root tear

Tears of the meniscal roots should be treated as a separate entity from tears of the menisci themselves since they can lead to substantial meniscal extrusion if the meniscus loses the ligaments that anchor it to the tibial plateau. Guermazi *et al.* demonstrated that isolated medial-posterior meniscal root tears (i.e., no tears in the body or anterior/posterior horns of the medial meniscus) are associated with incident and progressive medial tibiofemoral cartilage loss[112] (Fig. 3).

Quantitative techniques

In addition to semiquantitative scoring of menisci using the conventional MRI sequences described above, some publications have reported the use of different quantitative techniques as well as molecular imaging and experimental MRI sequences. A 3D meniscal segmentation technique provides quantitative measures of meniscal size and position and other parameters. One study showed that painful knees had decreased meniscal coverage of the tibial plateau and greater extrusion of the meniscal body when compared to knees without pain, in a subcohort from the Osteoarthritis Initiative[113]. A more recent study compared knees with medial compartment OA to knees without OA and found changes in meniscal position and shape in both compartments in the OA knees but not in the knees without OA[114].

Evaluation of physiologic changes of the meniscus

Using the delayed gadolinium-enhanced MRI (dGEMRIC) technique to assess the meniscal substance in OA knees and control non-OA knees of younger subjects, significant differences were found between those groups for both ionic and non-ionic contrast agents[115]. These results suggest that the difference in the distribution of meniscal T1 values between OA patients and normal subjects was not determined by the distribution of charged particles, but might be related to changes in wash-in and wash-out kinetics. Further, another study using dGEMRIC of menisci in a group of 21 asymptomatic subjects and nine patients with self-reported OA, showed that T1 values of the posterior horn of the medial meniscus correlated with those from the medial tibiofemoral articular cartilage[116]. T1rho values have been shown to be higher in specific subregions of the meniscus and tibiofemoral cartilage, suggesting that regional damage of both tibiofemoral hyaline cartilage and menisci may be associated with OA[117]. An ultrashort echo time-enhanced (UTE) T2* mapping technique has been

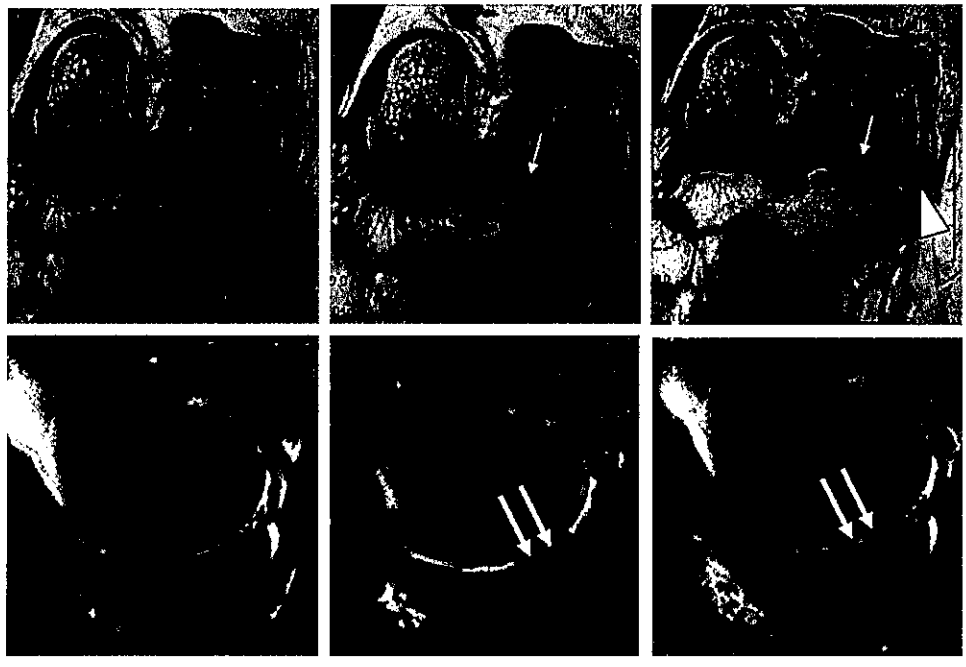


Fig. 3. Meniscal instability as a cause of incident OA. The upper row shows coronal intermediate-weighted non-fat-suppressed MRIs over 2 years; the lower row shows corresponding sagittal intermediate-weighted fat-suppressed MRIs of the medial compartment. The left column depicts normal meniscal and cartilage integrity. The middle column (12-month follow-up images) shows an incident root tear of the medial-posterior horn (small arrow). The corresponding sagittal image shows superficial cartilage thinning adjacent to the meniscus (thick arrows). The upper right image (24-month follow-up) shows widening of the meniscal tear (small arrow) and increasing medial meniscal subluxation (arrowhead). The corresponding sagittal image shows perimeniscal cartilage thinning. Radiographic OA was diagnosed at month 24.

deployed to detect meniscal degeneration *in vitro* and *in vivo* in subjects at risk of developing OA[118]. In this cadaveric and human study, significant elevations of UTE-T2* values were observed in the menisci of subjects with ACL injury but without clinical evidence of subsurface meniscal abnormality. UTE-T2* mapping may be a sensitive tool for detecting subclinical meniscal degeneration, but it remains to be seen whether altered intrameniscal biochemical values can actually predict progression to meniscal degeneration and tearing or the development of OA.

Ultrasound evaluation of meniscal pathology in OA

A study by Kawaguchi *et al.* using ultrasound to look at medial radial displacement of the meniscus in the supine and weight-bearing positions showed that the medial meniscus was significantly displaced radially by weight-bearing in control knees and in knees with Kellgren Lawrence grades 1–3[119]. Significant differences were noted between control knees and Kellgren Lawrence grade 2 or greater knees in the supine and standing positions, and displacement had increased in all weight-bearing knees at 1-year follow-up, except Kellgren Lawrence grade 4 knees. Another study also showed that ultrasound-detected medial radial displacement of the medial meniscus was more frequently seen in knees with radiographic OA compared to those without radiographic OA[120]. A study by Mermerci *et al.* found ultrasound-detected protrusion of the anterior horn of the medial meniscus associated with medial collateral ligament displacement in knee OA patients with knee pain, but not in those without knee pain[121].

Two studies examined the inter-observer reliability of ultrasound examination for evaluation of knee OA. Inter-observer reliability was excellent between senior and junior sonographers (kappa 0.77) but it was only fair between senior and beginning sonographers (kappa 0.31)[122]. The inter-observer agreement between two experienced rheumatologists was found to be moderate for ultrasound assessment of medial meniscal protrusion (kappa 0.54)[123].

Its use with dynamic and weight-bearing conditions is one of the inherent strengths of ultrasound. Acebes *et al.* used a dynamic ultrasound technique, and demonstrated that medial meniscal subluxation occurred more frequently in symptomatic OA knees than in controls in the unipodal weight-bearing position both before and after walking 50 m[124]. In both OA and control knees, an increase in medial meniscal subluxation was observed in the unipodal weight-bearing positions compared with the supine neutral position, but this increase was greater in OA knees than in controls.

Summary of imaging of meniscal pathology in OA

Currently MRI is the most commonly utilized modality for imaging evaluation of meniscal pathology. The rapid development of advanced MR imaging protocols and image processing techniques for research purposes opens up promising possibilities of future studies of early-stage pre-morphologic changes of meniscal matrix that may predict and better understand the causal chain of events in the onset and progression of the knee OA. Ultrasound enables imaging in dynamic and weight-bearing conditions and may be a useful adjunct to MRI.

Imaging of ligamentous pathology in OA

Prevalence of ligamentous pathology in knee OA and association with pain

A population-based epidemiological study (Framingham OA Study) demonstrated that the prevalence of MRI-detected ligamentous damages, defined as torn ACL and PCL and medial and lateral collateral ligaments (MCL and LCL), was 9% in knees with a normal radiographic appearance (Kellgren and Lawrence grade 0) regardless of the presence of knee pain[10]. Another population-based study (Hallym Aging Study) showed that MRI-detected cruciate ligament damage was present in 8% of elderly men and 27% of elderly women, and that the presence of cruciate ligament tears was associated with knee pain in subjects with or without radiographic OA[125].

Ligamentous pathology in knee OA and association with structural changes

OAI investigators determined that knees with OA and ACL tears had a smaller femoral notch width index (notch width/condylar width at 2/3 of the notch depth) compared to knees without ACL tears[126].They also reported that in knees with ACL tears, MRI-detected evidence of denuded areas and bone surface areas, bone marrow lesions, and meniscal derangement, predominantly in the lateral tibiofemoral compartment[127].

In a population-based cohort with knee pain, crepitus of the knee joint was associated with MRI-detected pathology of the MCL at the medial tibiofemoral compartment[128]. Another study by the OAI investigators showed that knees with MRI-detected ACL abnormalities had a greater prevalence of, and more severe, cartilage, meniscal, bone marrow, subchondral cysts, and MCL lesions compared to knees with normal ACL[129] (Fig. 4).

Ligamentous pathology in hand OA

A study using data from MRI and cadaveric histological analysis showed that, in the small joints of the hand, collateral ligaments at the distal and proximal interphalangeal joints seem to play a role in the early stage of hand OA and may determine the early expression of both the soft tissue and bony changes in the disease[130].

Scoring methods for MRI evaluation of ligamentous injury in knee OA

Available whole-organ scoring systems such as Whole-Organ Magnetic Resonance Imaging Score (WORMS)[16] and MRI Osteoarthritis Knee Score (MOAKS)[19] do include grading schemes for ligamentous pathology in knee OA, however they do not allow detailed evaluation of individual ligaments (Table II). Other grading schemes for ligamentous pathology itself, without whole-organ approach have been used by different authors[127,128,131]. The Anterior Cruciate Ligament OsteoArthritis Score (ACLOAS) has recently been developed for MRI-based assessment of acute ACL injury and follow-up of structural sequelae[132]. This scoring system includes grading of collateral ligaments, PCL and ACL grafts, as well as cartilage, bone marrow lesions, osteophytes, meniscal pathology and Hoffa- and effusion-synovitis, enabling the whole-organ analysis of the knee joint with detailed individual assessment of aforementioned ligaments. While this scoring system appears to allow reliable scoring of acute ACL injury and longitudinal changes, it remains to be validated by future studies.

Scoring methods for MRI evaluation of ligamentous injury in hand OA

OHOA-MRI[48], which was described earlier in the synovitis section, also includes evaluation for collateral ligaments of the small joints of the hand (Table II). However, a more recent HOAMRIS[50], a product of iterative development based on OHOA-MRI, eliminated the grading scheme for collateral ligaments. Thus, investigators

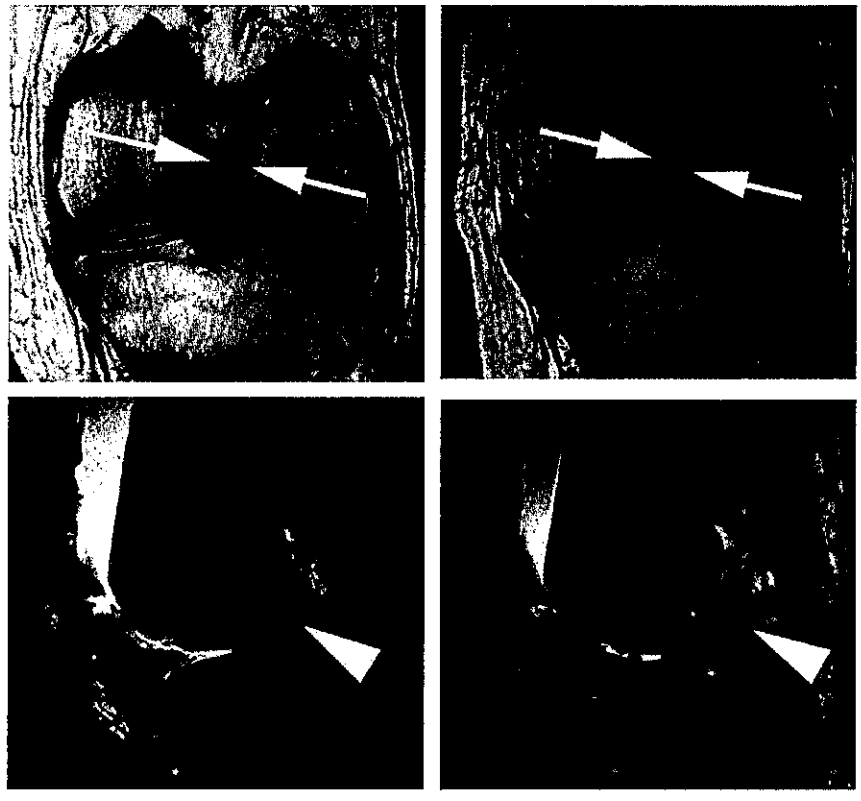


Fig. 4. ACL degeneration as part of the involvement of the entire joint in OA. The upper left image depicts a hypointense ACL of normal thickness (arrows) The lower left image shows the same knee and emphasizes the bi-fasciculated structure of the ligament (arrowhead), which commonly exhibits a striated appearance on sagittal images. The upper right image shows the same knee after 24 months. The ACL is now markedly hyperintense and thickened. The lower right sagittal intermediate-weighted fat-saturated image shows the same knee and confirms the hyperintense signal alterations and volume increase. This example represents mucoid degeneration of the ACL, which is difficult to distinguish from partial rupture based on imaging alone.

wishing to evaluate ligamentous pathology in hand OA need to use OHOA-MRI.

Imaging of other non-osteochondral tissues

Labrum of the hip

The hip labrum serves many functions, including shock absorption, joint lubrication, pressure distribution, and aiding in stability[133]. Labral damages are associated with hip OA. They can be caused by trauma, femoroacetabular impingement, capsular laxity/hip hypermobility, developmental dysplasia of the hip, and degeneration[133] (Fig. 5). A small study involving 21 subjects showed an association between MRI-detected labral damage and radiographic hip joint space narrowing[134]. However, to date, the longitudinal relationship between acetabular labral pathology and development of hip OA is not well demonstrated in the literature.

Two comprehensive and generally applicable MRI-based semi-quantitative scoring systems for hip labrum are available. One was published by Neumann *et al.*[135], and the other was developed by Roemer *et al.* (HOAMS[51]). In Neumann *et al.*'s method, the hip labrum is divided into four sections (anterior/posterior/medial/lateral) and labral damage is graded 0–3. In HOAMS, the labrum is assessed in the following locations: anterior on sagittal slice; superolateral/posteromedial on coronal slice; and anterior/posterior on axial slice. Severity of labral damage is also graded 0–3 in a similar fashion. Neumann *et al.* used MR arthrographic images, while HOAMS assesses the labrum based on high-resolution PD-weighted fat-saturated images without arthrogram. In HOAMS, inter-reader agreement for the labral score was moderate (best kappa 0.48), and correlation between the presence of high-grade labral tears and pain approached significance ($P = 0.09$). The study by Neumann *et al.* showed labral tears and cartilage loss are common in patients with mechanical symptoms in the hip and that cartilage loss and labral tears appear interrelated, implying that labral tears may represent important risk factors for development and progression of OA in the hip joint[135].

Muscles of the hip

One recent study investigated the possible association between hip flexor muscles and the presence of labral pathology[136]. Average muscle cross-sectional area (CSA) of the iliacus, psoas, iliopsoas, sartorius, tensor fascia latae and rectus femoris muscles were measured using MRI in subjects with hip labral pathology and control subjects without such pathology. However, no difference between groups or sides was found for any hip flexor muscle size.

Muscles of the thigh

Three studies based on the data from OAI measured the anatomic cross-sectional area (ACSA) of the quadriceps, hamstrings, adductors, and individual quadriceps heads at consistent

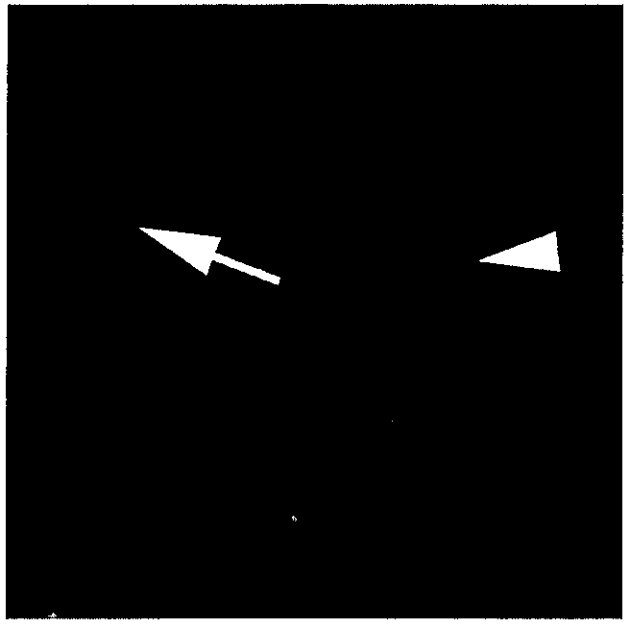


Fig. 5. Example of a labral lesion in early hip OA. Sagittal proton-density fat-saturated MRI exhibits a subtle anterior labral tear (arrow). Note diffuse superficial cartilage loss at the posterior circumference (arrowhead). Acetabular cartilage cannot be distinguished from the femoral cartilage surface, which is commonly the case whenever there is no joint fluid distending the two opposing surfaces.

locations using T1-weighted MRI in patients with painful radiographic knee OA[137–139]. These studies demonstrated that knees with frequent pain have lower ACSAs of the quadriceps (but not of the other thigh muscles) compared with contralateral knees without pain at the same radiographic stage[138]. Nonetheless, the ACSAs of the quadriceps and other thigh muscles are not independently associated with the degree of joint space narrowing once knees have reached the point of frequent pain[137]. As a marker of structural progression, the ACSA of the quadriceps seems to be more sensitive to longitudinal change than isometric extensor strength[139]. Quadriceps intra-muscular fat fractions measured by MRI were shown to be higher in people with knee OA and were related to the symptomatic and structural severity of knee OA, including MRI-detected cartilage and meniscal lesions[140]. In this study, in contrast to the aforementioned OAI-based studies, there was no association shown between quadriceps area and symptomatic and structural severity of knee OA. There is an ongoing non-pharmacologic intervention trial to determine whether combining greater duration with high-intensity strength training will alter thigh muscle composition sufficiently to attain short-term clinical benefits as well as long-term reductions in knee pain levels and slowing of OA progression[141]. In this trial, investigators measure the total thigh muscle and fat volume by CT.

Plica of the knee

Hayashi *et al.* demonstrated that MRI-detected mediopatellar plicae were commonly observed in a cohort of subjects with knee pain and that mediopatellar plicae were cross-sectionally associated with higher likelihood of the presence of MRI-detected medial patellar cartilage damage (adjusted odds ratio 2.12 with 95%CI 1.23–3.64)[142]. This finding is concordant with a recent immunohistochemical study that found a higher expression of matrix metalloproteinases—a biomarker for the cartilage extracellular matrix degradation in OA—in the mediopatellar plica of knees with end-stage OA and severe cartilage damage, compared to the knees with normal cartilage[143]. However, a longitudinal study is needed to determine whether the presence of mediopatellar plica itself is an independent risk factor for future cartilage damage in the medial patellofemoral joint.

Conclusion

MRI and ultrasound are currently the most useful imaging modalities for evaluation of non-osteochondral tissues in OA. MRI evaluation of any tissue requires the appropriate MR pulse sequences. Meniscal damage is a frequent finding on MRI in knees with or without OA, and meniscal tears can lead to incident and progressive knee OA. Synovitis is best assessed using CE-MRI and is associated with pain in OA. Ultrasound may be particularly useful for evaluation of small joints of the hand. While cartilage remains a major focus of OA studies, research efforts addressing non-osteochondral tissues described in this article should continue since these features play an integral part in the OA disease process.

Competing interests

Ali Guermazi received consulting fees from Sanofi Aventis, Tissue Gene and Merck Serono. He is the President of Boston Imaging Core Lab (BICL), LLC. Frank Roemer is the CMO of BICL and received consulting fees from Merck Serono and National Institute of Health. Michel Crema is a shareholder of BICL. Other authors declared nothing to disclose.

Author contribution

Guarantors of the integrity of entire study, AG; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; literature search, all authors; clinical studies, N/A; statistical analysis, N/A; and manuscript editing, all authors.

References

1. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis 1957;16:494–502.
2. Altman RD, Gold GE. Atlas of individual radiographic features in osteoarthritis, revised. Osteoarthr Cartil 2007;15(Suppl A): A1–A56.
3. Hunter DJ, Zhang W, Conaghan PG, Hirko K, Menashe L, Li L, *et al.* Systematic review of the concurrent and predictive validity of MRI biomarkers in OA. Osteoarthr Cartil 2011;19: 557–88.
4. Roemer FW, Guermazi A. Osteoarthritis year 2012 in review: imaging. Osteoarthr Cartil 2012;20:1440–6.
5. Mosher TJ, Walker EA, Petscavage-Thomas J, Guermazi A. Osteoarthritis year 2013 in review: imaging. Osteoarthr Cartil 2013;21:1425–35.
6. Guermazi A, Eckstein F, Hellio Le Graverand-Gastineau MP, Conaghan PG, Burstein D, Keen H, *et al.* Osteoarthritis: current role of imaging. Med Clin North Am 2009;93. 101–26, xi.
7. Keen HI, Wakefield RJ, Grainger AJ, Hensor EM, Emery P, Conaghan PG. An ultrasonographic study of osteoarthritis of the hand: synovitis and its relationship to structural pathology and symptoms. Arthritis Rheum 2008;59:1756–63.

8. Guermazi A, Hayashi D, Eckstein F, Hunter DJ, Duryea J, Roemer FW. Imaging of osteoarthritis. Rheum Dis Clin N Am 2013;39:67–105.
9. Hayashi D, Roemer FW, Katur A, Felson DT, Yang SO, Alomran F, *et al.* Imaging of synovitis in osteoarthritis: current status and outlook. Semin Arthritis Rheum 2011;41: 116–30.
10. Guermazi A, Niu J, Hayashi D, Roemer FW, Englund M, Neogi T, *et al.* Prevalence of abnormalities in knees detected by MRI in adults without knee osteoarthritis: population based observational study (Framingham Osteoarthritis Study). BMJ 2012;345:e5339.
11. Baker K, Grainger A, Niu J, Clancy M, Guermazi A, Crema MD, *et al.* Relation of synovitis to knee pain using contrast-enhanced MRIs. Ann Rheum Dis 2010;69:1779–83.
12. Guermazi A, Hayashi D, Roemer FW, Zhu Y, Niu J, Crema MD, *et al.* Synovitis in knee osteoarthritis assessed by contrast-enhanced magnetic resonance imaging (MRI) is associated with radiographic tibiofemoral osteoarthritis and MRI-detected widespread cartilage damage: The MOST Study. J Rheumatol 2014 Jan 15 (Epub ahead of print).
13. Roemer FW, Kassim Javaid M, Guermazi A, Thomas M, Kiran A, Keen R, *et al.* Anatomical distribution of synovitis in knee osteoarthritis and its association with joint effusion assessed on non-enhanced and contrast-enhanced MRI. Osteoarthr Cartil 2010;18:1269–74.
14. Crema MD, Felson DT, Roemer FW, Niu J, Marra MD, Zhang Y, *et al.* Peripatellar synovitis: comparison between non-contrast-enhanced and contrast-enhanced MRI and association with pain. The MOST study. Osteoarthr Cartil 2013;21:413–8.
15. Fotinos-Hoyer AK, Guermazi A, Jara H, Eckstein F, Ozonoff A, Khrad H, *et al.* Assessment of synovitis in the osteoarthritic knee: comparison between manual segmentation, semi-automated segmentation and semiquantitative assessment using contrast-enhanced fat-suppressed T1-weighted MRI. Magn Reson Med 2010;64:604–9.
16. Peterfy CG, Guermazi A, Zaim S, Tirman PF, Miaux Y, White D, *et al.* Whole-Organ Magnetic Resonance Imaging Score (WORMS) of the knee in osteoarthritis. Osteoarthr Cartil 2004;12:177–90.
17. Hunter DJ, Lo GH, Gale D, Grainger AJ, Guermazi A, Conaghan PG. The reliability of a new scoring system for knee osteoarthritis MRI and the validity of bone marrow lesion assessment: BLOKS (Boston Leeds Osteoarthritis Knee Score). Ann Rheum Dis 2008;67:206–11.
18. Kornaat PR, Ceulemans RY, Kroon HM, Riyazi N, Kloppenburg M, Carter WO, *et al.* MRI assessment of knee osteoarthritis: Knee Osteoarthritis Scoring System (KOSS)—inter-observer and intra-observer reproducibility of a compartment-based scoring system. Skelet Radiol 2005;34: 95–102.
19. Hunter DJ, Guermazi A, Lo GH, Granger AJ, Conaghan PG, Boudreau RM, *et al.* Evolution of semi-quantitative whole joint assessment of knee OA: MOAKS (MRI Osteoarthritis Knee Score). Osteoarthr Cartil 2011;19:990–1002.
20. Rhodes LA, Grainger AJ, Keenan AM, Thomas C, Emery P, Conaghan PG. The validation of simple scoring methods for evaluating compartment-specific synovitis detected by MRI in knee osteoarthritis. Rheumatology (Oxford) 2005;44: 1569–73.
21. Krasnokutsky S, Belitskaya-Levy I, Bencardino J, Samuels J, Attur M, Regatte R, *et al.* Quantitative magnetic resonance imaging evidence of synovial proliferation is associated with radiographic severity of knee osteoarthritis. Arthritis Rheum 2011;63:2983–91.
22. Meredith DS, Losina E, Neumann G, Yoshioka H, Lang PK, Katz JN. Empirical evaluation of the inter-relationship of articular elements involved in the pathoanatomy of knee osteoarthritis using magnetic resonance imaging. BMC Musculoskelet Disord 2009;10:133.
23. Guermazi A, Roemer FW, Hayashi D, Crema MD, Niu J, Zhang Y, *et al.* Assessment of synovitis with contrast-enhanced MRI using a whole-joint semiquantitative scoring system in people with, or at high risk of, knee osteoarthritis: the MOST study. Ann Rheum Dis 2011;70:805–11.
24. Ostergaard M, Ejbjerg B. Magnetic resonance imaging of the synovium in rheumatoid arthritis. Semin Musculoskelet Radiol 2004;8:287–99.
25. Hill CL, Gale DG, Chaisson CE, Skinner K, Kazis L, Gale ME, *et al.* Knee effusions, popliteal cysts, and synovial thickening: association with knee pain in osteoarthritis. J Rheumatol 2001;28:1330–7.
26. Hill CL, Hunter DJ, Niu J, Clancy M, Guermazi A, Genant H, *et al.* Synovitis detected on magnetic resonance imaging and its relation to pain and cartilage loss in knee osteoarthritis. Ann Rheum Dis 2007;66:1599–603.
27. Ostergaard M, Stoltenberg M, Lovgreen-Nielsen P, Volck B, Jensen CH, Lorenzen I. Magnetic resonance imaging-determined synovial membrane and joint effusion volumes in rheumatoid arthritis and osteoarthritis: comparison with the macroscopic and microscopic appearance of the synovium. Arthritis Rheum 1997;40:1856–67.
28. Roemer FW, Guermazi A, Felson DT, Niu J, Nevitt MC, Crema MD, *et al.* Presence of MRI-detected joint effusion and synovitis increases the risk of cartilage loss in knees without osteoarthritis at 30-month follow-up: the MOST study. Ann Rheum Dis 2011;70:1804–9.
29. Roemer FW, Hunter DJ, Guermazi A. Semiquantitative assessment of synovitis in osteoarthritis on non contrast-enhanced MRI. Osteoarthr Cartil 2009;17:820–1 (author reply 822–824).
30. Fernandez-Madrid F, Karvonen RL, Teitge RA, Miller PR, An T, Negendank WG. Synovial thickening detected by MR imaging in osteoarthritis of the knee confirmed by biopsy as synovitis. Magn Reson Imaging 1995;13:177–83.
31. Pelletier JP, Raynauld JP, Abram F, Haraoui B, Choquette D, Martel-Pelletier J. A new non-invasive method to assess synovitis severity in relation to symptoms and cartilage volume loss in knee osteoarthritis patients using MRI. Osteoarthr Cartil 2008;16(Suppl 3):S8–S13.
32. Yusuf E, Kortekaas MC, Watt I, Huizinga TW, Kloppenburg M. Do knee abnormalities visualised on MRI explain knee pain in knee osteoarthritis? A systematic review. Ann Rheum Dis 2011;70:60–7.
33. Hayes CW, Jamadar DA, Welch GW, Jannausch ML, Lachance LL, Capul DC, *et al.* Osteoarthritis of the knee: comparison of MR imaging findings with radiographic severity measurements and pain in middle-aged women. Radiology 2005;237:998–1007.
34. Torres L, Dunlop DD, Peterfy C, Guermazi A, Prasad P, Hayes KW, *et al.* The relationship between specific tissue lesions and pain severity in persons with knee osteoarthritis. Osteoarthr Cartil 2006;14:1033–40.
35. Lo GH, McAlindon TE, Niu J, Zhang Y, Beals C, Dabrowski C, *et al.* Bone marrow lesions and joint effusion are strongly and independently associated with weight-bearing pain in knee osteoarthritis: data from the osteoarthritis initiative. Osteoarthr Cartil 2009;17:1562–9.
36. Roemer FW, Guermazi A, Zhang Y, Yang M, Hunter DJ, Crema MD, *et al.* Hoffa's fat pad: evaluation on

unenhanced MR images as a measure of patellofemoral synovitis in osteoarthritis. AJR Am J Roentgenol 2009;192: 1696–700.
37. Roemer FW, Zhang Y, Niu J, Lynch JA, Crema MD, Marra MD, *et al.* Tibiofemoral joint osteoarthritis: risk factors for MR-depicted fast cartilage loss over a 30-month period in the multicenter osteoarthritis study. Radiology 2009;252:772–80.
38. Hayashi D, Roemer FW, Dhina Z, Kwoh CK, Hannon MJ, Moore C, *et al.* Longitudinal assessment of cyst-like lesions of the knee and their relation to radiographic osteoarthritis and MRI-detected effusion and synovitis in patients with knee pain. Arthritis Res Ther 2010;12:R172.
39. Loeuille D, Chary-Valckenaere I, Champigneulle J, Rat AC, Toussaint F, Pinzano-Watrin A, *et al.* Macroscopic and microscopic features of synovial membrane inflammation in the osteoarthritic knee: correlating magnetic resonance imaging findings with disease severity. Arthritis Rheum 2005;52:3492–501.
40. Song IH, Althoff CE, Hermann KG, Scheel AK, Knetsch T, Burmester GR, *et al.* Contrast-enhanced ultrasound in monitoring the efficacy of a bradykinin receptor 2 antagonist in painful knee osteoarthritis compared with MRI. Ann Rheum Dis 2009;68:75–83.
41. Song IH, Althoff CE, Hermann KG, Scheel AK, Knetsch T, Schoenharting M, *et al.* Knee osteoarthritis. Efficacy of a new method of contrast-enhanced musculoskeletal ultrasonography in detection of synovitis in patients with knee osteoarthritis in comparison with magnetic resonance imaging. Ann Rheum Dis 2008;67:19–25.
42. Liu L, Ishijima M, Futami I, Kaneko H, Kubota M, Kawasaki T, *et al.* Correlation between synovitis detected on enhanced-magnetic resonance imaging and a histological analysis with a patient-oriented outcome measure for Japanese patients with end-stage knee osteoarthritis receiving joint replacement surgery. Clin Rheumatol 2010;29:1185–90.
43. Loeuille D, Rat AC, Goebel JC, Champigneulle J, Blum A, Netter P, *et al.* Magnetic resonance imaging in osteoarthritis: which method best reflects synovial membrane inflammation? Correlations with clinical, macroscopic and microscopic features. Osteoarthr Cartil 2009;17:1186–92.
44. Roemer FW, Felson DT, Yang T, Niu J, Crema MD, Englund M, *et al.* The association between meniscal damage of the posterior horns and localized posterior synovitis detected on T1-weighted contrast-enhanced MRI—the MOST study. Semin Arthritis Rheum 2013;42:573–81.
45. de Lange-Brokaar BJ, Ioan-Facsinay A, Yusuf E, Visser AW, Kroon HM, Andersen SN, *et al.* Degree of synovitis on MRI by comprehensive whole knee semi-quantitative scoring method correlates with histologic and macroscopic features of synovial tissue inflammation in knee osteoarthritis. Osteoarthr Cartil 2013 Dec 21 (Epub ahead of print).
46. Partik B, Rand T, Pretterklieber ML, Voracek M, Hoermann M, Helbich TH. Patterns of gadopentetate-enhanced MR imaging of radiocarpal joints of healthy subjects. AJR Am J Roentgenol 2002;179:193–7.
47. Ejbjerg B, Narvestad E, Rostrup E, Szkudlarek M, Jacobsen S, Thomsen HS, *et al.* Magnetic resonance imaging of wrist and finger joints in healthy subjects occasionally shows changes resembling erosions and synovitis as seen in rheumatoid arthritis. Arthritis Rheum 2004;50:1097–106.
48. Haugen IK, Lillegraven S, Slatkowsky-Christensen B, Haavardsholm EA, Sesseng S, Kvien TK, *et al.* Hand osteoarthritis and MRI: development and first validation step of the proposed Oslo Hand Osteoarthritis Score. Ann Rheum Dis 2011;70:1033–8.
49. Haugen IK, Boyesen P, Slatkowsky-Christensen B, Sesseng S, van der Heijde D, Kvien TK. Associations between MRI-defined synovitis, bone marrow lesions and structural features and measures of pain and physical function in hand osteoarthritis. Ann Rheum Dis 2012;71:899–904.
50. Haugen IK, Ostergaard M, Eshed I, McQueen FM, Bird P, Gandjbakhch F, *et al.* Iterative development and reliability of the OMERACT Hand Osteoarthritis MRI Scoring System. J Rheumatol 2013 Dec 1 (Epub ahead of print).
51. Roemer FW, Hunter DJ, Winterstein A, Li L, Kim YJ, Cibere J, *et al.* Hip Osteoarthritis MRI Scoring System (HOAMS): reliability and associations with radiographic and clinical findings. Osteoarthr Cartil 2011;19:946–62.
52. Lambert RG, Maksymowych WP, Gracey D. Evaluation of bone marrow edema with the hip inflammation MRI scoring system (HIMRIS): is it reliable and do scores correlate with clinical status or response to therapy? (Abstract). Ann Rheum Dis 2011;70(Suppl 3):550.
53. Maksymowych WP, Cibere J, Loeuille D, Weber U, Zubler V, Roemer FW, *et al.* Preliminary validation of 2 magnetic resonance imaging scoring systems for osteoarthritis of the hip according to the OMERACT filter. J Rheumatol 2013 Nov 15 (Epub ahead of print).
54. Wenham CY, Hensor EM, Grainger AJ, Hodgson R, Balamoody S, Dore CJ, *et al.* A randomized, double-blind, placebo-controlled trial of low-dose oral prednisolone for treating painful hand osteoarthritis. Rheumatology (Oxford) 2012;51:2286–94.
55. Ostergaard M, Stoltenberg M, Lovgreen-Nielsen P, Volck B, Sonne-Holm S, Lorenzen I. Quantification of synovitis by MRI: correlation between dynamic and static gadolinium-enhanced magnetic resonance imaging and microscopic and macroscopic signs of synovial inflammation. Magn Reson Imaging 1998;16:743–54.
56. Tamai K, Yamato M, Yamaguchi T, Ohno W. Dynamic magnetic resonance imaging for the evaluation of synovitis in patients with rheumatoid arthritis. Arthritis Rheum 1994;37: 1151–7.
57. Kirkhus E, Bjornerud A, Thoen J, Johnston V, Dale K, Smith HJ. Contrast-enhanced dynamic magnetic resonance imaging of finger joints in osteoarthritis and rheumatoid arthritis: an analysis based on pharmacokinetic modeling. Acta Radiol 2006;47:845–51.
58. Wakefield RJ, Gibbon WW, Emery P. The current status of ultrasonography in rheumatology. Rheumatology (Oxford) 1999;38:195–8.
59. Micu MC, Bogdan GD, Fodor D. Steroid injection for hip osteoarthritis: efficacy under ultrasound guidance. Rheumatology (Oxford) 2010;49(8):1490–4.
60. Qvistgaard E, Kristoffersen H, Terslev L, Danneskiold-Samsoe B, Torp-Pedersen S, Bliddal H. Guidance by ultrasound of intra-articular injections in the knee and hip joints. Osteoarthr Cartil 2001;9:512–7.
61. Ingegnoli F, Soldi A, Meroni PL. Power Doppler sonography and clinical monitoring for hyaluronic acid treatment of rhizarthrosis: a pilot study. J Hand Microsurg 2011;3:51–4.
62. Keen HI, Conaghan PG. Ultrasonography in osteoarthritis. Radiol Clin N Am 2009;47:581–94.
63. D'Agostino MA, Conaghan P, Le Bars M, Baron G, Grassi W, Martin-Mola E, *et al.* EULAR report on the use of ultrasonography in painful knee osteoarthritis. Part 1: prevalence of inflammation in osteoarthritis. Ann Rheum Dis 2005;64: 1703–9.
64. Karim Z, Wakefield RJ, Quinn M, Conaghan PG, Brown AK, Veale DJ, *et al.* Validation and reproducibility of

ultrasonography in the detection of synovitis in the knee: a comparison with arthroscopy and clinical examination. Arthritis Rheum 2004;50:387–94.
65. Walther M, Harms H, Krenn V, Radke S, Faehndrich TP, Gohlke F. Correlation of power Doppler sonography with vascularity of the synovial tissue of the knee joint in patients with osteoarthritis and rheumatoid arthritis. Arthritis Rheum 2001;44:331–8.
66. Walther M, Harms H, Krenn V, Radke S, Kirschner S, Gohlke F. Synovial tissue of the hip at power Doppler US: correlation between vascularity and power Doppler US signal. Radiology 2002;225:225–31.
67. Schmidt WA, Volker L, Zacher J, Schlafke M, Ruhnke M, Gromnicalhle E. Colour Doppler ultrasonography to detect pannus in knee joint synovitis. Clin Exp Rheumatol 2000;18: 439–44.
68. Ostergaard M, Court-Payen M, Gideon P, Wieslander S, Cortsen M, Lorenzen I, *et al.* Ultrasonography in arthritis of the knee. A comparison with MR imaging. Acta Radiol 1995;36:19–26.
69. Kortekaas MC, Kwok WY, Reijnierse M, Huizinga TW, Kloppenburg M. In erosive hand osteoarthritis more inflammatory signs on ultrasound are found than in the rest of hand osteoarthritis. Ann Rheum Dis 2013;72:930–4.
70. Beitinger N, Ehrenstein B, Schreiner B, Fleck M, Grifka J, Lüring C, *et al.* The value of colour Doppler sonography of the knee joint: a useful tool to discriminate inflammatory from non-inflammatory disease? Rheumatology (Oxford) 2013;52: 1425–8.
71. Joshua F, Edmonds J, Lassere M. Power Doppler ultrasound in musculoskeletal disease: a systematic review. Semin Arthritis Rheum 2006;36:99–108.
72. Joshua F, Lassere M, Bruyn GA, Szkudlarek M, Naredo E, Schmidt WA, *et al.* Summary findings of a systematic review of the ultrasound assessment of synovitis. J Rheumatol 2007;34:839–47.
73. Keen HI, Lavie F, Wakefield RJ, D'Agostino MA, Hammer HB, Hensor E, *et al.* The development of a preliminary ultrasonographic scoring system for features of hand osteoarthritis. Ann Rheum Dis 2008;67:651–5.
74. Kingsbury SR, Tharmanathan P, Adamson J, Arden NK, Birrell F, Cockayne S, *et al.* Hydroxychloroquine effectiveness in reducing symptoms of hand osteoarthritis (HERO): study protocol for a randomized controlled trial. Trials 2013;14:64.
75. Kortekaas MC, Kwok WY, Reijnierse M, Watt I, Huizinga TW, Kloppenburg M. Pain in hand osteoarthritis is associated with inflammation: the value of ultrasound. Ann Rheum Dis 2010;69:1367–9.
76. Keen HI, Wakefield RJ, Hensor EM, Emery P, Conaghan PG. Response of symptoms and synovitis to intra-muscular methylprednisolone in osteoarthritis of the hand: an ultrasonographic study. Rheumatology (Oxford) 2010;49:1093–100.
77. Conaghan PG, D'Agostino MA, Le Bars M, Baron G, Schmidely N, Wakefield R, *et al.* Clinical and ultrasonographic predictors of joint replacement for knee osteoarthritis: results from a large, 3-year, prospective EULAR study. Ann Rheum Dis 2010;69:644–7.
78. Kristoffersen H, Torp-Pedersen S, Terslev L, Qvistgaard E, Holm CC, Ellegaard K, *et al.* Indications of inflammation visualized by ultrasound in osteoarthritis of the knee. Acta Radiol 2006;47:281–6.
79. Kumm J, Tamm A, Lintrop M, Tamm A. Association between ultrasonographic findings and bone/cartilage biomarkers in patients with early-stage knee osteoarthritis. Calcif Tissue Int 2009;85:514–22.
80. Wu PT, Shao CJ, Wu KC, Wu TT, Chern TC, Kuo LC, *et al.* Pain in patients with equal radiographic grades of osteoarthritis in both knees: the value of gray scale ultrasound. Osteoarthr Cartil 2012;20:1507–13.
81. Goupille P, Chevalier X, Valat JP, Garaud P, Perin F, Le Pape A. Macrophage targeting with 99mTc-labelled J001 for scintigraphic assessment of experimental osteoarthritis in the rabbit. Br J Rheumatol 1997;36:758–62.
82. Al-Janabi MA, Solanki K, Critchley M, Smith ML, Britton KE, Huskisson EC. Radioleucoscintigrpahy in osteoarthritis. Is there an inflammatory component? Nucl Med Commun 1992;13:706–12.
83. de Bois MH, Arndt JW, van der Velde EA, Pauwels EK, Breedveld FC. Joint scintigraphy for quantification of synovitis with 99mTc-labelled human immunoglobulin G compared to late phase scintigraphy with 99mTc-labelled diphosphonate. Br J Rheumatol 1994;33:67–73.
84. Wandler E, Kramer EL, Sherman O, Babb J, Scarola J, Rafii M. Diffuse FDG shoulder uptake on PET is associated with clinical findings of osteoarthritis. AJR Am J Roentgenol 2005;185: 797–803.
85. Nakamura H, Masuko K, Yudoh K, Kato T, Nishioka K, Sugihara T, *et al.* Positron emission tomography with 18F-FDG in osteoarthritic knee. Osteoarthr Cartil 2007;15:673–81.
86. Elzinga EH, van der Laken CJ, Comans EFI, Lammertsma AA, Dijkmans BAC, Voskuyl AE. 2-Deoxy-2-[F-18]fluoro-D-glucose joint uptake on positron emission tomography images: rheumatoid arthritis versus osteoarthritis. Mol Imaging Biol 2007;9:357–60.
87. Magee D, Tanner SF, Waller M, Tan AL, McGonagle D, Jeavons AP. Combining variational and model-based techniques to register PET and MR images in hand osteoarthritis. Phys Med Biol 2010;55:4755–69.
88. Tan AL, Keen HI, Emery P, McGonagle D. Imaging inflamed synovial joints. Methods Mol Med 2007;135:3–26.
89. Polster JM, Winalski CS, Sundaram M, Lieber ML, Schils J, Ilaslan H, *et al.* Rheumatoid arthritis: evaluation with contrast-enhanced CT with digital bone masking. Radiology 2009;252:225–31.
90. Englund M, Guermazi A, Gale D, Hunter DJ, Aliabadi P, Clancy M, *et al.* Incidental meniscal findings on knee MRI in middle-aged and elderly persons. N Engl J Med 2008;359: 1108–15.
91. Englund M, Roemer FW, Hayashi D, Crema MD, Guermazi A. Meniscus pathology, osteoarthritis and the treatment controversy. Nat Rev Rheumatol 2012;8:412–9.
92. Englund M, Roos EM, Lohmander LS. Impact of type of meniscal tear on radiographic and symptomatic knee osteoarthritis: a sixteen-year followup of meniscectomy with matched controls. Arthritis Rheum 2003;48: 2178–87.
93. Englund M, Guermazi A, Roemer FW, Aliabadi P, Yang M, Lewis CE, *et al.* Meniscal tear in knees without surgery and the development of radiographic osteoarthritis among middle-aged and elderly persons: the Multicenter Osteoarthritis Study. Arthritis Rheum 2009;60:831–9.
94. Badlani JT, Borrero C, Golla S, Harner CD, Irrgang JJ. The effects of meniscus injury on the development of knee osteoarthritis: data from the osteoarthritis initiative. Am J Sports Med 2013;41:1238–44.
95. Raynauld JP, Martel-Pelletier J, Haraoui B, Choquette D, Dorais M, Wildi LM, *et al.* Risk factors predictive of joint replacement in a 2-year multicentre clinical trial in knee osteoarthritis using MRI: results from over 6 years of observation. Ann Rheum Dis 2011;70:1382–8.

96. Kim HA, Kim I, Song YW, Kim DH, Niu J, Guermazi A, *et al.* The association between meniscal and cruciate ligament damage and knee pain in community residents. Osteoarthr Cartil 2011;19:1422–8.
97. Huysse WC, Verstraete KL, Verdonk PC, Verdonk R. Meniscus imaging. Semin Musculoskelet Radiol 2008;12:318–33.
98. Tarhan NC, Chung CB, Mohana-Borges AV, Hughes T, Resnick D. Meniscal tears: role of axial MRI alone and in combination with other imaging planes. AJR Am J Roentgenol 2004;183:9–15.
99. De Smet AA, Tuite MJ. Use of the "two-slice-touch" rule for the MRI diagnosis of meniscal tears. AJR Am J Roentgenol 2006;187:911–4.
100. Berthiaume MJ, Raynauld JP, Martel-Pelletier J, Labonté F, Beaudoin G, Bloch DA, *et al.* Meniscal tear and extrusion are strongly associated with progression of symptomatic knee osteoarthritis as assessed by quantitative magnetic resonance imaging. Ann Rheum Dis 2005;64:556–63.
101. Englund M, Felson DT, Guermazi A, *et al.* Risk factors for medial meniscal pathology on knee MRI in older US adults: a multicentre prospective cohort study. Ann Rheum Dis 2011;70:1733–9.
102. Katz JN, Brophy RH, Chaisson CE, de Chaves L, Cole BJ, Dahm DL, *et al.* Surgery versus physical therapy for a meniscal tear and osteoarthritis. N Engl J Med 2013;368:1675–84.
103. Sihvonen R, Paavola M, Malmivaara A, Itälä A, Joukainen A, Nurmi H, *et al.* Arthroscopic partial meniscectomy versus sham surgery for a degenerative meniscal tear. N Engl J Med 2013;369:2515–24.
104. Moseley JB, O'Malley K, Petersen NJ, Menke TJ, Brody BA, Kuykendall DH, *et al.* A controlled trial of arthroscopic surgery for osteoarthritis of the knee. N Engl J Med 2002;347:81–8.
105. Kirkley A, Birmingham TB, Litchfield RB, Giffin JR, Willits KR, Wong CJ, *et al.* A randomized trial of arthroscopic surgery for osteoarthritis of the knee. N Engl J Med 2008;359:1097–107 (Erratum in: N Engl J Med 2009; 361:2004).
106. Englund M, Guermazi A, Roemer FW, Yang M, Zhang Y, Nevitt MC, *et al.* Meniscal pathology on MRI increases the risk for both incident and enlarging subchondral bone marrow lesions of the knee: the MOST Study. Ann Rheum Dis 2010;69:1796–802.
107. Roemer FW, Felson DT, Yang T, Niu J, Crema MD, Englund M, *et al.* The association between meniscal damage of the posterior horns and localized posterior synovitis detected on T1-weighted contrast-enhanced MRI—the MOST study. Semin Arthritis Rheum 2013;42:573–81.
108. Ding C, Martel-Pelletier J, Pelletier JP, Abram F, Raynauld JP, Cicuttini, *et al.* Meniscal tear as an osteoarthritis risk factor in a largely non-osteoarthritic cohort: a cross-sectional study. J Rheumatol 2007;34:776–84.
109. Crema MD, Roemer FW, Felson DT, Englund M, Wang K, Jarraya M, *et al.* Factors associated with meniscal extrusion in knees with or at risk for osteoarthritis: the Multicenter Osteoarthritis study. Radiology 2012;264:494–503.
110. Stehling C, Souza RB, Hellio Le Graverand MP, Wyman BT, Li X, Majumdar S, *et al.* Loading of the knee during 3.0T MRI is associated with significantly increased medial meniscus extrusion in mild and moderate osteoarthritis. Eur J Radiol 2012;81:1839–45.
111. Ding C, Martel-Pelletier J, Pelletier JP, Abram F, Raynauld JP, Cicuttini, *et al.* Knee meniscal extrusion in a largely non-osteoarthritic cohort: association with greater loss of cartilage volume. Arthritis Res Ther 2007;9:R21.
112. Guermazi A, Hayashi D, Jarraya M, Roemer FW, Zhang Y, Niu J, *et al.* Medial posterior meniscal root tears are associated with development or worsening of medial tibiofemoral cartilage damage: the Multicenter Osteoarthritis Study. Radiology 2013;268:814–21.
113. Wenger A1, Englund M, Wirth W, Hudelmaier M, Kwoh K, Eckstein F. Relationship of 3D meniscal morphology and position with knee pain in subjects with knee osteoarthritis: a pilot study. Eur Radiol 2012;22:211–20.
114. Wenger A1, Wirth W, Hudelmaier M, Noebauer-Huhmann I, Trattnig S, Bloecker K, *et al.* Meniscus body position, size, and shape in persons with and persons without radiographic knee osteoarthritis: quantitative analyses of knee magnetic resonance images from the osteoarthritis initiative. Arthritis Rheum 2013;65:1804–11.
115. Li W, Edelman RR, Prasad PV. Delayed contrast enhanced MRI of meniscus with ionic and non-ionic agents. J Magn Reson Imaging 2011;33:731–5.
116. Krishnan N, Shetty SK, Williams A, Mikulis B, McKenzie C, Burstein D. Delayed gadolinium-enhanced magnetic resonance imaging of the meniscus: an index of meniscal tissue degeneration? Arthritis Rheum 2007;56:1507–11.
117. Wang L, Chang G, Xu J, Vieira RL, Krasnokutsky S, Abramson S, *et al.* T1rho MRI of menisci and cartilage in patients with osteoarthritis at 3T. Eur J Radiol 2012;81:2329–36.
118. Williams A, Qian Y, Golla S, Chu CR. UTE-T2* mapping detects sub-clinical meniscus injury after anterior cruciate ligament tear. Osteoarthr Cartil 2012;20:486–94.
119. Kawaguchi K, Enokida M, Otsuki R, Teshima R. Ultrasonographic evaluation of medial radial displacement of the medial meniscus in knee osteoarthritis. Arthritis Rheum 2012;64:173–80.
120. Yanagisawa S, Ohsawa T, Saito K, Kobayashi T, Yamamoto A, Takagishi K. Morphological evaluation and diagnosis of medial type osteoarthritis of the knee using ultrasound. J Orthop Sci 2014 Jan 6 (Epub ahead of print).
121. Mermerci BB, Garip Y, Uysal RS, Doqruel H, Karabulut E, Ozoran K, *et al.* Clinic and ultrasound findings related to pain in patients with knee osteoarthritis. Clin Rheumatol 2011;30:1055–62.
122. Iagnocco A, Perricone C, Scirocco C, Ceccarelli F, Modesti M, Gattamelata A, *et al.* The interobserver reliability of ultrasound in knee osteoarthritis. Rheumatology (Oxford) 2012;51:2013–9.
123. Bevers K, Zweers M, van den Ende C, Martens H, Mahler J, Bijlsma R, *et al.* Ultrasonography analysis in knee osteoarthritis: evaluation of inter-observer reliability. Clin Exp Rheumatol 2012;30:673–8.
124. Acebes C, Romero FI, Contreras MA, mahillo I, Herrero-Beaumont G. Dynamic ultrasound assessment of medial meniscal subluxation in knee osteoarthritis. Rheumatology (Oxford) 2013;52:1443–7.
125. Kim HA, Kim I, Song YW, Kim DH, Niu J, Guermazi A, *et al.* The association between meniscal and cruciate ligament damage and knee pain in community residents. Osteoarthr Cartil 2011;19:1422–8.
126. Stein V, Li L, Guermazi A, Zhang Y, Kent Kwoh C, Eaton CB, *et al.* The relation of femoral notch stenosis to ACL tears in persons with knee osteoarthritis. Osteoarthr Cartil 2010;18:192–9.
127. Stein V, Li L, Lo G, Guermazi A, Zhang Y, Kent Kwoh C, *et al.* Pattern of joint damage in persons with knee osteoarthritis and concomitant ACL tears. Rheumatol Int 2011;32:1197–208.

128. Crema MD, Guermazi A, Sayre EC, Roemer FW, Wong H, Thorne A, *et al.* The association of magnetic resonance imaging (MRI)-detected structural pathology of the knee with crepitus in a population-based cohort with knee pain: the MoDEKO study. Osteoarthr Cartil 2011;19:1429–32.
129. Hovis KK, Alizai H, Tham SC, Souza RB, Nevitt MC, McCulloch CE, *et al.* Non-traumatic anterior cruciate ligament abnormalities and their relationship to osteoarthritis using morphological grading and cartilage T2 relaxation times: data from the Osteoarthritis Initiative (OAI). Skelet Radiol 2012;41:1435–43.
130. Tan AL, Toumi H, Benjamin M, Grainger AJ, Tanner SF, Emery P, *et al.* Combined high-resolution magnetic resonance imaging and histological examination to explore the role of ligaments and tendons in the phenotypic expression of early hand osteoarthritis. Ann Rheum Dis 2006;65:1267–72.
131. Bergin D, Keogh C, O'Connell M, Rowe D, Shah B, Zoga A, *et al.* Atraumatic medial collateral ligament oedema in medial compartment knee osteoarthritis. Skelet Radiol 2002;31: 14–8.
132. Roemer FW, Frobell R, Lohmander LS, Niu J, Guermazi A. Anterior Cruciate Ligament OsteoArthritis Score (ACLOAS): longitudinal MRI-based whole joint assessment of anterior cruciate ligament injury. Osteoarthr Cartil 2014;22(5): 668–82.
133. Groh MM, Herrera J. A comprehensive review of hip labral tears. Curr Rev Musculoskelet Med 2009;2:105–17.
134. Ueshima K, Takahashi KA, Fujioka M, Arai Y, Horii M, Asano T, *et al.* Relationship between acetabular labrum evaluation by using radial magnetic resonance imaging and progressive joint space narrowing in mild hip dysplasia. Magn Reson Imaging 2006;24:645–50.
135. Neumann G, Mendicuti AD, Zou KH, Minas T, Coblyn J, Winalski CS, *et al.* Prevalence of labral tears and cartilage loss in patients with mechanical symptoms of the hip: evaluation using MR arthrography. Osteoarthr Cartil 2007;15:909–17.
136. Mendis MD, Wilson SJ, Hayes DA, Watts MC, Hides JA. Hip flexor muscle size, strength and recruitment pattern in patients with acetabular labral tears compared to healthy controls. Man Ther 2014 Mar 5, http://dx.doi.org/10.1016/j.math.2014.02.006. pii: S1356-689X(14)00028-9. (Epub ahead of print).
137. Ruhdorfer A, Dannhauer T, Wirth W, Hitzl W, Kwoh CK, Guermazi A, *et al.* Thigh muscle cross-sectional areas and strength in advanced versus early painful osteoarthritis: an exploratory between-knee, within-person comparison in osteoarthritis initiative participants. Arthritis Care Res (Hoboken) 2013;65:1034–42.
138. Sattler M, Dannhauer T, Hudelmaier M, Wirth W, Sänger AM, Kwoh CK, *et al.* Side differences of thigh muscle cross-sectional areas and maximal isometric muscle force in bilateral knees with the same radiographic disease stage, but unilateral frequent pain – data from the osteoarthritis initiative. Osteoarthr Cartil 2012;20:532–40.
139. Dannhauer T, Sattler M, Wirth W, Hunter DJ, Kwoh CK, Eckstein F. Longitudinal sensitivity to change of MRI-based muscle cross-sectional area versus isometric strength analysis in osteoarthritic knees with and without structural progression: pilot data from the Osteoarthritis Initiative. MAGMA 2013 Nov 22 (Epub ahead of print).
140. Kumar D, Karampinos DC, Macleod TD, Lin W, Nardo L, Li X, *et al.* Quadriceps intramuscular fat fraction rather than muscle size is associated with knee osteoarthritis. Osteoarthr Cartil 2014;22(2):226–34.
141. Messier SP, Mihalko SL, Beavers DP, Nicklas BJ, Devita P, Carr JJ, *et al.* Strength Training for Arthritis Trial (START): design and rationale. BMC Musculoskelet Disord 2013;14: 208.
142. Hayashi D, Xu L, Guermazi A, Kwoh CK, Hannon MJ, Jarraya M, *et al.* Prevalence of MRI-detected mediopatellar plica in subjects with knee pain and the association with MRI-detected patellofemoral cartilage damage and bone marrow lesions: data from the Joints on Glucosamine Study. BMC Musculoskelet Disord 2013;14:292.
143. Yang CC, Lin CY, Wang HS, Lyu SR. Matrix metalloproteases and tissue inhibitors of metalloproteinases in medial plica and pannus-like tissue contribute to knee osteoarthritis progression. PLoS One 2013;8:e79662.

Original Article

DOI: 10.7860/JCDR/2015/11927.5761

MRI Evaluation of Lumbar Disc Degenerative Disease

Radiology Section

POKHRAJ SUTHAR[1], RUPAL PATEL[2], CHETAN MEHTA[3], NARROTAM PATEL[4]

ABSTRACT

Introduction: Lower back pain secondary to degenerative disc disease is a condition that affects young to middle-aged persons with peak incidence at approximately 40 y. MRI is the standard imaging modality for detecting disc pathology due to its advantage of lack of radiation, multiplanar imaging capability, excellent spinal soft-tissue contrast and precise localization of intervertebral discs changes.

Aims and Objective: To evaluate the characterization, extent, and changes associated with the degenerative lumbar disc disease by Magnetic Resonance Imaging.

Study Design: Cross-sectional and observational study.

Materials and Methods: A total 109 patients of the lumbar disc degeneration with age group between 17 to 80 y were diagnosed & studied on 1.5 Tesla Magnetic Resonance Imaging machine. MRI findings like lumbar lordosis, Schmorl's nodes, decreased disc height, disc annular tear, disc herniation, disc bulge, disc protrusion and disc extrusion were observed. Narrowing of the spinal canal, lateral recess and neural foramen with compression of nerve roots observed. Ligamentum flavum thickening and facetal arthropathy was observed.

Result: Males were more commonly affected in Degenerative Spinal Disease & most of the patients show loss of lumbar lordosis. Decreased disc height was common at L5-S1 level. More than one disc involvement was seen per person. L4 – L5 disc was the most commonly involved. Annular disc tear, disc herniation, disc extrusion, narrowing of spinal canal, narrowing of lateral recess, compression of neural foramen, ligamentum flavum thickening and facetal arthropathy was common at the L4 –L5 disc level. Disc buldge was common at L3 – L4 & L4 – L5 disc level. Posterior osteophytes are common at L3 - L4 & L5 –S1 disc level. L1- L2 disc involvement and spondylolisthesis are less common.

Conclusion: Lumbar disc degeneration is the most common cause of low back pain. Plain radiograph can be helpful in visualizing gross anatomic changes in the intervertebral disc. But, MRI is the standard imaging modality for detecting disc pathology due to its advantage of lack of radiation, multiplanar imaging capability, excellent spinal soft-tissue contrast and precise localization of intervertebral discs changes.

Keywords: Degenerative disc disease, Intervertebral disc, Sciatica pain

INTRODUCTION

Lower back pain secondary to degenerative disc disease is a condition that affects young to middle-aged persons with peak incidence at approximately 40 y. With respect to radiologic evidence of lumbar disc degenerative disease, the prevalence of disc degeneration increases with age, but degenerated discs are not necessarily painful. Low back pain secondary to degenerative disc disease affects men more than women. The main symptom of disc degeneration after low back pain is sciatica. Sciatica pain occurs mostly on one side of the body. It is a sharp shooting type of pain. Mild tingling sensation, dull ache, or burning sensation can occur. Pain may radiate to the calf or sole of the foot. Sciatic pain aggravates on standing, walking, bending, straining and coughing. In severe case, patient becomes unable to move around [1,2]. Patients with lumbar disc degenerative disease can be presented with sensory disturbances in legs, claudication and relief of pain with bending forwards.[3] There are many risk factors associated with the lumbar disc degenerative disease like advancing age, smoking, obesity, trauma, heavy weight lifting, height, genetic factors[4] and hereditary factors. Certain occupations like machine drivers, carpenters and office workers are also associated with it [5].

The basic purpose of conducting this study is to evaluate the relation between different aspects of lumbar degenerative disc disease and their MRI findings. Antero-posterior (AP) and lateral views of the plain X-ray can be helpful in visualizing gross anatomic changes in the intervertebral disc. It is best visualized on lateral view of X-ray. However, MRI is the standard imaging modality for detecting disc pathology due to its advantage of lack of radiation, multiplanar imaging capability, excellent spinal soft-tissue contrast and precise localization of intervertebral discs changes [6,7].

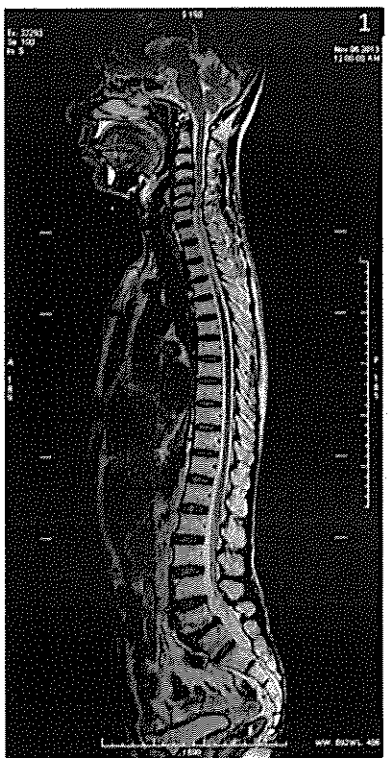
AIMS AND OBJECTIVE

- MR Imaging characterization of the disc degenerative changes of the lumbar spine.
- To evaluate extent of the involvement of the degenerative disc disease and its sequel.
- To identify the changes associated with the degenerative disc disease.

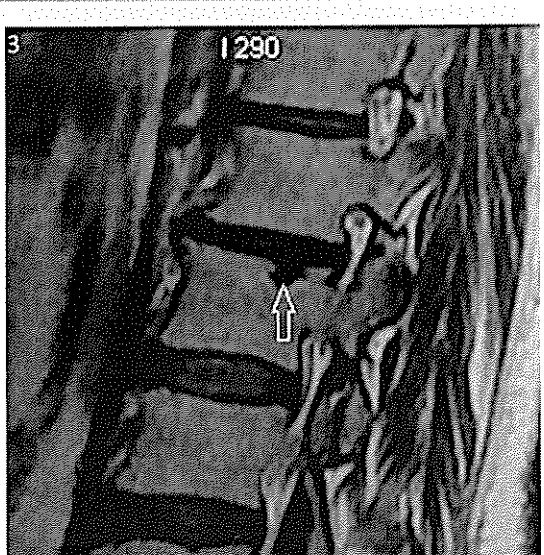
MATERIALS AND METHODS

This was a cross-sectional and observational study. The duration of the study was 2 months from 1st November 2013 to 31st December 2013. A total 109 patients of lumbar disc degeneration were diagnosed on 1.5 Tesla MRI machine. All the observation was done by three Radiologists (Professor, Associate Professor and Resident). Patients between 17 to 80 y of the age with low back pain were included in the study after obtaining a verbal consent. Patients with the history of trauma, prior surgery, spinal infections, active malignancy, pregnancy, cervical spine involvement, age<17 y and > 80 y were excluded from the study. In the study 109 patients were enrolled and their demographic findings noted. The following MRI findings were noted: lumbar lordosis preserved or not [Table/Fig-1,2], Schmorl's nodes present or not [Table/Fig-3], decreased disc height as compared to the upper and lower vertebral levels.

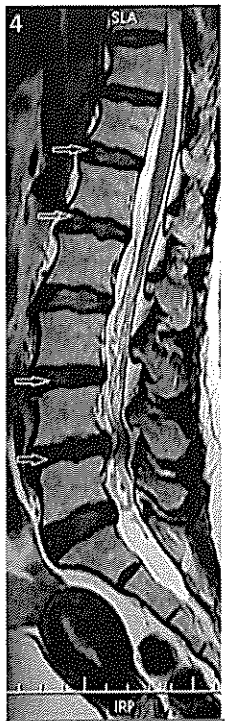
Disc desiccation: It is a common degenerative change of inter-vertebral discs. On MRI imaging, the disc loses its central high T2 signal [8] [Table/Fig-4]. Normally, central nucleus pulposus shows

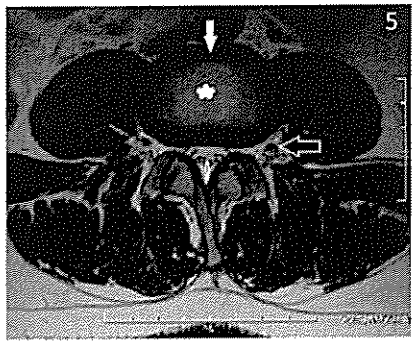


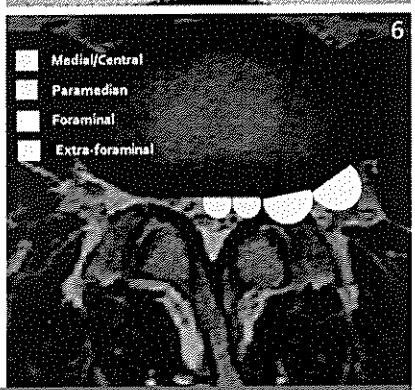
[Table/Fig-1]: Sagittal T2 Weighted MR Image: Normal lumbar lordosis
[Table/Fig-2]: Sagittal T2 Weighted MR Image: Loss of lumbar lordosis with straightening of lumbar spine. Decreased L4-L5 disc height with degenerative changes in adjacent end plate is present. L2-L3, L3-L4 & L4-L5 posterior disc bulge



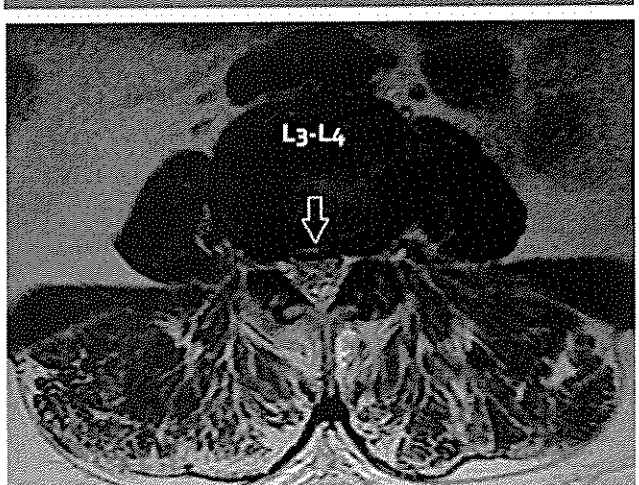
[Table/Fig-3]: Sagittal T2 WI shows Schmorl's node at the superior aspect of L2 vertebral body (open white arrow)







[Table/Fig-4]: T2 Weighted Sagittal MR Image: Lumbar Disc Desiccations(open white arrow) **[Table/Fig-5]:** Axial T2 Weighted MR Image: Normal: High signal intensity nucleolus pulposus in center (solid white star) and peripheral low signal intensity annulus fibroses in disc (solid white arrow). Look normal traversing (open small white arrow) & exiting nerve roots (open large white arrow) **[Table/Fig-6]:** Axial T2 Weighted MR Image for axial localization: Medial/Central, Paramedian, Foraminal & Extra-foraminal



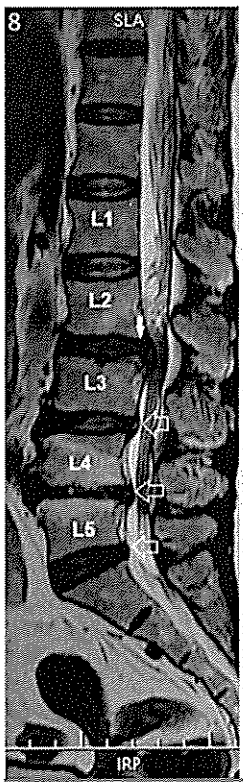
[Table/Fig-7]: Axial T2 WI: High signal intensity in annulus fibroses at medial position of L3- L4 disc suggestive of Annular Fissure/Tear (open white arrow). Narrowing of spinal canal & bilateral lateral recess with compression of bilateral exiting nerve roots noted

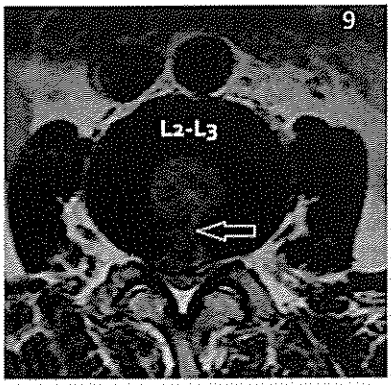
high signal intensity on T2WI and peripheral annulus, low signal intensity on T2WI [Table/Fig-5].

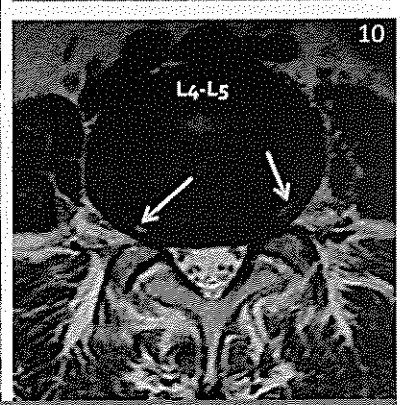
Annular tear: It is also called annular fissure and is a separation between annular fibers, avulsion of fibers from vertebral body insertion or break through fibers involving one or more layer of the annular lamella. Tear in the disc is seen as hyperintese on T2 Weighted images. Annular tear is further classified according to axial location into: central/medial, paramedian/lateral recess, foraminal/subarticular and extra-foraminal [Table/Fig-6-11]. Foraminal or subarticular disc herniation often very troublesome for the patient because compression of a 'Dorsal Root Ganglion'. Extra-foraminal is very rare.

Disc herniation: Whenever the displacement of disc material beyond the limits of the intervertebral disc space is called as a disc herniation. A herniated disc may or may not be covered by annulus fibroses. Herniation can be focal or bulging. When herniation is less than 180° disc circumference it is called a focal disc herniation and when it is 180° to 360° beyond the edges of the ring apophyses it is called disc buldge [Table/Fig-12]. If herniation & buldge was present, it was marked with a "Y".

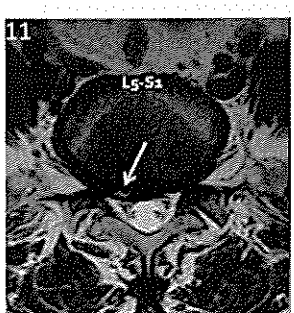
Disc protrusion & extrusion: Disc protrusion indicates that the distance between the edges of the disc herniation is less than the distance between the edges of the base. If disc protrusion was present it was marked with "Y". Whenever the distance between the edges of the disc material is greater than the distance at the base is called as disc extrusion [Table/Fig-13,14].

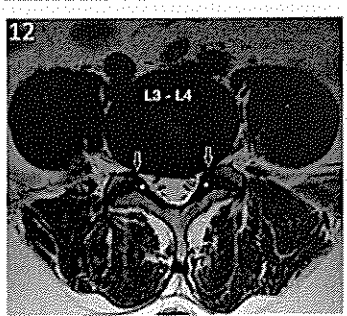




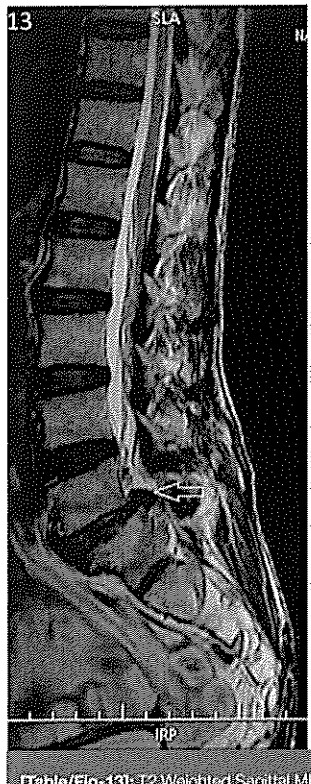


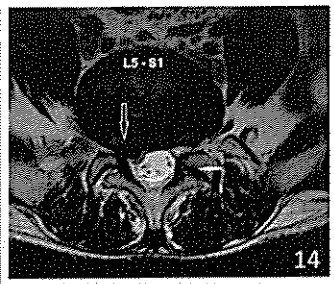
[Table/Fig-8]: Sagittal T2 Weighted MR Image of same patient: High signal intensity in annulus fibroses at L2- L3 disc suggestive of Annular Fissure with herniation of disc material in spinal canal & caudal migration of herniated disc material(solid white arrow). Narrowing of spinal canal is present. L3-L4, L4-L5 & L5-S1 shows posterior annular tears (open white arrow). Note Decreased disc height of L4-L5 with adjacent end plate high signal intensity. Loss of lumbar lordosis is seen **[Table/Fig-9]:** Axial T2 Weighted MR Image: High signal intensity in annulus fibroses at medial/central part of L2- L3 disc (open white arrow) suggestive of Annular Fissure with herniation of disc material in spinal canal. Narrowing of spinal canal & bilateral lateral recess with compression of bilateral traversing as well as exiting nerve roots is seen **[Table/Fig-10]:** Axial T2 Weighted MR Image: High signal intensity in annulus fibroses at bilateral foraminal position of L4- L5 disc (green arrow) suggestive of Annular Fissure with disc bulge. Narrowing of spinal canal & bilateral lateral recess with compression of bilateral exiting nerve roots is seen

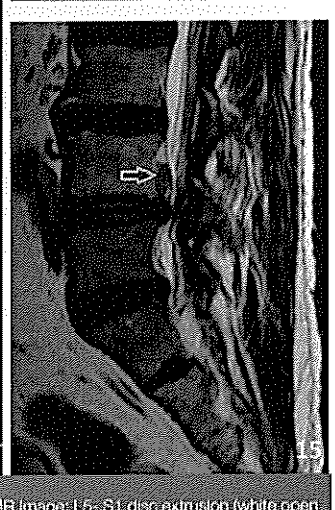




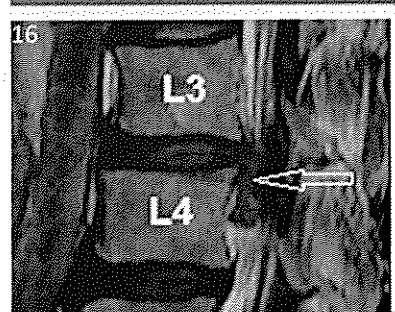
[Table/Fig-11]: T2 Weighted Axial MR Image: High signal intensity in annulus fibroses at right paramedian location of L5- S1 disc (green arrow) suggestive of Annular Fissure with disc herniation. Narrowing of spinal canal & bilateral lateral recess with compression of bilateral exiting nerve roots is seen **[Table/Fig-12]:** T2 Weighted Axial MR Image: L3-L4 Disc bulge (involvement of greater than 180° circumference). Narrowing of spinal canal and bilateral recess (open white arrow) with compression of exiting nerve roots is present. Ligamentum flavum appears thickened (solid white circle) with bilateral facetal arthropathy

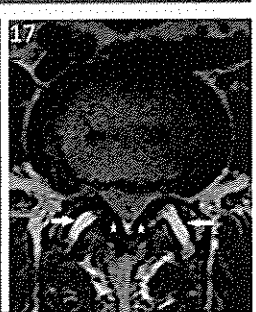






[Table/Fig-13]: T2 Weighted Sagittal MR Image: L5- S1 disc extrusion (white open arrow) with narrowing of spinal canal is seen **[Table/Fig-14]:** T2 Weighted Axial MR Image of same patient: High signal intensity in annulus fibroses at right forminal location of L5- S1 disc (open white arrow) suggestive of Annular Fissure with disc extrusion. Narrowing of spinal canal is present. Right lateral recess narrowing with compression of right exiting nerve roots is seen. Ligamentum flavum appears normal. However bilateral facetal arthropathy (solid white arrow) is present **[Table/Fig-15]:** Sagittal T2 Weighted MR Image : High signal intensity in annulus fibroses at L4- L5 disc with herniation of disc material in spinal canal & cranial migration of herniated disc material (open white arrow) leads to narrowing of spinal canal. Loss of lumbar lordosis is noted





[Table/Fig-16]: Sagittal T2 Weighted MR Image : High signal intensity in annulus fibroses at L3- L4 disc with herniation of disc material in spinal canal & caudal migration (open white arrow) of herniated disc material leads to narrowing of spinal canal **[Table/Fig-17]:** Axial T2 Weighted MR Image: Bilateral ligamentum thickening (solid white star). However facetal joints appear normal(open white arrow)

Migration: Whenever displacement of disc material is away from the site of extrusion it is called migration. Migration can occur either in cranial or caudal directions [Table/Fig-15,16].

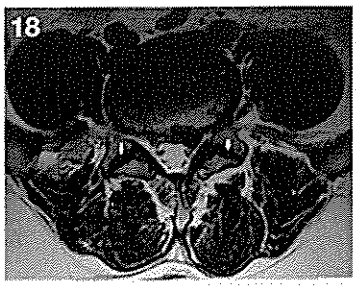
Sequestration: When the displaced disc material has completely lost any continuity with the parent disc it is called sequestration.

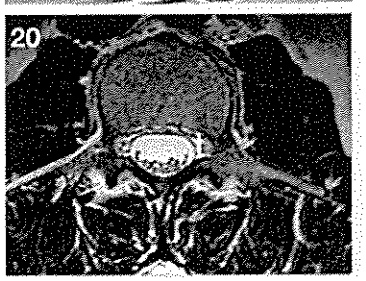
Ligamentum flavum thickening: Ligamentum flavum thickening was measured on the axial image, perpendicular to the spinal canal axis and parallel to the lamina, where ligamentum flavum were seen along their entire length & measurement were taken at the half length of ligament flavum. According to Park et al., a mean thickness of the ligamentum flavum of 4.44 mm in the patients with the spinal canal stenosis labeled as thickened and 2.44 mm thickness in the control group. So, we had labeled a >4 mm ligamentum flavum thickening as thickened [9] [Table/Fig-17].

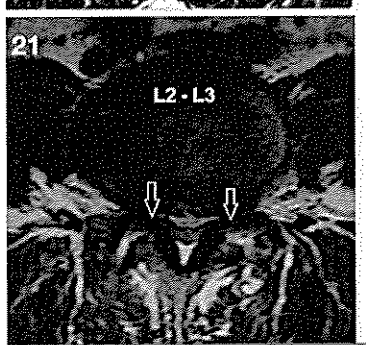
Facetal arthropathy: Facetal arthropathy was noted as reduction in synovial facetal joint space with loss of high signal intensity on T2WI [Table/Fig-18].

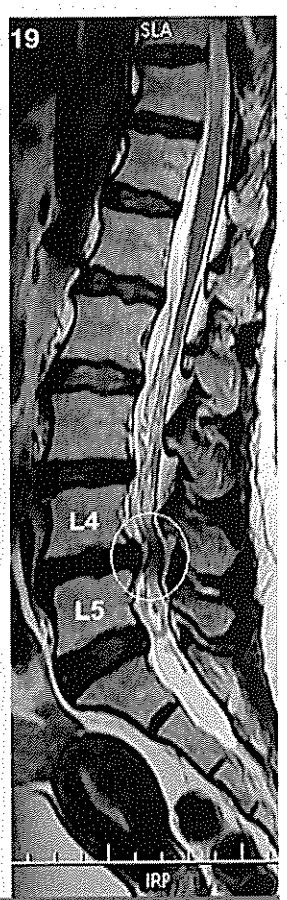
Narrowing of the spinal canal: In the mid sagittal T2 Weighted images spinal canal diameter was measured. Spinal canal diameter less than 12 mm, indicates narrowing of the canal [Table/Fig-19].

Narrowing of lateral recess: A lateral recess is the space which is bounded ventrally by the posterior surface of the vertebral body, dorsally by the superior articular facet, and laterally by the pedicle.

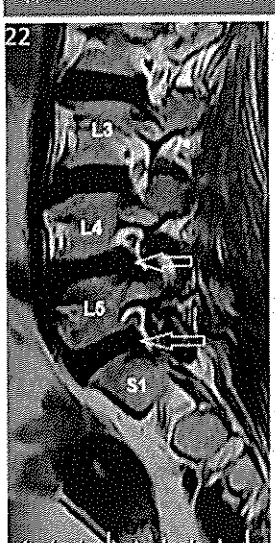


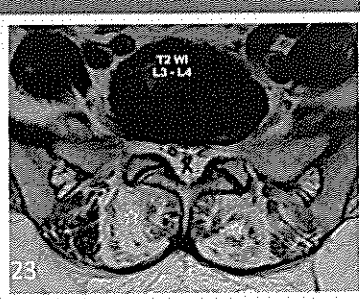


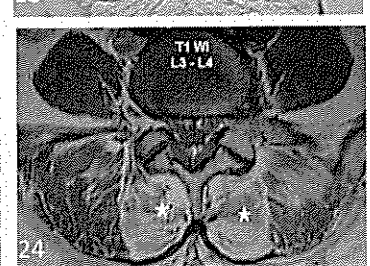




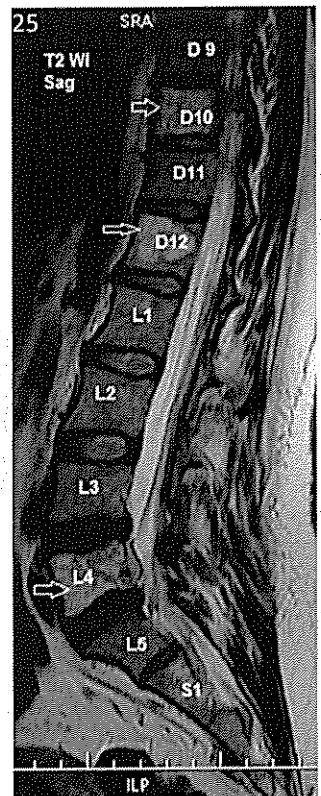
[Table/Fig-18]: Axial T2 Weighted MR Image: Narrowing of bilateral facetal joint space with loss of high signal of synovial fluid suggestive of facetal arthropathy (solid white arrow). Ligamentum flavum appears thickened **[Table/Fig-19]:** T2 Weighted Sagittal MR Image: L4-L5 disc herniation with narrowing of spinal canal (white open circle). Lumbar Disc Desiccations is seen to variable extent **[Table/Fig-20]:** Axial T2 Weighted MR Image: Normal Lateral recess: Space is bordered laterally by the pedicle, dorsally by the superior articular facet, and ventrally by the posterior surface of the vertebral body. Medially, it is open toward the spinal canal (solid white line). Normally it is greater than 4 mm **[Table/Fig-21]:** Axial T2 Weighted MR Image: L2-L3 Disc bulge with narrowing of spinal canal & bilateral lateral recess (open white arrow) with compression of exiting nerve roots. Ligamentum flavum and bilateral facetal joint appear normal

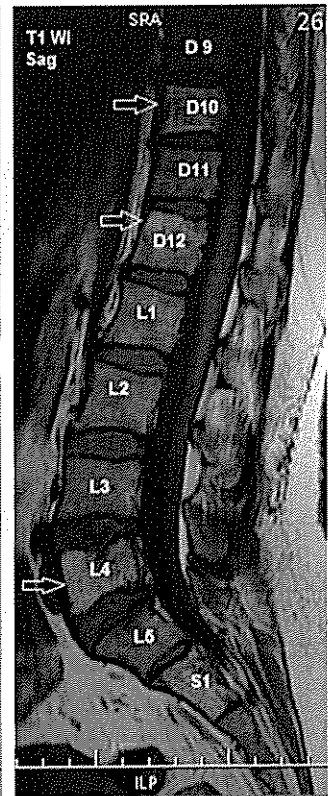






[Table/Fig-22]: Sagittal T2 Weighted MR Image: L4-L5 and L5-S1 herniated disc leads to narrowing neural foramen (open white arrow) with abutting exiting nerve roots **[Table/Fig-23]:** Axial T2 Weighted MR Image: Abnormal high signals in bilateral paraspinal muscles (open white star) on both T1WI & T2WI represents fatty infiltration of bilateral paraspinal muscles. Note left foraminal L3-L4 disc annular tear **[Table/Fig-24]:** Axial T1 Weighted MR Image: Abnormal high signals in bilateral paraspinal muscles (solid white star) on both T1WI & T2WI represents fatty infiltration of bilateral paraspinal muscles





[Table/Fig-25]: Sagittal T2 Weighted MR Image: Sacralization of L5 vertebral body. Abnormal high signal intensity in D10, D12 & L4 vertebral body in both T1WI and T2WI without fat suppression suggestive of vertebral body hemangioma (open white arrow). Note at L4 level there is epidural extension of hemangioma with spinal canal narrowing & central wedging of L4 vertebral body. L4-L5 disc shows posterior disc herniation **[Table/Fig-26]:** Sagittal T1 Weighted MR Image: Sacralization of L5 vertebral body. Abnormal high signal intensity in D10, D12 & L4 vertebral body in both T1WI (open white arrow) and T2WI without fat suppression suggestive of vertebral body hemangioma. Central wedging of L4 vertebral body is seen

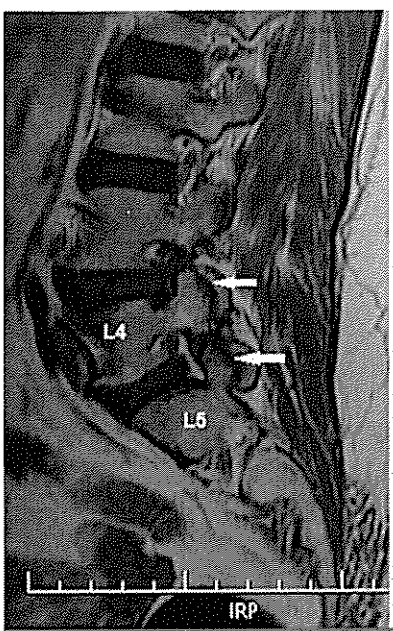
Medially, it is open toward the spinal canal. It is measured at the level of the pedicle in axial section as the distance between the post aspect of the vertebral body and superior articular facet. If it is less than 4 mm it is considered abnormal [Table/Fig-20,21]. Compression of neural foramen was observed in T2W Sagittal image [Table/Fig-22].

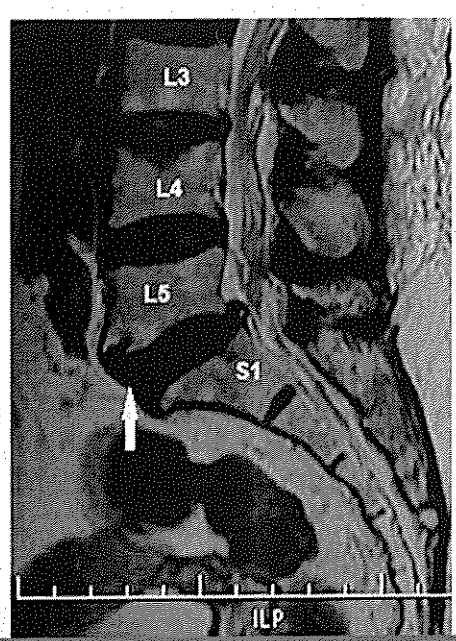
Abnormal hyper signal intensity in the spinal cord on T2 weighted images were evaluated for the spinal cord edema. Pre and Para vertebral soft tissue involvement [Table/Fig-23,24], vetertebral hemangioma [Table/Fig-25,26], sacroilitis, lumbarization and sacralization of the vertebra were observed.

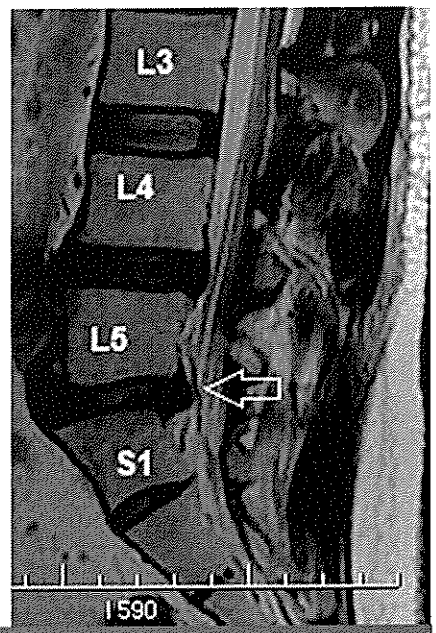
Spondylolysis is seen as low signal on T1WI in pars interarticularis [Table/Fig-27]. Spondylolisthesis was measured and diagnosed by the methods of Meyer ding. Antero-posterior diameter of the superior surface of the lower vertebral body is divided into four equal parts and is Graded as I,II,III and IV if there is a corresponding slip of <25%, 25-50%, 50-75% and >75%. But we could not divide our data according to the grades of the spondylolisthesis, we simply noted that whether spondylolisthesis were present or not & anterolisthesis or posterolisthesis were present or not [Table/Fig-28,29].

RESULTS

Total 109 patients were studied in the evaluation of MRI appearance of Degenerative Spinal Disease. Sixteen patients were excluded from the study as they had history of prior surgery, spinal infections, and active malignancy. From total 109 patients, 60 patients (i.e.55.04% of total patients) were male and 49 patients (i.e.44.95% of total patients) were female. Lumbar lordosis was preserved in 51 (i.e. 46.79% of total patients) patients and loss of the lumbar lordosis was seen in 58 (i.e. 53.21% of total patients) patients. Conus end at







[Table/Fig-27]: Sagittal T1 Weighted MR Image: Linear low signal intensity in para interarticularis of L4 and L5 vertebra (solid white arrow) represent spondylolysis without spondylolisthesis **[Table/Fig-28]:** Sagittal T2 Weighted MR Image: Posterior annular tear in L3-L4 and L5-S1 disc with herniation & spinal canal narrowing. Grade – I anterolisthesis of L5 over S1 vertebral body is seen (solid white arrow) **[Table/Fig-29]:** Sagittal T2 Weighted MR Image: L5- S1 posterior disc herniation with spinal canal narrowing. Grade – I retrolisthesis of L5 over S1 vertebral body is seen (open white arrow)

Inter-vertebral Disc Level	Disc Involvement (n= 241)	Decreased Disc Height (n = 31)	Central/ Medial Annular Tear (n = 55)	Paramedian Annular Tear (n = 43)	Right Paramedian Annular Tear (n = 21)	Left Paramedian Annular Tear (n = 22)	Foraminal Annular Tear (n = 41)	Right Foraminal Annular Tear (n = 16)	Left Foraminal Annular Tear (n = 25)
D10 – D11	1(0.41%)	-	-	-	-	-	-	-	-
D11 – D12	1(0.41%)	-	-	-	-	-	-	-	-
D12- L1	9(3.73%)	-	4(7.27%)	3(6.98%)	2(9.52%)	1(4.55%)	-	-	-
L1 – L2	14(5.81%)	3(9.68%)	4(7.27%)	-	-	-	2(4.88%)	1(6.25%)	1(4%)
L2 – L3	22(9.13%)	4(12.90%)	4(7.27%)	1(2.33%)	1(4.76%)	-	2(4.88%)	1(6.25%)	1(4%)
L3 – L4	42(17.43%)	5(16.13%)	8(14.55%)	6(13.95%)	2(9.52%)	4(18.18%)	12(29.27%)	6(37.50%)	6(24%)
L4 – L5	93(38.59%) #	9(29.03%)	21(38.18%) #	21(48.84%) #	10(47.62%) #	11(50.00%) #	24(58.54%) #	7(43.75%) #	17(68%) #
L5 – S1	56(23.24%)	10(32.26%) #	14(25.45%)	12(27.91%)	6(28.57%)	6(27.27%)	1(2.44%)	1(6.25%)	-
S1 – S2	3(1.24%)	-	-	-	-	-	-	-	-

[Table/Fig-30]: Different variables like Disc Involvement, Decreased Disc Height, Central/Medial Annular Tear, Paramedian Annular Tear, Right Paramedian Annular Tear, Left Paramedian Annular Tear, Foraminal Annular Tear, Right Foraminal Annular Tear, Left Foraminal Annular Tear and their correlation with the intervertebral disc level.
# indicates most common intervertebral disc level of involvement

Inter-vertebral Disc Level	Herniation (n= 150)	Disc Extrusion (n = 42)	Disc Bulge (n = 66)	Osteophytes (n = 17)	Spinal Canal Narrowing (n = 56)	Narrowing of lateral recess (n = 127)	Compression of neural foramen (n = 127)	Facetal Arthropathy (n =209)	Ligamentum Flavum Thickening (n = 209)
D10 – D11	-	-	-	-	-	-	-	1(0.47%)	1(0.47%)
D11 – D12	-	-	-	-	-	-	-	1(0.47%)	1(0.47%)
D12- L1	1(0.67%)	1(2.38%)	6(9.09%)	1(5.88%)	-	1(0.79%)	1(0.79%)	1(0.47%)	1(0.47%)
L1 – L2	3(2%)	1(2.38%)	10(15.15%)	1(5.88%)	1(1.78%)	2(1.57%)	2(1.57%)	9(4.30%)	9(4.30%)
L2 – L3	11(7.33%)	4(9.52%)	8(12.12%)	3(17.65%)	6(10.71%)	8(6.30%)	8(6.30%)	21(10.04%)	21(10.04%)
L3 – L4	21(14%)	6(14.29%)	17(25.76%) #	5(29.41%) #	13(23.21%)	21(16.54%)	21(16.54%)	40(19.13%)	40(19.13%)
L4 – L5	68(45.33%) #	18(42.86%) #	17(25.76%) #	2(11.76%)	25(44.64%) #	60(47.24%) #	60(47.24%) #	86(41.14%) #	86(41.14%) #
L5 – S1	45(30%)	12(28.57%)	7(10.61%)	5(29.41%) #	10(17.85%)	34(26.77%)	34(26.77%)	48(22.96%)	48(22.96%)
S1 – S2	1(0.67%)	-	1(1.52%)	-	1(1.78%)	1(0.79%)	1(0.79%)	2(0.96%)	2(0.96%)

[Table/Fig-31]: Different variables like Herniation, Disc Extrusion, Disc Bulge, Osteophytes, Spinal Canal Narrowing, Narrowing of lateral recess, Compression of neural foramen, Facetal Arthropathy, Ligamentum Flavum Thickening and their correlation with the intervertebral disc level.
# indicates most common intervertebral disc level of involvement

L1 vertebral level which was most common and seen in 63 patients (i.e. 57.80% of total patients).

As seen in [Table/Fig-30,31] there were a total 241 disc involvements, so per patients average 2.21 disc involvements were found. L4 – L5 disc involvement was common & seen in 93 discs (i.e. 38.59% of the disc involvement). Decrease disc heights were seen in 31 disc levels, from which decreased disc height common at L5-S1 level 10(i.e. 32.26% of decreased disc height). Two patients (1.83%) showed changes of discitis. Fifty five patients (i.e. 50.45% of total patients) showed medial annular disc tear. In medial annular disc tear L4 –L5 disc were common seen (i.e. 38.18% of medial annular tear). Forty three patients (i.e. 39% of total patients) showed

paramedian annular tear. In paramedian annular disc tear L4 –L5 disc were commonly seen 21 (i.e. 48.84% of paramedian annular tear). Left paramedian tear were seen in 22 patients and right paramedian tear were seen in 21 patients. So, left paramedian tear was common as compared to the right side. 41 patients (i.e. 37% of total patients) showed foraminal annular tear. In foraminal annular disc tear L4 –L5 disc were common 24(i.e. 58.54% of foraminal annular tear). Left foraminal tear were seen in 25 patients and right foraminal tear were seen in 16 patients. So, left foraminal tear was common as compare to the right side. Herniation in 150 discs (i.e. 62.24% of disc involvement), extrusion in 42 discs (i.e. 17.43% of disc involvement) and disc buldge in 66 disc (i.e. 27.39% of disc involvement). Herniation was common at L4 –L5 disc level 68(i.e. 45.33% of herniation). Extrusion was common at L4 – L5 disc level 18(i.e. 42.86% of extrusion). Disc bulge was common at L3 – L4 17(i.e. 25.76% disc buldge) & L4 – L5 disc level 17(i.e. 25.76% disc buldge). L3 – L4 & L5 – S1 level shows maximum osteophytes 5(i.e. 29.41% osteophytes). Spinal canal narrowing was seen in 56 discs (i.e. 23.24% of disc involvement). Spinal canal narrowing was common in L4 – L5 disc 25(i.e. 44.64% of spinal canal narrowing). Narrowing of lateral recess and compression of neural foramen were seen in 127 discs (i.e. 52.70% of disc involvement) and both were common at L4 –L5 disc 60(i.e. 47.24% of involvement). Facetal arthropathy and ligamentum flavum thickening was seen in 209 disc levels (i.e. 86.72% of the disc involvement) & both were common at the L4 – L5 disc level. Six patients (i.e. 5.5% of total patiertts) showed wedging in vertebral body and were equally common at L1, L4 & L5 vertebral body (i.e. 33% each). Fifteen patients (i.e. 13.76% of total patients) showed listhesis in the spine in the form of anterolisthesis or retrolisthesis. Anterolisthesis (i.e. 10.09% of spondylolisthesis) is common as compare to retrolisthesis (i.e. 3.67% of spondylolisthesis). L5 vertebral body listhesis over S1 vertebral body was common in both anterolisthesis & retrolisthesis. As incidental findings vertebral hemangioma in 12 patients (i.e. 11.01% of total patients), marrow edema in 2 patients (i.e. 1.83% of total patients), partial fusion of vertebral body in 1 patient (i.e. 0.92% of total patients), paraspinal muscles fatty infiltration and edema in 3 patients (i.e. 2.75% of total patients) and spinal cord syrinx in 1 patient (i.e. 0.92% of total patients) were found.

DISCUSSION

Lumbar disc degeneration is the most common cause of low back pain around the world and majority due to the disc herniation. Due to development of MRI, noninvasive excellent imaging of spine is possible. Men are more commonly affected to the disc degeneration than women. It is most likely due to the increased mechanical stress and injury [10]. The findings of our study were consistent with other studies [11].

Most common cause of disc degeneration was observed in 4th and 5th decades of life in our study, which was comparable with other studies [11]. Disc desiccation is a common degenerative change of intervertebral discs. It results from the replacement of the glycosaminoglycans within the nucleus pulposus with fibro cartilage which leads to reduced disc height due to reduction in nucleus pulposus volume [12]. Disc degeneration with diffuse disc changes are more commonly found at L4 - L5 and L5 – S1 level [11] and L1 – L2 is least common. This Cranio-caudal direction pattern is also followed by disc herniation. It also can be deduced that lower the lumbar level the higher is the prevalence of disc herniation. Multiplicity in the disc level involvement is common as compare to the single disc involvement; which is also concordance with past studies [13]. The lower back pain and sciatica were due to nerve root compression, which was significantly associated with disc degeneration [14]. Spondylolisthesis was more commonly found in the patients of lumbar stenosis as compare to disc herniation, reflecting the fact that during stenosis, laxity of capsule and ligament may result in the development of spondylolisthesis. Spondylolisthesis was most commonly present at L5 – S1 disc level. This findings is inconcordance with a previous study where spondylolisthesis was common at L4 – L5 disc level [3].

CONCLUSION

Lumbar disc degeneration is the most common cause of low back pain. Men are more frequently affected to the disc degeneration than women. Multiple levels of the disc involvement are seen per person. Annular disc tear, disc herniation, disc extrusion, narrowing of spinal canal, narrowing of lateral recess, compression of neural foramen, facetal arthropathy and ligamentum flavum thickening is common at the L4 –L5 disc level. L1- L2 disc involvement and spondylolisthesis are less common. MRI is the standard imaging modality for detecting disc pathology due to its advantage of lack of radiation, multiplanar imaging capability, excellent spinal soft-tissue contrast and precise localization of intervertebral discs changes.

REFERENCES

[1] Neuropathy-sciatic nerve: sciatic nerve dysfunction; low back pain-sciatica [Internet]. Bethesda (MD): A.D.A.M. Inc.; c2013 [cited 2012 Aug 12]. Available from: http://www.ncbi.nlm.nih.gov/pubmedhealth/ PMH0001706/.
[2] Bakhsh A. Long-term outcome of lumbar disc surgery: an experience from Pakistan. *J Neurosurg Spine*. 2010;12:666-70.
[3] Modic MT, Ross JS. Lumbar degenerative disc disease. *Radiology*. 2007;245: 43-61.
[4] Battie MC, Videman T, Gibbons LE, Fisher LD, Manninen H, Gill K. 1995 Volvo Award in clinical sciences: determinants of lumbar disc degeneration—a study relating lifetime exposures and magnetic resonance imaging findings in identical twins. *Spine*. 1995;20: 2601–12.
[5] Shafaq Saleem, Hafiz Muhammad Aslam, Muhammad Asim Khan Rehmani, Aisha Raees, Arsalan Ahmad Alvi, Junaid Ashraf. Lumbar Disc Degenerative Disease: Disc Degeneration Symptoms and Magnetic Resonance Image Findings. *Asian Spine J*. 2013;7(4):322–34.
[6] Haughton V. Imaging intervertebral disc degeneration. *J Bone Joint Surg Am*. 2006;88 (Suppl 2):15-20.
[7] Maravilla KR, Lesh P, Weinreb JC, Selby DK, Mooney V. Magnetic resonance imaging of the lumbar spine with CT correlation. *AJNR Am J Neuroradiol*. 1985;6(2):237-45.
[8] Modic MT, Pavlicek W, Weinstein MA, et al. Magnetic resonance imaging of intervertebral disk disease: clinical and pulse sequence considerations. *Radiology*. 1984;152:103–11.
[9] Park JB, Chang H, Lee JK. Quantitative analysis of transforming growth factor-beta 1 in ligamentum flavum of lumbar spinal stenosis and disc herniation. *Spine* (Phila Pa 1976). 2001;26:E492–95.
[10] Wang YX, Griffith JF. Effect of menopause on lumbar disc degeneration: potential etiology. *Radiology*. 2010;257:318-20.
[11] Cheung KM, Karppinen J, Chan D, Ho DW, Song YQ, Sham P, et al. Prevalence and pattern of lumbar magnetic resonance imaging changes in a population study of one thousand forty-three individuals. *Spine* (Phila Pa 1976). 2009;34(9):934-40.
[12] Lipson SJ, Muir H. Experimental intervertebral disc degeneration: morphologic and proteoglycan changes over time. *Arthritis Rheum*. 1981;24:12–21.
[13] Takatalo J, Karppinen J, Niinimäki J, Taimela S, Näyhä S, Järvelin MR, et al. Prevalence of degenerative imaging findings in lumbar magnetic resonance imaging among young adults. *Spine* (Phila Pa 1976). 2009;34(16):1716-21.
[14] Shambrook J, McNee P, Harris EC, et al. Clinical presentation of low back pain and association with risk factors according to findings on magnetic resonance imaging. *Pain*. 2011;152:1659–65.

PARTICULARS OF CONTRIBUTORS:
1. Third Year Resident Doctor, Department of Radiology, S.S.G. Hospital, Medical College, Vadodara, India.
2. Assistant Professor, Department of Orthopedics, Virginia Commonwealth University (VCU), Richmond, Virginia, USA.
3. Associate Professor, Department of Radiology, S.S.G. Hospital, Medical College, Vadodara, India.
4. Professor, Department of Radiology, S.S.G. Hospital, Medical College, Vadodara, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Pokhraj Prakashchandra Suthar,
5-Durga Nagar Society, Karodiya, Baroda, Gujarat-391310, India.
E-mail: pokhraj_suthar@yahoo.co.in

FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Submission: Nov 05, 2014
Date of Peer Review: Jan 20, 2015
Date of Acceptance: Feb 12, 2015
Date of Publishing: Apr 01, 2015

HSSJ (2012) 8:29–32
DOI 10.1007/s11420-011-9241-0

MR Imaging Tools to Assess Cartilage and Joint Structures

Hollis G. Potter, MD · Matthew F. Koff, PhD

Received: 31 August 2011/Accepted: 2 November 2011/Published online: 27 January 2012

Keywords cartilage · MRI · biochemistry

Introduction

Standing radiographs provide important information regarding angular deformities and weight-bearing alignment of the joints, but provide only indirect information about joint integrity. Given its superior soft tissue contrast and direct multiplanar acquisition with the ability to accurately assess the complex geometry of various joints, magnetic resonance imaging (MRI) is a highly suitable tool by which to assess osteoarthritis (OA).

Magnetic Resonance Imaging of Cartilage

Cartilage is a soft, viscoelastic tissue with strong imaging and anisotropic mechanical properties. The MRI signal properties are dependent on the cellular composition of collagen, proteoglycan, and water, but also the MR pulse sequence utilized. Several standardized pulse sequences are available that have been assessed for accuracy and reproducibility based on a suitable surgical standard [14]. 3D modeling of joint structures is now available with the use of standardized fat-suppressed gradient echo or 3D fast spin echo techniques, which when applied with isotropic voxels, are amenable to semiautomatic segmentation algorithms and volumetric quantification of cartilage. However, cartilage volume is a function of both surface area and thickness; longitudinal changes are affected by alteration in thickness, such as swelling in the presence of proteoglycan loss in early OA and alterations in surface area, such as the development of osteophytes. For this reason, geographic regional assessment of cartilage thickness is generally more useful than overall assessment of cartilage volume.

Normal cartilage also demonstrates "gray-scale stratification," with lower signal intensity closer to the tidemark and subchondral plate and higher signal intensity in the transitional zone, related largely to collagen orientation in the extracellular matrix. Loss of normal gray-scale stratification is an important clinical feature that may herald subsequent delamination of cartilage from the subchondral bone. It is also important to assess the global joint, inclusive of the menisci, subchondral bone, synovium, and ligaments. More rapid progression of OA is typically associated with a combination of factors yielding to loss of structural integrity of the entire joint (Fig. 1).

Magnetic Resonance Imaging and Osteoarthritis

OA commonly results in turnover of subchondral bone with sclerosis and varying amounts of bone marrow edema. Severe and disproportionate edema patterns should raise scrutiny for the presence of a focal subchondral fracture, which may serve as a precursor to the development of osteonecrosis (Fig. 2).

Several scoring systems have been devised for assessment of cartilage morphology. The most comprehensive scores involve assessment not just of cartilage thickness and loss but also of the integrity of the ligaments, menisci, and synovium. Several modifications have been suggested due to the sometimes cumbersome application of scoring systems in clinical trials. For example, the WORMS score divides osteophytes into a range of 0 to 7 [13]. Modifications have been suggested [8]. These scoring systems allow for identification of MR features associated with more rapid progression of OA, including more advanced radiographic disease at the time of the initial evaluation [4], high baseline BMI [2, 17], baseline meniscal tear or extrusion [17], or progressive bone marrow edema [7, 12, 16].

H. G. Potter, MD (✉) · M. F. Koff, PhD
Department of Radiology and Imaging,
Hospital for Special Surgery,
535 East 70th St., New York, NY 10021, USA
e-mail: potterh@hss.edu

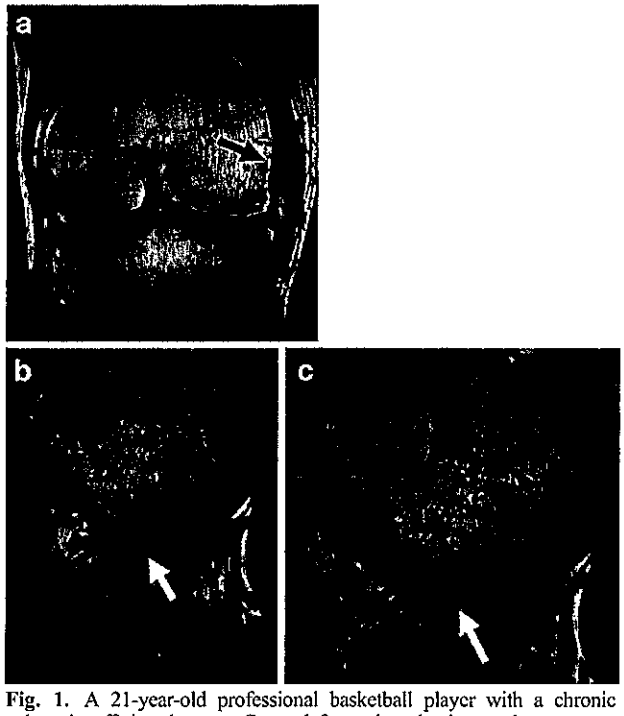


Fig. 1. A 21-year-old professional basketball player with a chronic valgus insufficient knee. **a** Coronal fast spin echo image demonstrates chronic deficiency of the medial collateral ligament (*arrow*). **b** On the initial MRI, focal loss of gray-scale stratification was noted on the corresponding fast spin echo image of the tibia (*arrow*). **c** Subsequent MRI obtained 7 months later demonstrated complete cartilage delamination, which was considered "at risk" on the study performed 7 months earlier

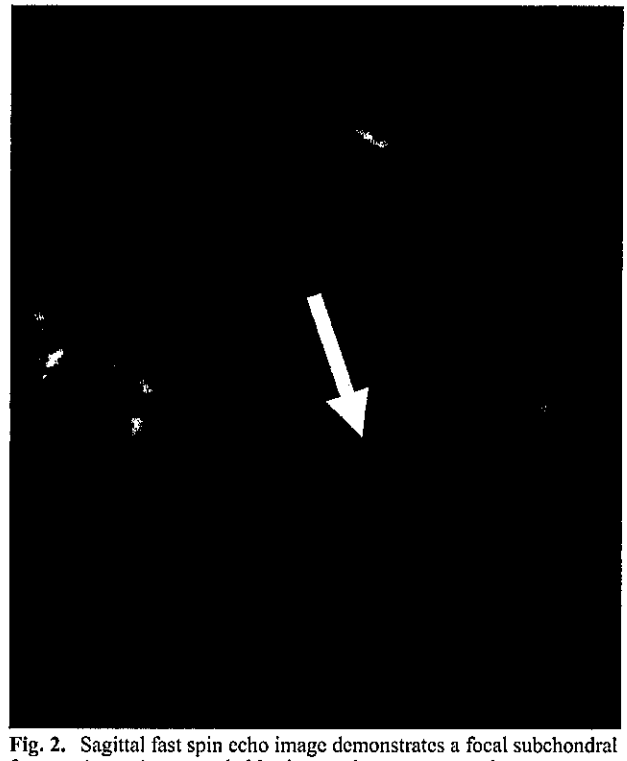


Fig. 2. Sagittal fast spin echo image demonstrates a focal subchondral fracture (*arrow*) surrounded by intense bone marrow edema pattern, a patient with early OA that has undergone partial medial meniscectomy

While these tools are established, important technical challenges remain, especially when planning multicenter cartilage repair trials. Standardization of field strength, imaging coils, and MR protocols is essential. Sufficient spatial resolution is important to detect partial thickness lesions, abnormal synovium, and subchondral sclerosis. Increased magnetic field strength results in an increased signal to noise ratio, but comes with increasing artifacts and safety issues. Most importantly, the choice of cartilage pulse sequence should use a series of parameters that have been independently validated, assessed for accuracy, and published in the literature.

MRI and Tissue Biochemistry

While these measures provide an effective means by which to assess joint morphology, they provide only indirect assessment of cartilage biology. The more recent development of quantitative MR techniques has provided indirect insight into tissue biochemistry. To assess cartilage proteoglycan or glycosaminoglycans (GAG), several techniques are available, including sodium MRI, performed at 3 or 7 T [6], delayed gadolinium enhanced MRI of cartilage (dGEMRIC) [21], and T1 rho imaging [20]. To assess cartilage orientation, quantitative T2 mapping is most often utilized, but may also be explored using the less commonly performed diffusion tensor weighted imaging [1, 9, 22]. To apply these MR techniques in a longitudinal fashion, registration of the quantitative MR data to morphologic imaging is important so as to provide reasonable correlation of anatomic regions of the joint over time.

These quantitative MR techniques are suitable for studying populations at risk for development of progressive or early OA, such as developmental dysplasia or femoroacetabular impingement in the hip or patellofemoral overload in the knee (Fig. 3). Kim et al. used dGEMRIC techniques to study a cohort of patients with developmental dysplasia treated with osteotomy and showed that patients who clinically failed osteotomy had lower dGEMRIC indices of GAG content; in fact, the dGEMRIC index was more predictive of failure than radiographs alone [3, 10].

Traumatic models of OA have also been studied, and recent data suggest that 100% of patients sustain chondral damage at the time of pivot shift following initial anterior cruciate ligament (ACL) tear, with an increase in cartilage degradation at longitudinal follow-up, particularly after 5 years [15]. The transchondral fracture associated with a pivot shift results in compression over the lateral femoral condyle and shear over the plateau, yielding variable degrees of cartilage loss. Tiderius et al. studied a small cohort of patients following acute ACL injury using dGEMRIC and noted a loss in GAG in both medial and lateral femorotibial surfaces, suggesting that the trauma had a negative effect on cartilage homeostasis, resulting in depletion of

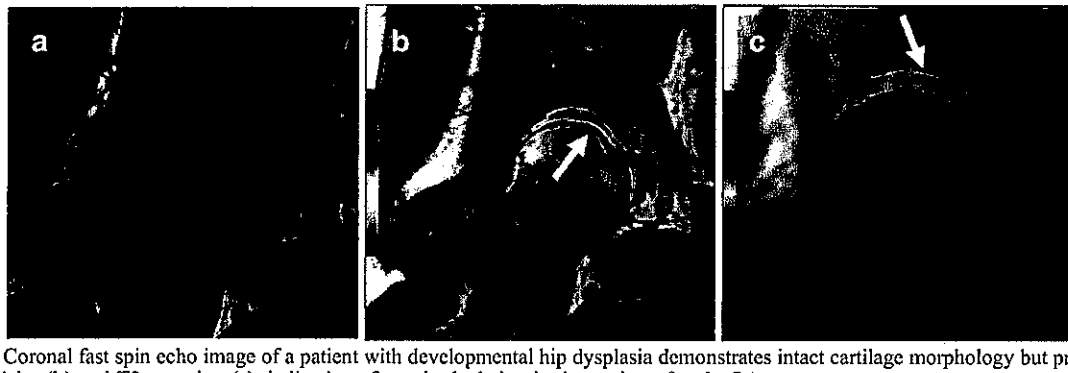


Fig. 3. a Coronal fast spin echo image of a patient with developmental hip dysplasia demonstrates intact cartilage morphology but prolongation of both T1rho (b) and T2 mapping (c), indicative of matrix depletion in the setting of early OA

matrix in areas that were not initially affected by the transchondral fracture sustained at pivot shift [18]. Li et al. also studied ACL injured patients, showing significant prolongation of T1 rho over the medial compartment and the lateral tibial plateau [11].

Following cartilage repair, these quantitative MR techniques may provide insight into repair tissue ultrastructure, providing an important noninvasive means by which to assess tissue biochemistry and obviate the need for post-repair biopsy [5, 19].

Summary

A combination of both morphologic and quantitative MR provides objective data to assess not only cartilage morphology but also cartilage biochemistry, inclusive of proteoglycan content and collagen orientation. Challenges still exist, however, as these quantitative techniques increase scan time, are not universally available across sites, and are sometimes restricted to higher magnetic field strengths of 3 T. Standardization of post-processing algorithms and registration software are important to provide more uniform data in multicenter trials. Several ongoing longitudinal registries are being established to study populations at risk, and these preliminary studies will provide important information suitable for powering studies aimed at assessing potential pharmaceutical intervention to delay the progression of OA. In addition, these MR data provide important insight into the appropriate timing of surgical treatments aimed at delaying progression and provide noninvasive and objective assessment of cartilage repair techniques.

Disclosures The institution of the authors has received funding from The National Institutes of Health (HGP and MFK). Institutional research support was from General Electric Healthcare (HGP and MFK).

References

1. Azuma T, Nakai R, Takizawa O, Tsutsumi S. In vivo structural analysis of articular cartilage using diffusion tensor magnetic resonance imaging. Magn Reson Imaging. 2009 Nov;27(9):1242–8.
2. Biswal S, Hastie T, Andriacchi TP, Bergman GA, Dillingham MF, Lang P. Risk factors for progressive cartilage loss in the knee: a longitudinal magnetic resonance imaging study in forty-three patients. Arthritis Rheum. 2002;46(11):2884–92.
3. Cunningham T, Jessel R, Zurakowski D, Millis MB, Kim YJ. Delayed gadolinium-enhanced magnetic resonance imaging of cartilage to predict early failure of Bernese periacetabular osteotomy for hip dysplasia. J Bone Joint Surg Am 2006; 88 (7):1540–1548
4. Eckstein F, Benichou O, Wirth W, Nelson DR, Maschek S, Hudelmaier M, Kwoh CK, Guermazi A, Hunter D; Osteoarthritis Initiative Investigators. Magnetic resonance imaging-based cartilage loss in painful contralateral knees with and without radiographic joint space narrowing: Data from the Osteoarthritis Initiative. Arthritis Rheum. 2009;61(9):1218–25.
5. Fortier LA., Potter HG, Rickey E.J, Schnabel LV., Ellsworth JR., Foo LF., Nixon A. Concentrated bone marrow aspirate improves full-thickness cartilage repair. Journal for Bone and Joint Surgery 2010; 92;1927–1937.
6. Gold GE, Burstein D, Dardzinski B, et al. MRI of articular cartilage in OA: novel pulse sequences and compositional/ functional markers. Osteoarthritis Cartilage 2006; 14:A76-A86.
7. Hunter DJ, Zhang Y, Niu J, Goggins J, Amin S, LaValley MP, Guermazi A, Genant H, Gale D, Felson DT. Increase in bone marrow lesions associated with cartilage loss: a longitudinal magnetic resonance imaging study of knee osteoarthritis. Arthritis Rheum. 2006;54(5):1529–35.
8. Hunter DG, Lo GH, Gale D, Grainger AJ, Guermazi A, Conaghan PG. The reliability of a new scoring system for knee osteoarthritis MRI and the validity of bone marrow lesion assessment: BLOKS (Boston–Leeds Osteoarthritis Knee Score). Ann Rheum Dis. 2008;67(2):206–11.
9. Kelly BT, Potter HG, Deng X, Pearle AD, Turner AS, Warren RF, Rodeo SA. Meniscal allograft transplantation in the sheep knee: evaluation of chondroprotective effects. Am J Sports Med 2006; 34:1464–1477.
10. Kim YJ, Jaramillo D, Millis MB, Gray ML, Burstein D. Assessment of early osteoarthritis in hip dysplasia with delayed gadolinium-enhanced magnetic resonance imaging of cartilage. J Bone Joint Surg Am 2003; 85:1987–1992
11. Li X, Kuo D, Theologis A, et al: Cartilage in Anterior Cruciate Ligament-Reconstructed Knees: MR Imaging T1{rho} and T2–Initial Experience with 1-year Follow-up. *Radiology* 2011; 258 (2): 505–514.
12. Lo GH, McAlindon TE, Niu J, Zhang Y, Beals C, Dabrowski C, Le Graverand MP, Hunter DJ; OAI Investigators Group. Bone marrow lesions and joint effusion are strongly and independently associated with weight-bearing pain in knee osteoarthritis: data from the osteoarthritis initiative. Osteoarthritis Cartilage. 2009;17 (12):1562–9.

13. Peterfy CG, Guermazi A, Zaim S, Tirman PF, Miaux Y, White D, Kothari M, Lu Y, Fye K, Zhao S, Genant HK. Whole-Organ Magnetic Resonance Imaging Score (WORMS) of the knee in osteoarthritis. Osteoarthritis Cartilage. 2004;12 (3):177–90.
14. Potter HG, et al. Magnetic resonance imaging of articular cartilage in the knee: An evaluation with use of fast spin-echo imaging. J Bone Joint Surg Am 1998; 80(A):1276–1284.
15. Potter HG, Jain SK, Ma Y, Black BR, Fung S, Lyman S. Cartilage injury following acute, isolated ACL tear: Immediate and longitudinal effect with clinical/MRI follow up. Am J Sports Med 2011, Epub ahead of print, PMID: 21952715.
16. Roemer FW, Guermazi A, Javaid MK, Lynch JA, Niu J, Zhang Y, Felson DT, Lewis CE, Torner J, Nevitt MC; MOST Study investigators. Change in MRI-detected subchondral bone marrow lesions is associated with cartilage loss: the MOST Study. A longitudinal multicentre study of knee osteoarthritis. Ann Rheum Dis. 2009;68(9):1461–5.
17. Roemer FW, Zhang Y, Niu J, Lynch JA, Crema MD, Marra MD, Nevitt MC, Felson DT, Hughes LB, El-Khoury GY, Englund M, Guermazi A; Multicenter Osteoarthritis Study Investigators. Tibiofemoral joint osteoarthritis: risk factors for MR-depicted fast cartilage loss over a 30-month period in the multicenter osteoarthritis study. Radiology. 2009;252(3):772–80.
18. Tiderius CJ, Olsson LE, Nyquist F, et al. Cartilage glycosaminoglycan loss in the acute phase after an anterior cruciate ligament injury: delayed gadolinium-enhanced magnetic resonance imaging of cartilage and synovial fluid analysis. Arthritis Rheum 2005;52: 120–127.
19. Trattnig S, Winalski CS, Marlovits S, Jurvelin JS, Welsch GH, Potter HG. Magnetic Resonance Imaging of Cartilage Repair: A Review. Cartilage 2011; 2(1):5–26
20. Wheaton AJ, Dodge GR, Borthakur A, et al. Detection of changes in articular cartilage proteoglycan by T(1rho) magnetic resonance imaging. J Orthop Res 2005; 23: 102–108.
21. Williams A, Gillis A, McKenzie C, Po B, Sharma L, Micheli L, McKeon B, Burstein D. Glycosaminoglycan distribution in cartilage as determined by delayed gadolinium-enhanced MRI of cartilage (dGEMRIC): potential clinical applications. AJR Am J Roentgenol. 2004;182(1):167–72.
22. Xia Y, Moody JB, Burton-Wurster N, et al. Quantitative in situ correlation between microscopic MRI and polarized light microscopy studies of articular cartilage. Osteoarthritis Cartilage 2001; 9:393–406

EXHIBIT

5

Hartford Hospital
A Hartford HealthCare Partner

December 17, 2015

This is a letter in support of the Hartford Hospital proposal to purchase a CT scanner and MRI scanner to be installed in its new Bone and Joint Institute, currently under construction.

As medical director of the CT and MRI sections at Hartford Hospital, I strongly support obtaining these advanced technology scanners as described in our proposal. The proposed CT and MRI scanners will provide needed inpatient and outpatient imaging capabilities for Bone and Joint Institute patients, as well as a better patient experience for other Hartford Hospital outpatients requiring CT and MRI exams.

The new CT scanner will provide dual energy scanning capability to reduce metal artifacts in orthopedic patients, and will utilize radiation dose reduction software to minimize patient radiation dose. It will also allow for rapid assessment of suspected pulmonary embolisms in post-surgical patients.

The MRI scanner is optimized for orthopedic exams and also includes advanced techniques to reduce image degradation due to presence of metal. It is essential the Hartford Hospital acquire the the proposed CT and MRI scanners to provide state-of-the-art imaging for and proper care of patients of the new Bone and Joint Institute

Sincerely,

Michael O'Loughlin, MD

Hartford HealthCare

Bone & Joint Institute

Hartford Hospital

December 21, 2015

As Physician in Chief of the Hartford Healthcare Bone & Joint Institute currently under construction, I strongly support Hartford Hospital's proposal to obtain new CT and MRI scanners to be located in the imaging center of the Institute.

An orthopaedic hospital of this kind cannot operate efficiently or safely without appropriate advanced medical imaging capabilities. The proposed CT and MRI scanners will provide our medical staff with the accurate diagnostic information needed to evaluate orthopaedic conditions and determine optimal treatment regimens. In addition, the scanners will provide the medical staff with tools needed for immediate, on-site follow-up of suspected pulmonary embolism and other potential post-surgical complications.

These advanced scanners are an integral part of our efforts to make the new Bone & Joint Institute a state-of-the-art orthopaedic facility for the patients we serve.

Sincerely,

Courtland, G. Lewis, MD
Physician-in-Chief
Bone & Joint Institute at Hartford Hospital

EXHIBIT

6

GE Healthcare

Date: 11-02-2015
Quote #: PR9-C53784
Version #: 3

Hartford Hospital
85 Jefferson St
Hartford CT 06106-2601

Attn: Keith Crosby
80 Seymour St Hartford
CT 06102-8000

Customer Number : 1-23LVTQ
Quotation Expiration Date: 12-19-2015

This Agreement (as defined below) is by and between the Customer and the GE Healthcare business ("GE Healthcare"), each as identified herein. "Agreement" is defined as this Quotation and the terms and conditions set forth in either (i) the Governing Agreement identified below or (ii) if no Governing Agreement is identified, the following documents:

1) This Quotation that identifies the Product offerings purchased or licensed by Customer;

2) The following documents, as applicable, if attached to this Quotation: (i) GE Healthcare Warranty(ies); (ii) GE Healthcare Additional Terms and Conditions; (iii) GE Healthcare Product Terms and Conditions; and (iv) GE Healthcare General Terms and Conditions.

In the event of conflict among the foregoing items, the order of precedence is as listed above.

This Quotation is subject to withdrawal by GE Healthcare at any time before acceptance. Customer accepts by signing and returning this Quotation or by otherwise providing evidence of acceptance satisfactory to GE Healthcare. Upon acceptance, this Quotation and the related terms and conditions listed above (or the Governing Agreement, if any) shall constitute the complete and final agreement of the parties relating to the Products identified in this Quotation.

No agreement or understanding, oral or written, in any way purporting to modify this Agreement, whether contained in Customer's purchase order or shipping release forms, or elsewhere, shall be binding unless hereafter agreed to in writing by authorized representatives of both parties.

Governing Agreement:	Premier
Terms of Delivery:	FOB Destination
Billing Terms:	80% on Delivery/ 20% on Acceptance or First Patient Use
Payment Terms:	NET 30
Total Quote Net Selling Price:	$454,313.98

INDICATE FORM OF PAYMENT:

If "GE HFS Loan" or "GE HFS Lease" is NOT selected at the time of signature, then you may NOT elect to seek financing with GE Healthcare Financial Services (GE HFS) to fund this arrangement after shipment.

____Cash/Third Party Loan

____GE HFS Lease

____GE HFS Loan

____Third Party Lease (please identify financing company) _____

By signing below, each party certifies that it (i) has received a complete copy of this Quotation, including the GE Healthcare terms, conditions and warranties, and (ii) has not made any handwritten or electronic modifications. Manual changes or mark-ups on this Agreement (except signatures in the signature blocks and an indication in the form of payment section below) will be void.

Each party has caused this agreement to be executed by its duty authorized representative as of the date set forth below.

CUSTOMER

_____ _____
Authorized Customer Signature Date

_____ _____
Print Name Print Title

_____
Purchase Order Number (if applicable)

GE HEALTHCARE
Colleen Kavanagh 11-02-2015
Signature Date

Product Sales Manager

Email: Colleen.Kavanagh@ge.com
Office: +1 262 290 1964
Mobile: 262-290-1964
Fax: 262-364-2650

GE Healthcare

Date: 11-02-2015
Quote #: PR9-C53784
Version #: 3

Total Quote Selling Price	**$454,313.98**
Trade-In and Other Credits	$0.00
Total Quote Net Selling Price	**$454,313.98**

To Accept this Quotation

Please sign and return this Quotation together with your Purchase Order To:
Colleen Kavanagh
Office: +1 262 290 1964
Mobile: 262-290-1964
Email: Colleen.Kavanagh@ge.com
Fax: 262-364-2650

Payment Instructions

Please **Remit** Payment for invoices associated with this quotation to:
GE Healthcare
P.O. Box 96483
Chicago, IL 60693

To Accept This Quotation

- Please sign the quote and any included attachments (where requested).
- If requested, please indicate, your form of payment.
- If you include the purchase order, please make sure it references the following information
  - The correct Quote number and version number above
  - The correct Remit To information as indicated in **"Payment Instructions"** above
  - The correct SHIP TO site name and address
  - The correct BILL TO site name and address
  - The correct Total Quote Net Selling Price as indicated above

GE Healthcare

Date: 11-02-2015
Quote #: PR9-C53784
Version #: 3

11-02-2015

GPO Agreement Reference Information

Customer:	Keith Crosby
Contract Number:	PLEASE SEE PREMIER CONTRACT # BELOW
Start Date:	
End Date:	09/30/2018
Billing Terms:	80% on Delivery/ 20% on Acceptance or First Patient Use
Payment Terms:	NET 30
Shipping Terms:	FOB Destination

NOTICE REGARDING COMPUTED TOMOGRAPHY ("CT") PRODUCTS. This notice applies only to the following GE Healthcare products: CT: Revolution CT and EVO, Optima 680 CT and Optima 520 CT. GE Healthcare has reclassified several advanced software tools and associated documentation to a GE Healthcare Technical Service Technology package that GE Healthcare feels will bring greater value and interest to our customers. GE Healthcare will continue to provide trained Customer employees with access to the GE Healthcare Technical Service Technology package under a separate agreement. GE Healthcare will continue to provide customers and their third party service providers with access to software tools and associated documentation in order to perform basic service on the CT, MR and NM products listed above upon a request for registration for such access. This will allow GE Healthcare to react faster to the future service needs of GE Healthcare customers. If you have any questions, you can contact your sales Service Specialist.

Offer subject to the Terms and Conditions of the applicable Group Purchasing Agreements currently in effect between GE Healthcare and Premier Purchasing Partners, L.P. include PP-IM-265(CT) and PP-IM-269 (Molecular Imaging).

GE Healthcare

Date: 11-02-2015
Quote #: PR9-C53784
Version #: 3

Item No.	Qty	Catalog No.	Description
	1		**GoldSeal CT750HD**
1	1	S9300HL	GS CT750 HD 2000MM TABLE
			GoldSeal(tm) Certified CT750HD(tm) with 2000 Table
			64 Channel Volara Digital DAS, 40mm coverage 64 Slice per rotation, 128i overlap axial reconstruction with .35 second rotation
			One year full warranty - System and Xray tube
			This product complies with NEMA Standard XR 29-2 2013
			System does not inlcude VEO or GSI
			POWER/GENERATOR * Performix(tm) HD 8Mhu Xray Tube * 100kw generator * 835Ma capacity
			SEE MORE - High Definition Image Quality * 230-micron resolution - 2 meter scan range * Variable speed scan (.4, .5, .6, .7, .8, .9, 1.0 second)
			LESS DOSE - Recon Technology * Up to 50% less dose for patients of all ages with ASiR(tm)
			WORKFLOW & ERGONOMICS Image Analysis * 3d Dose Modulation * Xtream(tm) HD Console (16fps recon & Transfer) * Direct MPR - 3 Axis reconstruction * SmartPrep Contrast Monitoring * 8460 Programmable protocols Table/Gantry * 2000mm scan-able range * In-room start * Remote Gantry Tilt * Breathing Lights with countdown timer * 500lb table weight limit Peripherals * ECG Trace on the operator console * DICOM Print, Store, and Work-list * Data Export & Interchange * Connect Pro HIS/RIS Interface * Store up to 250,000 images
			The Discovery CT750H is a head and whole body high definition CT system offering enhanced visual clarity and up to 50% dose reduction when scanning patients of all ages. Major subsystems within this HD CT scanner have been re-imagined and designed to work in harmony to improve image quality and reduce dose. The Discovery CT750HD output is a valuable medical tool for the diagnosis of disease, trauma, or abnormality and for planning, guiding and monitoring therapy.
			See More
			The Discovery CT750HD delivers unparalleled image quality enabling the visualization of greater anatomical detail, for assessment and diagnosis.
			* Up to 33% improvement in spatial resolution for body modes * Up to 47% improvement in spatial resolution for cardiac scan modes (cardiac acquisition is optional) * Accurate quantification of stenosis in coronary (optional)and vascular vessels * Up to 40% improvement is low contrast detectability for greater soft tissue

Item No.	Qty	Catalog No.	Description

visualization, allowing improved visualization of smaller low contrast structures down to 2mm in size.

Less Dose

The Discovery CT750HD innovations continue with advances in reconstruction technology resulting in dramatic dose reduction opportunities in the entire body compared to predecessor CT systems. Adaptive Statistical Iterative Recon (ASiR): provides users with innovative image reconstruction technology to reduce unwanted noise in diagnostic images, allowing users to improve image quality at up to 50% less dose.

Discovery CT750HD Technology

The revolutionary clinical advances of the Discovery CT750HD are achieved via technological leaps forward in the entire image chain including reconstruction hardware and algorithms.

The key technological advancement is GE's proprietary Gemstone(tm) Detector enabling the improvements in spatial resolution, low contrast detectability, and spectral imaging (optional).

The Gemstone detector is a garnet based CT scintillator chosen for its highly efficient optical properties. Gemstone detector sets a new standard in CT scintillator performance supporting high definition imaging and the next generation of CT imaging applications such as the spectral imaging option. This is the first new CT scintillator to be developed in the past

20 years and is designed to support high definition imaging.

* 98% efficient at 120kV * Supports higher resolution with lower noise per image * Isotropic gemstone garnet cubic structure

System components:

This whole body CT system includes a compact geometry premium gantry, table, Power Distribution Unit, high performance Xtream HD console with 2 high definition LCD's, customized keyboard and graphical user interface design for efficient workflow with one technologist.

Gantry:

GE's compact gantry design and advanced 10G baud slip ring design continuously rotates the Performix HD tube, HD generator, Gemstone Detector and Volara HD digital data acquisition around the patient. Exclusive VariSpeed allows short breath holds, more comfortable exams and the flexibility to customize protocols for unique patient needs.

Item No.	Qty	Catalog No.	Description

* Aperture: 70 cm * Rotational speeds: VariSpeed technology 360 degrees in .4,.5,.6,.7,.8,.9,1.0 Seconds * Integrated breathing lights & GE exclusive countdown timer * Integrated start scan button with countdown timer to indicate when x-ray will turn on * Tilt: +/- 30 degrees, speed: 1 degree/second * Remote tilt from operator's console

Gemstone Detector: The GE proprietary Gemstone detector enables high definition CT. Ultimately the performance of every CT system begins with the detector, and Gemstone sets a new standard in scintillator primary speed, afterglow and performance supporting the next generation of high definition CT imaging applications such as single source spectral imaging. The proprietary Gemstone scintillator is the first new detector material developed in the past 20 years.

The V-Res detector benefits are: * 98% efficient at 120kvp * Higher resolution with lower noise per image * 20 times less radiation damage of the scintillator when compared to competitive detector materials (Gadolinium Oxysulfide) * Isotropic ceramic with a cubic structure * Consistent Image Quality from the use of GE's exclusive patented detector material * Backlit diode technology provides 100% active area

Performix HD X-ray Tube:

Performix HD metal-ceramic tube unit with its unique electrostatic cathode collimator design allows the focal spot to be dynamically positioned and customized to the clinical protocol and patient. The anode heat storage capability and wide range of technique (10 ma to 835 ma, in 5 ma increments) give the technologist and physician the flexibility to tailor protocols for even the most demanding acute care without tube cooling. * Heat storage capacity: 8.0 MHU * Maximum power: 100 kW (835mA) * Small focal spot power: 570mA at 120kv,standard resolution * Small focal spot power: 420mA at 120kv, high resolution * Beam collimated to 56-degree fan angle * Heat dissipation: -Anode (Max)>2,100 KHU/min -Casing (cont) 648 KHU/min

HD High Voltage Generator:

The HD Generator is capable of switching energy at very high speed to support Gemstone Spectral Imaging. High Frequency on-board generator allows for continuous high power demands required for acute care and bariatric exams.

* 100 kW Output Power * kVp: 80, 100, 120,140 * Energy Switching Speed:up to 0.5 msec (optional) * mA: 10 to 835, in 5 mA increments Maximum mA for each kVp selection: kVp Max mA 80 700 100 800 120 835 140 715

Volara(tm) HD Digital DAS (Data Acquisition System): The Volara HD digital DAS is high-speed data,

Item No.	Qty	Catalog No.	Description

acquisition system that dramatically improves, image quality, especially spatial resolution,low dose exams, and artifact reduction. ,

* Up to 2,496 views per rotation for improvement in spatial resolution and improved image quality across the entire 50cm field of view. * 7,131Hz maximum sample rate * 58,368 available input channels * 23 bit dynamic range, 8,000,000 to 1

Integrated Laser Alignment Lights: * Defined internal and external scan planes to +/- 1 mm accuracy * Coronal light remains perpendicular to axial light as gantry tilts making visual readout easy from tableside or the operator console

Patient Table: * Cantilever design for easy patient access, and stability * Vertical range: 43 cm to 99.1 cm, scannable: 78.5 cm to 99.1 cm * Horizontal range: 2000mm * Horizontal speed: up to 137.5 mm/sec * Table automatically re-centers on scan plane with changes in vertical position * Helical pitches: 0.5:1, 0.9:1, 1.375:1 * Table capacity: 227kg(500lb) +/ 0.25mm positional accuracy

Xtream HD Workflow:

Xtream HD Workflow Platform built on the, LINUX operating system for flexibility and security, the next evolution of GE's workflow and reconstruction architecture built to help you maximize productivity and lower dose with, ASiR. The Split tabletop allows unrestricted patient viewing while supporting 2 - 19 inch color LCD monitors. Each work surface can be adjusted to accommodate a wide variety of operator preferences and site requirements.

Adaptive Statistical Iterative Recon (ASiR):

Provides the users with aninnovative image reconstruction technology to reduce unwanted noise in diagnostic images, allowing users to improve image quality at up to 50% less dose.

Xtream HD Reconstruction breaks through existing limits on speed, image quality and flexibility, to provide an optimized volumetric workflow solution from acquisition to final report.

* Delivers up to 35 full fidelity images per second (ips) reconstruction * Up to 16 ips network transfer rates * DMPR (Direct Multiplanar Reformates) enables prospective 3D review of sagittal, coronal and oblique planes automatically * Exam Split delivers the capability to split a series of patient images into separate groups for networking * Data Export and Interchange that allows you to easily share images with referring physicians and patients * Complete set of clinically proven, low dose protocols and the ability to customize your own for a total of 8,460 programmable protocols. Xtream allows you to automate or build every task into protocols to increase throughput. * Image decomposition to: -Retrospective thin images from data sets where thicker

Item No.	Qty	Catalog No.	Description
			images were initially reconstructed -Facilitates more detailed image and analysis -Improves 3D and reformat visualization * 3D Neuro filters provide image noise reduction by lowering the image noise, these filters allow for the reduction of radiation dose while maintaining the image quality
			Scan: Xtream HD workflow allows simultaneous scanning, image reconstruction, display, processing and analysis, as well as networking, archival and filming * Anatomical programmer allows quick and easy access to user programmable protocols. These are separate selector for adult and pediatric protocols * Protocols include preset scan time, kVp, mA, scan mode, image thickness and spacing, table speed, scan FOV, display FOV and center, recon algorithm, networking destination, archiving and special processing
			options like Direct MPR * AutoVoice: 3 preset (English) and 17 user defined messages automatically deliver patient breathing instructions, especially useful for multiple helical scanning * Trauma Patient mode: Allows patient scans and image display/analysis without entering patient data before scanning * Reconstruction Algorithms: Soft Tissue, Standard, Detail, Bone, Bone Plus, Lung and Edge
			OptiDose(tm) Features:
			OptiDose management features: bowtie filters optimized for whole body and pediatric exams, 3D dose modulation, Color coding for kids tracking collimator hardware and software for x-ray beam tracking, to name a few of GE's dose optimization features, All based on the ALARA principle. * 3D Dose modulation. Before the scan, clinicians can select the desired Noise/IQ: CT then tailored automatically exposure parameters, patient to patient and real-time x-y-z during each scan, resulting in up to 30 to 40% dose reduction. * Tracking collimator hardware and software for x-ray beam tracking to minimize patient dose * Filtration of the x-ray beam is optimized independently for body and head applications * DLP (dose length product)and dose efficiency display and reports during scan prescription provides patient dose information to the operator and can be saved with each exam * DICOM Dose report included with each exam
			Dynamic Z-Axis Tracking provides automatic and continuous correction of the x-ray beam position to block unused x-ray at the beginning and end of a helical scan to reduce unnecessary radiation.
			Image Networking:
			Exams can be selected and moved between the Discovery CT750HD System and any imaging system supporting the DICOM 3.0 protocol for network send, receive and pull/query. * Standard Auto-configuring Ethernet * Direct Network Connection * Supports 1GB or 10/100 BaseT * Supported Protocols -DICOM 3.0 Network -Advantage

Item No.	Qty	Catalog No.	Description

Net -InSite Point-to-Point -TCP/IP (for System Administration)

DICOM Conformance: * DICOM 3.0 Storage Service Class * Service Class User (SCU) for image send * Service Class Provider (SCP) for receive * DICOM 3.0 Query/Retrieve Service Class * DICOM 3.0 MOD Media Service Class * DICOM 3.0 Storage Commitment Class Push * DICOM 3.0 Modality Worklist (incl:Performed Procedure Step through ConnectPro option) * DICOM 3.0 Print

InSite Broadband included:

All hardware and software required to connect this CT system to GE's InSite On-Line Center via secure VPN high-speed internet connection. Enables customer to access services designed to reduce downtime, improve quality, enhance performance, increase productivity, and expand imaging capabilities, and increased privacy and security of data transmissions.

Enter the world of HD CT with the world's first High Definition CT scanner, the GE Discovery CT750HD.

Regulatory Compliance:

This product is designed to comply with applicable standards under the Radiation Control for Health and Safety Act of 1968.

Laser alignment devices contained within this product are appropriately labeled according to the requirements of the Center for Devices and Radiological Health. Siting Considerations: See the Pre-Installation manual for details of the siting requirements for GE Discovery CT750HD.

This product is a CT-compliant device, which satisfies regulations regarding Electro Magnetic Compatibility (EMC) and Electro Magnetic Interference (EMI), pursuant to IEC 601.

For US and Canadian Customers, this quotation includes access to the DoseWatch Explore application for a period of time concurrent with the system warranty. DoseWatch Explore is an introductory dose management software application that provides you secure access, via any PC with internet access, to dose and protocol data from this system. An InSite connection to the system and completion of the registration process is required to use the DoseWatch Explore application.

WARRANTY

The published company warranty in effect on the date of shipment shall apply. The Company reserves the right to make changes. All specifications are subject to change.

SITING CONSIDERATIONS

See the Pre-Installation manual for details of the siting requirements for this product.

Item No.	Qty	Catalog No.	Description
			AVAILABILITY Since GoldSeal Pre-owned Equipment may be offered simultaneously to several customers, its sale to you is subject to availability and subject to prior sale at the time you offer to purchase it.If the equipment is no longer available, (1) We will attempt to identify other GoldSeal Pre-owned Equipment in our inventory that meets your needs, and (2) if substitute equipment is not acceptable to you, we will cancel your order and refund any deposit you have paid us for the canceled order.
2	1	B7877EB	Global Console upgrade kit with new Smart Technologies The console upgrade package provides the latest advancements of GE hardware and new smart technologies in GE software performance available for the Discovery CT750 HD CT Scanners. New software features include GSI Assist, KV Assist, Low keV, Organ Dose Modulation, High Helical Pitch-1.531, mA Profile, Image Check, Priority Recon, Dynamic Transition, Temporal Enhance for GSI Cardiac, Uncapped Cardiac Helical Pitch, Veo User Selectable PResets. The hardware includes GOC6.6 console, Peripheral collector, GSCB, Trackball and updated monitors.
3	1	B7877MY	GemStone Spectral Imaging Option Gemstone Spectral Imaging is an innovative dual energy scan mode that uses two nearly simultaneous scans at two different energy levels to generate material characterization information. The LightSpeed CT750 HD Performix HD tube and HD generator are capable of switching energy at very high speeds. By acquiring this multiple energy scan data, patient data with different attenuation values corresponding to the energy levels is generated. These scan data are utilized to help identify material-specific defferences in attenuation in terms of Water & Iodine, Water & Calcium, and Iodine & Calcium basis-pair images, allowing mono-chromatic image representations via the Gemstone Spectral Imaging viewer. Gemstone Spectral Imaging option enables the LightSpeed CT750 HD system to switch the kV from high to low at a very fast switching rate of up to 4.8kHz and utilizes the fast response of the GE Gemstone Detector to capture the spectral imaging data sets that are registered to within micro-seconds. This fast switching reduces the registration artifacts generated by some dual energy methods. Gemstone Spectral Imaging has the following image quality benefits and capabilities: o registers energies more than 165 times faster than a dual source CT system at 0.35 second rotation speed. o generates derived images over a 50cm SFOV for the seperation of materials such as calcium, iodine and water. o provides derived monochromatic spectral images at 101 user selectable energy levels for image contrast optimization. o reduces beam hardening artifacts due to bone, metal, and other high contrast material (example: iodine) up to 50% o can detect iodine concentrations as low as

Item No.	Qty	Catalog No.	Description
			0.5% in density The LightSpeed CT750 HD system with Gemstone Spectral Imaging can acquire CT images using kV levels of the same anatomical region of a patient in a single rotation from a single source. The differences in the energy dependence of the attenuation coefficient of the different materials provide information about the chemical composition of body materials. This approach enables images to be generated at energies selected from the available spectrum to visualize and analyze information about anatomical and pathological structures.
4	1	B7870JA	Volume Viewer On Operator Console AW VA2, VR2 & Nav2 for the Operator Console includes Volume Analysis, Volume Rendering and Navigator Software. This Combination Allows the User to Render Volumetric Data in Three Dimensions for Use in Analysis of Patient Condition i.e.CT Angiography (CTA), gives more Information on the Spatial Relationships of Structures than Standard 3D, Allows the Translucent Visualization of Structures for Improved Problem Solving, can Perform "Virtual Endoscopies" of Air and Contrast Filled Structures. Enables 3D Reformats in any Plane ALL on the Xtream ready Console.
5	1	B7870JC	Advanced Vessel Analysis Xpress on Operator Console CT AVA is a Highly Automated Software Post-Processing Package for the CT Operator's Console. It is an Additional Tool for the Analysis of 3D Angiography Data Providing a Number of Display, Measurement and Batch Filming/Archive Features to Study User-Selected Vessels Which Include Stenosis Analysis; Pre/Post Stent Planning Procedures and Directional Vessel Tortuosity Visualization. Clinical Benefits This Package Provides Enhanced Analysis of Vascular Features. • Decreased Operator Dependence: Currently There is Heavy Operator Dependence to Produce True Vessel Cross Sections and Vessel Profiles. This Software Eliminates the Need for the Operator to Manually Identify the Center of the Vessel. Automated Batch Filming and the Ability to Rotate Around a Vessel, Reduces the Risk of Overlooking Vascular Structures. • Quick AVA - Two click vessel analysis • Measurement Tools: Quantitative Information on User-Selected Vessel Segments, Aids in the Proper Selection of Prosthesis. Distances to Bifurcations or Other Landmarks are Critical for Clinical Decisions. • Increased Value of Reports: A Single Report Provides a Complete 3D Context;

Item No.	Qty	Catalog No.	Description
			Measurements Cross-References and 3D Views. Consistency in the Format and Style of the Reports Also Help Referring Physicians. Productivity Benefits • Decreased Time to First Clinically Relevant Image: Automatic Centerline Detection Provides a Quick 3D Value Understanding of a Selected Vessel. The Anatomy Becomes Visible Once Two Points Identifying the Section of Interest Have Been Defined. • Background Auto-Filming: Replaces Manual Filming. System Requirements • Volume Viewer 3.1 (B7870JA) All Software Purchases are Non-transferable to Other Hardware and are Non-returnable.
6	1	B7870JD	AutoBone Xpress on Operator Console AutoBone is an exclusive image analysis software package that facilitates segmentation of bony structures from ABDOMINAL and LOWER EXTREMITY CT Angiography data. AutoBone Clinical Benefits: • One-click segmentation of bony structures. • Facilitates vessel feature visualization. Operator Productivity Benefits Include: • Decreased time to first clinically relevant image. • Identification and segmentation of bony structures providing a quick 3D MIP overview of vascular structures. • AutoSelect segmentation tools may be used to refine segmentation by quickly adding or removing data to achieve desired results. • The resulting VR image can be manipulated to view vessels only, or transparent bone can be restored for landmarks. Pre-requisite: Volume Viewer (B7870JA)
7	1	B7877NA	128i Axial Reconstruction Option 128i provides 128, 0.625mm images, per axial rotation allowing increased image-space sampling and enables improved visualization of small objects.
8	1	E4502F	14 KVA 3-Phase Partial UPS for VCT

Item No.	Qty	Catalog No.	Description
			The 14KVA Partial UPS has been specifically designed to coordinate with GE Healthcare CT & PET/CT scanners. In the event of a power outage a partial system UPS provides continuous backup power to the scanner host and control computers, thus assuring no loss of usable scan data. • Critical circuits in the gantry and table remain powered which facilitate the safe removal of the patient from the scanner. • If power is restored within the battery hold-up time, the operator can continue scanner operations without the need to reboot the system. • When longer power outages are anticipated, the UPS provides time for the operator to safely remove the patient and complete an orderly shutdown of the system software • Maintains system electronics and allows critical scanner operations to continue for 10 minutes (typical) after loss of power • Protects electronics from under voltage, brownouts, line sags, over voltage and transients SPECIFICATIONS • Dimensions (H x W x D): 49" x 12" x 32" • Weight: 620 lbs. • Output Frequency: 50 or 60 Hz, auto-sensing NOTE: ITEM IS NON-RETURNABLE AND NON-REFUNDABLE
9	1.	E4502AE	125A Main Disconnect Panel (US) The 125 Amp CT System Main Disconnect Panel (MDP) serves as the main facility power disconnect source installed ahead of the system PDU. The MDP will disconnect system power on first loss of incoming power, helping to prevent damage to system components. It also includes an automatic restart control circuit which restores power to the CT System PDU after a power outage. • Can reduce installation time and cost by eliminating delays in obtaining individually enclosed components and on site assembly (ex: main circuit breaker, feeder overcurrent devices, magnetic contactors and UPS emergency power off are combined into a single panel • Configuration flexibility - can be used as a stand-alone main disconnect or with the optional partial system UPS. (On systems where the optional partial system UPS is used the main disconnect panel also provides NEC mandated emergency power off control to both the PDU and UPS • Designed and tested for GEHC CT products

Item No.	Qty	Catalog No.	Description
			SPECIFICATIONS • Automatic restart incorporates an adjustable time delay to delay main power until the power has stabilized for 5 seconds • One flush wall mounted remote emergency off pushbutton furnished with each system • UL, cUL and CE labeled
10	1	E8007PP	Medrad CT Stellant D w/ Dual Flow - Medium Post 85 cm Medrad CT Stellant D w/ Dual Flow - Medium Post 85 cm
11	1	E8007PJ	OCS III MOUNTING PLATE OCS III MOUNTING PLATE
12	1	E8016AN	CT Table Slicker with Cushion - 2000 Systems (2-pc Set) CT Table Slicker with Cushion - 2000 Systems (2 Piece Set) FEATURES/BENEFITS • Two-piece, sealed slicker cushion set has comfort pads enclosed inside the slicker cover and extender cover • Durable, clear PVC plastic cover facilitates faster, more thorough cleanup of blood and fluids • Increase system uptime by protecting table from spills and particulate contaminants • Thermo-sealed seams and flaps prevent contaminate buildup in hard to clean areas COMPATIBILITY • VCT with GT 2000 Table, CT HD750
13	1	E8016BA	CT Footswitch Slicker - 2000 & 1700 Systems CT Footswitch Slicker - 2000 & 1700 Systems The footswitch slicker for CT VCT 2000 and 1700 systems is made of durable, clear PVC plastic that protects the footswitch and facilitates faster, more thorough cleanup of contamination caused by blood and other body fluids. Cover is held securely in place with Velcro...H
14	1	E8004FP	CT Global Table 2000 Table Pad

Item No.	Qty	Catalog No.	Description
			CT Global Table 2000 Table Pad
15	1	E8004GE	CT Straps, Medium (2) 540mm, 1060mm CT Straps, Medium (2) 540mm, 1060mm 1 side measures 21.25 in (540mm), other side measures 41.73 in (1060mm). Both straps with Velcro. Warranty Code: H
16	1	W0107CT	TiP Applications CT Succeed Advance TiP Applications CT Succeed Advance TiP Applications CT Succeed Advance training includes: • 14 onsite days covered over 5 site visits • 4 hrs TVA, 1hr per week • 1 TiP Headquarter Class Onsite training and TVA are delivered Monday through Friday between 8AM and 5PM. T&L expenses are included. Headquarters classes are delivered in the Milwaukee area and include travel and modest living expenses. This training program must be scheduled and completed within 24 months after the date of product delivery.
17	1	W0004CT	4 Days Ct Onsite 4 Days CT TiP Onsite Training Four Days CT Onsite Training provided from 8AM to 5PM, Monday through Friday. Includes T&L expenses. Days provided consecutively. This training program must be scheduled and completed within 12 months after the date of product delivery.
18	1	W0600CT	2 Days TiP Onsite Training Advantage Windows Workstation--CT 2 Days TiP Onsite Training Advantage Windows Workstation--CT One 2 day TiP onsite visit for CT Advantage Windows Workstation training. Includes T&L expenses. Days provided consecutively. This training program must be scheduled and completed within 12 months after the date of product delivery.
	1		**AW VOLUMESHARE 7**
19	1	M81561KB	AW VS7 HARDWARE UPGRADE AW Hardware Upgrade to VolumeShare 7 with Two Flat Panel Monitors and 32GB of RAM. All applicable existing licenses will be transferred at system install.

Item No.	Qty	Catalog No.	Description

NOTE: The AW Workstation that is to be Upgraded with this purchase becomes the Property of GE Healthcare. Upon Installation Of the New AW Workstation, the current AW Unit must be De-Installed and Returned To GE Healthcare.

NOTE: A Signed Trade-in Addendum Required Upon Order.

AW VolumeShare 7 is a multi-modality image review, comparison and post processing workstation built with simplicity and power at its core. Powerful software is optimized to take advantage of state of the art 64 bit technology and multiple cores to ensure leading edge performance.

AW VolumeShare 7 features include:

Hardware:

- HP Z820 Workstation
- CPU: 2x Intel Xeon E5-2630 Six Core 2.6 GHz CPUs with 15MB Shared L3 Cache each and 1866 MHz Dual Front Side Bus
- RAM: 32GB (8x4GB) DDR3 1866 MHz ECC DIMM
- NVIDIA Quadro NVS 310, 512MB Graphics card
- 1x 300GB SAS 10k rpm Hard Disk for OS and Apps
- 2x 300GB SAS 10k rpm Hard Disks for Data
- 2 x 19" 1280x1024 color monitors

Software:

- GE Healthcare HELiOS 6 operating system
- Volume Viewer for advanced post-processing
- Demo Exams for training and exploration
- Fast access to information you need through optional RIS integration & priors post-fetch
- Efficient workflow through dynamic load, end review and Key Image Notes features
- Productivity package to pre-process exams and allow up to 8 simultaneous sessions
- Applications usage monitor to track and view usage of your system
- Smart layouts with Volume Viewer General review protocol that optimizes comparison and single exam layouts
- Enhanced multi-modality contouring tool with support for PET SUVs
- Support for external DICOM USB media and preference management tool to exchange preferences across users

Item No.	Qty	Catalog No.	Description
			• Support for optional, broad suite of multi-modality advanced applications
20	1	M81501RS	AW 4.6 24GB RAM Capacity AW VolumeShare 5 (z800) RAM capacity Upgrade Kit Increasing RAM is important to support processing of larger volumes of data generated with sophisticated post processing applications, larger average slice counts or multi-dimensional modalities such as MR and GSI.
21	1	B79021GE	GSI VIEWER The GSI Viewer is the application tool for viewing and manipulating spectral images acquired with GE's Gemstone Spectral Imaging capability on Discovery CT750 HD. Key features include: • Protocol Driven Design - This feature provides a standard set of protocols with the additional ability for users to create and save their own protocols. • Monochromatic Image Review - With this feature the user has the ability to interactively change the monochromatic energy levels so that the user can select the best energy level for the exam being reviewed. • Image Overlay - The viewer provides a simple way for the user to move from review to analysis by overlaying material density, and effective atomic number (effective-Z) information on top of the monochromatic images. • Material Density Analysis - Users can visually see how the GSI data is segregated amongst a material density pair, e.g. water and iodine. • Plot Analysis - This feature displays ROI's as graphical plits in the form of a histogram, a scatter plot, spectral HU curve and an optimal CNR (contrast to noise) plot. Benefits are: • Material Decomposed images allow for the seperation of materials like calcium, iodine, and water. • Visualize a virtual non-contrast like image using water-iodine basis pair image. • Adjusting monochromatic energy levels can optimize image contrast and reduce beam-hardening artifacts. • Discriminate different tissue types based on material density and monochromatic image data. System Requirements: • AW VolumeShare 7 • 24GB RAM • Two monitor/flat panel configuration recommended

GE Healthcare

Date: 11-02-2015
Quote #: PR9-C53784
Version #: 3

Item No.	Qty	Catalog No.	Description

Note: All software are Non-Transferable to other hardware and are Non-Returnable.

Quote Summary:

Total Quote Net Selling Price **$454,313.98**

(Quoted prices do not reflect state and local taxes if applicable. Total Net Selling Price Includes Trade In allowance, if applicable.)

GE Healthcare

These GE Healthcare General Terms and Conditions supplement and incorporate by reference the GE Healthcare Quotation that identifies the Product and/or Service offering purchased or licensed by Customer and the following documents, as applicable, if attached to or referenced in the Quotation: the GE Healthcare (i) Warranty(ies); (ii) Additional Terms and Conditions or Statement of Service Deliverables and Product Schedule; and (iii) Product or Service Terms and Conditions, (collectively, referred to as the "Agreement").

References herein to "Products" and "Services" mean the Products (including equipment and software) and Services identified on the applicable GE Healthcare Quotation. References herein to "Healthcare IT Products" are (i) those software products identified in the Quotation as a "Centricity" product, any third party software licensed for use in connection with the Centricity software, all hardware used to operate the Centricity or the third party software, and services provided with respect to the implementation, installation or support and maintenance of the Centricity or the third party software, and/or (ii) any software, product or service that is included in a Quotation which Quotation is designated as an "Healthcare IT Quotation".

1. General Terms.

1.1. Confidentiality. Each party will treat the terms of this Agreement and the other party's written, proprietary business information as confidential if marked as confidential or proprietary. Customer will treat GE Healthcare's (and GE Healthcare's third party vendors') software and technical information as confidential information whether or not marked as confidential and shall not use or disclose to any third parties any such confidential information except as specifically permitted in this Agreement or as required by law (with reasonable prior notice to GE Healthcare) or as is required by the U.S. Federal government in its capacity as a customer. The receiving party shall have no obligation with respect to any information which (i) is or becomes within the public domain through no act of the receiving party in breach of this Agreement, (ii) was in the possession of the receiving party prior to its disclosure or transfer and the receiving party can so prove, (iii) is independently developed by the receiving party and the receiving party can so prove, or (iv) is received from another source without any restriction on use or disclosure. GE Healthcare understands that Customer may be subject to State Open Records laws. Customer shall not be prohibited from complying with such Open Records laws if required to do so; however, Customer shall (a) promptly notify GE Healthcare in writing of any such Open Records laws requests, (b) give GE Healthcare sufficient time to challenge the request or redact any necessary information to the extent permitted by law, and (c) only provide such information as is necessary to comply with such Open Records laws.

1.2. Governing Law. The law of the State where the Product is installed or the Service is provided will govern this Agreement.

1.3. Force Majeure. Neither party is liable for delays or failures in performance (other than payment obligations) under this Agreement due to a cause beyond its reasonable control. In the event of such delay, the time for performance shall be extended as reasonably necessary to enable performance.

1.4. Assignment; Use of Subcontractors. Neither party may assign any of its rights or obligations under this Agreement without the prior written consent of the other party, which consent shall not be unreasonably withheld; provided, however, that either party may transfer and assign this Agreement without the other party's consent to any person or entity (except to a GE Healthcare competitor) that is an affiliate of such party or that acquires substantially all of the stock or assets of such party's applicable business if any such assignee agrees, in writing, to be bound by the terms of this Agreement, including the payment of any existing or outstanding fees and invoices. Subject to such limitation, this Agreement shall be binding upon and inure to the benefit of the parties and their respective successors and permitted assigns. This Agreement shall not be terminable in the event of any Customer stock or asset sale, merger, acquisition or change in control, unless otherwise expressly agreed to in writing by GE Healthcare. GE Healthcare may hire subcontractors to perform work under this Agreement (including, but not limited to, work that involves access to Protected Health Information as such term is defined in 45 C.F.R. § 160.103 ("PHI")), provided that GE Healthcare will at all times remain responsible for the performance of its obligations and duties under this Agreement.

1.5. Amendment; Waiver; Survival. This Agreement may be amended only in writing signed by both parties. Any failure to enforce any provision of this Agreement is not a waiver of that provision or of either party's right to later enforce each and every provision. The terms of this Agreement that by their nature are intended to survive its expiration (such as the confidentiality provisions included herein) will continue in full force and effect after its expiration.

1.6. Termination. If either party materially breaches this Agreement and the other party seeks to terminate this Agreement for such breach, such other party shall notify the breaching party in writing, setting out the breach, and the breaching party will have sixty (60) days following receipt of such notice to remedy the breach. If the breaching party fails to remedy the breach during that period, the other party may terminate this Agreement by written notice to the breaching party. If GE Healthcare determines in good faith at any time that there are material credit issues, with this Agreement, then GE Healthcare may terminate this Agreement (including warranty services hereunder) immediately upon written notice to Customer. For the avoidance of doubt, this Agreement is not terminable for convenience and may only be terminated in accordance with this Agreement.

1.7. Entire Agreement and Waiver of Reliance. This Agreement constitutes the complete and final agreement of the parties relating to the Products and/or Services identified in the Quotation. The parties agree that they have not relied, and are not relying, on any oral or written promises, terms, conditions, representations or warranties, express or implied, outside those expressly stated or incorporated by reference in this Agreement. No agreement or understanding, oral or written, in any way purporting to modify this Agreement, whether contained in Customer's purchase order or shipping release forms, or elsewhere, shall be binding unless hereafter agreed to in writing and signed by authorized representatives of both parties. Each party objects to any terms inconsistent with this Agreement proposed by either party unless

agreed to in writing and signed by authorized representatives of both parties, and neither the subsequent lack of objection to any such terms, nor the delivery of the Products and/or Services, shall constitute an agreement by either party to any such terms. The parties agree that any provision in this Agreement in 'all caps' type satisfies any requirements at law or in equity that provisions be conspicuously marked.

2. Compliance.

2.1. Generally. Each party will comply with the requirements of Federal and State laws and regulations that are applicable to such party. This Agreement is subject to GE Healthcare's on-going determination that Customer and this Agreement comply with all applicable laws and regulations, including those relating to workplace safety, FDA matters, Federal Healthcare Program Anti-kickback compliance, export/import control and money laundering prevention. CUSTOMER ACKNOWLEDGES THAT THE PRODUCTS ARE OR MAY BE SUBJECT TO REGULATION BY THE FDA AND OTHER FEDERAL OR STATE AGENCIES. CUSTOMER SHALL NOT USE OR PERMIT THE PRODUCTS TO BE USED IN ANY MANNER THAT DOES NOT COMPLY WITH APPLICABLE FDA OR OTHER REGULATIONS OR FOR ANY NON-MEDICAL, ENTERTAINMENT, OR AMUSEMENT PURPOSES. Customer shall not use or permit the Product to be used or operated by any person who does not have sufficient knowledge to competently perform the required task and who is not fully trained on the operation of the Product. Customer is solely responsible for ensuring that Customer and its employees, licensed and unlicensed healthcare staff, representatives, agents and/or contractors who operate, maintain and/or have access to the Products and/or Services, excluding GE Healthcare employees, representatives, agents and/or contractors ("Customer Personnel") are properly trained and fully competent on the operation of the Product. Further, Customer represents that it is purchasing the Products for its own use consistent with the terms of this Agreement and that it does not intend to re-sell the Products to any other party or to export the Products outside the country to which GE Healthcare delivers the Products.

2.2. Cost Reporting. Customer represents and warrants that it shall comply with (a) the applicable requirements of the Discount Statutory Exception, 42 U.S.C. 1320a-7b(b)(3)(A), and the Discount Safe Harbor, 42 C.F.R. § 1001.952(h), with respect to any discounts Customer may receive under this Agreement and (b) the Warranties Safe Harbor, 42 C.F.R. § 1001.952(g), with respect to any price reductions of an item (including a free item) which were obtained as part of a warranty under this Agreement. Customer agrees that, if Customer is required to report its costs on a cost report, then (i) the discount must be based on purchases of the same good bought within a fiscal year; (ii) Customer must claim the benefit in the fiscal year in which the discount is earned or in the following year; (iii) Customer must fully and accurately report the discount in the applicable cost report; and (iv) Customer must provide, upon request, certain information required to be provided to Customer by GE Healthcare as a seller or offeror, as appropriate. If Customer is an individual or entity in whose name a claim or request for payment is submitted for the discounted items, the discount must be made at the time of the sale of the good; and Customer must provide, upon request, certain information required to be provided to Customer by GE Healthcare as a seller or offeror, as appropriate. GE Healthcare agrees to comply with the applicable requirements for sellers or offerors under the Discount Safe Harbor, as appropriate.

2.3. Network Security and Site Access Control. Customer shall be solely responsible for establishing and maintaining network security, virus protection, backup and disaster recovery plans for any data, images, software or equipment. GE Healthcare shall not be responsible for any recovery of lost data or images. Customer shall comply with all applicable laws and regulations related to site access control.

2.4. Environmental Health and Safety. GE Healthcare shall have no obligation to provide Products and/or perform Services until Customer (i) provides and maintains a suitable, safe and hazard-free location and environment for the GE Healthcare Products and personnel performing Services in material compliance with all applicable Federal, State, and local requirements, as well as any written requirements provided by GE Healthcare; (ii) performs GE Healthcare recommended routine maintenance and operator adjustments on the Product; and (iii) ensures that any service not provided by GE Healthcare is performed, and GE Healthcare Products are used, in accordance with applicable user documentation.

Customer shall provide written information to GE Healthcare personnel who will be present on Customer's site about Customer's safety procedures and practices as well as a list of any hazardous materials, such as asbestos, lead or mercury, on or near Customer's site that GE Healthcare personnel may come in contact with and any associated Safety Data Sheets. Customer shall be responsible for taking all necessary actions to properly abate, remove and/or remediate any hazardous conditions or materials, including removing blood, body fluids and other potentially infectious materials. GE Healthcare shall have no responsibility to abate, or liability for, any existing hazardous conditions at Customer site. Customer shall be responsible for proper management, storage and disposal of all service and/or installation-related waste, unless GE Healthcare is legally required to take back the materials (e.g., batteries, WEEE, packaging).

2.5. Parts Not Supplied By GE Healthcare. GE Healthcare recommends the use of parts that it has (i) validated through configuration and (ii) received from authorized suppliers. GE Healthcare is not responsible for the quality of parts supplied by third parties to Customer. GE Healthcare cannot assure Product functionality or performance when non-GE Healthcare parts are used on the Product.

2.6. Training. Any Product training identified in the Quotation shall be in accordance with GE Healthcare's then-current training offerings and terms. Customer agrees that completion of GE Healthcare's training offerings does not guarantee that Customer and Customer Personnel are fully and completely trained on the use, maintenance, and operation of the Product or that completion of GE Healthcare's training will satisfy any licensure and/or accreditation standards. Customer further agrees that it is Customer's sole and non-delegable duty to ensure that Customer and Customer Personnel are properly trained on and fully qualified in the use and operation of the Product. Unless otherwise stated in the training catalog description, training must be completed by Customer within twelve (12) months after (i) the date of Product delivery for training purchased with Products; (ii) the start date for Services for training purchased with Services; or (iii) the date Customer purchases training if such training is not purchased with Products and/or Services. If training is not completed within the applicable time period due to no fault of GE Healthcare, GE Healthcare's obligation to provide the training will expire without refund.

2.7. Medical Diagnosis and Treatment. All clinical and medical treatment and/or diagnostic decisions are the sole responsibility of Customer and Customer Personnel. Customer agrees that GE Healthcare is in no way responsible for the clinical and medical treatment and/or diagnostic decisions made by Customer and Customer Personnel.

2.8. Use of Data.

(a) Protected Health Information. To the extent GE Healthcare creates, receives, maintains, transmits or otherwise has access to any PHI in the course of performing under this Agreement, GE Healthcare shall only use and disclose such PHI as permitted by the administrative simplification section of the Health Insurance Portability and Accountability Act of 1996, Pub. Law 104-191 (August 21, 1996), its implementing regulations, and the Health Information Technology for Economic and Clinical Health ("HITECH") Act and its implementing regulations (collectively, "HIPAA"), and the applicable Business Associate Agreement between the Parties.

(b) Other Information. Customer agrees that GE Healthcare may also create, receive, maintain, transmit and otherwise have access to machine, technical, system, usage and related information that is not PHI, including, but not limited to, information about Customer's Product, Service, system and software, that is gathered periodically to facilitate the provision of Product support, consulting, training and other services to Customer (if any), and to verify compliance with the terms of this Agreement. GE Healthcare or its agents may use such information to provide, develop or improve GE Healthcare's products or services.

2.9. Compliance with Customer Policies. GE Healthcare will use commercially reasonable efforts to respect Customer policies to the extent that such policies apply to GE Healthcare under this Agreement, and do not materially contradict GE Healthcare policies, provided that Customer furnishes to GE Healthcare a complete copy of said policies prior to GE Healthcare's commencement of performance under this Agreement. Under no circumstances, however, will GE Healthcare's failure, or the failure of GE Healthcare's employees or contractors, to respect Customer policies constitute a material breach by GE Healthcare under this Agreement, unless such failure is willful and materially and adversely affects GE Healthcare's ability to perform its obligations under this Agreement.

2.10. Insurance. GE Healthcare shall maintain insurance coverage in accordance with its standard certificate of insurance, a copy of which is available upon Customer's request.

2.11. Excluded Provider. GE Healthcare represents that, to its knowledge, neither it nor its employees performing services under this Agreement have been excluded from participation in any Federal Healthcare Program. In the event an employee performing services under this Agreement is excluded, GE Healthcare will replace such employee within a commercially reasonable time. In the event GE Healthcare is excluded, Customer may terminate this Agreement upon written notice to GE Healthcare.

3. Disputes; Liability; and Indemnity.

3.1. Waiver of Jury Trial. UNLESS OTHERWISE EXPRESSLY PROHIBITED BY APPLICABLE LAW, EACH PARTY EXPRESSLY WAIVES ALL RIGHTS TO A JURY TRIAL IN CONNECTION WITH ANY DISPUTE ARISING UNDER THIS AGREEMENT.

3.2. Limitation of Liability. GE HEALTHCARE'S ENTIRE LIABILITY AND CUSTOMER'S EXCLUSIVE REMEDY FOR ANY DIRECT DAMAGES INCURRED BY CUSTOMER FROM ANY CAUSE, REGARDLESS OF THE FORM OF ACTION, WHETHER IN AN ACTION IN CONTRACT, TORT, PRODUCT LIABILITY, STATUTE, EQUITY OR OTHERWISE, ARISING UNDER THIS AGREEMENT OR RELATED HERETO, SHALL NOT EXCEED: (A) FOR PRODUCTS OR SERVICES, OTHER THAN SERVICES UNDER AN ANNUAL SERVICE CONTRACT, THE PRICE FOR THE PRODUCT OR SERVICE THAT IS THE BASIS FOR THE CLAIM; OR (B) FOR ANNUAL SERVICE CONTRACTS, THE ANNUAL CONTRACT PRICE FOR THE SERVICE THAT IS THE BASIS FOR THE CLAIM. THE FOREGOING LIMITATION OF LIABILITY SHALL NOT APPLY TO GE HEALTHCARE'S DUTIES TO INDEMNIFY CUSTOMER IN ACCORDANCE WITH THIS AGREEMENT. THE LIMITATION OF LIABILITY SHALL APPLY EVEN IF THE LIMITED REMEDIES FAIL OF THEIR ESSENTIAL PURPOSE.

3.3. Exclusion of Damages. NEITHER PARTY SHALL BE LIABLE TO THE OTHER PARTY UNDER THIS AGREEMENT (OR OTHERWISE IN CONNECTION WITH THE PRODUCTS AND SERVICES) FOR ANY INDIRECT, SPECIAL, PUNITIVE, INCIDENTAL OR CONSEQUENTIAL DAMAGES, OR FOR LOSS OF PROFITS, REVENUE, TIME, OPPORTUNITY OR DATA, WHETHER IN AN ACTION IN CONTRACT, TORT, PRODUCT LIABILITY, STATUTE, EQUITY OR OTHERWISE. THE EXCLUSION OF DAMAGES SHALL APPLY EVEN IF THE LIMITED REMEDIES FAIL OF THEIR ESSENTIAL PURPOSE.

3.4. IP Indemnification. GE HEALTHCARE WILL DEFEND, INDEMNIFY AND HOLD HARMLESS CUSTOMER FROM ANY THIRD PARTY CLAIMS FOR INFRINGEMENT OF UNITED STATES INTELLECTUAL PROPERTY RIGHTS ARISING FROM CUSTOMER'S USE OF GE HEALTHCARE MANUFACTURED EQUIPMENT AND/OR GE HEALTHCARE PROPRIETARY SOFTWARE LISTED IN THE QUOTATION (COLLECTIVELY, "INFRINGING PRODUCT") IN ACCORDANCE WITH THEIR SPECIFICATIONS AND WITHIN THE LICENSE SCOPE GRANTED IN THIS AGREEMENT. IF ANY SUCH CLAIM MATERIALLY INTERFERES WITH CUSTOMER'S USE OF SUCH EQUIPMENT AND/OR SOFTWARE, GE HEALTHCARE SHALL, AT ITS OPTION: (I) SUBSTITUTE FUNCTIONALLY EQUIVALENT NON-INFRINGING PRODUCTS; (II) MODIFY THE INFRINGING PRODUCT SO THAT IT NO LONGER INFRINGES BUT REMAINS FUNCTIONALLY EQUIVALENT; (III) OBTAIN FOR CUSTOMER AT GE HEALTHCARE'S EXPENSE THE RIGHT TO CONTINUE TO USE THE INFRINGING PRODUCT; OR (IV) IF THE FOREGOING ARE NOT COMMERCIALLY REASONABLE, REFUND TO CUSTOMER THE PURCHASE PRICE, AS DEPRECIATED (BASED ON FIVE (5) YEAR STRAIGHT-LINE DEPRECIATION), FOR THE INFRINGING PRODUCT. ANY SUCH CLAIMS ARISING FROM CUSTOMER'S USE OF SUCH INFRINGING PRODUCT AFTER GE HEALTHCARE HAS NOTIFIED CUSTOMER TO DISCONTINUE USE OF SUCH INFRINGING PRODUCT AND OFFERED ONE OF THE REMEDIES SET FORTH IN CLAUSES (I) THROUGH (IV) ABOVE ARE THE SOLE RESPONSIBILITY OF CUSTOMER. THIS SECTION REPRESENTS CUSTOMER'S SOLE AND EXCLUSIVE REMEDY (AND GE HEALTHCARE'S SOLE AND EXCLUSIVE LIABILITY) REGARDING ANY INFRINGEMENT CLAIM ASSOCIATED WITH SUCH INFRINGING PRODUCT. THE ABOVE INDEMNIFICATION OBLIGATION IS CONDITIONAL UPON CUSTOMER PROVIDING GE HEALTHCARE PROMPT WRITTEN NOTICE OF THE INFRINGEMENT CLAIM AFTER RECEIVING NOTICE OF SUCH CLAIM, ALLOWING GE HEALTHCARE TO CONTROL THE DEFENSE OF SUCH CLAIM, AND REASONABLY COOPERATING WITH GE HEALTHCARE IN SUCH DEFENSE. GE HEALTHCARE'S RIGHT TO CONTROL THE DEFENSE AND DISPOSITION OF THE INFRINGEMENT CLAIM SHALL INCLUDE THE RIGHT TO SELECT COUNSEL TO REPRESENT CUSTOMER AT GE HEALTHCARE'S EXPENSE; PROVIDED, HOWEVER, THAT CUSTOMER MAY RETAIN ADDITIONAL COUNSEL AT CUSTOMER'S EXPENSE. ANY EXPENSES, INCLUDING LEGAL FEES AND COSTS, INCURRED BY CUSTOMER PRIOR TO TENDERING CONTROL OF THE DEFENSE TO GE HEALTHCARE SHALL NOT BE REIMBURSABLE BY GE HEALTHCARE. NOTWITHSTANDING ANY OTHER PROVISION IN THIS AGREEMENT, GE HEALTHCARE SHALL NOT HAVE ANY OBLIGATION TO CUSTOMER HEREUNDER FOR INFRINGEMENT CLAIMS BASED ON OR RESULTING FROM: (A) USE OF SUCH INFRINGING PRODUCT IN COMBINATION WITH ANY COMPUTER SOFTWARE, TOOLS, HARDWARE, EQUIPMENT, MATERIALS, OR SERVICES, NOT FURNISHED OR AUTHORIZED IN WRITING FOR USE BY GE HEALTHCARE; (B) USE OF SUCH INFRINGING PRODUCT IN A MANNER OR ENVIRONMENT OR FOR ANY PURPOSE FOR WHICH GE HEALTHCARE DID NOT DESIGN OR LICENSE IT, OR IN VIOLATION OF GE HEALTHCARE'S USE INSTRUCTIONS; OR (C) ANY MODIFICATION OF SUCH INFRINGING PRODUCT BY CUSTOMER OR ANY THIRD PARTY. GE HEALTHCARE SHALL NOT BE RESPONSIBLE FOR ANY COMPROMISE OR SETTLEMENT OR

CLAIM MADE BY CUSTOMER WITHOUT GE HEALTHCARE'S WRITTEN CONSENT. THIS INDEMNIFICATION OBLIGATION IS EXPRESSLY LIMITED TO THE GE HEALTHCARE MANUFACTURED EQUIPMENT AND/OR GE HEALTHCARE PROPRIETARY SOFTWARE LISTED IN THE QUOTATION.

3.5. General Indemnification. GE HEALTHCARE AGREES TO RELEASE, INDEMNIFY AND HOLD CUSTOMER HARMLESS FOR ANY THIRD PARTY DAMAGES CUSTOMER BECOMES LEGALLY OBLIGATED TO PAY RELATED TO BODILY INJURY OR DAMAGE TO REAL PROPERTY OR TANGIBLE PERSONAL PROPERTY TO THE EXTENT THAT SUCH DAMAGES ARE DETERMINED TO BE PROXIMATELY CAUSED BY A MANUFACTURING DEFECT, DESIGN DEFECT, NEGLIGENT FAILURE TO WARN, NEGLIGENT INSTALLATION, OR NEGLIGENT SERVICE WITH RESPECT TO PRODUCTS DESIGNED AND MANUFACTURED BY GE HEALTHCARE AND SUPPLIED TO CUSTOMER UNDER THIS AGREEMENT. GE HEALTHCARE SHALL HAVE NO OBLIGATION TO RELEASE, INDEMNIFY AND HOLD CUSTOMER HARMLESS FOR ANY DAMAGES CAUSED BY (I) CUSTOMER'S FAULT OR ANY LEGAL EXPENSES INCURRED BY CUSTOMER IN DEFENDING ITSELF AGAINST SUITS SEEKING DAMAGES CAUSED BY CUSTOMER'S FAULT AND/OR (II) ANY MODIFICATION, CHANGES AND/OR ALTERATIONS TO THE GE HEALTHCARE PRODUCT BY CUSTOMER OR A THIRD PARTY NOT AUTHORIZED OR APPROVED IN WRITING BY GE HEALTHCARE.

CUSTOMER AGREES TO RELEASE, INDEMNIFY AND HOLD GE HEALTHCARE HARMLESS FROM ANY THIRD PARTY DAMAGES THAT GE HEALTHCARE BECOMES LEGALLY OBLIGATED TO PAY RELATED TO BODILY INJURY OR DAMAGE TO REAL PROPERTY OR TANGIBLE PERSONAL PROPERTY TO THE EXTENT THAT SUCH DAMAGES ARE DETERMINED TO BE PROXIMATELY CAUSED BY CUSTOMER'S AND/OR CUSTOMER PERSONNEL (I) MEDICAL DIAGNOSIS OR TREATMENT DECISIONS; (II) MISUSE OR NEGLIGENT USE OF THE PRODUCT; AND/OR (III) USE OF THE PRODUCT IN A MANNER OR ENVIRONMENT, OR FOR ANY PURPOSE, FOR WHICH GE HEALTHCARE DID NOT DESIGN IT, OR IN VIOLATION OF GE HEALTHCARE'S RECOMMENDATIONS OR INSTRUCTIONS ON USE.

THE INDEMNIFICATION OBLIGATIONS SET FORTH IN THIS SECTION 3.5 ARE CONDITIONAL UPON THE INDEMNIFIED PARTY PROVIDING THE INDEMNIFYING PARTY PROMPT WRITTEN NOTICE OF THE THIRD-PARTY CLAIM AFTER RECEIPT OF NOTICE OF SUCH CLAIM, ALLOWING THE INDEMNIFYING PARTY TO CONTROL THE DEFENSE AND DISPOSITION OF SUCH CLAIM, AND REASONABLY COOPERATING WITH THE INDEMNIFYING PARTY IN THE DEFENSE. THE INDEMNIFYING PARTY SHALL NOT BE RESPONSIBLE FOR ANY COMPROMISE MADE BY THE INDEMNIFIED PARTY OR ITS AGENTS WITHOUT THE INDEMNIFYING PARTY'S CONSENT.

4. Payment and Finance.

4.1. Generally. The payment and billing terms for the Product(s) and/or Service(s) are stated in the Quotation.

4.2. Late Payment. Failure to make timely payment is a material breach of this Agreement, for which (in addition to other available remedies) GE Healthcare may suspend performance under the GE Healthcare agreement at issue or suspend the provision of support and maintenance or licenses for the Product(s) licensed or sold under that agreement until all past due amounts are brought current. If GE Healthcare so suspends, GE Healthcare will not be responsible for the completion of planned maintenance due to be performed during the suspension period and any product downtime will not be included in the calculation of any uptime commitment. Interest shall accrue on past-due amounts at a rate equal to the lesser of one-and-one-half percent (1.5%) per month or the maximum rate permitted by applicable law. Customer will reimburse GE Healthcare for reasonable costs (including attorneys' fees) relating to collection of past due amounts. Any credits and/or unapplied cash that may be due to Customer under an agreement may be applied first to any outstanding balance. If Customer has a good faith dispute regarding payment for a particular Product (or subsystem thereof) or Service, Customer shall notify GE Healthcare in writing of such dispute within twenty (20) days of the invoice date and shall work with GE Healthcare in good faith to promptly resolve such dispute. GE Healthcare may revoke credit extended to Customer and designate Customer and all agreements with Customer to be on credit hold because of Customer's failure to pay for any Products or Services when due, and in such event all subsequent shipments and Services shall be paid in full on receipt.

4.3. Taxes. Prices do not include sales, use, gross receipts, excise, valued-added, services, or any similar transaction or consumption taxes ("Taxes"). Customer shall be responsible for the payment of any such Taxes to GE Healthcare unless it otherwise timely provides GE Healthcare with a valid exemption certificate or direct pay permit. In the event GE Healthcare is assessed Taxes, interest or penalty by any taxing authority, Customer shall reimburse GE Healthcare for any such Taxes, including any interest or penalty assessed thereon. Each party is responsible for any personal property or real estate taxes on property that the party owns or leases, for franchise and privilege taxes on its business, and for taxes based on its net income or gross receipts.

5. Loaner Systems. If GE Healthcare provides a loaner system ("Loaner") to Customer pursuant to the terms of this Agreement, such Loaner shall be subject to the following provisions: (i) the Loaner shall be for Customer's temporary use, and Customer agrees to keep the Loaner at the location identified in the Quotation, and shall not move the Loaner to another location without GE Healthcare's prior written consent; (ii) Customer agrees to return the Loaner to GE Healthcare on or before the date on which GE Healthcare returns Customer's Product to Customer, and if Customer does not return the Loaner within such time period, GE Healthcare may repossess the Loaner with ten (10) days prior written notice or invoice Customer for the full list price of the Loaner; (iii) the Loaner, and all programs, information, data, business information, or other information pertaining to such Loaner shall remain GE Healthcare property; (iv) title remains with GE Healthcare, but risk of loss passes to Customer upon delivery of the Loaner; (v) Customer agrees to maintain the Loaner in proper operating condition and in accordance with GE Healthcare's operating instructions and return it to GE Healthcare in this condition, normal wear and tear excepted; (vi) Customer will not repair, or permit others to repair, the Loaner without the prior written consent of GE Healthcare; (vii) Customer agrees to furnish GE Healthcare reasonable access to the Loaner with prior notification; (viii) as Customer does not own the Loaner and is not paying GE Healthcare for its use, it is Customer's responsibility to ensure that any charge or claim submitted by Customer to a government healthcare program or patient is submitted accordingly; (ix) prior to returning the Loaner to GE Healthcare, Customer shall ensure the complete deletion of any and all information, including PHI, that may have been stored in the Loaner, or any of its accessories; (x) such deletion shall be completed in accordance with any user instructions provided by GE Healthcare and/or industry standards; (xi) in the event Customer is unable for technical reasons to complete the deletion, Customer shall provide immediate notice of this to GE Healthcare, and GE Healthcare staff shall use commercially reasonable efforts to facilitate the deletion of information; (xii) Customer agrees to indemnify GE Healthcare for any loss whatsoever resulting from any information that is not removed from the Loaner and GE Healthcare shall have no obligations whatsoever in connection with any information that is not properly removed from such Loaner by Customer. It is within GE Healthcare's sole discretion to provide Customer with a Loaner while warranty or Service repairs are ongoing. This provision is not applicable to GE Healthcare IT Products.

GE Healthcare

These GE Healthcare Product Terms and Conditions supplement and incorporate by reference (i) the GE Healthcare Quotation that identifies the Product offering purchased or licensed by Customer; (ii) the following documents, as applicable, if attached to or referenced in the Quotation: the GE Healthcare (a) Warranty(ies) and (b) Additional Terms and Conditions; and (iii) the GE Healthcare General Terms and Conditions, (collectively, referred to as the "Agreement").

1. Commercial Logistics.

1.1. Order Cancellation and Modifications.

1.1.1. Cancellation and Payments. If Customer cancels an order at any time without GE Healthcare's prior written consent, GE Healthcare has the right to charge Customer a cancellation fee of up to one-and-one-half percent (1.5%), with a maximum amount of up to $5,000, of the price of the Products ordered. If the cancellation occurs less than thirty (30) days prior to the scheduled delivery date of any portion of the order, GE Healthcare has the right to charge Customer a cancellation fee of up to ten percent (10%), with a maximum amount of up to $50,000, of the price of the Products ordered. GE Healthcare will retain as a credit any payments received up to the amount of the cancellation charge. If Customer cancels an order for Products for which GE Healthcare has provided site evaluation services, Customer will also pay GE Healthcare reasonable charges for such services performed prior to cancellation. If applicable for the order, Customer will pay all progress payments (other than the final payment) prior to final Product calibration, and GE Healthcare may, at its option, delay final calibration until required progress payments are received. If Customer fails to schedule a delivery date with GE Healthcare within six (6) months after order entry, GE Healthcare may cancel Customer's order upon written notice to Customer. For the avoidance of doubt, GE Healthcare IT Product Quotations and orders are non-cancellable.

1.1.2. Order Modifications. No modifications may be made to an order without GE Healthcare's prior written consent. The Product configuration listed in the Quotation is based upon information furnished to GE Healthcare by Customer, and Customer is responsible to provide and pay for modifications, if any, to the configuration due to inaccuracies or incompleteness of the information furnished to GE Healthcare by Customer, changes in Customer's needs or requirements, or for other reasons attributable to Customer.

1.1.3. Exchanges and Substitutions. Prior to acceptance as defined in Section 1.5 below, GE Healthcare may, in its sole and reasonable discretion, exchange or substitute installation-related items having similar features, functionality and pricing as the originally delivered installation item that result in no price change to the Customer. This section shall not apply to Healthcare IT Products.

1.1.4. Used Product Orders. Products identified as pre-owned, refurbished, remanufactured or demonstration Products have been previously used ("Used Products"); they are not new. When delivered and/or released to Customer, such Used Products may have received reconditioning, as necessary, to meet GE Healthcare performance specifications. Since Used Products may be offered simultaneously to several customers, their sale to Customer is subject to their availability. If the Used Products are no longer available, (i) GE Healthcare will attempt to identify other Used Products in its inventory that meet Customer's needs, and (ii) if substitute Used Products are not acceptable to Customer, GE Healthcare will cancel the order and refund any deposit Customer has paid for such Used Products.

1.2. Site Preparation. If applicable, Customer will be responsible, at its sole expense, for evaluating and preparing the site where the Products will be installed in accordance with GE Healthcare's site preparation requirements and applicable laws. Customer must provide GE Healthcare with prompt written notice if Customer is unable to prepare the site before the mutually agreed installation date. Upon receipt of such notice, GE Healthcare will reschedule the installation to a mutually agreed date. Customer shall be liable for any costs or expenses GE Healthcare or its representatives incur resulting from Customer's failure to provide GE Healthcare with timely notice of Customer's failure to properly prepare the site. GE Healthcare may, in its discretion, delay delivery or installation if GE Healthcare determines that the site has not been properly prepared or there are any other impediments to installation; provided that GE Healthcare gives Customer written notice of such delay stating the reasons therefor. If GE Healthcare provides site evaluation services, such services are intended only to assist Customer in fulfilling Customer's responsibility to ensure that the site complies with GE Healthcare's applicable site preparation requirements.

1.3. Transportation, Title and Risk of Loss; Delivery; Returns.

1.3.1. Transportation, Title and Risk of Loss. Unless otherwise indicated in the Quotation, shipping terms are FOB Destination. Title and risk of loss to equipment passes to Customer upon delivery to Customer's designated delivery location. Software is licensed to Customer; no title to or other ownership interest in such software passes to Customer.

1.3.2. Delivery. When feasible, GE Healthcare reserves the right to make delivery in installments. All such installments shall be separately invoiced and paid for when due, without regard to subsequent deliveries. At the time of such delivery, Customer will pay GE Healthcare for any amounts due upon delivery. As a matter of convenience, GE Healthcare may invoice multiple installment deliveries on a consolidated basis; however, this does not release Customer from the obligation to pay for each installment delivery provided by GE Healthcare. Delivery dates are approximate. For GE Healthcare software or documentation, delivery means the first to occur of: (i) communication to Customer through electronic means that allows Customer to take possession of the first copy or product master or (ii) delivery to Customer's designated delivery location.

1.3.3. Product Returns. Customer shall not have any right to return Products for a refund after delivery except for products shipped in error that are different from the Products listed in the Quotation.

1.3.4. Replaced Component Returns. Except for Healthcare IT Products, for upgrades and revisions Customer agrees to return any replaced component to GE Healthcare at no charge to GE Healthcare.

1.4. Installation, Certification and Professional Services. GE Healthcare will provide Product assembly, installation and calibration, as required, at no additional charge, except (i) for items excluded herein and/or (ii) as otherwise indicated in the Quotation. If installation services are identified in the Quotation, GE Healthcare will perform such services from 8am to 5pm local time, Monday-Friday, excluding GE Healthcare holidays, in accordance with applicable GE Healthcare installation guides and/or project plans. After hours installation is available for an additional fee. Customer will review the applicable GE Healthcare installation guides and/or project plans, and perform Customer's obligations as set forth in those materials. Upon completion of assembly, installation and calibration of the Products, as applicable, GE Healthcare will perform prescribed tests using its own performance specifications, instruments and procedures to verify that the Products meet GE Healthcare's applicable performance specifications.

1.4.1. Customer-Supplied Items.

- Customer will install necessary system cable and assemble any necessary equipment or hardware not provided by GE Healthcare, unless agreed otherwise in writing by the parties.
- For Products that will be operated on or in connection with Customer supplied hardware or software, Customer is responsible for ensuring that such hardware and software conform to GE Healthcare's minimum hardware and software requirements as made available to Customer.
- Unless GE Healthcare has agreed in writing to maintain responsibility for an applicable service, Customer will be responsible for enabling the connectivity and interoperability between Customer-supplied hardware or software or other systems or devices and the Product, including, without limitation, procuring and installing any modifications, interfaces or upgrades consistent with GE Healthcare's written specifications.
- Unless otherwise agreed in writing by GE Healthcare, Customer is solely responsible for the (i) performance of and payment for any applicable rigging and/or facility costs and (ii) installation of accessory items.
- If applicable for the Product, electrical wiring and outlets, computer network infrastructure, conduit, cabinetry modification, wall mounts, ventilation and any other site preparation are not included in the purchase price and are the responsibility of Customer, unless otherwise agreed in writing by GE Healthcare.

1.4.2. Network. Unless Customer has elected to purchase network preparation and certification Services from GE Healthcare as set forth in the Quotation, Customer is solely responsible for ensuring that Customer's network is adequate for the proper operation and performance of the Products and otherwise meets GE Healthcare's written network configuration requirements.

1.4.3. License, Permits, and Approvals. Customer shall obtain and maintain all licenses, permits and other approvals necessary for installation, use and disposal/recycling of the Products, including, but not limited to, any government licenses required to use radioactive sources for Products that require the use of such sources. GE Healthcare will ship such sources to Customer only after Customer provides GE Healthcare with satisfactory evidence that Customer has obtained all required licenses for such sources. In addition, Customer will provide all radioactive sources for calibration and performance checks of Products that require the use of such sources. GE Healthcare will file any required Federal and State reports relating to its installation activities. GE Healthcare will not install, test, certify or provide its own software license or warranty for Products that are not listed in its on-line catalog or price pages at the time of sale (such Products are normally identified by NL or NW series numbers), unless otherwise agreed in writing by GE Healthcare.

1.4.4. Non-GE Healthcare Labor. If local labor conditions make it impractical to, or GE Healthcare is directed not to, use GE Healthcare's employees or pre-qualified contractors for the installation, all work will be performed by Customer's laborers or outside labor at Customer's expense; provided that GE Healthcare will, at Customer's request, furnish guidance for installation. GE Healthcare is not responsible for the quality or adequacy of any work performed by any party other than GE Healthcare or its pre-qualified contractors.

1.4.5. Non-GE Healthcare Installation. For Products that GE Healthcare is obligated to install under the terms of this Agreement, if GE Healthcare delivers the Product but fails to perform its installation obligations, then in such event Customer shall nevertheless be obligated to pay GE Healthcare an amount equal to (a) the Product purchase price set forth in the Quotation, if the Product purchase price and the installation Services price are shown as separate line items in the Quotation, or (b) if the Product purchase price and installation Services price are not shown as separate line items in the Quotation, then the Product purchase price less the fair market value of the applicable installation Services, taking into account the type of Product and level of installation required ("Installation Service FMV"). An independent third party shall determine the Installation Service FMV. Notwithstanding any other provision of this Agreement to the contrary, either the discharge of Customer's obligation to pay for installation Services shown as a separate line item(s) in the Quotation or the deduction of the Installation Service FMV, as applicable, shall be Customer's sole and exclusive remedy (and GE Healthcare's sole and exclusive liability) in the event GE Healthcare fails to perform its installation obligations under this Agreement.

1.4.6. Information Technology Professional Services ("ITPS"). ITPS must be performed within twelve (12) months of the later of the date (i) Customer orders ITPS or (ii) of Product delivery, ("ITPS Performance Date"). If ITPS is not performed within twelve (12) months of the ITPS Performance Date for reasons other than GE Healthcare's failure to perform, GE Healthcare's ITPS performance obligation will expire without refund. ITPS includes clinical applications training, project management, HL7/HIS systems integration, database conversion, network design and integration and separately cataloged software installations. This section shall not apply to Healthcare IT Products.

1.5. Acceptance. Unless expressly provided otherwise in this Agreement, Customer shall be deemed to have accepted a Product delivered by GE Healthcare under this Agreement on the earlier of: (i) if GE Healthcare installs the Product, five (5) days after GE Healthcare notifies Customer that it has completed assembly and the Product is operating substantially in accordance with GE Healthcare's published performance specifications; (ii) if GE Healthcare does not install the Product, five (5) days after delivery of the Product to Customer; or (iii) the date Customer first uses the Product for patient use.

1.6. Warranties. Product warranties (if applicable) are set forth in the GE Healthcare warranty forms delivered with the Quotation. GE Healthcare may use refurbished parts in new Products. Any part for which GE Healthcare has supplied a replacement (excluding biomed parts, which shall be properly disposed of by Customer) shall become GE Healthcare property.

1.7. Third Party Products and Services. If GE Healthcare has agreed to provide any third party products and/or services (other than GE Healthcare accessories and supplies) to Customer as part of the Quotation, including but not limited to any Commitment Account/Non-Inventory items, (i) GE Healthcare is acquiring such products and/or services on Customer's behalf and not as a supplier of such products and/or services, (ii) GE Healthcare provides no warranties or indemnification of any kind, express or implied, with respect to such products and/or services (warranties or indemnification, if any, on such products and/or services will be provided by the manufacturer or service provider), (iii) Customer is solely responsible for ensuring that the acquisition and use of such products and/or services is in compliance with applicable laws and regulations, including applicable FDA regulations, and (iv) Customer is solely responsible for any and all claims resulting from or related to the acquisition or use of such products and/or services. This section shall not apply to Healthcare IT Products.

2. Software License.

2.1. License Grant. GE Healthcare grants to Customer a non-exclusive, non-transferable license to use for Customer's internal business purposes the GE Healthcare software, third-party software and Documentation solely for use on the Products and at the location (or, for mobile systems, in the specific vehicle) as identified in the Quotation, subject to the license scope and Documentation and other restrictions set forth in this Agreement. "Documentation" means the GE Healthcare user manuals, on-line help functions, technical specifications and user instructions regarding the operation, installation and use of the software as made available by GE Healthcare to Customer under this Agreement. Customer may only use third-party software provided by GE Healthcare together with the GE Healthcare software and will comply with all third-party software license terms included in any click or shrink wrap license or of which GE Healthcare otherwise makes Customer aware. To the extent permitted by applicable law, licensors of third-party software shall be third-party beneficiaries of this Agreement with respect to third-party software sublicensed under this Agreement. Customer may permit its employees, agents, independent contractors and healthcare providers with privileges at Customer's facilities to use the software and Documentation; provided, however, that Customer shall be responsible for any acts of such third parties that are inconsistent with this Agreement. Notwithstanding the foregoing, independent contractors that supply products comparable to the software shall be provided access to the software only with GE Healthcare's prior written consent and subject to any conditions GE Healthcare deems appropriate to protect its confidential and proprietary information. Customer acknowledges that GE Healthcare may request Customer and Customer Personnel to register online as a licensee for receipt of certain service software and related Documentation.

2.2. Additional License Terms. Without GE Healthcare's prior written consent, Customer may not: (i) copy, sublicense, distribute, rent, lease, loan, resell, modify or translate the software or create derivative works based thereon, except that to the extent applicable, the software may be configured as specifically permitted in the Documentation; (ii) directly or indirectly decompile, disassemble, reverse engineer or otherwise attempt to learn the source code, structure, algorithms or ideas underlying the software; (iii) provide service bureau, time share or subscription services based on the software; (iv) remove, obscure or modify any markings, labels or any notice of the proprietary rights, including copyright, patent and trademark notices of GE Healthcare or its licensors; (v) electronically transfer the software outside Customer's intranet or network dedicated for the software, unless otherwise authorized in writing by GE Healthcare; or (vi) publicly release the results of any testing or benchmarking of the software without the prior written consent of GE Healthcare. Customer may transfer authorized copies of the software, and Documentation to a party that purchases or otherwise acquires the equipment and accepts any applicable license terms, except for software and Documentation that are (a) not a part of the base system standard operating software or Documentation for the equipment and (b) generally provided by GE Healthcare to its customers for a separate fee or charge. Advanced service software is subject to a separate fee and eligibility criteria and licensed under a separate agreement with GE Healthcare.

2.3. Backups. Customer may make a reasonable number of copies of the software in machine-readable form solely for backup, training, testing or archival purposes, so long as applicable license fees are paid. Customer shall reproduce on any such copy the copyright notice and any other proprietary legends that were on the original copy. GE Healthcare and its licensors, as applicable, retain all ownership and intellectual property rights to the software and Documentation. If Customer acquires any rights to the software or Documentation, Customer hereby assigns all of those rights to GE Healthcare or its licensors, as applicable. No license rights are granted (whether by implied license or otherwise), to Customer, except as specifically provided in this section.

2.4. Remedies. Customer agrees that a violation of GE Healthcare's license, confidentiality or intellectual property rights will cause irreparable harm to GE Healthcare for which the award of money damages alone are inadequate. In the event of any breach of this provision, GE Healthcare shall be entitled to seek injunctive relief in addition to immediately terminating the license granted herein and requiring that Customer cease use of the software and return all copies of stand-alone software in any media in addition to seeking any other legal or equitable remedies available to GE Healthcare. This paragraph shall survive the termination of this Agreement.

3. Payment and Finance.

3.1. Security Interest. Customer grants GE Healthcare a purchase money security interest in all items of hardware or equipment listed in the Quotation until full payment is received, and Customer shall perform all acts and execute all documents as may be necessary to perfect GE Healthcare's security interest.

3.2. Leases. If Customer is acquiring use of Products through an equipment lease ("Lease") with an equipment lessor ("Lessor"), certain provisions of this Agreement (including, but not limited to, terms related to payment, title transfer, warranties, and software licenses) may be modified as agreed to in writing between GE Healthcare, the applicable Lessor, and/or Customer, as the case may be. Acceptance of the Products as between GE Healthcare and Lessor will be defined by this Agreement; acceptance of the Products as between Lessor and Customer will be defined by the lease agreement. Notwithstanding the foregoing, if the Lessor does not comply with the terms of this Agreement, Customer shall continue to be responsible for the payment obligations hereunder.

3.3. Failure to Pay. If, after Product delivery, Customer does not make any payments for the Products within forty-five (45) days after such payments are due, GE Healthcare may, upon ten (10) days prior written notice to Customer, either (a) enter upon Customer's site and remove the Products or (b) temporarily disable the Products so that they are not operational.

GE Healthcare

Additional Terms and Conditions: Positron Emission Tomography ("PET") and Computed Tomography ("CT")

These GE Healthcare Additional Terms and Conditions: Positron Emission Tomography ("PET") and Computed Tomography ("CT") supplement and incorporate by reference the GE Healthcare (i) Quotation that identifies the Product offering purchased or licensed by Customer; (ii) Warranty(ies); (iii) Product Terms and Conditions; and (iv) General Terms and Conditions, (collectively, referred to as the "Agreement").

1. **Mobile Systems Only.** For Products that are approved by GE Healthcare for use as transportable, relocatable and mobile systems, GE Healthcare will deliver the system to Customer's van manufacturer and furnish final assembly services to place the system in Customer's van. At the time of order, Customer must notify GE Healthcare of the van manufacturer to which the system is to be shipped. It is Customer's responsibility to make arrangements with the van manufacturer for delivery of the van and to comply with any additional planning requirements of the van manufacturer.

2. **Tubes.** Certain Products that use x-ray or image intensifier tubes have been designed to recognize GE Healthcare-supplied tubes and report to the user the presence of a non-GE Healthcare tube. This will permit the user to know when a non-GE Healthcare tube is in use on the Product and will advise the user that GE Healthcare cannot assure that the performance of the Product with the non-GE Healthcare tube will conform to specifications. GE Healthcare assumes no liability for the use of non-GE Healthcare supplied tubes and disclaims any responsibility for any effect such tubes may have on Product performance.

3. **Radioactive Materials.** Customer will provide a site and surroundings suitable for installation and operation of such a system using and/or producing radiation. Further, Customer will be responsible for obtaining all required Federal, State, and local licenses and permits for radioactive sealed sources and radioisotopes used with such system. If permitted under applicable licensing requirements, GE Healthcare representatives will work under Customer's license and supervision when handling any radioactive substance for which a license is required, or Customer will provide such handling itself under an appropriate license. Customer will provide all radioactive sources and radioisotopes for calibration and performance checks of such system. Customer acknowledges that such systems utilize radioactive materials. As with all systems utilizing radioactive materials, hazards exist creating possible physical danger to persons in the vicinity.

4. **NOTICE REGARDING COMPUTED TOMOGRAPHY ("CT") PRODUCTS.** This notice applies only to the GE Healthcare Revolution CT and EVO, Optima 680 CT and Optima 520 CT products. GE Healthcare has reclassified several advanced software tools and associated documentation to a GE Healthcare Technical Service Technology package that GE Healthcare feels will bring greater value and interest to our customers. GE Healthcare will continue to provide trained Customer employees with access to the GE Healthcare Technical Service Technology package under a separate agreement.

GE Healthcare will continue to provide customers and their third party service providers with access to software tools and associated documentation in order to perform basic service on the Revolution CT and EVO, Optima 680 CT and Optima 520 CT products upon a request for registration for such access. This will allow GE Healthcare to react faster to the future service needs of GE Healthcare customers.

If you have any questions, you can contact your sales Service Specialist.

Additional Terms and Conditions: DoseWatch Explore

GE Healthcare

These GE Healthcare Additional Terms and Conditions: DoseWatch Explore (a) supplement and incorporate by reference the GE Healthcare (i) Quotation that identifies the Product offering purchased or licensed by Customer; and (ii) General Terms and Conditions, (collectively, referred to as the "Agreement") and (b) do not include the GE Healthcare Product Terms and Conditions or Warranties attached to the Quotation.

1. DoseWatch Explore Services. DoseWatch Explore is a web-based, cloud deployed, introductory dose management software application designed to track, analyze and report practice-level data for the Product. DoseWatch Explore collects radiation dose data directly from the Product, then summarizes and presents the data via a GE Healthcare web application ("Information"). DoseWatch Explore may help Customer with the following dose management activities:

- Review individual exam information including dose and protocol parameters
- Identify high dose protocols and trending over time
- Compare protocols to understand variation
- Receive alerts when exams have exceeded pre-defined thresholds
- Quantify results of protocol optimization activities
- Generate reports to communicate results to team members and leadership

DoseWatch Explore allows Customer to regularly obtain the above services ("DoseWatch Explore Services") and Information through a user interface such as a single internet site.

The DoseWatch Explore Services require GE Healthcare to collect, and allow Customer to obtain, exam information and protocol parameter data in relation to the Product.

The Information is regularly updated, but reflects data from completed exams. Accordingly, there is a time lapse between the examination and the data being reflected in the DoseWatch Explore software (i.e., the data reflected in the software is not real-time data and should not be relied upon as such). GE Healthcare disclaims all liability for such time lapse.

2. License for Use. GE Healthcare grants to Customer a non-exclusive, non-transferable, limited right to access and use, solely for Customer's internal business purposes, the GE Healthcare DoseWatch Explore Services and Information and to download the DoseWatch Explore site Information onto the hard drive of Customer's computer(s). Such license and right shall be in effect during the warranty period of the Product to which the DoseWatch Explore software accompanies. GE Healthcare retains all ownership and intellectual property rights to the DoseWatch Explore Services and Information. No license rights are granted (implied or otherwise) to Customer except as specifically provided in this Agreement.

GE Healthcare may monitor use of the DoseWatch Explore site, the DoseWatch Explore Services and the Information, for purposes including, but not limited to, (a) ensuring appropriate use of the site, (b) product and services enhancement opportunities, (c) performance monitoring, and (d) marketing.

Customer may permit Customer Personnel with privileges at Customer's facilities to use the DoseWatch Explore Services and Information; provided, however, that Customer shall be responsible for any acts of such third parties that are inconsistent with this Agreement. Customer's affiliates may use the DoseWatch Explore Services and Information only by agreeing to be bound by this Agreement.

3. Access and Confidentiality. In order to access DoseWatch Explore, Customer must have a computer with internet access, the minimum configuration indicated by GE Healthcare and a Product connected to GE Healthcare's InSite remote diagnostic service tool. All installation, telecommunication and network use costs shall be borne by Customer. For Products entitled with DoseWatch Explore, and upon Customer request to GE Healthcare, GE Healthcare shall provide Customer with DoseWatch Explore access-related information (e.g., internet address, confidential access code/password, login name) ("Access Code") for Customer's connection to the DoseWatch Explore site and access to the Information. Customer agrees to be solely responsible and liable for keeping the Access Code confidential. Customer shall immediately inform GE Healthcare of the need to deactivate an Access Code (e.g., in the event of Customer Personnel departure, loss or compromise of the Access Code).

4. Warranties and Remedies. The following warranties apply only to DoseWatch Explore and are in lieu of any other standard GE Healthcare warranties.

4.1. Information. All Information accessible as part of the DoseWatch Explore Services is provided "AS IS". GE Healthcare does not warrant the completeness, accuracy or reliability of any Information. All decisions based on the Information are the sole responsibility of Customer and Customer Personnel. Customer agrees that GE Healthcare is in no way responsible for any decision or evaluation relating to the activity or operation of the Product or DoseWatch Explore software.

The Information (a) is intended for general informational purposes only, (b) is not a substitute for professional medical advice, diagnosis or treatment, and (c) should not be relied upon, used or characterized as information to aid in Customer Personnel healthcare diagnosis, practices or decisions. GE Healthcare makes no representation or warranty with respect to and has no liability to Customer, Customer Personnel, or patients regarding the accuracy or completeness of anything contained in the Information. GE Healthcare does not promote or otherwise recommend any procedure suggested in any Information unless it is also described in a GE Healthcare user manual for the Product.

4.2. Access to Information. All Information accessible as part of the DoseWatch Explore Services is provided "AS AVAILABLE". GE Healthcare shall use reasonable efforts to ensure that the DoseWatch Explore site operates normally. In view of the state of information technology and the intervention of third parties in the operation of and access to Customer's site and network, GE Healthcare shall not be liable for any interruption or loss of connection or access whatsoever to DoseWatch Explore or for the speed of access or slowdown in the communication of Information. GE Healthcare does not guarantee nor does it warrant that the DoseWatch Explore Services or the Information will be constantly available, accurate, uninterrupted, error-free, or that defects/errors will be corrected.

GE Healthcare reserves the right, without notice to Customer, to suspend its provision of the DoseWatch Explore Services at any time and for the time required to carry out maintenance work and update the DoseWatch Explore site.

4.3. No Other Warranties. NO OTHER EXPRESS OR IMPLIED WARRANTIES, INCLUDING IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, QUIET ENJOYMENT, SYSTEM INTEGRATION OR DATA ACCURACY, WILL APPLY.

5. **Customer Responsibilities.** Customer shall be responsible for and bear all costs, expenses and liability for the following:

   (a) Transmitting to GE Healthcare, and allowing GE Healthcare to process, access, collate and analyze, all relevant and accurate data relating to the Product via the DoseWatch Explore Services.

   (b) Using the Information and DoseWatch Explore Services in accordance with all applicable laws and regulations, and to strictly comply with the limitations of use as set forth in this Agreement.

   (c) Providing GE Healthcare with the necessary level of access rights for GE Healthcare to provide individual user accounts.

   (d) Managing and controlling access to and use of the DoseWatch Explore Services and Information through individual user accounts affiliated with Customer.

6. **Use of Information by GE Healthcare.** DoseWatch Explore Services allow the Product to automatically send data to GE Healthcare (via internet connection). Customer acknowledges that GE Healthcare shall automatically receive certain data relating to the use and productivity of the Product. GE Healthcare shall process the data in order to provide DoseWatch Explore Services and as otherwise set forth in this Agreement. Unless Customer specifically requests in writing that GE Healthcare disable the remote connection, the remote connection will continue to connect to the Product following expiration or termination of the DoseWatch Explore Services.

7. **Data Retention.** For purposes of continuity, GE Healthcare shall continue data collection for thirty (30) days following the expiration or termination of the DoseWatch Explore Services, and, unless Customer purchases a continuation of the DoseWatch Explore Services, data shall be retained for no longer than one hundred eighty (180) days following such expiration or termination.

Warranty Statement (United States)

GE Healthcare

This GE Healthcare Warranty Statement (United States) supplements and incorporates by reference (i) the GE Healthcare Quotation that identifies the Product offering purchased or licensed by Customer; (ii) the following documents, as applicable, if attached to or referenced in the Quotation: the (a) Warranties and (b) Additional Terms and Conditions; (iii) the GE Healthcare Product Terms and Conditions; and (iv) the GE Healthcare General Terms and Conditions, (collectively, referred to as the "Agreement").

1. **Warranted Products.** These warranties cover the purchase and use of the following GE Healthcare products:

- Magnetic Resonance
- Computed Tomography
- Mammography
- Positron Emission Tomography (including scanners, cyclotrons & chemistry labs)
- Nuclear
- X-ray
- Surgical Navigation Systems
- Cardiology
- Ultrasound
- Bone Mineral Densitometry
- Physiological Monitoring
- Small Animal Imaging
- C-Arms
- Advantage Workstation and Server
- Anesthesia Delivery
- Respiratory Care
- Gold Seal
- Phototherapy and other infant care accessories
- Microenvironments, including Giraffe®, Panda®, Care Plus® and Ohio® Infant Warmer Systems
- Corometrics® Fetal Monitors

2. **GE Healthcare Warranties.**

2.1 Scope. GE Healthcare warrants that its services will be performed by trained individuals in a professional, workman-like manner. GE Healthcare will promptly re-perform any non-conforming services for no charge as long as Customer provides reasonably prompt written notice to GE Healthcare. The foregoing service remedy, together with any remedy provided herein, are Customer's sole and exclusive remedies (and GE Healthcare's sole and exclusive liability) for warranty claims. These exclusive remedies shall not have failed of their essential purpose (as that term is used in the Uniform Commercial Code) as long as GE Healthcare remains willing to repair or replace defective warranted products or re-perform any non-conforming services for no charge, as applicable, within a commercially reasonable time after being notified of Customer's warranty claim. NO OTHER EXPRESS OR IMPLIED WARRANTIES, INCLUDING IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, QUIET ENJOYMENT, SYSTEM INTEGRATION AND DATA ACCURACY, WILL APPLY.

2.2 Term Usage. "Warranted Product" is a collective term which includes both the above-listed GE Healthcare manufactured equipment and licensed software, with the exception of Healthcare IT Products, purchased by and/or licensed to (as applicable) Customer under the relevant GE Healthcare Quotation.

2.3 Equipment Warranty. Except as indicated otherwise below, GE Healthcare warrants the equipment will be free from defects in title and that for one (1) year from the Warranty Commencement Date (as defined below) (i) the equipment will be free from defects in material and workmanship under normal use and service and (ii) except for equipment manufactured in compliance with Customer's designs or specifications, the equipment will perform substantially in accordance with GE Healthcare's written technical specifications for the equipment (as such specifications exist on the date the equipment is shipped) (the "Specifications"). This warranty covers both parts and labor and is available only to end-users that purchase the equipment from GE Healthcare or its authorized distributors. Customers purchasing through an authorized distributor must contact GE Healthcare promptly following such purchase to enable this warranty.

2.4 Software Warranty. Except as indicated otherwise below, GE Healthcare warrants for ninety (90) days from the Warranty Commencement Date that (i) the licensed software will perform substantially in accordance with the applicable Documentation (as defined herein), (ii) it has not inserted any Disabling Code (as defined herein) into the licensed software and (iii) it will use reasonable commercial efforts consistent with industry standards to scan for and remove any software viruses before installation of the applicable Warranted Product. Where an item of equipment has software code embedded in it, the code will only be considered licensed software under this warranty statement if the applicable GE Healthcare Quotation provides a separate part number for that software. Except as indicated otherwise below, GE Healthcare warrants that it has the right to license or sublicense the licensed software to Customer for the purposes and subject to the terms and conditions set forth in the Agreement. As used in this warranty statement, (i) "Disabling Code" means computer code that is designed to delete, interfere with, or disable the normal operation of the Warranted Product; provided, however, that code included in the licensed software that prevents use outside of the license scope purchased for the software will not be deemed to be Disabling Code and (ii) "Documentation" means the GE Healthcare user manuals, on-line help functions, technical specifications and user instructions regarding the operation, installation and use of the software as made available by GE Healthcare to Customer.

2.5 Used Products. GE Healthcare's (i) Gold Seal Products (certain pre-owned GE Healthcare equipment), (ii) Ultrasound demonstration systems, and (iii) certified pre-owned Bone Mineral Densitometry Products are all provided with GE Healthcare's standard warranties carrying the same duration as the new equipment warranty, but in no event exceeding one (1) year (unless otherwise provided in writing

by GE Healthcare). Except as expressly provided in this paragraph or in the applicable GE Healthcare Quotation, all other pre-owned, refurbished, remanufactured or demonstration equipment is not warranted by GE Healthcare.

2.6 Healthcare IT and GE Brand Specialty Components. GE Healthcare IT Products and GE Brand Specialty Components (Detectors, Probes, X-Ray Tubes and Image Intensifier Tubes) are covered by a separate warranty statement provided in an applicable GE Healthcare Quotation.

2.7 Third-Party Software and Equipment. This warranty statement does not cover Third-Party Software and Equipment (as defined herein) delivered with the Warranted Products (commonly identified by NL or NW series numbers in GE Healthcare's Quotation). "Third-Party Software and Equipment" means any non-GE Healthcare software or equipment (i) delivered to Customer in the third-party manufacturer/supplier's packaging and with its labeling or (ii) for which GE Healthcare expressly indicates (either in the GE Healthcare Quotation or in the product documentation) that the software or equipment is provided with the third-party manufacturer/supplier's warranty in lieu of a GE Healthcare warranty. Such products are covered by the third-party manufacturer/supplier's warranties, to the extent available. Anesthesia monitor mounting solutions Third-Party Software and Equipment purchased directly from GE Healthcare will not be treated as Third-Party Software or Equipment.

3. Warranty Commencement. Unless expressly provided otherwise in this warranty statement or the applicable GE Healthcare Quotation, the warranty period begins (the "Warranty Commencement Date") on the earlier of: (i) if GE Healthcare installs the Warranted Product, five (5) days after GE Healthcare notifies Customer that it has completed assembly and the Warranted Product is operating substantially in accordance with GE Healthcare's Specifications; (ii) if GE Healthcare does not install the Warranted Product, five (5) days after delivery of the Warranted Product to Customer; (iii) the date Customer first uses the Warranted Product for patient use; or (iv) if GE Healthcare is contractually required to install the Warranted Product, the thirtieth (30th) day following shipment to the end-user Customer if installation is delayed for reasons beyond GE Healthcare's reasonable control. The warranty period for any Warranted Product or component furnished to correct a warranty failure will be the unexpired term of the warranty applicable to the repaired or replaced Warranted Product.

4. Remedies. If Customer promptly notifies GE Healthcare of Customer's warranty claim during the warranty period and makes the Warranted Product available for service, GE Healthcare will, at its option (i) with respect to equipment, either repair, adjust or replace (with new or exchange replacement parts) the non-conforming Warranted Product or components of the Warranted Product and (ii) with respect to GE Healthcare's licensed software, either correct the non-conformity or replace the applicable licensed software. GE Healthcare may, at its sole discretion and subject to (i) availability; (ii) any applicable regulatory approvals; and (iii) Section 5 of the GE Healthcare General Terms and Conditions, provide Customer with a comparable loaner system during periods of extended service to the Warranted Product. Warranty service will be performed without charge from 8:00am to 5:00pm (local site time), Monday-Friday, excluding GE Healthcare holidays, and outside those hours at GE Healthcare's then prevailing service rates and subject to the availability of personnel. For certain Warranted Products, GE Healthcare will perform warranty service only at an authorized service center or, in some instances, via a secure, remote connection to a GE Healthcare online center. With respect to GE Healthcare's warranty for the services it provides to Customer, Customer's exclusive remedy is set forth in Section 2.1 above.

Warranty claims for the Warranted Products should be directed through GE CARES at 1-800-437-1171. Warranty claims for accessories and supplies items should be directed through 1-800-558-5102.

5. Limitations. GE Healthcare shall not have any obligation to Customer hereunder if the warranty claim results from or arises out of: (a) the use of the Warranted Product in combination with any software, tools, hardware, equipment, supplies, accessories or any other materials or services not furnished by GE Healthcare or recommended in writing by GE Healthcare; (b) the use of the Warranted Product in a manner or environment, or for any purpose, for which GE Healthcare did not design or license it, or in violation of GE Healthcare's recommendations or instructions on use; or (c) any alteration, modification or enhancement of the Warranted Product by Customer or any third party not authorized or approved in writing by GE Healthcare. In addition, this warranty does not cover the Warranted Product to the extent it is used in any country other than the country to which GE Healthcare ships the Warranted Product (unless GE Healthcare expressly agrees otherwise in writing). GE Healthcare does not guarantee that licensed software will operate without error or interruption.

In addition, these warranties do not cover: (i) any defect or deficiency (including failure to conform to Specifications and/or Documentation, as applicable) that results, in whole or in part, from any improper storage or handling, failure to maintain the Warranted Products in the manner described in any applicable instructions or specifications, inadequate back-up or virus protection or any cause external to the Warranted Products or beyond GE Healthcare's reasonable control, including, but not limited to, power failure and failure to keep Customer's site clean and free of dust, sand and other particles or debris; (ii) the payment or reimbursement of any facility costs arising from repair or replacement of the Warranted Products or parts; (iii) any adjustment, such as alignment, calibration, or other normal preventative maintenance required of Customer; (iv) expendable supply items; (v) stockpiling of replacement parts; (vi) any failure of the Warranted Products to use or correctly process dates (other than systemic miscalculations not due to date value format); and (vii) products not listed in GE Healthcare's Accessories and/or Supplies catalogs at the time of sale, and all service manuals are provided AS IS. For network and antenna installations not provided by GE Healthcare or its authorized agent(s), network and antenna system troubleshooting will be billable at GE Healthcare's standard service rates.

For MR systems, these warranties do not cover (i) any defect or deficiency that results, in whole or in part, from failure of any water chiller system supplied by Customer, (ii) service to any water chiller systems supplied by Customer and (iii) for MR systems with LHe/LN or shield cooler configured superconducting magnets (except for MR Systems with LCC magnets), any cryogen supply, cryogenic service or service to the magnet, cryostat, coldhead, shield cooler compressor or superconductive or resistive shim coils unless the need for such supply or service is caused by a defect in material or workmanship covered by these warranties (GE Healthcare's MR Magnet Maintenance and Cryogen Service Agreement is available to provide supplemental coverage during the warranty period).

For Proteus XR/a, Definium and Precision 500D x-ray systems, these warranties do not cover collimator bulbs.

6. **Exceptions to GE Healthcare Standard Warranties Described Above.**

Partial System Equipment Upgrades for CT, MR, X-Ray, PET (Scanners, Cyclotrons and Chemistry Labs) and Nuclear systems: Six (6) months (warranty applies only to the upgraded components)

Cyclotron and Radiopharmacy: Unless expressly provided otherwise in the applicable GE Healthcare Quotation, the Warranty Commencement Date for Cyclotron and/or Radiopharmacy Products begins on the earlier of (i) three (3) months after the date on which GE Healthcare has completed the mechanical installation, or (ii) the date on which final testing of the Product has been successfully completed. GE Healthcare's sole liability and Customer's exclusive remedy for a breach of warranty is limited to repair, replacement or refund at GE Healthcare's sole option. Any such repairs or replacement will not extend the warranty period.

X-Ray High Voltage Rectifiers and TV Camera Pick-Up Tubes: Six (6) months

X-Ray Portable (Wireless & Tethered) Digital Detectors: Warranty does not cover damage caused by any use that does not conform to OEM guidelines, fire, power failures or surges, or abuse which is defined as use that causes fluid invasion, holes, deep scratches, or the detector case to crack.

FlashPad Wireless Detector: In addition to the standard warranty, GE Healthcare will also provide coverage for detector damage due to accidental dropping or mishandling (e.g., spills). In the event such accidental damage occurs, GE Healthcare shall provide Customer with one (1) replacement detector during the warranty period at no additional charge. If subsequent accidental damage occurs during the warranty period, each additional replacement shall be provided to Customer at a charge of $30,000 per replacement detector. Warranty coverage for the detector and its components also excludes failures due to detrimental exposure, abuse, theft, loss and/or fire. If the warranty is voided by these conditions, repair or replacement of the detector and/or the components is the Customer's responsibility.

GE OEC New or Exchange Service/Maintenance Parts: Ninety (90) days

GE OEC Refurbished C-Arms: Twelve (12) months after installation

HealthNet Lan, Advantage Review — Remote Products: Ninety (90) days

Vivid T8: Three (3) years parts and labor, includes TEE probes purchased with the Vivid T8

Vivid i, Vivid e, Vivid q, Voluson i, Voluson e and LOGIQBook XP: Standard warranty includes (i) repair services at GE Healthcare service facilities, (ii) three (3) business day turnaround repair time for systems shipped via overnight delivery (where available), measured from the date of shipment (GE Healthcare is not responsible for delays in overnight shipment), (iii) seventy-two (72) hour loaner systems or probe replacement service via Fed Ex (shipping charges included), and (iv) technical support via telephone from 7:00 am to 7:00 pm Central Time, Monday-Friday, excluding GE Healthcare holidays. For an additional charge, GE Healthcare may provide (a) field support/service, (b) preventative maintenance, and/or (c) coverage for system damage due to accidental dropping or mishandling with a maximum of two (2) replacement systems during the term of the warranty.

Vscan, LOGIQ e BT12 and later versions, and Venue 40 and 50 version BT12 and later versions: Supplemental warranty terms and conditions specific to Vscan systems, LOGIQ e BT12 and later version systems, and Venue 40 and 50 version BT12 and later version systems shall be as set forth in the Additional Terms and Conditions and Warranties for Ultrasound & Vscan Products attached to the Quotation.

Ultrasound Partial System Equipment Upgrades: Ninety (90) days (Warranty applies only to the upgraded components. Customer will not be credited the value of this warranty against pre-existing warranties or service agreements).

Bone Mineral Densitometry Partial System Equipment Upgrades: Thirty (30) days (Warranty applies only to the upgraded computer, printer and monitor components. Customer will not be credited the value of this warranty against pre-existing warranties or service agreements).

CARESCAPE Monitors B450, B650 and B850, and Dash: Three (3) years parts and one (1) year labor coverage, excluding displays

B40 Monitors: Two (2) years of parts only coverage, excluding displays, and one (1) year labor with (i) repair services performed at GE Healthcare service facilities; or (ii) onsite repair if deemed necessary by GE Healthcare, during such labor warranty period.

MAC 800, 1200, 1600 and 2000: Three (3) years of parts and labor

CARESCAPE V100 Vital Signs Monitors: Two (2) years parts and labor

Exergen: Four (4) years parts and labor

Batteries: Ninety (90) days, except (i) for LOGIQBook and Vscan batteries, which are warranted for twelve (12) months and (ii) for Nickel cadmium or lead acid batteries for X-ray and mammography systems (which will corry a sixty (60)-month warranty prorated as shown below). For Nickel cadmium or lead acid batteries for X-ray and mammography systems, warranty service will be performed without charge from 8:00 a.m. to 5:00 p.m. (local site time), Monday-Friday, excluding GE Healthcare holidays, and outside those hours at GE Healthcare's then prevailing service rates and subject to the availability of personnel only during the first twelve (12) months of the sixty (60)-month warranty period. For X-ray and mammography systems, if nickel cadmium or lead acid batteries need replacement during their applicable warranty period, Customer will pay the price of the replacement battery in effect on its delivery date less a Pro Rata Credit Allowance (as defined herein). The Pro Rata Credit Allowance for batteries that fail less than twelve (12) months after the warranty begins is one hundred percent (100%). The Pro Rata Credit Allowance for batteries that fail more than twelve (12) months after the warranty begins is:

1 - (# of Mos. After Warranty Commencement /60) x 100%

For the purpose of Pro Rata Credit Allowance, a fraction of a month less than fifteen (15) days will be disregarded, and a fraction of a month equal to or greater than fifteen (15) days will be regarded as a full month.

Giraffe® Shuttle Batteries: Ninety (90) days

Care Plus® Incubator: Three (3) years parts, one (1) year labor

Ohio® Infant Warmer Systems, Panda® iRes Warmers, Giraffe® Warmer and Giraffe® OmniBed: Seven (7) year parts warranty on heater cal rod

BiliBlanket® Plus High Output Phototherapy System: Two (2) years on Light Box and eighteen (18) months on Fiberoptic Pad

Microenvironment and Phototherapy expendable components, this includes but is not limited to patient probes, probe covers and light bulbs: Thirty (30) days

Corometrics® Fetal Monitoring Systems: Warranty includes: (i) Warranty Commencement at the earlier of (a) if GE Healthcare or Customer installs the Warranted Product, five (5) days after completion of installation of the Warranted Product or (b) forty (40) days after shipment of the Warranted Product; (ii) two (2) years parts, one (1) year labor; and (iii) repair services at GE Healthcare service facilities during labor warranty period or onsite repair if deemed necessary by GE Healthcare.

Corometrics® Nautilus Transducers: Two (2) years of parts and labor
Oximeters: Three (3) years from installation, or thirty-nine (39) months from GE Healthcare invoice, whichever occurs sooner
Tec 7 Vaporizers: Three (3) years of parts and labor
Tec 6 Plus Vaporizers: Two (2) years of parts and labor
Accessories and Supplies: GE Healthcare's catalog and/or website includes a "Service/Warranty Code" which identifies the installation, warranty, applications and post-warranty service, if any, provided for each accessory and supply product. Following are the warranty periods for accessories and supplies:

Service/Warranty Code T	100 Years
Service/Warranty Code V	25 Years
Service/Warranty Codes X	15 Years
Service/Warranty Code ZZ	5 Years
Service/Warranty Codes F	3 Years
Service/Warranty Codes D, J, N, O, R or Z	2 Years
Service/Warranty Codes A, B, C, E, G, L, P, Q, S or Y	1 Year
Service/Warranty Code H	6 Months
Service/Warranty Code K	3 Months
Service/Warranty Code M	1 Month
Service/Warranty Code W	Out of Box Failure Only

Warranty Codes For Accessories And Supplies

GE Healthcare

These GE Healthcare Warranty Codes For Accessories and Supplies supplements and incorporates by reference (i) the GE Healthcare Quotation that identifies the Product offering purchased or licensed by Customer; (ii) the following documents, as applicable, if attached to or referenced in the Quotation: the (a) Warranties and (b) Additional Terms and Conditions; (iii) the GE Healthcare Product Terms and Conditions; and (iv) the GE Healthcare General Terms and Conditions, (collectively, referred to as the "Agreement").

Service / Warranty Codes. If Customer promptly notifies GE Healthcare of its warranty claim and makes the Product available for service, GE Healthcare will provide the warranty service indicated in the applicable Service/Warranty Code description. The terms and conditions of GE Healthcare's Warranty Statement(s) apply to all warranty claims. Basic Service Premise for Products - GE Healthcare Field Engineers will take the first call for service and either provide direct support or arrange for support from the manufacturer or its dealers as indicated by the individual Service/Warranty Code. If the Service/Warranty Code calls for Product return for repair or in-warranty exchange, Customer must return the Product as GE Healthcare directs. GE Healthcare provides warranty service from 8:00 AM to 5:00 PM local time Monday-Friday EXCLUDING GE HEALTHCARE HOLIDAYS. If a Service/Warranty Code provides for warranty service to be performed on Customer's site, such service is available outside the above hours at GE Healthcare's prevailing service rates and subject to the availability of personnel.

A **GE Healthcare directly, or through a sub-contractor, provides the following:**

Installation; parts; on-site warranty service to repair, adjust or replace (at GE Healthcare's option and using new or exchange replacement parts) non-conforming products or parts; applications training in some cases (with additional charge); and post-warranty service, at prevailing hourly billed service ("HBS") rates and, in some cases, under GE Healthcare service contracts.

B **GE Healthcare directly provides the following through GE Healthcare's Global Parts Operation (GPO):**

New or exchange replacement parts at no charge to correct non-conforming products or parts during the warranty period; new or exchange replacement parts at GE Healthcare's normal prices for post-warranty repairs. ***Note:*** *Installation, applications training and on-site service is the Customer's responsibility. However, GE Healthcare's Field Engineers may be available at prevailing HBS rates. Contact GE CARES for availability.*

C **GE Healthcare arranges for the third-party Product Manufacturer or its dealers to provide the following:**

Installation (in some cases with an additional charge); parts; on-site warranty service to repair, adjust, or replace (at the manufacturer's or dealer's option and using new or exchange replacement parts) non-conforming products or parts; applications training in some cases (some with additional charge); and post-warranty service at prevailing service rates.

D **GE Healthcare refers to the Product Manufacturer warranty, which provides the following:**

Basic functional troubleshooting (no technical labor) with supplier phone support and repair or replacement (at the manufacturer's or dealer's option) of defective products or parts. ***Note:*** *The battery for Service/Warranty Code **D** has a 1-year warranty. For detailed warranty information, please refer to the Product Manufacturer's warranty certificate.*

E **GE Healthcare directly, or through a sub-contractor, provides:**

Installation (in some cases with an additional charge); basic functional troubleshooting (no technical labor) with supplier phone support; and coordination of unit exchange or loaner program for in-factory service.

GE Healthcare arranges for the third-party Product Manufacturer or its dealers to provide in-factory service:

At no charge during the warranty period and at manufacturers or dealer's prevailing service rates outside of the warranty period. Products must be returned to the manufacturer or dealer, at GE Healthcare's expense during warranty and Customer's expense after warranty, for repair.

F **GE Healthcare refers to the Product Manufacturer warranty, which provides the following:**

Basic functional troubleshooting (no technical labor) with supplier phone support and replacement of non-conforming products or parts, which Customer returns to the manufacturer or dealer during the warranty period. ***Note:*** *For detailed warranty information, please refer to the Product Manufacturer's warranty certificate.*

G, J, O and Q **GE Healthcare refers to the Product Manufacturer warranty, which provides the following:**

Start up and commissioning; basic functional troubleshooting (no technical labor) with supplier phone support 24/7; and warranty service to repair, adjust, or replace (at the manufacturer's or dealer's option) non-conforming products or parts (excluding installation, time and material). ***Note:*** *The UPS battery for Service/Warranty Code **G** has a 9-year pro-rated warranty to cover non-conforming material. Start up and commissioning for Service/Warranty Code **O** applies only to 10 KVA and above. The UPS battery for Service/Warranty Codes **O** and **Q** has a 1-year warranty to replace the product. For detailed warranty information, please refer to the Product Manufacturer's warranty certificate. Warranty service for Service/Warranty Codes **G** and **O** is provided On-site. For detailed warranty information, please refer to the Product Manufacturer's warranty certificate.*

H, K, L and M GE Healthcare directly provides the following:

Exchange of non-conforming products, which Customer returns to GE Healthcare during the warranty period. ***Note:*** *Installation, parts, applications training, and on-site service is the Customer's responsibility.*

N, R and S GE Healthcare refers to the Product Manufacturer warranty, which provides the following:

Installation; Preventative Maintenance; and parts and labor. ***Note:*** *Post-warranty service, at manufacturer's prevailing HBS rates, and in some cases, under GE Healthcare service contracts. The battery for Service/Warranty Code R has a 1-year warranty. For detailed warranty information, please refer to the Product Manufacturer's warranty certificate.*

P GE Healthcare directly provides the following:

Replacement of non-conforming components. ***Note:*** *Installation, parts, applications training, and on-site service is the Customer's responsibility.*

T, V and X GE Healthcare directly provides the following:

Replacement of Product only; GE Healthcare will not replace patient records; and product is warranted only for image legibility. ***Note:*** *Installation, parts, applications training, and on-site service is the Customer's responsibility.*

W GE Healthcare directly provides the following:

Replacement of Product only for Out of Box failure. ***Note:*** *Installation, parts, applications training, and on-site service is the Customer's responsibility.*

Y and Z GE Healthcare refers to the Product Manufacturer warranty, which provides the following:

Basic functional troubleshooting (no technical labor) with supplier phone support and replacement of non-conforming components. ***Note:*** *All electrical components (excluding the UPS) for Service/Warranty Code Z have a 1-year warranty. For detailed warranty information, please refer to the Product Manufacturer's warranty certificate.*

ZZ GE Healthcare refers to the Product Manufacturer warranty, which provides the following:

Basic functional troubleshooting (no technical labor) with supplier phone support and replacement of non-conforming components. ***Note:*** *The battery for Service/Warranty Code ZZ has a 2-year warranty for stationary applications and a 6-month warranty for mobile application. For detailed warranty information, please refer to the Product Manufacturer's warranty certificate.*

GE Healthcare

Warranty Statement: GE Brand Specialty Component(s) (Detectors, Probes, X-Ray Tubes and Image Intensifier Tubes) (United States)

This GE Healthcare Warranty Statement: GE Brand Specialty Component(s) (Detectors, Probes, X-Ray Tubes and Image Intensifier Tubes) (United States) supplements and incorporates by reference the GE Healthcare (i) Quotation that identifies the Product offering purchased or licensed by Customer; (ii) Warranties; (iii) Additional Terms and Conditions; (iv) Product Terms and Conditions; and (v) General Terms and Conditions, (collectively, referred to as the "Agreement").

1. **Warranted Products and Scope.** These warranties cover the purchase and use of the GE Healthcare detectors, probes and/or tubes (X-ray, CT, or image intensifier) (hereafter, "Specialty Component(s)") listed in the GE Healthcare Quotation. This warranty statement incorporates GE Healthcare's General Terms and Conditions, and to the extent applicable, (a) GE Healthcare's Product Terms and Conditions, (b) GE Healthcare's Service Terms and Conditions, and/or (c) GE Healthcare's OnDemand Agreement.

GE Healthcare warrants that, starting with the Warranty Commencement Date and for the Warranty Period (each as defined below): (i) the Specialty Component(s) will be free from defects in title, material and workmanship under normal use and service and (ii) except for any Specialty Component(s) manufactured in compliance with Customer's designs or specifications, the Specialty Component(s) will perform substantially in accordance with GE Healthcare's written technical specifications for the Specialty Component(s) (as such specifications exist on the date the Specialty Component(s) is shipped) ("Specialty Component(s) Specifications"). This warranty statement defines GE Healthcare's warranty obligations for both parts and labor and is available only to end-users that purchase the Specialty Component(s) from GE Healthcare or its authorized distributors. The Warranty Period for all warranties, except the warranty of title and the Patent and Copyright Warranty, is limited in time as shown below.

2. **Warranty Commencement Date and Warranty Periods.**

2.1. Determining Warranty Periods For A Specialty Component(s). The Warranty Period start date ("Warranty Commencement Date") for the Specialty Component(s) supplied as part of a new system installation will be the system installation date. The Warranty Commencement Date for a replacement Specialty Component(s) is determined by (i) the date GE Healthcare installs the Specialty Component(s) or (ii) if GE Healthcare is not the installer of the Specialty Component(s), five (5) days after shipment of such Specialty Component(s) by GE Healthcare or its authorized distributor.

Customer shall receive the Full Warranty Period (as set forth in the chart below) in the following situations:

- Specialty Component(s) furnished to Customer as part of a new system installation; or
- Specialty Component(s) purchased by Customer with or without a pro-rata allowance.

For a Specialty Component(s) furnished to Customer under terms of the Full Warranty Period (as set forth in the chart below) the Warranty Period for the replacement Specialty Component(s) will be the unexpired term of the warranty applicable to the last Specialty Component(s) for which Customer paid all or a portion of the cost of that Specialty Component(s). For the sake of clarification, the Warranty Period does not reset for a Specialty Component(s) supplied by GE Healthcare as a replacement under the Full Warranty Period.

This Warranty Statement does not apply to a Specialty Component(s) furnished to Customer under the terms of a GE Healthcare service agreement. For such Specialty Component(s), please refer to the terms and conditions of such service agreement for any Specialty Component(s) warranties.

Customer's failure to (i) properly use the Specialty Component(s), (ii) perform the maintenance described above, (iii) maintain the information required above, (iv) provide the above information or any other information required by this warranty within the designated time periods, or (v) permit GE Healthcare, to verify such information during GE Healthcare's normal working hours will invalidate this warranty.

2.2. Determining Specialty Component(s) Charge For A Replacement Specialty Component(s). Customer will pay the price of the replacement Specialty Component(s) in effect on its delivery date less the applicable Pro Rata Warranty Allowance (if applicable) described in the table that follows. For the purpose of the Pro Rata Warranty Allowance, a fraction of a month less than fifteen (15) days will be disregarded, and a fraction of a month equal to or greater than fifteen (15) days will be regarded as a full month.

3. **Specialty Component(s) Installation.**

3.1. Replacement Specialty Component(s). For a replacement Specialty Component(s), warranty service does not include installation of the replacement Specialty Component(s), but upon Customer's request, GE Healthcare, will install the Specialty Component(s) at GE Healthcare's then-prevailing service rates. If a replacement Specialty Component(s) is not installed by GE Healthcare, Customer must, not later than ten (10) days after its installation date, provide to GE Healthcare in writing: (i) the serial number of the replacement Specialty Component(s), (ii) the location and serial number of the system on which the Specialty Component(s) has been installed, (iii) the date of installation and (iv) for Non-CT Tubes, the exposure counter reading on the installation date.

3.2. New System Specialty Component(s). For a Specialty Component(s) sold with new equipment, no service charges will be billed to Customer for the installation of the replacement Specialty Component(s), so long as replacement occurs between 8:00 a.m. to 5:00 p.m. (local site time), Monday-Friday, excluding GE Healthcare holidays ("Standard Coverage Hours") and subject to the availability of personnel. Services performed outside Standard Coverage Hours will be provided at GE Healthcare's then prevailing hourly billed service rates at the time of service.

4. Remedies. If, within ten (10) days after the Specialty Component(s) failure, Customer (a) notifies GE Healthcare of Customer's warranty claim during the Warranty Period; (b) provides GE Healthcare with the information shown below; and (c) makes the Specialty Component(s) available for service, GE Healthcare will, at its option, either repair, adjust or replace (with new or exchange replacement parts) the non-conforming Specialty Component(s) or parts of the Specialty Component(s). Customer must provide to GE Healthcare in writing (i) the serial number of the Specialty Component(s), (ii) the location and serial number of the system on which the Specialty Component(s) was installed, (iii) the date the Specialty Component(s) failed, and (iv) the date the Specialty Component(s) was removed from service. Warranty service will be performed at the charge, if applicable, as detailed below during GE Healthcare's Standard Coverage Hours and subject to the availability of personnel. Services performed outside Standard Coverage Hours will be provided at GE Healthcare's then-prevailing hourly billed service rates at the time of service. GE Healthcare warrants that its installation or other services will be performed by trained individuals in a professional, workman-like manner. GE Healthcare will promptly re-perform any non-conforming services for no charge as long as Customer provides reasonably prompt written notice to GE Healthcare. The foregoing service remedies, together with any remedy provided herein, are Customer's sole and exclusive remedies (and GE Healthcare's sole and exclusive liability) for warranty claims. These exclusive remedies shall not have failed of their essential purpose (as that term is used in the Uniform Commercial Code) as long as GE Healthcare remains willing to repair or replace defective Specialty Component(s) or re-perform any non-conforming services for no charge, as applicable, within a commercially reasonable time after being notified of Customer's warranty claim. NO OTHER EXPRESS OR IMPLIED WARRANTIES, INCLUDING IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, QUIET ENJOYMENT, SYSTEM INTEGRATION AND DATA ACCURACY, WILL APPLY.

Customer must: (i) use the Specialty Component(s) in accordance with GE Healthcare service instructions and recommendations for the Specialty Component(s) and the system on which it is installed (including warm up and calibration procedures); (ii) perform preventive and corrective maintenance of the Specialty Component(s) utilizing maintenance procedures in accordance with GE Healthcare service instructions and recommendations and using GE Healthcare replacement parts or replacements parts of equivalent quality; and (iii) keep and make available to GE Healthcare, upon request records documenting the above maintenance.

5. Limitations. GE Healthcare shall not have any obligation to Customer hereunder if the warranty claim results from or arises out of: (i) the use of the Specialty Component(s) in combination with any hardware, equipment, supplies, accessories or any other materials or services not furnished by GE Healthcare or recommended in writing by GE Healthcare; (ii) the use of the Specialty Component(s) in a manner or environment, or for any purpose, for which GE Healthcare did not design or manufacture it, or in violation of GE Healthcare's recommendations or instructions on use; or (iii) any alteration, modification or enhancement of the Specialty Component(s) by Customer or any third party not authorized or approved in writing by GE Healthcare. In addition, this warranty does not cover the Specialty Component(s) to the extent it is used in any country other than the country to which GE Healthcare ships the Specialty Component(s) (unless GE Healthcare expressly agrees otherwise in writing).

In addition, these warranties do not cover: (i) any defect or deficiency (including failure to conform to Specialty Component(s) Specifications that results, in whole or in part, from any improper storage or handling, failure to maintain the Specialty Component(s) in the manner described in any applicable instructions or specifications or any cause external to the Specialty Component(s) or beyond GE Healthcare's reasonable control, including, but not limited to, power failure and failure to keep Customer's site clean and free of dust, sand and other particles or debris; (ii) any adjustment, such as alignment, calibration, or other normal preventative maintenance required of Customer; (iii) expendable supply items; and (iv) stockpiling of replacement parts.

With regard to Ultrasound Specialty Component(s) only, these warranties do not cover damage caused by any use that does not conform to OEM guidelines including accidental damage, improper cleaning, disinfecting, over-soaking or TEE bite marks.

6. Warranty Periods.

	New System Specialty Component(s)	Replacement Specialty Component(s)	
TUBE TYPE OR SYSTEM DESCRIPTION (a)	FULL WARRANTY PERIOD (b)	FULL WARRANTY PERIOD (b)	PRO-RATA WARRANTY PERIOD (c)
X-RAY TUBES			
Radiographic	12 months	30 days	24 months
Radiographic & Fluoroscopic	12 months	30 days	24 months
Vascular	12 months	30 days	24 months
Mammographic	12 months	30 days	12 months
Bone Mineral Densitometry	12 months	30 days	12 months
MX150 Vascular	36 months	12 months	N/A
Performix 160A (MX160)	36 months	12 months	N/A
Infinia Hawkeye	12 months	30 days	12 months

	New System Specialty Component(s)	Replacement Specialty Component(s)	
TUBE TYPE OR SYSTEM DESCRIPTION (a)	FULL WARRANTY PERIOD (b)	FULL WARRANTY PERIOD (b)	PRO-RATA WARRANTY PERIOD (c)
IMAGE INTENSIFIER TUBES			
Image Intensifier Tubes	12 months	30 days	24 months
CT TUBES			
CT/e, CT/e Dual	12 months	12 months	N/A
ProSpeed/Sytec 6000-8000	12 months	12 months	N/A
Solarix on LX/I, FX/I, DX/I	12 months	12 months	N/A
Solarix 350 on BrightSpeed Select 4, 8 or 16 (Lite)	12 months	12 months	N/A
Performix Solarix 630 on HiSpeed ZX/I, NX/I Pro	12 months	12 months	N/A
Performix-ADV on HiSpeed CT/I, LightSpeed QX/i	12 months	12 months	N/A
Performix Ultra on LightSpeed 16, LightSpeed Ultra, LightSpeed Plus, LightSpeed QX/I, HiSpeed QX/I, BrightSpeed 16 (Elite), BrightSpeed 8 (Edge), BrightSpeed 4 (Excel), Discovery LS, Discovery ST/STe, Discovery RX 16, Optima PET/CT560, Optima PET/CT560 FX, Discovery PET/CT600, Discovery PET/CT610 (8 or 16 slice), Discovery PET/CT690 Elite, Discovery PET/CT710 (16 slice), Discovery NM/CT670	12 months	12 months	N/A
Performix 40 on Optima CT660 – 32 Slice, Optima CT660 – 64 Slice	12 months	12 months	N/A
Performix Pro80 (D3634T) on LightSpeed Pro 16, LightSpeed RT	12 months	12 months	N/A
Performix Pro VCT100 (D3194T) on LightSpeed Pro16, LightSpeed VCT, LightSpeed VCT Select, LightSpeed RT16, LightSpeed Xtra, Optima CT580 RT, Optima CT580w, Discovery CT590 RT, Discovery VCT, Discovery RX VCT, Discovery PET/CT610 (64 or 128 slice), Discovery PET/CT690, Discovery PET/CT710 (64/128 slice), Discovery NM/CT570c	12 months	12 months	N/A
Performix HD on LightSpeed CT750 HD	12 months	12 months	N/A
Detectors			
Fixed Digital Detectors (XR, Vascular, Mammography)	12 months	12 months	N/A
Wireless & Tethered Digital Detectors	12 months (d)	12 months (d)	N/A
Ultrasound Probes			
New	12 months	12 months	N/A
Refurbished (e)	12 months	12 months	N/A
Purchased Loaner	6 months	6 months	N/A

COMMENTS

(a) For actual catalog numbers, please contact your local GE Healthcare representative.

(b) Initial period of time of use after warranty begins during which a full 100% warranty is provided for a Specialty Component(s) that fails.

(c) Maximum period of time during which a Pro Rata Warranty Allowance is provided for a Specialty Component(s) that fails. The Pro Rata Warranty Allowance is calculated as follows:

$$1 - \frac{\text{Number of months between date of Warranty commencement and date of failure}}{\text{Complete Warranty Time Period}} \times 100\%$$

The Pro Rata Warranty Period ends at the expiration of the maximum time period.

(d) Warranty coverage includes replacement of OEM/manufacturer defects. One (1) replacement due to accidental damage is included within the Warranty Period.

(e) Reconditioning of used equipment for which GE Healthcare has acquired ownership and/or intends to resell after additional processing. These activities include: decontamination, patient data, removal, repairs, installation of applicable updates, and other activities that are described in the existing operation/service manuals applicable to device.

Warranty Statement: Uptime Commitment

GE Healthcare

This GE Healthcare Warranty Statement: Uptime Commitment supplements and incorporates by reference the GE Healthcare (i) Quotation that identifies the Product offering purchased or licensed by Customer; (ii) Warranty(ies); (iii) Additional Terms and Conditions; (iv) Product Terms and Conditions; and (v) General Terms and Conditions, (collectively, referred to as the "Agreement". The following provisions will apply only to eligible diagnostic imaging systems as identified in the Quotation ("Eligible Systems") and only during the warranty period:

1. **Scope**. GE Healthcare will provide Customer with expanded warranty protection for Eligible Systems in consideration of Customer's commitment to provide a broadband network connection to enable GE Healthcare to better provide warranty service for the Eligible Systems during the warranty period.

2. **Eligibility**. To be eligible for this expanded warranty protection, Customer must: (i) establish (if not previously established) and maintain a broadband network connection at Customer's site that connects to the Eligible System, which broadband connection meets GE Healthcare's minimum specifications, (ii) provide GE Healthcare with access to the Eligible System through Customer's broadband network connection and maintain security for Customer's broadband network connection in accordance with appropriate industry best practices, (iii) provide necessary support to maintain such broadband network connection, including designation of a primary Customer contact person, (iv) provide GE Healthcare with at least two (2) business days advance notice of any planned changes to Customer's network that may impact such broadband connection and with notice of any unplanned changes (e.g., power outages, computer viruses, system crashes) to Customer's network that may impact such broadband connection within two (2) business days after the occurrence of the unplanned changes, (v) reasonably cooperate with GE Healthcare in maintaining such broadband connection during all such planned and unplanned changes, and (vi) use reasonable efforts to ensure that Customer's connection to the Internet and LAN systems operate at a maximum of 75% of capacity and have an uptime rate of at least 98%.

3. **Uptime Commitment**. If Customer performs these responsibilities, GE Healthcare will provide Customer, at no additional charge and in addition to other remedies available under GE Healthcare's warranty, an uptime commitment of 97% (95% for all covered nuclear imaging systems and all covered X-ray systems except digital mammography, digital radiographic and vascular X-ray systems), and uptime remedies, as described below.

4. **Definitions**. "Uptime Commitment" means GE Healthcare's commitment on Eligible System uptime during the warranty period, as defined below. "Uptime Remedy" is, in addition to the other remedies specified in the warranty, Customer's sole and exclusive remedy if GE Healthcare fails to meet any Uptime Commitment over a 26-week measurement period during the warranty period. Should the Eligible System fail to achieve the Uptime Commitment as calculated by the Uptime Commitment Calculation, GE Healthcare will provide an extension of Customer's service agreement with GE Healthcare for the Eligible System (or, if Customer has not entered into a service agreement with GE Healthcare, the warranty period for the Eligible System) at no additional charge, as follows:

% < Uptime Commitment	Extension
0	0 weeks
0.1 - 3.0	1 week
3.1 - 8.0	2 weeks
8.1 - 13.0	4 weeks
> 13.0	6 weeks

"Uptime Commitment Calculation" means the calculation used to determine achievement of the Uptime Commitment, as follows: The basis for each measurement period is GE Healthcare's standard warranty service coverage hours of A hours per day, B days per week for 26 weeks, less C hours spent on planned maintenance ("PM") during that interval:

Hours1 = A hours per day X B days per week X 26 weeks
Hours2 = Hours1 - C hours for planned maintenance
Required in-service hours at Customer's % commitment: Hours3 = Hours2 X Customer's %

5. **Eligible System**. An Eligible System will be considered inoperable and out of service under the Uptime Commitment if, due to GE Healthcare's design, manufacturing, material, or service or maintenance performance failure, the Eligible System is unavailable for scanning patients and diagnosing images on the Eligible System display console or operator's console. Peripheral equipment such as remote consoles, magnetic tape drives, hard copy devices, and multi-format and laser cameras are excluded from the terms of the Uptime Commitment. Repair and adjustments required for anything other than Eligible System failure, and damage or inoperability due to any cause other than GE Healthcare's design, manufacturing, material, or service or maintenance performance failure, will be excluded from the Uptime Commitment Calculation, including without limitation damage through misuse, operator error, inadequate environmental or air conditioning protection, power failure, and acts of God. PM time will not be included in the calculation of downtime. If GE Healthcare's responding representative agrees the Eligible System is inoperable due to GE Healthcare's design, manufacturing, material, or service or maintenance performance failure, the Eligible System will be considered out of service from the time the request for service was received by GE Healthcare until the Eligible System is again turned over to Customer for operation. If Customer fails to give GE Healthcare immediate and unencumbered access to the Eligible System or continues to obtain scans after notifying GE Healthcare of any Eligible System failure, the Eligible System will be considered to be in service.

GE Healthcare

Date: 11-02-2015
Quote #: PR5-C53578
Version #: 6

Hartford Hospital
85 Jefferson St
Hartford CT 06106-2601

Attn: Lee Goldman
80 Seymour St Hartford
CT 06102-8000

Customer Number : 1-23LVTQ
Quotation Expiration Date: 11-27-2015

This Agreement (as defined below) is by and between the Customer and the GE Healthcare business ("GE Healthcare"), each as identified herein. "Agreement" is defined as this Quotation and the terms and conditions set forth in either (i) the Governing Agreement identified below or (ii) if no Governing Agreement is identified, the following documents:

1) This Quotation that identifies the Product offerings purchased or licensed by Customer;

2) The following documents, as applicable, if attached to this Quotation: (i) GE Healthcare Warranty(ies); (ii) GE Healthcare Additional Terms and Conditions; (iii) GE Healthcare Product Terms and Conditions; and (iv) GE Healthcare General Terms and Conditions.

In the event of conflict among the foregoing items, the order of precedence is as listed above.

This Quotation is subject to withdrawal by GE Healthcare at any time before acceptance. Customer accepts by signing and returning this Quotation or by otherwise providing evidence of acceptance satisfactory to GE Healthcare. Upon acceptance, this Quotation and the related terms and conditions listed above (or the Governing Agreement, if any) shall constitute the complete and final agreement of the parties relating to the Products identified in this Quotation.

No agreement or understanding, oral or written, in any way purporting to modify this Agreement, whether contained in Customer's purchase order or shipping release forms, or elsewhere, shall be binding unless hereafter agreed to in writing by authorized representatives of both parties.

Governing Agreement:	Premier
Terms of Delivery:	FOB Destination
Billing Terms:	80% on Delivery/ 20% on Acceptance or First Patient Use
Payment Terms:	NET 30
Total Quote Net Selling Price:	$1,745,864.80

INDICATE FORM OF PAYMENT:

If "GE HFS Loan" or "GE HFS Lease" is NOT selected at the time of signature, then you may NOT elect to seek financing with GE Healthcare Financial Services (GE HFS) to fund this arrangement after shipment.

____Cash/Third Party Loan
____GE HFS Lease
____GE HFS Loan
____Third Party Lease (please identify financing company)

By signing below, each party certifies that it (i) has received a complete copy of this Quotation, including the GE Healthcare terms, conditions and warranties, and (ii) has not made any handwritten or electronic modifications. Manual changes or mark-ups on this Agreement (except signatures in the signature blocks and an indication in the form of payment section below) will be void.

Each party has caused this agreement to be executed by its duty authorized representative as of the date set forth below.

CUSTOMER

_____ _____
Authorized Customer Signature Date

_____ _____
Print Name Print Title

_____
Purchase Order Number (if applicable)

GE HEALTHCARE
Michael Wysocki 11-02-2015
Signature Date

Zone Modality Leader-CT

Email: michael.wysocki@ge.com
Office: +1 800 387 6682
Mobile: (781) 686-4691
Fax: (504) 586-8916

GE Healthcare

Date: 11-02-2015
Quote #: PR5-C53578
Version #: 6

Total Quote Selling Price	**$1,745,864.80**
Trade-In and Other Credits	$0.00
Total Quote Net Selling Price	**$1,745,864.80**

To Accept this Quotation

Please sign and return this Quotation together with your Purchase Order To:
Michael Wysocki
Office: +1 800 387 6682
Mobile: (781) 686-4691
Email: michael.wysocki@ge.com
Fax: (504) 586-8916

Payment Instructions

Please **Remit** Payment for invoices associated with this quotation to:
GE Healthcare
P.O. Box 96483
Chicago, IL 60693

To Accept This Quotation

- Please sign the quote and any included attachments (where requested).
- If requested, please indicate, your form of payment.
- If you include the purchase order, please make sure it references the following information
  - The correct Quote number and version number above
  - The correct Remit To information as indicated in "**Payment Instructions**" above
  - The correct SHIP TO site name and address
  - The correct BILL TO site name and address
  - The correct Total Quote Net Selling Price as indicated above

GE Healthcare

Date: 11-02-2015
Quote #: PR5-C53578
Version #: 6

11-02-2015

GPO Agreement Reference Information

Customer:	Lee Goldman
Contract Number:	PLEASE SEE PREMIER CONTRACT # BELOW
Start Date:	
End Date:	09/30/2018
Billing Terms:	80% on Delivery/ 20% on Acceptance or First Patient Use
Payment Terms:	NET 30
Shipping Terms:	FOB Destination

NOTICE REGARDING MAGNETIC RESONANCE ("MR") PRODUCTS. This notice applies only to the following GE Healthcare products: MR: Discovery MR750, Discovery MR750w, Discovery MR450 and Optima MR450w. GE Healthcare has reclassified several advanced software tools and associated documentation to a GE Healthcare Technical Service Technology package that GE Healthcare feels will bring greater value and interest to our customers. GE Healthcare will continue to provide trained Customer employees with access to the GE Healthcare Technical Service Technology package under a separate agreement. GE Healthcare will continue to provide customers and their third party service providers with access to software tools and associated documentation in order to perform basic service on the CT, MR and NM products listed above upon a request for registration for such access. This will allow GE Healthcare to react faster to the future service needs of GE Healthcare customers. If you have any questions, you can contact your sales Service Specialist.

Offer subject to the Terms and Conditions of the applicable Group Purchasing Agreements currently in effect between GE Healthcare and Premier Purchasing Partners, L.P. include PP-IM-270 (MRI).

Qty	Catalog No.	Description
1		**SIGNA Pioneer 3.0T**
1	S7550PD	SIGNA Pioneer 3.0T MR System

The SIGNA Pioneer 3.0T MR system is designed with pioneering technology to maximize your productivity and ROI while delivering unmatched patient comfort, uncompromised clinical performance and streamlined workflow.

This configuration includes the system electronics, operating software, imaging software, post-processing software and RF coil suite:

- 97 channel Total Digital Imaging Receive Technology
- Digital Surround Technology
- Ultra-High Efficiency Gradient System
- Quiet Technology (Acoustic Reduction Technology)
- Auto Protocol Optimization
- Multi-Drive Transmit & PERFORM 2.0
- Computing Platform & DICOM
- Comfort Plus Patient Table
- TDI Coil Suite
- Volume Reconstruction Engine
- Computing Platform and DICOM
- Express 2.0 Workflow
- ScanTools

Total Digital Imaging: The SIGNA Pioneer Total Digital Imaging RF architecture delivers 97 channels standard in every SIGNA Pioneer system. This pioneering technology delivers images with greater clarity and up to 25% increased SNR. TDI has three fundamental components:

- Direct Digital Interface (DDI) employs an independent analog-to-digital converter to digitize inputs from each of 97 RF channels. Every input is captured and every signal digitized to deliver high quality 3.0T images
- Digital Surround Technology (DST) delivers the capability to simultaneously acquire MR signal from the integrated body coil and the surface coil. By combining the digital signal from surface coil elements with the signal from the integrated RF body coil, the superior SNR and sensitivity of the high-density surface coils are combined with the superior homogeneity and deeper signal penetration of the integrated RF Body Coil. This results in richer, higher quality spine and body images.
- Digital Micro Switching (DMS) technology represents a revolutionary advance in RF coil

Qty	Catalog No.	Description

design by replacing analog blocking circuits with advanced Micro Electro-Mechanical System (MEMS) based blocking circuits enabling a coil design that supports ultrafast coil switching times for further expansion of zero TE imaging capabilities.

Ultra High Efficiency Gradient System: The SIGNA Pioneer gradient coil is 2x more efficient than previous gradient coil designs (i.e. the pioneer gradient coil requires half the amount of current required by previous designs to generate the same gradient field). This eco-friendly design enables the gradients to deliver superior performance while significantly reducing power consumption. Further, the SIGNA Pioneer gradient driver includes Intelligent Gradient Control (IGC) technology which employs a digital control system that utilizes predictive models of the electrical and thermal characteristics of the gradient coil to maximize the performance of the gradient system to deliver exceptional clinical performance.

Quiet Technology: The SIGNA Pioneer system features Acoustic Reduction Technology (ART) that delivers an enhanced patient experience by significantly reducing noise levels (up to 99% reduction in sound pressure). Acoustic reduction is achieved through:

- Gradient & RF coil isolation
- Acoustic dampening material
- Vibro-acoustic isolation
- Gradient waveform optimization

RF Transmit Technology: The SIGNA Pioneer integrates an innovative RF transmit architecture designed to enhance overall image uniformity, and a multi-faceted SAR optimization system.

The MultiDrive RF architecture adjusts/optimizes the phase and amplitude of each RF amplifier output channel that is applied to the 4-port drive whole-body RF transmit coil to enhance RF uniformity and signal homogeneity regardless of patient size and body habitus.

PERFORM 2.0 combines RF body coil design, optimized pulse sequences, detailed predictive SAR modeling during prescription, and real-time SAR feedback and correction during scanning to help ensure high performance across all applications, tailored for each patient.

Computing Platform: The Intel Xeon Nehalem Dual Core Processor computing platform utilizes a parallel, multi-processor design to enable simultaneous scanning, reconstruction, filming, post-processing, archiving, and networking. The keyboard assembly integrates an intercom speaker, microphone, volume controls, and emergency stop switch. Start scan, pause scan, stop scan and table advanced to center hot keys are also included.

- 32GB DDR3 Memory
- 3 x 300GB SAS disk subsystem

Qty	Catalog No.	Description

- 24" flat panel LCD with 1920x1200 resolution
- Single tower configuration
- DVD interchange

DICOM: The SIGNA Pioneer generates MR Image, Secondary Capture, Structured Report, and Gray Scale Softcopy Presentation State DICOM objects. The DICOM networking supports both send and query retrieve as well as send with storage commit to integrate with PACS archive. Please refer to the DICOM Compliance Statement for SIGNA Pioneer for further details.

M70012SK (1 unit included in S7550PD) Comfort Plus Patient Table: The SIGNA Pioneer offers a fully integrated Comfort Plus patient table (also known as TDI patient table), which features the embedded TDI Posterior Array, to help improve exam efficiency, and patient comfort. The Comfort Plus patient table can be lowered to very low heights to facilitate transfer of wheelchair patients. The cradle width has also been increased by 30% from previous generations to enable a more comfortable experience for patients.

- Maximum patient weight for scanning: 550 lbs
- Maximum patient weight mobile: 550 lbs
- Maximum patient weight for lift: 550 lbs
- Automated vertical and longitudinal power drive
- Fast longitudinal speed: 17 cm/sec
- Slow longitudinal speed: 1.9 cm/sec
- IntelliTouch & laser land-marking
- Laser alignment land-marking

TDI Coil Suite: The Total Digital Imaging Suite of coils is designed to enhance patient comfort and image quality while simplifying workflow. The Coil Package includes:

- T/R Body Coil
- TDI Posterior Array
- TDI Head Neck Unit
- Anterior Array

M7001KA (1 unit included in S7550PD) The TDI Posterior Array is the first coil to include the Digital Micro Switch. The Integrated Posterior Array is symmetrically positioned within the patient supporting cradle, and coil connection ports are located at both ends of the table. This design enables all components of the TDI Coil Suite to support either patient orientation and enable a more comfortable patient position. The PA is designed to provide optimal element geometry for each targeted anatomy by using different element geometries for the

Qty	Catalog No.	Description

cervical-to-thoracic spine transition, thoracic and lumbar spine, and the body.

- Elements: 32
- Length: 120.5 cm; Width: 48.6cm
- S/I coverage: 113cm head-first or feet-first
- Parallel imaging in all three scan planes
- Head-first or feet-first positioning

The TDI Posterior Array is designed to be used in conjunction with the TDI Head Neck Unit, the 3.0T Anterior Array, and the GEM Flex Coils. The TDI PA is invisible to additional surface coils when they are placed directly on top of the surface.

M7001KD (1 unit included in S7550PD) The TDI HNU consists of 3 imaging components: a head base-plate, an anterior neuro-vascular face-array, and the open face adapter. The open-face design provides a patient-friendly feel. The base plate may be used with the open face adaptor to accommodate cervical spine exams in large or claustrophobic patients or for patients with intubation. Improved access and patient comfort may be achieved through elevation of the superior end of the coil.

- Elements: up to 29 combined with PA and AA
- Length: 53 cm; Width: 35 cm
- Height with NV Array: 35 cm
- Height with Cervical Array: 32.6 cm
- Height with Open Array: 25.9 cm
- S/I coverage: up to 50 cm with PA and AA
- Parallel imaging in all three scan planes

M7001KB (1 unit included in S7550PD) The Anterior Array facilitates chest, abdomen, pelvis, and cardiac imaging. The GEM AA is lightweight, thin and flexible, and pre-formed to conform to the patient's size and shape. With 54 cm of S/I coverage, the GEM AA permits upper abdomen and pelvis imaging without repositioning the coil.

- Elements: up to 36 combined with PA
- Length: 55.6 cm; Width: 67.4 cm
- S/I coverage: 54 cm
- R/L coverage: up to the full 50 cm FOV
- Parallel imaging in all three scan planes
- Head-first or feet-first positioning

Qty	Catalog No.	Description

Express Workflow 2.0: Streamlined workflow on SIGNA Pioneer starts in the magnet room with the dual touch-screen In Room Displays enable interaction with the host computer from the magnet room. The user has direct control or selection of:

- Display of patient name, ID, study description
- Display and entry of patient weight
- Display and entry of patient orientation and position
- Cardiac gating waveform display
- EKG lead confirmation with gating control
- Respiratory waveform display
- IntelliTouch Landmarking
- AutoStart
- Display of coil connection and status
- Display of table location and scan time
- Screen saver

Express Exam enables complete control of protocols for prescription, archiving, searching, and sharing. Protocols are organized into two libraries – GE authored and Site authored – and Protocol Notes allow customized notes to be saved with each protocol. ProtoCopy enables a complete exam protocol, from either a library or previous exam, to be shared with a mouse click, and the Modality Worklist provides an automated method of linking exam and protocol information for a patient directly from a DICOM Worklist server.

The Workflow Manager controls the execution of scan prescription, acquisition, processing, viewing and networking and may automate these steps, when requested by the user. Auto Coil Prescription automatically selects the optimum subset of elements for scanning, and AutoStart automatically starts the first acquisition as soon as the technologist exits the magnet room.

Processing steps are automatically completed with Inline Processing once the data have been reconstructed and the images saved into the database. For certain tasks, the user must accept the results or complete additional steps prior to saving the images. These automatic Inline Processing steps can be saved into the Protocol Library.

Inline Viewing allows the user to conveniently view, compare, and analyze images from the Scan Desktop by selecting the desired series from the Workflow Manager.

ScanTools: The ScanTools clinical package delivers an expansive portfolio of advanced applications, imaging options, and visualization tools packaged with the system operating software to provide extensive clinical capability and enhanced productivity.

Qty	Catalog No.	Description

Advanced Neuro Applications:
- PROPELLER 3.0 motion robust radial FSE
- PROPELLER 3.0 FSE-based diffusion imaging
- Spin Echo & Fast Spin Echo Suites
- T1-FLAIR & T2-FLAIR Suite
- Gradient Echo & Fast GRE Suites
- Spoiled Gradient Echo & Fast SPGR Suites
- Echo Planar, EPI FLAIR & fMRI EPI Suites
- EchoPlus with RTFA diffusion imaging
- DWI Prep for diffusion imaging
- 3D FIESTA & 3D FIESTA-C steady-state imaging
- 3D BRAVO IR-prepped fast SPGR imaging
- 3D COSMIC modified steady-state imaging
- 2D/3D MERGE multi-echo recombined GRE imaging
- PROBE PRESS & STEAM single voxel spectroscopy
- BrainSTAT GVF parametric maps

Advanced Spine & MSK Applications:
- PROPELLER 3.0 motion-robust radial FSE
- Spin Echo & Fast Spin Echo Suites
- Gradient Echo & Fast GRE Suites
- 3D COSMIC modified steady-state imaging
- 2D/3D MERGE multi-echo recombined GRE imaging
- High Bandwidth FSE artifact reduction
- Spectral Spatial Fat Suppression

Advanced Body Applications:
- Auto Navigators pencil-beam diaphragm tracker
- PROPELLER 3.0 motion robust radial FSE
- Spin Echo & Fast Spin Echo Suites
- Gradient Echo & Fast GRE Suites
- 3D LAVA T1 DCE imaging with Turbo ARC
- 2D/3D Dual Echo Fat-Water Imaging

Qty	Catalog No.	Description
		• 3D FRFSE MRCP & HYDRO imaging • Enhanced SSFSE single-shot FSE imaging • 2D FS FIESTA steady-state imaging • Multi-phase DynaPlan • SmartPrep automated bolus detection • Fluoro Trigger real-time bolus monitoring • Respiratory Compensation, Gating & Triggering • iDrivePro & iDrivePro Plus real-time imaging • SPECIAL IR Fat Saturation • Auto Protocol Optimization Advanced Vascular Applications: • Auto Navigators pencil-beam diaphragm tracker • 2D/3D Time-Of-Flight & 2D Gated Time-of-Flight • 2D/3D Phase Contrast & Phase Contrast Cine • SmartPrep automated bolus detection • Fluoro Trigger real-time bolus monitoring • Magnetization Transfer& Flow Compensation • Peripheral & EKG Gating & Triggering • Respiratory Compensation, Gating & Triggering Advanced Cardiac Applications: • Double-Triple IR-FSE with spectral fat suppression • FastCine FGRE-based, gated multi-phase imaging • 2D FIESTA Cine steady-state, gated multi-phase imaging • 3D FS FIESTA steady-state coronary imaging • iDrivePro Plus real-time inter-active imaging • Blood Suppression • Cardiac Navigator diaphragm tracker • Cardiac Compensation, Gating & Triggering • Respiratory Compensation, Gating & Triggering • Cine Paging (128 images/4 windows @ 30fps) Advanced Imaging Tools:

Qty	Catalog No.	Description
		• ARC & Turbo ARC data-based parallel acceleration • ASSET 3.0 image-based parallel acceleration • Real Time Field Adjustment for DWI • DWI Prep for diffusion imaging • Chemical Shift Direction Selection • 2D/3D GradWarp compensation • Acoustic Reduction Technology • IR Prep, DE Prep & T2 Prep • Full Echo Train & Tailored RF • Spectral Spatial Fat Suppression • SPECIAL IR Fat Suppression • ASPIR Fat Suppression • Matrix ZIP 512 & ZIP 1024 • 3D Slice 2X ZIP & 4X ZIP • Square Pixel & Rectangular FOV • No Phase Wrap & No Frequency Wrap • Extended Dynamic Range Advanced Processing & Display: • Inline Viewing & Inline Processing • Image Fusion & Image Pasting • SCIC & PURE surface coil intensity correction • Multi-planar Volume Reformat • Interactive Vascular Reformat • ClariView Image Filtering • Compare Mode & Reference Image • Cine Paging (128 images/4 windows @ 30fps) Advanced FuncTool Analysis: • ADC maps & eADC mapping • Correlation Coefficient analysis • NEI Negative Enhancement Integral analysis • MTE Mean Time To Enhance analysis • Positive Enhancement Integral analysis

Qty	Catalog No.	Description
		• Signal Enhancement Ratio analysis • Maximum Slope Increase analysis • Maximum Difference Function analysis • Difference Function analysis
1	M7001KT	SIGNA Pioneer 3.0T Magnet The SIGNA Pioneer is equipped with GE's most-advanced 3.0T magnet design, a spacious 70cm patient bore with bright inner-bore lighting, 97ch Total Digital Imaging RF architecture and MultiDrive RF transmit technology delivering performance, productivity and exceptional image quality. GE's Wide-Bore Magnet Design: With GE's active shielding technology and space-age composite design, the lightweight 3.0T magnet minimizes weight while preserving homogeneity and minimizing fringe fields. The result is a 3.0T magnet that does not compromise performance yet can be installed almost anywhere. The magnet's high-homogeneity delivers excellent fat-saturation away from iso-center and ensures image quality over a full 50 cm field-of-view. Coupled with its zero-boil off technology and remote magnet monitoring technology, the SIGNA Pioneer 3.0T magnet is designed to provide years of worry-free, reliable, low-cost operation. The SIGNA Pioneer introduces pioneering RF technology called TDI which stands for Total Digital Imaging and delivers imaging with greater clarity and increased SNR by up to 25%. TDI is built on three fundamental components: • GE's Direct Digital Interface (DDI) employs an independent analog-to-digital converter to digitize inputs from each of 97 RF channels. Every input is captured and every signal digitized, literally redefining the concept of an RF channel. Not only does DDI technology improve SNR of our images, but it also works with legacy GE coils for unmatched flexibility. • Digital Surround Technology (DST) combines the digital signal from every coil element with the signal from the integrated RF body coil. The superior SNR and sensitivity of the high-density surface coils are combined with the superior homogeneity and deeper signal penetration of the integrated RF Body Coil resulting in richer, higher quality spine and body images. • Digital Micro Switching (DMS) technology represents a revolutionary advance in RF coil design by replacing analog blocking circuits with intelligent Micro Electro-Mechanical Switches (MEMS) by enabling coil design that supports ultrafast coil switching times for further expansion of zero TE imaging capabilities. Dual In-Room Displays (IRD): By consolidating all controls into one place, the Dual In-Room Displays (IDR) provides real-time feedback to the operator to improve exam room efficiency

Qty	Catalog No.	Description

With an in-room display monitor available at either side of the magnet, the technologist always has all the control he needs at his fingertips, irrespective of which side he is operating from. Further touch-screen capability makes the controls even more intuitive and easy to use. The display provides realtime interaction with the scanner and the host computer. The user has direct control or selection of the following:

- Display of patient name, ID, study description
- Display and entry of patient weight
- Display and entry of patient orientation and patient position
- Cardiac waveform display and ECG/EKG lead confirmation with gating control: trigger select, invert and reset
- Respiratory waveform display
- IntelliTouch technology landmarking
- AutoStart – initiate the scanner to automatically acquire, process, and network images
- Display connected coils and coil status
- Display of table location and scan time remaining
- Screen saver
- Control multiple levels of in-bore ventilation and lighting

Ultra High Efficiency (UHE) Gradient System: The SIGNA Pioneer gradient coil is 2x more efficient than previous generation of products (i.e. the pioneer gradient coil requires half the amount of current required by previous designs to generate the same gradient field). This eco-friendly design enables the gradients to deliver superior performance while significantly reducing power consumption. The gradient is non-resonant and actively shielded to minimize eddy currents and mechanical forces within the system. The gradient coil and the RF body coil are integrated into a single module, which is water and air-cooled for optimum duty-cycle performance and patient comfort. Further, the SIGNA Pioneer gradient driver includes Intelligent Gradient Control (IGC) technology which employs a digital control system that utilizes predictive models of the electrical and thermal charecteristics of the gradient coil to maximize the performance of the gradient system to deliver exceptional clinical performance. Utilizing a unique acoustic barrier material, acoustic noise levels are reduced for enhanced patient comfort without compromising imaging performance.

SIGNA Pioneer MultiDrive RF Whole-Body RF Coil: The SIGNA Pioneer system with GE's MultiDrive RF transmit technology as a standard system feature. This system features a high efficiency 4-port drive RF body coil and independent RF amplitude and phase control to improve RF signal homogeneity across the field of view. The system features a fully automated optimization to adjust the RF settings for each patient to deliver optimal image quality regardless of patient size or shape.

Qty	Catalog No.	Description
1	S7525NZ	Preinstallation Collector The Preinstallation Collector delivers to the site in advance of the magnet and main electronic components. This facilitates the later delivery and installation of supporting electronics. This collector contains the integrated cooling cabinet and the patient comfort and cryo hoses.
1	M70012RF	Concealment Cover Kit The Concealment Cover Kit and the Concealment Frame Kit contain a collection of covers and frames necessary to conceal the cables dropping from the ceiling to the magnet. Their look and feel are aligned with that of system covers for maximum aesthetic appeal.
1	M70012SB	Concealment Frame Kit The Concealment Cover Kit and the Concealment Frame Kit contain a collection of covers and frames necessary to conceal the cables dropping from the ceiling to the magnet. Their look and feel are aligned with that of system covers for maximum aesthetic appeal.
1	M70012LR	Pioneer Scan Room Collector - Long The Scan Room Collector contains a collection of cables such as gradient cables and other materials necessary for system interconnections. The long configuration is designed for room configurations that require a long length based on distance between system components.
1	M70012LT	Pioneer Equipment Room Collector - Long The Equipment Room Collector contains a collection of cables and parts required for interconnections between equipment room system components. The long configuration is designed for room configurations that require a long length based on distance between system components.
1	M70012RP	English Language Kit
1	M7000WL	Main Disconnect Panel The Main Disconnect Panel safeguards the MR system's critical electrical components, by providing complete power distribution and emergency-off control.
1	M1000MW	Operator's Console Table Wide table designed specifically for the color LCD monitor and keyboard.
1	R33002AC	SIGNA Pioneer Standard Service Package

Qty	Catalog No.	Description
1	S7525NE	Silent Expert Package The Silent Expert Package includes a complete set of sequences designed to generate high-resolution images which deliver T1, T2, FLAIR, and PD weighted contrasts. The Silenz imaging sequence delivers 3D isotropic images with T1, PD, and angiographic contrast with sound levels that are within 3dB of the ambient conditions. Newly enhanced gradient waveforms have been employed to minimize the acoustic signature of FSE, 3D Cube, and PROPELLER-based acquisitions to generate T2 and T2 FLAIR weighted images. In addition, the localizer, Prescan, and calibration sequences have been optimized as well to deliver a complete neuro exam at nearly silent levels. Silent Suite also includes a set of protocols including PROPELLER based acquisitions with Diffusion for high resolution brain exams with and without fat suppression. This allows a full exam to be conducted with less than 11 dB(A) from ambient room conditions.
1	S7525NB	MSK Expert Package • IDEAL & FLEX • Cartigram • Cube 2.0 • Cube DIR The IDEAL acquisition and reconstruction methods can generate a water-only, fat-only, in-phase and out-of-phase data sets for clear tissue differentiation in a single series. In addition susceptibility artifacts common to MR imaging such as incomplete or inaccurate fat saturation, and chemical shift can be eliminated as well. The IDEAL application acquires multiple echoes and uses unique reconstruction routines to generate the four image contrasts and correct for errors due to tissue susceptibility. IDEAL is ideally suited for imaging anatomical regions such as the brachial plexus, neck, spine, chest, foot, ankle, and axilla where inhomogeneous magnetic fields may yield failures with traditional fat saturation techniques. IDEAL is compatible with Fast Spin Echo, 3D Gradient Echo and parallel imaging. Cartigram is a non-invasive imaging method for early detection of osteoarthritis. It quantifies the T2 relaxation of knee cartilage and can overlay the quantified parametric maps over high resolution images for clear visualization of the anatomy. The imaging results are color mapped to indicate whether or not the cartilage structure is breaking down and, if so, to what extent. This information can be used to determine the best course of treatment for the individual patient. In addition, it can be used to monitor the cartilage post-treatment, obviating the need

Qty	Catalog No.	Description
		for follow-up arthroscopic surgeries or biopsies. The Cube technology can eliminate multiple independent two-dimensional datasets with a single three-dimensional volume (or cube) of high resolution data to provide better image quality in shorter exam times. Compared to traditional 3D fast spin echo acquisitions, Cube uses a combination of optimized echo train pulses and ARC parallel imaging to reduce SAR, extend the duration of the acquisition echo train, and reduce the echo spacing. The system automatically adjusts the echo train flip angle amplitudes to provide optimized tissue contrast based on the specific tissue T1 and T2 characteristics and prescription parameters. To further reduce exam time and improve image quality, Cube is compatible with ARC self-calibrating parallel imaging. Isotropic Cube datasets may be automatically reformatted from a single acquisition into any plane, without gaps, and with the same resolution as the original plane for improved anatomical review and tissue visualization. The maximum parallel imaging acceleration is dependent upon the surface coil in use. High resolution Cube data can be acquired with T1, T2, T2 FLAIR, or Proton Density weighted tissue contrasts for neuro, abdominal, pelvic, and musculoskeletal imaging. Cube DIR is a 3D volumetric acquisition delivering optimized inversion times to evaluate grey or white matter separately.
1	M7001SE	FOCUS FOCUS delivers a highly efficient method for increasing the resolution in Single Shot DW EPI sequences. The outcome delivers robust high resolution results while removing artifacts typically induced from motion, image backfolding or unsuppressed tissue. In addition, with the higher efficiency of the application, the reduced field of view imaging leads to a reduction in blurring that translates into an overall improvement to the image quality result. The sequence utilizes 2D selective excitation pulses in DW-EPI acquisitions to limit the prescribed phase encoded field of view at both 1.5T and 3.0T field strengths.
1	M7000PF	MAVRIC SL MAVRIC SL is an advanced magnetic resonance imaging technique for imaging soft tissue and bone near MR conditional metallic devices. MAVRIC SL is designed to greatly reduce susceptibility artifacts, compared to conventional fast spin echo techniques, and is suitable for use on all patients cleared for MR exams.
1	M7001KL	3.0T 18-ch TDI T/R Knee Array The 18-channel Knee Array is a transmit/receive coil that produces high resolution images of

Qty	Catalog No.	Description
		the knee and is optimized for parallel imaging in all three directions to reduce acquisition times.
1	M7001KE	3.0T 3-ch Shoulder Array The 3-Channel Shoulder Array takes orthopedic scanning to new performance levels. Designed to fit a large range of patients and optimized for off-center FOV imaging, this shoulder coil delivers homogenous and exquisite image quality.
1	M7000SK	3.0T GEM Flex Suite, Premium - P Connector The GEM Flex Suite is a versatile set of high density 16-channel receive coils designed to give high quality images in a wide range of applications. The high degree of flexibility was achieved by removing all non-essential electronics to an external interface assembly, ensuring reduced weight on the patient and better conformance to the anatomy. The high degree of flexibility is particularly advantageous when imaging patients that do not fit the constraints of rigid coils, improving patient and technologist experience, and enabling most exams to be completed with the same level of image quality expected from dedicated coils. This extended set includes all three sizes of coils, Small, Medium, and Large, and a knee stabilization fixture that is designed for compatibility with the flat GEM table. They cover a broad range of muscular skeletal applications, including hand, wrist, elbow, shoulder, hip (unilateral and bilateral), knee, ankle, and foot. In addition, the coils' versatility has been shown in a range of general purpose applications that include head, neck, and spine exams. This suite of flex coils is compatible with the MR750w + GEM with the flat table top. It is not compatible with the MR750 and MR750w systems configured with the standard curved table top. Includes: • 3.0T GEM Flex Coils - Small, Medium, and Large Arrays. • 3.0T GEM Flex Interface Module 16-channel Fixed, P-Connector. • GEM Flex Knee Stabilization fixture for flat table. • GEM Flex GP Strap and Interface Module Cover. • GEM Flex Cable Take-up Pad and General Purpose Stabilization Pad.
1	M7005BE	Flex Positioner The Flex Positioner is a multipurpose support for a broad range of exams including foot, ankle, forefoot, knee, and head. A dedicated forefoot attachment allows the flex array elements to be wrapped tightly around the foot, yielding improved image quality. A repositionable support pad in the foot and ankle attachment allows for selection of a 90 degree position, or a relaxed position of the ankle. The pads and straps included with the stabilizer facilitate rapid setup and allow for flexibility in how the anatomy is secured.

Qty	Catalog No.	Description
1	E8912CA	GE Optima MR450w/Pioneer Heat Exchangers - 49kW (20Tons)

Cooling for your GE Healthcare MR system has never been so easy. GE Healthcare has partnered with the Glen Dimplex Group, a world leader in cooling systems, to offer heat exchangers designed to meet the needs of your Discovery MR System. Now you can look to GE Healthcare for your entire MR purchase and support.

This heat exchanger is highly reliable and the only unit verified to perform with the new platform of GE Healthcare MR systems. As part of your integrated GE Healthcare solution, you'll work with a single contact throughout the whole installation. A Project Manager of Installation will help with building layout, room designs, delivery and installation - every step until your system is ready to scan. Our team will work seamlessly with architects, contractors and your internal team to help ensure timely, cost-effective completion.

Once your cooling system is running, you'll get fast, highly-skilled service support managed through GE Healthcare - with the same quality and response time you expect from your MR system.

FEATURES AND BENEFITS

- Designed to provide stable fully dedicated cooling for your MR system's needs
- Water/glycol outdoor-air-cooled heat exchangers to support your highest exam volumes and your full range of diagnostic procedures
- Redundant fluid pumps with automatic switchover let you keep operating with no loss of cooling even if one pump goes down
- Quad compressor, dual tandem refrigeration circuit design saves on energy while your system smoothly transitions through the 10% to 100% heat load capacity cycles of patient scanning and idling
- Quiet operation between patient exams and overnight - ideal for facilities in residential areas
- Comes with installation support, installation visits, preventative maintenance visit and 1 full year of parts and labor warranty
- Installation support includes: support through GE's Project Manager of Install, GE's Design Center, technical support from the Glen Dimplex company, two (2) installation visits
- Comprehensive and quality service rapidly delivered through our CARES service solution
- 65 gallons of 100% glycol concentrate for complete system filling and diluting
- Wall mounted remote display panel provides the ability to monitor the system's operation and indicates possible system errors
- Filter kit with flow meter helps to ensure purity of water prior to entry to the MR system
- Highly recommended that Vibration Isolation Spring Kit (E8911CJ) be added for systems that will be roof top mounted

Qty	Catalog No.	Description
		SPECIFICATIONS • Net Cooling Capacity: 49 kW / 20 Ton • Maximum Coolant Flow: 35 gpm (132 l/m) • Coolant Outlet Temperature: 48 F (8.9 C) • Coolant Temp Stability: E 1.8 F (E1.0 C) • Max Coolant Pressure : 70 Psi (4.8 Bar) • Refrigerant: R407C • Ambient Temp Range: -20 to 120 F (-30 to 50 C) • Condenser Air Flow (Approx): 18,000 Cfm • Tank Capacity: 100 gal (378 l) • Flow Meter Range: 4-40 gpm • Filters: 50 micron cartridge filters • Supply Voltage: 460v / 3 phase / 60 Hz • Coolant Connections: 2" NPTF • Overall Size (L x W x H) 44" x 136" x 84.5" COMPATIBILITY: • GE MR450w or Pioneer MR System NOTES: • Item is NON-RETURNABLE and NON-REFUNDABLE
1	E4504FM	700 VA Partial System UPS - MR Tested with all MR system computers, the 700VA Partial System UPS provides reliable, clean, consistent power for the data processing portion of the MR imaging system. The use of the double conversion UPS enables the MR system data processing portion electronics to operate when there is a power anomaly or total power loss. Valuable data and the system operating software are protected, if there is an extended outage the UPS allows for an orderly shutdown of the system. FEATURES/BENEFITS • True double-conversion, online technology provides reliable operation and uninterrupted glitch free power • Automatic frequency selection eases startup, i.e., 50 or 60 Hz compatible • Integral Electronic Static Bypass switch means zero transfer time • Improves user productivity, system reliability, reduces service costs and increases system uptime

Qty	Catalog No.	Description
		• Advanced Battery Management (ABM) software monitors / indicates battery health and improves battery service life SPECIFICATIONS • Dimensions (H x W x D): 9.09" x 6.3" x 13.9" • Weight: 26 lbs. • Input Voltage Range: Single Phase 80-138 V • Input Frequency Range: 47-70 Hz • Rating: 700 VA / 630 W COMPATIBILITY • MR Systems NOTES • This is a partial system UPS - it covers only the computer, not the entire MR imaging system. After a power event portions of the system will have to be reset before operation can resume • Customer is responsible for rigging and arranging for installation with a certified electrician • ITEM IS NON-RETURNABLE AND NON-REFUNDABLE
1	E8803BE	Physician's Chair with Padded Arms Physician's chair has padded arms for comfort and comes in a charcoal gray color that blends with any environment. Chair adjusts from 16.75 in. to 21 in. (42.5 cm x 53.3cm) and is only for use in the MR Control Room. Weighs 45 lbs.
1	E8823A	MR Coated Patient Positioning Accessories Kit MR accessories kit consists of a complete set of coated positioning pads in a lightweight tote case that can be a permanent fixture in an MR suite or can be easily carried from room to room. Also provides storage area for other accessories such as earplugs, electrodes, and film leads. The following pads are included: 1 knee rest, 1 knee coil insert, 1 extremity rest, 4 segment table pads, 4 body wedges, 4 rectangle stack pads, and 2 rectangle elbow pads. Sold per kit, but replacement pads can be ordered under separate part numbers...H NOTE: • This item is not compatible with the GEM patient table
1	W0105MR	TiP Discovery and Optima Family Succeed Advance This program is designed for CURRENT GE customers WITH HD/HDx experience who purchase

Qty	Catalog No.	Description
		the Discovery or Optima system. Program content focuses on features and differences between HD/HDx and Discovery or Optima. Blended content delivery and design promotes learner retention and more efficient and effective advanced skill development. Extended TVA support ensures learners maintain performance over the long term. • 1 Discovery or Optima HQ Class/session (One class is equivalent to one session.) • 17 onsite days • 4 hours TVA This training program must be scheduled and completed within 24 months after the date of product delivery.
1		**NonProducts**
1		Rigging of 3T into facility at $20,000.

Quote Summary:

Total Quote Net Selling Price **$1,745,864.80**

(Quoted prices do not reflect state and local taxes if applicable. Total Net Selling Price Includes Trade In allowance, if applicable.)

GE Healthcare

Date: 11-02-2015
Quote #: PR5-C53578
Version #: 6

Options

(These items are not included in the total quotation amount)

Qty	Catalog No.	Description	Ext Sell Price	
1	S7525NA	Enhanced Productivity Expert Package • Ready Brain • CUBE 2.0 • Cube DIR • BrainStat AIF • QuickStep	$55,800.00	X_____

Ready Brain automates scan prescription for brain exams, improving precision, repeatability and workflow. The steps involved are (A) Whole brain localizer with 3D slabs (B) Automatic detection of mid sagittal plane (C) 2D-registration of mid sagittal plane to high quality reference image (D) Computer transformations for standard axial, sagittal and coronal views and (E) Prescribe views to GRx and scan automatically.

The Cube technology can eliminate multiple independent two-dimensional datasets with a single three-dimensional volume (or cube) of high resolution data to provide better image quality in shorter exam times. Compared to traditional 3D fast spin echo acquisitions, Cube uses a combination of optimized echo train pulses and ARC parallel imaging to reduce SAR, extend the duration of the acquisition echo train, and reduce the echo spacing. The system automatically adjusts the echo train flip angle amplitudes to provide optimized tissue contrast based on the specific tissue T1 and T2 characteristics and prescription parameters. To further reduce exam time and improve image quality, Cube is compatible with ARC self-calibrating parallel imaging.

Isotropic Cube datasets may be automatically reformatted from a single acquisition into any plane, without gaps, and with the same resolution as the original plane for improved anatomical review and tissue visualization. The maximum parallel imaging acceleration is dependent upon the surface coil in use. High resolution Cube data can be acquired with T1,

Qty	Catalog No.	Description	Ext Sell Price	
		T2, T2 FLAIR, or Proton Density weighted tissue contrasts for neuro, abdominal, pelvic, and musculoskeletal imaging. Cube DIR is a 3D volumetric acquisition delivering optimized inversion times to evaluate grey or white matter separately. BrainStat is a standard post processing application that automatically generates parametric maps for neuro Blood Flow, Blood Volume, Mean Transit Time, and Time to Peak signal intensity. A Gamma Variant fitting algorithm is deployed to automatically estimate the values for the four parametric maps. The maps may be saved in DICOM format and fused with high-resolution anatomic datasets to visualization of tissue and anatomy. BrainStat AIF enables the user to automatically, or manually specify the arterial-input function (AIF) based on the temporal form of the signal, to provide normalized Blood Flow, Blood Volume, Mean Transit Time, and Time to Peak signal intensity maps based on the patients vascular flow dynamics. QuickStep is an automated multi-station acquisition for the evaluation of the vascular tree. This unique application automatically prescribes, acquires, and combines images from multiple stations for fast acquisition and exam completion. To complete the entire exam in as little as 6 minutes, the system will automatically acquire mask datasets from multiple stations without any user intervention. Secondary images are then acquired at the same independent table positions. The system will automatically subtract the mask images from the secondary dataset and combine the resulting images from the multiple stations into one series. The user only needs to complete a review and approval of the data prior to insertion of images into the database.		
1	S7024CB	Neuro Expert Package • eDWI • SWAN • DTI • FiberTrak	$37,980.00	X_____

Qty	Catalog No.	Description	Ext Sell Price	
		The eDWI application includes the acquisition sequence and post-processing tools. It is designed to provide high signal-to-noise-ratio diffusion images of the brain and liver with short-acquisition time. Its multi-B feature is designed to provide measurement of apparent diffusion coefficient (ADC) map with reduced effect of perfusion. In addition, "3 in 1" B value combining technique, applies diffusion weighting to all three gradients simultaneously, helping improve sensitivity. Its smart NEX feature significantly reduces the acquisition time. Inversion recovery has been deployed to provide robust fat suppression. SWAN is a volumetric 3D acquisition technique that is sensitive to differences in susceptibility between different tissues. This technique acquires multiple-echoes at different echo times to highlight regions with increased T2* (susceptibility-induced) decay. Utilizing multiple-echoes, SWAN generates images with higher SNR when compared with similar techniques that rely on a single echo. Diffusion Tensor Imaging (DTI) creates contrast based on the degree of diffusion anisotropy in cerebral tissues such as white matter. The DTI method expands Echo planar imaging capability to include diffusion imaging sequence using motion sensing gradient pulses along 6 to 155 orientations in order to generate tensor component images. With the Express Workflow, fractional anisotropy (FA) and Volume Ratio Anisotropy (VRA) maps may be automatically created after image acquisition without any user intervention. FiberTrak is a host computer post processing tool expands the capability of Diffusion Tensor imaging by generation of 2D color orientation maps, 2D eigenvector maps, and 3D tractography maps from the diffusion tensor image data. The resulting datasets may be easily saved and archived for later use.		
1	S7525NC	Body Expert Package	$70,200.00	X_____
		• IDEAL & Flex • IDEAL IQ		

Qty	Catalog No.	Description	Ext Sell Price

• StarMap

• eDWI

The IDEAL acquisition and reconstruction methods can generate a water-only, fat-only, in-phase and out-of-phase data sets for clear tissue differentiation in a single series. In addition susceptibility artifacts common to MR imaging such as incomplete or inaccurate fat saturation, and chemical shift can be eliminated as well. The IDEAL application acquires multiple echoes and uses unique reconstruction routines to generate the four image contrasts and correct for errors due to tissue susceptibility. IDEAL is ideally suited for imaging anatomical regions such as the brachial plexus, neck, spine, chest, foot, ankle, and axilla where inhomogeneous magnetic fields may yield failures with traditional fat saturation techniques. IDEAL is compatible with Fast Spin Echo, 3D Gradient Echo and parallel imaging.

For fast T1w multi-phase imaging of the abdomen and pelvis, LAVA Flex acquisition uses 2D ARC parallel imaging to reduce artifacts from breath hold misregistration and incorrect FOV placement while providing up to four types of T1w-based tissue contrasts: water-only, fat-only, in-phase and out-of-phase.

IDEAL IQ is an acquisition and reconstruction software package that generates water and fat images, relative fat concentration, and R2* relaxation maps. This technique builds upon GE's IDEAL (Iterative Decomposition of water and fat with Echo Asymmetry and Least-squares estimation) technology by incorporating a fast, volumetric multi-echo imaging sequence and an enhanced reconstruction algorithm to improve the visualization of regional fat deposits in-vivo.

IDEAL IQ incorporates the following features and functionality:

• A fast, multi-echo 3D gradient echo imaging sequence to generate volumetric data.

• Parallel imaging to improve acquisition speed and allow breath hold acquisitions.

Qty	Catalog No.	Description	Ext Sell Price

• A low flip angle excitation scheme to reduce T1 bias in the fat, water, and fat fraction maps.

• Multi-echo reconstruction processing to calculate R2* decay rate maps.

• Magnitude fitting to reduce the influence of phase errors due to system imperfections.

• A multi-peak fat model to account for the multiple resonant peaks of fat.

• Fully automated, generation and storage of R2* corrected fat and water maps, fat fraction maps, and R2* maps from the data acquired.

The IDEAL IQ reconstruction generates R2* corrected fat and water maps as well as an R2* map depicting the signal decay at each voxel in the image. Water and fat images produce the fat fraction map, a relative measure of the quantity of fat to total signal (water and fat signal combined) at each voxel in the image. The fat fraction image is scaled such that a full-scale value represents a voxel containing only fat while a value of zero represents no fat in that voxel.

StarMap enables the acquisition of multiple gradient echo images at each 2D slice at a range of echo-times. The resultant images can be processed using FuncTool to provide T2* maps within the anatomy of interest.

The eDWI application includes the acquisition sequence and post-processing tools. It is designed to provide high signal-to-noise-ratio diffusion images of the brain and liver with short-acquisition time. Its multi-B feature is designed to provide measurement of apparent diffusion coefficient (ADC) map with reduced effect of perfusion. In addition, "3 in 1" B value combining technique, applies diffusion weighting to all three gradients simultaneously, helping improve sensitivity. Built in tetrahedral feature applies four different diffusion weighing combinations of x, y, and z gradients simultaneously to acquire isotropic diffusion weighted images with high signal to noise ratio and shorter TE. Its smart NEX feature significantly reduces the acquisition time. Inversion recovery

Qty	Catalog No.	Description	Ext Sell Price	
		has been deployed to provide robust fat suppression.		
1	S7525ND	Breast Expert Package • VIBRANT • 8-channel Breast Array VIBRANT (Volume Imaged BReast AssessmeNT) is a fast, high resolution T1 weighted imaging sequence and application optimized for evaluation of breast tissue. VIBRANT uses GE exclusive technology and parallel imaging acceleration to quickly acquire multi-phase data without compromising spatial resolution. This 3D gradient echo technique, optimized for sagittal or axial acquisitions, uses an optimized inversion pulse and dual-shimming technology that yields enhanced image contrast and robust, uniform, bilateral fat suppression. Auto subtraction of the first dataset is also available to further background suppression. For enhanced speed, VIBRANT is compatible with both ASSET and ARC parallel imaging with acceleration factors up to four. As a result, VIBRANT enables reliable, high quality breast imaging. For improved tissue contrast, VIBRANT is compatible with Flex imaging (sold separately). VIBRANT Flex acquisition will provide a water-only, fat-only, in-phase and out of phase data sets in a single acquisition and produce images with significantly reduced chemical shift and susceptibility artifacts. This is critical for evaluation of the axilla and chest wall. The 8-channel Breast Array generates high-definition MR breast images on 3.0T MR systems. Optimized for use with ASSET and VIBRANT for up to 3X acceleration, this 8-element phased-array coil helps ensure excellent temporal and spatial resolution, patient after patient. The array is also compatible with Fast Spin Echo, Fast Gradient Echo, and Diffusion Imaging sequences. It provides uncompromised lateral and medial access. This collector contains a set of MR compatible biopsy grids that are compatible with this coil.	$46,800.00	X_____
1	S7024CK	Vascular Expert Package • Inhance Suite 2.0	$54,288.00	X_____

Qty	Catalog No.	Description	Ext Sell Price

- TRICKS
- Flow Analysis

The Inhance Suite application consists of several sequences designed to provide high-resolution images of the vasculature with short-acquisition times and excellent vessel detail. These sequences include: Inhance Inflow IR: Inhance Inflow IR is an angiographic method, which has been developed to image renal arteries with ability to suppress static background tissue and venous flow. This sequence is based on 3D FIESTA, which improves SNR, as well as produce bright blood images.

Inhance 3D Velocity: Inhance 3D Velocity is designed to acquire angiography images in brain and renal arteries with excellent background suppression in a short scan time. By combining a volumetric 3D phase contrast acquisition with parallel imaging, efficient k-space traversal, and pulse sequence optimization, Inhance 3D Velocity is capable of obtaining complete Neurovascular imaging in 5-6 minutes.

Inhance 3D Deltaflow is a 3D non-contrast enhanced MRA application for peripheral arterial imaging. Inhance 3D Deltaflow is based on the 3D Fast Spin Echo technique and it utilizes the systolic and diastolic flow differences to help generate arterial signal contrast. A subtraction of the systolic phase from the diastolic phase images results in arterial only images, with venous and background suppression.

Inhance 2D Inflow: The Inhance 2D Inflow pulse sequence is designed to acquire angiography images of arteries, which follow almost a straight path, i.e. femoral, popliteal, carotid arteries, etc.

TRICKS provides high resolution multi-phase 3D volumes of any anatomy for fast accurate visualization of the vasculature. With segmented complex data recombination, TRICKS can accelerate 3D dynamic vascular imaging without compromising spatial detail. TRICKS also uses elliptic centric data collection for optimized contrast resolution and auto-subtraction for optimized background suppression. The result is time course imaging that does not require timing or triggering, provides high temporal and high spatial resolution, and enables the extraction of optimum phases of data. As a

Qty	Catalog No.	Description	Ext Sell Price	
		result, TRICKS enables reliable, high quality vascular imaging. Flow Analysis automates the review and analysis of gated phase contrast magnetic resonance (MR) images and generates a report for the referring physician. This version is available on the host computer. Flow Analysis has an automated edge detection algorithm that propagates through all the phases of the cine phase contrast series. The flow analysis measurement tab displays a summary chart of peak velocities in addition to individual velocity results from each phase of the cardiac cycle. A background correction may also be applied which is particularly suited to slow flowing fluid such as cerebrospinal fluid. Customizable Macros are a feature of Flow Analysis 4.0. These Marcos allow the user to quickly write a report specific to the patient being assessed with simple mouse clicks. The macros are customizable to reflect the language used by the reporting physician. Flow Analysis offers the capability to archive reports or cine images as seen in a DICOM format so they may be viewed on any DICOM viewer.		
1	S7525CH	Cardiac Expert Package • 2D and PS-MDE (not compatible with ReportCard 4.0) • MDE+ • Cine IR • Blackblood SSFSE • FGRE Time Course 2D MDE combines a Fast Gradient Echo pulse sequence with an inversion pulse and cardiac gating to enable delayed enhancement imaging of the heart. The technique uses an IR preparation pulse with an inversion time (TI) typically selected to differentiate normal from enhancing myocardial tissue. Image data are collected in a 2D slice mode. Phase-sensitive myocardial delayed enhancement (PS-MDE) is	$36,000.00	X_____

Qty	Catalog No.	Description	Ext Sell Price

a variation of 2D MDE that uses a phase-sensitive inversion recovery reconstruction technique that can improve contrast between tissues with reduced dependency on the user-selected inversion time (TI) compared to conventional magnitude reconstruction.

MDE+ provides a B1 insensitive inversion pulse to improve the uniformity of the signal for MDE acquisitions. Additionally improved performance for delayed enhancement is introduced through utilization of a fat suppression pulse integrated into the MDE acquisition.

Cine IR is used for approximating the myocardial null point for a subsequent myocardial viability assessment with delayed enhancement (MDE) techniques. Cine IR is a conventional ECG-gated, gradient-recalled echo FastCard or FastCine acquisition sequence with a multi-phase readout and an inversion recovery (IR) preparation. A single adiabatic inversion pulse is generated upon detection of the cardiac R-wave to trigger the multi-phase readout. Multi-phase images are generated within the cardiac cycle, each at a progressively longer TI time.

Black Blood SSFSE is available for either dual or triple inversion pre-pulse single shot FSE based acquisition utilized for morphological imaging of the heart and vessels. The use of inversion pre-pulses allow for nulling of the blood pool for improved visualization of vessels and heart structures. Utilization of single shot acquisitions allows for single breath hold multi-slice coverage which leads to larger volume coverage in fewer breath holds for patient tolerance as well as reduction of overall exam times.

Fast Gradient Recalled Echo Time Course utilizes single-echo acquisition to reduce sensitivity to echo mis-alignment or system calibration variations, resulting in robust image quality with ghosting and artifact reduction. ASSET parallel imaging and shortened RF pulse design are incorporated to improve temporal resolution and reduce motion related artifacts. In addition to selective notch pulse, it also supports non-selective

Qty	Catalog No.	Description	Ext Sell Price	
		saturation pulse for excellent background suppression and multi-plane imaging capability.		
1	S7024CY	Cardiac Elite Package	$55,800.00	X_____

- 3D Heart
- MR Echo
- Tagging

3D Heart is a 3D Fat Sat FIESTA sequence (Optimized for 1.5T) or 3D IRPrep FGRE sequence (Optimized for 3T) that provides whole-heart coverage for coronary artery imaging or cardiac chamber imaging. It employs a T2 preparation pulse at 1.5T to provide myocardial suppression for better coronary visualization. A multi-slab localizer allows easy whole-heart prescription, and increase inflow effect for high vessel conspicuity. A navigator echo pulse that detects motion of the diaphragm is utilized to enable free breathing acquisition. The navigator has been optimized to improve robustness, and employs prospective real-time motion correction to improve motion suppression and increase scan efficiency.

As this sequence supports 3D IRPrep FGRE acquisition mode on both 1.5T and 3T, it can also be used for 3D MDE acquisition. With the purchase of 3D Heart, three additional options (3D MDE, Cine IR and Cardiac Navigator) are included.

MR Echo is a dedicated Cardiac MR interface that eases cardiac workflow and combines leading edge pulse sequences used specifically in cardiac imaging. It includes the following:

- 2D FIESTA imaging for cardiac wall motion visualization both in classic gated mode and with a real-time ability that needs no gating nor patient breath-holding. The real time imaging combines the resolution of MRI with the ease of use of Echocardiography and hence the product name MR Echo. FIESTA combined with parallel imaging permits acquisition times of approximately 50ms, which results in 20 frames/second in the real time mode.
- Time Course imaging includes two pulse sequences to visualize the myocardial tissue at a single phase over a period of time. The first of these is an FGRE pulse sequence which uses a notched saturation pulse to

Qty	Catalog No.	Description	Ext Sell Price	
		maximize contrast to noise ratio. The second is a FIESTA base time course technique, which permits time course imaging in multiple planes simultaneously. • Myocardial Evaluation, within the MR Echo interface, allows scar tissue assessment of the heart. With Cardiac Tagging, an even distribution of spatial saturation lines are applied across the myocardium in the FastCINE Gradient Echo pulse sequence to enable cardiac wall motion assessment. Tagging allows the application of 1D diagonal stripes or 2D grid saturation pulses once per R-R interval immediately following the R-wave trigger. Resulting images demonstrate motion (or lack of motion) effects.		
1	M7001SL	3D PROMO 3D PROMO provides a real time 3D navigator based motion correction algorithm correcting for the six rigid body terms where re-acquisition of severely corrupted data provides robust, high quality, motion free, 3D outcomes. 3D PROMO is compatible with both T2 and T2 FLAIR Cube acquisitions.	$16,800.00	X_____
1	M7000JC	3D ASL (Arterial Spin Labeling) 3D ASL utilizes water in arterial blood as an endogenous contrast media to help visualize tissue perfusion and provide quantitative assessment of cerebral blood flow (CBF) in ml/100 g/min. The quantitative CBF maps can be generated and stored in DICOM format. 3D ASL deploys stacked spiral FSE readout with modulated flip angle to acquire 3D data with increased SNR and less image distortion compared to conventional 2D EPI-based ASL techniques. A pulsed-continuous labeling is applied to label arterial blood close to the imaging volume thus improving conspicuity of flowing blood. Selective, interwoven pulses are then used to saturate and invert the imaging volume, in order to achieve better background suppression, and reduce sensitivity to motion. The isotropic 3D volume data can be reformatted to axial, sagittal, coronal or oblique planes. 3D ASL helps generate robust, reproducible images and perfusion maps with high SNR, reduced motion artifacts and	$48,000.00	X_____

GE Healthcare

Date: 11-02-2015
Quote #: PR5-C53578
Version #: 6

Qty	Catalog No.	Description	Ext Sell Price	
		less distortion in high magnetic susceptibility regions.		
1	M7005DB	DISCO DISCO provides highly accelerated LAVA FLEX based volumetric imaging for high resolution 3D volumetric results without compromising temporal imaging performance, and delivering 1.5mm isotropic results of whole organ coverage in as low as 5 seconds. DISCO utilizes a 2point DIXON method to increase the robustness of the technique.	$43,200.00	X_____
1	E8804SB	Medrad Spectris Solaris EP MR Injection System Medrad Spectris Solaris EP MR injector for use use in all MR scanner field strengths up to and including 3.0T. Optimized touch-screen for fewer keystrokes, KVO (keep vein open) allows patient to be prepared before beginning the scan. Larger 115 ml saline syringe for longer KVO or multiple flushes. Includes cables and starter kit...E NOTE: GE is responsible for unpacking, assembly, and installation of equipment. Medrad will be available for technical assistance by phone at (412)767-2400. An additional charge will apply for on-site installation assistance. Medrad will be responsible for operational checkout, final calibration, in-service of the equipment, and initial applications training. Please contact the local Medrad office two weeks in advance of installation.	$39,500.00	X_____

(Quoted prices do not reflect state and local taxes if applicable. Total Net Selling Price Includes Trade In allowance, if applicable.)

General Terms and Conditions

GE Healthcare

These GE Healthcare General Terms and Conditions supplement and incorporate by reference the GE Healthcare Quotation that identifies the Product and/or Service offering purchased or licensed by Customer and the following documents, as applicable, if attached to or referenced in the Quotation: the GE Healthcare (i) Warranty(ies); (ii) Additional Terms and Conditions or Statement of Service Deliverables and Product Schedule; and (iii) Product or Service Terms and Conditions, (collectively, referred to as the "Agreement").

References herein to "Products" and "Services" mean the Products (including equipment and software) and Services identified on the applicable GE Healthcare Quotation. References herein to "Healthcare IT Products" are (i) those software products identified in the Quotation as a "Centricity" product, any third party software licensed for use in connection with the Centricity software, all hardware used to operate the Centricity or the third party software, and services provided with respect to the implementation, installation or support and maintenance of the Centricity or the third party software, and/or (ii) any software, product or service that is included in a Quotation which Quotation is designated as an "Healthcare IT Quotation".

1. General Terms.

1.1. Confidentiality. Each party will treat the terms of this Agreement and the other party's written, proprietary business information as confidential if marked as confidential or proprietary. Customer will treat GE Healthcare's (and GE Healthcare's third party vendors') software and technical information as confidential information whether or not marked as confidential and shall not use or disclose to any third parties any such confidential information except as specifically permitted in this Agreement or as required by law (with reasonable prior notice to GE Healthcare) or as is required by the U.S. Federal government in its capacity as a customer. The receiving party shall have no obligation with respect to any information which (i) is or becomes within the public domain through no act of the receiving party in breach of this Agreement, (ii) was in the possession of the receiving party prior to its disclosure or transfer and the receiving party can so prove, (iii) is independently developed by the receiving party and the receiving party can so prove, or (iv) is received from another source without any restriction on use or disclosure. GE Healthcare understands that Customer may be subject to State Open Records laws. Customer shall not be prohibited from complying with such Open Records laws if required to do so; however, Customer shall (a) promptly notify GE Healthcare in writing of any such Open Records laws requests, (b) give GE Healthcare sufficient time to challenge the request or redact any necessary information to the extent permitted by law, and (c) only provide such information as is necessary to comply with such Open Records laws.

1.2. Governing Law. The law of the State where the Product is installed or the Service is provided will govern this Agreement.

1.3. Force Majeure. Neither party is liable for delays or failures in performance (other than payment obligations) under this Agreement due to a cause beyond its reasonable control. In the event of such delay, the time for performance shall be extended as reasonably necessary to enable performance.

1.4. Assignment; Use of Subcontractors. Neither party may assign any of its rights or obligations under this Agreement without the prior written consent of the other party, which consent shall not be unreasonably withheld; provided, however, that either party may transfer and assign this Agreement without the other party's consent to any person or entity (except to a GE Healthcare competitor) that is an affiliate of such party or that acquires substantially all of the stock or assets of such party's applicable business if any such assignee agrees, in writing, to be bound by the terms of this Agreement, including the payment of any existing or outstanding fees and invoices. Subject to such limitation, this Agreement shall be binding upon and inure to the benefit of the parties and their respective successors and permitted assigns. This Agreement shall not be terminable in the event of any Customer stock or asset sale, merger, acquisition or change in control, unless otherwise expressly agreed to in writing by GE Healthcare. GE Healthcare may hire subcontractors to perform work under this Agreement (including, but not limited to, work that involves access to Protected Health Information as such term is defined in 45 C.F.R. § 160.103 ["PHI"]), provided that GE Healthcare will at all times remain responsible for the performance of its obligations and duties under this Agreement.

1.5. Amendment; Waiver; Survival. This Agreement may be amended only in writing signed by both parties. Any failure to enforce any provision of this Agreement is not a waiver of that provision or of either party's right to later enforce each and every provision. The terms of this Agreement that by their nature are intended to survive its expiration (such as the confidentiality provisions included herein) will continue in full force and effect after its expiration.

1.6. Termination. If either party materially breaches this Agreement and the other party seeks to terminate this Agreement for such breach, such other party shall notify the breaching party in writing, setting out the breach, and the breaching party will have sixty (60) days following receipt of such notice to remedy the breach. If the breaching party fails to remedy the breach during that period, the other party may terminate this Agreement by written notice to the breaching party. If GE Healthcare determines in good faith at any time that there are material credit issues, with this Agreement, then GE Healthcare may terminate this Agreement (including warranty services hereunder) immediately upon written notice to Customer. For the avoidance of doubt, this Agreement is not terminable for convenience and may only be terminated in accordance with this Agreement.

1.7. Entire Agreement and Waiver of Reliance. This Agreement constitutes the complete and final agreement of the parties relating to the Products and/or Services identified in the Quotation. The parties agree that they have not relied, and are not relying, on any oral or written promises, terms, conditions, representations or warranties, express or implied, outside those expressly stated or incorporated by reference in this Agreement. No agreement or understanding, oral or written, in any way purporting to modify this Agreement, whether contained in Customer's purchase order or shipping release forms, or elsewhere, shall be binding unless hereafter agreed to in writing and signed by authorized representatives of both parties. Each party objects to any terms inconsistent with this Agreement proposed by either party unless

agreed to in writing and signed by authorized representatives of both parties, and neither the subsequent lack of objection to any such terms, nor the delivery of the Products and/or Services, shall constitute an agreement by either party to any such terms. The parties agree that any provision in this Agreement in 'all caps' type satisfies any requirements at law or in equity that provisions be conspicuously marked.

2. Compliance.

2.1. Generally. Each party will comply with the requirements of Federal and State laws and regulations that are applicable to such party. This Agreement is subject to GE Healthcare's on-going determination that Customer and this Agreement comply with all applicable laws and regulations, including those relating to workplace safety, FDA matters, Federal Healthcare Program Anti-kickback compliance, export/import control and money laundering prevention. CUSTOMER ACKNOWLEDGES THAT THE PRODUCTS ARE OR MAY BE SUBJECT TO REGULATION BY THE FDA AND OTHER FEDERAL OR STATE AGENCIES. CUSTOMER SHALL NOT USE OR PERMIT THE PRODUCTS TO BE USED IN ANY MANNER THAT DOES NOT COMPLY WITH APPLICABLE FDA OR OTHER REGULATIONS OR FOR ANY NON-MEDICAL, ENTERTAINMENT, OR AMUSEMENT PURPOSES. Customer shall not use or permit the Product to be used or operated by any person who does not have sufficient knowledge to competently perform the required task and who is not fully trained on the operation of the Product. Customer is solely responsible for ensuring that Customer and its employees, licensed and unlicensed healthcare staff, representatives, agents and/or contractors who operate, maintain and/or have access to the Products and/or Services, excluding GE Healthcare employees, representatives, agents and/or contractors ("Customer Personnel") are properly trained and fully competent on the operation of the Product. Further, Customer represents that it is purchasing the Products for its own use consistent with the terms of this Agreement and that it does not intend to re-sell the Products to any other party or to export the Products outside the country to which GE Healthcare delivers the Products.

2.2. Cost Reporting. Customer represents and warrants that it shall comply with (a) the applicable requirements of the Discount Statutory Exception, 42 U.S.C. 1320a-7b(b)(3)(A), and the Discount Safe Harbor, 42 C.F.R. § 1001.952(h), with respect to any discounts Customer may receive under this Agreement and (b) the Warranties Safe Harbor, 42 C.F.R. § 1001.952(g), with respect to any price reductions of an item (including a free item) which were obtained as part of a warranty under this Agreement. Customer agrees that, if Customer is required to report its costs on a cost report, then (i) the discount must be based on purchases of the same good bought within a fiscal year; (ii) Customer must claim the benefit in the fiscal year in which the discount is earned or in the following year; (iii) Customer must fully and accurately report the discount in the applicable cost report; and (iv) Customer must provide, upon request, certain information required to be provided to Customer by GE Healthcare as a seller or offeror, as appropriate. If Customer is an individual or entity in whose name a claim or request for payment is submitted for the discounted items, the discount must be made at the time of the sale of the good; and Customer must provide, upon request, certain information required to be provided to Customer by GE Healthcare as a seller or offeror, as appropriate. GE Healthcare agrees to comply with the applicable requirements for sellers or offerors under the Discount Safe Harbor, as appropriate.

2.3. Network Security and Site Access Control. Customer shall be solely responsible for establishing and maintaining network security, virus protection, backup and disaster recovery plans for any data, images, software or equipment. GE Healthcare shall not be responsible for any recovery of lost data or images. Customer shall comply with all applicable laws and regulations related to site access control.

2.4. Environmental Health and Safety. GE Healthcare shall have no obligation to provide Products and/or perform Services until Customer (i) provides and maintains a suitable, safe and hazard-free location and environment for the GE Healthcare Products and personnel performing Services in material compliance with all applicable Federal, State, and local requirements, as well as any written requirements provided by GE Healthcare; (ii) performs GE Healthcare recommended routine maintenance and operator adjustments on the Product; and (iii) ensures that any service not provided by GE Healthcare is performed, and GE Healthcare Products are used, in accordance with applicable user documentation.

Customer shall provide written information to GE Healthcare personnel who will be present on Customer's site about Customer's safety procedures and practices as well as a list of any hazardous materials, such as asbestos, lead or mercury, on or near Customer's site that GE Healthcare personnel may come in contact with and any associated Safety Data Sheets. Customer shall be responsible for taking all necessary actions to properly abate, remove and/or remediate any hazardous conditions or materials, including removing blood, body fluids and other potentially infectious materials. GE Healthcare shall have no responsibility to abate, or liability for, any existing hazardous conditions at Customer site. Customer shall be responsible for proper management, storage and disposal of all service and/or installation-related waste, unless GE Healthcare is legally required to take back the materials (e.g., batteries, WEEE, packaging).

2.5. Parts Not Supplied By GE Healthcare. GE Healthcare recommends the use of parts that it has (i) validated through configuration and (ii) received from authorized suppliers. GE Healthcare is not responsible for the quality of parts supplied by third parties to Customer. GE Healthcare cannot assure Product functionality or performance when non-GE Healthcare parts are used on the Product.

2.6. Training. Any Product training identified in the Quotation shall be in accordance with GE Healthcare's then-current training offerings and terms. Customer agrees that completion of GE Healthcare's training offerings does not guarantee that Customer and Customer Personnel are fully and completely trained on the use, maintenance, and operation of the Product or that completion of GE Healthcare's training will satisfy any licensure and/or accreditation standards. Customer further agrees that it is Customer's sole and non-delegable duty to ensure that Customer and Customer Personnel are properly trained on and fully qualified in the use and operation of the Product. Unless otherwise stated in the training catalog description, training must be completed by Customer within twelve (12) months after (i) the date of Product delivery for training purchased with Products; (ii) the start date for Services for training purchased with Services; or (iii) the date Customer purchases training if such training is not purchased with Products and/or Services. If training is not completed within the applicable time period due to no fault of GE Healthcare, GE Healthcare's obligation to provide the training will expire without refund.

2.7. Medical Diagnosis and Treatment. All clinical and medical treatment and/or diagnostic decisions are the sole responsibility of Customer and Customer Personnel. Customer agrees that GE Healthcare is in no way responsible for the clinical and medical treatment and/or diagnostic decisions made by Customer and Customer Personnel.

2.8. Use of Data.

(a) Protected Health Information. To the extent GE Healthcare creates, receives, maintains, transmits or otherwise has access to any PHI in the course of performing under this Agreement, GE Healthcare shall only use and disclose such PHI as permitted by the administrative simplification section of the Health Insurance Portability and Accountability Act of 1996, Pub. Law 104-191 (August 21, 1996), its implementing regulations, and the Health Information Technology for Economic and Clinical Health ("HITECH") Act and its implementing regulations (collectively, "HIPAA"), and the applicable Business Associate Agreement between the Parties.

(b) Other Information. Customer agrees that GE Healthcare may also create, receive, maintain, transmit and otherwise have access to machine, technical, system, usage and related information that is not PHI, including, but not limited to, information about Customer's Product, Service, system and software, that is gathered periodically to facilitate the provision of Product support, consulting, training and other services to Customer (if any), and to verify compliance with the terms of this Agreement. GE Healthcare or its agents may use such information to provide, develop or improve GE Healthcare's products or services.

2.9. Compliance with Customer Policies. GE Healthcare will use commercially reasonable efforts to respect Customer policies to the extent that such policies apply to GE Healthcare under this Agreement, and do not materially contradict GE Healthcare policies, provided that Customer furnishes to GE Healthcare a complete copy of said policies prior to GE Healthcare's commencement of performance under this Agreement. Under no circumstances, however, will GE Healthcare's failure, or the failure of GE Healthcare's employees or contractors, to respect Customer policies constitute a material breach by GE Healthcare under this Agreement, unless such failure is willful and materially and adversely affects GE Healthcare's ability to perform its obligations under this Agreement.

2.10. Insurance. GE Healthcare shall maintain insurance coverage in accordance with its standard certificate of insurance, a copy of which is available upon Customer's request.

2.11. Excluded Provider. GE Healthcare represents that, to its knowledge, neither it nor its employees performing services under this Agreement have been excluded from participation in any Federal Healthcare Program. In the event an employee performing services under this Agreement is excluded, GE Healthcare will replace such employee within a commercially reasonable time. In the event GE Healthcare is excluded, Customer may terminate this Agreement upon written notice to GE Healthcare.

3. Disputes; Liability; and Indemnity.

3.1. Waiver of Jury Trial. UNLESS OTHERWISE EXPRESSLY PROHIBITED BY APPLICABLE LAW, EACH PARTY EXPRESSLY WAIVES ALL RIGHTS TO A JURY TRIAL IN CONNECTION WITH ANY DISPUTE ARISING UNDER THIS AGREEMENT.

3.2. Limitation of Liability. GE HEALTHCARE'S ENTIRE LIABILITY AND CUSTOMER'S EXCLUSIVE REMEDY FOR ANY DIRECT DAMAGES INCURRED BY CUSTOMER FROM ANY CAUSE, REGARDLESS OF THE FORM OF ACTION, WHETHER IN AN ACTION IN CONTRACT, TORT, PRODUCT LIABILITY, STATUTE, EQUITY OR OTHERWISE, ARISING UNDER THIS AGREEMENT OR RELATED HERETO, SHALL NOT EXCEED: (A) FOR PRODUCTS OR SERVICES, OTHER THAN SERVICES UNDER AN ANNUAL SERVICE CONTRACT, THE PRICE FOR THE PRODUCT OR SERVICE THAT IS THE BASIS FOR THE CLAIM; OR (B) FOR ANNUAL SERVICE CONTRACTS, THE ANNUAL CONTRACT PRICE FOR THE SERVICE THAT IS THE BASIS FOR THE CLAIM. THE FOREGOING LIMITATION OF LIABILITY SHALL NOT APPLY TO GE HEALTHCARE'S DUTIES TO INDEMNIFY CUSTOMER IN ACCORDANCE WITH THIS AGREEMENT. THE LIMITATION OF LIABILITY SHALL APPLY EVEN IF THE LIMITED REMEDIES FAIL OF THEIR ESSENTIAL PURPOSE.

3.3. Exclusion of Damages. NEITHER PARTY SHALL BE LIABLE TO THE OTHER PARTY UNDER THIS AGREEMENT (OR OTHERWISE IN CONNECTION WITH THE PRODUCTS AND SERVICES) FOR ANY INDIRECT, SPECIAL, PUNITIVE, INCIDENTAL OR CONSEQUENTIAL DAMAGES, OR FOR LOSS OF PROFITS, REVENUE, TIME, OPPORTUNITY OR DATA, WHETHER IN AN ACTION IN CONTRACT, TORT, PRODUCT LIABILITY, STATUTE, EQUITY OR OTHERWISE. THE EXCLUSION OF DAMAGES SHALL APPLY EVEN IF THE LIMITED REMEDIES FAIL OF THEIR ESSENTIAL PURPOSE.

3.4. IP Indemnification. GE HEALTHCARE WILL DEFEND, INDEMNIFY AND HOLD HARMLESS CUSTOMER FROM ANY THIRD PARTY CLAIMS FOR INFRINGEMENT OF UNITED STATES INTELLECTUAL PROPERTY RIGHTS ARISING FROM CUSTOMER'S USE OF GE HEALTHCARE MANUFACTURED EQUIPMENT AND/OR GE HEALTHCARE PROPRIETARY SOFTWARE LISTED IN THE QUOTATION (COLLECTIVELY, "INFRINGING PRODUCT") IN ACCORDANCE WITH THEIR SPECIFICATIONS AND WITHIN THE LICENSE SCOPE GRANTED IN THIS AGREEMENT. IF ANY SUCH CLAIM MATERIALLY INTERFERES WITH CUSTOMER'S USE OF SUCH EQUIPMENT AND/OR SOFTWARE, GE HEALTHCARE SHALL, AT ITS OPTION: (I) SUBSTITUTE FUNCTIONALLY EQUIVALENT NON-INFRINGING PRODUCTS; (II) MODIFY THE INFRINGING PRODUCT SO THAT IT NO LONGER INFRINGES BUT REMAINS FUNCTIONALLY EQUIVALENT; (III) OBTAIN FOR CUSTOMER AT GE HEALTHCARE'S EXPENSE THE RIGHT TO CONTINUE TO USE THE INFRINGING PRODUCT; OR (IV) IF THE FOREGOING ARE NOT COMMERCIALLY REASONABLE, REFUND TO CUSTOMER THE PURCHASE PRICE, AS DEPRECIATED (BASED ON FIVE (5) YEAR STRAIGHT-LINE DEPRECIATION), FOR THE INFRINGING PRODUCT. ANY SUCH CLAIMS ARISING FROM CUSTOMER'S USE OF SUCH INFRINGING PRODUCT AFTER GE HEALTHCARE HAS NOTIFIED CUSTOMER TO DISCONTINUE USE OF SUCH INFRINGING PRODUCT AND OFFERED ONE OF THE REMEDIES SET FORTH IN CLAUSES (I) THROUGH (IV) ABOVE ARE THE SOLE RESPONSIBILITY OF CUSTOMER. THIS SECTION REPRESENTS CUSTOMER'S SOLE AND EXCLUSIVE REMEDY (AND GE HEALTHCARE'S SOLE AND EXCLUSIVE LIABILITY) REGARDING ANY INFRINGEMENT CLAIM ASSOCIATED WITH SUCH INFRINGING PRODUCT. THE ABOVE INDEMNIFICATION OBLIGATION IS CONDITIONAL UPON CUSTOMER PROVIDING GE HEALTHCARE PROMPT WRITTEN NOTICE OF THE INFRINGEMENT CLAIM AFTER RECEIVING NOTICE OF SUCH CLAIM, ALLOWING GE HEALTHCARE TO CONTROL THE DEFENSE OF SUCH CLAIM, AND REASONABLY COOPERATING WITH GE HEALTHCARE IN SUCH DEFENSE. GE HEALTHCARE'S RIGHT TO CONTROL THE DEFENSE AND DISPOSITION OF THE INFRINGEMENT CLAIM SHALL INCLUDE THE RIGHT TO SELECT COUNSEL TO REPRESENT CUSTOMER AT GE HEALTHCARE'S EXPENSE; PROVIDED, HOWEVER, THAT CUSTOMER MAY RETAIN ADDITIONAL COUNSEL AT CUSTOMER'S EXPENSE. ANY EXPENSES, INCLUDING LEGAL FEES AND COSTS, INCURRED BY CUSTOMER PRIOR TO TENDERING CONTROL OF THE DEFENSE TO GE HEALTHCARE SHALL NOT BE REIMBURSABLE BY GE HEALTHCARE. NOTWITHSTANDING ANY OTHER PROVISION IN THIS AGREEMENT, GE HEALTHCARE SHALL NOT HAVE ANY OBLIGATION TO CUSTOMER HEREUNDER FOR INFRINGEMENT CLAIMS BASED ON OR RESULTING FROM: (A) USE OF SUCH INFRINGING PRODUCT IN COMBINATION WITH ANY COMPUTER SOFTWARE, TOOLS, HARDWARE, EQUIPMENT, MATERIALS, OR SERVICES, NOT FURNISHED OR AUTHORIZED IN WRITING FOR USE BY GE HEALTHCARE; (B) USE OF SUCH INFRINGING PRODUCT IN A MANNER OR ENVIRONMENT OR FOR ANY PURPOSE FOR WHICH GE HEALTHCARE DID NOT DESIGN OR LICENSE IT, OR IN VIOLATION OF GE HEALTHCARE'S USE INSTRUCTIONS; OR (C) ANY MODIFICATION OF SUCH INFRINGING PRODUCT BY CUSTOMER OR ANY THIRD PARTY. GE HEALTHCARE SHALL NOT BE RESPONSIBLE FOR ANY COMPROMISE OR SETTLEMENT OR

CLAIM MADE BY CUSTOMER WITHOUT GE HEALTHCARE'S WRITTEN CONSENT. THIS INDEMNIFICATION OBLIGATION IS EXPRESSLY LIMITED TO THE GE HEALTHCARE MANUFACTURED EQUIPMENT AND/OR GE HEALTHCARE PROPRIETARY SOFTWARE LISTED IN THE QUOTATION.

3.5. General Indemnification. GE HEALTHCARE AGREES TO RELEASE, INDEMNIFY AND HOLD CUSTOMER HARMLESS FOR ANY THIRD PARTY DAMAGES CUSTOMER BECOMES LEGALLY OBLIGATED TO PAY RELATED TO BODILY INJURY OR DAMAGE TO REAL PROPERTY OR TANGIBLE PERSONAL PROPERTY TO THE EXTENT THAT SUCH DAMAGES ARE DETERMINED TO BE PROXIMATELY CAUSED BY A MANUFACTURING DEFECT, DESIGN DEFECT, NEGLIGENT FAILURE TO WARN, NEGLIGENT INSTALLATION, OR NEGLIGENT SERVICE WITH RESPECT TO PRODUCTS DESIGNED AND MANUFACTURED BY GE HEALTHCARE AND SUPPLIED TO CUSTOMER UNDER THIS AGREEMENT. GE HEALTHCARE SHALL HAVE NO OBLIGATION TO RELEASE, INDEMNIFY AND HOLD CUSTOMER HARMLESS FOR ANY DAMAGES CAUSED BY (I) CUSTOMER'S FAULT OR ANY LEGAL EXPENSES INCURRED BY CUSTOMER IN DEFENDING ITSELF AGAINST SUITS SEEKING DAMAGES CAUSED BY CUSTOMER'S FAULT AND/OR (II) ANY MODIFICATION, CHANGES AND/OR ALTERATIONS TO THE GE HEALTHCARE PRODUCT BY CUSTOMER OR A THIRD PARTY NOT AUTHORIZED OR APPROVED IN WRITING BY GE HEALTHCARE.

CUSTOMER AGREES TO RELEASE, INDEMNIFY AND HOLD GE HEALTHCARE HARMLESS FROM ANY THIRD PARTY DAMAGES THAT GE HEALTHCARE BECOMES LEGALLY OBLIGATED TO PAY RELATED TO BODILY INJURY OR DAMAGE TO REAL PROPERTY OR TANGIBLE PERSONAL PROPERTY TO THE EXTENT THAT SUCH DAMAGES ARE DETERMINED TO BE PROXIMATELY CAUSED BY CUSTOMER'S AND/OR CUSTOMER PERSONNEL (I) MEDICAL DIAGNOSIS OR TREATMENT DECISIONS; (II) MISUSE OR NEGLIGENT USE OF THE PRODUCT; AND/OR (III) USE OF THE PRODUCT IN A MANNER OR ENVIRONMENT, OR FOR ANY PURPOSE, FOR WHICH GE HEALTHCARE DID NOT DESIGN IT, OR IN VIOLATION OF GE HEALTHCARE'S RECOMMENDATIONS OR INSTRUCTIONS ON USE.

THE INDEMNIFICATION OBLIGATIONS SET FORTH IN THIS SECTION 3.5 ARE CONDITIONAL UPON THE INDEMNIFIED PARTY PROVIDING THE INDEMNIFYING PARTY PROMPT WRITTEN NOTICE OF THE THIRD-PARTY CLAIM AFTER RECEIPT OF NOTICE OF SUCH CLAIM, ALLOWING THE INDEMNIFYING PARTY TO CONTROL THE DEFENSE AND DISPOSITION OF SUCH CLAIM, AND REASONABLY COOPERATING WITH THE INDEMNIFYING PARTY IN THE DEFENSE. THE INDEMNIFYING PARTY SHALL NOT BE RESPONSIBLE FOR ANY COMPROMISE MADE BY THE INDEMNIFIED PARTY OR ITS AGENTS WITHOUT THE INDEMNIFYING PARTY'S CONSENT.

4. Payment and Finance.

4.1. Generally. The payment and billing terms for the Product(s) and/or Service(s) are stated in the Quotation.

4.2. Late Payment. Failure to make timely payment is a material breach of this Agreement, for which (in addition to other available remedies) GE Healthcare may suspend performance under the GE Healthcare agreement at issue or suspend the provision of support and maintenance or licenses for the Product(s) licensed or sold under that agreement until all past due amounts are brought current. If GE Healthcare so suspends, GE Healthcare will not be responsible for the completion of planned maintenance due to be performed during the suspension period and any product downtime will not be included in the calculation of any uptime commitment. Interest shall accrue on past-due amounts at a rate equal to the lesser of one-and-one-half percent (1.5%) per month or the maximum rate permitted by applicable law. Customer will reimburse GE Healthcare for reasonable costs (including attorneys' fees) relating to collection of past due amounts. Any credits and/or unapplied cash that may be due to Customer under an agreement may be applied first to any outstanding balance. If Customer has a good faith dispute regarding payment for a particular Product (or subsystem thereof) or Service, Customer shall notify GE Healthcare in writing of such dispute within twenty (20) days of the invoice date and shall work with GE Healthcare in good faith to promptly resolve such dispute. GE Healthcare may revoke credit extended to Customer and designate Customer and all agreements with Customer to be on credit hold because of Customer's failure to pay for any Products or Services when due, and in such event all subsequent shipments and Services shall be paid in full on receipt.

4.3. Taxes. Prices do not include sales, use, gross receipts, excise, valued-added, services, or any similar transaction or consumption taxes ("Taxes"). Customer shall be responsible for the payment of any such Taxes to GE Healthcare unless it otherwise timely provides GE Healthcare with a valid exemption certificate or direct pay permit. In the event GE Healthcare is assessed Taxes, interest or penalty by any taxing authority, Customer shall reimburse GE Healthcare for any such Taxes, including any interest or penalty assessed thereon. Each party is responsible for any personal property or real estate taxes on property that the party owns or leases, for franchise and privilege taxes on its business, and for taxes based on its net income or gross receipts.

5. Loaner Systems. If GE Healthcare provides a loaner system ("Loaner") to Customer pursuant to the terms of this Agreement, such Loaner shall be subject to the following provisions: (i) the Loaner shall be for Customer's temporary use, and Customer agrees to keep the Loaner at the location identified in the Quotation, and shall not move the Loaner to another location without GE Healthcare's prior written consent; (ii) Customer agrees to return the Loaner to GE Healthcare on or before the date on which GE Healthcare returns Customer's Product to Customer, and if Customer does not return the Loaner within such time period, GE Healthcare may repossess the Loaner with ten (10) days prior written notice or invoice Customer for the full list price of the Loaner; (iii) the Loaner, and all programs, information, data, business information, or other information pertaining to such Loaner shall remain GE Healthcare property; (iv) title remains with GE Healthcare, but risk of loss passes to Customer upon delivery of the Loaner; (v) Customer agrees to maintain the Loaner in proper operating condition and in accordance with GE Healthcare's operating instructions and return it to GE Healthcare in this condition, normal wear and tear excepted; (vi) Customer will not repair, or permit others to repair, the Loaner without the prior written consent of GE Healthcare; (vii) Customer agrees to furnish GE Healthcare reasonable access to the Loaner with prior notification; (viii) as Customer does not own the Loaner and is not paying GE Healthcare for its use, it is Customer's responsibility to ensure that any charge or claim submitted by Customer to a government healthcare program or patient is submitted accordingly; (ix) prior to returning the Loaner to GE Healthcare, Customer shall ensure the complete deletion of any and all information, including PHI, that may have been stored in the Loaner, or any of its accessories; (x) such deletion shall be completed in accordance with any user instructions provided by GE Healthcare and/or industry standards; (xi) in the event Customer is unable for technical reasons to complete the deletion, Customer shall provide immediate notice of this to GE Healthcare, and GE Healthcare staff shall use commercially reasonable efforts to facilitate the deletion of information; (xii) Customer agrees to indemnify GE Healthcare for any loss whatsoever resulting from any information that is not removed from the Loaner and GE Healthcare shall have no obligations whatsoever in connection with any information that is not properly removed from such Loaner by Customer. It is within GE Healthcare's sole discretion to provide Customer with a Loaner while warranty or Service repairs are ongoing. This provision is not applicable to GE Healthcare IT Products.

GE Healthcare

These GE Healthcare Product Terms and Conditions supplement and incorporate by reference (i) the GE Healthcare Quotation that identifies the Product offering purchased or licensed by Customer; (ii) the following documents, as applicable, if attached to or referenced in the Quotation: the GE Healthcare (a) Warranty(ies) and (b) Additional Terms and Conditions; and (iii) the GE Healthcare General Terms and Conditions, (collectively, referred to as the "Agreement").

1. Commercial Logistics.

1.1. Order Cancellation and Modifications.

1.1.1. Cancellation and Payments. If Customer cancels an order at any time without GE Healthcare's prior written consent, GE Healthcare has the right to charge Customer a cancellation fee of up to one-and-one-half percent (1.5%), with a maximum amount of up to $5,000, of the price of the Products ordered. If the cancellation occurs less than thirty (30) days prior to the scheduled delivery date of any portion of the order, GE Healthcare has the right to charge Customer a cancellation fee of up to ten percent (10%), with a maximum amount of up to $50,000, of the price of the Products ordered. GE Healthcare will retain as a credit any payments received up to the amount of the cancellation charge. If Customer cancels an order for Products for which GE Healthcare has provided site evaluation services, Customer will also pay GE Healthcare reasonable charges for such services performed prior to cancellation. If applicable for the order, Customer will pay all progress payments (other than the final payment) prior to final Product calibration, and GE Healthcare may, at its option, delay final calibration until required progress payments are received. If Customer fails to schedule a delivery date with GE Healthcare within six (6) months after order entry, GE Healthcare may cancel Customer's order upon written notice to Customer. For the avoidance of doubt, GE Healthcare IT Product Quotations and orders are non-cancellable.

1.1.2. Order Modifications. No modifications may be made to an order without GE Healthcare's prior written consent. The Product configuration listed in the Quotation is based upon information furnished to GE Healthcare by Customer, and Customer is responsible to provide and pay for modifications, if any, to the configuration due to inaccuracies or incompleteness of the information furnished to GE Healthcare by Customer, changes in Customer's needs or requirements, or for other reasons attributable to Customer.

1.1.3. Exchanges and Substitutions. Prior to acceptance as defined in Section 1.5 below, GE Healthcare may, in its sole and reasonable discretion, exchange or substitute installation-related items having similar features, functionality and pricing as the originally delivered installation item that result in no price change to the Customer. This section shall not apply to Healthcare IT Products.

1.1.4. Used Product Orders. Products identified as pre-owned, refurbished, remanufactured or demonstration Products have been previously used ("Used Products"); they are not new. When delivered and/or released to Customer, such Used Products may have received reconditioning, as necessary, to meet GE Healthcare performance specifications. Since Used Products may be offered simultaneously to several customers, their sale to Customer is subject to their availability. If the Used Products are no longer available, (i) GE Healthcare will attempt to identify other Used Products in its inventory that meet Customer's needs, and (ii) if substitute Used Products are not acceptable to Customer, GE Healthcare will cancel the order and refund any deposit Customer has paid for such Used Products.

1.2. Site Preparation. If applicable, Customer will be responsible, at its sole expense, for evaluating and preparing the site where the Products will be installed in accordance with GE Healthcare's site preparation requirements and applicable laws. Customer must provide GE Healthcare with prompt written notice if Customer is unable to prepare the site before the mutually agreed installation date. Upon receipt of such notice, GE Healthcare will reschedule the installation to a mutually agreed date. Customer shall be liable for any costs or expenses GE Healthcare or its representatives incur resulting from Customer's failure to provide GE Healthcare with timely notice of Customer's failure to properly prepare the site. GE Healthcare may, in its discretion, delay delivery or installation if GE Healthcare determines that the site has not been properly prepared or there are any other impediments to installation; provided that GE Healthcare gives Customer written notice of such delay stating the reasons therefor. If GE Healthcare provides site evaluation services, such services are intended only to assist Customer in fulfilling Customer's responsibility to ensure that the site complies with GE Healthcare's applicable site preparation requirements.

1.3. Transportation, Title and Risk of Loss; Delivery; Returns.

1.3.1. Transportation, Title and Risk of Loss. Unless otherwise indicated in the Quotation, shipping terms are FOB Destination. Title and risk of loss to equipment passes to Customer upon delivery to Customer's designated delivery location. Software is licensed to Customer; no title to or other ownership interest in such software passes to Customer.

1.3.2. Delivery. When feasible, GE Healthcare reserves the right to make delivery in installments. All such installments shall be separately invoiced and paid for when due, without regard to subsequent deliveries. At the time of such delivery, Customer will pay GE Healthcare for any amounts due upon delivery. As a matter of convenience, GE Healthcare may invoice multiple installment deliveries on a consolidated basis; however, this does not release Customer from the obligation to pay for each installment delivery provided by GE Healthcare. Delivery dates are approximate. For GE Healthcare software or documentation, delivery means the first to occur of: (i) communication to Customer through electronic means that allows Customer to take possession of the first copy or product master or (ii) delivery to Customer's designated delivery location.

1.3.3. Product Returns. Customer shall not have any right to return Products for a refund after delivery except for products shipped in error that are different from the Products listed in the Quotation.

1.3.4. Replaced Component Returns. Except for Healthcare IT Products, for upgrades and revisions Customer agrees to return any replaced component to GE Healthcare at no charge to GE Healthcare.

1.4. Installation, Certification and Professional Services. GE Healthcare will provide Product assembly, installation and calibration, as required, at no additional charge, except (i) for items excluded herein and/or (ii) as otherwise indicated in the Quotation. If installation services are identified in the Quotation, GE Healthcare will perform such services from 8am to 5pm local time, Monday-Friday, excluding GE Healthcare holidays, in accordance with applicable GE Healthcare installation guides and/or project plans. After hours installation is available for an additional fee. Customer will review the applicable GE Healthcare installation guides and/or project plans, and perform Customer's obligations as set forth in those materials. Upon completion of assembly, installation and calibration of the Products, as applicable, GE Healthcare will perform prescribed tests using its own performance specifications, instruments and procedures to verify that the Products meet GE Healthcare's applicable performance specifications.

1.4.1. Customer-Supplied Items.

- Customer will install necessary system cable and assemble any necessary equipment or hardware not provided by GE Healthcare, unless agreed otherwise in writing by the parties.
- For Products that will be operated on or in connection with Customer supplied hardware or software, Customer is responsible for ensuring that such hardware and software conform to GE Healthcare's minimum hardware and software requirements as made available to Customer.
- Unless GE Healthcare has agreed in writing to maintain responsibility for an applicable service, Customer will be responsible for enabling the connectivity and interoperability between Customer-supplied hardware or software or other systems or devices and the Product, including, without limitation, procuring and installing any modifications, interfaces or upgrades consistent with GE Healthcare's written specifications.
- Unless otherwise agreed in writing by GE Healthcare, Customer is solely responsible for the (i) performance of and payment for any applicable rigging and/or facility costs and (ii) installation of accessory items.
- If applicable for the Product, electrical wiring and outlets, computer network infrastructure, conduit, cabinetry modification, wall mounts, ventilation and any other site preparation are not included in the purchase price and are the responsibility of Customer, unless otherwise agreed in writing by GE Healthcare.

1.4.2. Network. Unless Customer has elected to purchase network preparation and certification Services from GE Healthcare as set forth in the Quotation, Customer is solely responsible for ensuring that Customer's network is adequate for the proper operation and performance of the Products and otherwise meets GE Healthcare's written network configuration requirements.

1.4.3. License, Permits, and Approvals. Customer shall obtain and maintain all licenses, permits and other approvals necessary for installation, use and disposal/recycling of the Products, including, but not limited to, any government licenses required to use radioactive sources for Products that require the use of such sources. GE Healthcare will ship such sources to Customer only after Customer provides GE Healthcare with satisfactory evidence that Customer has obtained all required licenses for such sources. In addition, Customer will provide all radioactive sources for calibration and performance checks of Products that require the use of such sources. GE Healthcare will file any required Federal and State reports relating to its installation activities. GE Healthcare will not install, test, certify or provide its own software license or warranty for Products that are not listed in its on-line catalog or price pages at the time of sale (such Products are normally identified by NL or NW series numbers), unless otherwise agreed in writing by GE Healthcare.

1.4.4. Non-GE Healthcare Labor. If local labor conditions make it impractical to, or GE Healthcare is directed not to, use GE Healthcare's employees or pre-qualified contractors for the installation, all work will be performed by Customer's laborers or outside labor at Customer's expense; provided that GE Healthcare will, at Customer's request, furnish guidance for installation. GE Healthcare is not responsible for the quality or adequacy of any work performed by any party other than GE Healthcare or its pre-qualified contractors.

1.4.5. Non-GE Healthcare Installation. For Products that GE Healthcare is obligated to install under the terms of this Agreement, if GE Healthcare delivers the Product but fails to perform its installation obligations, then in such event Customer shall nevertheless be obligated to pay GE Healthcare an amount equal to (a) the Product purchase price set forth in the Quotation, if the Product purchase price and the installation Services price are shown as separate line items in the Quotation, or (b) if the Product purchase price and installation Services price are not shown as separate line items in the Quotation, then the Product purchase price less the fair market value of the applicable installation Services, taking into account the type of Product and level of installation required ("Installation Service FMV"). An independent third party shall determine the Installation Service FMV. Notwithstanding any other provision of this Agreement to the contrary, either the discharge of Customer's obligation to pay for installation Services shown as a separate line item(s) in the Quotation or the deduction of the Installation Service FMV, as applicable, shall be Customer's sole and exclusive remedy (and GE Healthcare's sole and exclusive liability) in the event GE Healthcare fails to perform its installation obligations under this Agreement.

1.4.6. Information Technology Professional Services ("ITPS"). ITPS must be performed within twelve (12) months of the later of the date (i) Customer orders ITPS or (ii) of Product delivery, ("ITPS Performance Date"). If ITPS is not performed within twelve (12) months of the ITPS Performance Date for reasons other than GE Healthcare's failure to perform, GE Healthcare's ITPS performance obligation will expire without refund. ITPS includes clinical applications training, project management, HL7/HIS systems integration, database conversion, network design and integration and separately cataloged software installations. This section shall not apply to Healthcare IT Products.

1.5. Acceptance. Unless expressly provided otherwise in this Agreement, Customer shall be deemed to have accepted a Product delivered by GE Healthcare under this Agreement on the earlier of: (i) if GE Healthcare installs the Product, five (5) days after GE Healthcare notifies Customer that it has completed assembly and the Product is operating substantially in accordance with GE Healthcare's published performance specifications; (ii) if GE Healthcare does not install the Product, five (5) days after delivery of the Product to Customer; or (iii) the date Customer first uses the Product for patient use.

1.6. Warranties. Product warranties (if applicable) are set forth in the GE Healthcare warranty forms delivered with the Quotation. GE Healthcare may use refurbished parts in new Products. Any part for which GE Healthcare has supplied a replacement (excluding biomed parts, which shall be properly disposed of by Customer) shall become GE Healthcare property.

1.7. Third Party Products and Services. If GE Healthcare has agreed to provide any third party products and/or services (other than GE Healthcare accessories and supplies) to Customer as part of the Quotation, including but not limited to any Commitment Account/Non-Inventory items, (i) GE Healthcare is acquiring such products and/or services on Customer's behalf and not as a supplier of such products and/or services, (ii) GE Healthcare provides no warranties or indemnification of any kind, express or implied, with respect to such products and/or services (warranties or indemnification, if any, on such products and/or services will be provided by the manufacturer or service provider), (iii) Customer is solely responsible for ensuring that the acquisition and use of such products and/or services is in compliance with applicable laws and regulations, including applicable FDA regulations, and (iv) Customer is solely responsible for any and all claims resulting from or related to the acquisition or use of such products and/or services. This section shall not apply to Healthcare IT Products.

2. Software License.

2.1. License Grant. GE Healthcare grants to Customer a non-exclusive, non-transferable license to use for Customer's internal business purposes the GE Healthcare software, third-party software and Documentation solely for use on the Products and at the location (or, for mobile systems, in the specific vehicle) as identified in the Quotation, subject to the license scope and Documentation and other restrictions set forth in this Agreement. "Documentation" means the GE Healthcare user manuals, on-line help functions, technical specifications and user instructions regarding the operation, installation and use of the software as made available by GE Healthcare to Customer under this Agreement. Customer may only use third-party software provided by GE Healthcare together with the GE Healthcare software and will comply with all third-party software license terms included in any click or shrink wrap license or of which GE Healthcare otherwise makes Customer aware. To the extent permitted by applicable law, licensors of third-party software shall be third-party beneficiaries of this Agreement with respect to third-party software sublicensed under this Agreement. Customer may permit its employees, agents, independent contractors and healthcare providers with privileges at Customer's facilities to use the software and Documentation; provided, however, that Customer shall be responsible for any acts of such third parties that are inconsistent with this Agreement. Notwithstanding the foregoing, independent contractors that supply products comparable to the software shall be provided access to the software only with GE Healthcare's prior written consent and subject to any conditions GE Healthcare deems appropriate to protect its confidential and proprietary information. Customer acknowledges that GE Healthcare may request Customer and Customer Personnel to register online as a licensee for receipt of certain service software and related Documentation.

2.2. Additional License Terms. Without GE Healthcare's prior written consent, Customer may not: (i) copy, sublicense, distribute, rent, lease, loan, resell, modify or translate the software or create derivative works based thereon, except that to the extent applicable, the software may be configured as specifically permitted in the Documentation; (ii) directly or indirectly decompile, disassemble, reverse engineer or otherwise attempt to learn the source code, structure, algorithms or ideas underlying the software; (iii) provide service bureau, time share or subscription services based on the software; (iv) remove, obscure or modify any markings, labels or any notice of the proprietary rights, including copyright, patent and trademark notices of GE Healthcare or its licensors; (v) electronically transfer the software outside Customer's intranet or network dedicated for the software, unless otherwise authorized in writing by GE Healthcare; or (vi) publicly release the results of any testing or benchmarking of the software without the prior written consent of GE Healthcare. Customer may transfer authorized copies of the software, and Documentation to a party that purchases or otherwise acquires the equipment and accepts any applicable license terms, except for software and Documentation that are (a) not a part of the base system standard operating software or Documentation for the equipment and (b) generally provided by GE Healthcare to its customers for a separate fee or charge. Advanced service software is subject to a separate fee and eligibility criteria and licensed under a separate agreement with GE Healthcare.

2.3. Backups. Customer may make a reasonable number of copies of the software in machine-readable form solely for backup, training, testing or archival purposes, so long as applicable license fees are paid. Customer shall reproduce on any such copy the copyright notice and any other proprietary legends that were on the original copy. GE Healthcare and its licensors, as applicable, retain all ownership and intellectual property rights to the software and Documentation. If Customer acquires any rights to the software or Documentation, Customer hereby assigns all of those rights to GE Healthcare or its licensors, as applicable. No license rights are granted (whether by implied license or otherwise), to Customer, except as specifically provided in this section.

2.4. Remedies. Customer agrees that a violation of GE Healthcare's license, confidentiality or intellectual property rights will cause irreparable harm to GE Healthcare for which the award of money damages alone are inadequate. In the event of any breach of this provision, GE Healthcare shall be entitled to seek injunctive relief in addition to immediately terminating the license granted herein and requiring that Customer cease use of the software and return all copies of stand-alone software in any media in addition to seeking any other legal or equitable remedies available to GE Healthcare. This paragraph shall survive the termination of this Agreement.

3. Payment and Finance.

3.1. Security Interest. Customer grants GE Healthcare a purchase money security interest in all items of hardware or equipment listed in the Quotation until full payment is received, and Customer shall perform all acts and execute all documents as may be necessary to perfect GE Healthcare's security interest.

3.2. Leases. If Customer is acquiring use of Products through an equipment lease ("Lease") with an equipment lessor ("Lessor"), certain provisions of this Agreement (including, but not limited to, terms related to payment, title transfer, warranties, and software licenses) may be modified as agreed to in writing between GE Healthcare, the applicable Lessor, and/or Customer, as the case may be. Acceptance of the Products as between GE Healthcare and Lessor will be defined by this Agreement; acceptance of the Products as between Lessor and Customer will be defined by the lease agreement. Notwithstanding the foregoing, if the Lessor does not comply with the terms of this Agreement, Customer shall continue to be responsible for the payment obligations hereunder.

3.3. Failure to Pay. If, after Product delivery, Customer does not make any payments for the Products within forty-five (45) days after such payments are due, GE Healthcare may, upon ten (10) days prior written notice to Customer, either (a) enter upon Customer's site and remove the Products or (b) temporarily disable the Products so that they are not operational.

Additional Terms and Conditions: Magnetic Resonance ("MR")

GE Healthcare

These GE Healthcare Additional Terms and Conditions: Magnetic Resonance ("MR") supplement and incorporate by reference the GE Healthcare (i) Quotation that identifies the Product offering purchased or licensed by Customer; (ii) Warranty(ies); (iii) Product Terms and Conditions; and (iv) General Terms and Conditions, (collectively, referred to as the "Agreement").

1. Mobile Systems Only. For Products that are approved by GE Healthcare for use as transportable, relocatable and mobile systems, GE Healthcare will deliver the system to Customer's van manufacturer and furnish final assembly services to place the system in Customer's van. At the time of order, Customer must notify GE Healthcare of the van manufacturer to which the system is to be shipped. It is Customer's responsibility to make arrangements with the van manufacturer for delivery of the van and to comply with any additional planning requirements of the van manufacturer. For MR systems, GE Healthcare's product tests will be performed when assembly in the van is completed and MR system operation will be re-checked when the van is delivered to Customer.

2. MR Systems. Customer will provide a site and surroundings suitable for installation and operation of an MR system producing strong magnetic and electric fields, and Customer will be required to provide a water chiller meeting GE Healthcare specifications. Customer acknowledges that the magnetic fields of MR systems attract ferro-magnetic articles and are capable of rapidly accelerating such articles toward the magnet, creating corresponding physical danger to persons in the vicinity and possible damage to such systems. In addition, the magnetic and radio frequency fields of such systems may adversely affect the operation of pacemakers, equipment containing magnetic reed switches, and aneurysm or surgical clips.

3. Magnet Maintenance and Cryogens. The price of MR systems includes all cryogens necessary for final assembly and testing of the MR system. Cryogen loss attributable to power loss or water chiller failure for the MR system's shield cooler or condenser system during installation is Customer's responsibility, and Customer will be billed for cryogen replacement plus the associated cryogen transfill labor at GE Healthcare's then applicable rates. After final assembly, Customer will be responsible to supply and install all cryogens, unless cryogen loss is caused by a defect in material or workmanship within the scope of GE Healthcare's applicable MR system warranty. Following final assembly, provided cryogen boil-off rates have not been adversely affected by actions of Customer, its representatives or contractors, or any third party not authorized by GE Healthcare, GE Healthcare will provide a super-conductive magnet which, at the expiration of the warranty period, has cryogen boil-off rates not exceeding those stated in GE Healthcare's applicable magnet specifications. GE Healthcare has no responsibility to Customer for cryogen boil-off rates subsequent to expiration or termination of the applicable MR system warranty, unless Customer elects to receive magnet maintenance and cryogen service under a separate agreement with GE Healthcare.

Warranty Statement (United States)

GE Healthcare

This GE Healthcare Warranty Statement (United States) supplements and incorporates by reference (i) the GE Healthcare Quotation that identifies the Product offering purchased or licensed by Customer; (ii) the following documents, as applicable, if attached to or referenced in the Quotation: the (a) Warranties and (b) Additional Terms and Conditions; (iii) the GE Healthcare Product Terms and Conditions; and (iv) the GE Healthcare General Terms and Conditions, (collectively, referred to as the "Agreement").

1. **Warranted Products.** These warranties cover the purchase and use of the following GE Healthcare products:

- Magnetic Resonance
- Computed Tomography
- Mammography
- Positron Emission Tomography (including scanners, cyclotrons & chemistry labs)
- Nuclear
- X-ray
- Surgical Navigation Systems
- Cardiology
- Ultrasound
- Bone Mineral Densitometry
- Physiological Monitoring
- Small Animal Imaging
- C-Arms
- Advantage Workstation and Server
- Anesthesia Delivery
- Respiratory Care
- Gold Seal
- Phototherapy and other infant care accessories
- Microenvironments, including Giraffe®, Panda®, Care Plus® and Ohio® Infant Warmer Systems
- Corometrics® Fetal Monitors

2. **GE Healthcare Warranties.**

2.1 Scope. GE Healthcare warrants that its services will be performed by trained individuals in a professional, workman-like manner. GE Healthcare will promptly re-perform any non-conforming services for no charge as long as Customer provides reasonably prompt written notice to GE Healthcare. The foregoing service remedy, together with any remedy provided herein, are Customer's sole and exclusive remedies (and GE Healthcare's sole and exclusive liability) for warranty claims. These exclusive remedies shall not have failed of their essential purpose (as that term is used in the Uniform Commercial Code) as long as GE Healthcare remains willing to repair or replace defective warranted products or re-perform any non-conforming services for no charge, as applicable, within a commercially reasonable time after being notified of Customer's warranty claim. NO OTHER EXPRESS OR IMPLIED WARRANTIES, INCLUDING IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, QUIET ENJOYMENT, SYSTEM INTEGRATION AND DATA ACCURACY, WILL APPLY.

2.2 Term Usage. "Warranted Product" is a collective term which includes both the above-listed GE Healthcare manufactured equipment and licensed software, with the exception of Healthcare IT Products, purchased by and/or licensed to (as applicable) Customer under the relevant GE Healthcare Quotation.

2.3 Equipment Warranty. Except as indicated otherwise below, GE Healthcare warrants the equipment will be free from defects in title and that for one (1) year from the Warranty Commencement Date (as defined below) (i) the equipment will be free from defects in material and workmanship under normal use and service and (ii) except for equipment manufactured in compliance with Customer's designs or specifications, the equipment will perform substantially in accordance with GE Healthcare's written technical specifications for the equipment (as such specifications exist on the date the equipment is shipped) (the "Specifications"). This warranty covers both parts and labor and is available only to end-users that purchase the equipment from GE Healthcare or its authorized distributors. Customers purchasing through an authorized distributor must contact GE Healthcare promptly following such purchase to enable this warranty.

2.4 Software Warranty. Except as indicated otherwise below, GE Healthcare warrants for ninety (90) days from the Warranty Commencement Date that (i) the licensed software will perform substantially in accordance with the applicable Documentation (as defined herein), (ii) it has not inserted any Disabling Code (as defined herein) into the licensed software and (iii) it will use reasonable commercial efforts consistent with industry standards to scan for and remove any software viruses before installation of the applicable Warranted Product. Where an item of equipment has software code embedded in it, the code will only be considered licensed software under this warranty statement if the applicable GE Healthcare Quotation provides a separate part number for that software. Except as indicated otherwise below, GE Healthcare warrants that it has the right to license or sublicense the licensed software to Customer for the purposes and subject to the terms and conditions set forth in the Agreement. As used in this warranty statement, (i) "Disabling Code" means computer code that is designed to delete, interfere with, or disable the normal operation of the Warranted Product; provided, however, that code included in the licensed software that prevents use outside of the license scope purchased for the software will not be deemed to be Disabling Code and (ii) "Documentation" means the GE Healthcare user manuals, on-line help functions, technical specifications and user instructions regarding the operation, installation and use of the software as made available by GE Healthcare to Customer.

2.5 Used Products. GE Healthcare's (i) Gold Seal Products (certain pre-owned GE Healthcare equipment), (ii) Ultrasound demonstration systems, and (iii) certified pre-owned Bone Mineral Densitometry Products are all provided with GE Healthcare's standard warranties carrying the same duration as the new equipment warranty, but in no event exceeding one (1) year (unless otherwise provided in writing

by GE Healthcare). Except as expressly provided in this paragraph or in the applicable GE Healthcare Quotation, all other pre-owned, refurbished, remanufactured or demonstration equipment is not warranted by GE Healthcare.

2.6 Healthcare IT and GE Brand Specialty Components. GE Healthcare IT Products and GE Brand Specialty Components (Detectors, Probes, X-Ray Tubes and Image Intensifier Tubes) are covered by a separate warranty statement provided in an applicable GE Healthcare Quotation.

2.7 Third-Party Software and Equipment. This warranty statement does not cover Third-Party Software and Equipment (as defined herein) delivered with the Warranted Products (commonly identified by NL or NW series numbers in GE Healthcare's Quotation). "Third-Party Software and Equipment" means any non-GE Healthcare software or equipment (i) delivered to Customer in the third-party manufacturer/supplier's packaging and with its labeling or (ii) for which GE Healthcore expressly indicates (either in the GE Healthcare Quotation or in the product documentation) that the software or equipment is provided with the third-party manufacturer/supplier's warranty in lieu of a GE Healthcare warranty. Such products are covered by the third-party manufacturer/supplier's warranties, to the extent available. Anesthesia monitor mounting solutions Third-Party Software and Equipment purchased directly from GE Healthcare will not be treated as Third-Party Software or Equipment.

3. Warranty Commencement. Unless expressly provided otherwise in this warranty statement or the applicable GE Healthcare Quotation, the warranty period begins (the "Warranty Commencement Date") on the earlier of: (i) if GE Healthcare installs the Warranted Product, five (5) days after GE Healthcare notifies Customer that it has completed assembly and the Warranted Product is operating substantially in accordance with GE Healthcare's Specifications; (ii) if GE Healthcare does not install the Warranted Product, five (5) days after delivery of the Warranted Product to Customer; (iii) the date Customer first uses the Warranted Product for patient use; or (iv) if GE Healthcare is contractually required to install the Warranted Product, the thirtieth (30th) day following shipment to the end-user Customer if installation is delayed for reasons beyond GE Healthcare's reasonable control. The warranty period for any Warranted Product or component furnished to correct a warranty failure will be the unexpired term of the warranty applicable to the repaired or replaced Warranted Product.

4. Remedies. If Customer promptly notifies GE Healthcare of Customer's warranty claim during the warranty period and makes the Warranted Product available for service, GE Healthcare will, at its option (i) with respect to equipment, either repair, adjust or replace (with new or exchange replacement parts) the non-conforming Warranted Product or components of the Warranted Product and (ii) with respect to GE Healthcare's licensed software, either correct the non-conformity or replace the applicable licensed software. GE Healthcare may, at its sole discretion and subject to (i) availability; (ii) any applicable regulatory approvals; and (iii) Section 5 of the GE Healthcare General Terms and Conditions, provide Customer with a comparable loaner system during periods of extended service to the Warranted Product. Warranty service will be performed without charge from 8:00am to 5:00pm (local site time), Monday-Friday, excluding GE Healthcare holidays, and outside those hours at GE Healthcare's then prevailing service rates and subject to the availability of personnel. For certain Warranted Products, GE Healthcare will perform warranty service only at an authorized service center or, in some instances, via a secure, remote connection to a GE Healthcare online center. With respect to GE Healthcare's warranty for the services it provides to Customer, Customer's exclusive remedy is set forth in Section 2.1 above.

Warranty claims for the Warranted Products should be directed through GE CARES at 1-800-437-1171. Warranty claims for accessories and supplies items should be directed through 1-800-558-5102.

5. Limitations. GE Healthcare shall not have any obligation to Customer hereunder if the warranty claim results from or arises out of: (a) the use of the Warranted Product in combination with any software, tools, hardware, equipment, supplies, accessories or any other materials or services not furnished by GE Healthcare or recommended in writing by GE Healthcare; (b) the use of the Warranted Product in a manner or environment, or for any purpose, for which GE Healthcare did not design or license it, or in violation of GE Healthcare's recommendations or instructions on use; or (c) any alteration, modification or enhancement of the Warranted Product by Customer or any third party not authorized or approved in writing by GE Healthcare. In addition, this warranty does not cover the Warranted Product to the extent it is used in any country other than the country to which GE Healthcare ships the Warranted Product (unless GE Healthcare expressly agrees otherwise in writing). GE Healthcare does not guarantee that licensed software will operate without error or interruption.

In addition, these warranties do not cover: (i) any defect or deficiency (including failure to conform to Specifications and/or Documentation, as applicable) that results, in whole or in part, from any improper storage or handling, failure to maintain the Warranted Products in the manner described in any applicable instructions or specifications, inadequate back-up or virus protection or any cause external to the Warranted Products or beyond GE Healthcare's reasonable control, including, but not limited to, power failure and failure to keep Customer's site clean and free of dust, sand and other particles or debris; (ii) the payment or reimbursement of any facility costs arising from repair or replacement of the Warranted Products or parts; (iii) any adjustment, such as alignment, calibration, or other normal preventative maintenance required of Customer; (iv) expendable supply items; (v) stockpiling of replacement parts; (vi) any failure of the Warranted Products to use or correctly process dates (other than systemic miscalculations not due to date value format); and (vii) products not listed in GE Healthcare's Accessories and/or Supplies catalogs at the time of sale, and all service manuals are provided AS IS. For network and antenna installations not provided by GE Healthcare or its authorized agent(s), network and antenna system troubleshooting will be billable at GE Healthcare's standard service rates.

For MR systems, these warranties do not cover (i) any defect or deficiency that results, in whole or in part, from failure of any water chiller system supplied by Customer, (ii) service to any water chiller systems supplied by Customer and (iii) for MR systems with LHe/LN or shield cooler configured superconducting magnets (except for MR Systems with LCC magnets), any cryogen supply, cryogenic service or service to the magnet, cryostat, coldhead, shield cooler compressor or superconductive or resistive shim coils unless the need for such supply or service is caused by a defect in material or workmanship covered by these warranties (GE Healthcare's MR Magnet Maintenance and Cryogen Service Agreement is available to provide supplemental coverage during the warranty period).

For Proteus XR/a, Definium and Precision 500D x-ray systems, these warranties do not cover collimator bulbs.

6. **Exceptions to GE Healthcare Standard Warranties Described Above.**

Partial System Equipment Upgrades for CT, MR, X-Ray, PET (Scanners, Cyclotrons and Chemistry Labs) and Nuclear systems: Six (6) months (warranty applies only to the upgraded components)

Cyclotron and Radiopharmacy: Unless expressly provided otherwise in the applicable GE Healthcare Quotation, the Warranty Commencement Date for Cyclotron and/or Radiopharmacy Products begins on the earlier of (i) three (3) months after the date on which GE Healthcare has completed the mechanical installation, or (ii) the date on which final testing of the Product has been successfully completed. GE Healthcare's sole liability and Customer's exclusive remedy for a breach of warranty is limited to repair, replacement or refund at GE Healthcare's sole option. Any such repairs or replacement will not extend the warranty period.

X-Ray High Voltage Rectifiers and TV Camera Pick-Up Tubes: Six (6) months

X-Ray Portable (Wireless & Tethered) Digital Detectors: Warranty does not cover damage caused by any use that does not conform to OEM guidelines, fire, power failures or surges, or abuse which is defined as use that causes fluid invasion, holes, deep scratches, or the detector case to crack.

FlashPad Wireless Detector: In addition to the standard warranty, GE Healthcare will also provide coverage for detector damage due to accidental dropping or mishandling (e.g., spills). In the event such accidental damage occurs, GE Healthcare shall provide Customer with one (1) replacement detector during the warranty period at no additional charge. If subsequent accidental damage occurs during the warranty period, each additional replacement shall be provided to Customer at a charge of $30,000 per replacement detector. Warranty coverage for the detector and its components also excludes failures due to detrimental exposure, abuse, theft, loss and/or fire. If the warranty is voided by these conditions, repair or replacement of the detector and/or the components is the Customer's responsibility.

GE OEC New or Exchange Service/Maintenance Parts: Ninety (90) days

GE OEC Refurbished C-Arms: Twelve (12) months after installation

HealthNet Lan, Advantage Review — Remote Products: Ninety (90) days

Vivid T8: Three (3) years parts and labor, includes TEE probes purchased with the Vivid T8

Vivid i, Vivid e, Vivid q, Voluson i, Voluson e and LOGIQBook XP: Standard warranty includes (i) repair services at GE Healthcare service facilities, (ii) three (3) business day turnaround repair time for systems shipped via overnight delivery (where available), measured from the date of shipment (GE Healthcare is not responsible for delays in overnight shipment), (iii) seventy-two (72) hour loaner systems or probe replacement service via Fed Ex (shipping charges included), and (iv) technical support via telephone from 7:00 am to 7:00 pm Central Time, Monday-Friday, excluding GE Healthcare holidays. For an additional charge, GE Healthcare may provide (a) field support/service, (b) preventative maintenance, and/or (c) coverage for system damage due to accidental dropping or mishandling with a maximum of two (2) replacement systems during the term of the warranty.

Vscan, LOGIQ e BT12 and later versions, and Venue 40 and 50 version BT12 and later versions: Supplemental warranty terms and conditions specific to Vscan systems, LOGIQ e BT12 and later version systems, and Venue 40 and 50 version BT12 and later version systems shall be as set forth in the Additional Terms and Conditions and Warranties for Ultrasound & Vscan Products attached to the Quotation.

Ultrasound Partial System Equipment Upgrades: Ninety (90) days (Warranty applies only to the upgraded components. Customer will not be credited the value of this warranty against pre-existing warranties or service agreements).

Bone Mineral Densitometry Partial System Equipment Upgrades: Thirty (30) days (Warranty applies only to the upgraded computer, printer and monitor components. Customer will not be credited the value of this warranty against pre-existing warranties or service agreements).

CARESCAPE Monitors B450, B650 and B850, and Dash: Three (3) years parts and one (1) year labor coverage, excluding displays

840 Monitors: Two (2) years of parts only coverage, excluding displays, and one (1) year labor with (i) repair services performed at GE Healthcare service facilities; or (ii) onsite repair if deemed necessary by GE Healthcare, during such labor warranty period.

MAC 800, 1200, 1600 and 2000: Three (3) years of parts and labor

CARESCAPE V100 Vital Signs Monitors: Two (2) years parts and labor

Exergen: Four (4) years parts and labor

Batteries: Ninety (90) days, except (i) for LOGIQBook and Vscan batteries, which are warranted for twelve (12) months and (ii) for Nickel cadmium or lead acid batteries for X-ray and mammography systems (which will carry a sixty (60)-month warranty prorated as shown below). For Nickel cadmium or lead acid batteries for X-ray and mammography systems, warranty service will be performed without charge from 8:00 a.m. to 5:00 p.m. (local site time), Monday-Friday, excluding GE Healthcare holidays, and outside those hours at GE Healthcare's then prevailing service rates and subject to the availability of personnel only during the first twelve (12) months of the sixty (60)-month warranty period. For X-ray and mammography systems, if nickel cadmium or lead acid batteries need replacement during their applicable warranty period, Customer will pay the price of the replacement battery in effect on its delivery date less a Pro Rata Credit Allowance (as defined herein). The Pro Rata Credit Allowance for batteries that fail less than twelve (12) months after the warranty begins is one hundred percent (100%). The Pro Rata Credit Allowance for batteries that fail more than twelve (12) months after the warranty begins is:

1 - (# of Mos. After Warranty Commencement /60) x 100%

For the purpose of Pro Rata Credit Allowance, a fraction of a month less than fifteen (15) days will be disregarded, and a fraction of a month equal to or greater than fifteen (15) days will be regarded as a full month.

Giraffe® Shuttle Batteries: Ninety (90) days

Care Plus® Incubator: Three (3) years parts, one (1) year labor

Ohio® Infant Warmer Systems, Panda® iRes Warmers, Giraffe® Warmer and Giraffe® OmniBed: Seven (7) year parts warranty on heater cal rod

BiliBlanket® Plus High Output Phototherapy System: Two (2) years on Light Box and eighteen (18) months on Fiberoptic Pad

Microenvironment and Phototherapy expendable components, this includes but is not limited to patient probes, probe covers and light bulbs: Thirty (30) days

Corometrics® Fetal Monitoring Systems: Warranty includes: (i) Warranty Commencement at the earlier of (a) if GE Healthcare or Customer installs the Warranted Product, five (5) days after completion of installation of the Warranted Product or (b) forty (40) days after shipment of the Warranted Product; (ii) two (2) years parts, one (1) year labor; and (iii) repair services at GE Healthcare service facilities during labor warranty period or onsite repair if deemed necessary by GE Healthcare.

Corometrics® Nautilus Transducers: Two (2) years of parts and labor
Oximeters: Three (3) years from installation, or thirty-nine (39) months from GE Healthcare invoice, whichever occurs sooner
Tec 7 Vaporizers: Three (3) years of parts and labor
Tec 6 Plus Vaporizers: Two (2) years of parts and labor
Accessories and Supplies: GE Healthcare's catalog and/or website includes a "Service/Warranty Code" which identifies the installation, warranty, applications and post-warranty service, if any, provided for each accessory and supply product. Following are the warranty periods for accessories and supplies:

Service/Warranty Code T	100 Years
Service/Warranty Code V	25 Years
Service/Warranty Codes X	15 Years
Service/Warranty Code ZZ	5 Years
Service/Warranty Codes F	3 Years
Service/Warranty Codes D, J, N, O, R or Z	2 Years
Service/Warranty Codes A, B, C, E, G, L, P, Q, S or Y	1 Year
Service/Warranty Code H	6 Months
Service/Warranty Code K	3 Months
Service/Warranty Code M	1 Month
Service/Warranty Code W	Out of Box Failure Only

Warranty Codes For Accessories And Supplies

GE Healthcare

These GE Healthcare Warranty Codes For Accessories and Supplies supplements and incorporates by reference (i) the GE Healthcare Quotation that identifies the Product offering purchased or licensed by Customer; (ii) the following documents, as applicable, if attached to or referenced in the Quotation: the (a) Warranties and (b) Additional Terms and Conditions; (iii) the GE Healthcare Product Terms and Conditions; and (iv) the GE Healthcare General Terms and Conditions, (collectively, referred to as the "Agreement").

Service / Warranty Codes. If Customer promptly notifies GE Healthcare of its warranty claim and makes the Product available for service, GE Healthcare will provide the warranty service indicated in the applicable Service/Warranty Code description. The terms and conditions of GE Healthcare's Warranty Statement(s) apply to all warranty claims. Basic Service Premise for Products – GE Healthcare Field Engineers will take the first call for service and either provide direct support or arrange for support from the manufacturer or its dealers as indicated by the individual Service/Warranty Code. If the Service/Warranty Code calls for Product return for repair or in-warranty exchange, Customer must return the Product as GE Healthcare directs. GE Healthcare provides warranty service from 8:00 AM to 5:00 PM local time Monday-Friday EXCLUDING GE HEALTHCARE HOLIDAYS. If a Service/Warranty Code provides for warranty service to be performed on Customer's site, such service is available outside the above hours at GE Healthcare's prevailing service rates and subject to the availability of personnel.

A GE Healthcare directly, or through a sub-contractor, provides the following:

Installation; parts; on-site warranty service to repair, adjust or replace (at GE Healthcare's option and using new or exchange replacement parts) non-conforming products or parts; applications training in some cases (with additional charge); and post-warranty service, at prevailing hourly billed service ("HBS") rates and, in some cases, under GE Healthcare service contracts.

B GE Healthcare directly provides the following through GE Healthcare's Global Parts Operation (GPO):

New or exchange replacement parts at no charge to correct non-conforming products or parts during the warranty period; new or exchange replacement parts at GE Healthcare's normal prices for post-warranty repairs. ***Note:*** *Installation, applications training and on-site service is the Customer's responsibility. However, GE Healthcare's Field Engineers may be available at prevailing HBS rates. Contact GE CARES for availability.*

C GE Healthcare arranges for the third-party Product Manufacturer or its dealers to provide the following:

Installation (in some cases with an additional charge); parts; on-site warranty service to repair, adjust, or replace (at the manufacturer's or dealer's option and using new or exchange replacement parts) non-conforming products or parts; applications training in some cases (some with additional charge); and post-warranty service at prevailing service rates.

D GE Healthcare refers to the Product Manufacturer warranty, which provides the following:

Basic functional troubleshooting (no technical labor) with supplier phone support and repair or replacement (at the manufacturer's or dealer's option) of defective products or parts. ***Note:*** *The battery for Service/Warranty Code **D** has a 1-year warranty. For detailed warranty information, please refer to the Product Manufacturer's warranty certificate.*

E GE Healthcare directly, or through a sub-contractor, provides:

Installation (in some cases with an additional charge); basic functional troubleshooting (no technical labor) with supplier phone support; and coordination of unit exchange or loaner program for in-factory service.

GE Healthcare arranges for the third-party Product Manufacturer or its dealers to provide in-factory service:

At no charge during the warranty period and at manufacturers or dealer's prevailing service rates outside of the warranty period. Products must be returned to the manufacturer or dealer, at GE Healthcare's expense during warranty and Customer's expense after warranty, for repair.

F GE Healthcare refers to the Product Manufacturer warranty, which provides the following:

Basic functional troubleshooting (no technical labor) with supplier phone support and replacement of non-conforming products or parts, which Customer returns to the manufacturer or dealer during the warranty period. ***Note:*** *For detailed warranty information, please refer to the Product Manufacturer's warranty certificate.*

G, J, O and Q GE Healthcare refers to the Product Manufacturer warranty, which provides the following:

Start up and commissioning; basic functional troubleshooting (no technical labor) with supplier phone support 24/7; and warranty service to repair, adjust, or replace (at the manufacturer's or dealer's option) non-conforming products or parts (excluding installation, time and material). ***Note:*** *The UPS battery for Service/Warranty Code **G** has a 9-year pro-rated warranty to cover non-conforming material. Start up and commissioning for Service/Warranty Code **O** applies only to 10 KVA and above. The UPS battery for Service/Warranty Codes **O** and **Q** has a 1-year warranty to replace the product. For detailed warranty information, please refer to the Product Manufacturer's warranty certificate. Warranty service for Service/Warranty Codes **G** and **O** is provided On-site. For detailed warranty information, please refer to the Product Manufacturer's warranty certificate.*

H, K, L and M GE Healthcare directly provides the following:

Exchange of non-conforming products, which Customer returns to GE Healthcare during the warranty period. ***Note:*** *Installation, parts, applications training, and on-site service is the Customer's responsibility.*

N, R and S GE Healthcare refers to the Product Manufacturer warranty, which provides the following:

Installation; Preventative Maintenance; and parts and labor. ***Note:*** *Post-warranty service, at manufacturer's prevailing HBS rates, and in some cases, under GE Healthcare service contracts. The battery for Service/Warranty Code R has a 1-year warranty. For detailed warranty information, please refer to the Product Manufacturer's warranty certificate.*

P GE Healthcare directly provides the following:

Replacement of non-conforming components. ***Note:*** *Installation, parts, applications training, and on-site service is the Customer's responsibility.*

T, V and X GE Healthcare directly provides the following:

Replacement of Product only; GE Healthcare will not replace patient records; and product is warranted only for image legibility. ***Note:*** *Installation, parts, applications training, and on-site service is the Customer's responsibility.*

W GE Healthcare directly provides the following:

Replacement of Product only for Out of Box failure. ***Note:*** *Installation, parts, applications training, and on-site service is the Customer's responsibility.*

Y and Z GE Healthcare refers to the Product Manufacturer warranty, which provides the following:

Basic functional troubleshooting (no technical labor) with supplier phone support and replacement of non-conforming components. ***Note:*** *All electrical components (excluding the UPS) for Service/Warranty Code Z have a 1-year warranty. For detailed warranty information, please refer to the Product Manufacturer's warranty certificate.*

ZZ GE Healthcare refers to the Product Manufacturer warranty, which provides the following:

Basic functional troubleshooting (no technical labor) with supplier phone support and replacement of non-conforming components. ***Note:*** *The battery for Service/Warranty Code ZZ has a 2-year warranty for stationary applications and a 6-month warranty for mobile application. For detailed warranty information, please refer to the Product Manufacturer's warranty certificate.*

Warranty Statement: Uptime Commitment

GE Healthcare

This GE Healthcare Warranty Statement: Uptime Commitment supplements and incorporates by reference the GE Healthcare (i) Quotation that identifies the Product offering purchased or licensed by Customer; (ii) Warranty(ies); (iii) Additional Terms and Conditions; (iv) Product Terms and Conditions; and (v) General Terms and Conditions, (collectively, referred to as the "Agreement". The following provisions will apply only to eligible diagnostic imaging systems as identified in the Quotation ("Eligible Systems") and only during the warranty period:

1. Scope. GE Healthcare will provide Customer with expanded warranty protection for Eligible Systems in consideration of Customer's commitment to provide a broadband network connection to enable GE Healthcare to better provide warranty service for the Eligible Systems during the warranty period.

2. Eligibility. To be eligible for this expanded warranty protection, Customer must: (i) establish (if not previously established) and maintain a broadband network connection at Customer's site that connects to the Eligible System, which broadband connection meets GE Healthcare's minimum specifications, (ii) provide GE Healthcare with access to the Eligible System through Customer's broadband network connection and maintain security for Customer's broadband network connection in accordance with appropriate industry best practices, (iii) provide necessary support to maintain such broadband network connection, including designation of a primary Customer contact person, (iv) provide GE Healthcare with at least two (2) business days advance notice of any planned changes to Customer's network that may impact such broadband connection and with notice of any unplanned changes (e.g., power outages, computer viruses, system crashes) to Customer's network that may impact such broadband connection within two (2) business days after the occurrence of the unplanned changes, (v) reasonably cooperate with GE Healthcare in maintaining such broadband connection during all such planned and unplanned changes, and (vi) use reasonable efforts to ensure that Customer's connection to the Internet and LAN systems operate at a maximum of 75% of capacity and have an uptime rate of at least 98%.

3. Uptime Commitment. If Customer performs these responsibilities, GE Healthcare will provide Customer, at no additional charge and in addition to other remedies available under GE Healthcare's warranty, an uptime commitment of 97% (95% for all covered nuclear imaging systems and all covered X-ray systems except digital mammography, digital radiographic and vascular X-ray systems), and uptime remedies, as described below.

4. Definitions. "Uptime Commitment" means GE Healthcare's commitment on Eligible System uptime during the warranty period, as defined below. "Uptime Remedy" is, in addition to the other remedies specified in the warranty, Customer's sole and exclusive remedy if GE Healthcare fails to meet any Uptime Commitment over a 26-week measurement period during the warranty period. Should the Eligible System fail to achieve the Uptime Commitment as calculated by the Uptime Commitment Calculation, GE Healthcare will provide an extension of Customer's service agreement with GE Healthcare for the Eligible System (or, if Customer has not entered into a service agreement with GE Healthcare, the warranty period for the Eligible System) at no additional charge, as follows:

% < Uptime Commitment	Extension
0	0 weeks
0.1 - 3.0	1 week
3.1 - 8.0	2 weeks
8.1 - 13.0	4 weeks
> 13.0	6 weeks

"Uptime Commitment Calculation" means the calculation used to determine achievement of the Uptime Commitment, as follows: The basis for each measurement period is GE Healthcare's standard warranty service coverage hours of A hours per day, B days per week for 26 weeks, less C hours spent on planned maintenance ("PM") during that interval:

Hours1 = A hours per day X B days per week X 26 weeks
Hours2 = Hours1 - C hours for planned maintenance
Required in-service hours at Customer's % commitment: Hours3 = Hours2 X Customer's %

5. Eligible System. An Eligible System will be considered inoperable and out of service under the Uptime Commitment if, due to GE Healthcare's design, manufacturing, material, or service or maintenance performance failure, the Eligible System is unavailable for scanning patients and diagnosing images on the Eligible System display console or operator's console. Peripheral equipment such as remote consoles, magnetic tape drives, hard copy devices, and multi-format and laser cameras are excluded from the terms of the Uptime Commitment. Repair and adjustments required for anything other than Eligible System failure, and damage or inoperability due to any cause other than GE Healthcare's design, manufacturing, material, or service or maintenance performance failure, will be excluded from the Uptime Commitment Calculation, including without limitation damage through misuse, operator error, inadequate environmental or air conditioning protection, power failure, and acts of God. PM time will not be included in the calculation of downtime. If GE Healthcare's responding representative agrees the Eligible System is inoperable due to GE Healthcare's design, manufacturing, material, or service or maintenance performance failure, the Eligible System will be considered out of service from the time the request for service was received by GE Healthcare until the Eligible System is again turned over to Customer for operation. If Customer fails to give GE Healthcare immediate and unencumbered access to the Eligible System or continues to obtain scans after notifying GE Healthcare of any Eligible System failure, the Eligible System will be considered to be in service.

ADDENDUM TO QUOTATION

This Addendum to Quotation(s) ("Addendum"), effective as of last signature date indicated in the signature area of this Addendum ("Effective Date") is entered into by and between the Customer and the GE Healthcare business ("GE Healthcare"), each as identified on the GE Healthcare quotation(s) which are listed below and incorporated herein by reference (each, a "Quotation" and, collectively, the "Quotations"):

Quotation Number	Quotation Date
PR9-C53784V3	Sunday, December 27, 2015

Quotation Number	Quotation Date
PR5-C53578V6	Sunday, December 27, 2015

WHEREAS, GE Healthcare has provided Customer with the Quotation(s) concerning GE Healthcare's desire to sell to Customer, and Customer's agreement to purchase from GE Healthcare, certain GE Healthcare products and/or services listed on each Quotation in accordance with the terms and conditions set forth on each Quotation (each, an "Agreement" and collectively, the "Agreements"); and

WHEREAS, the parties now desire to amend and/or supplement the Agreement(s) in accordance with the terms and conditions set forth herein.

NOW THEREFORE, in consideration of the premises and the representations and mutual undertakings hereinafter set forth, and for good and valuable consideration, the receipt and sufficiency of which is hereby acknowledged, the parties agree to the foregoing and as follows:

- Each Agreement is revised as set forth in Exhibit A, which is attached hereto and incorporated herein by reference.
- Customer's form of payment is as follows:

Initial to indicate form of payment:
(If potential for a lease exists, GE HFS or otherwise, select lease)
_____ Cash* _____Lease _____HFS Loan
If leasing please provide name of finance company below:

_____

*Selecting cash declines option for GE HFS financing

Entire Agreement. In the event of any conflict between the terms and conditions of this Addendum on the one hand, and each Agreement on the other hand, the terms and conditions of this Addendum shall govern and control. Except as otherwise expressly provided in the Addendum, the parties agree that all provisions of each Agreement are hereby ratified and agreed to be in full force and effect and are incorporated herein by reference. This Addendum and each Agreement contain the entire agreement among the parties related to the subject matter herein and all prior proposals, discussions and writings by and among the parties and relating to the subject matter herein are superseded hereby and thereby.

In WITNESS WHEREOF, Customer and GE Healthcare have caused this Addendum to be executed by their duly authorized representatives as of the Effective Date.

Hartford Hospital	GE Healthcare
Signature:	Signature:
Print Name:	Print Name:
Title:	Title:
Date:	Date:

ID#: 142302567

EXHIBIT A

Each Agreement is revised as follows:

- Section 1.1.1 ("Cancellation and Payments") of the GE Healthcare Product Terms and Conditions (the "GE Healthcare Product Terms") is amended by adding the following to such section: "Except for Healthcare IT Products, Customer may terminate the Agreement(s), without penalty, by providing written notice to GE Healthcare up to sixty (60) days prior to the scheduled delivery date of any portion of the order."

EXHIBIT

7

Hartford Healthcare
Financial Assistance Policy

Update Date: 12/16/2010

Purpose: The purpose of this Policy is to set forth the policy of Hartford Healthcare Corporation (sometimes referred to as the "System") governing the provision of free or discounted Health Care Services to patients who meet the System's criteria for Financial Assistance. Specifically, this Policy will describe: (i) the eligibility criteria for Financial Assistance, and whether such assistance includes free or discounted care; (ii) the basis for calculating amounts charged to patients; (iii) the method for applying for Financial Assistance from the System's Hospitals; (iv) the actions the System may take in the event of non-payment, including collections action and reporting to credit agencies for patients that qualify for Financial Assistance; and (v) the System measures to widely publicize this Policy within the community served by Hartford Healthcare.

Scope: This Policy applies to all Hartford Health facilities Health Care Services regardless of the location at which they are being provided by the System.

Definitions:

"Charges" means for a Health Care Service for a patient who is either Uninsured or Underinsured and who is eligible for Financial Assistance, the average of the System's facility three best negotiated commercial payor rates for the Health Care Services.

"Eligibility Criteria" means the criteria set forth in this Policy to determine whether a patient qualifies for Financial Assistance for the Health Care Services provided by the System's facility.

"EMTALA" means the Emergency Medical Treatment and Labor Act, 42 USC 1395dd, as amended from time to time.

"Family" means pursuant to the Census Bureau definition, a group of two or more people who reside together and who are related by birth, marriage, civil union or adoption. For purposes of this Policy, if the patient claims someone as a dependent on their income tax return, they may be considered a dependent for purposes of the provision of financial assistance.

"Family Income" means the following income when calculating Federal Poverty Level Guidelines of liquid assets: earnings, unemployment compensation, workers' compensation, Social Security, Supplemental Security Income, public assistance, veterans' payments, survivor benefits, pension or retirement income, interest, dividends, rents, royalties; income from estates, trusts, educational assistance, alimony, child support, assistance from outside the household, and other miscellaneous sources of

income. If a person lives with a Family, Family Income includes the income of all Family members.

"Federal Poverty Level Guidelines" means the federal poverty level guidelines established by the United States Department of Health and Human Services.

"Financial Assistance" means free or discounted Health Care Services provided to persons who, pursuant to the Eligibility Criteria, the Hospital has determined to be unable to pay for all or a portion of the Health Care Services.

"Free Bed Funds" means any gift of money, stock, bonds, financial instruments or other property made by any donor to Hartford Healthcare facilities for the purpose of establishing a fund to provide medical care to an inpatient or outpatient of Hartford Healthcare.

"Health Care Services" means Hartford Healthcare facilities (i) emergency medical services as defined by EMTALA; (ii) services for a condition which, if not promptly treated, will result in adverse change in the health status of the individual; (iii) non-elective services provided in response to life-threatening circumstances in a non-emergency department setting; and (iv) medically necessary services as determined by the System facility on a case-by-case basis at the facility's discretion.

"Medically Indigent" means persons whom the System facility has determined to be unable to pay some or all of their medical bills because their medical bills exceed a certain percentage of their Family Income or Family assets even though they have income or assets that otherwise exceed the generally applicable Eligibility Criteria for free or discounted care under the Policy.

"Uninsured" means a patient who has no level of insurance or third party assistance to assist in meeting his or her payment obligations for Health Care Services and is not covered by Medicare, Medicaid or Champus or any other health insurance program of any nation, state, territory or commonwealth, or under any other governmental or privately sponsored health or accident insurance or benefit program including, but not limited to workers' compensation and awards, settlements or judgments arising from claims, suits or proceedings involving motor vehicle accidents or alleged negligence.

"Underinsured" means the patient has some level of insurance or third-party assistance but still has out-of-pocket expenses such as high deductible plans that exceed his or her level of financial resources.

Policy: It is Hartford Healthcare's policy to provide Financial Assistance to all eligible individuals who are Uninsured, Underinsured, ineligible for a government program, or otherwise unable to pay for Health Care Services due to their limited financial resources. It is also the System's policy to provide without discrimination care for emergency medical conditions (as defined by EMTALA) to individuals regardless of their eligibility for Financial Assistance under this Policy or for government assistance.

I. Determining Eligibility.

In determining eligibility for Financial Assistance, it is important that both the System facility and the patient work collaboratively. Specifically, the System facilities will do its best to apply the Eligibility Criteria in a flexible and reasonable manner and the patient will do its best in responding to Hartford Healthcare requests for information in a timely manner.

1. Eligibility for Financial Assistance. Individuals who are Uninsured, Underinsured, ineligible for any government health care benefit program and unable to pay for their Health Care Services may be eligible for Financial Assistance pursuant to this Policy. The granting of Financial Assistance shall be based upon an individualized determination of financial need, and shall not take into account age, gender, race, color, national origin, marital status, social or immigrant status, sexual orientation or religious affiliation.

2. Process for Determining Eligibility for Financial Assistance. In connection with determining eligibility for Financial Assistance, the System (i) will require that the patient complete an application for Financial Assistance along with providing other financial information and documentation relevant to making a determination of financial eligibility; (ii) may rely upon publicly available information and resources to determine the financial resources of the patient or a potential guarantor; (iii) may pursue alternative sources of payment from public and private payment benefit programs; (iv) may review the patient's prior payment history; and (v) may consider the patient's receipt of state-funded prescription programs, participation in Women, Infants and Children programs, food stamps, subsidized school lunches, subsidized housing, or other public assistance as presumptive eligibility when there is insufficient information provided by the patient to determine eligibility.

3. Processing Requests. Hartford Healthcare will use its best efforts to facilitate the determination process prior to rendering services so long as the determination process does not interfere with the provision of emergency medical services as defined under federal law. However, eligibility determinations can be made at any time during the revenue cycle. During the eligibility determination process, the System facilities will at all times treat the patient or their authorized representative with dignity and respect and in accordance with all state and federal laws.

4. Financial Assistance Guidelines. Eligibility criteria for Financial Assistance may include, but is not limited to, such factors as Family size, liquid and non-liquid assets, employment status, financial obligations, amount and frequency of healthcare expense (i.e. Medically Indigent) and other financial resources available to the patient. Family size is determined based upon the number of dependents living in the household. In particular, eligibility for Financial Assistance will be determined in accordance with the following guidelines:

(a) ***Uninsured Patients:***

(i) If Family income is at or below 250% of the Federal Poverty Level Guidelines, the patient may qualify for up to a 100% discount against the System facility's Charges for Health Care Services;

(ii) If Family income is between 250% and 400% of the Federal Poverty Level Guidelines, the patient may qualify for up to a 50% discount against the System facility's Charges for Health Care Services;

(iii) Patients may also qualify for Free Bed Funds in accordance with the Hartford Healthcare Free Bed Funds Policy; and

(iv) Patients may have presumptive eligibility if they are homeless and have no assets or qualify for other means-tested government programs.

(b) ***Underinsured Patients:***

(i) Payment plans will be extended for any patient liability (including without limitation to amounts due under high deductible plans) identified in a manner consistent with the System's Payment Plan Policy;

(ii) If Family Income is at or below 250% of the Federal Poverty Level Guidelines, the patient may qualify for up to a 100% discount against the lesser of (a) the account balance after insurance payments from third-party payors are applied; or (b) the Charges for the Health Care Services;

(iii) If Family Income is between 250% and 400% of the Federal Poverty Level Guidelines, the patient may qualify for up to 50% discount against the lesser of (a) the account balance after insurance payments from third-party payors are applied; or (b) the Charges for the Health Care Services;

(v) Patients may also qualify for Free Bed Funds in accordance with Hartford Healthcare Free Bed Funds Policy; and

(vi) Patients may have presumptive eligibility if they are homeless and have no assets or qualify for other means-tested government programs.

(c) ***Medically Indigent:*** Patients will be required to submit a Financial Assistance application along with other supporting documentation, such as medical bills, drug and medical device bills and other evidence relating to high-dollar medical liabilities, so that the Hartford Healthcare System Hardship Committee can determine whether the patient qualifies for Financial Assistance due to the patient's medical expenses and liabilities.

II. Method for Applying for Financial Assistance. Patients may ask any nurse, physician, chaplain, or staff member from Patient Registration, Patient Accounts, Office of Professional Services, Case Coordination, or Social Services about initiating the Financial Assistance application process. Information about applying for Financial Assistance is also available online at www.hartfordhealthcare.org. Signage and written information regarding how to apply for Financial Assistance will be available in Hartford Healthcare facilitiesl emergency service and patient registration areas. Once a patient or his or her legal representative requests information about Financial Assistance, a Financial Counselor will provide the patient or his or her legal representative with the Financial Assistance application along with a list of the required documents that must be provided to process the application. If the patient or his or her legal representative does not provide the necessary documentation and information required to make a Financial Eligibility determination within fourteen (14) calendar days of the Hartford Healthcare facility's request, the Financial Assistance application will be deemed incomplete and rendered void. However, if an application is deemed complete by the System facility, the System facility will provide to the patient or his or her legal representative a written determination of financial eligibility within five (5) business days. Decisions by the System facilities that the patient does not qualify for Financial Assistance may be appealed by the patient or his or her legal representative within fourteen (14) calendar days of the determination. If the patient or his or her legal representative appeals the determination, the Director of Patient Access will review the determination along with any new information and render a final decision within five (5) business days.

III. Relationship to Hartford Healthcare Collection Practices. In the event a patient fails to qualify for Financial Assistance or fails to pay their portion of discounted Charges pursuant to this Policy, and the patient does not pay timely their obligations to Hartford Healthcare, the System reserves the right to institute and pursue collection actions and to pursue any remedies available at law or in equity, including but not limited to, imposing wage garnishments or filing and foreclosing on liens on primary residences or other assets, instituting and prosecuting legal actions and reporting the matter to one or more credit rating agencies. For those patients who qualify for Financial Assistance and who, in the System's sole determination, are cooperating in good faith to resolve the System's outstanding accounts, the System facilities may offer extended payment plans to eligible patients, will not impose wage garnishments or liens on primary residences, will not send unpaid bills to outside collection agencies and will cease all collection efforts.

IV. Publication and Education. Hartford Healthcare facilities will disseminate information about its Financial Assistance Policy as follows: (i) provide signage

regarding this Policy and written summary information describing the Policy along with financial assistance contact information in the Emergency Department, Labor and Delivery areas and all other System patient registration areas; (ii) directly provide to each patient written summary information describing the Policy along with financial assistance contact information in all admission, patient registration, discharge, billing and collection written communications; (iii) post the Policy on the System's web site with clear linkage to the Policy on the System's home page; (iv) educate all admission and registration personnel regarding the Policy so that they can serve as an informational resource to patients regarding the Policy; and (v) include the tag line "Please ask about our Financial Assistance Policy" in all Hartford Healthcare written advertisements.

V. Relation to Free Bed Funds. If a patient applies for Financial Assistance, Hartford Healthcare facilities will determine his or her eligibility for Financial Assistance and or Free Bed Funds.

VI. Regulatory Compliance. The System will comply with all state and federal laws, rules and regulations applicable to the conduct described in this Policy.

Reviewed By:	Niobus Queiro, Revenue Cycle Director, Hartford Healthcare Corporation
	Shelly McCafferty, PFS Director, Hartford Healthcare Corporation
	Becky Peters, PAS Director, Hartford Hospital
	Joan Feldman, Legal Counsel to Hartford Healthcare Corporation
Approved By:	_____ **Thomas Marchozzi, EVP & CFO Hartford Healthcare Corp.**
Date:	**October 1, 2010**

Issued Date: 08/16/2010

EXHIBIT

8

NON-PROFIT

Applicant:
Financial Worksheet (A)

Please provide one year of actual results and three years of projections of **Total Entity** revenue, expense and volume statistics without, incremental to and with the CON proposal in the following reporting format:

LINE	Total Entity:	(1) FY14 Actual	(2) FY16 Budget	(3) FY16 Projected	(4) FY16 Projected	(5) FY17 Projected	(6) FY17 Projected	(7) FY17 Projected	(8) FY18 Projected	(9) FY18 Projected	(10) FY18 Projected	(11) FY19 Projected	(12) FY19 Projected	(13) FY19 Projected
	Description	Results	W/out CON	Incremental	With CON	W/out CON	Incremental	With CON	W/out CON	Incremental	With CON	W/out CON	Incremental	With CON
A.	**OPERATING REVENUE**													
1	Total Gross Patient Revenue	$2,554,085,582	$2,685,195,019	$0	$2,685,195,019	$2,699,292,909	$27,303,878	$2,726,596,787	$2,713,588,170	$29,451,933	$2,743,040,103	$2,728,083,565	$31,766,299	$2,759,849,864
2	Less: Allowances	$1,464,020,247	$1,573,384,661	$0	$1,573,384,861	$1,581,645,492	$20,652,061	$1,602,297,554	$1,590,021,773	$22,278,185	$1,612,299,959	$1,598,515,322	$24,030,413	$1,622,545,735
3	Less: Charity Care	$32,901,514	$24,430,085	$0	$24,430,085	$24,558,349	$320,666	$24,879,015	$24,688,408	$345,915	$25,034,323	$24,820,288	$373,122	$25,193,410
4	Less: Other Deductions	$56,367,695	$73,828,902	$0	$73,828,902	$74,216,521	$969,069	$75,185,590	$74,609,566	$1,045,373	$75,654,939	$75,008,114	$1,127,594	$76,135,708
	Net Patient Service Revenue	**$1,000,796,127**	**$1,013,551,171**	**$0**	**$1,013,551,171**	**$1,018,872,547**	**$5,362,081**	**$1,024,234,628**	**$1,024,268,423**	**$5,782,459**	**$1,030,050,882**	**$1,029,739,841**	**$6,235,170**	**$1,035,975,011**
5	Medicare	$424,421,836	$395,836,850	$0	$395,836,850	$397,915,084	$1,477,056	$399,392,140	$400,022,414	$1,593,143	$401,615,557	$402,159,246	$1,718,201	$403,877,447
6	Medicaid	$131,175,003	$129,566,385	$0	$129,566,385	$130,246,638	$559,295	$130,805,933	$130,936,415	$603,078	$131,539,493	$131,635,849	$650,220	$132,286,069
7	CHAMPUS & TriCare	$5,219,349	$3,925,983	$0	$3,925,983	$3,946,595	$37,316	$3,983,911	$3,967,496	$40,215	$4,007,711	$3,988,690	$43,334	$4,032,023
8	Other	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Total Government	**$560,816,188**	**$529,329,218**	**$0**	**$529,329,218**	**$532,108,318**	**$2,073,666**	**$534,181,984**	**$534,926,325**	**$2,236,436**	**$537,162,762**	**$537,783,785**	**$2,411,755**	**$540,195,539**
9	Commercial Insurers[d]	$486,238,198	$542,868,761	$0	$542,868,761	$545,718,947	$3,131,263	$548,850,209	$548,609,035	$3,376,413	$551,985,448	$551,539,584	$3,640,369	$555,179,953
10	Uninsured	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
11	Self Pay[d]	$43,010,950	$39,613,392	$0	$39,613,392	$39,821,371	$157,152	$39,978,524	$40,032,263	$169,610	$40,201,873	$40,246,106	$183,047	$40,429,153
12	Workers Compensation	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
13	Other[e]	($89,269,208)	($98,260,199)	$0	($98,260,199)	($98,776,089)	$0	($98,776,089)	($99,299,200)	$0	($99,299,200)	($99,829,635)	$0	($99,829,635)
	Total Non-Government	**$439,979,939**	**$484,221,954**	**$0**	**$484,221,954**	**$486,764,229**	**$3,288,415**	**$490,052,644**	**$489,342,097**	**$3,546,023**	**$492,888,120**	**$491,956,056**	**$3,823,415**	**$495,779,471**
	Net Patient Service Revenue[a] (Government+Non-Government)	**$1,000,796,127**	**$1,013,551,172**	**$0**	**$1,013,551,172**	**$1,018,872,547**	**$5,362,081**	**$1,024,234,628**	**$1,024,268,423**	**$5,782,459**	**$1,030,050,882**	**$1,029,739,841**	**$6,235,170**	**$1,035,975,011**
14	Less: Provision for Bad Debts	$24,640,388	$16,571,692	$0	**$16,571,692**	$16,658,697	$376,316	**$17,035,014**	$16,746,920	$406,115	**$17,153,036**	$16,836,379	$438,249	**$17,274,628**
	Net Patient Service Revenue less provision for bad debts	**$976,155,739**	**$996,979,479**	**$0**	**$996,979,479**	**$1,002,213,850**	**$4,985,765**	**$1,007,199,615**	**$1,007,521,503**	**$5,376,344**	**$1,012,897,847**	**$1,012,903,462**	**$5,796,921**	**$1,018,700,383**
15	Other Operating Revenue	$74,586,939	$72,737,399	$0	**$72,737,399**	$75,283,208	$0	**$75,283,208**	$77,918,120	$0	**$77,918,120**	$80,645,254	$0	**$80,645,254**
17	Net Assets Released from Restrictions	$8,337,418	$20,257,110	$0	**$20,257,110**	$21,067,394	$0	**$21,067,394**	$21,910,090	$0	**$21,910,090**	$22,786,494	$0	**$22,786,494**
	TOTAL OPERATING REVENUE	**$1,059,080,096**	**$1,089,973,988**	**$0**	**$1,089,973,988**	**$1,098,564,452**	**$4,985,765**	**$1,103,550,217**	**$1,107,349,713**	**$5,376,344**	**$1,112,726,057**	**$1,116,335,210**	**$5,796,921**	**$1,122,132,131**
B.	**OPERATING EXPENSES**													
1	Salaries and Wages	$428,888,306	$398,978,199	$0	$398,978,199	$398,406,781	$315,001	$398,721,782	$404,748,121	$322,876	$405,070,997	$412,221,694	$330,948	$412,552,642
2	Fringe Benefits	$134,941,400	$86,912,928	$0	$86,912,928	$108,433,314	$72,450	$108,505,764	$110,691,391	$74,261	$110,765,652	$113,279,894	$76,118	$113,356,012
3	Physicians Fees	$54,386,076	$54,395,765	$0	$54,395,765	$53,373,201	$0	$53,373,201	$53,279,724	$0	$53,279,724	$53,319,808	$0	$53,319,808
4	Supplies and Drugs	$149,340,181	$159,740,112	$0	$159,740,112	$166,413,140	$144,324	$166,557,464	$163,660,518	$155,468	$163,815,986	$161,045,863	$167,444	$161,213,307
5	Depreciation and Amortization	$48,593,411	$56,985,204	$0	$56,985,204	$52,749,834	$278,702	$53,028,536	$51,555,176	$278,702	$51,834,878	$52,169,704	$278,702	$52,448,406
6	Provision for Bad Debts-Other[b]	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
7	Interest Expense	$8,386,515	$11,961,059	$0	$11,961,059	$13,532,626	$0	$13,532,626	$13,419,008	$0	$13,419,008	$13,429,378	$0	$13,429,378
8	Malpractice Insurance Cost	$8,573,872	$9,135,820	$0	$9,135,820	$10,438,469	$0	$10,438,469	$11,935,082	$0	$11,935,082	$12,096,738	$0	$12,096,738
9	Lease Expense	$17,458,932	$18,699,046	$0	$18,699,046	$18,347,530	$0	$18,347,530	$18,315,397	$0	$18,315,397	$18,329,176	$0	$18,329,176
10	Other Operating Expenses	$172,226,217	$227,662,644	$0	$227,662,644	$221,845,362	$19,273	$221,864,635	$219,932,544	$325,731	$220,258,275	$218,583,072	$327,369	$218,910,441
	TOTAL OPERATING EXPENSES	**$1,022,794,910**	**$1,024,470,777**	**$0**	**$1,024,470,777**	**$1,043,540,257**	**$829,750**	**$1,044,370,007**	**$1,047,537,962**	**$1,157,038**	**$1,048,695,000**	**$1,054,475,328**	**$1,180,581**	**$1,055,655,909**
	INCOME/(LOSS) FROM OPERATIONS	**$36,285,186**	**$65,503,211**	**$0**	**$65,503,211**	**$55,024,195**	**$4,156,015**	**$59,180,210**	**$59,811,751**	**$4,219,306**	**$64,031,057**	**$61,859,883**	**$4,616,340**	**$66,476,222**
	NON-OPERATING REVENUE	**$16,278,210**	**$20,157,500**	**$0**	**$20,157,500**	**$20,157,500**	**$0**	**$20,157,500**	**$20,157,500**	**$0**	**$20,157,500**	**$20,157,500**	**$0**	**$20,157,500**
	EXCESS/(DEFICIENCY) OF REVENUE OVER EXPENSES	**$52,563,396**	**$85,660,711**	**$0**	**$85,660,711**	**$75,181,695**	**$4,156,015**	**$79,337,710**	**$79,969,251**	**$4,219,306**	**$84,188,557**	**$82,017,383**	**$4,616,340**	**$86,633,722**
	Principal Payments	**$88,386,723**	$2,086,000	$0	**$2,086,000**	$2,209,000	$0	**$2,209,000**	$2,209,000	$0	**$2,209,000**	$2,339,000	$0	**$2,339,000**
C.	**PROFITABILITY SUMMARY**													
1	Hospital Operating Margin	**3.4%**	**5.9%**	**0.0%**	**5.9%**	**4.9%**	**83.4%**	**5.3%**	**5.3%**	**78.5%**	**5.7%**	**5.4%**	**79.6%**	**5.8%**
2	Hospital Non Operating Margin	**1.5%**	**1.8%**	**0.0%**	**1.8%**	**1.8%**	**0.0%**	**1.8%**	**1.8%**	**0.0%**	**1.8%**	**1.8%**	**0.0%**	**1.8%**
3	Hospital Total Margin	**4.9%**	**7.7%**	**0.0%**	**7.7%**	**6.7%**	**83.4%**	**7.1%**	**7.1%**	**78.5%**	**7.4%**	**7.2%**	**79.6%**	**7.6%**
D.	**FTEs**	5,807	5,291	0	**5,291**	5,343	5	**5,348**	5,343	5	**5,348**	5,343	5	**5,348**
E.	**VOLUME STATISTICS[c]**													
1	Inpatient Discharges	42,755	43,449	0	**43,449**	43,449	0	**43,449**	43,449	0	**43,449**	43,449	0	**43,449**
2	Outpatient Visits	294,488	229,747	0	**229,747**	232,963	0	**232,963**	236,224	0	**236,224**	239,531	0	**239,531**
3	CT Scans	44,237	47,259	0	**47,259**	49,746	5,951	**55,697**	53,735	6,427	**60,162**	58,032	6,941	**64,973**
4	MRI Scans	10,123	9,138	0	**9,138**	9,619	3,013	**12,632**	10,357	3,244	**13,601**	11,148	3,492	**14,640**
	TOTAL VOLUME	**391,603**	**329,593**	**0**	**329,593**	**335,777**	**8,964**	**344,741**	**343,765**	**9,671**	**353,436**	**352,160**	**10,433**	**362,593**

[a] Total amount should equal the total amount on cell line "Net Patient Revenue" Row 14.
[b] Provide the amount of any transaction associated with Bad Debts not related to the provision of direct services to patients. For additional information, refer to FASB, No.2011-07, July 2011.
[c] Provide projected inpatient and/or outpatient statistics for any new services and provide actual and projected inpatient and/or outpatient statistics for any existing services which will change due to the proposal.
[d] *Commercial and Self Pay are gross of charity care and bad debt.*
[e] *Other Non-Government represents credit of other deductions and charity care, in order to crosswalk OHCA Report 165 back to OHCA Report 150.*

Supplemental CON Application Form

Acquisition of Equipment

Conn. Gen. Stat. § 19a-638(a)(10),(11)

Applicant: Hartford Hospital

Project Name: Acquisition of CT Scanner and 3T MRI Scanner

Affidavit

Applicant: Hartford Hospital

Project Title: Acquisition of CT Scanner and 3T MRI Scanner

I, Stuart Markowitz, Sr. VP Hartford HealthCare and President of the Hartford Region of Hartford Hospital being duly sworn, depose and state that Hartford Hospital complies with the appropriate and applicable criteria as set forth in the Sections 19a-630, 19a-637, 19a-638, 19a-639, 19a-486 and/or 4-181 of the Connecticut General Statutes.

Signature

1-13-16
Date

Subscribed and sworn to before me on 1.13.16

Martha Santilli

Notary Public/Commissioner of Superior Court

My commission expires: MARTHA SANTILLI
NOTARY PUBLIC OF CONNECTICUT
My Commission Expires 5/31/2019

1. **Project Description: Acquisition of Equipment**

   a. **Provide the manufacturer, model and number of slices/tesla strength of the proposed scanner (as appropriate to each piece of equipment).**

   - CT Scanner: General Electric CT750HD 64-slice CT with 3D dose modulation, ASIR dose-reducing reconstruction and dual energy scanning

   - MRI Scanner: General Electric SIGNA Pioneer 3.0T with MSK Expect Package, orthopedic coils, MAVRIC SL for imaging near MR-conditional metallic devices, SILENT Expert noise reduction technology

   b. **List each of the Applicant's sites and the imaging modalities currently offered by location.**

Imaging Modality	Location
(1) General Purpose CT Scanning	Hartford Hospital 80 Seymour Street, Hartford CT, 06102 GE VCT 64-slice CT (Radiology Department)
(2) General Purpose CT Scanning	Hartford Hospital 80 Seymour Street, Hartford CT, 06102 GE VCT 64-slice CT (Emergency Department)
(3) Specialized* CT Scanning	Hartford Hospital 80 Seymour Street, Hartford CT, 06102 GE QX/I 8-Slice CT* (Radiology Department)
(4) General Purpose MRI Scanning	Hartford Hospital 85 Jefferson Street, Hartford CT, 06102 Radiology Department; MRI Center GE Signa Echospeed 1.5T
(5) General Purpose MRI Scanning	Hartford Hospital 85 Jefferson Street, Hartford CT, 06102 Radiology Department; MRI Center GE Signa Twinspeed 1.5T

*The QX/I 8 scanner is primarily used for lengthy CT guided interventional procedures.

2. Clear Public Need

a. Complete Table A for each piece of equipment of the type proposed currently operated by the Applicant at each of the Applicant's sites.

TABLE A
EXISTING EQUIPMENT OPERATED BY THE APPLICANT

Provider Name/Address	Service*	Days/Hours of Operation **	Utilization*** FY 2015
Hartford Hospital 80 Seymour Street, Hartford CT, 06102 (Radiology Department)	GE VCT 64-slice CT	Always Open	16,029 (a)
Hartford Hospital 80 Seymour Street, Hartford CT, 06102 (Emergency Department)	GE VCT 64-slice CT	Always Open	26,803 (a)
Hartford Hospital 80 Seymour Street, Hartford CT, 06102 (Radiology Department)	GE QX/I 8-Slice CT****	Mon-Sat 7:00 am -12:00 am	4,927 (a), (b)
Hartford Hospital 85 Jefferson Street, Hartford CT, 06102 (Radiology Department; MRI Center)	GE Signa Echospeed 1.5T (Closed)	Always Open	6,802 (c)
Hartford Hospital 85 Jefferson Street, Hartford CT, 06102 (Radiology Department; MRI Center	GE Signa Twinspeed 1.5T (Closed)	M-F All hours Sat-Sun: 7:00 to 11:30 PM	4097 (c), (d)

*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
***Number of scans/exams performed on each unit for the most recent 12-month period (identify period).

(a) Volumes based on totals for Fiscal Year 2015 (Oct 1, 2014 to Sept 30, 2015)
(b) This 15 year old scanner is used primarily for CT guided procedures (biopsies, aspirations, etc), scheduled for 90 to 120 minutes with three to five of these procedures are scheduled per weekday. This type of utilization, as well as its higher radiation doses and older, limited technology constrains the type of conventional CT exams that can be performed on this unit.
(c) Volumes based on totals for Fiscal Year 2015 (Oct 1, 2014 to Sept 30, 2015)
(d) Longer anesthesia cases (usually taking four normal scheduled slots) and breast biopsy exams are all performed on the Twinspeed unit

b. Provide the rationale for locating the proposed equipment at the proposed site;

The CT Scanner will allow medically necessary imaging services to be provided at the new Bone & Joint Institute, including standard orthopedic imaging and surgical planning scans. In addition, CTA for post-surgical follow-up of potential embolisms provided by the new CT Scanner will allow rapid assessment of post-surgical patients with suspected lung and other emboli. Otherwise, such post-surgical patients would need to be transferred to the main Hospital for angiography or CTA. The MRI Scanner will allow medically necessary imaging services to be provided at the new Bone & Joint Institute, including timely and appropriate follow-up of post-surgical assessment of patients returning with potential complications.

In addition, because even ambulatory orthopedic patients often have limited mobility, proximity of the needed services such as MRI or CT to the offices of patients' physicians, who will be located within/at the Bone & Joint Institute, is critical to proper patient care. Also, as a facility designed for outpatient care, availability of MRI and CT services in the Bone & Joint Institute will allow for a timelier and better experience for other Hospital outpatients requiring MRI and CT imaging.

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 B, report the units of service by piece of equipment, and in Table C, 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 B

HISTORICAL, CURRENT, AND PROJECTED VOLUME, BY EQUIPMENT UNIT

Equipment***	Actual Volume (Last 3 Completed FYs)			CFY Volume*	Projected Volume (First 3 Full Operational FYs)**		
	FY2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019
GE VCT-Rad-Inpt	9401	10,685	11,944	1956	12,938	13,973	15,090
Outp	2616	3305	4086	707	1206	1302	1406
GE QX/I Rad-Inpt	3016	3298	3672	611	3970	4297	4640
Outp	840	1020	1256	220	370	400	432
GE VCT-ED Dept	23,196	25,929	26,803	5064	31,262	33,763	36,464
GE 750HD Inpt	---	---	---	---	1297	1401	1513
Oupt	---	---	---	---	4654	5026	5428
Total	**39,068**	**44,237**	**47,759**	**8558**	**55,706**	**60,162**	**64,973**
Echospeed Inpt	2865	2975	3234	628	3151	3394	3653
Outp	3128	3294	3568	486	2851	3070	3305
Twinspeed Inpt	1730	1829	1948	381	1898	2044	2200
Outp	1889	2025	2149	295	1717	1849	1990
Pioneer 3T Inpt	---	---	---	---	956	1029	1108
Oupt	---	---	---	---	2057	2215	2384
Total	**9,613**	**10,124**	**10,899**	**1790**	**12,632**	**13,599**	**14,640**

*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.

NOTE: the growth rate from 2014 to 2015 were used to project future volume

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

****Applicant's FY is Oct to September.

TABLE C

HISTORICAL, CURRENT, AND PROJECTED VOLUME, BY TYPE OF SCAN/EXAM

	Actual Volume (Last 3 Completed FYs)****			CFY Volume*	Projected Volume (First 3 Full Operational FYs)**		
	FY2013	FY2014	FY2015	FY 2016	FY 2017	FY2018	FY 2019
Body/Torso	13,066	15,506	16,584	2838	18,910	20,423	22,057
Cardiac	89	133	156	26	178	192	207
Head/Neck	15019	15609	17236	3228	21,223	22,921	24,755
Orthopedic	995	1285	1481	252	1615	1744	1884
Spine *****	5081	6139	6637	1328	7470	8068	8713
Vascular	3172	3592	3979	751	4563	4928	5322
Interven Procedures	1645	1937	1686	135	1747	1887	2038
Total CT Exams	**39068**	**44237**	**47759**	**8558**	**55,706**	**60,163**	**64,976**
Body/Torso	644	724	957	166	1109	1194	1285
Cardiac	458	508	554	81	642	691	744
Head/Neck	4693	5052	5484	890	6356	6842	7366
Orthopedic	963	1046	1050	176	1217	1310	1410
Spine ****	1606	1840	1889	338	2190	2358	2539
Vascular	276	390	371	49	430	463	498
Breast	973	564	594	90	688	741	798
Total MRI EXAMS	**39068**	**10124**	**10899**	**1790**	**12,632**	**13,599**	**14,640**

*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.).
The applicant's Fiscal year is October to September.
***** All spine, including orthopedic and neurological (these cannot be distinguished from available statistics)

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

Prior and current volumes are taken directly from Hospital Information System. Projected volumes were estimated from actual FY15 volumes by using the volume growth observed from FY14 to FY 15.

c. Explain any increases and/or decreases in the volume reported in the tables above.

The increase in aggregate volume assumed a volume growth the same as that observed between that last two full fiscal years (FY14 and FY15). The reduction in projected volumes for all existing CT and MRI scanners (except for the emergency department CT scanner) reflects outpatient and inpatient volumes and orthopedic and spine volumes that are expected to move to the new Scanners if this Proposal is approved. Those volumes expected to move include all current non-ED CT outpatient scans, all orthopedic CT and MRI inpatient scans, 50% of existing inpatient CT spine scans, and all current MRI outpatient head scans.

d. Provide a breakdown, by town, of the volumes provided in **Table C** for the most recently completed FY.

TABLE D
UTILIZATION BY TOWN

Equipment*	Town	Utilization FY XX**

*Identify each scanner separately and add lines as necessary. Also, break out inpatient/outpatient/ED volumes if applicable and include equipment strength (e.g., slices, tesla strength), whether the unit is open or closed (for MRI).
**Fill in year

This information is not available as the Hospital does not track or collect this data by piece of equipment.

Greer, Leslie

From: Carney, Brian
Sent: Thursday, February 11, 2016 3:36 PM
To: Barbara.Durdy@hhchealth.org
Cc: Greer, Leslie; Armah, Olga; Riggott, Kaila
Subject: 16-32062-CON Completeness Letter
Attachments: 16-32062 Hartford Hospital Completeness Letter.docx

Good afternoon Barbara,

Please see the attached completeness letter in the matter to acquire a computed tomography ("CT") scanner and a 3T magnetic resonance imaging ("MRI") scanner for the Hartford Hospital Bone and Joint Institute in Hartford. In responding to the completeness letter questions, please follow the instructions included in the letter and provide the response document as an attachment only (no hard copies required). Please provide your written responses to OHCA no later than **April 11, 2016**.

Email to OHCA@ct.gov and cc: Brian.Carney@ct.gov, Olga.Armah@ct.gov and Kaila.Riggott@ct.gov.

If you have any questions, please contact Brian Carney at (860) 418-7014, Olga Armah (860) 418-7070 or Kaila Riggott at (860) 418-7037.

Sincerely,
Brian A. Carney

Ps. Please confirm receipt of this email and corresponding attachments.

Brian A. Carney, MBA
Associate Research Analyst
Office of Health Care Access
CT Department of Public Health
410 Capitol Avenue, MS #13HCA
P.O. Box 340308
Hartford, CT 06134-0308

Phone: (860) 418-7014
Fax: (860) 418 7053
Email: brian.carney@ct.gov
Web: www.ct.gov/ohca

STATE OF CONNECTICUT
DEPARTMENT OF PUBLIC HEALTH

Raul Pino, M.D., M.P.H.
Acting Commissioner

Dannel P. Malloy
Governor
Nancy Wyman
Lt. Governor

Office of Health Care Access

February 11, 2016 Via Email Only

Barbara Durdy
Director, Strategic Planning
Hartford HealthCare
181 Patricia Genova Boulevard
Newington, CT 06111
barbara.durdy@hhchealth.org

RE: Certificate of Need Application Docket Number: 16-32062-CON
Acquisition of Computed Tomography and 3T Magnetic Resonance Imaging Scanners
Certificate of Need Completeness Letter

Dear Ms. Durdy:

On January 15, 2016, OHCA received the Certificate of Need application from Hartford Hospital ("Applicant") to acquire a computed tomography ("CT") scanner and a 3T magnetic resonance imaging ("MRI") scanner for the Hartford Hospital Bone and Joint Institute in Hartford.

OHCA requests additional information pursuant to Connecticut General Statutes §19a-639a(c). *Please electronically confirm receipt of this email as soon as you receive it.* Provide responses to the questions below in both a Word document and PDF format as an attachment to a responding email. ***Please email your responses as an attachment to each of the following email addresses: OHCA@ct.gov; olga.armah@ct.gov, brian.carney@ct.gov; and kaila.riggott@ct.gov.***

Pursuant to Section 19a-639a(c) of the Connecticut General Statutes, you must submit your response to this request no later than sixty days from the date of this email transmission. Therefore, please provide your written responses to OHCA no later than **Monday, April 11, 2016**, otherwise your application will be automatically considered withdrawn.

Paginate and date your response (i.e., each page in its entirety). Repeat each OHCA question before providing your response. Information filed after the initial CON application submission (e.g., completeness response letter, prefiled testimony, late file submissions, etc.) must be numbered

sequentially from the Applicant's preceding document. Begin your submission using **Page 226** and reference "**Docket Number: 16-32062-CON**."

1) Define the primary and secondary service area towns related to the proposed imaging services as requested in question 3.b. of the CON Main Form.

TABLE 2
SERVICE AREA TOWNS

List the official name of town* and provide the reason for inclusion.

Town*	Reason for Inclusion

* Village or place names are not acceptable.

2) Revise and resubmit Table 8 on pages 34 and 35 (as Excel file) to reflect only official Connecticut towns, as requested in the application form. *Note: out-of-state towns can remain on the list; however, areas in Connecticut (e.g., Weatogue) and their associated volumes should be reflected in the official town (e.g., Simsbury) total.*

3) Describe any consideration given to relocating an existing underutilized Hartford Healthcare scanner to the Bone & Joint Institute.

4) Revise utilization volumes reported on pages 31 and 224 of the application as follows:

   a) reconcile historical CT utilization volumes for fiscal years ("FY") 2013 and 2014 with Hospital Reporting System - Report 450;
   b) reconcile MRI utilization volumes for FY 2013 with Hospital Reporting System - Report 450;
   c) update FY 2016 volumes to include October 1, 2015 through January 31, 2016 data; and
   d) reconcile several minor differences between volumes reported on pages 31 and 224 (numbers on both pages should match and confirm that the numbers reflect scan volume).

5) Provide specific examples of how this proposal will improve health care outcomes in the service area.

6) Elaborate and provide specific evidence to support the assertion that the need for orthopedic scans will continue to increase.

7) Provide the type/percentage of orthopedic surgery patients that would benefit from a follow-up Computed Tomography Angiography (CTA) and describe the impact on the quality of patient care.

8) Elaborate and provide additional evidence on the clear public need for a 3T MRI at the Bone & Joint Institute.

9) Provide additional detail on the scheduling difficulties experienced for routine outpatient CT and MRI scans.

10) The Hartford Hospital license provided on page 42 of the application expired on December 31, 2015. Provide the current license.

11) Revise the payer mix table provided on page 33 of the application to include both patient volume and the corresponding percentages. Begin with FY 2015 and confirm that the numbers reflect scan volumes. Totals should match the revised utilization numbers provided in response to question four.

TABLE 7
APPLICANT'S CURRENT & PROJECTED PAYER MIX

Payer	FY 2015		FY 2016 YTD		Projected					
					FY 2017		FY 2018		FY 2019	
	Volume	%	Volume	%	Volume	%	Volume	%	Volume	%
Medicare*										
Medicaid*										
CHAMPUS & TriCare										
Total Government										
Commercial Insurers										
Uninsured										
Workers Compensation										
Total Non-Government										
Total Payer Mix										

If you have any questions concerning this letter, please feel free to contact Olga Armah at (860) 418-7070, Brian Carney at (860) 418-7014 or Kaila Riggott at (860) 418-7037.

Greer, Leslie

From: Armah, Olga
Sent: Tuesday, March 22, 2016 12:34 PM
To: Greer, Leslie
Subject: FW: OHCA Filing - PDF Entire Packet + Word + Excel Documents
Attachments: FINAL Exhibit 10 MRI by Town 2015.xlsx; FINAL Exhibit 10 CT by Town 2015.xlsx; Final HH Completeness Response 3-16-16.DOCX; Completeness Responses Docket Number 16-32062-CON.PDF

Importance: High

FYI

Olga Armah
Office of Health Care Access (OHCA)
CT Department of Public Health
Phone: 860 418 7070
Fax: 860 418 7053
Mailto: olga.armah@ct.gov
Web: www.ct.gov/ohca

From: Durdy, Barbara [mailto:Barbara.Durdy@hhchealth.org]
Sent: Tuesday, March 22, 2016 12:26 PM
To: Carney, Brian; Armah, Olga; Riggott, Kaila
Cc: Carannante, Vincenzo <VCarannante@goodwin.com> (VCarannante@goodwin.com)
Subject: OHCA Filing - PDF Entire Packet + Word + Excel Documents
Importance: High

Olga,
On behalf of Hartford Hospital, attached please find:

1. Copy of the entire and numbered completeness question response filing;
2. Microsoft Word Document containing our responses; and
3. The excel files you requested in question # 2.

Please let me know if you need anything else.

Barbara

Barbara A. Durdy
Director, Strategic Planning

Hartford HealthCare

181 Patricia M. Genova Blvd.

Newington, CT 06111

Office: 860.972.4231

Cell: 203.859.8174

barbara.durdy@hhchealth.org

www.hartfordhealthcare.org

Hartford HealthCare

March 21, 2016

Ms. Olga Armah
Health Care Analyst
State of Connecticut Department of Public Health
Office of Health Care Access Division
410 Capital Avenue
P.O. Box 340308
Hartford, CT 06134-0308

RE: Certificate of Need Application Docket Number: 16-32062-CON
Acquisition of Computed Tomography and 3T Magnetic Resonance Imaging Scanners
Certificate of Need Completeness Letter Responses

Ms. Armah:

Enclosed please find Hartford Hospital's responses to the Office of Health Care Access's completeness questions dated February 11, 2016.

Please do not hesitate to contact me if you need additional information or have any further questions.

Sincerely,

Barbara A. Durdy
Director, Strategic Planning
Hartford HealthCare

SN: bd.

Encl.

1) Define the primary and secondary service area towns related to the proposed imaging services as requested in question 3.b. of the CON Main Form.

TABLE 2
SERVICE AREA TOWNS

List the official name of town* and provide the reason for inclusion.

Town*	Reason for Inclusion

* Village or place names are not acceptable.

Hartford Hospital (the "Hospital") defines its primary service area as those towns from which 80% of inpatient discharges originate. The Hospital's secondary service area is defined as the remainder of the State of Connecticut, excluding Fairfield County.

Please see Exhibit 9 for a listing of primary service area and secondary service area towns.

2) Revise and resubmit Table 8 on pages 34 and 35 (as Excel file) to reflect only official Connecticut towns, as requested in the application form. *Note: out-of-state towns can remain on the list; however, areas in Connecticut (e.g., Weatogue) and their associated volumes should be reflected in the official town (e.g., Simsbury) total.*

Please see Exhibit 10 for Table 8 revised to include only official Connecticut towns.

3) Describe any consideration given to relocating an existing underutilized Hartford Healthcare scanner to the Bone & Joint Institute.

The Hospital currently operates three CT scanners and 2 MRI scanners. With the exception of the oldest, 15 year old CT scanner, all scanners are operating at or near capacity. The oldest CT scanner is the GE QX/i, which is 15 years old and has limited but essential utility on the main Hospital campus. The Hospital has not considered relocating this scanner because it serves a very specific and essential function on the main Hospital campus. This scanner is used for CT guided procedures such as biopsies and aspirations, which are longer procedures, typically scheduled for 90 to 120 minutes. Due to the duration of these procedures, they cannot be accommodated on any other CT scanner at the main Hospital campus. Accordingly, the GE QX/I scanner will be maintained at the main Hospital campus to accommodate these longer procedures.

4) Revise utilization volumes reported on pages 31 and 224 of the application as follows:

a) reconcile historical CT utilization volumes for fiscal years ("FY") 2013 and 2014 with Hospital Reporting System - Report 450;

Please see Exhibit 11 for CT utilization reconciliation.

b) reconcile MRI utilization volumes for FY 2013 with Hospital Reporting System - Report 450;

Please see Exhibit 11 for MRI utilization reconciliation.

c) update FY 2016 volumes to include October 1, 2015 through January 31, 2016 data; and

Please see Tables below revised to reflect FYTD January 2016 volume data.

Table 5
Revised - FYTD 2016 October 2015 through January 2016
Historical Utilization by Service

	Actual Volume (Last 3 Completed FYs)			CFY Volume*
Service**	FY 2013	FY 2014	FY 2015	FY 2016 YTD
CT Scanners:				
GE VCT- Radiology Dept	12,017	13,990	15,188	5851
GE QX/i- Radiology Dept (a)	3798	3552	4078	1799
GE VCT – ED Dept	23,195	25,929	28,793	9784
CT Total:	**39,010**	**43,471**	**48,059**	**17434**
MRI Scanners				
GE Signa Echospeed 1.5T	6077	6269	6802	2211
GE Signa Twinspeed 1.5T	3644	3855	4097	1331
MRI Total:	**9721**	**10,124**	**10,899**	**3542**

Table B
Revised - FYTD 2016 October 2015 through January 2016
Historical, Current and Projected Volume by Equipment Unit

Equipment***	Actual Volume (Last 3 Completed FYs)			CFY Volume*	Projected Volume (First 3 Full Operational FYs)**		
	FY2013	FY 2014	FY 2015	FY 2016-YTD	FY 2017	FY 2018	FY 2019
GE VCT-Rad-Inpt	9401	10,685	11,317	4360	13441	14,651	15,970
Outp	2616	3305	3871	1492	1253	1,366	1,488
GE QX/I Rad-Inpt	2971	2713	2877	1340	4124	4,495	4,900
Outp	827	839	1201	459	385	419	457
GE VCT-ED Dept	23,195	25,929	28793	9783	32478	35,401	38,587
GE 750HD Inpt	---	---	---	---	1183	1,290	1,406
Oupt	---	---	---	---	4246	4,628	5,044
Total	**39,010**	**43,471**	**48,059**	**17,434**	**57,110**	**62,250**	**67,852**
Echospeed Inpt	2905	2975	3234	1051	3151	3394	3653
Outp	3172	3294	3568	1160	2851	3070	3305
Twinspeed Inpt	1754	1830	1948	633	1898	2044	2200
Outp	1890	2025	2149	698	1717	1849	1990
Pioneer 3T Inpt	---	---	---	---	956	1029	1108
Oupt	---	---	---	---	2057	2215	2384
Total	**9,721**	**10,124**	**10,899**	**3542**	**12,632**	**13,599**	**14,640**

Table C
Revised - FYTD 2016 October 2015 through January 2016
Historical, Current and Projected Volume by Type of Scan/Exam

	Actual Volume (Last 3 Completed FYs)****			CFY Volume*	Projected Volume (First 3 Full Operational FYs)**		
	FY2013	FY2014	FY2015	FY 2016	FY 2017	FY2018	FY 2019
Body/Torso	13,430	14,975	16654	6011	19787	21568	23509
Cardiac	91	128	155	47	184	201	219
Head/Neck	15437	16809	18683	6644	22197	24194	26371
Orthopedic	904	1110	1295	512	1539	1678	1829
Spine *****	5171	6015	6549	2449	7780	8480	9243
Vascular	3260	3611	4020	1482	4788	5219	5689
Interv imaging	717	823	703	289	835	910	992
Total CT Exams	**39,010**	**43,471**	**48,059**	**17434**	**57,110**	**62,250**	**67,852**
Body/Torso	653	724	957	313	1109	1194	1285
Cardiac	464	508	554	155	642	691	744
Head/Neck	4759	5052	5484	1826	6356	6842	7366
Orthopedic	976	1046	1050	337	1217	1310	1410
Spine ****	1628	1840	1889	669	2190	2358	2539
Vascular	280	390	371	79	430	463	498
Breast	961	564	594	163	688	741	798
Total MRI EXAMS	**9721**	**10,124**	**10,899**	**3542**	**12,632**	**13,599**	**14,640**

d) reconcile several minor differences between volumes reported on pages 31 and 224 (numbers on both pages should match and confirm that the numbers reflect scan volume).

The total listed for MRI in 2013 in Table C was incorrectly entered and has been corrected. The remaining differences, mostly of +/- 1, have also been corrected, and the values in the corrected tables of Exhibit 11 reflect correct totals.

Please note that the data used to complete the OHCA form 450 was derived from the "Revenue Distribution by Service Code" report or SMS 6506. The volumes reported in the SMS 6506 are based on gross revenue posting dates. The data reported in Table 5 of the CON Application was based on dates of service. This difference produces variation in the volume reported.

Please see Exhibit 11 for a schedule of MRI and CT volumes reconciled to the OHCA 450 report.

5) Provide specific examples of how this proposal will improve health care outcomes in the service area.

The Bone & Joint Institute is specifically designed to bring timely, patient centered musculoskeletal care to the community. The grouping of orthopaedic, rheumatology, pain management and rehabilitation services as well as appropriate imaging are designed to streamline and expedite the care of acute injury as well as facilitate the management of complex chronic conditions. For example, a patient who sees a rheumatologist for knee pain and whom is suspected of meniscal pathology will be able to have this confirmed by MRI and have orthopaedic care initiated immediately to avoid further injury. A patient seen in orthopaedics for low back pain will have plain x-rays followed by CT or MRI as appropriate and would be able to initiate pain management on a single visit. An orthopaedic oncologist will be able to order CT or MRI on a sarcoma/cancer patient and consult with the musculoskeletal radiologist on site. All scenarios are focused on bringing the right care to the right patient at the right time and at the same location.

6) Elaborate and provide specific evidence to support the assertion that the need for orthopedic scans will continue to increase.

The numbers of patients admitted with orthopaedic injury or complex musculoskeletal pathology through the Hartford Hospital transfer center have increased each year from 112 in FY 2013 to 126 in FY 2015, reflecting a significant change in care patterns for these injuries in northern Connecticut.

Overall inpatient orthopaedic care, based on population demographics (specifically, the needs of the baby boomer generation) is consistently projected to increase by 250 % over the next fifteen years.

Please see Exhibit 12 for copies of journal articles supporting growth projections for orthopedic surgery.

These patients will primarily require arthritis and spine care. Complex total joints will require CT capability to plan and execute surgeries in the face of advanced deformity or bone loss. Spine patients (as delineated in #5 above), frequently require CT and/or MRI for appropriate diagnosis and management.

7) Provide the type/percentage of orthopedic surgery patients that would benefit from a follow-up Computed Tomography Angiography (CTA) and describe the impact on the quality of patient care.

The importance of CTA to the care of orthopedic surgical patients is associated most critically with the evaluation of emergent post-surgical complications, particularly pulmonary emboli PE) and blood clots that could lead to pulmonary emboli (deep vein thrombosis or DVT).

Please see Exhibit 13 for an article from The Musculoskeletal Journal of Hospital for Special Surgery, describing the use and value of CT in orthopedic surgical care.

Hartford Hospital itself does not currently have the ability to track statistics on the number or percentages of such cases. However, of the 91 chest CTA exams that were ordered for patients from predominantly orthopedic surgical nursing units, 70 listed reasons and/or symptoms potentially consistent with PE (e.g., "Rule out PE, "Hypoxia, etc.). Since there were 4426 orthopedic surgical cases performed in FY2015, the resulting rate of CT use (71/4426 = 1.6%) is consistent with those cited in the aforementioned article.

8) Elaborate and provide additional evidence on the clear public need for a 3T MRI at the Bone & Joint Institute.

The value of 3T MRI for orthopedic medical care is associated primarily with the higher spatial resolution of 3T MRI compared with the older 1.5 technology. A 3T MRI can provide a four-fold increase in signal strength, which can translate into at least a two-fold improvement in resolution by allowing images with smaller pixels to be acquired. This higher spatial resolution improves the ability of MRI to visualize smaller structures, especially in spine and small body part imaging. In conclusion, the 3T MRI will yield improved image quality, contrast and resolution. Accordingly, the public (i.e. Hartford Hospital's patients) will benefit from having access to the best diagnostic care possible.

9.)Provide additional detail on the scheduling difficulties experienced for routine outpatient CT and MRI scans.

The Hospital attempts to provide the best possible care for all inpatients requiring CT and MRI scans as well as outpatients referred to it for CT and MRI scans. However, daily scheduling interruptions and delays occur due to the add-on of critical exam inpatient scans and frequent delays in handling of inpatients needing to be transported on beds or stretchers. Due to the unpredictability of critical inpatient exam scheduling and delays resulting from transporting patients who are immobile or physically debilitated, it is extremely difficult to adhere to the times of scheduled exams for outpatients. On most

days, outpatient exams are significantly delayed which causes dissatisfaction and inconvenience for both physicians and patients. Since fewer inpatients would need to be scanned on the Bone & Joint Institute scanners, outpatient delays can be significantly improved.

10) The Hartford Hospital license provided on page 42 of the application expired on December 31, 2015. Provide the current license.

Please see Exhibit 14 attached for a copy of the Hospital's current license.

11) Revise the payer mix table provided on page 33 of the application to include both patient volume and the corresponding percentages. Begin with FY 2015 and confirm that the numbers reflect scan volumes. Totals should match the revised utilization numbers provided in response to question four.

TABLE 7 - REVISED
APPLICANT'S CURRENT & PROJECTED PAYER MIX

CT	FY 2015		Current** FY 2016		Year 1*** FY 2017		Year 2*** FY 2018		Year 3*** FY 2019	
Medicare*	21755	45%	7589	44%	24864	44%	27102	44%	29541	44%
Medicaid*	11646	24%	4228	24%	13851	24%	15097	24%	16456	24%
Other Government	308	1%	125	1%	403	1%	439	1%	479	1%
Total Government	**33,709**	**70%**	**11,942**	**69%**	**38854**	**69%**	**42639**	**69%**	**46476**	**70%**
Commercial Insurers*	11958	25%	4417	25%	14471	25%	15773	25%	17192	25%
Uninsured/Selfpay	2377	5%	1074	6%	3518	6%	3835	6%	4180	6%
Workers Compensation	14	0%	1	<1%	3	<1%	4	<1%	4	<1%
Total Non-Government	**14350**	**30%**	**5400**	**31%**	**16852**	**30%**	**19611**	**31%**	**21376**	**31%**
Total Payer Mix	**48059**	**100%**	**17434**	**100%**	**57110**	**100%**	**62250**	**100%**	**67852**	**100%**

MRI	FY 2015		Current** FY 2016		Year 1 FY 2017		Year 2 FY 2018		Year 3 FY 2019	
Medicare*	4168	38%	1384	39%	4936	38%	5314	38%	5720	38%
Medicaid*	2360	22%	733	21%	2614	22%	2814	22%	3030	22%
Other Government	71	1%	22	1%	78	1%	84	1%	91	1%
Total Government	**6599**	**61%**	**2139**	**60%**	**7628**	**60%**	**8212**	**60%**	**8841**	**60%**
Commercial Insurers*	4132	38%	1200	34%	4280	38%	4607	38%	4960	38%
Uninsured/Selfpay	153	1%	200	6%	713	1%	768	1%	827	1%
Workers Compensation	15	0%	3	<1%	11	<1%	12	<1%	12	<1%
Total Non-Government	**4300**	**39%**	**1403**	**40%**	**5004**	**40%**	**5387**	**40%**	**5799**	**40%**
Total Payer Mix	**10899**	**100%**	**3542**	**100%**	**12632**	**100%**	**13599**	**100%**	**14640**	**100%**

EXHIBIT

9

Exhibit 9

Hartford Hospital PSA and SSA by Town and Zip Code

Territory	Hartford PSA	zip_code
Hartford PSA	ANDOVER	06232
Hartford PSA	AVON	06001
Hartford PSA	BERLIN	06023
Hartford PSA	BERLIN	06037
Hartford PSA	BLOOMFIELD	06002
Hartford PSA	BOLTON	06043
Hartford PSA	BRISTOL	06010
Hartford PSA	BRISTOL	06011
Hartford PSA	BURLINGTON	06013
Hartford PSA	CANTON	06059
Hartford PSA	CANTON	06019
Hartford PSA	CANTON	06020
Hartford PSA	CANTON	06022
Hartford PSA	COLUMBIA	06231
Hartford PSA	COLUMBIA	06237
Hartford PSA	COVENTRY	06238
Hartford PSA	CROMWELL	06416
Hartford PSA	EAST GRANBY	06026
Hartford PSA	EAST HARTFORD	06108
Hartford PSA	EAST HARTFORD	06118
Hartford PSA	EAST HARTFORD	06128
Hartford PSA	EAST HARTFORD	06138
Hartford PSA	EAST WINDSOR	06016
Hartford PSA	EAST WINDSOR	06088
Hartford PSA	ENFIELD	06082
Hartford PSA	ENFIELD	06083
Hartford PSA	FARMINGTON	06030
Hartford PSA	FARMINGTON	06032
Hartford PSA	FARMINGTON	06034
Hartford PSA	FARMINGTON	06085
Hartford PSA	GLASTONBURY	06025
Hartford PSA	GLASTONBURY	06033
Hartford PSA	GLASTONBURY	06073
Hartford PSA	GRANBY	06035
Hartford PSA	GRANBY	06060
Hartford PSA	GRANBY	06090
Hartford PSA	HARTFORD	06101
Hartford PSA	HARTFORD	06102
Hartford PSA	HARTFORD	06103
Hartford PSA	HARTFORD	06104
Hartford PSA	HARTFORD	06105
Hartford PSA	HARTFORD	06106
Hartford PSA	HARTFORD	06112
Hartford PSA	HARTFORD	06114

Hartford PSA	HARTFORD	06115
Hartford PSA	HARTFORD	06120
Hartford PSA	HARTFORD	06123
Hartford PSA	HARTFORD	06126
Hartford PSA	HARTFORD	06132
Hartford PSA	HARTFORD	06134
Hartford PSA	HARTFORD	06140
Hartford PSA	HARTFORD	06141
Hartford PSA	HARTFORD	06142
Hartford PSA	HARTFORD	06143
Hartford PSA	HARTFORD	06144
Hartford PSA	HARTFORD	06145
Hartford PSA	HARTFORD	06146
Hartford PSA	HARTFORD	06147
Hartford PSA	HARTFORD	06152
Hartford PSA	HARTFORD	06153
Hartford PSA	HARTFORD	06176
Hartford PSA	HEBRON	06248
Hartford PSA	MANCHESTER	06040
Hartford PSA	MANCHESTER	06042
Hartford PSA	MANCHESTER	06045
Hartford PSA	MERIDEN	06450
Hartford PSA	MERIDEN	06451
Hartford PSA	MIDDLETOWN	06457
Hartford PSA	MIDDLETOWN	06459
Hartford PSA	NEW BRITAIN	06050
Hartford PSA	NEW BRITAIN	06051
Hartford PSA	NEW BRITAIN	06052
Hartford PSA	NEW BRITAIN	06053
Hartford PSA	NEW HARTFORD	06057
Hartford PSA	NEW HARTFORD	06061
Hartford PSA	NEWINGTON	06111
Hartford PSA	NEWINGTON	06131
Hartford PSA	PLAINVILLE	06062
Hartford PSA	PORTLAND	06480
Hartford PSA	ROCKY HILL	06067
Hartford PSA	SIMSBURY	06070
Hartford PSA	SIMSBURY	06081
Hartford PSA	SIMSBURY	06089
Hartford PSA	SIMSBURY	06092
Hartford PSA	SOUTH WINDSOR	06074
Hartford PSA	SOUTHINGTON	06444
Hartford PSA	SOUTHINGTON	06467
Hartford PSA	SOUTHINGTON	06479
Hartford PSA	SOUTHINGTON	06489
Hartford PSA	SUFFIELD	06078
Hartford PSA	SUFFIELD	06093
Hartford PSA	TORRINGTON	06790

Hartford PSA	VERNON	06066
Hartford PSA	WEST HARTFORD	06107
Hartford PSA	WEST HARTFORD	06110
Hartford PSA	WEST HARTFORD	06117
Hartford PSA	WEST HARTFORD	06119
Hartford PSA	WEST HARTFORD	06127
Hartford PSA	WEST HARTFORD	06133
Hartford PSA	WEST HARTFORD	06137
Hartford PSA	WETHERSFIELD	06109
Hartford PSA	WETHERSFIELD	06129
Hartford PSA	WINDHAM	06226
Hartford PSA	WINDHAM	06256
Hartford PSA	WINDHAM	06266
Hartford PSA	WINDHAM	06280
Hartford PSA	WINDSOR	06006
Hartford PSA	WINDSOR	06064
Hartford PSA	WINDSOR	06095
Hartford PSA	WINDSOR LOCKS	06096
Hartford SSA	ANSONIA	06401
Hartford SSA	ASHFORD	06278
Hartford SSA	BARKHAMSTED	06063
Hartford SSA	BARKHAMSTED	06065
Hartford SSA	BEACON FALLS	06403
Hartford SSA	BETHANY	06524
Hartford SSA	BOZRAH	06334
Hartford SSA	BOZRAH	06336
Hartford SSA	BRANFORD	06405
Hartford SSA	BROOKLYN	06234
Hartford SSA	CANAAN	06018
Hartford SSA	CANAAN	06024
Hartford SSA	CANAAN	06031
Hartford SSA	CANTERBURY	06331
Hartford SSA	CHAPLIN	06235
Hartford SSA	CHESHIRE	06410
Hartford SSA	CHESHIRE	06411
Hartford SSA	CHESTER	06412
Hartford SSA	CLINTON	06413
Hartford SSA	COLCHESTER	06415
Hartford SSA	COLEBROOK	06021
Hartford SSA	CORNWALL	06753
Hartford SSA	CORNWALL	06754
Hartford SSA	CORNWALL	06796
Hartford SSA	DEEP RIVER	06417
Hartford SSA	DERBY	06418
Hartford SSA	DURHAM	06422
Hartford SSA	EAST HADDAM	06423
Hartford SSA	EAST HADDAM	06439
Hartford SSA	EAST HADDAM	06469

Hartford SSA	EAST HAMPTON	06414
Hartford SSA	EAST HAMPTON	06424
Hartford SSA	EAST HAMPTON	06456
Hartford SSA	EAST HAVEN	06512
Hartford SSA	EAST LYME	06333
Hartford SSA	EAST LYME	06357
Hartford SSA	EAST WINDSOR	06028
Hartford SSA	EAST WINDSOR	06049
Hartford SSA	EASTFORD	06242
Hartford SSA	ELLINGTON	06029
Hartford SSA	ESSEX	06409
Hartford SSA	ESSEX	06426
Hartford SSA	ESSEX	06442
Hartford SSA	FARMINGTON	06087
Hartford SSA	FRANKLIN	06254
Hartford SSA	GOSHEN	06756
Hartford SSA	GRISWOLD	06337
Hartford SSA	GRISWOLD	06351
Hartford SSA	GROTON	06340
Hartford SSA	GROTON	06349
Hartford SSA	GROTON	06388
Hartford SSA	GUILFORD	06437
Hartford SSA	HADDAM	06438
Hartford SSA	HADDAM	06441
Hartford SSA	HAMDEN	06514
Hartford SSA	HAMDEN	06517
Hartford SSA	HAMDEN	06518
Hartford SSA	HAMPTON	06247
Hartford SSA	HARTLAND	06027
Hartford SSA	HARTLAND	06091
Hartford SSA	HARWINTON	06791
Hartford SSA	KENT	06757
Hartford SSA	KENT	06785
Hartford SSA	KILLINGLY	06233
Hartford SSA	KILLINGLY	06239
Hartford SSA	KILLINGLY	06241
Hartford SSA	KILLINGLY	06243
Hartford SSA	KILLINGLY	06263
Hartford SSA	KILLINGWORTH	06419
Hartford SSA	LEBANON	06249
Hartford SSA	LEDYARD	06335
Hartford SSA	LEDYARD	06338
Hartford SSA	LEDYARD	06339
Hartford SSA	LITCHFIELD	06750
Hartford SSA	LITCHFIELD	06759
Hartford SSA	LITCHFIELD	06778
Hartford SSA	LYME	06371
Hartford SSA	MADISON	06443

Hartford SSA	MANSFIELD	06250
Hartford SSA	MANSFIELD	06251
Hartford SSA	MANSFIELD	06268
Hartford SSA	MANSFIELD	06269
Hartford SSA	MARLBOROUGH	06447
Hartford SSA	MIDDLEBURY	06762
Hartford SSA	MIDDLEFIELD	06455
Hartford SSA	MIDDLEFIELD	06481
Hartford SSA	MILFORD	06460
Hartford SSA	MILFORD	06461
Hartford SSA	MONTVILLE	06353
Hartford SSA	MONTVILLE	06370
Hartford SSA	MONTVILLE	06382
Hartford SSA	MONTVILLE	06474
Hartford SSA	MORRIS	06758
Hartford SSA	MORRIS	06763
Hartford SSA	NAUGATUCK	06770
Hartford SSA	NEW HAVEN	06501
Hartford SSA	NEW HAVEN	06502
Hartford SSA	NEW HAVEN	06503
Hartford SSA	NEW HAVEN	06504
Hartford SSA	NEW HAVEN	06505
Hartford SSA	NEW HAVEN	06506
Hartford SSA	NEW HAVEN	06507
Hartford SSA	NEW HAVEN	06508
Hartford SSA	NEW HAVEN	06509
Hartford SSA	NEW HAVEN	06510
Hartford SSA	NEW HAVEN	06511
Hartford SSA	NEW HAVEN	06513
Hartford SSA	NEW HAVEN	06515
Hartford SSA	NEW HAVEN	06519
Hartford SSA	NEW HAVEN	06520
Hartford SSA	NEW HAVEN	06521
Hartford SSA	NEW HAVEN	06530
Hartford SSA	NEW HAVEN	06531
Hartford SSA	NEW HAVEN	06532
Hartford SSA	NEW HAVEN	06533
Hartford SSA	NEW HAVEN	06534
Hartford SSA	NEW HAVEN	06535
Hartford SSA	NEW HAVEN	06536
Hartford SSA	NEW LONDON	06320
Hartford SSA	NEW MILFORD	06755
Hartford SSA	NEW MILFORD	06776
Hartford SSA	NORFOLK	06058
Hartford SSA	NORTH BRANFORD	06471
Hartford SSA	NORTH BRANFORD	06472
Hartford SSA	NORTH HAVEN	06473
Hartford SSA	NORTH STONINGTON	06359

Hartford SSA	NORWICH	06360
Hartford SSA	NORWICH	06365
Hartford SSA	NORWICH	06380
Hartford SSA	NORWICH	06389
Hartford SSA	OLD LYME	06371
Hartford SSA	OLD LYME	06376
Hartford SSA	OLD SAYBROOK	06475
Hartford SSA	ORANGE	06477
Hartford SSA	OXFORD	06478
Hartford SSA	PLAINFIELD	06332
Hartford SSA	PLAINFIELD	06354
Hartford SSA	PLAINFIELD	06374
Hartford SSA	PLAINFIELD	06387
Hartford SSA	PLYMOUTH	06781
Hartford SSA	PLYMOUTH	06782
Hartford SSA	PLYMOUTH	06786
Hartford SSA	POMFRET	06230
Hartford SSA	POMFRET	06258
Hartford SSA	POMFRET	06259
Hartford SSA	PROSPECT	06712
Hartford SSA	PUTNAM	06260
Hartford SSA	ROXBURY	06783
Hartford SSA	SALEM	06420
Hartford SSA	SALISBURY	06039
Hartford SSA	SALISBURY	06068
Hartford SSA	SALISBURY	06079
Hartford SSA	SCOTLAND	06264
Hartford SSA	SEYMOUR	06483
Hartford SSA	SHARON	06069
Hartford SSA	SOMERS	06071
Hartford SSA	SOMERS	06072
Hartford SSA	SOUTHBURY	06488
Hartford SSA	SPRAGUE	06330
Hartford SSA	SPRAGUE	06350
Hartford SSA	SPRAGUE	06383
Hartford SSA	STAFFORD	06075
Hartford SSA	STAFFORD	06076
Hartford SSA	STAFFORD	06077
Hartford SSA	STERLING	06373
Hartford SSA	STERLING	06377
Hartford SSA	STONINGTON	06355
Hartford SSA	STONINGTON	06372
Hartford SSA	STONINGTON	06378
Hartford SSA	STONINGTON	06379
Hartford SSA	THOMASTON	06787
Hartford SSA	THOMPSON	06245
Hartford SSA	THOMPSON	06246
Hartford SSA	THOMPSON	06255

Hartford SSA	THOMPSON	06262
Hartford SSA	THOMPSON	06277
Hartford SSA	TOLLAND	06084
Hartford SSA	VOLUNTOWN	06384
Hartford SSA	WALLINGFORD	06492
Hartford SSA	WALLINGFORD	06495
Hartford SSA	WASHINGTON	06777
Hartford SSA	WASHINGTON	06793
Hartford SSA	WASHINGTON	06794
Hartford SSA	WATERBURY	06701
Hartford SSA	WATERBURY	06702
Hartford SSA	WATERBURY	06703
Hartford SSA	WATERBURY	06704
Hartford SSA	WATERBURY	06705
Hartford SSA	WATERBURY	06706
Hartford SSA	WATERBURY	06708
Hartford SSA	WATERBURY	06710
Hartford SSA	WATERBURY	06720
Hartford SSA	WATERBURY	06721
Hartford SSA	WATERBURY	06722
Hartford SSA	WATERBURY	06723
Hartford SSA	WATERBURY	06724
Hartford SSA	WATERBURY	06725
Hartford SSA	WATERBURY	06726
Hartford SSA	WATERBURY	06751
Hartford SSA	WATERFORD	06375
Hartford SSA	WATERFORD	06385
Hartford SSA	WATERTOWN	06779
Hartford SSA	WATERTOWN	06795
Hartford SSA	WEST HAVEN	06516
Hartford SSA	WESTBROOK	06498
Hartford SSA	WILLINGTON	06265
Hartford SSA	WILLINGTON	06279
Hartford SSA	WINCHESTER	06094
Hartford SSA	WINCHESTER	06098
Hartford SSA	WOLCOTT	06716
Hartford SSA	WOODBRIDGE	06525
Hartford SSA	WOODBURY	06798
Hartford SSA	WOODSTOCK	06244
Hartford SSA	WOODSTOCK	06267
Hartford SSA	WOODSTOCK	06281
Hartford SSA	WOODSTOCK	06282

EXHIBIT

10

Harford Hospital
MRI Scans by Connecticut Town
FY 2015

CITY	MRI Exams
HARTFORD	1961
EAST HARTFORD	589
WEST HARTFORD	437
WETHERSFIELD	391
MANCHESTER	389
WINDSOR	337
GLASTONBURY	336
NEWINGTON	300
NEW BRITAIN	240
ROCKY HILL	236
MIDDLETOWN	224
SOUTH WINDSOR	213
BLOOMFIELD	198
BRISTOL	174
MERIDEN	171
ENFIELD	165
TORRINGTON	153
VERNON	141
NORWICH	139
WINDSOR LOCKS	135
WILLIMANTIC	115
COLCHESTER	113
FARMINGTON	92
AVON	91
SOUTHINGTON	91
CROMWELL	90
ELLINGTON	86
SIMSBURY	84
COVENTRY	83
GRISWOLD	74
BERLIN	73
WATERBURY	72
TOLLAND	71
EAST HAMPTON	69
MARLBOROUGH	69
PLAINVILLE	66
WALLINGFORD	62
GRANBY	60
LEBANON	57
SOUTH GLASTONBURY	56
HEBRON	56
WINSTED	52
BURLINGTON	46
STAFFORD SPRINGS	44
UNION	44
SUFFIELD	44
MANSFIELD	43
COLUMBIA	43
EAST WINDSOR	42
SOMERS	42
EAST WINDSOR	41
BOLTON	41
NEW HARTFORD	40
CANTON	39
PORTLAND	37
GRANBY	37
CHESHIRE	36
KILLINGLY	34
WILLINGTON	33
UNCASVILLE	31
SOUTHINGTON	29
ANDOVER	27
WALLINGFORD	27
LITCHFIELD	27
PUTNAM	26
ASHFORD	26
WINDHAM	26
WINDHAM	24
OLD LYME	24
MANSFIELD	23
SIMSBURY	23
PLAINFIELD	22
WINDHAM	22
OLD SAYBROOK	21
AMSTON	21

HARWINTON	21
PLAINFIELD	21
DURHAM	19
HADDAM	19
HAMDEN	19
NEW LONDON	19
KILLINGLY	17
NEW LONDON	16
PRESTON	16
WOLCOTT	16
CANTERBURY	15
BALTIC	15
GROTON	15
SALEM	15
NORWICH	14
EAST HADDAM	13
LEDYARD	13
HARTFORD	13
THOMASTON	13
EAST HADDAM	12
MYSTIC	12
GRANBY	12
GOSHEN	11
WATERTOWN	11
CHESTER	11
LITCHFIELD	10
SOUTHBURY	10
VOLUNTOWN	10
All Other	795
	10,899

Harford Hospital (Table 8)
CT Scans by Connecticut Town
FY 2015

CITY	CT EXAMS
HARTFORD	11332
EAST HARTFORD	3228
WEST HARTFORD	2236
WETHERSFIELD	1979
MANCHESTER	1658
GLASTONBURY	1478
WINDSOR	1465
NEWINGTON	1442
ROCKY HILL	1346
NEW BRITAIN	1003
BLOOMFIELD	989
SOUTH WINDSOR	959
ENFIELD	896
MERIDEN	892
MIDDLETOWN	888
VERNON	583
WINDSOR LOCKS	513
BRISTOL	499
TORRINGTON	468
COLCHESTER	371
NORWICH	367
FARMINGTON	344
AVON	337
WILLIMANTIC	323
SOUTHINGTON	321
BERLIN	317
SIMSBURY	305
CROMWELL	287
SUFFIELD	283
COVENTRY	273
WATERBURY	271
EAST HAMPTON	271
GRANBY	266
WALLINGFORD	263
TOLLAND	257
EAST WINDSOR	249
ELLINGTON	229
GLASTONBURY	215
STAFFORD SPRINGS	215
PLAINVILLE	206
PORTLAND	199
EAST WINDSOR	194
CANTON	187
WINSTED	167
HEBRON	157
GRISWALD	150
MARLBOROUGH	140
NEW HARTFORD	136
EAST GRANBY	131
MANSFIELD	130
UNION	130
LEBANON	129
BURLINGTON	127
BOLTON	122
SOMERS	121
WILLINGTON	114
KILLINGLY	104
MONTVILLE	100
HADDAM	93
PLAINFIELD	92
CHESHIRE	92
COLUMBIA	84
ANDOVER	82
MANSFIELD	81
TOLLAND	81
BROOKLYN	79
KILLINGLY	77
SOUTHINGTON	73
WINDHAM	73
SIMSBURY	72
WINDHAM	66
PLAINFIELD	65
DURHAM	65
MIDDLEFIELD	64
HARWINTON	64
EAST HADDAM	62
OLD SAYBROOK	59
PUTNAM	58
SIMSBURY	57
HARTLAND	56
PLYMOUTH	55
ASHFORD	55
NAUGATUCK	54
OLD LYME	52
HADDAM	50
WALLINGFORD	49
BRIDGEPORT	48
CLINTON	47
EAST LYME	45
CANTERBURY	45
SUFFIELD	44
PRESTON	43
CHESTER	43
WATERTOWN	42
GRANBY	42
LITCHFIELD	42
DEEP RIVER	40
BERLIN	39
SIMSBURY	38
WOODSTOCK	38
NORWICH	38
SALEM	37
LEDYARD	37
GROTON	37
BOZRAH	37
EAST HADDAM	35
PROSPECT	34
NEW HAVEN	34
GRANBY	34
WATERFORD	34
HAMDEN	34
CANAAN	32
SALISBURY	30
SPRAGUE	29
CANAAN	29
POMFRET	28
WATERTOWN	27
MYSTIC	27
VOLUNTOWN	27
MILFORD	27
BERLIN	27
NEW MILFORD	26
LEDYARD	26
EASTFORD	26
CHAPLIN	25
WEST HAVEN	24
MORRIS	23
THOMASTON	23
WOLCOTT	21
SOUTHBURY	21
MIDDLEBURY	20
WESTBROOK	19
NEW LONDON	19
KILLINGWORTH	19
LITCHFIELD	18
SCOTLAND	17
NORTH HAVEN	16
WINDHAM	16
MADISON	16
GOSHEN	16
TRUMBULL	15
ANSONIA	14
EAST LYME	13
OXFORD	12
WOODBRIDGE	12
COLEBROOK	12
ESSEX	12
ESSEX	12
SEYMOUR	11
SHELTON	11
SHARON	10
BETHLEHEM	10
GUILFORD	10
STAMFORD	7
BRANFORD	7
FAIRFIELD	7
BETHANY	6
DANBURY	6
STONINGTON	5
WOODBURY	5
NORTH STONINGTON	5
BRIDGEWATER	5
BEACON FALLS	5
POMFRET	4
STRATFORD	4
CENTERBROOK	4
EAST HAVEN	3
SANDY HOOK	2
All Other	1,897
Grand Total	**48059**

0244 (03/21/16)

EXHIBIT

11

Hartford Hospital
Reconciliation to OHCA Report 450

Question 4 a.

CT Volume Reconciliation

	FY 2013	FY 2014
CT Volume per OHCA Report 450	38,877	43,363
Timing difference between date of service and posting date	133	108
Total CT volume per Table 5 - CON filing	**39,010**	**43,471**

Question 4 b

MRI Volume Reconciliation

	FY 2013
MRI Volume per OHCA Report 450	9,676
Timing difference between date of service and posting date	45
Total MRI volume per Table 5 - CON filing	**9,721**

EXHIBIT

12

Projections of Primary and Revision Hip and Knee Arthroplasty in the United States from 2005 to 2030

By Steven Kurtz, PhD, Kevin Ong, PhD, Edmund Lau, MS, Fionna Mowat, PhD, and Michael Halpern, MPH, MD, PhD

Investigation performed at Exponent Inc., Philadelphia, Pennsylvania

Background: Over the past decade, there has been an increase in the number of revision total hip and knee arthroplasties performed in the United States. The purpose of this study was to formulate projections for the number of primary and revision total hip and knee arthroplasties that will be performed in the United States through 2030.

Methods: The Nationwide Inpatient Sample (1990 to 2003) was used in conjunction with United States Census Bureau data to quantify primary and revision arthroplasty rates as a function of age, gender, race and/or ethnicity, and census region. Projections were performed with use of Poisson regression on historical procedure rates in combination with population projections from 2005 to 2030.

Results: By 2030, the demand for primary total hip arthroplasties is estimated to grow by 174% to 572,000. The demand for primary total knee arthroplasties is projected to grow by 673% to 3.48 million procedures. The demand for hip revision procedures is projected to double by the year 2026, while the demand for knee revisions is expected to double by 2015. Although hip revisions are currently more frequently performed than knee revisions, the demand for knee revisions is expected to surpass the demand for hip revisions after 2007. Overall, total hip and total knee revisions are projected to grow by 137% and 601%, respectively, between 2005 and 2030.

Conclusions: These large projected increases in demand for total hip and knee arthroplasties provide a quantitative basis for future policy decisions related to the numbers of orthopaedic surgeons needed to perform these procedures and the deployment of appropriate resources to serve this need.

Over the past thirteen years, there has been an increase in the number of revision total hip arthroplasties and total knee arthroplasties performed in the United States[1], while the revision burden—defined as the ratio of revision arthroplasties to the total number of arthroplasties—has remained relatively constant. Previous analyses of nationwide data on the procedures have indicated that the revision burden for total hip arthroplasty was approximately 17.5% between 1990 and 2002, whereas the revision burden for total knee arthroplasty was approximately 8.2%[1]. In economic terms, revision total hip arthroplasty is estimated to have consumed 19% of the Medicare hip replacement expenditures between 1997 to 2003, whereas total knee arthroplasty revisions consumed only 8% of the total annual Medicare expenditures for knee replacement[2].

In Scandinavia, England, Australia, and Canada, the numbers of these procedures that have been performed are readily obtainable from national arthroplasty registries[3-6]. However, in the United States, the American Academy of Orthopaedic Surgeons (AAOS)[7] and other investigators have had to rely on representative surveys of hospital discharge records to provide estimates of the prevalence of primary and revision arthroplasties[1,8].

Given the many years required for the training of surgeons and the equally complex task of planning for hospital capacity, reliable projections regarding the demand for arthroplasties are crucial for policy makers in government, education, and industry. Importantly, reliable projections of revision arthroplasties would be particularly useful, as they consume greater economic resources than do primary procedures[9].

Disclosure: The authors did not receive any outside funding or grants in support of their research for or preparation of this work. Neither they nor a member of their immediate families received payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, division, center, clinical practice, or other charitable or nonprofit organization with which the authors, or a member of their immediate families, are affiliated or associated.

For this study, we hypothesized that the demand for total hip and total knee arthroplasties in the United States will increase substantially over the next twenty-five years. To test this hypothesis, we performed statistical projections of the number of primary and revision total hip and total knee arthroplasties between 2005 and 2030 on the basis of the available historical Nationwide Inpatient Sample (NIS) data from 1990 to 2003[10], compared with projections assuming a constant prevalence.

Materials and Methods

Data Sources

The National Hospital Discharge Survey (NHDS) and the NIS are national (United States) sample surveys of hospital discharge records. Comparisons of the two surveys conducted by the Agency for Healthcare Research and Quality have found that, on a year-by-year basis, the numbers of surgical procedures estimated to have been performed from the NIS and the NHDS are similar, differing by approximately 10%[11]. However, the NIS collects a substantially larger number of discharge records than does the NHDS and is therefore better suited to accurately quantify the prevalence of inpatient arthroplasty procedures in the United States. Consequently, we relied on the NIS data from 1990 to 2003 for our projections for the current study. The NIS is a federal-state cooperative database designed to compile annually a representative sample of hospital discharge records in the United States. In 2003, the NIS had a sample size of about eight million discharge records from approximately 1000 hospitals, which represent approximately 20% of all United States community hospitals. All of the discharge records from 1990 to 2003 were examined for this study.

We obtained demographic data on the patients (e.g., age, gender, and race and/or ethnicity) from the NIS. Disease diagnoses and surgical procedures performed (if any) were recorded for the NIS with use of the Ninth Revision of the International Classification of Diseases (ICD-9-CM). Specifically, primary hip and knee arthroplasty are identified by the ICD-9-CM codes 81.51 and 81.54, respectively. For revisions, the corresponding codes are 81.53 and 81.55. From 1990 to 2003, the ICD-9-CM codes for these procedures were consistent, thereby allowing the determination of longitudinal trends in the prevalence of both primary and revision joint arthroplasty. We also used projected population statistics for the nation and for individual states by age, gender, and race and/or ethnicity through 2025 that were published by the Census Bureau in 1997[12].

Projection Methodology and Statistical Analyses

The annual prevalence of arthroplasty surgery was modeled with use of a Poisson regression with age, gender, race and/or ethnicity, census region, and calendar year as covariates to account for differences in prevalence among population subgroups as well as changes over time. Age was categorized into eight subgroups (less than forty-five, forty-five to fifty-four, fifty-five to sixty-four, sixty-five to sixty-nine, seventy to seventy-four, seventy-five to seventy-nine, eighty to eighty-four, and eighty-five or more years old), while race and/or ethnicity was grouped into five categories (white, black, Asian, Hispanic, and Native American). "Hispanic" included all patients of Hispanic origin, regardless of race. Four census regions (Northeast, South, Midwest, and West) and the two genders were also categorical covariates in the analysis. Two-way interactions between age, gender, race, census region, and calendar year were included in the regression model. Surgery prevalence was calculated by dividing the number of procedures estimated from the NIS for each population subgroup by the corresponding population from the Census Bureau. The projected number of procedures was estimated by applying the surgery prevalence estimated from the regression model to the projected population data for each subgroup. The projected national total is the sum of the projected number of procedures from each subpopulation. Independent models were used for each type of primary and revision hip and knee arthroplasty.

To evaluate the methodological sensitivity of our results, we compared our primary projections obtained from the NIS (in which the prevalence of surgery is allowed to vary over time on the basis of the actual data) with projections in which the prevalence of each population subgroup was held constant on the basis of the 1990 to 2003 averages. Deviance and Pearson chi-square values were determined to describe the goodness of fit for the Poisson regression model for the various arthroplasty data. Additional detailed descriptions of the statistical analyses are presented in the Appendix.

Results

In 2003, the most recent year for which national inpatient procedure data are currently available from NIS, a total of 202,500 primary total hip arthroplasties and 402,100 primary total knee arthroplasties were performed nationally in the United States. During the same year, a total of 36,000 revision total hip arthroplasties and 32,700 revision total knee arthroplasties were performed.

Sensitivity of Projection Methodology

Between 1990 and 2003, the prevalence of primary and revision total hip and knee arthroplasties all increased substantially over time. The overall goodness of fit of the regression models, represented by the value of the scaled Pearson chi square (a measure of the lack of fit between model and data), averaged 1.11 (range, 1.03 for primary total knee replacement to 1.26 for revision total knee replacement procedures) (see Appendix). When the year of surgery was excluded from the Poisson regression model to simulate a constant prevalence over time, the models fitted with the remaining covariates all showed a substantial increase in the deviance value (i.e., poorer fit), especially for knee arthroplasty.

The projections of primary and revision total joint replacement were found to be highly sensitive to assumptions regarding trends in the prevalence of surgery. If the trends

TABLE I Summary of Sensitivity Analysis of the Projected Number of Hip and Knee Arthroplasties with Use of Models Comparing Variable Prevalence (Baseline) with Constant Prevalence

Type of Procedure*	Annual Number of Procedures (in Thousands)†			
	2005	2010	2020	2030
Primary total hip arthroplasty				
Variable	209 (193-225)	253 (232-276)	384 (339-435)	572 (481-681)
Constant	179 (156-202)	194 (169-219)	236 (205-268)	277 (240-315)
Primary total knee arthroplasty				
Variable	450 (425-477)	663 (618-711)	1520 (1362-1700)	3481 (2948-4136)
Constant	301 (265-337)	329 (289-370)	415 (364-467)	488 (425-550)
Revision total hip arthroplasty				
Variable	40.8 (34.9-47.0)	47.8 (40.3-56.1)	67.6 (54.0-83.9)	96.7 (72.1-130.0)
Constant	36.0 (29.5-42.6)	38.9 (31.8-46.0)	47.2 (38.3-56.0)	56.6 (45.8-67.5)
Revision total knee arthroplasty				
Variable	38.3 (32.6-44.3)	55.3 (46.5-65.1)	121 (95.9-153)	268 (193-381)
Constant	25.9 (21.3-30.5)	28.1 (23.0-33.3)	35.1 (28.6-41.7)	41.7 (33.6-49.9)

*The variable prevalence (baseline) and the constant prevalence are based on 1990 to 2003 data from the Nationwide Inpatient Sample.
†The values are given as the projected value with the 95% prediction interval in parentheses.

(i.e., increases in the prevalence of surgery) observed from 1990 to 2003 were to continue, by 2030 the projections with use of the NIS data could range from two to five times greater than the projections assuming a constant surgery prevalence over time (Table I). The projections for primary and revision total knee surgery were more sensitive to modeling assumptions than those for primary or revision total hip arthroplasty because of the steep increase in the number of knee procedures from 1990 to 2003.

Projected Primary and Revision Arthroplasty Procedures with Use of the Nationwide Inpatient Sample Baseline Model

Our projection model predicted substantial increases in the numbers of hip and knee replacement procedures (Figs. 1 and 2). On the basis of the NIS model, the demand for primary total hip arthroplasty was estimated to grow by 174%, from 208,600 (95% prediction interval, 193,300 to 224,600) in 2005 to 572,000 (95% prediction interval, 481,000 to 681,000) by 2030 (Fig. 1). If the number of total knee arthroplasties performed continues at the current rate, the demand for primary total knee arthroplasty is projected to grow by 673%, from 450,000 (95% prediction interval, 425,000 to 477,000) in 2005 to 3.48 million procedures (95% prediction interval, 2.95 to 4.14 million) by 2030.

Overall, the total number of revision arthroplasty procedures performed in 2005 is expected to double by the year 2026 for revision total hip arthroplasty and by 2015 for revision total knee arthroplasty. Although more revision total hip arthroplasties than revision total knee arthroplasties are currently performed, the number of revision total knee arthroplasties performed were predicted to outnumber total hip arthroplasty revisions after 2007 (Fig. 2). Total hip arthroplasty revisions were projected to grow from 40,800 (95% prediction interval, 34,900 to 47,000) in 2005 to 96,700 (95% prediction interval, 72,100 to 130,000) in 2030 (an increase of 137%). If the trend observed from 1990 to 2003 were to continue, total knee arthroplasty revisions were projected to grow from 38,300 (95% prediction interval, 32,600 to 44,300) in 2005 to 268,200 (95% prediction interval, 192,700 to 381,400) in 2030 (an increase of 601%).

On the basis of these estimates, the revision burden for total hip replacements was projected to be 16.3% in 2005 and 14.5% in 2030. The corresponding revision burden for total knee replacements was projected to be 7.8% in 2005 and 7.2% in 2030.

Discussion

In this study, arthroplasty projections were derived by considering temporal changes in arthroplasty rates, as well as in population subgroups. As the official demographer of the United States, the Census Bureau has devoted considerable effort to developing reliable projections of the future United States population. In contrast, little information is available to quantify the expected number of hip and knee revision arthroplasties in the future. For example, the projection recently developed by the AAOS[7] was limited to primary hip and knee replacements. The AAOS projections were found to have underpredicted the expected utilization of primary joint replacement surgery[1] because they were based on the NHDS survey, which has a much lower sample size than the NIS. Additionally, the AAOS estimates assumed a constant prevalence of surgery over time. In contrast, our results underscore the importance of accounting for changes in the rate of surgery

for future projections because the prevalence of surgery is changing rapidly over time.

The present study provides, for the first time to our knowledge, quantification of the demand for primary and revision hip and knee arthroplasties in the United States through 2030. We project a massive increase in demand for primary and revision total joint procedures over the next two decades—a demand that, to be met, will need to be addressed with a combination of increased economic resources, operative efficiency, technical capacity (i.e., additional surgeons), and implant longevity.

The projections in this study are limited on the basis of an extrapolation of historical procedural data. As demonstrated in this study, the uncertainties inherent in such an extrapolation can be minimized by choosing a suitably large set of historical data (e.g., NIS instead of NHDS), and by incorporating as many covariates as possible into the model. Nevertheless, these projections are limited by the quantity

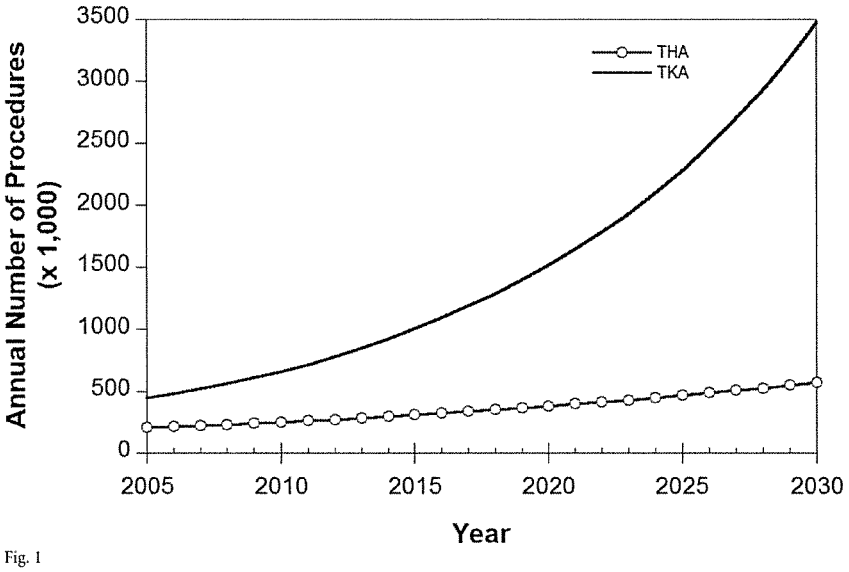


Fig. 1

The projected number of primary total hip arthroplasty (THA) and total knee arthroplasty (TKA) procedures in the United States from 2005 to 2030.

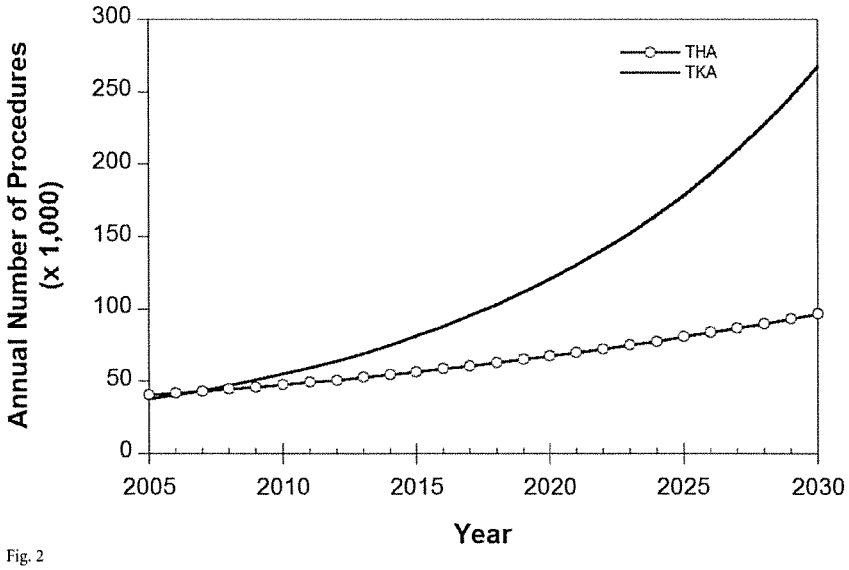


Fig. 2

The projected number of revision total hip arthroplasty (THA) and total knee arthroplasty (TKA) procedures in the United States from 2005 to 2030.

and quality of available data. The trends established by historical data, even if accurate, may not persist in the future because of improvements in implant technology, such as advanced bearing materials or designs. Furthermore, it is impossible to anticipate, at present, whether future orthopaedic treatment technologies or newer pharmaceutical nonoperative interventions will lead to a reduced demand for primary total joint replacements by 2030. Our model also does not incorporate unforeseen changes in economic factors associated with these arthroplasties. It is uncertain, for example, to what extent the United States health-care system will be able to finance the future demand for arthroplasties anticipated by the present study.

We selected a twenty-five-year time frame for the study, extending to 2030, purely to facilitate comparisons with previous AAOS projections, which employed an identical time frame. Intuitively, we appreciate that long-term projections will be more prone to unexpected disruptions than those spanning a near-term horizon. Nevertheless, such uncertainties in no way diminish the value and necessity of conducting projections for the purpose of long-range planning and policy-making.

Consequently, it is inevitable that the projections performed in the present study will be superseded in the future as new years of procedure data become available. Other methodological approaches to the prediction problem, such as age-period-cohort models or generalized additive models, should also be attempted to further validate the reliability of the projections established by the present approach. It is relatively straightforward to update the projections reported in this study with use of the present methodology, but continued monitoring and updating will need to occur.

In addition, it is clear from the different trends observed that the sensitivity of the projections appears to be procedure-dependent. For example, because of the substantially higher rate of increase in knee arthroplasty between 1990 and 2003, the models simulating a constant prevalence over time produced a considerably poorer fit. Consequently, the specific findings for total hip and knee replacement should not be generalized to other orthopaedic procedures, which may exhibit entirely different historical growth histories. However, this study establishes a methodology whereby an investigator can systematically evaluate orthopaedic surgery projections in a generalized statistically based framework. Although the data and projected number of procedures can be updated regularly, the methodology we have developed is expected to remain relevant for years to come.

The projections for revision procedures in this study were limited by the generality of the ICD-9-CM codes in the existing data, which currently do not yet discriminate between partial or total revision of an artificial joint. As of October 2005, new ICD-9-CM codes had been introduced by the Center for Medicare and Medicaid Services (CMS) for revision hip and knee arthroplasties. New ICD-9-CM codes also had been introduced to track the type of bearing (ceramic, metal, or polyethylene) used for total hip replacements. However, 2006 will provide the first full year of data incorporating this new coding scheme, and there is a two and a half-year lag between the end of the calendar year and the production of the corresponding NIS dataset. Furthermore, at least four years of data would be necessary to perform even the most rudimentary projection. Consequently, it will be well into the second decade of this century that sufficient years of information will be available for mathematically sound projections with use of the recently introduced ICD-9-CM procedure codes.

We modeled revision hip and knee replacement as independent orthopaedic procedures for this study, although it is feasible to construct a predictive model for future revisions on the basis of the number of primary procedures performed and an assumed Kaplan-Meier-type survivorship model for the different population subgroups. However, the necessary survival data for such a model can only be derived from a longitudinal database, such as a national implant registry, which does not yet exist in the United States. The only rationale for developing such a complex model would be historical evidence that the revision burden was changing over time, as has been documented in Sweden. However, available data in the United States between 1990 and 2003 do not support such a hypothesis; indeed, the revision burden has remained essentially unchanged in this country for over a decade[1]. Between 1990 and 2002, the national revision burden for total hip arthroplasty ranged between 15.2% and 20.5% (average, 17.5%); for total knee arthroplasty, the revision burden varied between 7.3% and 9.7% (average, 8.2%)[1]. Without compelling evidence that either implant technology or surgical technique have improved the survival of primary replacements at a national level, it is difficult to say whether a more sophisticated projection method for revisions than the one we employed in the present study would be of use. The revision projections in the current study may be interpreted as a conservative upper bound for what awaits the orthopaedic community if improvements in primary implant survival cannot be achieved at a national level.

The recent ICD-9-CM coding changes for hip and knee revisions in the United States were accompanied by 26.5% increases in reimbursement by the CMS and the formation of separate diagnosis-related group codes for primary and revision procedures (544 and 545, respectively)[13]. The changes in coding and reimbursement reflect heightened awareness and acceptance by CMS of the greater burden that revisions place on patients, surgeons, and hospitals. The revision projections in the current study provide the necessary foundation for future cost-benefit analyses at a national level, to quantify the increasing societal impact of revision arthroplasty in the United States.

Appendix

(eA) A table showing the summary of multivariate Poisson regression analysis results and a detailed description of the projection methodology and statistical analysis are available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on "Sup-

plementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

Steven Kurtz, PhD
Kevin Ong, PhD
Exponent Inc., 3401 Market Street, Suite 300, Philadelphia, PA 19104.

E-mail address for K. Ong: kong@exponent.com

Edmund Lau, MS
Fionna Mowat, PhD
Exponent Inc., 149 Commonwealth Drive, Menlo Park, CA 94025

Michael Halpern, MPH, MD, PhD
Exponent Inc., 1800 Diagonal Road, Suite 355, Alexandria, VA 22314

References

1. Kurtz S, Mowat F, Ong K, Chan N, Lau E, Halpern M. Prevalence of primary and revision total hip and knee arthroplasty in the United States from 1990 through 2002. J Bone Joint Surg Am. 2005;87:1487-97.

2. Ong KL, Mowat FS, Chan N, Lau E, Halpern MT, Kurtz SM. Economic burden of revision hip and knee arthroplasty in Medicare enrollees. Clin Orthop Relat Res. 2006;446:22-8.

3. National Joint Registry. National Joint Registry for England and Wales. 2nd Annual Report. 2005.

4. Malchau H, Herberts P, Eisler T, Garellick G, Soderman P. The Swedish Total Hip Replacement Register. J Bone Joint Surg Am. 2002;84 Suppl 2:2-20. Erratum in: J Bone Joint Surg Am. 2004;86:363.

5. Canadian Institute for Health Information, Canadian Joint Replacement Registry (CJRR). 2004 report: total hip and total knee replacements in Canada. 2004.

6. Australian Orthopaedic Association. National Joint Replacement Registry annual report 2005. 2005.

7. Frankowski JJ, Watkins-Castillo S. Primary total knee and hip arthroplasty projections for the U.S. population to the year 2030. 2002. http://www.aaos.org/wordhtml/research/stats/TJR_projections.pdf. Accessed 2004 Feb 20.

8. Mahomed NN, Barrett JA, Katz JN, Phillips CB, Losina E, Lew RA, Guadagnoli E, Harris WH, Poss R, Baron JA. Rates and outcomes of primary and revision total hip replacement in the United States medicare population. J Bone Joint Surg Am. 2003;85:27-32.

9. Bozic KJ, Katz P, Cisternas M, Ono L, Ries MD, Showstack J. Hospital resource utilization for primary and revision total hip arthroplasty. J Bone Joint Surg Am. 2005;87:570-6.

10. Agency for Healthcare Research and Quality. NIS technical documentation. Rockville, MD: Agency for Healthcare Research and Quality; June 2003. http://www.hcup-us.ahrq.gov/db/nation/nis/nisdbdocumentation.jsp.

11. Agency for Healthcare Research and Quality. Comparative analysis of HCUP and NHDS inpatient discharge data: technical Supplement 13. 1996. http://www.ahrq.gov/data/hcup/nhds/comptb9.htm. Accessed 2005 Oct 8.

12. National Center for Health Statistics. State Population Projections. 1997. http://www.census.gov/population/www/projections/stproj.html. Accessed 2005 Jan 5.

13. Center for Medicare and Medicaid Services. Changes to the hospital inpatient prospective payment systems and fiscal year 2006 rates. Federal Register. 2005;70:47278. http://www.cms.hhs.gov/QuarterlyProviderUpdates/downloads/cms1500f.pdf. Accessed 2005 Oct 2.

Clin Orthop Relat Res (2009) 467:2606–2612
DOI 10.1007/s11999-009-0834-6

SYMPOSIUM: ABJS CARL T. BRIGHTON WORKSHOP ON HEALTH POLICY ISSUES IN ORTHOPAEDIC SURGERY

Future Young Patient Demand for Primary and Revision Joint Replacement

National Projections from 2010 to 2030

Steven M. Kurtz PhD, Edmund Lau MS, Kevin Ong PhD, Ke Zhao MA, MS, Michael Kelly MD, Kevin J. Bozic MD, MBA

Published online: 10 April 2009

Abstract Previous projections of total joint replacement (TJR) volume have not quantified demand for TJR surgery in young patients (< 65 years old). We developed projections for demand of TJR for the young patient population in the United States. The Nationwide Inpatient Sample was used to identify primary and revision TJRs between 1993 and 2006, as a function of age, gender, race, and census region. Surgery prevalence was modeled using Poisson regression, allowing for different rates for each population subgroup over time. If the historical growth trajectory of joint replacement surgeries continues, demand for primary THA and TKA among patients less than 65 years old was projected to exceed 50% of THA and TKA patients of all ages by 2011 and 2016, respectively. Patients less than 65 years old were projected to exceed 50% of the revision TKA patient population by 2011. This study underscores the major contribution that young patients may play in the future demand for primary and revision TJR surgery.

Level of Evidence: Level II, prognostic study. See Guidelines for Authors for a complete description of levels of evidence.

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

S. M. Kurtz, E. Lau, K. Ong (✉), K. Zhao
Exponent, Inc., 3401 Market St, Suite 300, Philadelphia, PA 19104, USA
e-mail: kong@exponent.com

M. Kelly, K. J. Bozic
Department of Orthopaedic Surgery and Institute for Health Policy Studies, University of California, San Francisco, San Francisco, CA, USA

Introduction

The aging of the Baby Boom generation, who will start reaching 65 years old in 2011, is a factor in the increased future demand for joint replacement surgery in the United States. Total hip arthroplasty was originally conceived by Sir John Charnley as a procedure for elderly patients of low activity levels [2]. Over time, the indications for lower extremity joint arthroplasty have expanded to include both younger and more active patients. Indeed, over the past decade, the incidence of total joint replacement (TJR) has increased not only in older (> 65 years) but also in younger patients (< 65 years) [7]. The implication of patient age-related differences in future demand for TJR has remained unexplored. Since TJR was primarily intended to treat the elderly patient population, it is unclear if the incidence of these procedures in younger patients would exceed that in older patients in the future.

Historically, young patients have been considered at higher risk for revision due to their higher activity level relative to elderly patients [8]. "Premium" implant technologies, such as hard-on-hard bearings and hip resurfacing, have been introduced to address the increased activity and need for improved implant longevity in younger patients. However, these bearings are associated with higher costs and questions regarding their cost-effectiveness for the elderly patient population have been raised [1]. Previous projections by our group focused on estimating the total nationwide demand for primary and revision TJR [6], and not quantified the relative future size of the young TJR population in the United States that may benefit from premium implants. Due to the likelihood that the young patient population will utilize more costly premium bearings, the future size of this patient group could have a substantial impact on the healthcare costs associated with TJR.

We therefore developed nationwide projections for primary and revision TJR for the young patient population in the United States. First, we evaluated the historical changes in demand for primary and revision TJR in the younger and older patient populations. We also tested the hypothesis that patients younger than 65 years will represent the majority (> 50%) of the anticipated demand for primary and revision TJR in the United States between 2010 and 2030. We also asked whether current trends are advancing according to earlier expectations.

Methods and Materials

We used the Nationwide Inpatient Sample (NIS) to identify primary and revision arthroplasty procedures performed between 1993 and 2006. The NIS is an annual, statistically valid survey of ~ 1000 hospitals conducted by the Federal Healthcare Cost and Utilization Project (HCUP). HCUP recommends using 1993 and later years for longitudinal analyses, that being the period in the NIS program with a consistent sampling design. NIS contains approximately 20% of the inpatient hospitalizations performed in the United States, regardless of payment source. Because of the large size of the database, the NIS is particularly well-suited for epidemiological studies of procedures primary and revision TJR in the national population. We also employed statistical trend files, recently published by HCUP [3], to standardize the treatment of the data for longitudinal analysis of historical trends for inpatient healthcare utilization in the United States.

Patient demographics (eg, age, gender, race/ethnicity) are captured in the NIS. Disease diagnoses and surgical procedures performed (if any) were recorded using the 9th Revision of the International Classification of Diseases (ICD-9-CM). We used ICD-9-CM codes 81.51 and 81.53 for primary and revision total hip arthroplasty (THA); 81.54 and 81.55 were used for primary and revision total knee arthroplasty (TKA). In October 2005, new ICD-9-CM codes were introduced for revisions (00.70–00.73 for revision THA and 00.80–00.84 for revision TKA), which were incorporated into our analysis.

The incidence of primary and revision THA/TKA surgeries was calculated using NIS between 1993 and 2006 for population subgroups in the United States as a function of age, gender, race, and census region. The size of the population subgroups was determined from the Census Bureau's census data in 1990 and 2000 and intracensus estimates [9]. The prevalence of surgery was modeled using Poisson regression allowing for different rates for each population subgroup, as reported previously [6]. Briefly, the multivariate Poisson model allows differences in prevalence between population subgroups, as well as changes over time, to be assessed. The future size of each population subgroup was obtained from the population projection data reported by the Census Bureau. These population projections take into account the future mortality and increased life expectancy for the oldest population groups. National TJR projections were obtained by summing the projections for each subgroup, for which both the population and the prevalence of surgery were modeled to vary over time ("variable rate" approach). A conservative estimate of the TJR projections was also determined by assuming a constant prevalence of surgery, while accounting only for population changes over time ("constant rate" approach). Unlike the variable rate approach where the future prevalence of surgery was modeled to change with time, the constant rate approach assumed that the future prevalence of surgery (i.e., number of procedures per 100,000 population in each demographic subgroup) did not change and remained constant based on the average historical prevalence between 2004 and 2006. Independent models were used for primary and revision hip and knee arthroplasty. To evaluate the nationwide projections for primary and revision TJR for the young patient population, the number and proportion of procedures, along with 95% confidence intervals, were further stratified by patients aged under and over 65 years. The confidence intervals for the proportion of procedures was estimated from the ratio of the confidence intervals for the procedure counts stratified by the specific age group and the entire population.

To evaluate whether TJR trends are advancing according to earlier estimates [6], which were derived from 1990 to 2003 data, we compared the previous projections against TJR utilization data obtained from the NIS within the three most recent years (2004 to 2006). The previous projections were also compared against the current projections to assess changes in the estimated trends.

Results

The relative size of the younger patient population grew between 1993 and 2006, especially for TKA. In 1993, 32% of primary or revision THAs and 25% to 27% of primary or revision TKAs were performed in patients less than 65 years old. In 2006, the most recent year of NIS data available, the relative size of the young patient population had increased to 40% to 46% of primary and revision TJR recipients (Table 1). Substantial increases in the utilization of primary hip as well as primary and revision knee replacement surgery among patients under 65 years old were predicted over time based on the variable rate approach (Fig. 1) (Tables 1–3). A similar trend was not projected for revision THA, for which younger patients

Table 1. Number of primary and revision TJR procedures in patients younger than 65 years old in 2006 (NIS Data)

Procedure	Age			Total	Percentage younger than 65 years
	< 45 years	45 to 54 years	55 to 64 years		
Primary THA	14,300 (12,800–15,900)	34,300 (31,100–37,600)	56,300 (51,100–61,500)	229,900 (211,000–248,800)	46% (45%–46.3%)
Revision THA	2,400 (2,000–2,700)	5,000 (4,300–5,700)	7,500 (6,500–8,400)	37,200 (33,300–41,200)	40% (34.3%–41%)
Primary TKA	9,900 (8,900–11,000)	59,100 (54,100–64,100)	147,100 (135,100–159,100)	524,600 (484,000–565,100)	41% (40.9%–41.5%)
Revision TKA	1,800 (1,400–2,100)	6,400 (5,600–7,200)	12,100 (10,700–13,500)	46,400 (41,600–51,300)	44% (42.5%–44.4%)

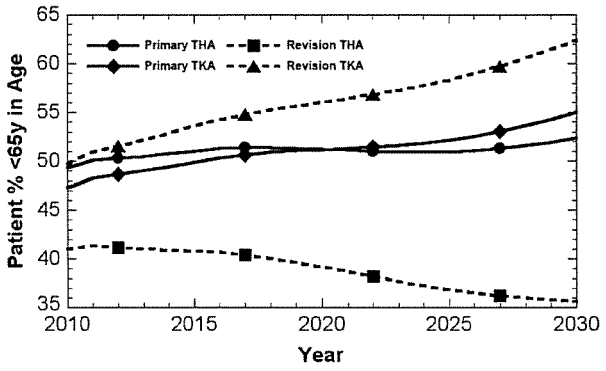


Fig. 1 The projected relative proportion of the younger patient population (< 65 y) for primary and revision total joint replacement between 2010 and 2030 is shown.

were not modeled to increase substantially in relative prevalence over time.

The demand for primary THA and TKA among patients younger than 65 years was projected to exceed 50% of TJR recipients by 2011 and 2016, respectively (Fig. 1). Patients under 65 were projected to exceed 50% of the candidate population for revision TKA by 2011 (Fig. 1). By 2030, the demand for TJA by patients less than 65 years is projected to be 52% of primary THAs and 55% to 62% of primary or revision TKAs (Fig. 1) (Table 3). The future demand was projected to grow the fastest for the 45 to 54 years age category for primary TKA, which was anticipated to grow from 59,077 in 2006 to 994,104 (17 times) by 2030. For primary THA, the demand in the same age category was only projected to grow by a factor of 5.9 (2006–2030).

The previous projections, which used a variable rate approach, provided reasonably accurate estimates of the primary (Fig. 2A–B) and revision (Fig. 3A–B) TJR trends between 2004 and 2006, particularly for revision THA (Fig. 3A) and TKA (Fig. 3B) procedures. The historical data for revision TJR were within the 95% confidence intervals of the previous projections (Fig. 3A–B), but the previous projections underestimated the historical number of primary TJR procedures (Fig. 2A–B). As such, the updated projections were greater than the previous projections for primary TJA, but relatively unchanged for revision TJA.

Discussion

When TJR was first developed, it was primarily intended for treating the elderly patient population. However, with the increasing utilization of TJR [6], the age-related differences in the future incidence of TJR remain unexplored. This is of particular concern because more costly premium hard-on-hard bearings are intended for the younger patient population [1], which could have substantial impact on future healthcare resources. We therefore evaluated the historical changes in demand for primary and revision TJR in the younger and older patient populations. We also tested the hypothesis that patients younger than 65 years will represent the majority (> 50%) of the anticipated demand for primary and revision TJR in the United States between 2010 and 2030. We also asked whether current trends are advancing according to earlier expectations [6].

Our study has several limitations. Our projections are based on the historical growth trajectory of joint replacement surgeries, and do not take into account potential limitations in the availability of surgeons or limited economic resources by private and public payers and hospitals in the future. For example, a shortage in the number of surgeons will have a substantial influence on the actual number of procedures that are performed. We also have not incorporated the potential for future alternative technologies, such as cartilage regeneration or tissue engineering, or drug therapies that limit the progression of joint diseases, which may preempt the need for TJR. We were also unable to account for the potential impact of changes in economy, which may place additional economic burden on patients to pay substantial out-of pocket expenses for these procedures, depending on their insurance coverage. Our study also did not consider potential changes in healthcare

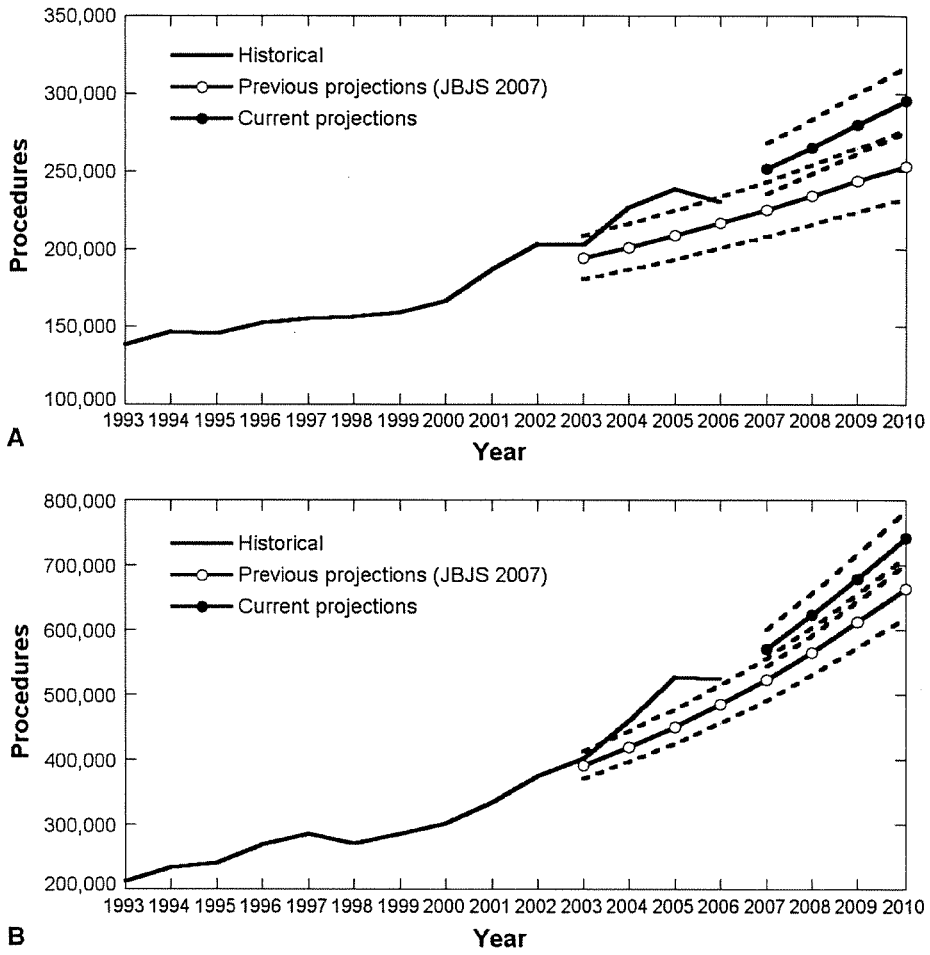


Fig. 2A–B Historical incidence of primary total hip arthroplasty (**A**) and primary total knee arthroplasty (**B**) from 1993–2006, superimposed with previous projections [6], and the updated projections from the current study. The dotted lines represent the 95% CI for the projections.

policies, such as adoption of volume standards or regionalization of TJR to high volume centers [5], which could limit the access to care and decrease the future demand. The above economic, policy, and scientific factors cannot be readily incorporated in the statistical model. Our study was also focused on the procedural trends in the U.S.; followup research may include an analysis of trends in other countries, though the availability of historical TJR trends in other countries may be limited. Nonetheless, these limitations in no way diminish the importance of conducting and regularly updating surgical projections to help guide future research, surgeon training, and public health policy decisions. Our study also incorporated a more conservative projection, which relied only on the future changes in population growth, while maintaining current rates of adoption of TJR. Despite these limitations, our current findings are expected to have implications in the private coverage and reimbursement of joint replacement procedures in the future, as patients less than 65 years of age are not typically covered by Medicare, which today funds the majority of total joint replacement procedures in the United States.

We found the relative size of the young patient population for TJR has grown between 1993 and 2006. While 25% to 32% of primary or revision TJRs were performed in patients less than 65 years old in 1993, these proportions have increased to 40% to 46% in the most recent NIS data. The increasing trend in younger patients undergoing TJR has also been reported for different, but partly overlapping, historical periods. For example, Jain et al. reported that the proportion of primary TKA patients aged less than 60 years increased from 12.5% to 19.5% (+56%) between 1990–1993 and 1998–2000 [4]. In addition, for patients aged under 70 years, the proportion increased by 9% from 45.6% to 49.6%. Due to the difference in the stratification by age categories, we were unable to make a direct comparison with the data by Jain et al. [4]. However, our findings that the historical volume of TJR procedures in the younger patient population have been increasing is consistent with these previously reported trends.

While we previously forecasted an increase in demand for primary hip and knee replacement in 2030 by 174% and 673% [6], respectively, the current study underscores the contribution that young patients are expected to play in the

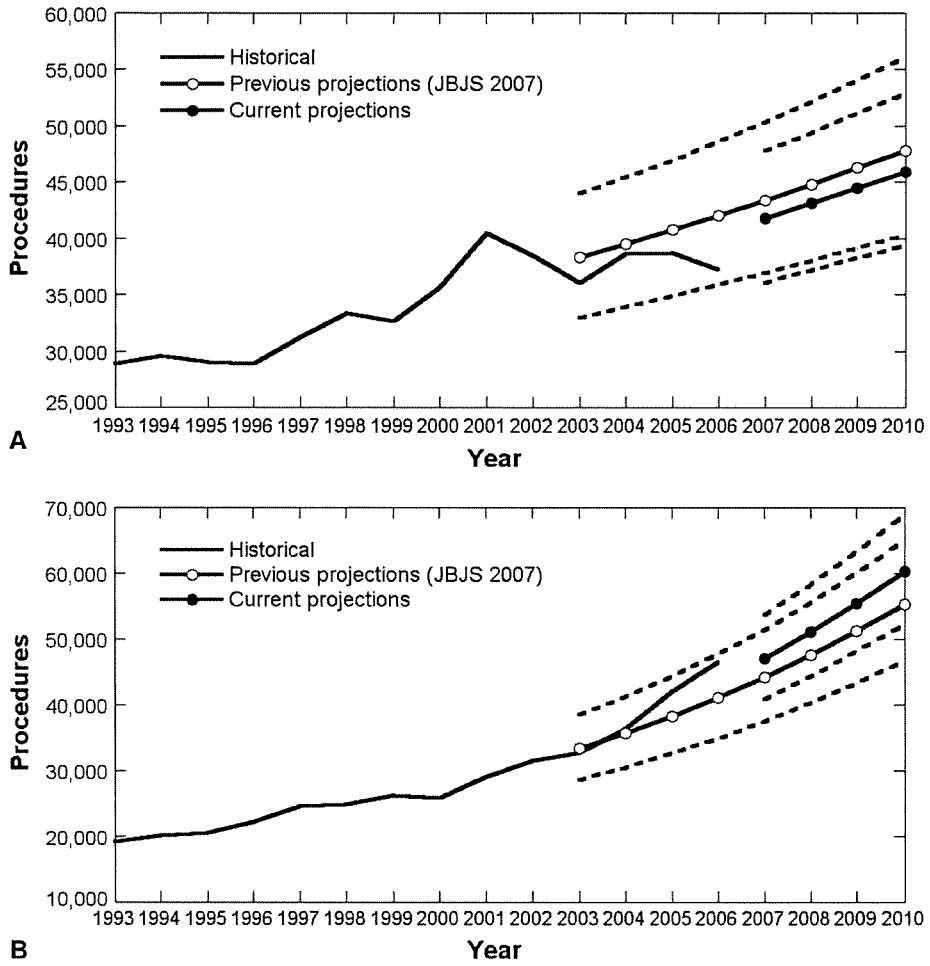


Fig. 3A–B Historical incidence of revision total hip arthroplasty (**A**) and revision total knee arthroplasty (**B**) from 1993–2006, superimposed with previous projections [6], and the updated projections from the current study. The dotted lines represent the 95% CI for the projections.

future utilization of primary TJR surgery, if historical trends in prevalence continue into the future. The statistical modeling approach we have employed in the current and previous study fits a multivariate but linear Poisson regression model to the historical prevalence of TJR procedures. However, because the size of the population subgroups is free to change nonlinearly in the future based on the Census Bureau's projection, the actual projected incidence of surgical demand is therefore not constrained to be a linear function over time. The demand for primary hip and knee arthroplasty between 2004 and 2006 generally exceeded our previous projections, which employed an identical methodology. However, we are unable to judge, based on the limited window of new data for validation, whether a more complex modeling approach would provide a more reliable forecast of demand for surgical procedures.

Our previous methodology provided a reasonable short-term forecast of the demand for revision hip and knee surgeries between 2004 and 2006. In particular, for 2006, we observed a slight decrease in the estimated number of primary THA and TKA procedures compared to 2005 (Fig. 2), but this decrease fell within the uncertainty of the estimates. Additional years of data will continue to be necessary to determine whether the historical trends will continue to apply in the future. Furthermore, if the future demand for TJR procedures is based only on the population growth with no change in the surgical prevalence (constant rate approach), then the projected increase in demand is not expected be as dramatic as previously predicted for the overall patient population and young patient population (Tables 2, 3). Furthermore, these findings have implications for the economic burden associated with TJR procedures, as younger patients often receive higher demand, more costly "premium" implants (such as hard-on-hard bearings and hip resurfacing implants), which are intended to perform better and improve implant longevity in more active patients.

The NIS data from 2004–2006 provide a basis to judge the validity of our previous projections [6], which were derived from 1990–2003 data. During the most recent 3-year period, the incidences of primary total hip and total

Table 2. Projected future demand of primary and revision TJR procedures in patients less than 65 years old by 2010

Procedure	Variable rate (Poisson regression)					Constant rate (2004–2006 average)				
	< 45 y	45–54 y	55–64 y	Total	% < 65 y	< 45 y	45–54 y	55–64 y	Total	% < 65 y
Primary THA	18,300 (16,500–20,200)	49,900 (46,500–53,500)	77,700 (73,400–82,200)	295,600 (275,500–316,600)	49% (49.2%–49.5%)	14,800 (11,600–17,900)	35,000 (28,700–41,300)	63,300 (52,600–74,100)	250,900 (208,500–293,200)	45% (44.6%–45.4%)
Revision THA	2,800 (2,200–3,400)	6,500 (5,600–7,600)	9,500 (8,300–10,700)	45,900 (39,300–52,900)	41% (40.9%–41.1%)	2,600 (1,700–3,400)	5,100 (3,700–6,500)	8,400 (6,300–10,400)	41,200 (30,900–51,400)	39% (38.1%–39.7%)
Primary TKA	14,900 (13,000–17,000)	103,400 (97,200–110,000)	232,200 (222,200–242,700)	741,400 (701,600–783,100)	47% (47.2%–47.4%)	9,400 (7,400–11,500)	57,800 (48,500–67,100)	160,800 (137,100–184,400)	552,600 (469,700–635,600)	41% (41.1%–41.4%)
Revision TKA	2,500 (1,900–3,200)	10,200 (8,800–11,700)	17,200 (15,400–19,200)	60,300 (52,200–68,900)	50% (49.4%–50.2%)	1,700 (1,000–2,300)	5,900 (4,300–7,500)	12,200 (9,400–15,000)	45,500 (34,300–56,600)	43% (43%–43.7%)

Table 3. Projected future demand of primary and revision TJR procedures in patients less than 65 years old by 2030

Procedure	Variable rate (Poisson regression)					Constant rate (2004–2006 average)				
	< 45 y	45–54 y	55–64 y	Total	% < 65 y	< 45 y	45–54 y	55–64 y	Total	% < 65 y
Primary THA	46,900 (39,100–56,300)	202,500 (174,400–235,900)	217,700 (190,700–249,300)	891,800 (774,000–1,030,200)	52% (52.2%–52.6%)	15,600 (12,200–19,000)	31,000 (25,100–36,800)	62,800 (51,500–74,100)	345,700 (285,300–406,000)	32% (31.1%–32%)
Revision THA	3,200 (2,200–4,400)	13,200 (10,100–17,400)	16,100 (12,500–20,600)	91,400 (70,800–117,600)	36% (35.1%–36.1%)	2,700 (1,800–3,700)	4,600 (3,300–6,000)	8,500 (6,200–10,800)	59,000 (43,600–74,300)	27% (25.9%–27.5%)
Primary TKA	95,200 (73,900–122,900)	994,100 (856,000–1,158,800)	1,300,200 (1,149,400–1,477,500)	4,344,900 (3,797,600–4,994,900)	55% (54.8%–55.2%)	9,800 (7,600–12,000)	51,500 (42,900–60,100)	162,300 (137,300–187,400)	792,200 (668,700–915,700)	28% (28.1%–28.3%)
Revision TKA	16,300 (11,000–24,200)	102,300 (77,000–137,700)	93,000 (72,700–120,800)	339,000 (258,500–451,100)	62% (62.2%–62.7%)	1,700 (1,000–2,400)	5,300 (3,800–6,800)	12,500 (9,400–15,600)	64,600 (47,900–81,100)	30% (29.7%–30.5%)

knee replacements were higher than the 95% confidence limits of the previous projections. The results of our current study for primary hip and knee replacement are, therefore, higher than those reported previously. On the other hand, the 2004–2006 NIS data for revision hip and knee replacement generally fell within the 95% confidence limits of the previous projections, and little difference was observed between current and previous long-term projections. The latest findings for primary TJRs continue to underscore the importance of routinely monitoring and regularly updating projections based on the latest available national data on procedure volumes.

Based on 1993–2006 NIS data, our current projections update and supercede previous modeling efforts that employed 1990–2003 NIS data [6]. In light of the current and anticipated demand for total joint replacement procedures by patients less than 65 years in age, emphasis on improving the reliability and survivorship of joint replacements continues to be a critical element in meeting future demands for joint replacement. It remains clear from the projected increases in the demand for revision surgery that efforts to minimize the national revision burden will be beneficial, especially in light of the increased resources that we project will be needed to meet the future demand for primary hip and knee arthroplasty procedures. A national TJR registry, which has been credited with decreasing the revision burden in Sweden [8], does not exist in the United States and would provide a mechanism for tracking the longitudinal performance of specific implants of all age groups in this country. Current administrative databases, such as NIS or Medicare, lack this capability. The projected demand for both primary and revision joint replacements provides a basis for cost-effectiveness studies for a United States TJR registry.

References

1. Bozic KJ, Morshed S, Silverstein MD, Rubash HE, Kahn JG. Use of cost-effectiveness analysis to evaluate new technologies in orthopaedics. The case of alternative bearing surfaces in total hip arthroplasty. *J Bone Joint Surg Am.* 2006;88:706–714.
2. Charnley J. Arthroplasty of the hip: A new operation. *Lancet.* 1961;I:1129–1132.
3. Houchens RL, Elixhauser A. Using the HCUP Nationwide Inpatient Sample to Estimate Trends (Updated for 1988–2004). http://www.hcup-us.ahrq.gov/reports/methods.jsp. Accessed 24 October, 2005.
4. Jain NB, Higgins LD, Ozumba D, Guller U, Cronin M, Pietrobon R, Katz JN. Trends in epidemiology of knee arthroplasty in the United States, 1990–2000. *Arthritis Rheum.* 2005;52:3928–3933.
5. Katz JN, Barrett J, Mahomed NN, Baron JA, Wright RJ, Losina E. Association between hospital and surgeon procedure volume and the outcomes of total knee replacement. *J Bone Joint Surg Am.* 2004;86:1909–1916.
6. Kurtz S, Ong K, Lau E, Mowat F, Halpern M. Projections of primary and revision hip and knee arthroplasty in the United States from 2005 to 2030. *J Bone Joint Surg Am.* 2007;89:780–785.
7. Kurtz SM, Mowat F, Ong K, Chan N, Lau E, Halpern M. Prevalence of primary and revision total hip and knee arthroplasty in the United States from 1990 through 2002. *J Bone Joint Surg Am.* 2005;87:1487–1497.
8. Malchau H, Herberts P, Eisler T, Garellick G, Soderman P. The Swedish Total Hip Replacement Register. *J Bone Joint Surg Am.* 2002;84 Suppl 2:2–20.
9. National Center for Health Statistics. U.S. Population Projections. http://www.census.gov/population/www/projections/stproj.html. Accessed 24 October, 2005.

EXHIBIT

13

HSSJ (2010) 6: 95–98
DOI 10.1007/s11420-009-9128-5

ORIGINAL ARTICLE

Detection of Pulmonary Embolism in the Postoperative Orthopedic Patient Using Spiral CT Scans

Han Jo Kim, MD · Sarah Walcott-Sapp, BA · Kristi Leggett, AA · Anne Bass, MD · Ronald S. Adler, PhD, MD · Helene Pavlov, MD · Geoffrey H. Westrich, MD

Received: 2 March 2009/Accepted: 14 July 2009/Published online: 23 September 2009

Abstract Orthopedic surgery is associated with a significant risk of postoperative pulmonary embolism (PE) and/or deep vein thrombosis (DVT). This study was performed to compare the clinical presentations of a suspected versus a documented PE/DVT and to determine the actual incidence of PE/DVT in the post-operative orthopedic patient in whom CT was ordered. All 695 patients at our institution who had a postoperative spiral CT to rule out PE/DVT from March 2004 to February 2006 were evaluated and information regarding their surgical procedure, risk factors, presenting symptoms, location of PE/DVT, and anticoagulation were assessed. Statistical analysis was performed using an independent samples t test with a two-tailed p value to examine significant associations between the patient variables and CT scans positive for PE. Logistic regression models were used to determine which variables appeared to be significant predictors of a positive chest CT. Of 32,854 patients admitted for same day surgery across all services, 695 (2.1%) had a postoperative spiral CT based on specific clinical guidelines. The incidence of a positive scan was 27.8% (193/695). Of these, 155 (22.3%) scans were positive for PE only, 24 (3.5%) for PE and DVT, and 14 (2.0%) for DVT only. The most common presenting symptoms were tachycardia (56%, 393/695), low oxygen saturation (48%, 336/695), and shortness of breath (19.6%, 136/695). Symptoms significantly associated with DVT were syncope and chest pain. A past medical history of PE/DVT was the only significant predictor of a positive scan. Patients who have a history of thromboembolic disease should be carefully monitored in the postoperative setting.

Keywords spiral CT · orthopedic surgery · thromboembolic complications

Each author certifies that his or her institution has approved the reporting of these cases and that all investigations were conducted in conformity with ethical principles of research.

Each author certifies that he or she has no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

A. Bass, MD
Department of Rheumatology,
Hospital for Special Surgery,
535 East 70th Street, New York, NY 10021, USA

H. J. Kim, MD · S. Walcott-Sapp, BA · G. H. Westrich, MD (✉)
Department of Orthopedic Surgery,
Hospital for Special Surgery,
535 East 70th Street, New York, NY 10021, USA
e-mail: westrichg@hss.edu

K. Leggett, AA · R. S. Adler, PhD, MD · H. Pavlov, MD
Department of Radiology,
Hospital for Special Surgery,
535 East 70th Street, New York, NY 10021, USA

Introduction

Orthopedic surgery patients are at a high risk for thromboembolic complications including deep vein thrombosis (DVT), pulmonary embolism (PE), and, as a consequence, death. Hip and knee arthroplasty traditionally carry the highest risk of thromboembolic disease of all orthopedic procedures. The incidence of DVT in patients without prophylaxis is 40–84% for total knee replacement [1] and 39–74% for total hip replacement [2]. The incidence of fatal PE following total joint replacement has ranged from 0.19% to 3.4% [2–4], and the incidence of asymptomatic PE has been reported to be as high as 12% [1]. Trauma patients also have notoriously high rates of DVT, although these clots are often detected prior to any fracture fixation procedures. Geerts et al. [5] found a 69% rate of DVT in patients with lower extremity fractures, a 62% rate in patients with spine fractures, and a 54% rate of DVT in patients with major head injuries. Research has shown that

the rate of DVT in spine surgery patients ranges from 0.8% to 15.5% [6–9]. A recent study found an incidence of DVT of 0.5% and an incidence of PE of 0.23% in total shoulder arthroplasty patients [10]. The rate of DVT following foot and ankle procedures is typically between 0.2% and 3.5%, and the rate of symptomatic PE is even lower, ranging from 0% to 0.2% [11–12].

Because clinical presentation is unreliable for diagnosis of thromboembolic complications, imaging modalities have become the most effective way to diagnose PE. In the past, ventilation–perfusion (VQ) scans were used to determine the probability of PE. The VQ lung scan involves the inhalation of xenon gas and is advantageous because of low radiation exposure to the patient undergoing the exam (<2.5 mSv) and relatively low cost when compared to spiral CT. However, VQ scans have serious limitations as the results are based on the indirect visualization of the clot, and diagnosis is, therefore, restricted to "high, intermediate, or low probability". The study also takes approximately 1 h to complete. Spiral CT is currently the most popular test to aid in the diagnosis of pulmonary emboli [13] as it provides high specificity (81% to 100%) with direct visualization of the pulmonary vasculature, can reliably detect compounding or additional pulmonary conditions, and can be completed in less than 30 s. Reports validating the clinical significance of this sensitive and specific imaging for PE/DVT and identifying the potential for identifying clinically insignificant PE do not currently exist.

The symptoms of PE can range from nonexistent to mild to severe and are strongly related to a patient's underlying pulmonary reserve [14–16]. Pulmonary emboli pose a diagnostic challenge because of their lack of consistent, specific presentation. The goal of this study was to determine the overall incidence of positive spiral CT scans in a postoperative orthopedic surgical patient population who underwent the scans for suspected PE/DVT and to determine the relationship between the type of procedure and a positive scan. Another aim was to determine which symptoms were associated with positive spiral CT scans in this patient population. The final goal was to determine which risk factors were associated with a positive spiral CT scan in this patient population.

Materials and methods

All orthopedic surgery patients who underwent spiral CT scans of the chest, pelvis, or lower extremities at our institution during the 2-year period from March 2004 to February 2006 were screened for inclusion. Of these 771 patients, 76 were excluded immediately because they were non-surgical patients (43), had medical records that were missing documentation of the scan (18), or had preoperative instead of postoperative scans (15). After this initial review, there were 695 patients who had the designated spiral CT scans following an orthopedic surgical procedure and were included in this retrospective case series.

The hospital medical records and spiral CT scan reports of these 695 patients were reviewed to collect demographic and surgical data. Risk factors for the development of PE were defined as including a history of previous PE or DVT, smoking, current hormone replacement therapy or oral contraceptives, and current malignancy The clinical signs, symptoms and abnormal test results which prompted the ordering of the scans were noted. The anticoagulation prophylaxis, size and location of identified PEs, and treatment of PE and/or DVT in patients with positive scans were also recorded. The spiral CT scans included the chest, pelvis, and lower extremities, so only DVT proximal to the popliteal vein was detected and recorded.

The location of the PE/DVT was stratified into left and/or right main, lobar, segmental, and subsegmental arteries and peripherally into pelvic and lower extremity clots. Only the largest vessel order clot was noted for each side.

All of the hip, knee, shoulder, trauma, and spine patients had pneumatic compression sleeves placed. All patients undergoing total hip and total knee replacement also received pharmacological anti-coagulation with warfarin, low-molecular-weight heparin, or aspirin in accordance with the standard protocol for DVT prophylaxis at our institution. Arthroscopy, foot, ankle, and hand patients were not given anticoagulation therapy.

Statistical analysis was performed by a medical statistician using an independent samples t test with a two-tailed p value. Significance was defined as a p value less than 0.05. Logistic regression models were used to determine which variables appeared to be significant predictors of a positive chest CT in this patient population.

Results

One hundred ninety-three of the 695 scans were interpreted as indicating the presence of DVT and PE. The overall incidence of PE/DVT was 27.8% (193/695). One hundred fifty-five scans (22.3%) were positive for PE only, 24 (3.5%) for PE and proximal DVT, and 14 (2.0%) for proximal DVT only. A total of 179 patients had a scan positive for PE, comprising 0.5% of the total surgical population (155/32,854). The location of the identified PE and/or DVT was as follows: 3 main-single, 7 main-multiple, 28 lobar-single, 42 lobar-multiple, 29 segmental-single, 35 segmental-multiple, 30 subsegmental-single, 24 subsegmental-multiple, 15 pelvic clots, and 26 lower extremity clots.

Total joint arthroplasty and spine procedures were observed to have the highest incidence of positive scans in this sample of patients that underwent scans for suspected PE/DVT. The incidence of positive findings for total shoulder arthroplasty was 8 of 11 or 72%, for total knee arthroplasty 84 of 244 or 34.4%, for total hip arthroplasty 52 of 188 or 27.7%, for revision total knee arthroplasty 8 of 29 or 27.6%, and for spine procedures 33 of 136 or 24.3%. The highest incidence of positive scans for PE only were in total shoulder arthroplasty (63.6%, 7/11), primary total knee arthroplasty (32.4%, 79/244), primary total hip arthroplasty (25%, 47/188), and spine patients (22.8%, 31/136).

The symptoms that prompted the ordering of a scan included tachycardia, fever, syncope, chest pain, shortness

of breath, low oxygen saturation defined as <90% on pulse oximetry, atrial fibrillation, confusion, nausea, and dizziness. Tachycardia (54.4%, 105/193), low oxygen saturation (49.7%, 96/193), and shortness of breath (23.3%, 45/193) were the symptoms most commonly associated with positive scans. Atrial fibrillation (p=0.057, 15/78, 19.2%), confusion (p=0.058, 5/35, 14.3%), and nausea (p=0.075, 13/14, 92.9%) were not predictive of a positive scan. Patients with low oxygen saturation were significantly (p=0.0001) more likely to have scans positive for PE. Using a logistic regression model, oxygen saturation (p=0.003) and a history of PE/DVT (p=0.008) were found to be significant predictors of PE. Atrial fibrillation and estrogen use were not significant predictors (p=0.09).

Of the risk factors analyzed as predictive of a positive scan, a history of PE and/or DVT was significantly associated with a scan positive for PE (p=0.004, 21/48, 43.8%). In addition, patients with a higher BMI (BMI>30) were more likely to have scans positive for PE (p=0.048, mean 28.98 negative vs. mean 30.10 positive) than those with a lower BMI. When patient demographic variables were entered into a logistic regression model, a history of previous PE/DVT was found to be a significant predictor (p=0.006) of having a positive scan for PE, while BMI and estrogen use were found to be marginally significant predictors (p=0.06 and p=0.07, respectively). The odds of having a positive chest CT scan were 2.3 times higher if patients had a history of PE/DVT than if they did not (95% CI, 1.3–4.3). Smoking was not found to be a positive predictor of a positive scan. There was no detectable relationship between patient risk factors or presenting symptoms with respect to the detection of proximal (pelvic) DVTs. Syncope and age were found to have a trend towards significance with pelvic clots (p=0.075, p=0.103). Positive lower extremity CT scans were significantly related to previous PE/DVT (p=0.03, 5/48, 10.4%), syncope (p=0.005, 4/20, 20%), and chest pain (p=0.04, 8/109, 7.3%).

Discussion

The purpose of the study was to examine those post-operative orthopedic surgical patients with documented positive spiral CT for detecting PE/DVT as related to the clinical symptoms at presentation, medical history, and risk factors. We hoped to use this information to determine appropriate and optimal utilization of this sensitive but costly diagnostic imaging evaluation, which exposes patients to both ionizing radiation and potential contrast reaction.

In our study, patients with low oxygen saturation were significantly more likely to have a spiral CT scan positive for PE than those with normal saturation values. In addition, when all risk factors were considered (previous history of PE or DVT, smoking, current hormone replacement therapy or oral contraceptive use, and current malignancy), patients with a history of prior DVT and/or PE were more likely to have a positive CT scan, which suggests that a patient's propensity for developing DVT and/or PE may depend on individual factors (i.e., variation in coagulation factors, genetics, etc.).

Parvizi et al. [18] suggested that sensitive imaging studies like spiral CT result in an increase in detection of pulmonary emboli and may lead to the unnecessary treatment of single, isolated subsegmental clots. Over the 5-year study period, the incidence of PE increased from 0.21% with VQ scans to 0.98% with spiral CT without changes in mortality rates [18]. The patients whose clots were not detected with the less sensitive VQ scans did not seem to suffer a greater risk of death and were spared the risk of complications associated with the prolonged anticoagulation therapy which is the accepted treatment for pulmonary emboli. Furthermore, as the technology continues to improve, the resolution and ability to observe smaller subsegmental PE will undoubtedly increase along with the required anticoagulation. Further research is needed to determine the risk/benefit profile for the treatment of small and/or isolated subsegmental clots and determine if patients diagnosed with only small tertiary pulmonary emboli would benefit from not being treated. In our study, the overall incidence of detected PE was approximately 0.5%, which is an incidence consistent with that reported in the literature [2–4].

Because of the low overall incidence of PE [1–4], it is unreasonable to perform postoperative CT scans on all orthopedic patients or even all patients who have undergone higher risk procedures like total joint arthroplasty. Such an approach would increase the risk of unnecessary radiation exposure to patients and would be imprudent from a cost–benefit analysis of health care. In the outpatient setting, D-dimer measurement may be useful in stratifying patients into groups with high or low suspicion of venous thromboembolism [17]; however, D-dimers are almost universally positive in the postoperative setting and are therefore unhelpful in this setting [19].

In our study, total joint arthroplasty and spine procedures were observed to have the highest incidence of positive scans. Common symptoms at presentation prompting a scan to rule out PE were tachycardia, shortness of breath, and a low O_2 saturation (<90%), and although not all of these symptoms were positive predictors of a scan, it is possible that a combination of symptoms with certain demographics can lead to highly specific presentations for PE. When analyzing risk factors, a past medical history of PE/DVT and BMI>30 were significantly associated with a positive scan. Larger clinical trails need to be done to integrate sensitive and specific risk factors for deterring life-threatening PE/DVT with clinical presentation in order to develop the most appropriate algorithm for ordering a spiral CT to rule out PE/DVT in the postoperative orthopedic setting.

Acknowledgment The authors would like to acknowledge Lindsey Bornstein for her assistance in the preparation of this manuscript.

References

1. Freedman KB, Brookenthal KR, Fitzgerald RH et al, A meta-analysis of thromboembolic prophylaxis following elective total hip arthroplasty. J. Bone Jt. Surg. Am. 2000; 82-A: 929–938

2. Westrich GH, Haas SB, Mosca P, et al, Meta-analysis of thromboembolic prophylaxis after total knee arthroplasty. J. Bone Jt. Surg. Br. 2000; 82: 795–800
3. Kim YH, Oh SH, Kim JS, Incidence and natural history of deep-vein thrombosis after total hip arthroplasty. A prospective and randomized clinical study. J. Bone Jt. Surg. Br. 2003; 85: 661–665
4. Lawton RL, Morrey BF, Narr BJ, Validity of index of suspicion for pulmonary embolism after hip arthroplasty. Clin. Orthop. Relat. Res. 2003; 415: 180–192
5. Geerts WH, Code KI, Jay RM, A prospective study of venous thromboembolism after major trauma. N. Engl. J. Med. 1994; 331: 1601–1606
6. Brambilla S, Ruosi C, LaMaida GA, et al, Prevention of venous thromboembolism in spinal surgery. Eur. Spine J. 2004; 13: 1–8
7. Catre MG Anticoagulation in spinal surgery. A critical review of the literature. Can. J. Surg. 1997; 40: 413–419
8. Dearborn JT, Hu SS, Tribus CB, et al, Thromboembolic complications after major thoracolumbar spine surgery. Spine. 1999; 24: 1471–1476
9. Oda T, Fuji T, Kato Y, et al, Deep venous thrombosis after posterior spinal surgery. Spine 2000; 25: 2962–2967
10. Lyman S, Sherman S, Carter TI, et al, Prevalence and risk factors for symptomatic thromboembolic events after shoulder arthroplasty. Clin. Orthop. Relat. Res. 2006; 448: 152–156
11. Hanslow SS, Grujic L, Slater HK, et al, Thromboembolic disease after foot and ankle surgery. Foot Ankle Int. 2006; 27: 693–695
12. Mizel MS, Temple HT, Michelson JD, et al Thromboembolism after foot and ankle surgery. Clin. Orthop. Relat. Res. 1998; 348: 180–185
13. Ghaye B, Ghuysen A, Bruyere PJ, et al, Can CT pulmonary angiography allow assessment of severity and prognosis in patients presenting with pulmonary embolism? What the radiologist needs to know. Radiographics. 2006; 26: 23–39
14. Kokturk N, Oguzulgen IK, Demir N, et al, Differences in clinical presentation of pulmonary embolism in older vs. younger patients. Circ. J. 2005; 69:981–986
15. Miniati M, Prediletto R, Formichi B, et al, Accuracy of clinical assessment in the diagnosis of pulmonary embolism. Am. J. Respir. Crit. Care Med. 1999;159:864–871
16. Stein PD, Henry JW Clinical characteristics of patients with acute pulmonary embolism stratified according to their presenting syndromes. Chest 1997; 112:974–979
17. Wells PS, Ginsberg JS, Anderson DR, et al, Use of a clinical model for safe management of patients with suspected pulmonary embolism. Ann. Intern. Med. 2005; 129: 997–1005
18. Parvizi J, Smith EB, Pulido L, et al, The rise in the incidence of pulmonary embolus after joint arthroplasty: is modern imaging to blame? Clin. Orthop. Relat. Res. 2007; 463: 107–113
19. Douketis JD, The clinical utility of a rapid beside d-dimer assay for screening of deep vein thrombosis following orthopaedic surgery. Thrombosis Haemost. 1997; 78: 1300
20. Douketis JD, The clinical utility of a rapid beside d-dimer assay for screening of deep vein thrombosis following orthopaedic surgery. Thrombosis Haemost. 1997; 78: 1300

EXHIBIT

14

STATE OF CONNECTICUT

Department of Public Health

LICENSE

License No. 0046

General Hospital

In accordance with the provisions of the General Statutes of Connecticut Section 19a-493:

Hartford Hospital of Hartford, CT d/b/a Hartford Hospital is hereby licensed to maintain and operate a General Hospital.

Hartford Hospital is located at 80 Seymour Street and 200 Retreat Avenue, Hartford, CT 06106.

The maximum number of beds shall not exceed at any time:

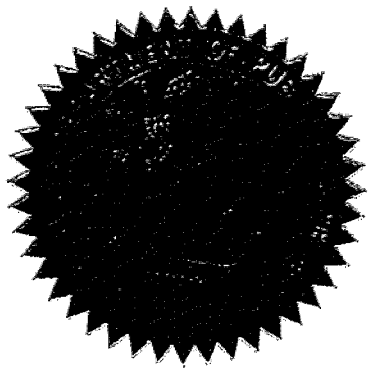
48 Bassinets
819 General Hospital Beds

This license expires **December 31, 2017** and may be revoked for cause at any time.

Dated at Hartford, Connecticut, January 1, 2016. RENEWAL.

Satellites:

West Hartford Surgery Center, 65 Memorial Road, Suite 500, West Hartford
Hartford Hospital, 505 Willard Avenue, Bldg. 3, Newington
Duncaster Primary Care Satellite, 40 Loeffler Road, Bloomfield



Jewel Mullen, MD, MPH, MPA
Commissioner

Greer, Leslie

From: Armah, Olga
Sent: Tuesday, April 19, 2016 3:58 PM
To: Barbara.Durdy@hhchealth.org
Cc: User, OHCA; Carney, Brian; Riggott, Kaila
Subject: Docket # 16-32062-CON Deemed Complete
Attachments: 16-32062-CON Notification of Application Deemed Complete.pdf

Dear Ms. Durdy:

Please note that OHCA has deemed complete the above noted CON application. See the attached.

Olga Armah, M. Phil
Associate Research Analyst
Office of Health Care Access
CT Department of Public Health
410 Capitol Avenue, MS #13HCA
P.O. Box 340308
Hartford, CT 06134

Phone: 860 418 7070
Fax: 860 418 7053
mailto: olga.armah@ct.gov
Web: www.ct.gov/ohca

STATE OF CONNECTICUT
DEPARTMENT OF PUBLIC HEALTH

Raul Pino, M.D., M.P.H.
Commissioner

Dannel P. Malloy
Governor
Nancy Wyman
Lt. Governor

Office of Health Care Access

April 19, 2016 Via Email Only

barbara.durdy@hhchealth.org
Barbara Durdy
Director, Strategic Planning
Hartford HealthCare
181 Patricia Genova Boulevard
Newington, CT 06111

RE: Certificate of Need Application Docket Number: 16-32062-CON
Acquisition of Computed Tomography and 3T Magnetic Resonance Imaging Scanners
Certificate of Need Completeness Letter

Dear Ms. Durdy:

This letter is to inform you that, pursuant to Section 19a-639a (d) of the Connecticut General Statutes, the Office of Health Care Access has deemed the above-referenced application complete as of April 19, 2016.

If you have any questions concerning this letter, please feel free to contact Brian Carney or me at (860) 418-7001.

Sincerely,

Olga Armah
Associate Research Analyst

Phone: (860) 509-8000 • Fax: (860) 509-7184 • VP: (860) 899-1611
410 Capitol Avenue, P.O. Box 340308
Hartford, Connecticut 06134-0308
www.ct.gov/dph
Affirmative Action/Equal Opportunity Employer

Greer, Leslie

From: Armah, Olga
Sent: Thursday, June 30, 2016 11:57 AM
To: Durdy, Barbara
Cc: Carannante, Vincenzo <VCarannante@goodwin.com> (VCarannante@goodwin.com); Riggott, Kaila; User, OHCA
Subject: Docket No. 16-32062-CON

Dear Barbara,

One more question regarding the above application.

Has an assessment been done on the existing CT and MRI equipment in the entire Hartford Healthcare system to determine that there is not an existing CT or MRI scanner that could be relocated, upgraded or replaced in order to serve patients at the Bone and Joint Institute? If an assessment has been conducted, please provide evidence detailing the results. If not, please provide an assessment of existing CT and MRI equipment in the Hartford Healthcare system.

Thank you in advance.

Sincerely,

Olga Armah, M. Phil
Associate Research Analyst
Office of Health Care Access
CT Department of Public Health
410 Capitol Avenue, MS #13HCA
P.O. Box 340308
Hartford, CT 06134

Phone: 860 418 7070
Fax: 860 418 7053
mailto: olga.armah@ct.gov
Web: www.ct.gov/ohca

Greer, Leslie

From: Armah, Olga
Sent: Monday, July 18, 2016 9:11 AM
To: Greer, Leslie
Subject: FW: Docket No. 16-32062-CON
Attachments: 0718166520.pdf; HHC CT MRI Capacity 2015 v3.xlsx

Good morning Leslie,

Please append to docket.

Thanks.

Olga

Olga Armah
Office of Health Care Access (OHCA)
CT Department of Public Health
Phone: 860 418 7070
Fax: 860 418 7053
Mailto: olga.armah@ct.gov
Web: www.ct.gov/ohca

From: Carannante, Vincenzo [mailto:VCarannante@goodwin.com]
Sent: Monday, July 18, 2016 8:58 AM
To: Armah, Olga
Cc: Riggott, Kaila; Durdy, Barbara
Subject: RE: Docket No. 16-32062-CON

Hi Olga: Please see attached for the information you requested.
Thank you,
Vin

Shipman & Goodwin LLP
COUNSELORS AT LAW

Vincenzo Carannante
Partner
One Constitution Plaza
Hartford, CT 06103-1919

Tel (860) 251-5096
Fax (860) 251-5211
vcarannante@goodwin.com
www.shipmangoodwin.com

From: Armah, Olga [mailto:Olga.Armah@ct.gov]
Sent: Monday, July 18, 2016 8:02 AM
To: Durdy, Barbara
Cc: Carannante, Vincenzo; Riggott, Kaila
Subject: RE: Docket No. 16-32062-CON

Thanks Barbara.

Olga Armah
Office of Health Care Access (OHCA)
CT Department of Public Health
Phone: 860 418 7070
Fax: 860 418 7053
Mailto: olga.armah@ct.gov
Web: www.ct.gov/ohca

From: Durdy, Barbara [mailto:Barbara.Durdy@hhchealth.org]
Sent: Saturday, July 16, 2016 4:49 PM
To: Armah, Olga
Cc: Carannante, Vincenzo <VCarannante@goodwin.com> (VCarannante@goodwin.com)
Subject: Re: Docket No. 16-32062-CON

Olga
We have drafted our response and will send it to you shortly
Thank you
Barbara

Sent from my iPhone

On Jul 15, 2016, at 1:16 PM, Armah, Olga <Olga.Armah@ct.gov> wrote:

> Hi Barbara,
>
> Are you close to getting a response to us on the question below?
>
> Thanks.
>
> Olga
>
> ***Olga Armah***
> Office of Health Care Access (OHCA)
> CT Department of Public Health
> Phone: 860 418 7070
> Fax: 860 418 7053
> Mailto: olga.armah@ct.gov
> Web: www.ct.gov/ohca
> <image001.jpg>
>
> ---
>
> **From:** Armah, Olga
> **Sent:** Thursday, June 30, 2016 11:58 AM
> **To:** 'Durdy, Barbara'
> **Cc:** Carannante, Vincenzo <VCarannante@goodwin.com> (VCarannante@goodwin.com); Riggott, Kaila; User, OHCA
> **Subject:** Docket No. 16-32062-CON
>
> Dear Barbara,
>
> One more question regarding the above application.

Has an assessment been done on the existing CT and MRI equipment in the entire Hartford Healthcare system to determine that there is not an existing CT or MRI scanner that could be relocated, upgraded or replaced in order to serve patients at the Bone and Joint Institute? If an assessment has been conducted, please provide evidence detailing the results. If not, please provide an assessment of existing CT and MRI equipment in the Hartford Healthcare system.

Thank you in advance.

Sincerely,

Olga Armah, M. Phil
Associate Research Analyst
Office of Health Care Access
CT Department of Public Health
410 Capitol Avenue, MS #13HCA
P.O. Box 340308
Hartford, CT 06134

Phone: 860 418 7070
Fax: 860 418 7053
mailto: olga.armah@ct.gov
Web: www.ct.gov/ohca
<image002.png>

Hartford HealthCare
Connect to healthier.™

July 15, 2016

Via Electronic Mail
Olga Armah
Associate Research Analyst
Office of Health Care Access
CT Department of Public Health
410 Capitol Avenue, MS #13HCA
P.O. Box 340308
Hartford, CT 06134
olga.armah@ct.gov

Re: Docket No. 16-32062-CON

Dear Ms. Armah:

Please see below for our responses to your correspondence dated June 30, 2016 in which you asked if Hartford Hospital (the "Applicant" or "Hospital") completed an assessment of the existing CT and MRI equipment in the Hartford HealthCare system.

A. Harford Hospital's Assessment of its CT and MRI Equipment

The Applicant did perform an assessment of its (i.e. the Hospital's) existing CT and MRI equipment. Please see **Exhibit 1** attached hereto for the relevant pages and excerpts from our CON Application that reflect our assessment, and the results of this assessment which necessitated the Applicant filing the present CON Application (the "Application") to acquire an additional CT and MRI scanner for the Hospital's new Bone & Joint Institute.

In summary, our assessment evidenced that the Hospital's CT and MRI scanners were at or near capacity, that its existing CT and MRI scanners needed to remain in their current locations, and that an additional CT and MRI Scanner are needed for the Bone & Joint Institute for the reasons previously set forth in our Application.

B. Harford HealthCare's Assessment of its CT and MRI Equipment

The Applicant believes that this information is not applicable to the present CON Application. As reflected in OHCA's Health Care Facilities and Services Plan, a CON application for the acquisition of imaging equipment focuses on the relevant applicant and the

need for the imaging equipment in the applicant's primary service area or PSA. The Applicant in the present matter is the Hospital and not Hartford HealthCare. Hartford Hospital believes it has demonstrated the need for the CT and MRI scanners within its PSA and believes that CT and MRI scanners that are located outside of its PSA including, those owned by hospitals within the Hartford HealthCare system, are irrelevant.

Regardless of the foregoing, and because time is of the essence with respect to the opening of the Bone & Joint Institute in October of 2016, we have updated our assessment to include all CT and MRI imaging capacity at Hartford HealthCare acute care hospitals. Please see **Exhibit 2**.[1] Our assessment in **Exhibit 2** demonstrates that there are no CT or MRI scanners that can be relocated to the Bone & Joint Institute. More specifically, each and all of the CT and MRI scanners set forth in **Exhibit 2** cannot be relocated or repurposed at the present time because: (1) the CT or MRI scanner is at capacity and, thus, needed in its current location to service the applicable patient population; (2) the CT or MRI scanner serves (a) a specific purpose (e.g. handles the excess capacity of the other MRI or CT scanner(s) operated by the applicable hospital) or (b) a specific patient population (e.g. patients requiring interventional procedures) and, thus, is needed in its current location to service the applicable patient population; or (3) it is the only CT or MRI currently operated/located at the applicable hospital and, thus, relocating it would leave the applicable hospital without an MRI or CT scanner, which is not a possibility or option.

C. Additional/Miscellaneous Information:

As stated above and reflected in **Exhibit 2**, there are no existing MRI or CT scanners that can be relocated to the Bone & Joint Institute at this time. In addition to this information, we would also like to stress the following to OHCA:

1. Approving this Application will result in a positive impact on the Hospital's existing services including, avoiding delays in timely diagnosis or treatment of patients. More specifically, and as reflected in our Application, delays caused by inpatient transport, handling and medical care frequently disrupt the schedule, leading to often substantial delays in outpatient MRI and CT scans. The availability of the new CT and MRI Scanner will provide for easier scheduling, a better overall outpatient experience for our patient population, and faster diagnoses. Moreover, access for all patients, including Medicaid patients, requiring CT and MRI scans will be positively impacted as a result of fewer scheduling delays and more proximate access for patients receiving care at the Bone & Joint Institute.

2. Finally, we respectfully remind OHCA that the relocation of a CT or MRI scanner between hospitals in the Hartford HealthCare system is not a simple undertaking. It would require the sale of the equipment from one entity to another, which as you know, would require a CON application to approve the transfer of ownership. Moreover, and more importantly, if we were to relocate a scanner from one hospital to another, we have been informed by OHCA that this would also require a CON for

[1] Capacity estimates (as of June 30, 2016) have been calculated based on the utilization standards for CT and MRI scanners established by OHCA in its Statewide Health Care Facilities and Services Plan (October 2012). The source of this data is Schedule 450, which is on file with OHCA.

the termination of a hospital service at the location where the relocated scanner was removed from. However, as noted above, these issues are irrelevant at the present time as relocation of any of the existing scanners reflected on **Exhibit 2** is not feasible at this time.

3. The approval of this Application is paramount to the Hospital's patients and the operations of the Hospital's Bone & Joint Institute. All Bone & Joint Institute clinical services will be clinically integrated within one central location so that the patient can physically navigate within the Bone & Joint Institute with ease and convenience. Essentially, there will be no reason for the patient to leave the premises of the Bone & Joint Institute to receive any of their services. This is particularly advantageous for patients who by virtue of their musculoskeletal problems often have moderate to severe mobility limitations. For example, a patient who is seen for an orthopedics consultation, may immediately proceed to have a scan or undergo diagnostic laboratory tests, proceed to a rheumatology consult, return for infusion therapy, or have inpatient or outpatient surgery, and then return for rehabilitation, all of which will be proximately located in one central location. The objective of a centralized location is to improve the patient experience so that a visit to the Bone & Joint Institute neither stresses nor exhausts the patient, especially the elderly and those in pain.

   As reflected above, one of the main goals and benefits of the Bone & Joint Institute is to offer patients an unparalleled network of coordinated services for those with musculoskeletal disorders and orthopedic injuries. In furtherance of the aforementioned objectives, the Bone & Joint Institute will have and offer, as a critical component, the latest MRI and CT imaging services. Accordingly, the Hospital is seeking CON authorization to acquire a CT and MRI scanner for installation and operation at the Bone & Joint Institute, which opens in October of this year. Without said equipment, the Hospital will not be able to operate the Bone & Joint Institute in the manner in which it was intended, which will be a severe detriment to the Hospital and, more importantly, to the detriment of its patients.

Please contact me if you have any questions.

Sincerely,

Barbara Durdy

Barbara Durdy
Director, Strategic Planning
Hartford HealthCare

EXHIBIT 1

a) **CON App. Pg. 0012:**

Better Patient Access, Scheduling and Overall Experience:

- CT Scanner: It is also expected that many CT scan outpatients from the Hospital's main campus will be scheduled on the new CT Scanner. Currently, Hospital outpatients requiring CTs are scanned on the Hospital's heavily scheduled inpatient scanner. Delays caused by inpatient transport, handling and medical care frequently disrupt the schedule, leading to often substantial delays in outpatient scans. The availability of the new CT Scanner will provide an easier scheduling and a better overall outpatient experience for our patient population.

- MRI Scanner: It is also expected that many MRI outpatients from the Hospital's main campus will be scheduled on the new MRI Scanner. Currently, Hospital outpatients requiring MRI services are scanned on the Hospital's two existing, heavily scheduled MRI scanners. Delays caused by inpatient transport, handling and medical care frequently disrupt the schedule, leading to often substantial delays in outpatient scans. The availability of the new MRI Scanner will provide a better scheduling and a better overall outpatient experience for our patient population.

b) **CON App. Pg. 0013:**

- In FY 2013, planning began for the establishment of the Bone & Joint Institute on the main campus of Hartford Hospital. At that time, it was anticipated that the Hospital would need to acquire the Scanners in order to accommodate MRI and CT scans for inpatients and outpatients of the Bone & Joint Institute, to alleviate the demand on the usage of other MRI and CT scanners on the Hospital's main campus, and further implement its plan to create a state of the art, all-inclusive musculoskeletal treatment center.

c) **CON App. Pgs. 0016 - 0017:**

- In the past three fiscal years, patients have undergone an average of 43,688 CT exams/scans per year on the Applicant's three current CT scanners. Excluding the older technology QX/i scanner, whose schedule is mostly filled by lengthy CT-guided interventional procedures, the Hospital's two existing CT scanners in the main department and emergency department or "ED" averaged 14,000 and 25,000 exams/year, respectively. Those volumes have increased by 8-10% per year mostly due to increased needs for inpatient and ED CT scans.

- In the past three fiscal years, patients have undergone an average of 10,212 MRI exams/scans per year on the Applicant's two general purpose MRI scanners. The

Hospital's two existing MRI scanners in the Radiology MRI center averaged 6,355 and 3,857exams per year, respectively. Those volumes have increased by 8-10% per year.

d) **CON App. Pg. 0017:**

- CT Scanning: The Hospital currently operates three CT scanners on the main campus, all of which are operating at or near capacity. Depending on the circumstance, patients requiring CT scans are scheduled on one of the Hospital's three main campus scanners. Hospital outpatients requiring CTs are scanned on the Hospital's primary, heavily scheduled inpatient scanner. Delays caused by inpatient transport, handling and medical care along with urgent scanning requests frequently disrupt the schedule and cause long delays for routine outpatient scans.

- MRI Scanning: The patient population is currently being served in the Radiology MRI Center located at 85 Jefferson Street (attached to Hartford Hospital), Hartford CT, 06012. The patient population will be the same as those currently imaged with the Hospital's two existing MRI scanners, which are operating at or near capacity.

- The volume of and difficulty of patients currently handled by the main Hospital's current CT scanners are such that outpatient scans are more difficult to schedule and are subject to frequent delays to transport, handling and medical care of inpatients being scanned. By augmenting existing Hospital scanning capacity, outpatients will be better served in a facility more conducive for managing outpatients.

e) **CON App. Pg. 0018:**

- The MRI Scanner will provide appropriate and more timely imaging of other Hospital outpatients requiring MRI imaging. The volume of and difficulty of patients currently handled by the Hospital's existing MRI scanners are such that outpatients are difficult to schedule in a timely manner, and are subject to frequent delays due to transport, handling and medical care of inpatients needed MRI. By augmenting existing Hospital scanning capacity, outpatient will be better served in a facility more conducive for managing outpatients.

f) **CON App. Pg. 0019:**

- The Hospital currently operates three CT scanners and two MRI scanners on the main campus, all of which are operating at or near capacity. Depending on the circumstance, patients requiring CT and/or MRI scans are scheduled on one of the Hospital's main campus scanners. Hospital outpatients requiring CTs and MRIs are scanned on the

Hospital's primary, heavily scheduled inpatient scanners. Delays caused by inpatient transport, handling and medical care along with urgent scanning requests frequently disrupt the schedule and cause long delays for routine outpatient scans. Overall, access to imaging services for persons requiring CT and MRI scans will be vastly improved as the Hospital's other CT and MRI scanners are operating at or near capacity.

g) **CON App. Pg. 0020:**

- Access to imaging services for persons requiring CT and/or MRI scans will be improved as the Hospital's existing MRI and CT scanners are operating at or near capacity. As previously stated, Hospital outpatients often experience significant scheduling delays as a result of sharing the main Hospital scanners with inpatients. In particular, access for patients requiring imaging as part of an orthopedic or musculoskeletal episode of care will be greatly enhanced by having conveniently located, proximate imaging within the physical location of the Bone & Joint Institute.

h) **CON App. Pg. 0021:**

- Moreover, access for all patients, including Medicaid patients, requiring CT and MRI scans will be positively impacted as a result of fewer scheduling delays and more proximate access for patients receiving care at the Bone & Joint Institute.

i) **CON App. Pgs. 0026-0027:**

- The Hospital will be using the proposed Scanners to serve its existing patient population to alleviate capacity and scheduling issues and to provide higher quality care at the Bone & Joint Institute.

- The primary purpose of the new CT Scanner is to provide needed imaging services to inpatients and outpatients of the new Bone & Joint Institute. Although the Bone & Joint Institute is on the campus of Hartford Hospital, there is not easy access to facilities of the Hospital for imaging purposes, especially for inpatients requiring post-surgical scans. The new CT Scanner also provides dual energy imaging, which alleviates severe artifacts associated with metal within the CT-scanned field of view, a frequent occurrence among orthopedic patients. In addition, the two fully capable Hospital CT scanners are at or near capacity, making it difficult to schedule outpatients in a timely fashion and to image those patients without delays. The additional capacity that the new CT Scanner will provide will allow for a better scheduling, scanning and overall better experience for the Hospital's outpatient CT patients.

- The primary purpose of the new MRI Scanner is to provide needed imaging services to inpatients and outpatients of the new Bone & Joint Institute. Although the Bone & Joint Institute is on the campus of Hartford Hospital, there is not easy access to facilities of the Hospital for imaging purposes, especially for inpatients requiring post-surgical scans. The new MRI Scanner also provides advanced technology to allow better imaging for patients with MRI-conditional metallic implants and prostheses. In addition, the two fully capable Hospital MRI scanners are at or near capacity, making it difficult to schedule outpatients in a timely fashion and to image those patients without delays. The additional capacity that the new MRI Scanner will provide will allow for a better scheduling, scanning and overall better experience for the Hospital's outpatient MRI patients.

j) **CON App. Pg. 0221:**

Imaging Modality	Location
(1) General Purpose CT Scanning	Hartford Hospital 80 Seymour Street, Hartford CT, 06102 GE VCT 64-slice CT (Radiology Department)
(2) General Purpose CT Scanning	Hartford Hospital 80 Seymour Street, Hartford CT, 06102 GE VCT 64-slice CT (Emergency Department)
(3) Specialized* CT Scanning	Hartford Hospital 80 Seymour Street, Hartford CT, 06102 GE QX/I 8-Slice CT* (Radiology Department)
(4) General Purpose MRI Scanning	Hartford Hospital 85 Jefferson Street, Hartford CT, 06102 Radiology Department; MRI Center GE Signa Echospeed 1.5T
(5) General Purpose MRI Scanning	Hartford Hospital 85 Jefferson Street, Hartford CT, 06102 Radiology Department; MRI Center GE Signa Twinspeed 1.5T

*The QX/I 8 scanner is primarily used for lengthy CT guided interventional procedures.

k) CON App. Pg. 0222:

TABLE A
EXISTING EQUIPMENT OPERATED BY THE APPLICANT

Provider Name/Address	Service*	Days/Hours of Operation **	Utilization*** FY 2015
Hartford Hospital 80 Seymour Street, Hartford CT, 06102 (Radiology Department)	GE VCT 64-slice CT	Always Open	16,029 (a)
Hartford Hospital 80 Seymour Street, Hartford CT, 06102 (Emergency Department)	GE VCT 64-slice CT	Always Open	26,803 (a)
Hartford Hospital 80 Seymour Street, Hartford CT, 06102 (Radiology Department)	GE QX/I 8-Slice CT****	Mon-Sat 7:00 am -12:00 am	4,927 (a), (b)
Hartford Hospital 85 Jefferson Street, Hartford CT, 06102 (Radiology Department; MRI Center)	GE Signa Echospeed 1.5T (Closed)	Always Open	6,802 (c)
Hartford Hospital 85 Jefferson Street, Hartford CT, 06102 (Radiology Department; MRI Center	GE Signa Twinspeed 1.5T (Closed)	M-F All hours Sat-Sun: 7:00 to 11:30 PM	4097 (c), (d)

(a) Volumes based on totals for Fiscal Year 2015 (Oct 1, 2014 to Sept 30, 2015)
(b) This 15 year old scanner is used primarily for CT guided procedures (biopsies, aspirations, etc), scheduled for 90 to 120 minutes with three to five of these procedures are scheduled per weekday. This type of utilization, as well as its higher radiation doses and older, limited technology constrains the type of conventional CT exams that can be performed on this unit.
(c) Volumes based on totals for Fiscal Year 2015 (Oct 1, 2014 to Sept 30, 2015)
(d) Longer anesthesia cases (usually taking four normal scheduled slots) and breast biopsy exams are all performed on the Twinspeed unit

l) CON App. Pg. 0227

- The Hospital currently operates three CT scanners and 2 MRI scanners. With the exception of the oldest, 15 year old CT scanner, all scanners are operating at or near capacity. The oldest CT scanner is the GE QX/i, which is 15 years old and has limited but essential utility on the main Hospital campus. The Hospital has not considered relocating this scanner because it serves a very specific and essential function on the main Hospital campus. This scanner is used for CT guided procedures such as biopsies and aspirations, which are longer procedures, typically scheduled for 90 to 120 minutes. Due to the duration of these procedures, they cannot be accommodated on any other CT scanner at the main Hospital campus. Accordingly, the GE QX/I scanner will be maintained at the main Hospital campus to accommodate these longer procedures.

EXHIBIT 2

(See attached)

Hartford HealthCare
Assessment of MR and CT Inventory
Acute Care Hospitals

Hartford Hospital	MRI scanners		FY 2015 Annual Filing Schedule 450 Total Volume	% Capacity (a)	FY 2016 Volume FTYD June 2016 (9 months)	FTYD June Annualized	% Capacity (a)
		Total Volume:	10869	136%			
	GE Echo Speed 1.5T	80 Seymour			5752	7669	96%
	GE Twin 1.5T	80 Seymour					
	Siemens SKYRA 3T	Institute of Living					N/A
	CT Scanners		Total Volume	% Capacity (a)	FY 2016 Volume FTYD June 2016 (9 months)	FTYD June Annualized	% Capacity (a)
		Total Volume:	47321	131%			
	GE Lightspeed VCT 64 Slice	Radiology Department			27056	36075	100%
	GE Lightspeed VCT xte 64 Slice	Emergency Department					
	GE Lightspeed Ultra 8 Slice	80 Seymour					
	Toshiba Aquilion LB 16 slice	Radiation Oncology					N/A

MidState Medical Center	MRI scanners		Total Volume	% Capacity (a)	FY 2016 Volume FTYD June 2016 (9 months)	FTYD June Annualized	% Capacity (a)
	Siemens Symphony 1.5T	435 Lewis Avenue	6510	163%	2903	5806	145%
	CT Scanners		Total Volume	% Capacity (a)	FY 2016 Volume FTYD June 2016 (9 months)	FTYD June Annualized	% Capacity (a)
		Total Volume:	16965	71%			
	GE VCT 64 Slice	435 Lewis Avenue			6541	13082	109%
	GE Discovery 610	435 Lewis Avenue			1368	2736	23%

William W. Backus Hospital	MRI scanners		Total Volume	% Capacity (a)	FY 2016 Volume FTYD June 2016 (9 months)	FTYD June Annualized	% Capacity (a)
		Total Volume:	11267	141%			
	Siemens Avanto 1.5T (fixed)	326 Washington Ave			4690	6253	156%
	Siemens Avanto 1.5T (mobile)	326 Washington Ave			698	931	23%
	CT Scanners		Total Volume	% Capacity (a)	FY 2016 Volume FTYD June 2016 (9 months)	FTYD June Annualized	% Capacity (a)
		Total Volume:	39266	164%			
	Siemens Somotom Definition 64	326 Washington Ave			5400	7200	60%
	Phillips Brilliance 128 Slice	326 Washington Ave			10800	14400	120%

Windham Community Hospital	MRI scanners		Total Volume	% Capacity (a)	FY 2016 Volume FTYD June 2016 (9 months)	FTYD June Annualized	% Capacity (a)
	G.E. Signa HD 1.5T	112 Mansfield Avenue	3531	88%	2721	3628	91%
	CT Scanners		Total Volume	% Capacity (a)	FY 2016 Volume FTYD June 2016 (9 months)	FTYD June Annualized	% Capacity (a)
	GE LightSpeed VCT 7x64 Slice	112 Mansfield Avenue	10293	86%	8158	10877	91%

Hospital Of Central Connecticut	MRI scanners		Total Volume	% Capacity (a)	FY 2016 Volume FTYD June 2016 (9 months)	FTYD June Annualized	% Capacity (a)
		Total Volume:	7655	96%			
New Britain Campus	Philips Acheiva XR 1.5T	100 Grand Street, New Britain			4173	5564	139%
Bradley Campus	Hitachi Oasis 1.2T	81 Meridan Ave. Southington			2601	3468	87%
	CT Scanners		Total Volume	% Capacity (a)	FY 2016 Volume FTYD June 2016 (9 months)	FTYD June Annualized	% Capacity (a)
		Total Volume:	27214	76%			
New Britain Campus	GE LightSpeed Pro 16 Slice	100 Grand Street			3014	4019	N/A
	GE LightSpeed Pro 32 Slice	100 Grand Street (Emergency Department)			11426	15235	127%
Bradley Campus	GE Brightspeed 16 Slice	81 Meridan Ave. Southington			4487	5983	50%

Notes:
(a) MRI capacity based on 4,000 scans per scanner- OHCA standard for hospital-based MRI scanner
CT capacity based on 12,000 scans per scanner - OHCA standard for hospital based CT scanner

Comments:
Hartford Hospital no longer tracks volume by scanner.
Volumes presented represent aggregate volume for CT and MRI scanners.
Operational 24/7
Operational 24/7

Used almost exclusively for research studies per CON

Comments:
Hartford Hospital no longer tracks volume by scanner.
Volumes presented represent aggregate volume for CT and MRI scanners.
Operational 24/7
Operational 24/7
Open 8 hrs / day

516 radiation simulations YTD
Used exclusively for radiation treatment planning

Comments:
Operational 24/7

Comments:

Operational 24/7
Used for interventional procedures which require longer time slots.

Comments:

Operational 24/7

Comments:

Used for interventional procedures
Operational 24/7

Comments:
Operational 24/7

Comments:
Used for both diagnostic and interventional procedures

Comments:

Hours of operation Mon - Fri 7a - 10p and Sat 7a - 3p
Hours of operation Mon - Fri 7a - 9p and Sat 7a - 2p

Comments:

Used for interventional procedures and to accommodate
overflow from main CT scanner.
Operational 8 hours per day, M-F only
Operational 24/7

The only CT scanner at Bradley campus, essential for
acute care operations at the location.

STATE OF CONNECTICUT
DEPARTMENT OF PUBLIC HEALTH

Raul Pino, M.D., M.P.H.
Commissioner

Dannel P. Malloy
Governor
Nancy Wyman
Lt. Governor

Office of Health Care Access

Certificate of Need
Final Decision

Applicant: **Hartford Hospital**
80 Seymour Street
Hartford, CT 06115

Docket Number: **16-32062-CON**

Project Title: **Acquisition of a Computed Tomography ("CT") Scanner and a 3 Tesla Magnetic Resonance Imaging ("MRI") Scanner for Hartford Hospital in Hartford, Connecticut**

Project Description: Hartford Hospital ("Applicant" or "Hospital") seeks authorization to acquire a new computed tomography ("CT") scanner and a new 3T magnetic resonance imaging ("MRI") scanner for its main campus Bone & Joint Institute ("Institute"). The total capital expenditure associated with this proposal is $2,787,021.

Procedural History: The Applicant published notice of its intent to file a Certificate of Need ("CON") application in *The Hartford Courant* on December 14, 15 and 16, 2015. On January 15, 2016, the Office of Health Care Access ("OHCA") received the initial CON application from the Applicant for the above-referenced project and deemed the application complete on April 19, 2016.

OHCA received no responses from the public concerning the Applicant's proposal and no hearing requests were received from the public per Connecticut General Statutes ("Conn. Gen. Stat.") § 19a-639a(e). Deputy Commissioner Addo considered the entire record in this matter.

DPH
Connecticut Department of Public Health

Phone: (860) 418-7001 • Fax: (860) 418-7053
410 Capitol Avenue, MS#13HCA
Hartford, Connecticut 06134-0308
www.ct.gov/dph

Findings of Fact and Conclusions of Law

1. The Applicant is an 867-bed[1] hospital located at 80 Seymour Street, Hartford, Connecticut and provides primary, secondary and tertiary acute care services. The Applicant is a member of the Hartford Healthcare, an integrated health care delivery system. Exhibit A, pp. 11, 42.

2. The Hospital is constructing a Bone & Joint Institute ("Institute"), a department on the main campus, dedicated to providing comprehensive and coordinated diagnostic and treatment services integrated with research and educational services for musculoskeletal disorders. Exhibit A, p. 11, 21.

3. The Institute will be a patient-centered facility with medical subspecialties in foot, ankle, hand, shoulder and upper extremity, sports medicine, spine, joint, urgent care, arthritis and pain management, embedded with orthopedics and neurological services. Docket No.13-31851-CON.

4. Since musculoskeletal disorders typically involve more than one body system, the Institute will utilize a multidisciplinary approach for diagnosis and treatment, which will contribute to better patient outcomes. Docket No.13-31851-CON.

5. OHCA authorized the Hospital to establish an orthopedic ambulatory surgery center as a critical and central component of the Institute (Docket No.13-31851-CON) as well as to remove one of the Hospital's existing operating rooms from service (Docket No. 16-31851-MDF). Due to severe weather delays, construction of the Institute commenced on January 7, 2015 with anticipated completion and opening dates in December 2016. Exhibit A, p. 13.

6. The Applicant is proposing the acquisition of two new scanners to be located at the Institute for inpatient and outpatient care with the following special features resulting in better images for improved patient diagnosis and treatment:
    1. A General Electric (GE) 750HD 64-slice CT scanner with 3D dose modulations for managing or reducing radiation doses, dose-reducing reconstruction and dual energy scanning to alleviate severe artifacts associated with scans of anatomic areas containing metal; and
    2. A GE SIGNA Pioneer 3.0T MRI scanner optimized with orthopedic coils, capability for imaging near metallic devices and advanced imaging techniques to reduce image degradation due to the presence of metal for better images, higher accuracy and sensitivity.

    Exhibit A, pp. 11-12, 221.

[1] Includes 48 bassinets.

7. The following table lists the Applicant's CT and MRI scanners currently in use. All the scanners are operating at or near capacity and heavily scheduled.

TABLE 1
APPLICANT'S EXISTING CT AND MRI SCANNERS

Location	Area	Service	Days/Hours of Operation	FY 2015* Utilization
Hartford Hospital 80 Seymour Street Hartford, CT 06102	Radiology Dept.	GE VCT 64-slice CT	Always open	16,029
Hartford Hospital 80 Seymour Street Hartford, CT 06102	Radiology Dept.	GE QX/I 8 slice CT**	Mon-Sat 7:00 am – 12:00 a.m.	4,927
Hartford Hospital 80 Seymour Street Hartford, CT 06102	Emergency Dept.	GE VCT 64-slice CT	Always open	26,803
Hartford Hospital 80 Seymour Street Hartford, CT 06102	Radiation Oncology	Toshiba Aquillion LB 16-slice CT	N/A	516***
Hartford Hospital 85 Jefferson Street Hartford, CT 06102	Radiology Dept., MRI Center	GE Signa Echospeed 1.5T (Closed)	Always open	6,802
Hartford Hospital 85 Jefferson Street Hartford, CT 06102	Radiology Dept., MRI Center	GE Signa Twinspeed 1.5T (Closed)****	Mon – Fri All hours Sat – Sun 7:00 to 10:30 p.m.	4,096
Institute of Living 400 Washington Street Hartford, CT 06102	Olin Center for Neuropsychiatry Research	Siemens SKYRA 3.0T	N/A	*****

* October 1, 2014 – September 30, 2015
**15 years old and used for lengthy CT guided interventional procedures.
***Year to date and used exclusively as CT simulator for radiation treatment planning.
****Used for longer anesthesia cases and breast biopsy exams.
***** Used exclusively for research studies per Docket Number 14-31901-CON.
Exhibit A, pp. 16, 17, 221, 236.

8. The 15-year old GE QX/I 8-slice CT scanner is used primarily for lengthy CT guided procedures (biopsies, aspirations, etc.) and scheduled for 90-120 minutes for three to five procedures per weekday. The scanner's higher radiation doses and older technology limit the type of conventional CT exams that can be performed on the unit and it cannot be relocated as it serves this specific and essential function. Exhibit A, pp. 32, 227.

9. The GE Signa Twinspeed 1.5T closed MRI scanner is used for longer anesthesia cases, usually taking four normal slots, and breast biopsy exams. Exhibit A, p 222.

10. There are no CT and MRI scanners in the Hartford Healthcare system that can be relocated to or repurposed for the Institute at present because each scanner is at or near capacity and is

needed in its current location or serves a specific purpose or patient population. Exhibit A, p. 228

11. Patients admitted with orthopedic injury or complex musculoskeletal pathology increased from 112 to 126 (or 13%) between FY 2013 and FY 2015, and is expected to increase. The number of patients with metal implants who undergo imaging is also increasing. Based on scholarly articles the Applicant provided, national overall inpatient orthopedic care is projected to increase by an average of 250% over the next fifteen years. Exhibit A, pp. 12, 230; Kurtz, M. Steven Ph. D et al, Future Young Patient Demand for Primary and Revision Joint Replacement: National Projection from 2010 to 2030, Clinical Orthopedics journal; Exhibit A, p. 256.

12. Orthopedic patients, who often have moderate to severe mobility limitations, currently receive consultation care at one location Hospital and medically necessary imaging diagnostic scans, treatment and rehabilitation at other Hospital locations. Exhibit A, pp. 11, 230.

13. Transport and personnel needs, handling and medical care, add-on critical exam scans and urgent requests for orthopedic inpatients frequently disrupt daily scheduling and lead to scheduling difficulties and substantial delays for outpatient scans. Exhibit A, pp. 12, 17, 231.

14. Timely CT and MRI scans are needed for standard orthopedic imaging and surgical planning and to evaluate pre- and post-discharge surgical patients for potential emboli and complications. Currently post-surgical patients needing rapid assessments are transferred to the main Hospital for angiography or CTA on the Hospital's primary, heavily scheduled inpatient scanners. Exhibit A, pp. 17-18, 231.

15. Grouping orthopedic, rheumatology, pain management and rehabilitation services and appropriate imaging streamline and expedite the care of acute injury and the management of complex chronic conditions. Exhibit A, p. 230.

16. Orthopedic surgery patients are at high risk for thromboembolic complications including deep vein thrombosis (DVT), pulmonary embolism (PE) and as a consequence, death. For example, the incidence of DVT is 40-84% for total knee replacement without prophylaxis and 39-74% for total hip replacement; the incidence of fatal PE following a total joint replacement is 0.19-3.4%. Imaging modalities are the most effective ways to diagnose PE with spiral CT scan providing 81-100% specificity. Kim, Han Jo et al, Detection of Pulmonary Embolism in the Postoperative Patient Using Spiral CT Scans, Section of Hospital of Special Surgery Journal, Exhibit A, pp. 67-68.

17. The main campus conventional CT scans for post-operative patients with metal hardware is frequently limited by beam-hardening artifacts which result in x-rays attenuation, gaps on CT projection data and streaking, making it challenging to evaluate such patients' skeleton. The proposed 3D CT scanner is most effective for post-surgical examinations of the integrity of the patients' hardware and healing. Exhibit A, pp. 14, 72; Fayad, Laura m. et al, Value of 3D CT Defining Skeletal Complications of Orthopedic Hardware in the Postoperative Patient, American Journal of Roentgenology, Exhibit A p.71; Pessis, Eric, MD et al, Virtual Monochromatic Spectral Imaging with Fast Kilovoltage Switching: Reduction of Metal Artifacts at CT, RadioGraphics Journal, Exhibit A, p. 80.

18. The proposed 3D CT scanner will provide:
    - surgical planning scans and CT angiography for rapid assessments in post-surgical follow-up of suspected lung and other emboli without scheduling delays; and
    - higher quality imaging scans for patients that have metal implants and prostheses that seriously degrade the quality of images on the existing scanners.

    Exhibit A, pp. 12, 18.

19. MRIs and ultrasounds are demonstrated to be the most valuable imaging techniques for assessing meniscal damage, the standard imaging modality for detecting disc pathology for lower back pain and important insight for the appropriate timing of surgical treatment. Exhibit A, p.15; Potter, Hollis G. MD, Koff, E. Matthew, Ph., MR Imaging Tools to Assess Cartilage and Joint Structures, Hospital for Special Surgery Journal, Exhibit A, p. 102; Suthar, Pokraj P. et al, MRI Evaluation of Lumbar Disc Degenerative Disease, MRI Degenerative Spine Journal, Exhibit A, p. 108.

20. The proposed optimized MRI scanner will be utilized:
    - for pre-discharge and timely post-discharge follow-up assessment of post-surgical patients exhibiting symptoms of complications, without scheduling delays; and
    - with advanced techniques to reduce image degradation due to the presence of metal.

    Exhibit A, p. 12.

21. Based on historical utilization, the Applicant projects increases of 8% to 10% per year in total utilization. The reduction in projected volumes for the existing CT and MRI scanners reflects all current non-ED outpatient scans, orthopedic CT and MRI inpatients scans and 50% of existing inpatient CT spine scans and MRI outpatient head scans expected to move to the proposed scanners.

TABLE 2
APPLICANT'S HISTORIC AND PROJECTED UTILIZATION

Equipment	Historical Volume			CFY Volume*	Projected Volume		
	FY 13	FY 14	FY 15	FY 16	FY 17	FY 18	FY 19
CT Scanners							
GE VCT – Radiology Dept.	12,017	13,990	15,188	5,851	14,694	16,017	17,458
GE QX/I – Radiology Dept.	3,798	3,552	4,078	1,799	4,509	4,914	5,357
GE VCT – ED Dept.	23,195	25,929	28,793	9,784	32,478	35,401	38,587
GE CT750HD 64-slice CT	-	-	-	-	5,429	5,918	6,450
CT Total	**39,010**	**43,471**	**48,059**	**17,434**	**57,110**	**62,250**	**67,852**
MRI Scanners:							
GE Signa Echospeed 1.5T	6,077	6,269	6,802	2,211	6,002	6,464	6,958
GE Signa Twinspeed 1.5T	3,644	3,855	4,097	1,331	3,615	3,893	4,190
GE SIGNA Pioneer 3.0T MRI	-	-	-	-	3,013	3,244	3,492
MRI Total:	**9,721**	**10,124**	**10,899**	**3,542**	**12,630**	**13,599**	**14,640**

FY is October 1 to September 30.
* CFY is based on 4 months, that is, 10/1/2015 through 1/30/2016.
Exhibit A, pp. 15, 16, 25, 31-32, 228-229

22. Over 75% of the Hospital's scan volume is from the following primary service area towns: Andover, Avon, Berlin, Bloomfield, Bolton, Bristol, Burlington, Canton, Columbia, Coventry, Cromwell, East Granby, East Hartford, East Windsor, Enfield, Farmington, Glastonbury, Granby, Hartford, Hebron, Manchester, Meriden, Middletown, New Britain, New Hartford, Newington, Plainville, Portland, Rocky Hill, Simsbury, South Windsor, Southington, Suffield, Torrington, Vernon, West Hartford, Wethersfield, Windham, Windsor and Windsor Locks. Exhibit A, pp. 234-237, 242-244.

23. There will be no change in existing referral patters as the Hospital will be utilizing the proposed scanners to serve the existing patient population referred to by an attending physician. Exhibit A, p. 26.

24. The Applicant's current and projected payer mix is shown below and projected to remain unchanged.

TABLE 3
APPLICANT'S CURRENT & PROJECTED PAYER MIX BY CT SCAN VOLUME

Payer	Current FY16		Projected*					
			FY17		FY18		FY19	
	Volume	%	Volume	%	Volume	%	Volume	%
Medicare*	7,589	44%	24,864	44%	27,102	44%	29,541	44%
Medicaid*	4,228	24%	13,851	24%	15,097	24%	16,456	24%
CHAMPUS & TriCare	125	1%	403	1%	439	1%	479	1%
Total Government	**11,942**	**69%**	**39,118**	**69%**	**42,638**	**69%**	**46,476**	**69%**
Commercial Insurers	4,417	25%	14,471	25%	15,773	25%	17,192	25%
Uninsured	1,074	6%	3,518	6%	3,835	6%	4,180	6%
Workers Compensation	1	<1%	3	<1%	4	<1%	4	<1%
Total Non-Government	**5,490**	**31%**	**17,992**	**31%**	19,612	**31%**	**21,376**	**31%**
Total Payer Mix	**17,434**	**100%**	**57,110**	**100%**	**62,250**	**100%**	**67,852**	**100%**

TABLE 4
APPLICANT'S CURRENT & PROJECTED PAYER MIX BY MRI SCAN VOLUME

Payer	Current FY16		Projected*					
			FY17		FY18		FY19	
	Volume	%	Volume	%	Volume	%	Volume	%
Medicare*	1,384	39%	4,936	38%	5,314	38%	5,720	38%
Medicaid*	733	21%	2,614	22%	2,814	22%	3,030	22%
CHAMPUS & TriCare	22	1%	78	1%	84	1%	91	1%
Total Government	**2,139**	**60%**	**7,628**	**60%**	**8,212**	**60%**	**8,841**	**60%**
Commercial Insurers	1,200	34%	4,280	34%	4,607	34%	4,960	34%
Uninsured	200	6%	713	6%	768	6%	827	6%
Workers Compensation	3	<1%	11	<1%	12	<1%	12	<1%
Total Non-Government	**1,403**	**40%**	**5,004**	**40%**	**5,387**	**40%**	**5,799**	**40%**
Total Payer Mix	**3,542**	**100%**	**12,632**	**100%**	**13,599**	**100%**	**14,640**	**100%**

* Projected payer mix is based on the observed historical payer mix from last full fiscal year distribution (FY 2015).
Exhibit A, p. 232

25. The proposal will have no impact on Medicaid and indigent persons. Currently 24% (CT) and 21% (MRI) of the scans the Applicant provides are for Medicaid recipients and this trend is not projected to change. Exhibit A, p. 232

26. As the Institute is a Hospital department, Medicaid and indigent patients will be subject to the Hospital Charity Care Policy which provides for free or reduced charge services to the poor or indigent on the basis of ability to pay. Exhibit A, p. 21.

27. There will be no changes to the Hospital's price structure for imaging services as a result of this proposal. Exhibit A, p. 22.

28. Total capital expenditure for the proposal includes approximately $454,314 for the CT scanner and $1,745,865 for the MRI scanner. The Hospital will finance the proposal with operational funds.

TABLE 5
TOTAL PROPOSED CAPITAL EXPENDITURE

Purchase/Lease	Cost*
Equipment (Medical, Non-medical Imaging)	$2,200,179
Construction/Renovation	$586,842
Total Capital Expenditure (TCE)	**$2,787,021**

*Numbers have been rounded.
Exhibit A, pp. 22-23.

29. The Applicant projects incremental gains largely due to increasing revenue from an 8% to 10% increase in scan volumes in each of the three fiscal years following implementation of the program.

TABLE 6
APPLICANT'S PROJECTED INCREMENTAL REVENUES AND EXPENSES

	FY 2017	FY 2018	FY 2019
Revenue from Operations	$4,985,765	$5,376,344	$5,796,921
Total Operating Expenses	$829,750	$1,157.038	$1,180,581
Gain/Loss from Operations	**$4,156,015**	**$4,219,306**	**$4,616,340**

Assumptions:

- Increasing net patient revenues from average increases of 8% to 10% in scan volumes.
- Operating expenses include annual depreciation of approximately $22,000 per year for the two scanners over 10 years, annual depreciation for space renovation of $58,684 per year over 10 years, FY 2018 and forward annual equipment maintenance expense of the scanners for $304,000 and competitive salaries and benefits for 2 CT techs, 2 MRI techs and 1 registration/receptionist.

Ex. A, p. 30.

30. OHCA is currently in the process of establishing its policies and standards as regulations. Therefore, OHCA has not made any findings as to this proposal's relationship to any regulations not yet adopted by OHCA. (Conn. Gen. Stat. § 19a-639(a)(1)).

31. This CON application is consistent with the Statewide Health Care Facilities and Services Plan. (Conn. Gen. Stat. § 19a-639(a)(2)).

32. The Applicant has established that there is a clear public need for its proposal. (Conn. Gen. Stat. § 19a-639(a)(3)).

33. The Applicant has demonstrated that its proposal is financially feasible. (Conn. Gen. Stat. § 19a-639(a)(4)).

34. The Applicant has satisfactorily demonstrated that its proposal will improve quality and accessibility of health care delivery in the region and that Medicaid services would not be affected. (Conn. Gen. Stat. § 19a-639(a)(5)).

35. The Applicant has shown that there will be no change in access to the provision of health care services to the relevant populations and payer mix. (Conn. Gen. Stat. § 19a-639(a)(6)).

36. The Applicant has satisfactorily identified the population to be served and has satisfactorily demonstrated that this population has a need. (Conn. Gen. Stat. § 19a-639(a)(7)).

37. The utilization of existing health care facilities and health care services in the Applicant's service area supports this proposal. (Conn. Gen. Stat. § 19a-639(a)(8)).

38. The Applicant has satisfactorily demonstrated that this proposal would not result in an unnecessary duplication of existing services in the area. (Conn. Gen. Stat. § 19a-639(a)(9)).

39. The Applicant has satisfactorily demonstrated that the proposal will not result in a reduction or change in access to services for Medicaid recipients or indigent persons. (Conn. Gen. Stat. § 19a-639(a)(10)).

40. The Applicant has satisfactorily demonstrated that the proposal will have not negatively impact the diversity of services providers in the area. (Conn. Gen. Stat. § 19a-639(a)(11)).

41. The Applicant has satisfactorily demonstrated that the proposal will not result in any consolidation or adversely affect health care cost or accessibility to care. (Conn. Gen. Stat. § 19a-639(a)(12)).

Discussion

CON applications are decided on a case by case basis and do not lend themselves to general applicability due to the uniqueness of the facts in each case. In rendering its decision, OHCA considers the factors set forth in Conn. Gen. Stat. § 19a-639(a). The Applicant bears the burden of proof in this matter by a preponderance of the evidence. *Jones v. Connecticut Medical Examining Board, 309 Conn. 727 (2013).*

Hartford Hospital is an 867-bed hospital located at 80 Seymour Street, provides primary, secondary and tertiary acute care services and is a member of Hartford Healthcare. *FF1.* In December 2016, the Hospital will open, on the main campus, a newly constructed patient-centered Institute which will house an ambulatory surgery center and provide medical subspecialties in foot, ankle, hand, shoulder and upper extremity, sports medicine, spine, joint, urgent care, arthritis and pain management, embedded with orthopedics and neurological services. *FF3, FF5.* The Institute will integrate comprehensive and coordinated inpatient and outpatient diagnostic and treatment services with research and educational services in musculoskeletal disorders for better patient outcomes. *FF2, FF4.*

The Applicant is proposing the acquisition of a 64-slice 3D CT scanner and a 3.0T MRI scanner to be located and utilized at the Institute for inpatient and outpatient orthopedic care. *FF6.* Currently the Hospital operates four CT and three MRI scanners that are heavily scheduled, at or near capacity or dedicated to cancer treatment or neuropsychiatry research. *FF7.* Two existing scanners, with lower volumes, are utilized primarily for needed highly specialized procedures, such as biopsies, aspirations and anesthesia cases that require relatively longer time slots per patient. *FF8, FF9.* None of the CT and MRI scanners in the Hartford Healthcare system can be relocated to or repurposed for the Institute at present as each scanner is at or near capacity, is needed in its current location or serves a specific purpose or patient population. *FF10.*

At present, services for orthopedic patients are decentralized at the Hospital. *FF12.* As these patients often have moderate to severe mobility limitations, inpatients need transport and personnel assistance which, in addition to unscheduled add-on exam scan requests, cause substantial scheduling delays and disruptions in obtaining medically necessary imaging diagnostic scans for outpatients. *FF13.* These delays prevent timely scheduling of surgery, rapid assessment to detect and to care for potential emboli and complications for pre- and post-surgery orthopedic patients at high risk for thromboembolic complications. *FF16.* Currently, post-surgical patients needing rapid assessments are transferred to the main Hospital for angiography or CTA on the Hospital's primary, heavily scheduled inpatient scanners. *FF14.*

Locating the proposed scanners at the Institute will improve access to care as medically necessary imaging and coordinated comprehensive services will become more available and accessible to orthopedic patients who often have moderate to severe mobility limitations. *FF12, FF15.* Acute injury care and complex chronic condition management will be streamlined and expedited. *FF15.* The proposal will improve the quality of orthopedic care at the Hospital as the proposed CT scanner provides higher quality images than existing scanners for patients with metal implants or prostheses. *FF18.* The proposed scanner corrects for existing scanner image attenuation that makes evaluating patient skeletons, hardware integrity and healing, challenging.

FF17. The proposed MRI scanner will also reduce image degradation due to the presence of metal and provide important insight for the appropriate timing of surgical treatment and assessment of post-surgical patients. *FF19, FF20.* The Applicant has satisfactorily demonstrated that the quality of care for orthopedic patients in the proposal's service area will be improved.

The Hospital projects its total scan volumes will grow by nearly 10%, annually, between FY17 and FY19, based on historical volume. *FF21.* Demand for orthopedic care at the Hospital increased by 13% between FY13 and FY15 and is anticipated to continue to increase. Based on national estimates the Hospital projects demand for inpatient orthopedic care will increase by an average of 250% over the next fifteen years. *FF11.*

The proposal will not impact Medicaid patients' access to care. The Applicant anticipates treating the same payer mix following implementation of the proposal, with 24% (CT) and 21% (MRI) scans being for Medicaid insured from FY17 through FY19. *FF24, FF25.*

As a result of the proposal, the Applicant projects incremental gains of $4,156,015 to $4,616,340 from FY17 through FY19 and a capital expenditure of $454,314 for the CT scanner and $1,745,865 for the MRI scanner. *FF28, FF29.* Thus, the Applicant has demonstrated that its proposal is financially feasible.

The proposed scanners will allow timely comprehensive and coordinated diagnosis and treatment of orthopedic patients at the patient-centered Institute. The Applicant has demonstrated clear public need for this proposal as access to and quality of care will be improved. These benefits are consistent with the Statewide Health Care and Facilities Plan.

Order

Based upon the foregoing Findings of Fact and Discussion, the Certificate of Need application of Hartford Hospital for the acquisition of a CT scanner and an MRI scanner is hereby **APPROVED**.

All of the foregoing constitutes the final order of the Office of Health Care Access in this matter.

By Order of the
Department of Public Health
Office of Health Care Access

7/22/2016
Date

Yvonne Addo
Yvonne T. Addo, MBA
Deputy Commissioner