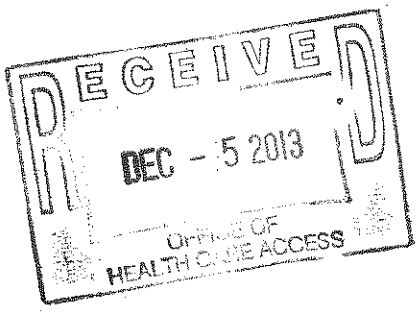
SHIPMAN & GOODWIN LLP®

COUNSELORS AT LAW

Joan W. Feldman
Phone: (860) 251-5104
Fax: (860) 251-5211
jfeldman@goodwin.com



December 5, 2013

Kimberly Martone
Director of Operations
Department of Public Health
Office of Health Care Access
410 Capitol Avenue, MS#13HCA
P.O. Box 340308
Hartford, CT 06134-0308

RE: Purchase of a SPECT/CT Camera System

Dear Ms. Martone:

On behalf of Hartford Hospital, enclosed please find a Certificate of Need Application for the purchase of a SPECT/CT Camera System. As requested, I have included 1 original and 4 hard copies of the Certificate of Need Application in 3-ring binders along with a CD with the electronic version of the enclosed documents and materials. Also attached to this letter is a check in the amount of $500.00 for the filing fee.

Please do not hesitate to contact me at 860-251-5104 if you have any questions.

Sincerely,

Joan W. Feldman

JWF/kad
Enclosures

Application Checklist

Instructions:

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

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

For OHCA Use Only:

Docket No.: 13878 **Check No.:** 456274
OHCA Verified by: KR **Date:** 12·6·13

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

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

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

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

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

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

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

AFFIDAVIT

Applicant: **Hartford Hospital**

Project Title: **Acquisition of a SPECT/CT Nuclear Camera System**

I, **Stuart Markowicz, Chief Executive Officer**
(Individual's Name) (Position Title – CEO or CFO)

of **Hartford Hospital** being duly sworn, depose and state that
(Hospital or Facility Name)

Hartford Hospital's information submitted in this Certificate of
(Hospital or Facility Name)

Need Application is accurate and correct to the best of my knowledge.

Signature

12-2-13
Date

Subscribed and sworn to before me on 12-2-13

Florence N. Leishman

Notary Public/Commissioner of Superior Court

My commission expires: 5-31-18

Florence N. Leishman
Notary Public
State of Connecticut
My Commission Expires May 31, 2018

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

51-57
119

Check Number
486274
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
OFFICE OF HEALTHCARE ACCESS
410 CAPITAL AVE #MS13HCA
PO BOX 340308
HARTFORD, CT 06134-0308

Date	Payment Amount
12/03/2013	*******$500.00

VOID AFTER 90 DAYS

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

⑈486274⑈ ⑆011900571⑆ 00014 60536⑈

TREASURER STATE OF CONNECTICUT
OFFICE OF HEALTHCARE ACCESS
410 CAPITAL AVE #MS13HCA
PO BOX 340308
HARTFORD, CT 06134-0308

Entity	Vendor ID / Location	Check Number
PNK	08112 008	486274

HARTFORD HOSPITAL

Invoice Number	Invoice Date	Gross Amount	Discount Amount	Withholding Amount	Net Amount
CONAPPLSPECTFILING	11/26/2013	500.00			500.00
BARBARA DURDY CCH PLANNING- 860-972-4231					
TOTALS		$500.00	0.00	0.00	$500.00

0003 (12/05/13)

HH571485 1/03

The Hartford Courant.
A TRIBUNE PUBLISHING COMPANY

Affidavit of Publication

State of Connecticut

Friday, September 20, 2013

County of Hartford

I, Susan Carta, 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 dates as follows:	9/10/2013	$52.06
	9/11/2013	$47.06
	9/12/2013	$47.06

In the amount of $146.18
MINTZ & HOKE 012139
254626
ZONE 6

Susan Carta
Sales Assistant
Susan Carta

Subscribed and sworn to before me on September 20, 2013

Renee N Janes
Notary Public

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

2557993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• Sell us your STERLING SILVER TABLEWARE regardless of condition.
• Sell us your GOLD & SILVER COINS.
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• We'll pay you on the spot.
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965 Silas Deane Hwy • Wethersfield • 860-529-1187

PUBLIC NOTICES

LEGAL NOTICE
TOWN OF WEST HARTFORD

The West Hartford Town Council will hold a public hearing on September 24, 2013 at 6:45 p.m. in the Legislative Chamber, Room 314, Town Hall, 50 South Main Street, West Hartford, Connecticut, on the Application on behalf of Webster Bank N.A. ("Webster Bank"), Lessee of 774 North Main Street, one of several properties owned by SEA Crossroads West Hartford, LLC, at 714-772 and 774 North Main Street, which together comprise Special Development District #4 known as Crossroads Plaza at Bishop's Corner ("Premises") to amend SDD #4 to renovate the existing Webster Bank's facade, including new signage and the addition of a new canopy to be installed over expanded drive-through; expansion of the existing drive-through facilities to provide for a vehicle bypass lane, a drive-up ATM and a drive-up remote teller pneumatic tube; and provision of pedestrian, bicycle, parking and landscaping amenities.

A complete copy of the application is on file open to public inspection in the Office of the Town Clerk/Council Clerk, Room 312, Town Hall, 50 South Main Street, West Hartford, Connecticut. All interested persons are invited to attend to be heard.

Essie S. Labrot,
Town Clerk/Council Clerk

Any individual with a disability who needs special assistance to participate in the public hearing should contact the Human and Leisure Services Department, Susan Hofeatt, at 860 561-7578, five days prior to the hearing.

LEGAL ADVERTISEMENT

ADVERTISEMENT FOR BIDS

The Town of Bloomfield (HA) is seeking sealed bids for:

Heating Upgrades for 50 Joyce Street, 20 Woodland Drive, 15 Daniel Blvd, 17 Daniel Blvd, 69 Daniel Blvd, 26 Pine Grove Road, 13 Patton Road, and 162 School Street Bloomfield, CT.

Bids will be received and publicly opened and read aloud at the Town of Bloomfield, 800 Bloomfield Avenue, Bloomfield, CT 06002-0337. Bids are due by 2:00 p.m. on Tuesday, October 1, 2013.

The work of the contract includes, but is not limited to, residential heating upgrades at 50 Joyce Street, 20 Woodland Drive, 15 Daniel Blvd, 17 Daniel Blvd, 69 Daniel Blvd, 26 Pine Grove Road, 13 Patton Road, and 162 School Street Bloomfield, CT.

Site review by all bidders will be on Tuesday, September 17, 2013 at 2:00 p.m. at 50 Joyce Street, 2:30 p.m. at 20 Woodland Drive, 3:00 p.m. at 15 Daniel Blvd., 3:30 p.m. at 17 Daniel, 4:00 p.m. at 69 Daniel Blvd, 4:30 p.m. at 26 Pine Grove Road, 5:00 p.m. at 13 Patton Road, and 5:30 p.m. at 162 School Street Bloomfield, CT 06002.

Contract Documents, Plans and Specifications will be available at the Town of Bloomfield, in the office of Planning and Zoning, Town Hall, Tuesday, September 10, 2013 with $25.00 non-refundable deposit. Additional sets at $25.00 each nonrefundable.

Bids must include a 5% Bid Security. Successful bidder must furnish a 100% Performance/Payment Bond.

Bidders will note requirements of nondiscrimination/equal opportunity rules (Executive Order 11246) and related provisions in the General Conditions.

Contractors are expected to make a good faith effort in complying with Section 3 requirements for hiring and local contracting. All contractors must be licensed in the State of CT and also must be trained in Healthy Homes requirements.

No bid shall be withdrawn for ninety (90) days. Complete bidding requirements are noted in the Contract Documents.

Philip K. Schenck, Jr.
Town Manager

LEGAL NOTICE
TOWN OF WEST HARTFORD
ZONING BOARD OF APPEALS
PUBLIC HEARING, WEDNESDAY, SEPTEMBER 18, 2013, 7:00 P.M.
LEGISLATIVE CHAMBER,
ROOM 314, TOWN HALL
50 SOUTH MAIN STREET,
WEST HARTFORD, CT 06107

The Zoning Board of Appeals will hold a public hearing in the Legislative Chamber, Room 314, 50 South Main Street, West Hartford, on Wednesday, September 18, 2013 at 7:00 p.m., to hear and act on the following petitions:

New Business:

#26-13 1424-1426 Boulevard - Petition of C. Roberts, Applicant, (D. Canales, R.O.) requesting a Special Exception for a customary home occupation in order to operate a one-on-one yoga instruction practice as an accessory use to the residence per Section 177-49 of the Zoning Ordinances for a period of one (1) year per plans on file.
RM-3R Zone

#27-13 80 Knollwood Road - Petition of M. Jarvis requesting a variance in Section 177-20, Obstructions in yards. Requesting an 8 inch variance to the 10 foot side yard setback requirement for the construction of a two-story addition, per plans on file.
R-10 Zone

#28-13 8 Walker Lane - Petition of S. Lesser requesting a variance to Section 177-32(E)(13), Parking. Requesting a variance to the requirement that a lot be 150 feet wide at the building line for circular driveways in order to construct this type of driveway on a lot with +/- 66 feet of frontage, per plans on file.
R-20 Zone

Regular meeting of the Zoning Board of Appeals following the presentation of petition:
1. Discussion and vote on each petition
2. Approval of minutes
a-Minutes of the regular meeting held Wednesday, July 17, 2013.
3. Adjournment

ALL INTERESTED PERSONS ARE INVITED TO ATTEND THE PUBLIC HEARING.

Any individual with a disability who needs special assistance to participate in the meeting should contact Human & Leisure Services Department, 860-561-7578, five days prior to the meeting.

Dated at West Hartford, CT,
this 3rd day of September 2013.
Donald Neville, Chairperson
of the Zoning Board of Appeals
Brian Pudlik, Secretary to the Board

NOTICE TO CREDITORS

ESTATE OF Birute S. Bernotas, late of West Hartford (13-0490)

The Hon. Sydney W. Elkin, Judge of the Court of Probate, West Hartford Probate District, by decree dated September 9, 2013, ordered that all claims must be presented to the fiduciary at the address below. Failure to promptly present any such claim may result in the loss of rights to recover on such claim.

James Felice, Clerk

The fiduciary is:
Leonas Bernotas, 11 Sunset Drive, Sharon, MA 02067

NOTICE TO CREDITORS

ESTATE OF Mary L. DeMorais, late of West Hartford, AKA Maria L. DeMorais (13-0528)

The Hon. Walter A. Cichowicz, acting Judge of the Court of Probate, West Hartford Probate District, by decree dated September 5, 2013, ordered that all claims must be presented to the fiduciary at the address below. Failure to promptly present any such claim may result in the loss of rights to recover on such claim.

James Felice, Clerk

The fiduciary is:
Richard L. DeMorais
c/o Alan S. Parker, Esq. Pullman & Comley, LLC 90 State House Square, Hartford, CT 06103

LEGAL AD
WINDSOR ZONING BOARD OF APPEALS

The Town of Windsor Zoning Board of Appeals will hold their regularly scheduled meeting on Sept. 18, 2013 at 7:00 p.m., Council Chambers, 275 Broad Street, to hear the following variance requests:

13-14 1005 Kennedy Rd. Sec 3.7.5B(1)(a)(ii) Sign area Variance

13-15 133 Mountain Rd. Sec 4.4.1A(3) Maximum accessory structure coverage

13-16 152 Broad St. Various variances to Sec. 3.1; 3.2; 3.4; 14.1; & 5.2 for business site redevelopment.

Max Kuziak, Secretary

NOTICE TO CREDITORS

ESTATE OF Wayne A. Owen, late of West Hartford (13-0505)

The Hon. Sydney W. Elkin, Judge of the Court of Probate, West Hartford Probate District, by decree dated September 9, 2013, ordered that all claims must be presented to the fiduciary at the address below. Failure to promptly present any such claim may result in the loss of rights to recover on such claim.

James Felice, Clerk

The fiduciary is:
Nancy A. Elswith
c/o Kenneth J. Carta, Esq., Cams, Williams & Richardson, 130 West Main Street, PO Box 1507, New Britain, CT 06050-1597

LEGAL NOTICE
TOWN OF ROCKY HILL
ZONING BOARD OF APPEALS

The Rocky Hill Zoning Board of Appeals will conduct a public hearing on Tuesday, September 17, 2013 beginning at 7:00 p.m. in the Council Room, Second Floor of the Town Hall, 761 Old Main Street, Rocky Hill, CT 06067 to consider the following:

1. Appeal 2013 - 10, RCCC 2000 LLC, application requesting a Certificate of Approval of Location for automotive dealers and repairers license as provided in Connecticut General Statutes Section 14-54 and Rocky Hill Zoning Regulations Section 8.7.5, for property located at 2000 Silas Deane Highway in a C-Commercial Zoning District, ID#84-401;

2. Appeal 2013 – 11, Raymond J. Hamos (Trustee) and Gisael Kamil (Trustee), application requesting variances of the Rocky Hill Zoning Regulations, Sections 3.5.1 to allow for a 3.6 foot variance of the 40 foot front yard setback and a 5.0 foot reduction in one of the 15 foot side yard setbacks to construct a 12 foot by 37.3 foot addition to a home located at 201 Pheasant Drive in a R-20 Residential Zoning District, ID# 09-276.

At this hearing, all interested persons may be heard and written communications will be received, texts and/or maps of these applications are on file in the Planning Office, Town Hall, Rocky Hill, Connecticut.

Dated at Rocky Hill, CT this 5th and 12th day of September 2013

Zoning Board of Appeals
James Reilly, Chairman
Phil Dennis, Secretary

NOTICE TO CREDITORS

ESTATE OF James A. Hatfield, Sr., Late of Newington, CT, deceased, AKA James A. Hatfield (13-0565)

The Hon. Robert A. Randich, Judge of the Court of Probate, Newington Probate District, by decree dated September 9, 2013, ordered that all claims must be presented to the fiduciary at the address below. Failure to promptly present any such claim may result in the loss of rights to recover on such claim.

Pamela B. Friedeberg, Clerk

The fiduciary is:

James A. Hatfield, Jr., P.O. Box 9575, Bolton, CT 06043

LEGAL NOTICE
TOWN OF BLOOMFIELD
ZONING BOARD OF APPEALS

Notice is hereby given that the Zoning Board of Appeals, at a meeting held on September 9, 2013, rendered the following decisions:

1. Request by Bank of America for a Use Variance for a drive-through kiosk located at 1061 Blue Hills Avenue, GWB zone: Denied due to lack of hardship.

2. Approved minutes of July 1, 2013.

Dated at Bloomfield, Connecticut this 10nd day of September, 2013.

ZONING BOARD OF APPEALS

Jacqueline Isaacson, Chairperson

Fannie Pittman, Secretary

NOTICE TO CREDITORS

ESTATE OF Majorie Wilder, late of West Hartford (13-0633)

The Hon. Sydney W. Elkin, Judge of the Court of Probate, West Hartford Probate District, by decree dated September 9, 2013, ordered that all claims must be presented to the fiduciary at the address below. Failure to promptly present any such claim may result in the loss of rights to recover on such claim.

James Felice, Clerk

The fiduciary is:
Michael S. Wilder,
c/o Frederick J. Mullen, Jr., Esquire, Reid & Riege, 1 Financial Plaza, 21st Flr., Hartford, CT 06103

LEGAL NOTICE
TOWN OF WEST HARTFORD

The West Hartford Town Council will hold a public hearing on September 24, 2013 at 6:30 p.m. in the Legislative Chamber, Room 314, Town Hall, 50 South Main Street, West Hartford, Connecticut, on the Ordinance revising various definitions for zoning purposes.

A complete copy of the ordinance is on file open to public inspection in the Office of the Town Clerk/Council Clerk, Room 312, Town Hall, 50 South Main Street, West Hartford, Connecticut. All interested persons are invited to attend to be heard.

Essie S. Labrot,
Town Clerk/Council Clerk

Any individual with a disability who needs special assistance to participate in the public hearing should contact the Human and Leisure Services Department, Susan Hofeatt, at 860 561-7578, five days prior to the hearing.

LEGAL NOTICE
TOWN OF ROCKY HILL
PLANNING AND ZONING COMMISSION

The Rocky Hill Planning and Zoning Commission will conduct a public hearing on Wednesday, September 18, 2013 beginning immediately following the closure and/or recess of another hearing which is to commence at 6:30 p.m. in the Town Council Room, second floor of the Town Hall, 761 Old Main Street, Rocky Hill, CT 06067 for the purpose of the following:

1. Special Permit/Site Plan Application, Elm Street Ext. Rocky Hill, LLC, proposing a three-story medical office building of approximately 28,500 square feet and associated site improvements for property located on Elm Street Extension in the immediate west of Hillview Plaza in a C-Commercial Zoning District, ID#12-157;

At this hearing all interested persons may be heard and written communications will be received. Texts and/or maps of these applications are on file in the Planning Department, Town Hall, and/or the Town Clerk Office, Rocky Hill, Connecticut.

Dated in Rocky Hill, CT this 5th and 12th day of September, 2013.

Planning and Zoning Commission
Alan Mordhorst, Chairman
Ronald Angelo, Sr., Secretary

Statutory Reference:	Connecticut General Statutes §19a-638
Applicant:	Hartford Hospital
Project Address:	Located on the Hartford Hospital campus 80 Seymour Street Hartford, CT 06102
Proposal:	The Applicant intends to file a Certificate of Need application with the State of Connecticut Office of Health Care Access for purchase of a SPECT/CT camera system.
Capital Expenditure:	$650,000

WEST HARTFORD PLAN AND ZONING COMMISSION
PUBLIC NOTICE

The West Hartford Town Plan and Zoning Commission also acting as the Inland Wetlands and Watercourses Agency, at the Regular Meeting on Monday, September 9, 2013 took the following actions:

INLAND WETLAND APPLICATION FOUND TO BE NON-SIGNIFICANT AND PERMIT GRANTED:

61 Glenwood Road – Application (IWW #983) of VH, LLC (Brandon Handfield, Engineer) requesting approval of an Inland Wetlands and Watercourses Permit to conduct certain regulated activities which may have an adverse impact on a wetland and watercourse area. The applicant is proposing the construction of a new residential home and attached garage with a footprint of approximately 2,243 s.f. and to perform associated site grading. (Submitted for IWWA receipt on September 9, 2013. Determined to be non-significant and permit granted on September 9, 2013.)

INLAND WETLAND PERMITS APPROVED WITH CONDITIONS:

59 Old Oak Road – Application (IWW #978) of Telluride, LLC (James Cassidy, P.E.) requesting approval of an Inland Wetlands and Watercourses Permit to conduct certain regulated activities which may have an adverse impact on a wetland and watercourse area (Mountain Farms Brook). The applicant is proposing to remove an existing 428 sf sunroom and construct a 623 sf two story addition with related site grading in the 150' regulated area. (Submitted for IWWA receipt on August 5, 2013. Determined to be significant and set for public hearing on September 9, 2013. Inland Wetland Permit granted with conditions on September 9, 2013.)

61 Waterside Lane – Application (IWW #980) of Robert & Deborah Katz (Jack Kemper, Architect) requesting approval of an Inland Wetlands and Watercourses Permit to conduct certain regulated activities which may have an adverse impact on a wetland and watercourse area. The applicant is proposing to remove the existing 1,600 sf home and construct an approximately 4,300 sf single family home in the 150' regulated area. (Submitted for IWWA receipt on August 5, 2013. Determined to be significant and set for public hearing on September 9, 2013. Inland Wetland Permit granted with conditions on September 9, 2013.)

INLAND WETLAND PERMIT APPLICATION FOUND TO BE POTENTIALLY SIGNIFICANT AND SET FOR PUBLIC HEARING ON OCTOBER 7, 2013:

East of East Maxwell Drive and Rear of 137 North Main Street (aka 139 North Main Street) – Application (IWW #982) of Sard Custom Homes, LLC (Wilson Alford, Jr., Engineer) requesting approval of an Inland Wetlands and Watercourses Permit to conduct certain regulated activities which may have an adverse impact on a wetland and watercourse area (Trout Brook). The applicant is proposing a twelve (12) lot subdivision on a 9.32 acre parcel of land and associated site improvements. (Submitted for IWWA receipt on September 9, 2013. Determined to be potentially significant and set for public hearing on October 7, 2013.)

SPECIAL USE PERMIT APPROVED WITH CONDITIONS:

950 Trout Brook Drive – Application (SUP #1236) of the Children's Museum (Robert Graesner, President) seeking a Special Use Permit pursuant to Section 177-42A of the Code of West Hartford to construct a temporary structure (hoop house) to accommodate special exhibits at the museum. The applicant is requesting this temporary structure be allowed for up to four (4) years. (Submitted for TPZ receipt on July 1, 2013. Required public hearing scheduled for August 5, 2013. Public hearing opened on August 5, 2013 and continued to September 9, 2013. Special Use Permit granted on September 9, 2013 with conditions.)

The final approved plans and the applications related to the above items are available for public review in the Town Planning Office, Town Hall, Room 214, 50 South Main Street, West Hartford, CT. The effective date of these actions is September 27, 2013.

Kevin Ahern, Chairman TPZ/IWWA
Todd Dumais, TPZ/IWW Administrative Officer

Statutory Reference:	Connecticut General Statutes §19a-638
Applicant:	Hartford Hospital
Project Address:	Located on the Hartford Hospital campus 80 Seymour Street Hartford, CT 06102
Proposal:	The Applicant intends to file a Certificate of Need application with the State of Connecticut Office of Health Care Access for purchase of a SPECT/ CT camera system.
Capital Expenditure:	$850,000

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

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

Docket Number:	
Applicant:	Hartford Hospital
Contact Person:	Barbara A. Durdy
Contact Person's Title:	Director, Strategic Planning, Hartford HealthCare
Contact Person's Address:	181 Patricia M. Genova Drive, Newington, Connecticut 06111
Contact Person's Phone Number:	860-972-4231
Contact Person's Fax Number:	860-972-4650
Contact Person's Email Address:	barbara.durdy@hhchealth.org
Project Town:	Hartford, Connecticut
Project Name:	Purchase of a SPECT/CT Camera System
Statute Reference:	Section 19a-638, C.G.S.
Estimated Total Capital Expenditure:	$850,000

1. Project Description: Acquisition of Equipment

a. Please provide a narrative detailing the proposal.

End of Useful Life: The purpose of this Certificate of Need Application (this "Application" or "Proposal") is for Hartford Hospital (the "Applicant") to obtain approval from the State of Connecticut Office of Health Care Access ("OHCA") for a new SPECT/CT camera to replace one of the Applicant's two existing SPECT cameras. The Applicant proposes to replace its Phillips Cardio 60 SPECT Camera, which was purchased by the Applicant in 2002 and is at the end of its useful life (the "Phillips 60 Camera") with a Siemens Symbia T SPECT/CT Camera (the "Proposed Siemens Camera"). The Proposed Siemens Camera, with IQ SPECT technology, represents a substantial improvement in imaging technology. The IQ SPECT technology consists of a new collimator, cardio-centric image acquisition, and new iterative reconstruction software allowing for more rapid image acquisition. See Exhibit 1 attached hereto.

Higher Quality Imaging: More specifically, the IQ SPECT technology coupled with the CT attenuation correction will allow the Proposed Siemens Camera to provide higher quality myocardial perfusion imaging studies than that which is currently possible with the older Phillips 60 Camera.[1] The CT component of the Proposed Siemens Camera provides attenuation correction for the myocardial perfusion imaging studies which improves the diagnostic accuracy of the studies. Nuclear Cardiology imaging has certain inherent limitations due to the variation in the density of tissues within the body. For example, when imaging the heart, overlying breast or adipose tissue can create shadows or attenuation artifacts which confound the ability to interpret the studies and diagnose heart disease. To mitigate these attenuation artifacts, the CT component of the Proposed Siemens Camera will remove these artifacts. This will result in a higher quality myocardial perfusion imaging study which decreases false positive results and eliminates unnecessary follow-up testing. While the current Phillips 60 Camera also has some attenuation correction capabilities (in the form of a Gd-153 scanning line source), this older form of attenuation correction is no longer commercially available with large field of view cameras such as the Proposed Siemens Camera.

Larger Field of View: The Applicant needs a larger field of view camera to accommodate its larger sized patients. With the increasing obesity epidemic in the United States, obese patients are difficult to image on smaller footprint cameras. The Phillips 60 Camera has a small footprint, whereas, the Proposed Siemens Camera is a large field of view camera able to accommodate obese and non-ambulatory patients which the smaller footprint cameras cannot. Moreover, the table of the large field of view cameras can accommodate heavier and more debilitated patients who require adaptive and other medical equipment.

If the Proposal is approved, the current volume of myocardial perfusion imaging studies previously performed on the Phillips 60 Camera will be performed on the Proposed Siemens

[1] During a myocardial perfusion imaging study, a small amount of radioactive tracer is injected into a patient and the SPECT camera is used to collect the photons emitted from the patient's heart to produce a noninvasive image of the blood flow to the heart. Approximately 8 million SPECT myocardial perfusion imaging studies are performed annually in the United States to evaluate chest pain symptoms, diagnose coronary artery disease, and assess the extent and severity of known heart disease.

Camera. The Proposed Siemens Camera will be located in the Nuclear Cardiology Laboratory suite on the second floor of the South Building of Hartford Hospital along with the Applicant's Phillips Cardio MD SPECT Camera (the "Phillips MD Camera"). The Applicant's Phillips MD Camera will remain in use for stress tests with myocardial perfusion. The Applicant believes that the addition of the Proposed Siemens Camera is necessary in order to safely accommodate larger and more debilitated patients and to continue to provide nuclear cardiology services that meet the demands and expectations of physicians and patients seeking care at the Applicant's hospital facility.[2]

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

Please see Exhibit 2 attached hereto for a letter in support of the Proposed Siemens Camera from W. Lane Duvall, MD, FACC, Director of Nuclear Cardiology, Hartford Hospital.

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

The Proposed Siemens Camera is a Siemens Symbia T SPECT/CT camera with 2 slice CT component for attenuation correction.

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

Nuclear Cardiology at Hartford Hospital currently provides stress testing and myocardial perfusion imaging services.

Please see Table 1 below for a list of Hartford Hospital nuclear imaging locations.

2. Clear Public Need

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

There is a clear public need for the Proposed Siemens Camera for the following reasons:

- The Proposed Siemens Camera will provide superior image quality with shorter image acquisition times and thus, less radiation exposure to patients;
- The Applicant's existing Phillips 60 Camera is at the end of its useful life and must be replaced;
- The Proposed Siemens Camera will allow the Hospital to more effectively provide myocardial perfusion imaging studies for larger and more physically debilitated patients; and

[2] The non-diagnostic 2 slice CT component of the Proposed Siemens Camera cannot be used as a standalone CT scanner as it is not approved by the FDA for such use.

- The volume of myocardial perfusion imaging studies performed annually at the Applicant's hospital facility continues to require two SPECT cameras.

The Proposed Siemens Camera can perform myocardial perfusion imaging studies with more rapid image acquisition (i.e. less than 5 minutes compared to 20 minutes) as well as utilizing a lower dose of radioactive tracer than the Phillips 60 Camera, thereby reducing radiation exposure to the patient. Moreover, maintenance parts for the older generation of SPECT cameras such as the Phillips 60 Camera have become increasingly scarce and thus, difficult to locate for repairs and maintenance purposes. By way of example, GD-153 line source for attenuation corrections is no longer commercially available for large field of view SPECT cameras. In order for the Applicant to continue to provide high quality nuclear cardiology services, the Applicant is proposing to replace the Phillips 60 Camera with the Proposed Siemens Camera.

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

The Applicant does not have access to this information.

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

Table 1: Existing Equipment Operated by the Applicant

Provider Name Street Address Town, Zip Code	Description of Service *	Hours/Days of Operation **	Utilization *** (FY 2013)
Hartford Hospital Nuclear Cardiology Laboratory 80 Seymour Street	SPECT Camera Philips Cardio 60 SPECT Camera Philips Cardio MD	M-F: 7am -5pm Sat-Sun: 7am-3:30pm M-F 7am -5pm Sat-Sun 7am-3:30pm	2026 scans for the two cameras located at this location
Hartford Hospital 100 Simsbury Road Avon, CT	SPECT Camera Philips Cardio 60	M-F 7am-5pm	172 scans
Hartford Hospital Blue Back Square 65 Memorial Road, #405 West Hartford, CT 06107	SPECT Camera Philips Cardio MD	M-F 7am-5pm	145 scans
Hartford Hospital 703 Hebron Ave. Glastonbury, CT 06033	SPECT Camera Philips Cardio 60	M-F 7am-5pm	200 scans

Hartford Hospital 100 Retreat Ave Suite 811, Hartford, CT 06106.	**SPECT Camera Philips Cardio MD**	**M-F 7am-5pm**	**463 scans**
Hartford Hospital 21 South Rd Suite 100, Farmington, CT 06032.	**SPECT Camera Philips Cardio MD**	**M-F 7am-5pm**	**254 scans**

*** Include equipment strength (e.g. slices, tesla strength), whether the unit is open or closed (for MRI)**
**** Days of the week unit is operational, and start and end time for each day; and**
***** Number of scans/exams performed on each unit for the most recent 12-month period (identify period).**

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

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

The Proposed Siemens Camera will replace an existing Phillips 60 Camera located in the Nuclear Cardiology Laboratory at Hartford Hospital. The Proposed Siemens Camera will be installed in the same physical location as the old Phillips 60 Camera once modifications have been made to the physical space to accommodate the Proposed Siemens Camera. All of Applicant's stress testing and myocardial perfusion imaging is performed at this location.

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

The population to be served by the Proposed Siemens Camera is the same population currently being served by the existing Phillips 60 Camera. The population includes the Applicant's primary service area as well as patients referred from outside of primary and secondary service areas. In the past three calendar years, an average of 2,100 patients annually have undergone stress testing with myocardial perfusion imaging in the Nuclear Cardiology Laboratory at the Applicant's hospital facility using its two existing Phillips SPECT cameras. The volume of studies is expected to remain stable. However, with the aging of Connecticut's population[1] and the fact that there are proportionately more residents over the age of 65 in 2010 than in 2000, the Applicant expects the volumes of studies to increase rather than decrease as heart disease disproportionately affects the elderly. In addition, as reported in the Connecticut State Health Assessment, heart disease is a leading cause of death for Connecticut residents. Please see Exhibit 3 attached hereto for relevant excerpts from the Connecticut State Health Assessment; preliminary Findings, January 2013.

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

The patient population is currently being served in the Nuclear Cardiology Laboratory at Hartford Hospital, 80 Seymour Street, Hartford, CT 06102. The patient population will be the same with the Proposed Siemens Camera.

[1] See Connecticut State Health Assessment: Preliminary Findings, published by the Connecticut Department of Public Health, January 2013 at http://www.ct.gov/dph/lib/dph/state_health_planning/sha-ship/coalition_kickoff/ct_sha_prelim_rev020413.pdf.

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

The Applicant does not have access to this information.

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

There should be no significant impact on existing providers because the Proposed Siemens Camera is replacing one of the Applicant's existing Phillips SPECT cameras that has reached the end of its useful life and the Proposed Siemens Camera is expected to serve the same population being served now with the Phillips 60 Camera.

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

Not Applicable

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

The Proposed Siemens Camera will replace the Phillips 60 Camera, which is at the end of its useful life. Therefore, there will be no duplication of equipment. The Proposed Siemens Camera will perform the same diagnostic studies (myocardial perfusion imaging) as the old Phillips 60 Camera it is replacing. Once the Proposed Siemens Camera is installed and available for use, the Philips 60 Camera will be dismantled.

3. Actual and Projected Volume

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

Table 21a: Historical, Current, and Projected Volume, by Equipment Unit

	Actual Volume (Last 3 Completed FYs)			CFY Volume*	Projected Volume (First 3 Full Operational FYs)**		
	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016
Scanner***							
Phillips Cardio 60	706	1043	1116	See total below*****	N/A	N/A	N/A
Phillips Cardio MD	706	1043	1116	See total below*****	1050	1050	1050
Siemens Symbia T	N/A	N/A	N/A	N/A	1050	1050	1050
Total	**1412**	**2086**	**2232**	**2026**	**2100**	**2100**	**2100**

*** For periods greater than 6 months, report annualized volume, identifying the number of actual months covered and the method of annualizing. For periods less than six months, report actual volume and identify the period covered.**
**** If the first year of the proposal is only a partial year, provide the first partial year and then the first three full FYs. Add columns as necessary.**
***** Identify each scanner separately and add lines as necessary. Also break out inpatient/outpatient/ED volumes if applicable.**
****** Fill in years. In a footnote, identify the period covered by the Applicant's FY (e.g. July 1-June 30, calendar year, etc.).**

Please note that:
***** (1) Hartford Hospital does not keep track of the number of scans performed on each of the Phillips SPECT cameras in the Nuclear Cardiology Laboratory. The volumes presented in Table 2a above are estimated based on the number of total scans performed and assumes approximately equal utilization between both cameras;

(2) FY 2010 volumes were lower due to an intermittent shortage of the Tc-99m isotope during that time period. Patients at Hartford Hospital were imaged with Tc-99m when it was available. However, when not available patients were imaged with a PET scanner which uses a different isotope than Tc-99m, and is a more expensive diagnostic test. Also patients were imaged with Tl-201 which was not affected by the Tc-99m shortage; and

(3) The Applicant's Fiscal Year covers the period of October 1st - September 30th.

Table 2b: 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)**		
	FY 2010	**FY 2011**	**FY 2012**	**FY 2013**	**FY 2014**	**FY2015**	**FY 2016**
Myocardial SPECT stress /test	1026	1356	1482	1386	1400	1400	1400
Myocardial SPECT single study	386	730	750	640	700	700	700
Total	**1412**	**2086**	**2232**	**2026**	**2100**	**2100**	**2100**

*** 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.).**

Please note that:

(1) FY 2010 volumes were lower due to an isotope shortage during that time period; and

(2) The Applicant's Fiscal Year covers the period of October 1st - September 30th.

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

Please see Exhibit 4 for patient volume by town for the data provided in Table 2a.

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

Patients are referred to the Hartford Hospital Nuclear Cardiology Laboratory from various internal medicine and cardiology practices within the Applicant's primary and secondary service areas.

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

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

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

There will be no increases or decreases in volumes as a result of this Proposal.

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

Volumes were based on historical and current fiscal year volume. Since this Proposal is for equipment replacement, there will no incremental gain in volumes.

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

Please see Exhibit 5 for copies of the following articles in support of this Application:

1) "A method for improving the efficiency of myocardial perfusion imaging using conventional SPECT and SPECT/CT imaging systems" which describes the clinical efficiencies associated with the SPECT/CT imaging system including a reduction in patient scan times and the need for repeat studies due to false positive study results.
2) "Clinical Applications of SPECT/CT: New Hybrid Nuclear Medicine Imaging System" which provides a comprehensive review of this technology including the advantages of SPECT/CT over SPECT, clinical applications, scan protocols and technical specifications of the equipment.

4. Quality Measures

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

Key Personnel:

- W. Lane Duvall, MD, FACC

- Stuart K. Markowitz, MD, FACR
- April Mann, BA, CNMT, NCT, RT (N)
- Gerald J. Boisvert, CPA, FHFMA

Please see Exhibit 6 for copies of curriculum vitae for key administrative and clinical personnel related to this Proposal.

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

The Proposal contributes to the quality of health care delivery in the region by providing patients who are being evaluated for new or chronic coronary artery disease with advanced diagnostic accuracy, and improved capacity to determine risk stratification and patient prognosis.

5. Organizational and Financial Information

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

Hartford Hospital is a non-profit corporation.

b. Does the Applicant have non-profit status?

X Yes ☐ No

Please see Exhibit 7 for a copy of the IRS Determination letter for Hartford Hospital.

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

Please see Exhibit 8 attached hereto for a copy of the Hartford Hospital license issued by the Connecticut Department of Public Health. This Proposal does not involve any change to licensure.

d. Financial Statements

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

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

ii. If the Applicant is not a Connecticut hospital (other health care facilities): Audited financial statements for the most recently completed fiscal year. If audited financial statements do not exist, in lieu of audited financial statements,

provide other financial documentation (e.g. unaudited balance sheet, statement of operations, tax return, or other set of books.)

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

Table 3: Proposed Capital Expenditures/Costs

Medical Equipment Purchase	$481,500
Imaging Equipment Purchase	
Non-Medical Equipment Purchase	
Land/Building Purchase *	
Construction/Renovation **	$368,500
Other Non-Construction (Specify)	
Total Capital Expenditure (TCE)	**$850,000**
Medical Equipment Lease (Fair Market Value) ***	
Imaging Equipment Lease (Fair Market Value) ***	
Non-Medical Equipment Lease (Fair Market Value) ***	
Fair Market Value of Space ***	
Total Capital Cost (TCC)	**$850,000**
Total Project Cost (TCE + TCC)	**$850,000**
Capitalized Financing Costs (Informational Purpose Only)	
Total Capital Expenditure with Cap. Fin. Costs	$850,000

* 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.

The construction and renovations relating to this Proposal includes the build-out of a new 330 square foot scanner room with an adjacent and supporting Staff Control Room. Construction within the space will include a complete, floor slab to floor slab demolition. All new walls, doors & door frames, viewing window, etc. will be lead lined construction. The mechanical air ventilation system will be upgraded to meet requirements and increase the fresh air and cooling needs. A new upgraded 480 volt, 3 phase electrical feed is being provided to supply the increased load requirements of the new scanning equipment. Structural steel is being added below the floor slab to support the increased weight of the new equipment. All new room finishes including welded seam sheet vinyl flooring, wall coverings, and an acoustical tile ceiling system are part of the scope.

Please see Exhibit 9 for schematic drawings related to this project.

Please see Exhibit 10 attached hereto for a copy of the quote for the Siemens Symbia T SPECT/CT camera system.

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

The project will be funded from Applicant's operating capital.

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

The replacement of the Phillips 60 Camera system with the Proposed Siemens Camera will improve the accuracy and clarity of nuclear imaging at Hartford Hospital, decrease scan times and reduce the need for follow up testing to assess false positives or negatives. Overall, this Proposal will result in safer and more effective nuclear cardiology services.

6. Patient Population Mix: Current and Projected

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

Table 4: Patient Population Mix

	Current** FY 2012	Year 1 FY 2014	Year 2 FY 2015	Year 3 FY 2016
Medicare*	41%	41%	41%	41%
Medicaid*	12%	12%	12%	12%
CHAMPUS & TriCare	1%	1%	1%	1%
Total Government	**54%**	**54%**	**54%**	**54%**
Commercial Insurers*	45%	45%	45%	45%
Uninsured	1%	1%	1%	1%
Workers Compensation				
Total Non-Government	**46%**	**46%**	**46%**	**46%**
Total Payer Mix	**100%**	**100%**	**100%**	**100%**

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

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

The payer mix represented above in Table 4 is based on the patient population currently being served by the Applicant's nuclear imaging service.

7. Financial Attachments I & II

a. Provide a summary of revenue, expense, and volume statistics, without the CON project, incremental to the CON project, and with the CON project. Complete Financial Attachment I. (Note that the actual results for the fiscal year reported in the first column

must agree with the Applicant's audited financial statements.) The projections must include the first three full fiscal years of the project.

Please see Exhibit 11 for Financial Attachment I.

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

Please see Exhibit 12 for Financial Attachment II.

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

Please see Exhibits 11 and 12 for assumptions used in Financial Attachments I and II.

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

The rates used in the financial projections are based on the Applicant's actual rates for these procedures. There are no significant rate changes anticipated.

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

This Proposal is for equipment replacement. Please see Tables 2a and 2b for volume projections related to this project.

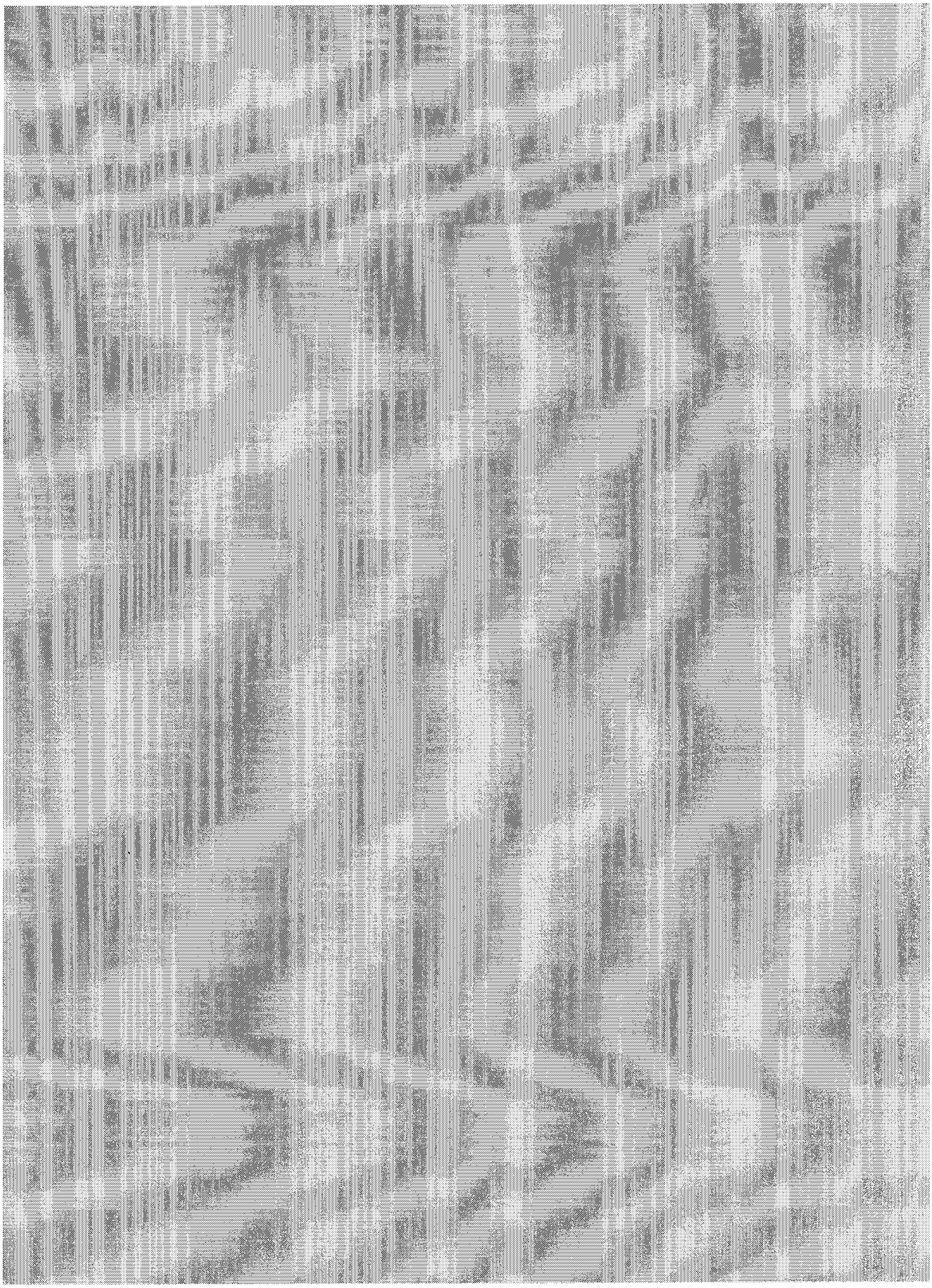
f. Explain any projected incremental losses from operations contained in the financial projections that result from the implementation and operation of the CON proposal.

The incremental losses are due to the depreciation associated with the purchase of the new equipment (i.e. the Proposed Siemens Camera).

g. Describe how this proposal is cost effective.

Replacement of outdated nuclear imaging equipment with more efficient and effective equipment results in greater quality in the study findings and reduction in the number of false positive tests that would require additional follow up and testing. Please see response to question 5g above.

EXHIBIT 1



IQ•SPECT Technology

Hans Vija, Ph.D., James Chapman, Ph.D., and Manjit Ray, Ph.D.

www.siemens.com/mi

SIEMENS

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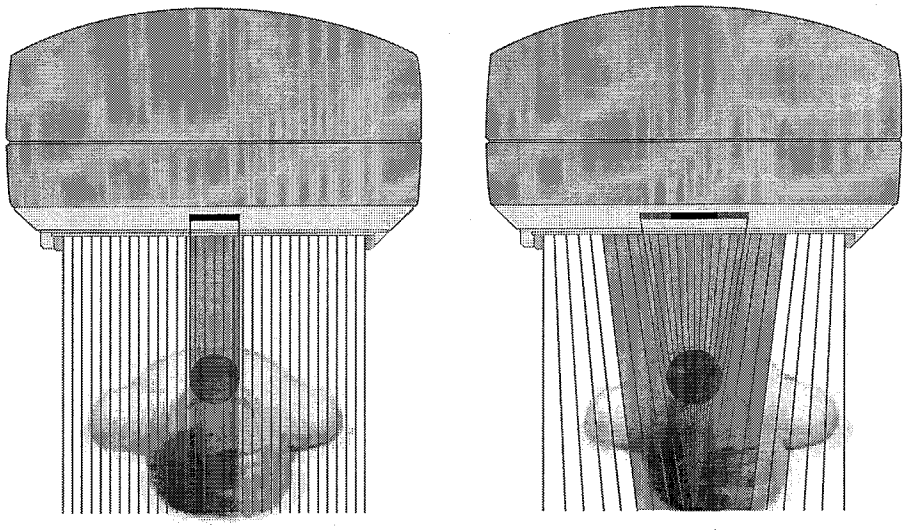


Figure 1. The varying geometry of the holes in the SMARTZOOM collimator provides magnification of the heart while avoiding truncation of the torso.

Introduction

IQ•SPECT is an intelligent solution to reduce the acquisition time for myocardial perfusion SPECT on Siemens Symbia S and Symbia T Series imaging systems. The technology can also be used to adapt acquisition times for improved image quality in clinically challenging imaging situations. When combined with a Symbia T2, T6 or T16, IQ•SPECT is able to reconfigure and provide a diagnostic CT in only 1 minute. The results of the attenuation corrected SPECT and the calcium score are visualized in a comprehensive display that represents the **5 minute cardiac workup.**

IQ•SPECT consists of three new components: the **SMART**ZOOM collimator, the cardio-centric acquisition, and the IQ•SPECT reconstruction.

SMARTZOOM Collimator

The collimator is designed so that the center of the field of view magnifies the heart, while the edges sample the entire body to avoid the truncation artifacts which are common to pinhole and focusing collimators. It is important to note that the **SMART**ZOOM collimator achieves a gain in counts without compromising image resolution as is the case with conventional, large bore, parallel hole collimators.

Cardio-Centric Acquisition

IQ•SPECT takes advantage of the flexible gantry motions that are available on the Symbia platform. The cardio-centric orbit allows the detectors to rotate around a virtual center of rotation that is positioned so that the heart is always in the most sensitive area of the collimator, a.k.a. the sweet spot. The characteristic elements of the cardio-centric orbit are the relative detector position, the radius of rotation, and the arc used to acquire the heart from all view angles.

IQ•SPECT Reconstruction

This proprietary 3D iterative reconstruction algorithm fully models the unique position of each of the 48,000 collimator holes. IQ•SPECT reconstruction also includes state-of-the-art distant-dependent isotropic (3D) resolution recovery, CT-based attenuation correction, and energy window-based scatter correction.

IQ•SPECT is seamlessly integrated with Symbia. The **SMART**ZOOM collimator can be included in the Integrated or Automated Collimator Changers. Automatic Quality Control will perform all common system calibrations and provides a full characterization of the complex collimator geometry necessary for accurate image reconstruction.

Extreme care has been given to ensure simple and intuitive user interaction. The entire patient setup adds just one additional step to identify the position of the heart on the touch screen patient positioning monitor, and image distortion, common to magnifying collimators is eliminated.

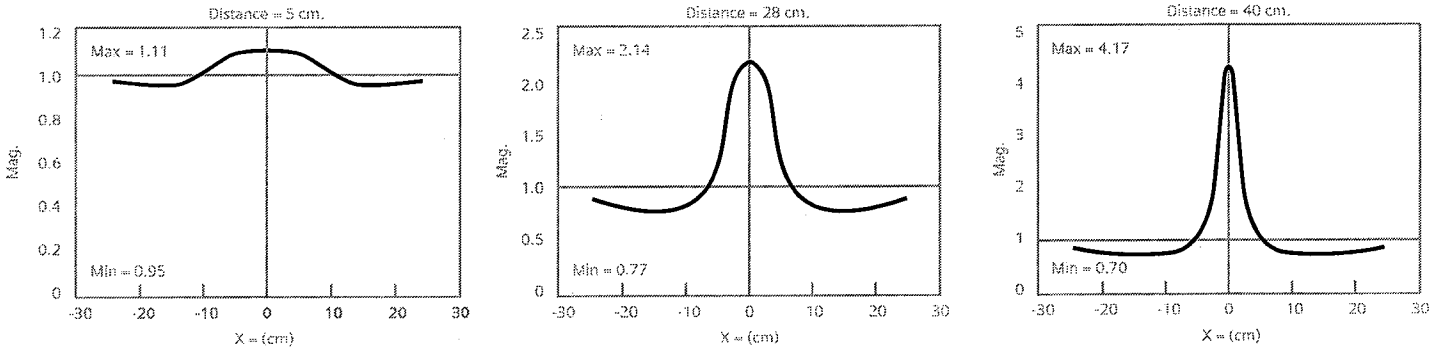
SMARTZOOM Collimation

The focus of the collimator varies continuously from cone-like in the central region to parallel at the edge (Figure 1). This provides magnification of the cardiac region while avoiding truncation of the surrounding tissue. The focal length as a function of distance u from the principal ray at the center of the collimator face is described by a polynomial, where F_S and F_I denote the short and long focal lengths. The focusing properties are orthogonally independent, i.e. the focusing in the transverse $u_\perp$ direction is independent of the focusing in the axial $u_\parallel$ direction. The transverse and axial focal length functions are symmetric fourth-order polynomials:

$$F(u_\perp) = F_{s_\perp} + (F_{I_\perp} - F_{s_\perp})\left(\frac{u_\perp}{u_{\perp,\max}}\right)^4 \quad |u_\perp| \le u_{\perp,\max}$$

$$F(u_\parallel) = F_{s_\parallel} + (F_{I_\parallel} - F_{s_\parallel})\left(\frac{u_\parallel}{u_{\parallel,\max}}\right)^4 \quad |u_\parallel| \le u_{\parallel,\max}$$

Figure 2: Magnifications at difference distances (D) to the collimator: D = 5 cm (left), 28 cm (middle), 40 cm (right).



Cardio-Centric Acquisition

Here, $u_{\perp,\max}$ and $u_{\parallel,\max}$ are the half widths of the collimator in the transverse and axial directions.

The magnification varies as a function of the distance to the collimator face and to the principal ray position (Figure 2). For objects which are close to the collimator face, the magnification effect is minimized, and little gain in counts are achieved. For objects which are near the collimator focal length, the magnification is maximal, however the "sweet spot" of the collimator is extremely narrow. This might be appropriate for imaging small stationary organs. For cardiac imaging the gain achieved must be maximized while insuring that the heart remains fully within the **SMART**ZOOM "sweet spot". This compromise is illustrated by the middle graph of Figure 2 although the exact values of the optimal configuration may vary somewhat from what is shown.

For optimal acquisition gain, the heart must remain in the **SMART**ZOOM "sweet spot" in all views. IQ•SPECT uses the flexibility of the Symbia gantry to achieve this focus throughout the acquisitions. During patient setup, the location of the heart is identified on the patient positioning monitor. IQ•SPECT then computes and executes an orbit which optimizes the gain and image quality for the specific patient. Unlike a conventional acquisition (or orbit) where the detectors maintain close proximity to the patient, the detectors in the cardio-centric orbit maintain a larger constant distance from the center of the heart to maintain its position in the collimator "sweet spot". The larger collimator distance also increases patient comfort and may reduce motion artifacts. The unique cardio-centric configuration exploits the flexibility of the Symbia gantry to position each detector at the optimal distance from the user identified heart over the expected variation of patient population. The angular separation of the detectors is slightly less than the traditional 90 degrees which improves angular sampling over the most information rich portion of the cardiac orbit (Figure 3). The cardio-centric acquisition will have a scan arc of 208 degrees (104 degrees per head) to compensate for the fan angle of the **SMART**ZOOM collimator and to ensure complete sampling. The angle between the detectors is set to 76 degrees.

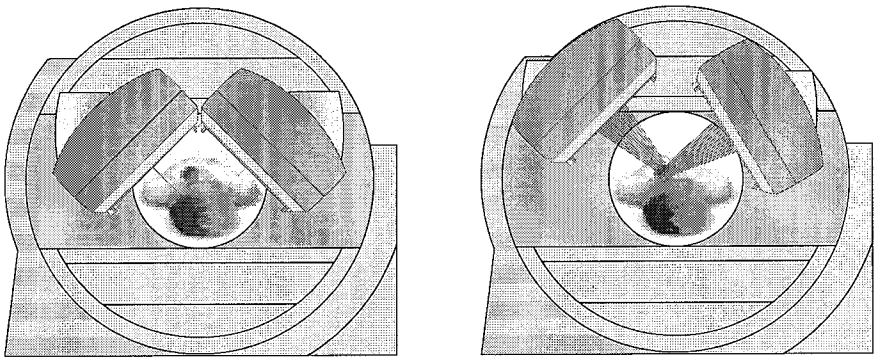


Figure 3. Orbit and detector configuration for conventional parallel hole collimator (left) and SMARTZOOM collimator with a cardio-centric orbit (right).

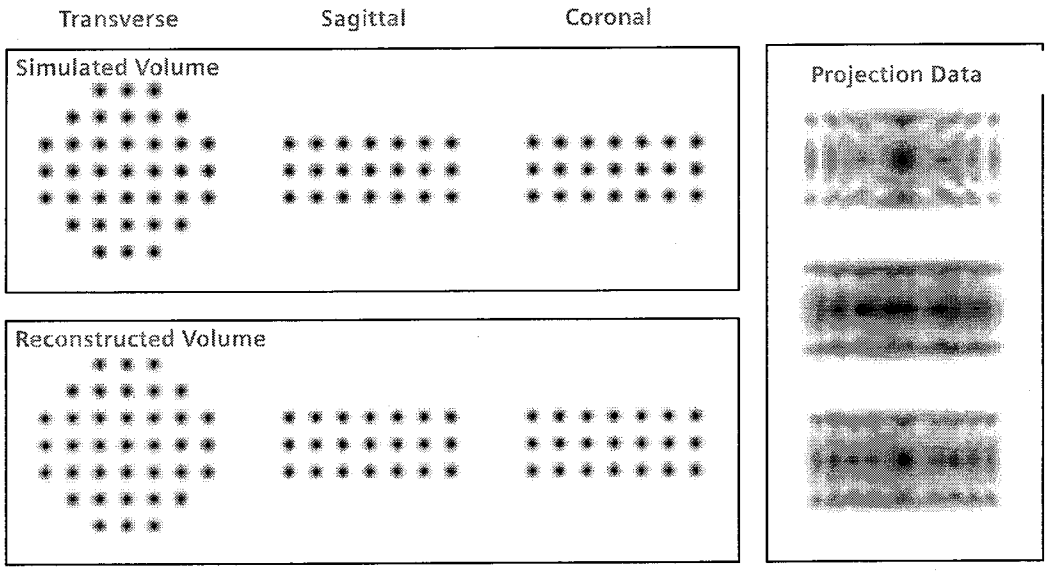


Figure 4. Transverse (left), sagittal (middle) and coronal (right) cross sections of a simulated volume of point sources (top row) and the volume reconstructed using IQ•SPECT reconstruction (bottom row). Three sample views of the distorted projection data (far right column) were generated using the forward projector of the SMARTZOOM collimator. The reconstructed volume is statistically consistent with original simulated volume.

Reconstruction

The IQ•SPECT reconstruction algorithm achieves the following objectives:

1. It correctly models the geometry of the **SMART**ZOOM collimator.
2. It realizes the improvement in noise due to better statistics in the cardiac region.
3. It corrects for the effects of patient attenuation, scatter and motion.
4. It performs reconstructions in a clinically acceptable time.

IQ•SPECT reconstruction is a proprietary implementation of an iterative OSEM-3D algorithm, incorporating depth dependent isotropic resolution recovery, attenuation correction, and scatter correction. The forward and back projection operations model the focusing geometry of the collimator by resampling the image-space volume to a collimator-space volume that is aligned along the collimator projection lines. The detector collimator response is modeled using depth-dependent Gaussian kernels that estimate the point spread function (PSF). Corrections for attenuation, scatter and patient motion are also performed using pre-calculated registered mu-maps derived from CT, scatter estimates and motion estimates.

To demonstrate the fidelity of the reconstruction, a 3D point grid of activity distribution was simulated, forward-projected using the **SMART**ZOOM collimator and reconstructed using IQ•SPECT. The reconstructed volume is statistically consistent with the original simulated volume. (Figure 4). To demonstrate concept feasibility and effective gain, the acquisition of a numerical torso phantom containing a heart, lung and spine model with only primary photons was simulated. The activity concentration ratio of heart: lung:background is 4:0:1 for the phantom in Figure 5, and a clinically relevant 8:0:1 for the phantom in Figure 6. Attenuation ratio between bone:soft tissue:lung was chosen as 1.85:1:0.25 with 0.161 1/cm for soft tissue at 140keV. The liver is not included. The count density of myocardial pixel is set for a maximum of 100/pixel per view at the nominal 16 minute scan, which is in the clinical range of a typical view in a summed stress scan. A numerical torso phantom was forward-projected and reconstructed using both a conventional LEHR collimator and an OSEM-3D reconstruction with attenuation compensation and IQ•SPECT (Figure 5). Comparison of both reconstructions with the attenuation map shows excellent recovery of the cardiac shape and dimension with significant reduction in the reconstructed noise of the IQ•SPECT phantom. This comparison suggests an effective gain of about 4x at equivalent image quality using IQ•SPECT (Figure 6).

A complete LEHR versus IQ•SPECT comparison of data shows equivalent image quality in 16 and 4 minutes respectively (Figure 7).

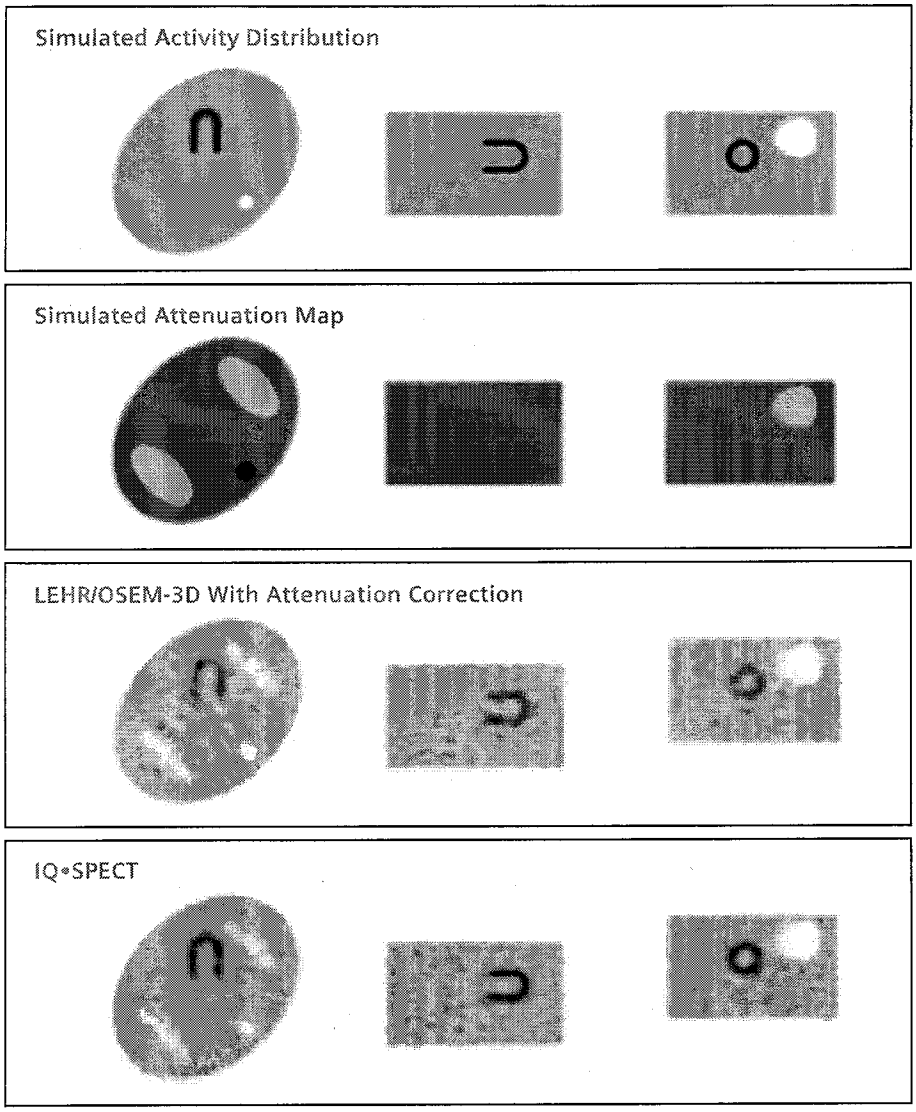


Figure 5: Numerical Torso Phantom. Acquisition Parameters: 128x128 matrix, circular orbit, 30 cm radius, 60 views, 180° scan arc (LEHR) and about 208° (SMARTZOOM) Reconstruction Parameters: 128^3 matrix, 15 subsets, 10 iterations, 7.2mm post smooth, attenuation correction. Rows 1 and 2 show simulated activity distribution and attenuation map data respectively. Row 3 shows a torso phantom reconstructed using forward and backward projectors of a conventional low-energy, high-resolution parallel hole collimator. Row 4 shows IQ•SPECT reconstruction of the same volume. Note that both reconstructions are free from distortion and accurately correct for attenuation. The IQ•SPECT reconstruction shows less noise in the cardiac region due to the increased efficiency of count collection in that region.

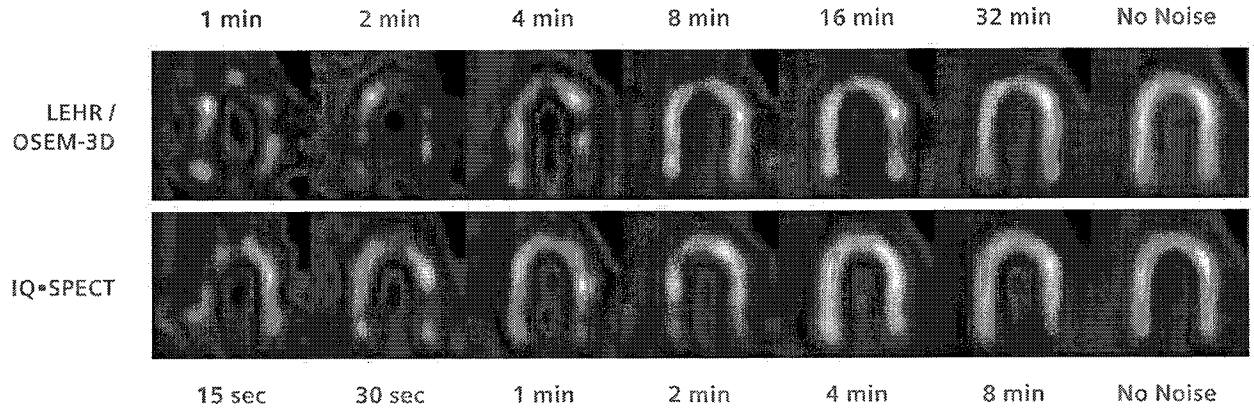


Figure 6: Comparison of LEHR and SMARTZOOM reconstructed image quality as a function of time, where the 8 minute scan represents the base line. Acquisitions simulated the Data Spectrum cardiac insert inside the large anthropomorphic torso phantom. Reconstruction Parameters: 128^3 matrix, 15 subsets, 10 iterations, 7.2mm post smooth, and attenuation.

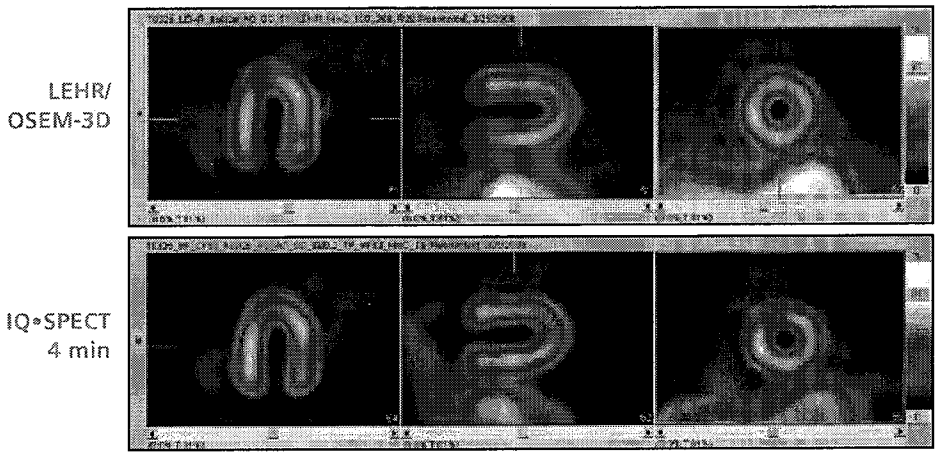


Figure 7: Comparison of LEHR and IQ•SPECT reconstructed image quality as a function of time. Acquisitions employed the Data Spectrum anthropomorphic torso phantom with clinically relevant loading of liver and background activities. Reconstruction Parameters: 128^3 matrix, 8 subsets, 8 iterations, 9.8 mm post smooth, and attenuation and scatter correction.

Conclusion

IQ•SPECT technology provides a significant gain in counts for the cardiac region while avoiding the effects of truncation. Initial measurements and simulations indicate the potential for a reduction of acquisition scan time from 16 minutes with LEHR and conventional reconstruction to an acquisition scan time of 2 to 4 minutes using IQ•SPECT with **SMART**ZOOM collimators (Figure 6 and Figure 7) and equivalent image quality. Seamless integration of reduced acquisition scan times combined with automated patient setup, data correction and reconstruction enables a total realized study time of 5 minutes for a SPECT•CT study.

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Everaert H, Vanhove C, Hamill JJ, Franken PR, "Cardiofocal collimators for gated single-photon emission tomographic myocardial perfusion imaging", EJNM, 25(1), 1998, p.3-7.

Note: Original images always lose a certain amount of detail when reproduced.

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Address of legal manufacturer
Siemens Medical Solutions USA
Molecular Imaging
2501 N. Barrington Road
Hoffman Estates, IL 60192-5203
USA

Headquarters
Siemens Medical Solutions USA, Inc.
51 Valley Stream Parkway
Malvern, PA 19355-1406
USA
Telephone: +1-888-826-9702
www.usa.siemens.com/mi

Contact Address
Siemens Medical Solutions USA
Molecular Imaging
2501 N. Barrington Road
Hoffman Estates, IL 60192-5203
USA
Telephone: +1-888-826-9702
www.siemens.com/mi

Siemens Medical Solutions USA
Molecular Imaging
810 Innovation Drive
Knoxville, TN 37932-2751
USA
Telephone: +1-888-826-9702
www.siemens.com/mi

EXHIBIT 2

Hartford Hospital
A Hartford HealthCare Partner

W. Lane Duvall, MD, FACC
Director of Nuclear Cardiology
Hartford Hospital
Division of Cardiology
Henry Low Heart Center

80 Seymour Street, SB2 • Hartford, CT 06102
Phone (860) 545-5518 • Fax (860) 545-5631
E-mail: lane.duvall@hhchealth.org

October 16, 2013

State of Connecticut
Office of Health Care Access

RE: Certificate of Need Letter of Support

To Whom it May Concern:

The Hartford Hospital Nuclear Cardiology Laboratory will be replacing one of its current SPECT cameras used for myocardial perfusion imaging and gated blood pool scans with a newer, updated camera. An outdated (2002) Philips Cardio 60 SPECT camera equipped with Gd-153 line sources used for attenuation correction which is approaching its effective end-of-life will be replaced with a Siemens Symbia-T Series SPECT/CT system. This new camera is replacing the no longer commercially available Gd-153 line sources with a 2-slice non-diagnostic CT unit to perform attenuation correction only. The CT component of this unit is not FDA approved for diagnostic CT and therefore, will only be used for the purpose of performing attenuation correction on nuclear cardiology patients referred for myocardial perfusion imaging. The volume of myocardial perfusion imaging studies performed annually at Hartford Hospital requires two SPECT cameras and the improved technology afforded by the new SPECT/CT camera is needed to meet the demands and expectations of physicians and patients seeking care at Hartford Hospital.

The current outdated Phillips Cardio 60 SPECT camera is being replaced as it has reached its useful end of life after having been in operation for over 10 years. The imaging technology employed by this camera has been greatly improved in the intervening years and maintenance parts for this older generation of SPECT camera are increasingly scarce. In order to continue to provide high quality nuclear cardiology services, Hartford Hospital has decided to replace the camera. The current volume of myocardial perfusion imaging studies performed on the outdated camera will now be performed on the new SPECT/CT camera.

The new Siemens Symbia T SPECT/CT camera with IQ SPECT technology represents an improvement in imaging technology compared to the camera that it will replace. The IQ SPECT technology consists of a new collimator, cardio-centric image acquisition, and new iterative reconstruction software and allows for more rapid image acquisition (less than 5 minutes compared to 20 minutes) as well as reduced radiation exposure to the patient (as much as a 75%

reduction). This IQ SPECT technology coupled with the CT attenuation correction will allow the new SPECT/CT camera to provide higher quality myocardial perfusion imaging studies than those possible on the older SPECT camera being replaced. This new technology will allow Hartford Hospital to provide even better quality nuclear cardiology services.

To continue to have attenuation correction with the myocardial perfusion imaging studies, a SPECT/CT camera was needed as the previous generation of attenuation correction using a Gd-153 line source are no longer commercially available for large field of view SPECT cameras. It is this CT aspect of the camera that is necessitating the certificate of need application. The non-diagnostic CT associated with the SPECT camera provides attenuation correction which can eliminate artifacts due to variation in tissue density when performing myocardial perfusion imaging studies allowing for more accurate interpretation of the imaging studies.

The Siemens Symbia T SPECT/CT camera and the Phillips Cardio 60 camera which it replaces are both large field of view cameras and are able accommodate obese and non-ambulatory patients who are becoming increasingly more prevalent. The table of the large field of view cameras can accommodate heavier patients and the gantry is larger to physically fit these large patients. In addition, these large field of view cameras can also accommodate the infirm and debilitated patients often encountered with hospitalized patients because of the greater ease of transferring patients onto their larger tables.

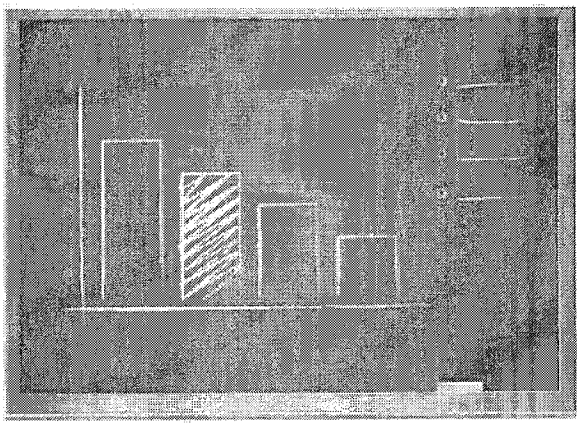
In summary, the replacement SPECT/CT camera will continue to serve our current patient needs but in a way that provides higher quality care. The new camera technology will provide improved image quality, better diagnostic accuracy, improved efficiency, and reduced radiation exposure to patients and staff.

Sincerely,

W. Lane Duvall, MD, FACC
Director of Nuclear Cardiology
Hartford Hospital

EXHIBIT 3

CONNECTICUT
State Health Assessment



Preliminary Findings

January 31, 2013

Connecticut Department of Public Health

DPH

Connecticut State Health Assessment: Preliminary Findings

Prepared for the Kick-off Meeting of the
Connecticut Health Improvement Planning Coalition

January 31, 2013

(Rev. 2/4/13)

Acknowledgement of Funding Source:

This report was supported by funds made available from the Centers for Disease Control and Prevention, Office for State, Tribal, Local, and Territorial Support, under Grant No. 5U58CD001324-03

CONTENTS

Connecticut State Health Assessment: *Preliminary Findings*

Lisa Wolff, ScD

Director, Research and Evaluation

Health Resources in Action, Inc.

CONNECTICUT HEALTH IMPROVEMENT PLANNING COALITION

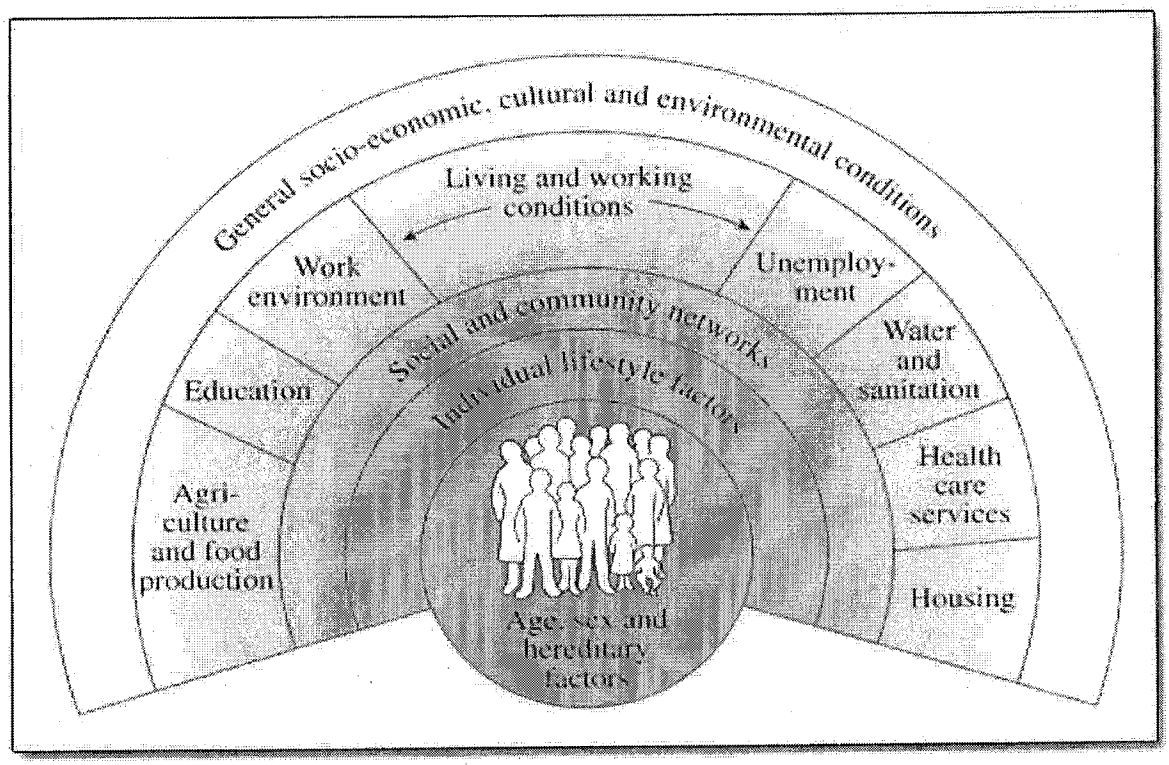
KICK-OFF MEETING

January 31, 2013

Rev. 020413

Connecticut Department of Public Health
www.ct.gov/dph/SHIPcoalition

Social Determinants of Health



Source: World Health Organization, Commission on the Social Determinants of Health. Towards a Conceptual Framework for Analysis and Action on the Social Determinants of Health: Discussion paper for the Commission on Social Determinants of Health, 2005.

DEMOGRAPHIC CHARACTERISTICS

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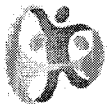

Changes in Population Characteristics, Connecticut, 2000 and 2010

	Connecticut		Change
	2000	2010	2000-2010
Population	3,405,565	3,574,097	**+4.9%**
Median age	37.4 yrs	40.0 yrs	**+2.6 yrs**
65+ yrs of age	13.8%	14.2%	+36,376 **(+7.7%)**
Race/ethnicity			
White only	81.6%	77.6%	-7,945 **(-0.3%)**
Black/Afr. Am. only	9.1%	10.1%	+52,653 **(+17%)**
Asian only	2.4%	3.8%	+53,252 **(+65%)**
American Indian only	0.3%	0.3%	+9,637 **(+17%)**
Other/2+ races	6.6%	8.20	+69,155 **(+31%)**
Hispanic any race	9.4%	13.4%	+158,764 **(+50%)**

U.S. Census Bureau, 2000 and 2010 Census

Connecticut Department of Public Health
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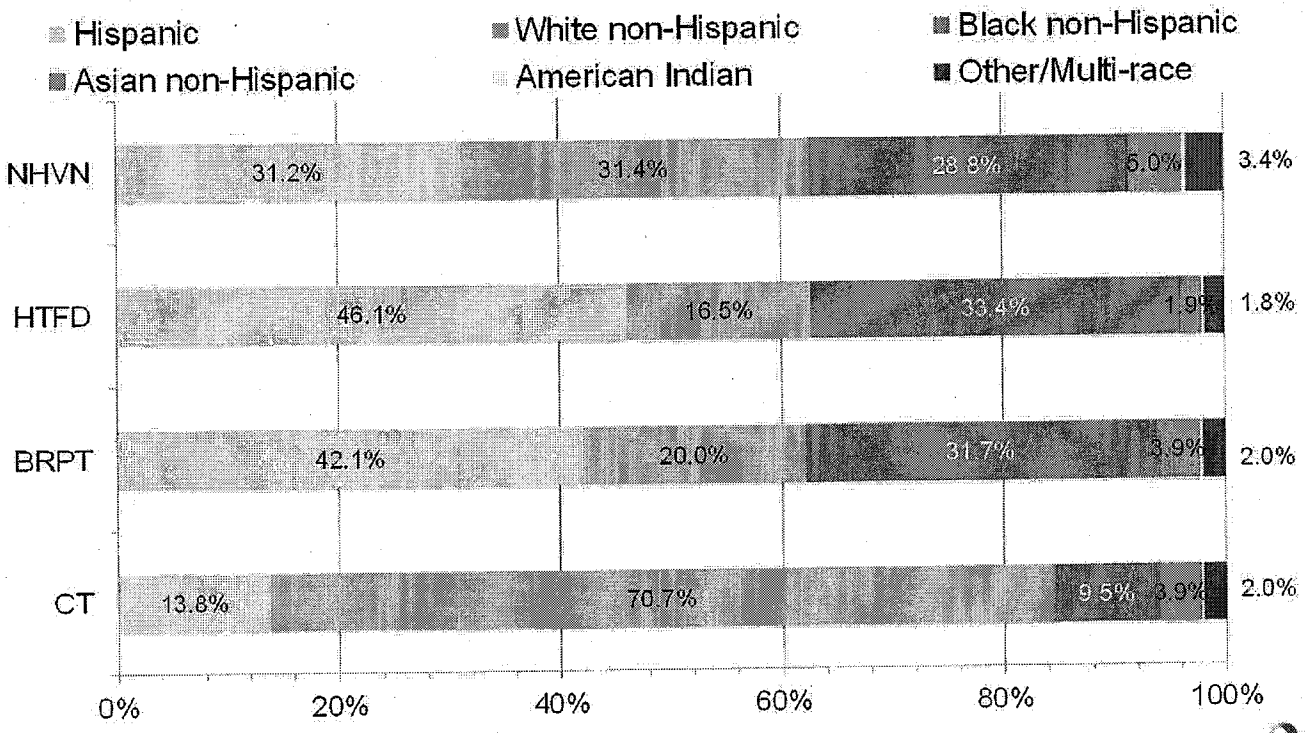
Percent of Population by Race/Ethnicity, Connecticut and Its Largest Towns, 2011



Source: US Census Bureau, American Community Survey, 1-Year Estimates, 2011, DP05 File.

Connecticut Department of Public Health
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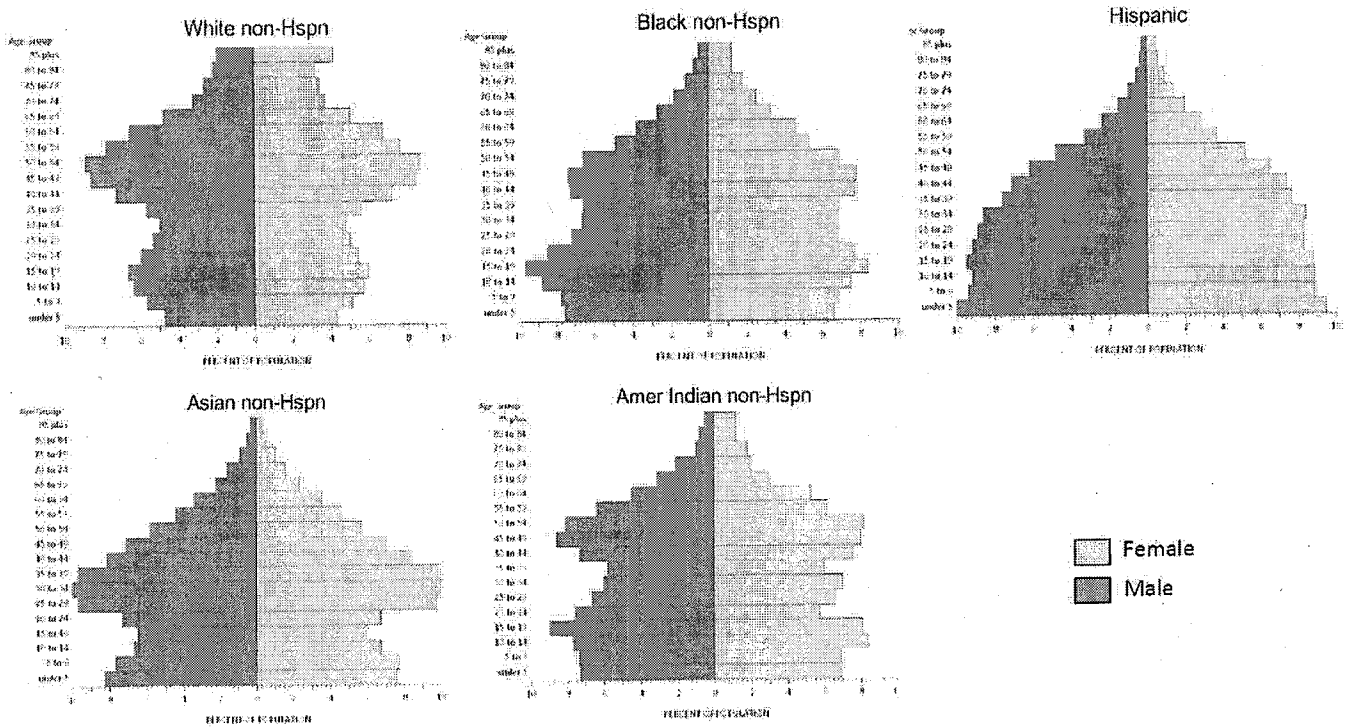
Population Distribution by Age, Sex, Race, and Ethnicity Connecticut, 2010



Source: Connecticut Department of Public Health, Public Health Systems Improvement, 2013. Data from U.S. Census Bureau Postcensal Estimates, 7/1/2010 to 7/1/2011.

Connecticut Department of Public Health
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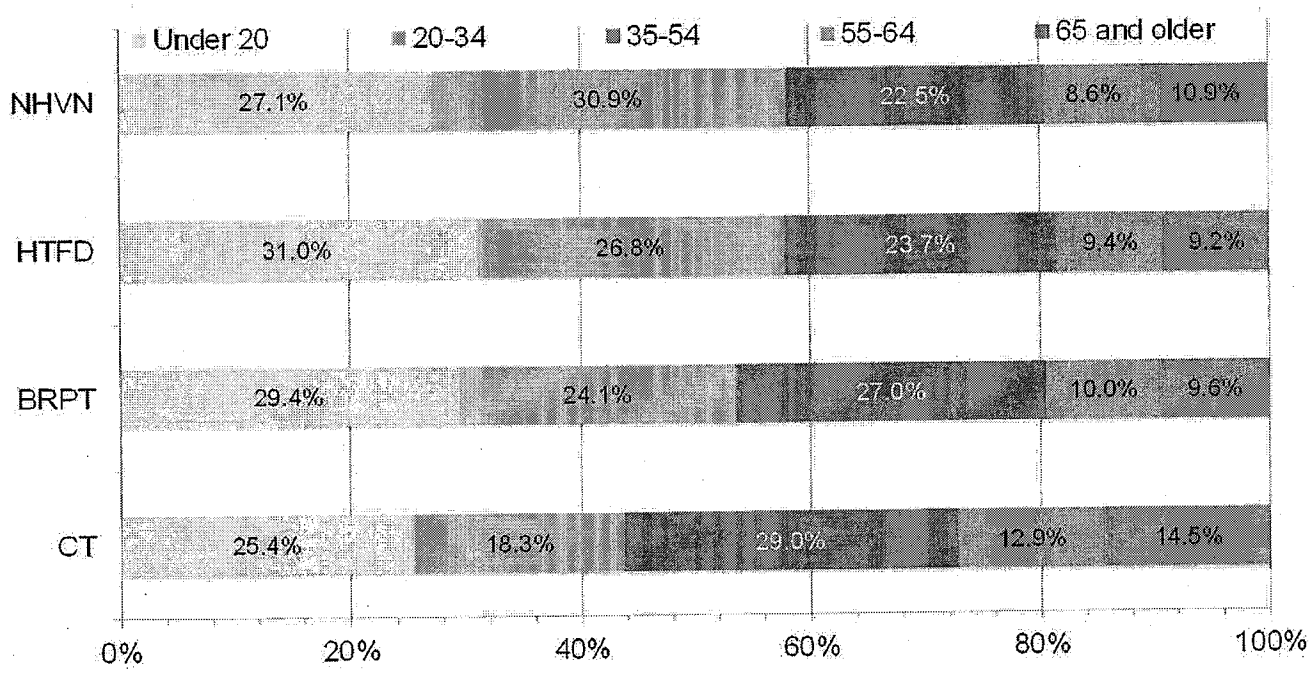
Percent of Population by Age
Connecticut and its Largest Towns, 2011



Source: US Census Bureau, American Community Survey, 1-Year Estimates, 2011, DP05 File.

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DETERMINANTS OF HEALTH

Connecticut Department of Public Health
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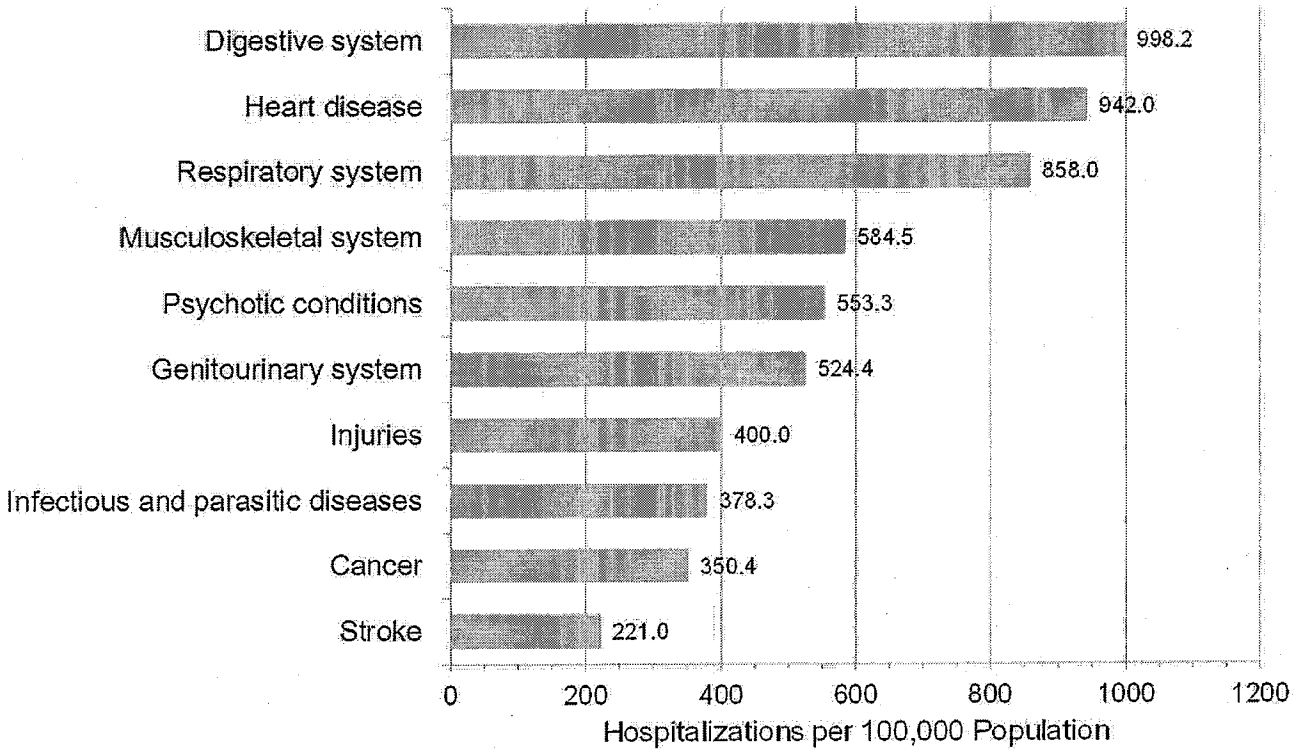
Hospitalization Rates for Leading Causes Connecticut, 2010



Source: Connecticut Department of Public Health, Hospitalization Tables, 2010, Table H-1.

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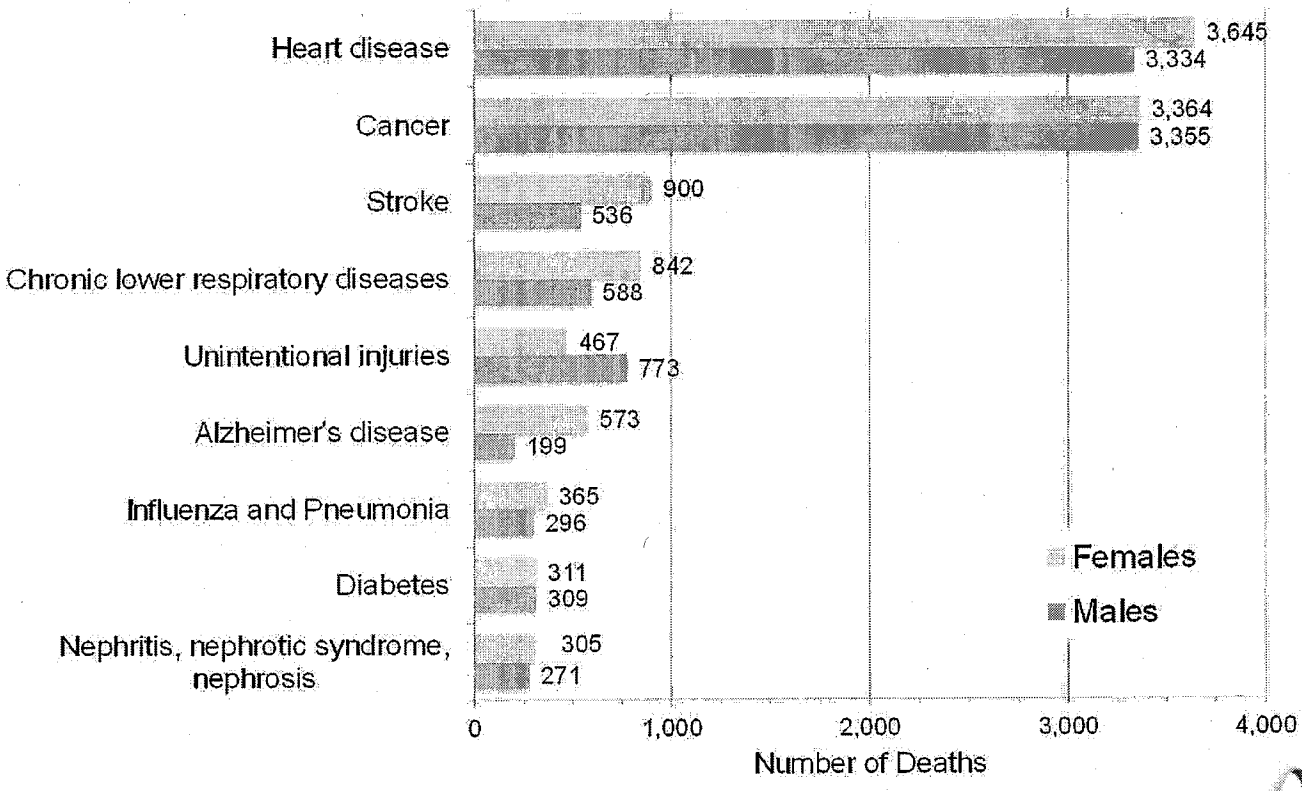
MORTALITY AND HOSPITALIZATION

Connecticut Department of Public Health
www.ct.gov/dph/SHIPcoalition

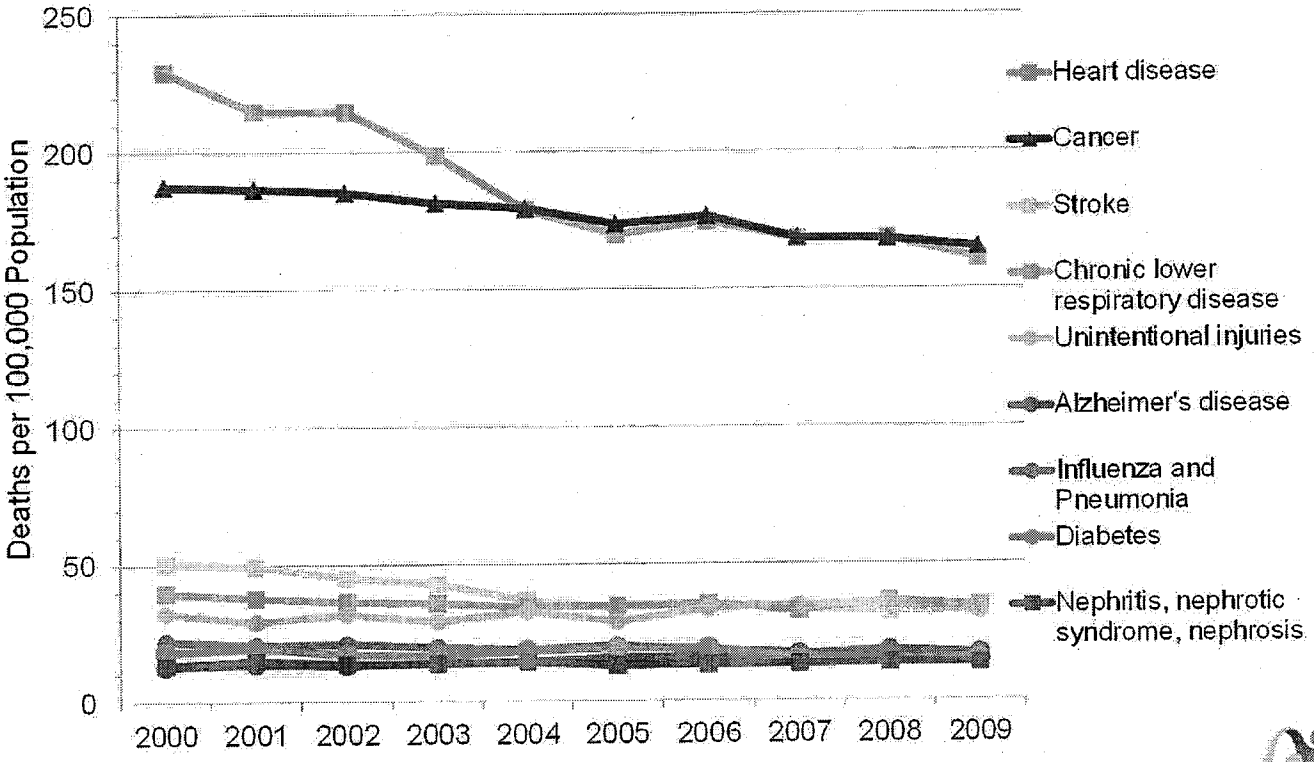
Leading Causes of Death, by Sex
Connecticut, 2009



Source: Connecticut Department of Public Health, Mortality Tables, 2009, Tables 9 and 10.

Connecticut Department of Public Health
www.ct.gov/dph/SHIPcoalition

Age-adjusted Death Rates for Leading Causes of Death Connecticut, 2000-2009



Source: Connecticut Department of Public Health, Mortality Tables, Age-Adjusted Mortality Rate, 2000-2009.

Connecticut Department of Public Health
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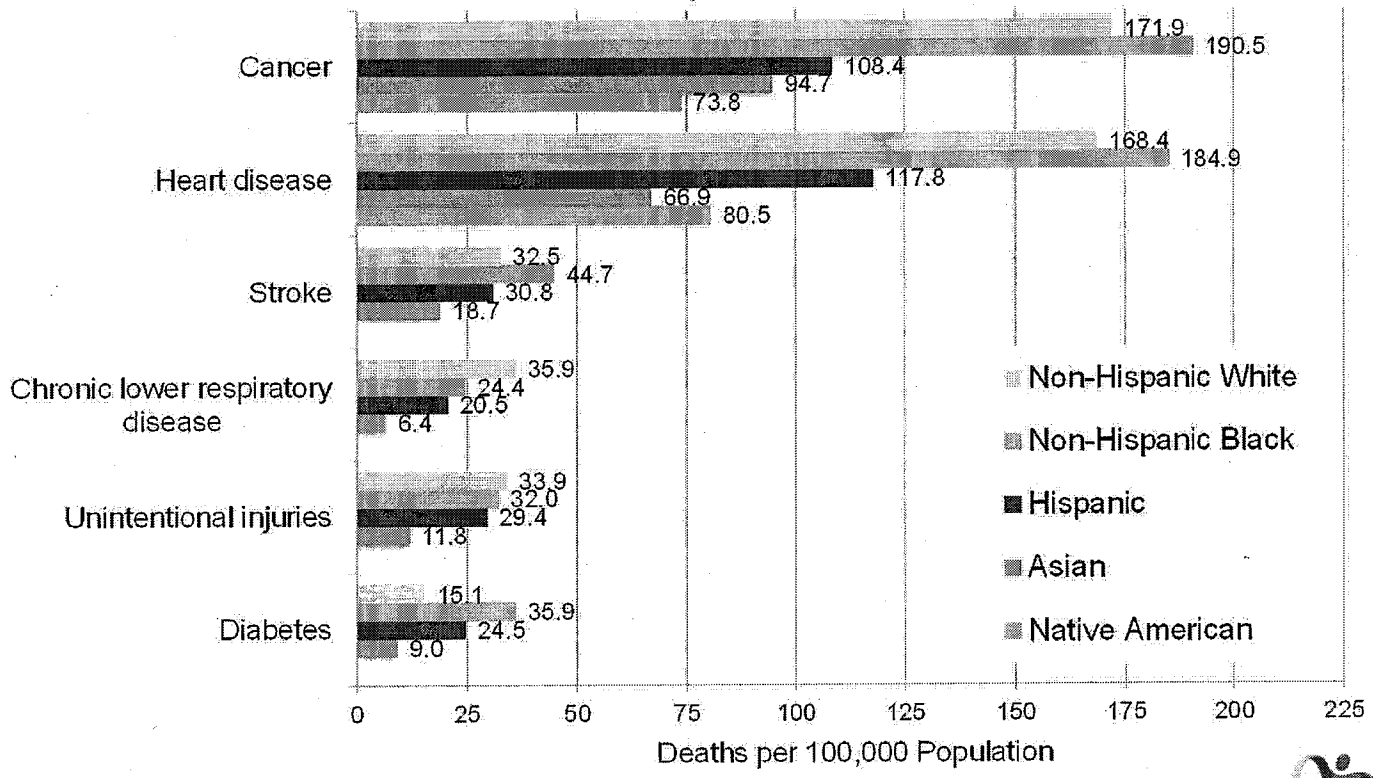
Leading Causes of Death by Age Group Connecticut, 2009

Rank	Age Group			
	Children (0-14 yrs)	**Young Adults (15-34 yrs)**	**Adults (35-64 yrs)**	**Elderly (65+ yrs)**
1	Congenital anomalies	Unintentional injuries	Cancer	Heart disease
2	Unintentional Injuries	Suicide	Heart disease	Cancer
3	Cancer	Homicide	Unintentional injuries	Stroke
4	Septicemia	Heart disease	Chronic liver disease and cirrhosis	Chronic lower respiratory disease
5	Chronic lower respiratory disease, Homicide, Heart disease	Cancer	Suicide	Alzheimer's disease

Source: Connecticut Department of Public Health, Mortality Tables, Leading Causes of Death, 2009, Table 10.

Connecticut Department of Public Health
www.ct.gov/dph/SHIPcoalition

Age-adjusted Death Rates for Leading Causes of Death, by Race and Ethnicity Connecticut, 2005-2009



Source: Connecticut Department of Public Health, Mortality Tables, Age-Adjusted Mortality Rate 2005-2009.

Connecticut Department of Public Health
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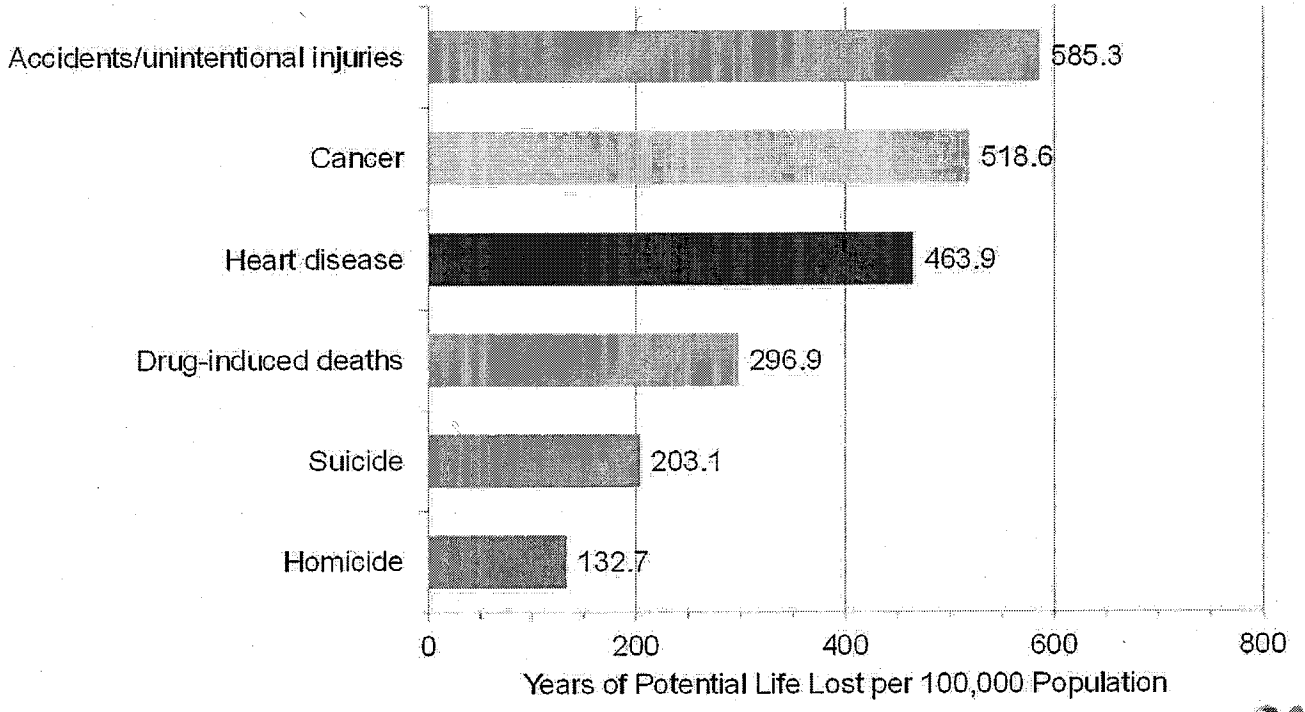
Leading Causes of Premature Death

[Years of Potential Life Lost (YPLL) before 65 Yrs of Age]

Connecticut, 2009



Source: Connecticut Department of Public Health, YPLL Tables, Age-Adjusted YPLL Rate <65, 2009.

Connecticut Department of Public Health
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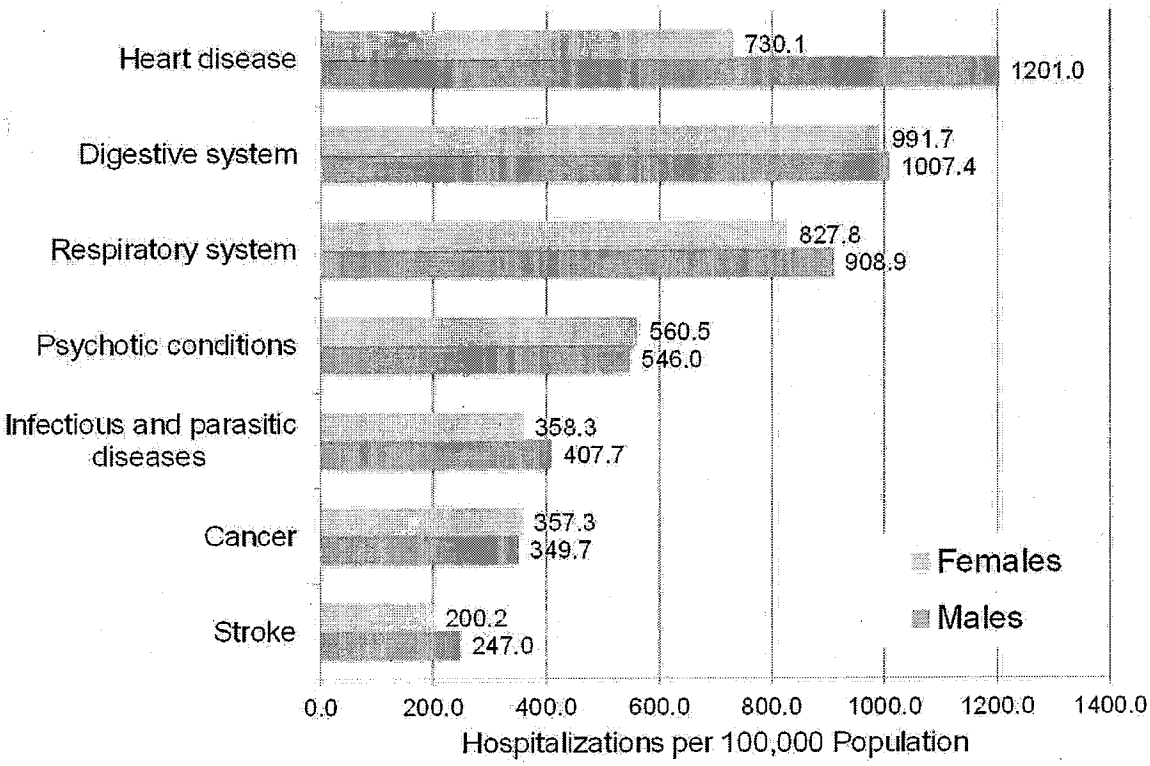
Hospitalization Rates for Leading Causes, by Sex Connecticut, 2010



Source: Connecticut Department of Public Health, Hospitalization Tables, 2010, Table H-1.

Connecticut Department of Public Health
www.ct.gov/dph/SHIPcoalition

Leading Causes of Hospitalization, by Age Group Connecticut, 2010

Rank	Age Group			
	Children (0-14 yrs)	**Young Adults (15-24 yrs)**	**Adults (25-64 yrs)**	**Elderly (65+yrs)**
1	Respiratory system	Mental disorders	Mental disorders	Circulatory system
2	Injury & poisoning	Digestive system	Digestive system	Respiratory system
3	Nervous system & sense organs	Injury and poisoning	Injury & Poisoning	Digestive system
4	Mental disorders	Respiratory system	Circulatory system	Genitourinary system
5	Digestive system	Endocrine, nutritional, metabolic, and immunological disorders	Genitourinary & Musculoskeletal systems	Musculoskeletal system

Source: Connecticut Department of Public Health, Hospitalization Tables, 2010, Table H-1.

Leading Causes of Hospitalization, by Race/Ethnicity, Connecticut, 2010

Rank	Race and Ethnicity		
	White	Black	Hispanic
1	Circulatory system	Circulatory system	Circulatory system
2	Digestive system	Respiratory system	Digestive system
3	Mental disorders	Digestive system	Respiratory system
4	Respiratory system	Mental disorders	Mental disorders
5	Injury & Poisoning	Injury & Poisoning	Injury & Poisoning

Source: Connecticut Department of Public Health, Hospitalization Tables, 2010, Table H-2.

EXHIBIT 4

Hartford Hospital

Patient Volume by Town

Fiscal Years 2010, 2011, 2012 and 2013

Fiscal Year 2013

CITY	#	CITY	#	CITY	#
Hartford	524	Simsbury	24	Burlington	9
East Hartford	127	Granby	24	East Hampton	9
West Harford	112	Cromwell	22	Broad Brook	9
Windsor	84	Meriden	20	Wallingford	8
Newington	74	Torrington	20	West Suffield	8
Rocky Hill	61	Avon	19	East Granby	8
Glastonbury	60	Farmington	17	Coventry	8
Manchester	56	East Windsor	16	Amston	8
Bloomfield	47	Southington	15	Winsted	7
Enfield	42	Suffield	15	New Hartford	7
Middletown	40	Tolland	13	Portland	7
South Windsor	39	Colchester	13	Ellington	7
New Britain	35	Hebron	11	South Glastonbury	7
Windsor Locks	26	Bolton	10	Plainville	6
Bristol	26	Marlborough	10	Lebanon	6
Vernon Rockville	25	Berlin	10	All Others*	234

* All other towns (n=101) with ≤ 6 patients each

Fiscal Year 2012

CITY	#	CITY	#	CITY	#
Hartford	544	Vernon Rockville	28	East Windsor	11
East Hartford	184	Meriden	28	Suffield	10
West Harford	140	Torrington	23	Norwich	9
Wethersfield	105	Avon	23	Stafford Springs	9
Windsor	96	Ellington	19	Tolland	8
Manchester	78	Granby	19	Lebanon	7
Glastonbury	77	Southington	19	South Glastonbury	7
Bloomfield	62	Farmington	18	Unionville	7
Newington	61	Berlin	18	New Hartford	7

Rocky Hill	58	East Granby	18	East Haddam	7
Enfield	58	Cromwell	18	Wallingford	6
New Britain	46	Colchester	15	Salem	6
South Windsor	44	Bristol	15	North Ganby	6
Middletown	39	Willimantic	15	Plainville	6
Windsor Locks	35	Coventry	11	North Windham	6
Simsbury	30	East Hampton	11	All Others*	250

* All other towns (n=145) with ≤ 6 patients each

Fiscal Year 2011

CITY	#	CITY	#	CITY	#
Hartford	555	Meriden	19	Colchester	10
East Hartford	152	Granby	18	Suffield	9
West Harford	125	Avon	18	Marlborough	9
Wethersfield	102	Vernon Rockville	16	Portland	9
Windsor	88	Tolland	16	South Glastonbury	8
Glastonbury	81	Farmington	16	New Hartford	8
Newington	73	Ellington	15	Hebron	8
Rocky Hill	73	Coventry	15	Canton	7
Bloomfield	66	Bristol	14	Storrs Mansfield	7
Manchester	64	East Granby	13	East Windsor	7
Enfield	42	East Hampton	12	Plainville	7
South Windsor	40	Cromwell	12	Winsted	7
Middletown	34	Torrington	12	West Simsbury	7
New Britain	29	Berlin	11	Old Saybrook	5
Simsbury	24	Kensington	10	Ashford	5
Windsor Locks	21	Southington	10	All Others*	220

* All other towns (n=124) with ≤ 5 patients each

Fiscal Year 2010

CITY	#	CITY	#	CITY	#
Hartford	525	Suffield	19	Marlborough	9
East Hartford	152	Vernon Rockville	18	Wallingford	9
West Harford	110	Meriden	18	Canton	9
Windsor	91	Granby	16	Coventry	8
Wethersfield	89	Torrington	16	Cromwell	8
Glastonbury	81	Berlin	14	Bolton	7
Newington	70	East Windsor	13	East Hampton	7
Manchester	55	Avon	13	Hebron	7
Rocky Hill	52	Colchester	12	East Granby	7
Bloomfield	39	Ellington	12	Broad Brook	6
Enfield	35	Tolland	11	South Glastonbury	6
New Britain	34	Bristol	11	Winsted	6
South Windsor	27	Farmington	10	Weatogue	6
Middletown	26	Plainville	10	West Simsbury	6
Simsbury	26	Kensington	9	South Glastonbury	6
Windsor Locks	21	Willimantic	9	All Others*	223

* All other towns (n=133) with ≤ 6 patients each

EXHIBIT 5

A method for improving the efficiency of myocardial perfusion imaging using conventional SPECT and SPECT/CT imaging systems

A. H. Vija*, *Member, IEEE*, R. Malmin, , *Member, IEEE*, A. Yahil, *Member, IEEE*, J. Zeintl, *Member, IEEE*, M. Bhattacharya, *Member, IEEE*, T. D. Rempel, *Member, IEEE*, E. G. Hawman, *Member, IEEE*, B. Bendriem, *Member, IEEE*

Abstract– **Siemens has developed a new IQ•SPECT™ product to improve the efficiency of myocardial perfusion imaging (MPI) using conventional large-field-of-view SPECT and SPECT/CT systems. In this article we present the key technology components that enable this product to perform MPI in less than 5 minutes or at an equivalently lower dose. The enabling hardware is a specially designed variable-focus collimator for cardiac imaging. Images are acquired with the collimator mounted on a Symbia SPECT/CT system rotating about the patient in a cardio-centric orbit at a fixed radius of 28 cm. The acquired data are reconstructed using an iterative reconstruction technique employing the conjugate-gradient method with the Mighell chi-square objective function accounting for Poisson statistics. Each collimator is characterized by measuring the orientations of its holes to account for the deviations from design specifications that are introduced in the casting process. In addition, the 3D point-response function (PRF) is modeled from the autocorrelation of the hexagonal shapes of the collimator holes at the entrance and exit sides. This PRF is no longer just an approximate Gaussian but is more conical at the distances of interest. The system matrix accounts for the deflection of the heads as they rotate about the patient. The deflections were measured for a number of systems using an Optotrak™ optical fixture to obtain accurate 3D orbit information for each head. The reconstruction engine applies the flood-field uniformity corrections (instead of being applied to the raw data) and also estimates patient motion vectors from the distortion-corrected projection images. Attenuation compensation is applied using a patient-specific CT-derived mu map, and an energy-window-based estimate is used to correct for patient-induced scatter. Phantom and patient studies are presented to demonstrate the diagnostic quality of the images acquired using fast or low-dose protocols.**

I. Introduction

We present the characteristics of our high-sensitivity IQ•SPECT myocardial perfusion imaging (MPI) system, which is capable of reducing scan times, patient dose, or a combination thereof, by a factor of four. This is accomplished by using a variable-focus collimator, which is focusing in nature at its center but morphs to near parallel collimation at its edges, thus avoiding truncation [1,2,3]. The resulting data are reconstructed using an enhanced reconstruction technique based on a conjugate gradient method. The scan orbit is cardio-centric so that the heart is maintained in the region of high magnification through the entire scan. This article presents the key technology components contributing to the reconstructed image fidelity, *viz.*, incorporating the characteristics of the gantry and collimator into the system matrix, and an improved reconstruction algorithm.

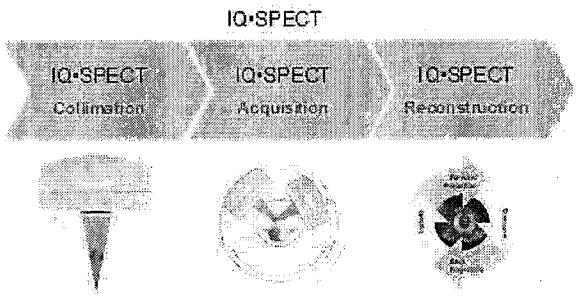


Fig. 1. Main components of IQ•SPECT: Variable focus collimation, cardio-centric orbit, iterative reconstruction.

II. Material and Methods

This work is a rather brief summary of the key components of this technology, deployed on both of our SPECT and SPECT/CT platforms (Symbia® S and T-Series).

The key technology components that we describe here address the need for increased accuracy of the image formation model due to the very nature of the variable-focus collimator. The collimator has a response that is not only distance dependent, but is also variable across the face of the collimator, As a result, it is crucial to accurately model the a) magnification, and b) the point response function for this collimator. The variable magnification is due to the changing direction of each borehole with respect to the collimator

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*A. Hans Vija (hans.vija@siemens.com), R. Malmin, J. Zeintl, M. Bhattacharya, T.D. Rempel, E.G. Hawman are with Siemens Medical Solution USA, Inc., Molecular Imaging, Hoffman Estates, IL, USA.

B. Bendriem is with Siemens Medical Solution USA, Inc., Molecular Imaging, Knoxville, TN, USA

Amos Yahil is with Image Recon LLC, Stony Brook, NY, USA.

surface normal vector, while the point response function depends on the finite size of the bore holes.

The technical justifications for choosing the particular characteristics of the cardio-focal orbit, *viz.*, a fixed radius of 28 cm from the center of rotation (user selectable, cardio centric), heads at an angle of 104°, scan arc of 104° with ~6° angular step size, and a nominal dwell time of 9 s for a specific protocol (injected dose > 370 MBq of ^{99m}Tc), will not be presented here due to the limited scope. Clinical trials have been conducted to both adjust and verify such parameters, as well as the equivalency of the entire method. Those results will be presented in a forthcoming publication.

The key technology components of the IQ.SPECT system are:

1. Measured Deflections of the Gantry
2. Measured Collimator Vector Map
3. Collimator Point Response Function
4. Iterative Reconstruction

1) Gantry Deflections

Gravitational deflections of the detector heads during gantry rotation degrade tomographic resolution unless they are included in the system matrix. Precise Optotrak™ measurements on multiple systems have shown that the deflections are highly repeatable. These deviations from rigid-body rotation are described by three angular deflections (pitch, yaw, and roll) and three translations, as shown in Fig. 2. The dashed lines represent the standard deviation of the 13 units measured.

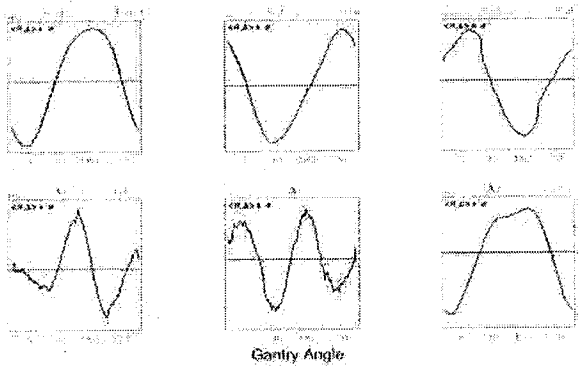


Fig. 2. Rotational and translational deflections of a detector head (H0) during an orbit in a specified configuration.

We obtained similar data for all possible detector head configurations, orbit orientations, radial distances, and collimators varying in their weights. This allows us to completely characterize the motion of each detector head. Typical values are in the order of a few tenths of degrees and fractions of mm[1]. These are not large values; however, if not accounted for, these deviations amount to inaccuracies at a distance of 28 cm of about 2 mm in the object area, that are no longer negligible. Figure 3a shows the difference in the projected location of a point at 28 cm with and without inclusion of the gantry deflection corrections for a LEHR collimator. While Figure 3b shows the same effect for the VectorMap for a SZ collimator.

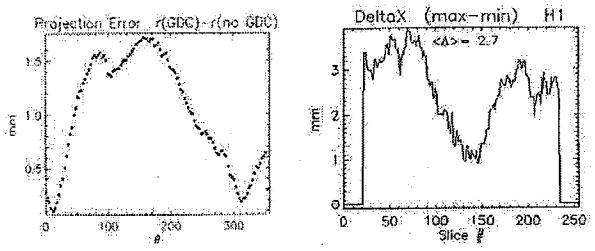
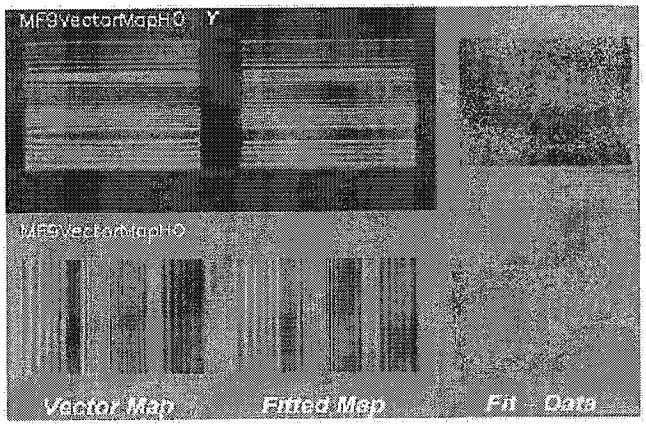


Fig. 3. Difference in projected position with/without gantry deflection correction for LEHR collimators. (b) Variation in projected position due collimator hole angle variations from design specifications for a SZ collimator.

2) Collimator Vector map: directions of the collimator holes

The cast fabrication technique of the collimators introduces subtle, collimator-specific deviations of the hole orientations from their design. An example of this unique signature of the collimator, which we call its vector map, is shown in Fig. 4 for the axial (top) and transverse (bottom) dimensions. These were measured using proprietary techniques developed by Siemens. The lines represent iso-contours of constant hole angle. The images in the center of Fig. 4 are the vector maps of the "ideal" collimator determined by fitting the hole angles to the design equations. The right hand panel shows the difference between empirical and ideal hole angles. The rms error of the VectorMap measurement technique itself is less than 0.06°. The absolute error of determining the pointing angles of the holes is less than ±0.5°. The details of this technique can not be described here because of intellectual property issues. Each collimator is characterized at the factory before shipment and its unique fingerprint stored and shipped with collimators. The reconstruction incorporates these vector maps into the projection operator.



[1] Detailed scale has been removed for proprietary reason.

Fig. 4. VectorMap (depiction of angles) axial (top) and transverse (bottom) dimensions (left) and deviation (right) from design (center).

3) Collimator point-response function

A geometrical point-response function (GPRF) is used to account for collimation. The GPRF is modeled using a convolution of the hexagonal aperture functions representing the entry and exit holes of the collimator. The current model of the GPRF results is a "hex-cone" shape, deviating significantly from the Gaussian approximation that had been used in the past. The GPRF is then convolved with the intrinsic detector PRF or IPRF, which is Gaussian in shape with a measured fwhm. However, the combined PRF is dominated by the conical GPRF at the distances of interest.

Figure 4 shows results from a test of modeled PRF shape vs. measured data. Beyond a point source distance of 15 cm the standard error of the hex-cone is preferred.

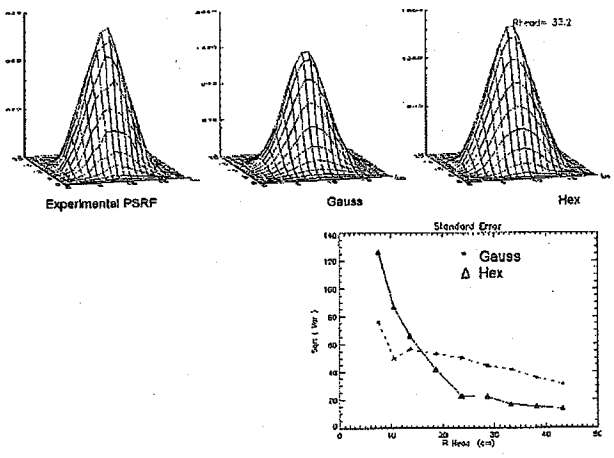


Fig. 5. Point response function: measured (left), 3d Gaussian model (center), 3D hexagonal autocorrelation model (right). Standard error as function of distance, showing that the Gaussian model is well suited for close distances, but less so farther away.

4) Iterative Reconstruction

Our new reconstruction engine is based on a conjugate gradient method with ordered subsets, where we use a modification of Mighell's merit function to characterize the Poisson statistics [4],[5].

Mighell [4] introduced a chi-squared-gamma merit function for fitting models to Poisson-distributed counts. In the context of image reconstruction, his merit function is given by

$$\chi^2_\gamma = \sum_i \left(\tilde{d}_i - \sum_\alpha H_{i\alpha} I_\alpha \right)^2 \Big/ \left(d_i + 1 \right) \quad (1).$$

Here d_i is the count in pixel i, I_α is the model image intensity in voxel α, and $H_{i\alpha}$ is the forward projection matrix from image to data space. The quantity

$$\tilde{d}_i = d_i + \mathrm{Min}\left(d_i, 1 \right) \quad (2)$$

in the numerator of (1) is the modified count, used to ensure that parameters estimated from (1) are unbiased.

The conjugate-gradient method is a minimization scheme with quadratic convergence, without the need to explicitly compute the Hessian matrix, which would be totally impractical given the number of voxels. The conjugate-gradient method, like any other gradient minimization, is greatly accelerated by modifying the gradient by means of a preconditioner. The purpose of the preconditioner is to point the minimization away from the negradient (negative of the gradient), which is in the direction of the greatest local decrease in the merit function, in a direction that heads more closely toward its global minimum. We derived a computationally efficient preconditioner under the assumptions that intensity change ΔI_α does not vary strongly over the geometrical coupling range. Since the IQ•SPECT design is optimized for cardiac applications, it justifies this assumption in our choice of the preconditioner.

We use 3D rotations to incorporate gantry deflection and estimated motion vectors. Motion is estimated from the distortion corrected projection views. The distortion corrected projection views are generated only for visualization and quality control, but not for reconstruction. They allow the user to inspect the data and identify the heart with greater ease. The system matrix includes the measured vector map and PRF (as described above) and an optional CT-derived attenuation correction averaged over the PRF. The forward projection also includes an additive scatter-projection term, estimated from the dual or triple energy acquisition windows. Collimator-specific flood field uniformity are measured and used by the reconstruction engine to correct for nonuniformities in the projection data. It should be noted, that the reconstruction engine does not modify the data in any way, so as not to alter Poisson characteristics of the data. The reconstruction the image is post smoothed with a 3D Gaussian spatial filter with a FWHM of 13 mm. The reconstruction parameters of subset, iteration and post smoothing FWHM are user adjustable. It is also worth noting that OSCGM behaves differently from OSEM, and choosing a single subset yields the best reconstructed image quality. The iteration number is typically set to be 30. ECG-Gated data are reconstructed by reconstructing each time bin and using a temporal smoothing between the gates [6]. Based on clinical trials conducted to product release we suggest reconstruction parameters for various conditions, and results such work will be presented elsewhere.

III. Results

In Fig. 6 we show the reconstructed data acquired using a Data Spectrum normal male anthropomorphic torso phantom loaded with 74, 370, and 407 MBq of ^{99m}Tc in the heart, liver, and background respectively. These activities correspond to

typical clinical concentrations of a ^{99m}Tc-Sestamibi found in humans. Rows 1-2 show Siemens OSEM3D (Flash3D) reconstructions [7],[8] of scans with an LEHR parallel-hole collimator and rows 3-4 with an IQ•SPECT variable-focus collimator. Rows 2 and 4 include attenuation and scatter corrections and rows 1 and 3 do not.

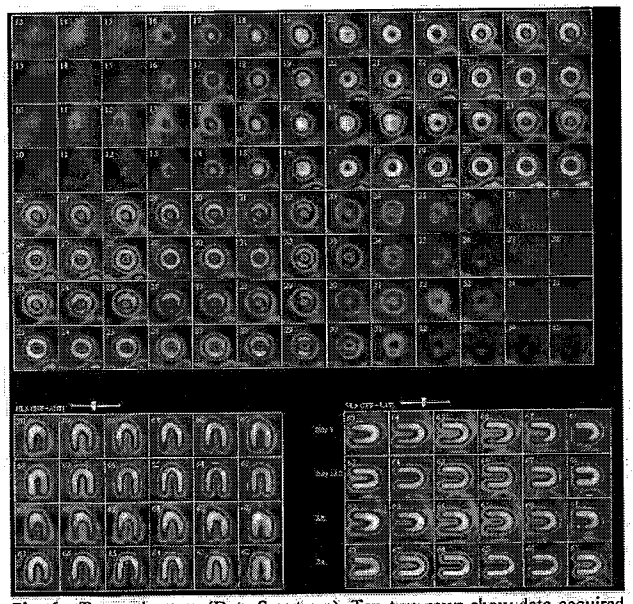


Fig. 6. Torso phantom (Data Spectrum). Top two rows show data acquired using LEHR collimators, bottom two rows show IQSPECT. Row 2 and 4 include attenuation and scatter correction, and rows 1 and 3 do not.

In Fig. 7 we compare a standard 20-min clinical LEHR acquisition (rows 1-2) with a 4-min IQ•SPECT protocol (rows 3-4) of the same patient, injected with 222 MBq injection at stress (rows 1 and 3), and 888 MBq at rest (rows 2 and 4).

All reconstructions include attenuation and scatter corrections. (Data Courtesy of University of Erlangen, Germany.)

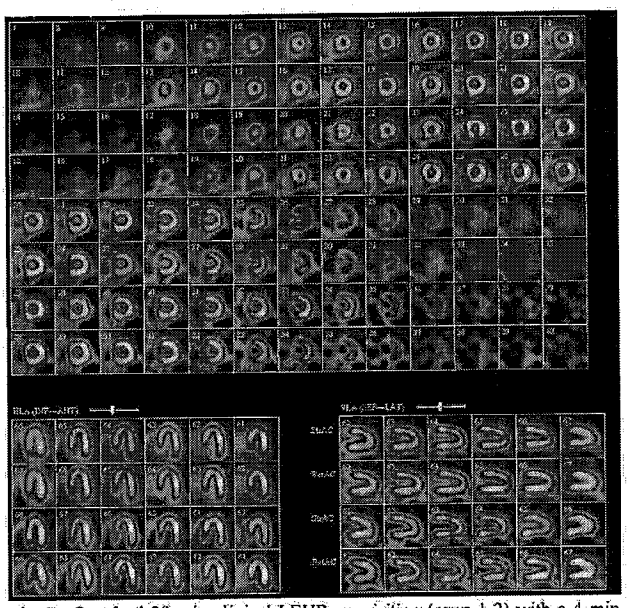


Fig. 7. Standard 20-min clinical LEHR acquisition (rows 1-2) with a 4-min IQ•SPECT protocol (rows 3-4) of the same patient, injected with 222 MBq (6 mCi) injection at stress (rows 1 and 3), and 888 MBq (24 mCi) at rest (rows 2 and 4). All reconstructions include attenuation and scatter corrections. (Data Courtesy of University of Erlangen, Germany.)

IV. Conclusion

We have presented the key technology components of the Siemens IQ•SPECT product that is capable of performing MPI studies at about a quarter of the time taken by a conventional SPECT protocol. We have shown phantom as well as clinical images to demonstrate the diagnostic quality of the reconstructed images.

Acknowledgments

The authors would like to thank the entire IQ•SPECT team at Hoffman Estates for their hard work in transferring these technologies into the product.

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Clinical Applications of SPECT/CT: New Hybrid Nuclear Medicine Imaging System

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FOREWORD

Interest in multimodality imaging shows no sign of subsiding. New tracers are spreading out the spectrum of clinical applications and innovative technological solutions are preparing the way for yet more modality marriages: hybrid imaging.

Single photon emission computed tomography (SPECT) has enabled the evaluation of disease processes based on functional and metabolic information of organs and cells. Integration of X ray computed tomography (CT) into SPECT has recently emerged as a brilliant diagnostic tool in medical imaging, where anatomical details may delineate functional and metabolic information.

SPECT/CT has proven to be valuable in oncology. For example, in the case of a patient with metastatic thyroid cancer, neither SPECT nor CT alone could identify the site of malignancy. SPECT/CT, a hybrid image, precisely identified where the surgeon should operate.

However SPECT/CT is not just advantageous in oncology. It may also be used as a one-stop-shop for various diseases.

Clinical applications with SPECT/CT have started and expanded in developed countries. It has been reported that moving from SPECT alone to SPECT/CT could change diagnoses in 30% of cases. Large numbers of people could therefore benefit from this shift all over the world.

This report presents an overview of clinical applications of SPECT/CT and a relevant source of information for nuclear medicine physicians, radiologists and clinical practitioners. This information may also be useful for decision making when allocating resources dedicated to the health care system, a critical issue that is especially important for the development of nuclear medicine in developing countries. In this regard, the IAEA may be heavily involved in the promotion of programmes aimed at the IAEA's coordinated research projects and Technical Cooperation projects.

The IAEA wishes to express its thanks to all experts who have contributed to this publication. The IAEA officer responsible for this publication was N. Watanabe of the Division of Human Health.

EDITORIAL NOTE

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CONTENTS

1. INTRODUCTION

During the past several years there has been growing utilization of PET/CT, based on the fact that functional and morphologic correlative images produced by this methodology improve diagnostic accuracy. Similar progress is now being reported for SPECT/CT, a modality which is rapidly evolving from a somewhat under-utilized technical option to gain an acknowledged status for optimizing the diagnostic capabilities of single photon imaging, with potential impact on patient management.

SPECT and CT are tomographic imaging procedures, each one with separately proven good diagnostic performance. SPECT produces computer-generated images of local radiotracer uptake, while CT produces 3-D anatomic images of X ray density of the human body. Combined SPECT/CT imaging provides sequentially functional information from SPECT and the anatomic information from CT, obtained during a single examination. CT data are also used for rapid and optimal attenuation correction of the single photon emission data.

By precisely localizing areas of abnormal and/or physiological tracer uptake, SPECT/CT improves sensitivity and specificity, but can also aid in achieving accurate dosimetric estimates as well as in guiding interventional procedures or in better defining the target volume for external beam radiation therapy.

Gamma camera imaging with single photon emitting radiotracers represents the majority of procedures in a routine nuclear medicine practice. Many of these examinations are tumour or cardiac imaging studies. The development of better instruments, newer computer based procedures for image analysis and display, new ^{99m}Tc labelled agents for visualizing biologically significant events (such as cellular growth, hypoxia, angiogenesis, apoptosis) may enhance the future value of SPECT/CT in terms of both clinical impact on patient care and cost effectiveness, as compared to PET/CT.

Diagnosis and characterization of disease by CT imaging is based on morphologic criteria such as size, texture and tissue attenuation. CT provides information regarding changes in organ size and tissue density, as well as their precise spatial localization and topographic landmarks. However, structural data do not necessarily correlate with the metabolic status of disease. On the other hand, nuclear medicine imaging is based on the bio-distribution of a radioactive agent over time and space, thus visualizing dynamic physiological and pathophysiological processes that define the functional characteristics of disease. Furthermore, whole body assessment is possible with a single radiation exposure, as the ionizing agent is administered to patients rather than being delivered from an external source to each region of the body to be evaluated, as performed with radiologic imaging (e.g. conventional X ray or CT). However, scintigraphic images lack accurate anatomic landmarks for precise localization and characterization of findings, in spite of the fact that specific radiopharmaceuticals are used for assessment and diagnosis of specific disease processes. The above mentioned considerations explain why morphologic and functional imaging modalities are complementary and not competing techniques, especially if precise image registration is made possible by using a single imaging unit combining the emission based data (SPECT) with the transmission based data (CT, which also serve to correct the emission data for tissue attenuation). Image registration is the process of determining the geometric relationship between multimodality imaging studies, in order to use information provided by one test in the context of the other modality.

2. OVERVIEW OF SPECT/CT TECHNOLOGY

2.1. Update on SPECT/CT installations worldwide

While image fusion techniques have been in clinical use for many years, the first commercial SPECT/CT system was only introduced in 1999. This system combined a low-power X ray tube with separate gamma and X ray detectors mounted on the same slip ring gantry. The X ray system operated at 140 kV with a tube current of only 2.5 mA. This resulted in a significantly lower patient dose than that received during a conventional CT imaging procedure (by a factor of 4–5), but the quality of the CT images was inferior to state of the art CT. Nevertheless, the fan beam formed by the X ray tube on the detectors allowed the measurement of patient attenuation along discrete paths providing significantly higher quality attenuation maps than those available with conventional ^{153}Gd scanning lines sources [1, 2].

This system has recently been equipped with a 4 slice low-dose CT scanner yielding an axial slice thickness of 5 mm with each rotation instead of one 10 mm slice. This tool retains the very compact design of the previous system, delivers a low radiation dose to the patient and requires minimal room shielding [2, 3]. Over the last 2–3 years there has been a large expansion of SPECT/CT technology worldwide and, as at June 2007, there are approximately 600 of these installations around the world and over 200 across the United States. The relatively large distribution of these SPECT/CT systems equipped with a low definition CT tube versus those equipped with high definition, standard diagnostic CT tubes (see below) can be explained by two main factors: 1) this is the first SPECT/CT system made commercially available, and 2) the overall cost of these tomographs (equipped with a low definition CT component) is considerably lower than that of tomographs equipped with a CT component having full diagnostic capabilities.

In this regard, following the commercial success of PET/CT systems that employ multi-slice CT scanners, there has been growing interest in the development of comparable SPECT/CT systems. Thus, in an effort to further improve imaging quality and reduce acquisition time, new hybrid systems employing state of the art spiral CT scanners have been developed. These systems combine dual-head gamma cameras with full diagnostic, up to 16 slice CT scanners that allow variation of CT slice thickness from 0.6 mm up to 10 mm, yielding diagnostic quality CT images with a scan speed shorter than 30 s for a 40 cm axial field of view [2, 3]. However, because of the addition of a separate CT gantry, these systems are considerably larger than conventional SPECT systems and have very different setting and shielding requirements compared with the system equipped with the low definition CT tube. Since their introduction in the market, over 210 such units have been installed worldwide.

Access to hybrid systems is limited in several countries due to their high cost. SPECT/CT systems based on combining a 'gantry-free' commercial SPECT system with a single- or multiple-slice CT scanner have recently been developed [4, 5]. In the future, further cost reduction and technological improvement are desirable in order to encourage a larger diffusion of such devices worldwide.

2.2. General architecture of SPECT/CT devices

SPECT/CT systems have the same SPECT component as conventional nuclear medicine systems, the dual-head gamma cameras are generally used for planar and tomographic imaging of single photon emitting radiotracers. As mentioned above, the CT component of the first-generation hybrid devices used a low resolution CT detector while recently

developed, second-generation SPECT/CT systems incorporate a variety of multi-slice CT scanners. SPECT/CT systems include separate CT and gamma camera devices using common or adjacent mechanical gantries, and sharing the same scanning table. Integration of SPECT and X ray imaging data is performed by a process that is similar to that of PET/CT.

X ray scatter can reach and possibly damage the SPECT detectors designed for radionuclide low count rate imaging. Therefore, in a hybrid system the SPECT detectors are off-set in the axial direction from the plane of the X ray source and detector. In a hybrid system both detectors have to be able to rotate and position accurately for tomographic imaging. In this regard, accuracy of translation and angular motion differs from one imaging system to another. While CT requires the highest accuracy, SPECT (with a lower spatial resolution) can perform clinical images with a motion accuracy of slightly less than one millimetre.

SPECT/CT systems using a low-dose single- or multi-slice CT have both the SPECT and the CT detectors mounted on the same rotating platform. Imaging is performed while the detectors are rotating sequentially around the patient. While this concept has the advantage of using the gantry of a conventional gamma camera for both imaging modalities, it limits the rotational speed of the SPECT/CT option to approximately 20 seconds per rotation. In SPECT/CT systems incorporating diagnostic CT scanners, the gamma camera detectors are mounted on a different platform, separated from the high speed rotating CT device (0.25 to 0.5 s per revolution). This design increases the performance of the CT subsystem, but it also increases the complexity of the gantry and the cost of the technology.

Dual modality imaging requires longer stretchers than single modality imaging devices. While built to support patients weighing up to 500 pounds, these scanning tables, extended to accommodate the needs of both components (SPECT and CT), deflect to some degree while loaded with normal adult patients. The extension and degree of deflection of the table can introduce a patient-dependent mis-registration between CT and SPECT data. One solution to this problem is the design of a table supported on its base at the front of the scanner as well as at the far end of the X ray system, thus minimizing the table deflection. Another solution is to use a table fixed on a base, moving on the floor to introduce the patient into the scanner.

The workstation of the SPECT/CT device is responsible for system control, data acquisition, image reconstruction and display, as well as data processing and analysis. CT data are calibrated in order to obtain attenuation correction maps for the SPECT images. SPECT and CT images are displayed on the same screen in addition to the fused images, which represent the overlay of a coloured SPECT over a grey-scale CT image. A 3-D display with triangulation options allows to locate lesions and sites of interest on the CT image and to redisplay them on the registered SPECT and fused SPECT/CT images.

2.3. SPECT/CT acquisition protocols

Acquisition on SPECT/CT systems is performed in a sequential mode. With devices that have a low-dose CT component, data are typically acquired by rotating the X ray detector 220° around the patient, with the X ray tube operated at 140 kV and 2.5 mA. The CT images obtained have an in-plane spatial resolution of 2.5 mm, and of 10 mm in the axial direction. Scan time is approximately 16 s per slice, for a total study duration of 10 min for the CT. SPECT/CT systems using a diagnostic CT component are characterized by higher spatial resolution and faster scanning time (approximately 30 s for the whole field of view),

associated however with higher radiation doses. An attenuation map is created at the end of the CT acquisition time.

The SPECT component is represented by a rotating, dual-head, variable angle sodium-iodide scintillation camera. The detectors can be placed either in a 180° or a 90° position. Regardless of the type of SPECT/CT that is used, SPECT acquisition currently requires a routine scanning time of approximately 20–30 min, depending on the radiotracer, as for stand-alone SPECT acquisition protocols. SPECT is reconstructed using iterative methods incorporating photon attenuation correction based on the X ray transmission map and scatter correction.

Since X ray and radionuclide data are not acquired simultaneously, SPECT images are not contaminated by scatter radiation generated during the X ray image acquisition. Also, since the patient is not removed from the table, both imaging components are acquired with a consistent and identical patient position, allowing accurate image registration if we assume that the patient has not moved during the entire duration of the SPECT/CT study. CT is usually acquired in matrices of 512 × 512 with the newest CT scanners, or 256 × 256 in older scanners, and has to be resized into slices with the same pixel format and slice width as SPECT. Spatial registration of the CT and SPECT acquisitions is important since misalignment of the attenuation map relative to corresponding radionuclide images can cause 'edge artefacts', bright and dark 'rims' across edges of these regions.

SPECT/CT image mis-registration or blurring may occur, mainly due to patient movement as well as respiration, cardiac motion, and peristalsis. Differences in urinary bladder filling can lead to erroneous co-registration between SPECT and CT acquisitions. With SPECT/CT devices equipped with low-dose X ray tubes, CT is performed during shallow breathing to facilitate image registration. However, the longer acquisition time increases the chances for patient motion. With hybrid devices equipped with multi-slice CT, anatomic imaging is acquired following breath-hold, during tidal breathing, or during a short part of the respiratory cycle, whereas SPECT data are acquired over several minutes. This again can lead to mis-registration. In addition to faulty localization, non-registered attenuation maps can lead to under- or overestimation of radionuclide uptake.

The presence of contrast media in the CT images acquired as part of the SPECT/CT study complicates the attenuation correction process. Also, high concentrations of intra-venous contrast material captured during the CT acquisition may have redistributed by the time the SPECT acquisition is performed. Image segmentation techniques separating different areas inside the images may solve this problem, or alternatively, a very low powered non-contrast CT can be performed prior to the SPECT for attenuation correction, followed by the contrast CT study as the last step.

2.4. Technical staffing for SPECT/CT

A major asset for proper implementation of novel SPECT/CT procedures is the technologist. It is important to take the time to train and educate the technologists so that they can deliver an end product of the highest quality. While it is preferable for technologists to have their work product directly checked by the interpreting physician before the patient leaves the department, in some outpatient settings technologists must make their own decision, and therefore they need to be well trained and using robust and reproducible protocols. The new generation technologists therefore have to be trained in nuclear medicine and CT, to have experience in reviewing scans and to be able to identify artefacts occurring during acquisition

of studies. Instructing the technologists about pertinent history questions and designing a template to be filled out for each patient will ensure that all of the clinical information to further assist in the reading of the images is available. Training requirements for CT and SPECT technologists differ in various countries. Under ideal circumstances a technologist should be fully trained, experienced and certified in both nuclear and X ray/CT technologies.

3. GENERAL NUCLEAR MEDICINE SPECT/CT PROCEDURES

The SPECT component of the SPECT/CT procedure is performed using the acquisition protocols routinely employed for the dual-head gamma camera. This device is equipped with collimators adequate for the specific radioisotope in use, such as low energy, high resolution parallel hole collimators for ^{99m}Tc, or medium energy collimators for ^{67}Ga, ^{111}In or ^{131}I. Imaging is typically performed with the detectors facing each other at 180°, typically acquiring 120 projections over a 360° orbit and using a time per projection of 40–50 s. A 64 × 64 matrix is commonly employed for the low count isotopes, while the higher resolution 128 × 128 matrix can be applied for the higher count rates typically generated by ^{99m}Tc.

CT images are obtained immediately following the SPECT acquisition. For the low-dose CT devices the acquisition parameters include settings at 140 kV, 1–2.5 mA, 13 s/slice, 256 × 256 image matrix, 5 mm slice thickness and slice spacing. For diagnostic CT acquisitions the settings are 140 kV, 80 mA, 1 s/slice, 512 × 512 image matrix, 48 cm reconstruction diameter, 5 mm slice thickness and slice spacing. Skeletal CTs of diagnostic quality can be performed at lower mAs products to reduce the radiation exposure of the patient. A variety of other settings are possible depending on the specific diagnostic question asked of the CT scanner. These include, in particular, protocols to perform low powered CT with the multi-detector scanners, e.g. when a CT of diagnostic quality is already available or high powered CT is not deemed necessary for the particular question under study. Some strategies restrict the CT field of view to the regions exhibiting SPECT abnormalities, thus reducing the radiation dose delivered to the patient even further [6]. Data are reconstructed using filtered back-projection software and filters provided by the manufacturer.

Co-registered CT and SPECT are acquired by translating the patient from one detector to the other while the patient remains lying on the same table. This allows the CT and radionuclide images to be acquired with a consistent scanner geometry and body habitus, and with a minimal delay between the two acquisitions.

3.1. ^{131}I-Iodide SPECT/CT in thyroid cancer

Well differentiated thyroid cancer has an incidence of approximately 1:10 000 [7]. Its standard treatment includes total thyroidectomy and therapy with ^{131}I-iodide [8, 9]. With this combined approach, overall 5 year survival rates exceed 95%. However, the long term prognosis is worse for patients who present with locally advanced tumours or distant metastases at diagnosis, as well as in case of dedifferentiated neoplasms (because of their reduced iodine-trapping property) [10]. This subgroup accounts for approximately 20% of patients with well differentiated thyroid carcinomas and deserves special attention on follow-up.

The therapeutic effect of ^{131}I is provided by its beta-emission. In addition, this isotope of iodine emits 364 keV gamma rays that can be detected by gamma cameras. Therefore, ^{131}I is also used as a diagnostic agent since most, but not all metastases of thyroid carcinoma have

retained the normal thyroid parenchyma's ability to accumulate iodine. The bio-distribution of ^{131}I is usually sufficiently defined by planar scintigraphy. SPECT is only rarely used for this purpose, as the image quality of ^{131}I-SPECT is hampered by the high energy of the gamma radiation emitted by this radionuclide.

^{131}I is only poorly concentrated by most extrathyroidal tissues. The salivary glands, stomach, intestines, and urinary bladder are the most notable exception to this rule. Thus, gamma camera images of ^{131}I distribution in the human body lack anatomical detail, because no clear reference landmarks can be recognized. This renders localization of radioiodine foci difficult, if not impossible at times, and may constitute a problem in those patients in whom surgical removal of metastases is indicated.

Iodine-avid metastases can be small. Furthermore, they may occur in regions exhibiting distorted anatomy due to previous surgery. Their localization using CT or MRI may therefore also not be possible. SPECT/CT co-registration certainly is an elegant method of localization (Fig. 1), although the evidence to this effect is still scarce. Papillary and, albeit to a lesser extent, follicular thyroid carcinomas metastasize frequently to the cervical and mediastinal lymph nodes. Therefore, dissection of the central cervical lymph nodes is, in many cases, part of the initial surgical procedure [11]. Despite a theoretically total thyroidectomy, a variable amount of normal thyroid parenchyma persists within the patient. This provides the rationale for postoperative radioiodine therapy for ablation of thyroid remnants. On the post-therapeutic radioiodine scans, the high activity contained in this parenchymal residue may hamper cervical N staging in many cases. With SPECT/CT, this problem may be overcome (Fig. 2). Preliminary data using SPECT/CT indicate that approximately one fourth of patients may actually harbour cervical lymph node metastases at the time of radioiodine ablation, the majority of which elude detection by planar imaging [12]. Clearly, further longitudinal studies are needed to define the possible clinical impact of this previously unavailable early information on cervical lymph node involvement.

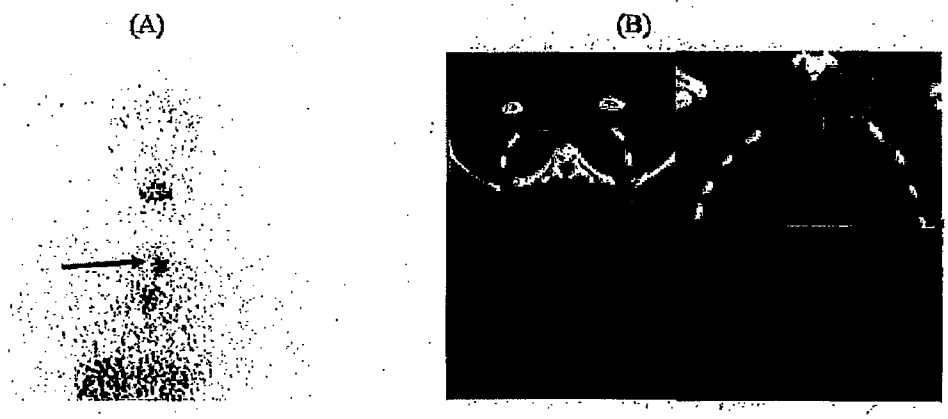

FIG. 1. (A) The planar ^{131}I-iodide scan in a 16 year old patient with thyroid cancer discloses an iodine-avid focus (arrow). The patient had had three surgical procedures (including total thyroidectomy) and 37 GBq of ^{131}I, so that this focus indicates the presence of a further lymph node metastasis. Considering scarring from prior surgeries, exact localization of this lesion is an essential requisite for its surgical resection. This anatomic information can only be achieved by SPECT/CT (B).

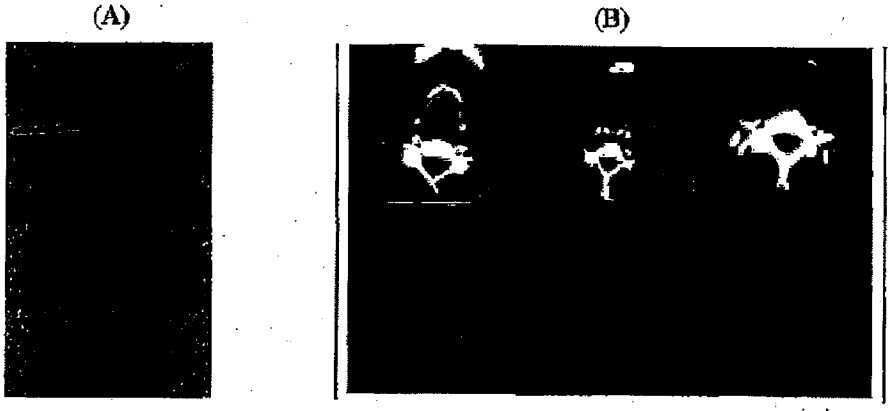

FIG. 2. (A) The planar scan post-radioiodine ablation of thyroid remnants shows radioiodine-avid tissue in the neck of a patient after total thyroidectomy, without the possibility of discriminating ^{131}I uptake in remnant normal thyroid parenchyma from possible lymph node metastasis. (B) SPECT/CT demonstrates two cervical lymph nodes in this patient (arrows) that cannot be differentiated from benign remnant tissue in the planar scan.

Although ^{131}I uptake is quite specific for tissue originating from the thyroid gland, the list of false–positive findings on planar whole body scans is quite long [13]. Only in rare instances, false–positive findings are accounted for by ^{131}I uptake in cancers of non-thyroid origin, such as small-cell bronchial carcinomas. Persisting thymic tissue has been described to concentrate radioiodine and may be the benign correlate of mediastinal ^{131}I accumulation frequently seen in children and young adults. In addition, many false–positive scans are caused by structural abnormalities of organs physiologically excreting radioiodine, or by contaminations of the skin. All such false–positive findings reduce specificity of the scan.

Clearly, ^{131}I uptake in metastases may be mistaken for physiological uptake if it is seen in regions where this usually occurs, thus lowering the sensitivity of ^{131}I scintigraphy. However, probably due to the lack of a reliable gold standard, evidence on sensitivity and specificity of radioiodine scanning is scarce. Furthermore, the recent introduction of ultra-sensitive assays for serum thyroglobulin (a marker of persistent/recurrent disease after surgery and radioiodine ablation of thyroid remnants) is somewhat changing the approach to the follow-up of these patients, especially in the low-risk group [14–18]. Nevertheless, by offering the possibility to precisely localize ^{131}I uptake, SPECT/CT is expected to improve the diagnostic accuracy of radioiodine scanning and therefore to have a significant effect on patient management. As yet two publications have dealt with this issue [12, 19]. Tharp and colleagues retrospectively studied the diagnostic impact of ^{131}I-SPECT/CT imaging in a heterogeneous group of 71 patients with thyroid cancer [12]. In 61 of these, SPECT/CT was used to evaluate the neck, allowing a precise characterization of equivocal lesions on planar imaging in 14/17 patients and changing the assessment of the lesion localization in five patients as compared with planar studies. Thirty-six patients of that group had SPECT/CT for foci of uptake distant from the neck. In this subgroup, SPECT/CT identified equivocal lesions as definitely benign in nine patients. Furthermore, it helped to precisely localize malignant lesions in seventeen patients. The incremental diagnostic value of SPECT/CT was reported to be 57% in the whole group. Ruf et al. investigated the benefit of SPECT/CT hybrid imaging in 25 patients with thyroid carcinoma exhibiting 41 foci of ^{131}I uptake considered inconclusive on planar imaging

[19]. Of these foci, 95% were correctly classified as benign or malignant by hybrid imaging, the gold standard for final classification being represented by clinical follow-up and/or additional ultrasound, CT, or MRI. In the patient based analysis, SPECT/CT was found to change the therapeutic procedure in 25% of the subjects studied.

These pilot studies suggest that diagnostic improvements brought about by SPECT/CT in patients with thyroid carcinoma are considerable. However, considering the variable clinical presentations of differentiated thyroid cancer, validity of the above conclusion should be based on large-scale multi-centre prospective studies enabling stratification of patients into statistically meaningful homogeneous subgroups.

3.2. Neural crest and adrenal tumours

Pheochromocytomas and paragangliomas are chromaffin cell tumours originating from the adrenal medulla and from the paraganglia, respectively. Sympathetic-derived paragangliomas are most frequently located in the retroperitoneum and thorax, while parasympathetic paragangliomas are located near the aortic arch, neck and skull base. These tumours are said to follow in general the 10% rule: approximately 10% are malignant, 10% familial, 10% extra-adrenal, 10% bilateral, and 10% occur in children [20, 21].

Early diagnosis, accurate pre-treatment staging and adequate follow-up are crucial as to the possibility of curing such tumours. Although multi-detector row CT and high-field MRI are reliable for accurate evaluation of these tumours and are usually employed for initial imaging, they are inadequate for whole body assessment (especially MRI).

Radioiodinated metaiodobenzylguanidine (MIBG), an analogue of norepinephrine and guanethidine, was the first radiopharmaceutical capable of specifically depicting and localizing catecholamine-secreting tumours, including pheochromocytomas and paragangliomas. Nowadays, MIBG scintigraphy (generally performed with the ^{123}I labelled radiopharmaceutical) is still regarded as one of the first-choice imaging techniques for diagnosis and follow-up, as it depicts primary and residual or recurrent tumours, as well as metastatic lesions, with an overall accuracy of about 90% [22]. Moreover, in patients with malignant disease, MIBG scintigraphy is an essential step to select patients for ^{131}I-MIBG therapy.

However, the clinical utility of MIBG scintigraphy is often impaired by a lack of accurate anatomical information, in particular with regard to lesion localisation. Nevertheless, the combination of anatomical maps and scintigraphic imaging, as provided by the SPECT/CT hybrid systems, has allowed a significant improvement in localizing MIBG-avid foci (Fig. 3), mainly by more precisely defining the tumoural extension and by increasing specificity (as it permits to exclude disease in foci of tracer uptake identified as sites of physiological accumulation). In this respect, major benefits have been observed in case of tumours located near organs with high physiological tracer uptake, such as liver and myocardium, and when characterizing areas of normal MIBG bio-distribution or excretion, thus avoiding the need for delayed imaging [23, 24].

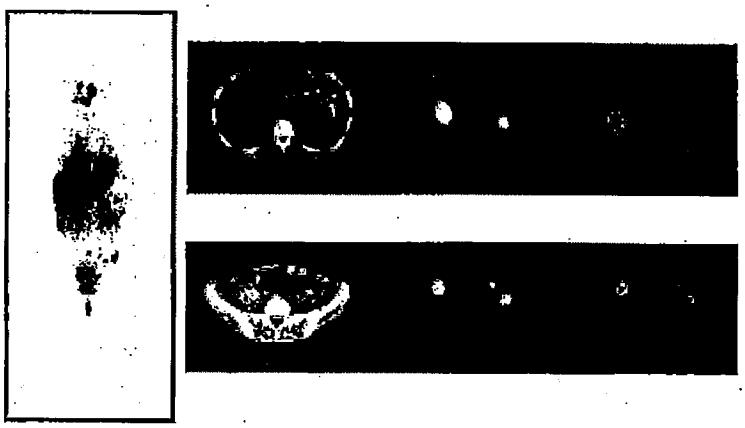

FIG. 3. ^{123}I-MIBG scintigraphy in a 26 year old woman who had undergone laparoscopic left adrenalectomy 5 years earlier because of pheochromocytoma. Despite histological appearance of benign pheochromocytoma, symptoms and biochemical markers of disease recurred, leading to the diagnostic scan. The whole body planar scan (left panel) shows multiple foci of tracer uptake in the abdominal area, most notably in the liver and in other areas suggesting possible lymph node metastases. However, SPECT/CT images (upper and lower right panels) show that such foci represent peritoneal implants rather than visceral or lymph node metastases, possibly secondary to intra-surgical dissemination of benign pheochromocytoma cells.

Ozer et al. have explored the role of fused SPECT/CT imaging for MIBG scintigraphy in a series of 31 patients with suspected pheochromocytoma [25]. In 81% of the cases, fused images correctly characterized the focal tracer uptake detected on planar ^{123}I-MIBG scan as physiological intestinal, renal or hepatic accumulation. Furthermore, SPECT/CT correctly localized focal accumulation in the adrenal glands of four patients and differentiated bone metastases from a local recurrence of pheochromocytoma in two patients. SPECT/CT also discriminated MIBG uptake in a retroperitoneal recurrence from adrenal hyperplasia consequent to contralateral adrenalectomy [26].

Neuroblastomas and ganglioneuroblastomas are poorly differentiated tumours arising from precursors of the sympathetic nervous system that typically occur in infants and young children. Neuroblastoma is the most common extracranial solid tumour of childhood. It may arise anywhere along the sympathetic chain, but most commonly occurs in the adrenal gland, with metastases present in 50–60% of patients at the time of diagnosis. Prognosis is affected by age, site of the primary tumour, and surgical resectability. Ganglioneuroblastomas are transitional tumours of sympathetic cell origin that contain elements of both malignant neuroblastoma and benign ganglioneuroma [21]. The most common tumour sites are the adrenal medulla (35%), retroperitoneum (30–35%), posterior mediastinum (20%), neck (1–5%), and pelvis (2–3%).

MIBG scintigraphy is useful not only for identifying the primary tumours, but also to monitor the pattern of metastatic spread (with an overall 92% sensitivity and 96% specificity) and response to treatment [22]. However, fused SPECT/CT images are expected to further improve its diagnostic accuracy, especially if performed in selected cases, i.e. in patients with inconclusive planar or SPECT imaging with respect to the exact anatomic localization of the lesions detected on the scintigraphy. In particular, given the relatively high frequency of

skeletal metastases in neuroblastomas, SPECT/CT can differentiate between bone and bone marrow involvement. Moreover, hybrid imaging helps to characterize tumour recurrence in close vicinity to the heart or liver, organs with high physiological MIBG uptake. On the other hand, in paediatric patients SPECT/CT may help to clarify the diffuse physiologic tracer uptake in the right heart sometimes misinterpreted as malignant mediastinal, sternal or vertebral sites of tumour involvement [23, 26].

SPECT/CT provides therefore a clinically useful option for localizing sites of abnormal MIBG uptake and for characterizing their benign or malignant nature. In addition to increasing specificity of staging and providing useful anatomic information on surgical resectability, the procedure also has an impact on the selection of patients to be treated with ^{131}I-MIBG.

3.3. ^{111}In-octreotide SPECT/CT for assessing neuroendocrine tumours

^{111}In-octreotide scintigraphy is widely employed to image somatostatin–receptor-positive neuroendocrine tumours. Over the last decades, lesion detection and overall clinical accuracy have improved due to optimized imaging techniques. The currently injected dose of 6 mCi of ^{111}In-octreotide (^{111}In-DTPA-pentetreotide) has doubled as compared to the 3 mCi dose administered in the initial studies. SPECT imaging is now routinely performed.

Neuroendocrine (NE) tumours of the gastrointestinal tract include carcinoid and islet-cell tumours, and surgery is the treatment of choice. Detection of all tumour sites is critical for referring patients to surgery and for its optimal planning. Localization of lesions may be difficult, due to their small diameter and lack of anatomical delineation [27]. The sensitivity of conventional imaging modalities, mainly CT and ultrasound, ranges between 13% and 85%, depending on the type, site and size of the tumour and on the imaging protocol [28].

Many neuroendocrine tumours show an increased expression of somatostatin receptors. A variety of analogues with high binding affinity to somatostatin receptors have been synthesized. One of these is octreotide, an eight amino acid cyclic peptide, with a biologic half-life measured in hours, which is used as an injectable therapeutic agent to inhibit excess secretions from neuroendocrine tumours. Somatostatin receptor scintigraphy is based on the use of octreotide as a carrier of radionuclides for diagnostic imaging or targeting therapy. A tyrosyl moiety in position 3 of the cyclic amino acid ring, the tyrosyl^3-octreotide has been substituted initially with ^{123}I [29]. Since ^{123}I is an expensive and short lived radioisotope, the use of ^{111}In bound to the octreotide molecule, ^{111}In-DTPA-pentetreotide, has been further developed, with the original octreotide eight amino acid molecule covalently bound to DTPA that, in turn, serves to link the radiometal [30].

Diagnosis, staging and follow-up of neuroendocrine tumours have advanced considerably with the advent of ^{111}In labelled pentetreotide scintigraphy. This modality has a reported sensitivity of 82–95%, and can successfully detect previously unknown sites of disease, undetected by conventional imaging techniques, in 30–50% of various NE tumours [31, 32]. Octreotide scintigraphy improves the localization and staging of primary tumours and enables early detection of recurrence [33]. In addition, octreotide scintigraphy facilitates the detection of receptor-dense microscopic foci during radio-guided surgery and is being used to determine if the whole tumour has been resected. Scintigraphy is also being used to define the receptor-status of metastases for octreotide treatment [34–36] or for targeted receptor-mediated radiotherapy [37–39]. It has been previously demonstrated that octreotide scintigraphy induced a change in classification in 24% and in surgical strategy in 25% of

patients with gastro-entero-pancreatic tumours [40], and changed the patient management in 47% of patients with gastrinomas [41].

Despite the valuable contribution of planar and/or SPECT ^{111}In-octreotide scintigraphy to the diagnosis and management of patients with known or suspected neuroendocrine tumours or other processes characterized by the increased expression of somatostatin receptors, the patterns of distribution of ^{111}In-octreotide have raised the need for correlating scintigraphic findings with anatomic imaging results. The overall specificity of scintigraphy may be affected by tracer uptake in physiological sites or in benign conditions. False-positive interpretations may be caused by the high receptor status of normal organs, such as the pituitary gland, thyroid, liver and spleen, or by physiological excretion of the tracer via the kidneys or the bowel. Hepatobiliary excretion, accounting for clearance of 2% of the administered dose, may lead to occasional visualization of the gallbladder which may potentially be misinterpreted as hepatic metastasis [42]. Guidelines for octreotide scintigraphy therefore recommend performing delayed studies that demonstrate changes in tracer kinetics and thus provide the differential diagnosis between benign, physiologic and malignant sites of radiotracer uptake. Neuroendocrine tumours are often localized in the abdomen and it can be difficult to precisely localize a suspicious lesion, or to differentiate whether a focus of abnormal uptake is in the pancreas, small bowel, liver or bone without anatomic correlation. In the region of the liver, it is difficult to distinguish between physiologic gallbladder accumulation versus a lesion in the head of the pancreas, in the right adrenal or in the small bowel.

Octreotide scintigraphy, although highly sensitive, is limited by the lack of precise anatomic localization, and requires correlation with high resolution anatomic imaging modalities in a large number of cases [40, 43]. Side by side interpretation of the two image sets (SPECT and CT) acquired separately, as well as co-registration of separately acquired anatomic (usually CT) and SPECT ^{111}In-octreotide imaging data have been developed. These techniques work quite well for fusion of studies of the brain, as there is no shift of the intra-cranial content from one study to another. In the thorax, there are differences in organ and lesion position depending on respiratory dynamics. Central mediastinal structures have limited excursion so that satisfactory co-registration, although very cumbersome and time-consuming, can be achieved. In the abdomen and the pelvis, there is the potential for significant shift of lesions depending upon patient positioning and variations in stomach, bowel or bladder distension. This represents a challenge for co-registration of separately performed SPECT and CT examinations, even when they are obtained within a close temporal interval, leading to possible mis-alignment of suspicious foci. A software package has been used to fuse helical CT and SPECT images of 28 lesions identified in 10 patients, using either external fiducial markers or internal anatomic landmarks (spleen and kidney contour) [44], and a shift of a few mm in organ location between SPECT and CT has been demonstrated. The use of image co-registration in the preoperative staging of patients with gastro-entero-pancreatic neuroendocrine tumours following ^{111}In-octreotide administration has also been evaluated in 38 patients with 87 lesions [45]. The accuracy of successfully assigning the anatomical location by two independent readers increased from 57% and 61% to 91% and 93%, respectively, using co-registration. Diagnosis and localization of liver metastases to a specific segment improved from 45% and 58% to 98% and 100%, respectively, with relevant information for further therapeutic decisions in 19% of the patients [45]. Nevertheless, the approach of co-registering separately performed octreotide-SPECT and CT studies cannot be considered as the optimal approach for assessment of function and anatomy of neuroendocrine tumours.

SPECT/CT may localize foci of increased tracer activity to normal organs with known physiological activity, without the need for performing delayed scans on additional days. SPECT/CT may also improve image interpretation when the foci of increased tracer uptake can be precisely localized to octreotide-avid benign processes, such as recent surgery or colostomy, increased thyroid uptake in Graves' disease, accessory spleen, parapelvic cyst, benign breast lesions and granulomatous lung disease (e.g. sarcoidosis) [34, 46]. When active malignant disease is diagnosed, SPECT/CT can precisely define the organ involved and determine the presence or absence of invasion into surrounding tissues. Following the diagnosis and localization of neuroendocrine tumours, SPECT/CT may also help in determining the extent of disease, defining it as localized or disseminated, and thus influence the choice of the most appropriate treatment modality [47–49]. When disease is confined to a single organ, a localized mode of organ-specific therapy is suggested, such as surgery or chemoembolization (Figs 4, 5). When a soft-tissue tumour has invaded the adjacent bone, surgery is inadvisable. In extensive, unresectable disease, systemic therapy is required.

Initial studies have shown that SPECT/CT had an impact on patient management in 5 out of 10 patients with neuroendocrine tumours [50]. Further studies have indicated that octreotide SPECT/CT has a specificity of 86% and a positive predictive value of 85% for diagnosis of neuroendocrine tumours, and resulted in a change in management in 3–14% of patients [46, 49]. Pfannenberg et al., in an analysis of 43 patients with neuroendocrine tumours, compared SPECT/CT results to those of SPECT and to high-end CT stand-alone images, histopathology or clinical and imaging follow-up representing the diagnostic standard. Separate SPECT and CT interpretations were in agreement for 56 of 114 lesions overall (49% concordance). For the remaining 58 lesions (51%), consensus readings of the fused SPECT/CT images resulted in a change from the original interpretation of 39 CT and 19 SPECT examinations. Overall, SPECT/CT outperformed significantly both SPECT and high-end CT. The greatest accuracy involved the use of SPECT/CT with side by side availability of high-end CT. In fact, in this report SPECT and side by side high-end CT performed slightly better than SPECT/CT [51]. A preliminary report of ^{111}In-octreotide SPECT/CT in 27 patients with suspected or known neuroendocrine tumours, primarily of the gastro-entero-pancreatic type, indicated that fused images improved the overall diagnostic confidence in 15 of 27 cases [52].

In a large series including 72 patients with neuroendocrine tumours, Krausz et al. evaluated the impact of SPECT/CT on the diagnostic accuracy of octreotide scintigraphy and on further clinical patient management [47]. SPECT/CT improved the study interpretation in 32% of the total study population (52% of the positive studies). SPECT/CT allowed for the precise localization of foci of increased ^{111}In-octreotide activity thereby defining the whole extent of disease in 17 patients, it diagnosed previously unsuspected bone metastases in 3 patients and defined suspicious lesions as sites of physiologic activity, unrelated to cancer, in 3 additional patients. SPECT/CT altered the subsequent management of 10 patients (14%). Results of fused images modified the previously planned surgical approach in 6 patients, spared unnecessary surgery in 2 patients with newly diagnosed involvement of the skeleton, and led to referral of one patient each to liver transplant and to chemoembolization, rather than to systemic therapy.

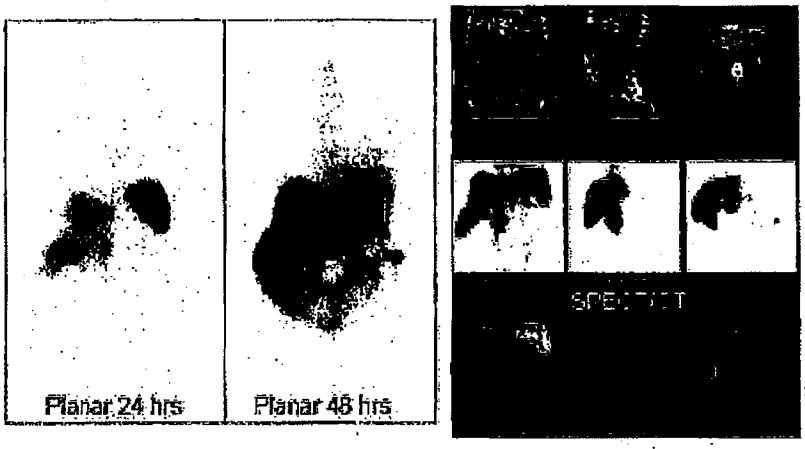

FIG. 4. ^{111}In-octreotide SPECT/CT in duodenal carcinoid. A 56 year old woman with duodenal carcinoid diagnosed following biopsy of a duodenal ulcer was referred for defining extent of disease prior to treatment planning. Whole body planar scans performed at 24 and 48 h after tracer injection are normal. SPECT demonstrates a small focus of abnormal tracer activity in the right mid-abdomen, localized by SPECT/CT fused images to the duodenum, consistent with the known primary tumour. No additional sites of abnormal tracer activity are seen. The patient was referred for surgery.

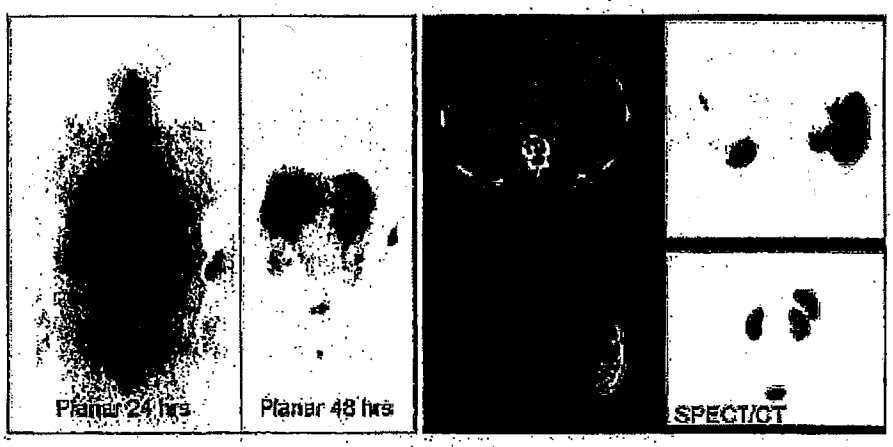

FIG. 5. ^{111}In-octreotide SPECT/CT in pancreatic insulinoma. A 68 year old woman was hospitalized because of severe hypoglycemia. CT indicated a suspicious lesion in the tail of the pancreas. Whole body planar scans performed at 24 and 48 h after tracer injection are normal. SPECT demonstrates a small focus of abnormal tracer activity in the left upper abdomen, in close proximity to the high ^{111}In-octreotide uptake in the spleen. This suspicious lesion is localized by SPECT/CT fused images to the small lesion seen on CT in the tail of the pancreas, consistent with a pancreatic insulinoma. No additional sites of abnormal tracer activity are seen. The patient was referred for surgery.

Octreotide-SPECT/CT provides information regarding the functional status of the tumour, its precise localization and the whole extent of disease. Fused images are therefore useful tools to choose the optimal treatment strategy, mainly in patients with advanced disease. When scintigraphy is negative, SPECT/CT is of no additional value except for verification of receptor density in a tumour visualized on CT. SPECT/CT provides greater accuracy in localization of findings than functional SPECT imaging alone and greater specificity than anatomic CT as a stand-alone procedure.

In summary, despite the favourable impact that ^{111}In-octreotide scintigraphy, particularly SPECT, has had on the diagnosis and management of patients with neuroendocrine tumours, these features improve even further when correlated with anatomic imaging data acquired sequentially during a single imaging session. Criteria for improvement include higher diagnostic sensitivity and specificity, as well as impact on patient management. Thus, it can be concluded that near simultaneous acquisition of both CT and SPECT image sets (hybrid SPECT/CT) represents the state of the art for diagnostic ^{111}In-octreotide imaging of neuroendocrine tumours.

3.4. ^{67}Ga-citrate SPECT/CT in lymphoma

^{67}Ga-citrate scintigraphy has long been shown to be useful for evaluating patients with lymphoma, and SPECT/CT has further improved its diagnostic sensitivity as well as localization of areas with abnormal tracer uptake [53]. In particular, SPECT/CT proved to be very helpful for distinguishing spinal lesions from adjacent nodal involvement. It was also able to clarify the tracer uptake at the edges of the lower chest, projecting over the hepatic dome, ribs or sternum. Furthermore, SPECT/CT imaging has been shown to provide additional information or diagnosis from CT-detected abnormalities leading to significant change in patient's management [54].

3.5. Lymphoscintigraphy

Accurate lymph node staging is essential for the treatment and prognosis in patients with cancer. The sentinel lymph node is the first node to which lymphatic drainage and metastasis from the primary tumour occur. Procedures for sentinel lymph node detection and biopsy have already been implemented into clinical practice [55, 56]. Precise anatomic localization of the sentinel lymph node is critical for minimally invasive surgery and to avoid incomplete removal of the sentinel node, especially in the regions of the head and neck, the chest and the pelvis.

In the head and neck the lymphatic drainage is in the levels I through VII. A node in level I-A is in the subdigastric muscle area, and a node in level I-B is in the submandibular area. A node in level II-A is anterior to the sternocleidomastoid (SCM) muscle, and a node in level II-B is adjacent to the SCM muscle. Nodes in level II are above the hyoid bone. A node in level III is adjacent to the SCM muscle, between the hyoid bone and the cricoid cartilage. A node in level IV is adjacent to the SCM muscle below the cricoid cartilage. A node in level V-A is behind the SCM muscle above the cricoid cartilage, and a node in level V-B is behind the SCM muscle below the cricoid cartilage. A node in level VI is in the anterior middle neck between bilateral SCM muscles, and a node in level VII is in the superior mediastinum.

Axillary lymph node levels are level I (low) lateral to the pectoralis minor (PM) muscle, level II (mid) behind the PM muscle, and level III (high) medial to the PM muscle.

The resection of external iliac *versus* inguinal lymph nodes requires significantly different surgical approaches, and thus precise preoperative localization is crucial for optimal surgical approach. A node above the level of the inferior epigastric artery which is anterior and lateral to the bladder base is an external iliac node, and the nodes below the inferior epigastric artery are inguinal nodes, further subdivided into superficial and deep ones by the sapheno-femoral venous junction.

Only SPECT/CT imaging can precisely locate the sentinel lymph node since CT images provide critical anatomical landmarks such as the hyoid bone, cricoid cartilage, SCM and PM muscles, inferior epigastric artery and sapheno-femoral venous junction.

SPECT/CT increases the sensitivity and specificity of lymphoscintigraphy, and also provides the additional diagnostic information from the CT images [57–62]. A standard dose of 0.5 mCi ^{99m}Tc labelled colloid (5–80 nm) is injected intradermally around the melanoma lesion, interstitially around the breast cancer lesion and subcutaneously around other tumours. SPECT/CT is usually obtained immediately after identifying drainage of the activity on serial planar images (Fig. 6).

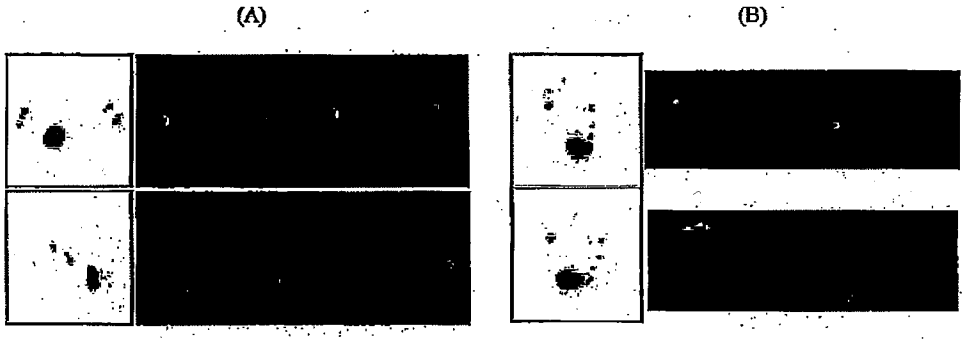

FIG. 6. Additional information over planar scintigraphy provided by SPECT/CT in two patients with malignant cutaneous melanoma submitted to lymphoscintigraphy with ^{99m}Tc-albumin nanocolloid before radioguided sentinel lymph node biopsy. (A) Left panels show the planar posterior (top) and left lateral (bottom) views in a patient with melanoma located on her back: multiple bilateral lymph nodes can be detected, without however clear reference to precise anatomic structures. Right panels show SPECT/CT tomographic sections at different levels, demonstrating bilateral lymphatic draining to both axillary (top) and subscapular (bottom) lymph nodes. (B) Left panels show the planar right oblique (top) and anterior (bottom) views in a patient with melanoma located on his anterior right chest: multiple lymph nodes can be detected, without however clear reference to precise anatomic structures. Right panels show SPECT/CT tomographic sections at different levels, demonstrating lymphatic draining to both axillary and internal mammary chain lymph nodes

3.6. Skeletal scintigraphy for staging malignant disease

Scintigraphic imaging of bone metabolism is a cost efficient way to prove or exclude skeletal metastases in patients with tumours prone to metastasize to the skeleton, such as breast, prostate, or lung carcinomas [63]. Therefore, bone scintigraphy is included in the majority of guidelines addressing management of these neoplastic conditions in many countries and is one of the most frequently performed radionuclide imaging procedures performed worldwide.

In a recent study comparing the diagnostic accuracy of ^{99m}Tc-phosphonate skeletal scintigraphy to that of [^{18}F]FDG-PET in patients with thyroid carcinoma [64], sensitivity of the conventional procedure was not significantly different from that of [^{18}F]FDG-PET. However, its specificity was significantly worse. This result can be considered representative also of other tumours and is not at all unexpected, since there are several highly prevalent benign conditions leading to focally increased uptake of the radiolabelled phosphonates in the skeleton. Most of these conditions reflect degenerative processes of the joints increasing in frequency with age, such as spondylarthrosis or coxarthrosis. Additional benign causes of enhanced uptake are rheumatic disease or benign bone tumours.

Since most of these benign conditions are readily identifiable on CT, SPECT/CT is expected to improve specificity of skeletal scintigraphy without reducing its sensitivity. Besides single case reports illustrating this assumption, several prospective studies have investigated this issue.

In 2004, Horger et al. demonstrated significantly increased specificity when using SPECT/low-dose non-spiral-CT for classifying 104 lesions in 47 subjects exhibiting indeterminate findings on conventional planar imaging [65]. This study is particularly valuable considering that the reference gold standard for final classification of lesions was either histological confirmation or extended clinical follow-up, and thus independent from the results obtained by SPECT/CT.

Römer et al. employed a SPECT/CT camera equipped with a two slice spiral-CT for classifying 52 lesions in 44 patients, defined as indeterminate on SPECT imaging [6]. These authors reported that SPECT/CT enabled correct classification of the scintigraphic abnormalities in 92% of the subjects studied.

Utsunomiya et al. used a hardware set-up comparable to that of a hybrid SPECT/CT camera, by transferring the patient positioned on the same table in an identical position from a stand-alone SPECT camera to a gantry of an 8 slice CT [66]. By studying 45 patients and based on receiver-operation curve (ROC) analysis, they confirmed the significant increase in diagnostic accuracy brought about by co-registration of these two modalities. Furthermore, they also showed that co-registration performs significantly better than side by side viewing of the two sets of images (SPECT and CT, respectively) on the same workstation.

Considering the evidence summarized above, one cannot but conclude that skeletal SPECT/CT is the new imaging gold standard when searching for osseous metastases and that for this purpose conventional scintigraphy becomes obsolete (Fig. 7). Unsettled issues include the quality of the CT integrated into the hybrid system needed for this purpose, as well as the relative diagnostic accuracy of this approach compared to whole body MRI and PET using [^{18}F]FDG or ^{18}F-fluoride. Although these options appear attractive, a cost effectiveness analysis might strengthen the role of SPECT/CT in this context.

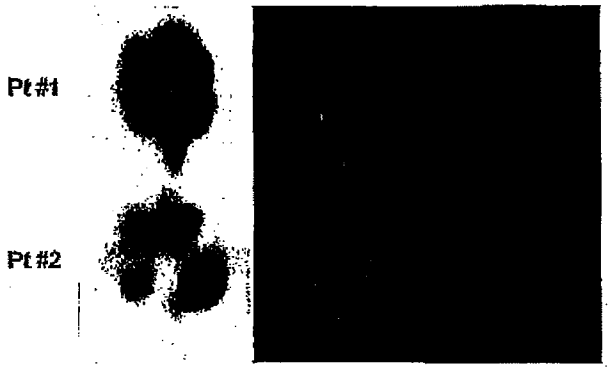

FIG. 7. The upper row shows SPECT, CT, and fused images of a lumbar vertebra in a patient with breast cancer (Pt #1). In this patient, increased uptake of ^{99m}Tc-MDP is due to arthrosis of the facet joint. The lower row depicts similar images in another breast cancer patient (Pt #2). Although the SPECT appearance of the lesion is quite similar to that in Pt #1, the CT overlay proves it to be a small osteolysis.

3.7. Skeletal SPECT/CT in orthopaedics

Up until approximately 20 years ago, planar X ray and skeletal scintigraphy were the imaging procedures of choice in patients with benign orthopaedic disease. Although MRI has brought a dramatic change to the predominance of radionuclide imaging in this field, skeletal scintigraphy still holds the promise of sensitively depicting functional alterations of bone. However, difficulties in precisely localizing abnormalities of bone metabolism relative to the complex anatomy of the skeleton have greatly weakened its clinical role, despite its much lower costs than MRI.

In principle, SPECT/CT would be suited to overcome these problems as demonstrated in several case reports (Fig. 8) [67]. However, so far only one study has systematically studied the clinical benefit of SPECT/CT in orthopaedic disease [68]. Using a SPECT/multi-slice non-spiral CT, Even-Sapir et al. analysed skeletal image data from 89 consecutively studied, non-oncological patients. These patients had non-specific lesions on planar skeletal scintigraphy for which correlation with morphological imaging was considered necessary. The indications for radionuclide bone imaging were pain in 61, prior trauma in 7, suspected infection or inflammation in 6, and fever of unknown origin in the remaining 2 patients. Gold standard for final classification was consensus opinion among the readers, and this represents a possible limitation of the study since it was not independent from SPECT/CT itself. Hybrid imaging enabled a definite diagnosis to be reached in 59% of the patients studied, obviating the need to perform additional imaging. In another 30% of patients, SPECT/CT provided information relevant for their further diagnostic workup. The authors therefore concluded that SPECT/CT is a clinically relevant component of the diagnostic process in patients with non-oncological disease referred for bone scintigraphy.

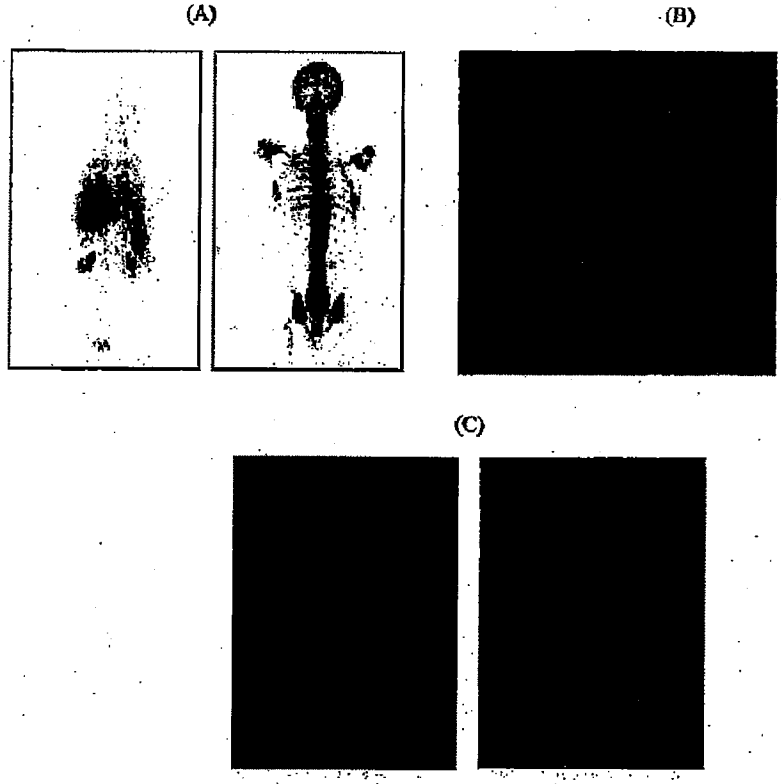

FIG. 8. (A) Early (left panel) and late (right panel) posterior planar skeletal scintigrams of a 74 year old patient after recent trauma, showing enhanced uptake of ^{99m}Tc-MDP in a vertebral body of the lower thoracic spine. 3-D-volume rendering of the SPECT/CT fusion (B) shows that the lesion is in the twelfth vertebral body. The inspection of the fused tomograms (C) proves it to be a fracture; moreover, the one-stop shop examination discloses it to be unstable since the posterior corticalis is involved, thus motivating immediate surgery.

3.8. ^{201}Tl-chloride in cerebral masses

The diagnosis of a postoperative residual brain tumour is a challenging clinical problem, since both contrast-enhanced CT and T1-weighted MRI after surgery are difficult to interpret while precise diagnosis is needed for planning radiation therapy. Likewise, in HIV infected patients, the differential diagnosis between primary lymphoma and cerebral toxoplasmosis is often problematic.

Thallium is a metallic monovalent cationic element in group III-A of the periodic table of elements. ^{201}Tl is cyclotron-generated and is administered in the form of thallous chloride. The cellular uptake of ^{201}Tl after i.v. administration depends on both blood flow and the cellular extraction fraction, which mainly occurs via the Na^+/K^+-ATPase active transport membrane pump in viable cells. A minor fraction of ^{201}Tl uptake is also related to co-transport system, calcium ion channel system, vascular immaturity with 'leakage', and increased cell membrane permeability. Tumour cells have shown greater ^{201}Tl uptake than normal

connective tissue or inflammatory cells. In primary brain tumours alterations in the blood-brain barrier play a key role in ^{201}Tl accumulation [69].

In normal subjects little ^{201}Tl activity is seen in the cerebral substance, since ^{201}Tl cannot pass the blood-brain barrier and diffuse into the brain tissue. Conversely, high radioactivity is seen in the orbits, the base of the skull and nasopharyngeal region, and around the scalp. There are no significant differences between early (10 minutes) and delayed (3 hours) images. In case of brain haematoma, ^{201}Tl uptake seen in early images significantly decreases on delayed scans [70].

Postoperative ^{201}Tl SPECT demonstrated a significantly better accuracy than contrast-enhanced CT in detecting residual tumour in 33 patients [71]. Actually, disruption of the blood-brain barrier during the postoperative period often leads to uncertainty in CT interpretation. Co-registration and fusion of ^{201}Tl SPECT with CT could thus optimize postoperative radiation therapy planning through a truly anatomo-metabolic image.

^{201}Tl SPECT has also been seen to be useful for differentiating brain tumour recurrence from radiation necrosis or gliosis after radiotherapy, with more reliable information than CT and MRI in identifying progression, improvement or no change in brain tumours in follow-up studies [72, 73].

Because ^{201}Tl does not accumulate in normal brain parenchyma, anatomical localization of increased tracer uptake is difficult. Registration and fusion with anatomical images facilitates this task during the clinical workup of patients with brain tumours [74]. Appropriate attenuation correction based on the CT transmission data could also help in the reconstruction of ^{201}Tl SPECT images, which will further improve image contrast and detectability of areas of increased uptake, leading to a higher sensitivity of ^{201}Tl imaging, particularly for infratentorial and small size tumours. Until now, physicians have relied mainly on their spatial sense to mentally reorient and overlap ^{201}Tl images with the anatomic data. This approach is inconsistent and highly subjective and can yield suboptimal results because it does not take full advantage of all the available information [74]. Image fusion allows accurate determination of the anatomic sites of normal and abnormal uptake (Fig. 9). The precise localization of ^{201}Tl accumulation is essential to guide the choice of biopsy site (conventional or stereotactic), in an effort to decrease the potential for tissue sampling error in the pathologic specimen, or for planning radiosurgery [75]. Moreover, the accurate assessment of ^{201}Tl uptake can be of significant value after surgical and/or radiotherapy treatment in planning further therapeutic strategies, such as additional surgery or radiotherapy, because CT and MRI are often unable to distinguish residual tumour from post-therapy changes. Fused images can also help in optimizing the treatment specifically to the viable malignant tissue and in the early diagnosis of recurrence during follow-up.

3.9. ^{99m}Tc-depreotide in solitary pulmonary nodules

The characterization of solitary pulmonary nodules (SPNs) represents an important clinical problem because, although they may be caused by many benign conditions, bronchogenic carcinoma is being increasingly identified as one of the main etiologies, especially in the elderly. Survival rate at 5 years may be ≥80% in patients with resected malignant SPN, while it is <5% for patients with advanced malignant disease. Ideally, diagnostic approaches to SPN would permit definitive resection when possible and avoid resection in patients with benign disease [76].

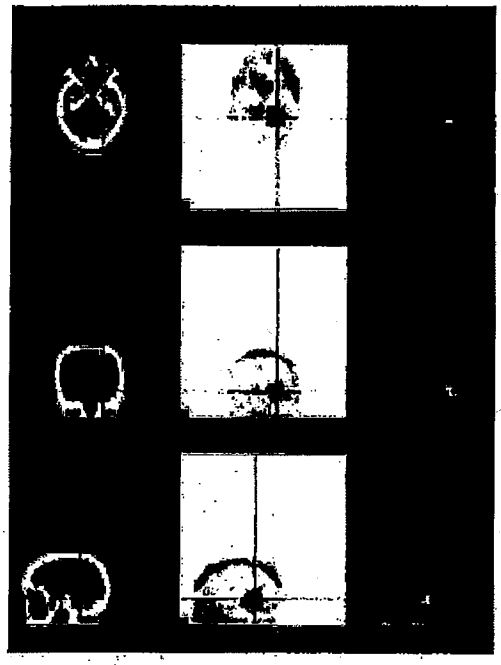

FIG. 9. SPECT/CT performed after administration of ^{201}Tl-chloride in an HIV infected patient referred for differential diagnosis between primary lymphoma and cerebral toxoplasmosis. ^{201}Tl accumulation in the left hemi-cerebellum supports the diagnosis of primary lymphoma.

Depreotide is a synthetic cyclic peptide, an analog of somatostatin, that binds with high affinity to somatostatin receptors 2, 3, and 5. Radiolabelled with ^{99m}Tc, this agent has successfully been used for SPN imaging [77]. In fact, ^{99m}Tc-depreotide has been approved by the US Food and Drug Administration for the noninvasive differentiation of SPN, and it represents a cost effective alternative to [^{18}F]FDG-PET in this application [78]. ^{99m}Tc-depreotide SPECT and [^{18}F]FDG-PET have demonstrated the same specificity (86%) for small (up to 1.5 cm), and equal sensitivity (92%) for large (more than 1.5 cm) SPNs [79]. The role of ^{99m}Tc-depreotide in staging patients with non-small cell lung cancer is still under investigation, although an elevated number of false–positive results have been reported in the hilar/mediastinal regions due to nonspecific tracer uptake [80, 81]. SPECT/CT may help image interpretation by improving specificity at diagnosis and staging and by differentiating physiologic activity (parahilar mediastinal region, bone marrow uptake in the spine, ribs and sternum) from malignant uptake in the primary tumour or into metastatic lymph nodes (Fig. 10). Additionally, the improvement in image quality by the use of X ray based attenuation-correction could increase the detection rate of smaller nodules.

3.10. ProstaScintigraphy

Functional or molecular imaging of prostate cancer presents a challenging problem because of the deep anatomical location of the prostate gland in the pelvis, which causes significant attenuation and scattering problems. Patient's movement, changes of the prostate volume, as well as changes in the shapes and contents of the rectum or bladder during imaging can further exacerbate the problem in image-fusion multimodality imaging visualization of the prostate.

FIG. 10. Transaxial, coronal, and sagittal tomograms of SPECT/CT imaging obtained after injection of ^{99m}Tc-depreotide in a patient with a solitary pulmonary mass occasionally discovered on chest X ray. Intense tracer uptake indicates malignancy, while the fused SPECT/CT images suggest that, while there is no extension of the tumour to infiltrate the chest wall, there is possible involvement of the pericardium.

The overall diagnostic accuracy of imaging using 5 mCi ^{111}In-ProstaScint (monoclonal antibody against the prostate-specific membrane antigen) has been reported to be 76%, with 44% sensitivity and 86% specificity relative to histologic findings [82, 83]. Increased accuracy of the ProstaScint scan for diagnosis of prostate cancer has been reported when fusing SPECT images with either CT or MRI [84, 85]. In addition, ProstaScint imaging can be applied to guide brachytherapy or intensity-modulated external-beam radiation therapy [86], as well as radioimmunotherapy using ^{90}Y-capromab pendetide for recurrent prostate cancer [87].

3.11. SPECT/CT in the preoperative localization of parathyroid adenomas

Parathyroid scintigraphy with ^{99m}Tc-sestamibi (employed either as a single-tracer, dual-phase protocol or in combination with other tracers with exclusive uptake in the thyroid for subtraction imaging) is critical for preoperative localization of parathyroid adenomas, especially in the perspective of applying mini-invasive parathyroid surgery [88–90]. Even before the introduction of hybrid SPECT/CT instrumentation into clinical routine, stand-alone SPECT procedures had already demonstrated clear superiority to planar ^{99m}Tc-sestamibi scintigraphy for imaging and localizing parathyroid adenomas, especially when planning the best surgical approach to ectopic adenomas, mainly located in the mediastinum [91–98].

However, because of the paucity of anatomic landmarks in pure SPECT images, some form of multimodality co-registration often turned out to be useful for better localization of adenomas relative to critical anatomic structures, such as those available through side by side viewing with, e.g. CT images or by post-acquisition image fusion. Useful complementary information as to location of ectopic parathyroid adenomas can also be derived by sequential acquisition, after ^{99m}Tc-sestamibi scintigraphy, of scintigraphic images obtained by injecting a second tracer, e.g. an intravascular indicator such as radiolabelled albumin or red blood cells, to identify the topographic relationships of adenomas with the principal vascular structures [88].

The recent growing-scale implementation of hybrid SPECT/CT equipments has dramatically improved this scenario, by enabling simultaneous acquisition and accurate single hardware

co-registration of functional images (derived from ^{99m}Tc-sestamibi scintigraphy) and of the corresponding morphologic images (derived from CT). Thus, it can be concluded that, at present, SPECT/CT represents the state of the art in preoperative localization of parathyroid adenomas, especially in cases of ectopic location and in the presence of concomitant multinodular goiter (Fig. 11). In all these conditions the localizing performance of SPECT/CT is clearly superior to both planar scintigraphy and stand-alone SPECT.

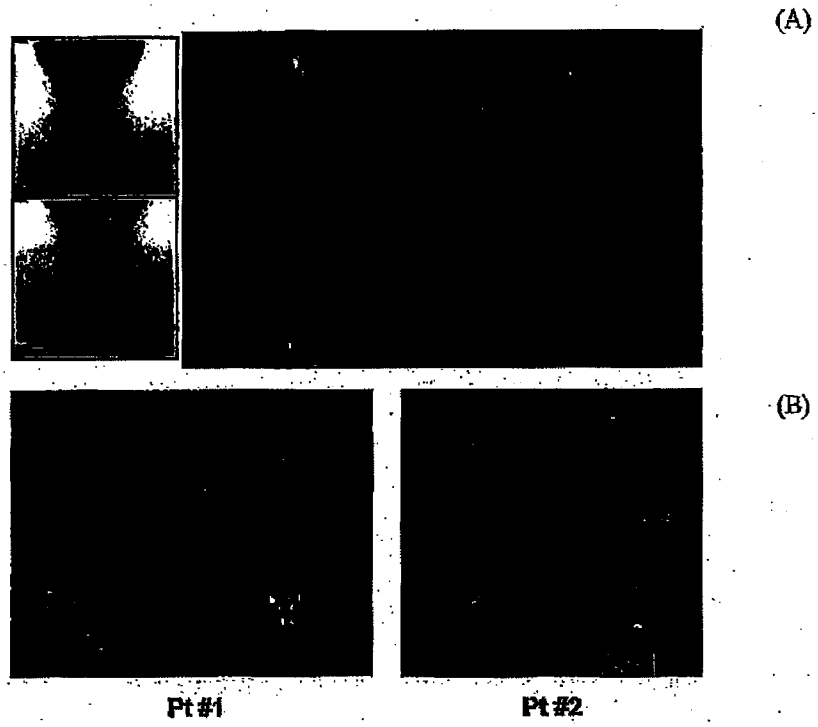

FIG. 11. Patients with parathyroid adenomas in whom hybrid SPECT/CT imaging turned out to be crucial for accurate preoperative localization and for planning the most adequate surgical approach. (A) Early (top left) and delayed (bottom left) planar ^{99m}Tc-sestamibi scans in a patient who had undergone unsuccessful parathyroid surgery during which the left thyroid lobe was also resected because of concomitant nodular goiter (persistent primary hyperparathyroidism despite removal of an enlarged parathyroid gland ectopically located in the anterior mediastinum that had been identified on a planar ^{99m}Tc-sestamibi scan). While both scans (left panels) are negative for parathyroid adenoma, SPECT/CT imaging (right panel) enabled to identify abnormal tracer uptake located posteriorly to the trachea. (B) Two patients in whom SPECT/CT imaging with ^{99m}Tc-sestamibi localized hyperfunctioning parathyroid adenomas and led to plan the optimal surgical approach for their successful resection. In Pt #1 the adenoma was located adjacent to the right wall of the trachea, while in Pt #2 the adenoma was located in the anterior mediastinum.

An early report by Gayed et al. suggested that SPECT/CT had a significant impact on surgical management of patients in only a limited fraction of patients (5 out of 48 cases in their experience), and considered therefore that the added value of CT (with the related radiation exposure) did not justify the routine application of the procedure, except perhaps in patients with ectopically located adenomas [99]. However, more recent reports emphasize the impact of SPECT/CT compared to planar and/or SPECT scintigraphy (either as a stand-alone imaging or as side by side viewing with the corresponding CT images) on surgical

management of patients. This conclusion has been reached by Krausz et al. who report a change in the surgical approach in 10/33 ectopic and 4/23 orthotopic parathyroid adenomas [100].

Similarly, Serra et al. have shown that SPECT/CT improves preoperative localization of parathyroid adenomas, with significant surgical impact in 39% of the cases [101]. In their patients, SPECT alone correctly localized 14/23 parathyroid adenomas (61%), while SPECT/CT correctly localized all 23 lesions (100%, 14 of which were ectopically located). Furthermore, SPECT/CT was crucial in demonstrating the retrotracheal location of an adenoma in three patients. Better performance of SPECT/CT versus planar or stand-alone SPECT has also been reported by Lavely et al. [102], while Ruf et al. have emphasized in particular the role of SPECT/CT for attenuation correction of the SPECT data based on the CT transmission data [103].

In conclusion, image fusion as obtained by hybrid SPECT/CT imaging with ^{99m}Tc-sestamibi is of value for surgical planning in both primary and secondary hyperthyroidism [104]. Concerning in particular secondary hyperparathyroidism, it is crucial that all parathyroid tissue showing ^{99m}Tc-sestamibi uptake is removed, because these parathyroid glands are those responsible for the increased production of parathyroid hormone. When relying only on visual inspection of the surgical field, in the absence of functional information some simply hyperplastic (but not hyperfunctioning) parathyroid glands might be removed unnecessarily. Wider clinical expertise using the hybrid SPECT/CT technology will certainly have a relevant impact in this field.

3.12. SPECT/CT for diagnosing infection and inflammation

Infection and inflammation can represent a major diagnostic challenge for physicians. Diagnosis and precise delineation of infectious foci may be critical in certain clinical scenarios and render decisions concerning further patient management problematic [105, 106].

Both morphologic and functional imaging modalities have been extensively employed for diagnosing and monitoring infections. CT and MR images provide high-quality anatomic details. However, the structural abnormalities underlying the infectious process are, in some cases, non-specific or appreciable only in a subacute or late phase of the disease. Nuclear medicine has gained a crucial role in the evaluation of patients suspected of harbouring infection, especially because of its capability of demonstrating physiologic processes and metabolic changes that often precede anatomic changes by several days or even weeks [106–123].

Although a variety of new radiopharmaceuticals have been explored as to their ability to detect and localize infectious and inflammatory processes, ^{67}Ga-citrate scintigraphy and scintigraphy with ^{111}In- or ^{99m}Tc-HMPAO labelled autologous white blood cell (WBC) remain the functional imaging techniques of choice for diagnostic work-up of infection [105].

However, both ^{67}Ga-scintigraphy and WBC-scintigraphy suffer from poor spatial resolution and somewhat low specificity because of the absence or paucity of anatomic landmarks. These limitations make precise localization and characterization of areas with focal abnormal tracer uptake problematic, even when employing SPECT imaging. At least part of these difficulties can be overcome when contemporary CT images are available, by either side by side viewing

and, even better, by software based image fusion analysis [124, 125]. However, similar as with other scintigraphic applications, the introduction into clinical routine of integrated SPECT/CT scanners for combined anatomic and functional imaging has offered new opportunities for infection imaging, especially for facilitating precise anatomic localization and accurate characterization of infectious foci [2].

Recent reports have explored the contribution of SPECT/CT to a more accurate interpretation of WBC-scintigraphy for an array of clinical indications in different regions of the body, by distinguishing normal physiologic distribution of labelled WBCs from accumulation due to underlying infection. Major advantages have been observed for infectious processes with thoracic or abdominal localization, because of the potential difficulty of characterizing foci of WBC accumulation near the major vessels. In such cases, the hybrid technology helps in discriminating blood-pool activity from infectious sites, with substantial benefits for the evaluation of suspected vascular graft infection and fever of unknown origin [126].

Moreover, SPECT/CT with ^{99m}Tc-HMPAO-WBC can be very useful to image bone and joint infections, by allowing accurate localization of labelled WBC accumulation. In particular, in some cases of bone infection with adjacent soft-tissue involvement, while planar images alone are not able to distinguish soft tissue from bone, hybrid imaging is able to localize additional sites of leukocyte uptake in neighbouring soft tissue and to precisely define the extent of infection, thus modifying clinical patient management and therapeutic approaches in several cases.

After traumatic injury, skeletal changes can often be observed in morphologic imaging (i.e. CT or radiography). Although fusion imaging with a hybrid camera can improve the diagnostic accuracy of SPECT, it cannot be a substitute for conventional high resolution CT, which maintains its diagnostic role in most clinical situations. However, with regard to bone imaging, reports show that even the low-dose CT of the hybrid device may provide sufficient diagnostic anatomic information.

In this regard, Filippi and Schillaci have recently evaluated the usefulness of SPECT/CT for interpreting ^{99m}Tc-HMPAO-WBC scintigraphy in 15 patients with suspected osteomyelitis and 13 patients with suspected infection of orthopaedic prosthesis [127]. SPECT/CT fusion correctly characterized and localized the site of labelled WBC uptake in all patients with osteomyelitis, discriminating soft tissue from bone and having a substantial impact on the clinical management. Moreover, among patients with suspected infection of orthopaedic implants, SPECT/CT offered a more accurate anatomic localization of the site of infection than SPECT alone allowing differentiation between prosthesis and soft-tissue uptake. The authors concluded that hybrid imaging provided additional anatomic information on all patients with positive scan results (64.2%) leading to a more accurate definition of the extent of infection with significant impact in decisions therapeutics. In particular, major benefits were achieved for the diagnosis of relapsing osteomyelitis in patients with structural bone abnormalities after trauma.

Although ^{67}Ga-citrate has been used for scintigraphic imaging of infection and inflammation for many decades, its bio-distribution (with high accumulation in the gastrointestinal tract) and its sub-optimal physical emission characteristics result in a relatively poor imaging quality, making interpretation of abdominal imaging quite problematic. In an attempt to improve the quality of ^{67}Ga-citrate imaging, Bar-Shalom et al. have explored the added value provided by hybrid SPECT/CT imaging as an adjunct to ^{67}Ga-scintigraphy (in 47 patients)

and to ^{99m}Tc-HMPAO-WBC scintigraphy (in 31 patients) [126]. The contribution of SPECT/CT was analysed on a patient- and site-basis and was compared for the two tracers and for various clinical indications. SPECT/CT provided an additional contribution for diagnosis and localization of infection in 48% of the patients and in 47% of the sites. Although SPECT/CT, because of its capability to localize abdominal uptake within the bowel, enabled the correct exclusion of infection in four patients undergoing ^{67}Ga-scintigraphy, the investigators found that the clinical added value of SPECT/CT was significantly higher for WBC-scintigraphy than for ^{67}Ga scanning (63% versus 36% of patients). This data can be explained by the high specificity of WBC, with low background activity and therefore limited anatomic information.

New agents such as radiolabelled anti-granulocyte monoclonal antibodies, radiolabelled ciprofloxacin, radiolabelled biotin, may benefit from hybrid imaging, as reported in some preliminary studies. Biotin (or vitamin H) is utilized by growing bacteria at the site of infection according to the rate of their metabolism. This feature is the basis for the successful utilization of ^{111}In-biotin for imaging infection, especially in difficult to interpret conditions such as the spondylo-discitis. However, since Biotin does not appreciably accumulate in normal bone and/or bone marrow, the exact identification of the vertebral body harbouring infection can be problematic. Therefore, in order to improve diagnostic accuracy and to differentiate between vertebral and soft tissue paravertebral infection, SPECT/CT acquisitions may be performed. In a preliminary study, Lazzeri et al. have investigated the role of ^{111}In-biotin SPECT/CT in 70 patients with suspected spinal infection [128], and have thus confirmed the high diagnostic potential of one-step ^{111}In-biotin hybrid imaging. Moreover, these authors demonstrated that SPECT/CT imaging allows accurate evaluation of spinal infection differentiating between vertebral and soft tissue paravertebral involvement.

Other radiopharmaceuticals, such as ^{99m}Tc labelled anti-granulocyte antibodies (AGA), are known to be highly sensitive and specific for diagnosing infectious disease, but image analysis and exact anatomical definition of the infectious foci is often difficult. In a series of 27 patients with suspected chronic post-traumatic osteomyelitis, Horger et al. have evaluated the value of fused SPECT/CT imaging after injection of ^{99m}Tc-AGA [129]. All patients underwent planar and SPECT/CT imaging studies 4 h and 24 h after injection. The authors found high sensitivity (100%) for both planar and SPECT/CT imaging, associated however with different results in terms of specificity (78% for planar versus 89% for SPECT/CT). SPECT/CT correctly localized all abnormal foci of tracer uptake detected on planar and SPECT images, and also enabled accurate discrimination between soft-tissue infection, septic arthritis, and osteomyelitis.

Although the potential of fused SPECT/CT imaging in infectious and inflammatory disease has not yet been fully elucidated and further validation is required, hybrid imaging provides precise anatomic localization with significantly improved diagnostic accuracy over planar or SPECT alone (Figs 12–14). These new techniques, in conjunction with the use of highly specific radiotracers for detection of inflammatory disease, are creating a whole new and powerful armamentarium for diagnosing infectious foci.

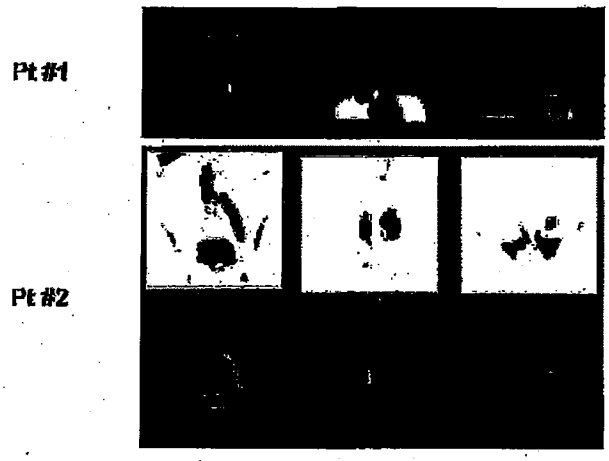

FIG. 12. Patients with cardiovascular infection imaged with autologous ^{99m}Tc-HMPAO-leukocytes and SPECT/CT. Although the most likely site of endocardial infection in Pt # 1 was expected to be a mitral valve implant (visible on the CT component of the examination), SPECT/CT correctly identified the tricuspidal valve as the actual site of infection (top panel). In Pt #2 (previously submitted to implant of aorto-bis-iliac vascular prosthesis), SPECT/CT defined the extent of infection as involving only the left side of the vascular graft (bottom panel).

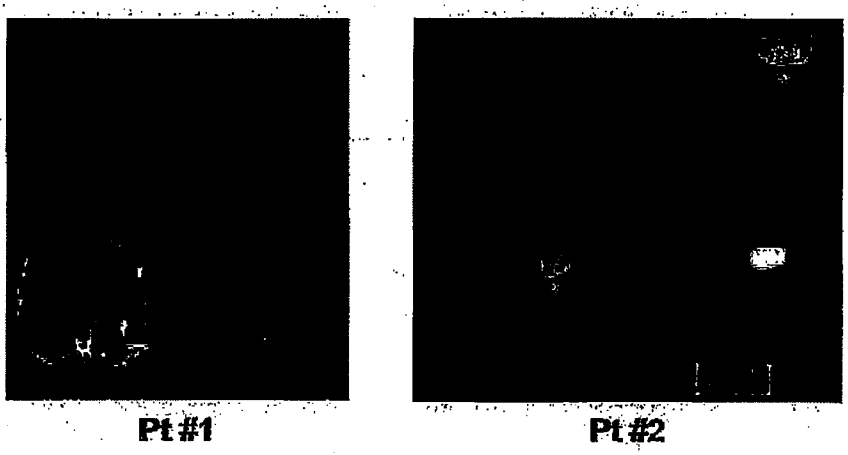

FIG. 13. Patients with infectious foci in the abdominal area. Pt # 1 (left panel) developed persistent fever resistant to antibiotic treatment shortly after combined pancreasectomy and splenectomy, performed because of a pancreatic adenocarcinoma of the tail infiltrating the splenic hilus. SPECT/CT performed as part of autologous ^{99m}Tc-HMPAO-leukocyte scintigraphy reveals a sub-diaphragmatic abscess at the tip of the draining catheter that had been placed during surgery. Pt #2 (right panel) had instead fever of unknown origin. During autologous ^{99m}Tc-HMPAO-leukocyte scintigraphy, it is only SPECT/CT that reveals location of an abscess at the upper pole of the left kidney, which on planar scan could only be generically located below the lower pole of the spleen.

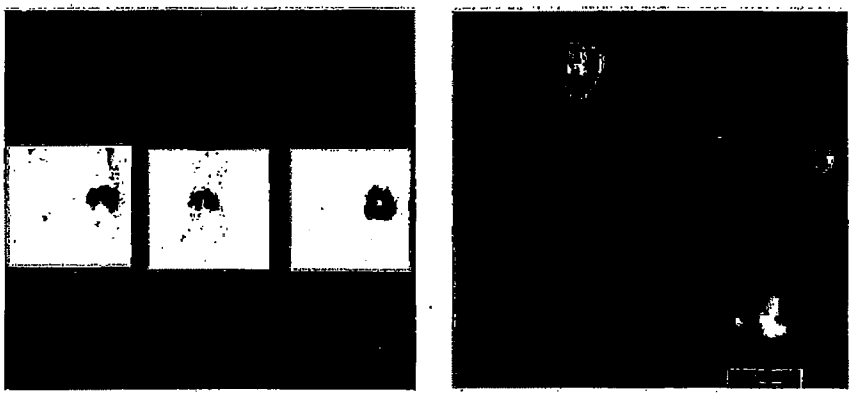

FIG. 14. Patients with different forms of osteomyelitis, with accurate definition of the extent of infection by SPECT/CT. Post-traumatic osteomyelits of the left ankle in Pt #1 (left panel), imaged after injection of ^{99m}Tc-anti-granulocyte antibody. In Pt #2 (right panel) SPECT/CT performed during autologous ^{99m}Tc-HMPAO-leukocyte scintigraphy demonstrates that infection arising in a diabetic foot involves not only the soft tissue but also bone structures. Such accurate localization of the disease process was problematic not only on planar scintigraphy but also on stand-alone SPECT.

3.13. Cardiac SPECT/CT procedures

3.13.1. Myocardial perfusion imaging — CT based attenuation correction

Myocardial perfusion imaging (MPI), using ^{201}Tl and ^{99m}Tc labelled radiopharmaceuticals for stress/rest SPECT studies is at present the main non-invasive modality for evaluation of coronary artery disease [130]. Its accuracy is, however, limited by image artefacts that can cause false–positive perfusion defects and therefore reduce the test specificity. Although the initial validation of MPI-SPECT performed in luminary sites reported a specificity of greater than 90%, further large-scale clinical use of the technique has been associated with specificity in the range of 60% or lower [131, 132]. One of the most common image artefacts is caused by non-uniform reduction of photon activity from attenuation by soft tissue. This can be recognized, or at least suspected by experienced readers, because of the typical location and shape relative to the heart. Attenuation artefacts usually occur in the anterior wall in women with large breasts and in the inferior wall in obese men [133–135]. Although the true prevalence of soft tissue artefacts is unknown, estimates range between 20% and 50% of patients [136, 137].

Several approaches have been used to address the issue of spurious false positive results in MPI due to photon attenuation including, among other options, awareness of their potential occurrence and location, routine assessment of raw imaging data, comparative assessment of studies performed following a change in the patient's position (prone versus supine) and gated imaging which assesses wall motion. These approaches improve artefact recognition but they all have limitations. Although guidelines of the American Society of Nuclear Cardiology recommend that attenuation correction should be performed in all patients, there are clearly some patient populations that benefit more from this procedure, generally the largest-size patients. Depending on equipment availability and daily workload, the rest SPECT study is

used in some centres as the criterion for triage decisions for performing attenuation correction acquisition.

In order to determine the true radiotracer distribution in the myocardium, several techniques have been developed with the goal of generating patient-specific attenuation maps. Attenuation maps generated by transmission sources at the time of the scan have, until the last decade, been the most commonly used method of correction. Various transmission geometries have been adopted, including sheet, multiple lines, or scanning line sources, a fixed source positioned at the focal line of a fan-beam collimator, or a moving point source [138]. Commercial systems use mainly Gadolinium-153 (^{153}Gd, 100 keV) with a 100-day half-life, supplied at a maximum of 400–500 mCi/source. With decay of the source, a degradation in the attenuation map leads to a central underestimation of the true attenuation coefficients.

An additional approach has attempted to use anatomic images imported from CT, but has been limited by difficulties in correct matching of the morphologic and scintigraphic data sets since images are acquired on different systems, at different time points, with the patients lying on different stretchers. These limitations are, at least in part, overcome by near-simultaneous acquisition of MPI and CT on a single imaging device. Historically, SPECT/CT systems have been initially developed with the specific goal of achieving optimal CT based attenuation of myocardial perfusion scintigraphy.

Cardiac SPECT is performed using a dual-head gamma camera equipped with low energy, high resolution parallel hole collimators, and with the detectors at 90° to each other. The acquisition is performed over a 180° orbit during a period of 12–20 minutes. Dual isotopes acquisition uses ^{201}Tl for rest and ^{99m}Tc-sestamibi or ^{99m}Tc-tetrofosmin for stress, while single isotope acquisition uses the same isotope, ^{99m}Tc-sestamibi or ^{99m}Tc-tetrofosmin for both rest and stress. For ^{201}Tl, imaging energy windows of 30% and 20% for the 70 keV and 167 keV peaks, respectively, are used, while the energy window width for ^{99m}Tc is 20% for the 149 keV peak. Both the rest and stress SPECT studies are followed by a low-dose CT (20–30 mAs, 140 keV for the diagnostic CT, or 2.5 mA, 140 keV for a camera-mounted CT), which is used for photon attenuation correction of the scintigraphic data. The CT-attenuation correction study is performed only over the area of the heart, as defined by the operator. The patient is asked not to move during study progression, in order to obtain good co-registration between the emission and the transmission scans [139].

CT based attenuation correction has been shown to provide the most reliable and accurate high quality cardiac SPECT images through high resolution, high count-rate and low noise attenuation maps resulting in predictable uniform tracer activity in patients with a low likelihood of haemodynamically significant coronary artery disease. The CT based attenuation correction method can be successfully implemented with all clinical cardiac SPECT protocols, including same-day or 2-days rest-stress, single and dual isotope rest-stress procedures.

3.13.2. Cardiac SPECT/CTA for assessing the significance of coronary artery lesions

Stress/rest MPI is the established imaging modality for non-invasive diagnosis of presence, severity and extent of coronary artery disease (CAD), with high sensitivity and specificity. MPI determines the physiologic significance of angiographically borderline stenosis, and defines the presence of viable but dysfunctional, hypoperfused myocardium. MPI cannot, however, diagnose early atherosclerosis and often underestimates the extent of coronary artery disease. In addition, MPI does not provide accurate anatomical information, essential

prior to coronary revascularization procedures. The recently developed multi-detector CT (MDCT) technology characterized by high spatial, contrast and temporal resolution enables non-invasive CT coronary angiography (CTCA) and provides also accurate information regarding the structure and motion of the heart chambers. CT, however, does not predict the benefit of revascularization [140–142].

Cardiac SPECT/CT is a novel hybrid imaging technique that combines detailed anatomical information of coronary vessels (provided by CTCA) with physiologic information of myocardial perfusion and function (provided by MPI), through accurate spatial alignment of both data sets. This evolving modality has the potential to become the future imaging test of choice for non-invasive assessment of CAD [140–142].

While co-registration of separately performed CT and MPI may provide a very similar type of data, this process is difficult to implement beyond research purposes in dedicated centres, due to its logistical limitations. Single devices combining SPECT/CTCA data are characterized by ease of use and simple logistic set-ups, and have the potential of making cardiac hybrid imaging user-friendly and easy to plan, major factors in their future routine clinical use. SPECT/CT can provide accurate non-invasive diagnosis of the culprit coronary lesion, including its location and morphology, in conjunction with assessment of the physiologic significance of this lesion on myocardial function. SPECT/CT images precisely localize regions of impaired perfusion to the corresponding vascular territory. Cardiac SPECT/CTCA may prove of significance in a series of potential indications, which will however need to be proven by large, multi-centre studies. By allowing visualization of stenoses, the addition of CTCA to MPI can potentially eliminate one of the major reasons for false negative MPI results in patients with advanced 3-vessel disease, showing a balanced reduction of blood flow in all myocardial segments. On the other hand, by assessing the functional consequences of stenosis through its stress/rest MPI component, it may improve the performance of CTCA in patients with dense coronary plaques. CTCA results are often insufficient to guide patient management. A need for functional information will arise in many patients demonstrating anatomic coronary abnormalities on CT.

In summary, reliable attenuation correction of MPI-SPECT enhances significantly the clinical decision making process; decreases morbidity related to invasive procedures and also saves costs related to additional work-up induced by equivocal reports. High speed multislice coronary CT has a growing impact on assessment of patients with known or suspected coronary artery disease. Combined data regarding myocardial perfusion, calcium scoring and the presence or absence of coronary stenosis may, in future, enable better stratification of patients with or without ischemic heart disease. Referral algorithms will have to define patient groups that will benefit from hybrid SPECT/CTCA imaging of both myocardial perfusion and the anatomy of the coronary tree.

3.14. Added values of CT in patients with coronary artery disease

3.14.1. Coronary artery calcium

Calcium accumulates in the coronary arteries as a result of the body's response to contain and stabilize inflamed coronary plaques. Calcified plaque assessment correlates with pathologic assessment of the total amount of calcified plus noncalcified plaques [143]. The burden of coronary artery calcium (CAC) generally reflects an advanced stage of plaque development, and CAC serves as an indirect but proportional marker for global atherosclerotic burden. The CT based method of quantifying CAC was initially developed using electron-beam

tomography (EBT), but multi-slice CT provides measurements of CAC comparable to those derived from EBT [144].

The CAC score is derived using highly reproducible semiautomatic computer methods based on the product of calcified plaque area by the coefficient of its density. The score is calculated as the product of the CAC area by the peak Hounsfield unit (1 for 131–199 HU, 2 for 200–299 HU, 3 for 300–399 HU, and 4 for ≥400 HU). Visually, coronary calcification can be categorized into mild (minimal), moderate, and marked (extensive) degrees of severity.

Accumulation of CAC is common in adults and increases with age. The presence of CAC is often associated with only insignificant (<50% luminal narrowing) coronary stenosis. However, there is a graded relationship between the extent of CAC and the annual risk of coronary heart disease. Patients with extensive CAC are likely to have marked non-calcified plaques that may be rupture-prone. Plaque erosions are infrequently calcified and associated with acute coronary syndromes [145].

3.14.2. Coronary computed tomography angiography

Coronary computed tomography angiography (CTA) visualizes not only the coronary vessel lumen but also the wall, allowing the non-invasive assessment of the presence and, potentially, the size of non-calcified coronary plaque. Furthermore, the assessment of ventricular function is possible from a single first-pass acquisition of the chest CT data, which may be of value in the emergency department setting, along with the potential to provide assessment of pulmonary embolism, acute coronary syndrome, and aortic dissection in a single study.

The relative roles of myocardial perfusion SPECT and CTA have not yet been defined. In patients with intermediate likelihood of CAD, coronary CTA may be the initial test to perform, attending to the apparently superior sensitivity over SPECT imaging. When a coronary CTA is entirely normal, no further testing would be required. In case of proximal and critical coronary stenoses, invasive coronary angiography would be indicated for possible revascularization therapy. When CTA detects coronary lesions of uncertain significance, SPECT imaging would be appropriate for further diagnostic assessment.

In patients with known disease (or likely having extensive coronary calcium) in whom risk-stratification is needed, SPECT imaging would remain the initial test.

If SPECT imaging has been performed as the initial test, further testing by CTA would be indicated whenever discordant results are obtained. This includes patients with a strong clinical suggestion of CAD after a normal or equivocal SPECT; patients with marked discordance between SPECT and clinical or stress ECG; or patients with SPECT and stress ECG results suggestive of left main or triple-vessel CAD (e.g. transient ischaemic dilation, post-stress LV dysfunction, exercise hypotension with normal SPECT), with balanced reduction of coronary flow in the LV. Coronary CTA can also be of use in patients with suspected nonischaemic cardiomyopathy, patients with coronary anomalies, and young patients undergoing valvular surgery.

Since rest/stress SPECT studies can be performed as routine in conjunction with coronary CTA, SPECT/CT systems provide data about coronary calcium, coronary stenosis and functional significance in one clinical setting, thus allowing more appropriate selection of patients who may benefit from revascularization procedures [146]. A recent study with an

experimental SPECT/CT scanner (16-MSCT) showed that integrated functional and anatomic results improved specificity and positive predictive value to detect haemodynamically significant CAD in patients with angina pectoris [141]. The sensitivity, specificity, positive predictive value, and negative predictive value of CTA were 96%, 63%, 31%, and 99%, respectively, as compared with 96%, 95%, 77%, and 99%, respectively, for SPECT/CT. Patients and arterial segments excluded from the analysis raised to 21% and 23%, respectively. Another investigation described the incremental diagnostic value of integrating SPECT/CT (64-MSCT) data through three-dimensional (3-D) image fusion on the functional relevance of coronary artery lesions [140]. 3-D volume-rendered fused SPECT/CT images were generated from patients with at least one perfusion defect on SPECT imaging, and compared with the findings from the side by side analysis with regard to coronary lesion interpretation by assigning the perfusion defects to their corresponding coronary lesion. In addition to being intuitively convincing, 3-D SPECT/CT fusion images added significant information on pathophysiological lesion severity in 22% of coronary stenoses of 29% of patients. Among equivocal lesions on side by side analysis, the fused interpretation confirmed haemodynamic significance in 35% of lesions and excluded functional relevance in 25% of lesions. In 7.5% of lesions, assignment of perfusion defect and coronary lesion appeared to be reliable on side by side analysis but proved to be inaccurate on fused interpretation. Added diagnostic information by SPECT/CT was more commonly found in patients with stenoses of small vessels and involvement of diagonal branches.

3.15. Pulmonary artery imaging in pulmonary embolism

Pulmonary embolism (PE) is one of the greatest diagnostic challenges in emergency medicine. It should be suspected in any patient with unexplained dyspnea, tachypnea, or chest pain. A negative D-dimer assay reliably excludes PE in low-risk patients. Otherwise, pulmonary CT angiography is now considered by several authors to be the initial imaging study of choice for stable patients. Nevertheless, ventilation/perfusion (V/Q) scans or even perfusion scintigraphy alone (as in the PISA-PED approach [147–152]) still retain a considerable diagnostic accuracy and are valid alternatives to pulmonary CT angiography, in particular when CT is not available, or in patients with contraindications to CT scanning or intravenous contrast.

The results of the Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) study established the diagnostic criteria of V/Q scanning for the diagnosis of PE, as compared with pulmonary angiography [153]. The interpretation ranges from normal to high probability, each with its own diagnostic characteristics. However, more than 60% of patients fell into the low and intermediate probability (or non-diagnostic category), and there was a 4% incidence of PE when the scan was read as normal. Similarly troubling, high probability scans were associated with a 12% false positive rate [153]. Therefore, it is recommended to consider patients with low-to-moderate pretest probability and a normal V/Q scan as not having a significant PE. Nevertheless, if the same patients have a non-diagnostic V/Q scan, the recommendation is that, in order to exclude significant PE without going to pulmonary angiogram, the patient must have a negative whole blood D-dimer, negative bilateral ultrasound in low probability group, or negative serial bilateral ultrasound for the moderate probability group. In patients with high pretest probability a normal V/Q scan can only rule out PE if the patient has a normal chest X ray and no baseline cardiopulmonary disease. Otherwise, the patient must go on to CT angiography.

Because of the high number of indeterminate studies using V/Q scanning [153], pulmonary CT angiography (PCTA) is becoming the initial diagnostic test for PE for stable patients with

no signs and symptoms of deep venous thrombosis. PCTA with 100 ml of iodinated contrast medium and dedicated imaging procedures and protocols can directly visualize thromboembolic filling defects as well as pleural effusions, vascular remodelling, and oligoemia, any of which may be present with PE [154]. In addition, PCTA may reveal alternative diagnoses, such as pneumonia, aortic dissection, tumour or pneumothorax that in the absence of PE may yield a previously unsuspected reason for symptoms mimicking PE [155]. Current multi-slice CT scanners can image the entire pulmonary vasculature in one breath-hold, allowing 1 mm to sub-millimeter resolution, and the data can be transformed into 2-D and 3-D reconstructed images. Such procedure can significantly increase the detection of 'clinically significant' subsegmental thrombi and evaluate pulmonary vasculature down to 6th order branches [156–158].

The PIOPED II study [159] recently reported the high accuracy of multi-slice CT scanners for the diagnosis of PE, with 83% sensitivity, 96% specificity, 95%, 89% and 60% negative predictive values, as well as 96%, 92% and 58% positive predictive values, respectively for high, intermediate, and low clinical probability groups. These data support the use of PCTA for suspected PE as a stand-alone imaging technique in most patients. However, the false negative rate of 17% should be noted. The most likely explanation for this is that multi-slice CT scanners (mainly 4 slice) still miss small, peripheral subsegmental clots that are better detected by V/P scanning or by classic pulmonary angiography. Therefore, clinicians should be cautious with results that are discordant with their clinical judgment, particularly in front of a normal PCTA in a patient with a high clinical probability of PE [160].

While the clinical significance and treatment requirements of small, peripheral subsegmental thrombi are controversial [161], image fusion of SPECT V/Q and PCTA has demonstrated to be feasible. A recent investigation in 30 consecutive patients who underwent both imaging studies during their admission for investigation of potential PE reported good accuracy of co-registered images as determined subjectively by correlation of the anatomical boundaries and co-existent pleuro-parenchymal abnormalities [160]. Nine patients who had positive PCTA performed as an initial investigation had co-localized perfusion defects on the subsequent fused PCTA/SPECT images. Three of the 11 V/Q scans initially reported as intermediate probability could be reinterpreted as low probability owing to co-localization of defects with parenchymal or pleural pathology [162]. Therefore, the introduction of SPECT/CT hybrid systems will probably provide a single diagnostic tool that will overcome limitations of each imaging modality separately.

4. ADVANTAGES OF UTILIZING SPECT/CT

4.1. Anatomical accuracy of image registration in SPECT/CT hybrid imaging

Image registration is defined as the transfer of two image data sets into one common coordinate system. It may be mono or bimodal, i.e. between images acquired by one single modality or by two different modalities. Depending on the nature of the transformations used, rigid or non-rigid approaches can be used for this purpose, the former allowing for non-linear, 'plastic' deformation of the image data sets. A further distinction can be made between software based registration of data sets acquired independently one from each other by two different imaging devices and hardware based registration where the two data sets are obtained by hybrid equipment in a single imaging session.

In the past decade, the clinical impact of interactive software based registration between SPECT and CT data has received some attention in the literature [163, 164]. In particular, it has been repeatedly demonstrated that patient management may benefit significantly from the integration of functional and morphological data.

One major drawback of software based image fusion is logistic in nature: in the daily clinical routine of many institutions, image data sets from different modalities can be exchanged between different departments only with some difficulty. Although the implementation of hospital-embracing picture-archiving systems should overcome these difficulties, software based registration suffers from anatomical inaccuracies stemming from different positioning of the patient in the two separate imaging devices as well as by difficulties in identifying landmarks common to both data sets to be registered. In addition, the more specific a radiopharmaceutical is for a certain tissue, the poorer images of its distribution are with regard to anatomical detail, and the more difficult software based registration becomes.

These limitations are greatly reduced in hardware based registration that should therefore offer a higher anatomical accuracy of image fusion, as it obviously emerges when reviewing articles investigating the quality of alignment between [^{18}F]FDG-PET and CT. In these studies, anatomical accuracy of fusion is usually quantified by determining the average distance between landmarks or lesions identifiable on both images. This distance ranges between 4 and 12 mm for software based fusion of PET and CT images [165–169], but is reduced 3–5 mm for PET/CT hybrid scanning [168, 169], thus confirming the assumption of a higher anatomical accuracy for hybrid imaging.

Nevertheless, similar data for registration between SPECT and CT images are scarce. Förster et al. studied the accuracy of software based fusion between ^{111}In-octreotide SPECT and multi-row CT in a small group of patients [44]. They reported anatomical inaccuracies in the range of 7 mm, similar to those determined for fusion between PET and CT. Nömayr et al. reported a much higher accuracy of image fusion for SPECT/CT hybrid imaging of the lower lumbar spine [170]. In their study, misalignment ranged between 0.7–1.8 mm, smaller than pixel width in the SPECT images. Notably, software based registration performed on the data sets acquired by SPECT/CT could still significantly improve these results and bring misalignment down to values averaging 1 mm. However, their results cannot be extrapolated to regions of the human body involved in respiratory movements affecting SPECT and CT images to a different degree.

The development of hybrid imaging devices witnessed in the last decade marks a new trend in medical imaging involving the registration and fusion of all image data sets of one individual patient using the same computer platform. Current available data has already proven a major clinical impact of this approach, which is also expected to increase cost effectiveness. The field will be driven by the development of new hybrid imaging devices, but also by significant improvements of software based image fusion. Future medical imaging departments will offer a multimodal environment integrating both hybrid imaging and software based image fusion into the daily clinical routine.

4.2. The effects of CT based attenuation correction of SPECT image data sets and potential future applications

Attenuation artefacts considerably degrade the quality of SPECT images, and also hamper accurate quantification of tracer accumulation in specific volumes of interest. Various methods of attenuation correction have been proposed [171, 172], to be further subdivided

into those with and those without transmission measurements. The latter calculate tissue attenuation coefficients on the basis of an assumption of their distribution in the body segment examined, using various methods to determine the body outline. This approach is widely used in studies of brain perfusion, since it is generally assumed that attenuation is homogeneous within the skull.

This assumption does not hold valid for the abdomen or the chest, since these body segments contain tissues with variable attenuation coefficients. Radionuclide transmission scanning has been used to derive maps of abdominal and thoracic attenuation coefficients. However, it has been repeatedly shown that this approach can introduce artefacts that may be difficult to identify [173]. Another major problem inherent to this approach is the low activity of the radioactive sources used for this purpose, leading either to long acquisition times or to attenuation maps with poor quality due to low counting statistics.

This problem is overcome by employing CT data to correct SPECT data for tissue attenuation. A study investigating the visualization of radioactivity in a heart phantom has indeed shown that this variable is homogenized by CT based attenuation correction [174]. Recently, Fricke et al. have demonstrated that the concordance between PET and SPECT studies of myocardial perfusion was improved after using CT based attenuation correction for the SPECT data [175]. Similar results have been reported for skeletal SPECT [176].

Nevertheless, the clinical impact of CT based attenuation correction for SPECT imaging is currently unclear. In a multi-centre trial, Masood et al. demonstrated a moderate, but statistically significant increase in the accuracy of diagnosis of coronary artery disease for myocardial perfusion SPECT [174]. Shiraishi et al. reported a significantly higher accuracy for attenuation-corrected ^{201}Tl-SPECT in staging lung cancer compared to the non-attenuation studies [177]. Likewise, improved identification of sentinel lymph nodes has been shown with the use of attenuation correction [60].

When using CT based attenuation correction for SPECT data, one should be aware of possible artefacts caused by misalignment between SPECT and CT data sets (see above). Figure 15 demonstrates such an artefact in a phantom simulation. In myocardial perfusion SPECT, a 7 mm misalignment between emission and transmission data, corresponding to the width of one pixel in that study, was shown to produce a 15% change in relative regional activity [178]. Similar data have been published for CT based attenuation correction in myocardial SPECT [179] and a method for automated control for misalignment between CT and SPECT has been proposed [180]. In skeletal SPECT, misalignment of the CT by 1 cm was shown to change even the visualization of symmetry of uptake [176]. Therefore, the anatomical accuracy of fusion should be carefully checked before applying CT based attenuation correction.

Attenuation correction of SPECT data constitutes an important step in the development of truly quantitative SPECT, which may improve dosimetric estimates of molecular radiotherapy. More sophisticated phantom studies are needed to better understand variability related to different photon energies. However, for accurate SPECT, quantitation issues related to scatter and partial volume artefacts need to be overcome. In particular, the correction of the latter could also capitalize on the use of CT images aligned to SPECT. Therefore, the new hybrid systems will stimulate research work also along that avenue.

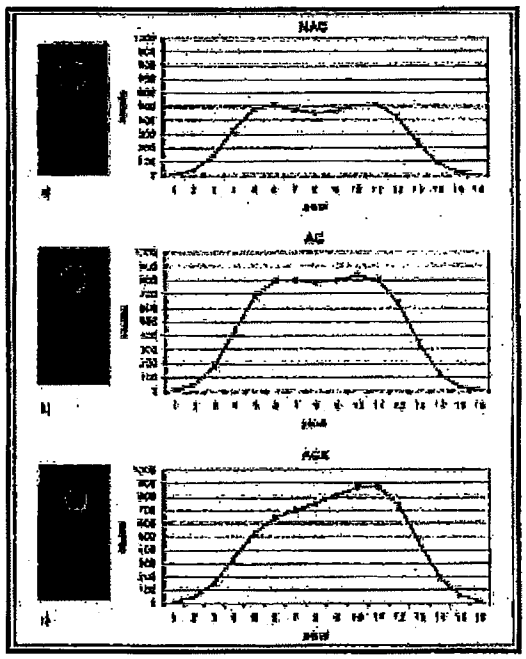

FIG. 15. Transversal SPECT images of two rods in a phantom filled with ^{99m}Tc (a) without (NAC) and (b) with attenuation correction (AC): attenuation correction homogenizes the visualization of activity in the homogeneously filled rods; (c) a CT misalignment by 1 cm in X-direction (ACX) produces a significant artefact in the visualization of activity. The curves are profiles from left to right for the rod filled with the lower activity concentration in NAC, AC, and ACX (from TKL31; with permission).

4.3. Additional information or diagnosis from CT

With continuous higher-speed and thinner sliced CT, small lung lesions (less than 1 cm in diameter) showing interval increase in size may often be detected. Small non-specific lymph nodes, low-density hepatic or renal lesion, and osteolytic or osteoblastic lesion with interval increase in size are also incidentally identified. These lesions are generally beyond the resolution of our current SPECT or PET system and may require further short term follow-up studies to confirm/exclude the diagnosis of new metastases.

4.4. Use of SPECT/CT data for estimating internal radiation dosimetry

As will be better detailed in the next section, the radiation dose is energy absorbed per unit of mass. Accurate dosimetric estimates are extremely critical in radiometabolic therapy, both for calculating radiation dose to the target organ/tissue (generally tumour, but also non-tumour lesions such as hyperfunctioning thyroid parenchyma) and for defining dose-limiting toxicities to normal organs/tissues with high physiologic accumulation of radioactivity (e.g. bone marrow, kidneys). It is well known that internal dosimetry estimates are burdened by a significant degree of estimation regarding absolute concentration of radioactivity in a given organ/tissue, and represent therefore only rough approximations with variabilities that can be

as high as 50% or even 100%. Part of this variability is due to the fact that bio-distribution data are usually derived from planar imaging (such as conjugated-view whole body scans), and a-priori models and assumptions on the organ shapes/sizes are employed for the radiodosimetric analysis. Also stand-alone SPECT entails some unwarranted assumptions, since standard factors are usually applied for attenuation correction. In this regard, SPECT/CT certainly holds the promise for developing more accurate approaches to internal radiation dosimetry estimates, since the CT component of the study enables correct attenuation of the emission map specifically in each single patient.

Few reports have been published on this important application of SPECT/CT. Boucek and Turner employed SPECT/CT data to estimate bone marrow dosimetry following the administration of ^{131}I labelled anti-CD20-monoclonal antibody (rituximab) in patients with non-Hodgkin's lymphoma. These patients are usually heavily pretreated with chemotherapy, and myelosuppression is the dose-limiting toxicity. The authors demonstrated a statistically significant correlation ($p = 0.001$) between whole body effective half-life of the radiolabelled antibody and effective marrow half-life. They also found that bone marrow activity concentration was proportional to administered activity per unit weight, height or body surface area ($p < 0.001$). In their experience, SPECT/CT enabled accurate quantification of activity accumulations and thus validated patient-specific prospective dosimetric estimates methods [181].

SPECT/CT has also been advocated for the quantification of radiation doses delivered during radiometabolic therapy with ^{131}I-MIBG, using CT based tumour volume-of-interest [23]. Although based on a single patient, Song et al. have demonstrated that patient-specific 3-D dosimetry based on SPECT/CT is feasible and important in the dosimetry of thyroid cancer patients with radioiodine-avid lung metastases and prolonged retention in the lungs. In their opinion, this procedure could constitute the breakthrough for rationally planning radionuclide therapy in patients with thyroid cancer [182].

A preliminary report from the Pisa group described a novel SPECT/CT based approach to calculate attenuation- and scatter-corrected dosimetry to the bone marrow and to tumour lesions following the administration of ^{153}Sm-EDTMP for palliation of bone pain in patients with hormone-refractory metastatic prostate cancer [183]. The system was phantom-calibrated for tissue densities, and the CT images were utilized to identify bone structures. Dedicated software was developed for automatic edge recognition of skeletal uptake, which was corrected for attenuation and scatter. An S-value matrix was then derived from the attenuation map voxel-by-voxel for each individual patient (rather than pixel-by-pixel as in conventional evaluations) (Fig. 16). It was found that the conventional approach based on planar imaging and standard-factor corrections overestimated dose to bone marrow by an average 67% versus the SPECT/CT method. The new SPECT/CT based method therefore opens the perspective of calculating radiation dose to the bone marrow and to skeletal lesions (or other sites), and therefore to correlate dosimetry to lesions with efficacy of therapy (bone palliation, or true anti-tumour effect [184]).

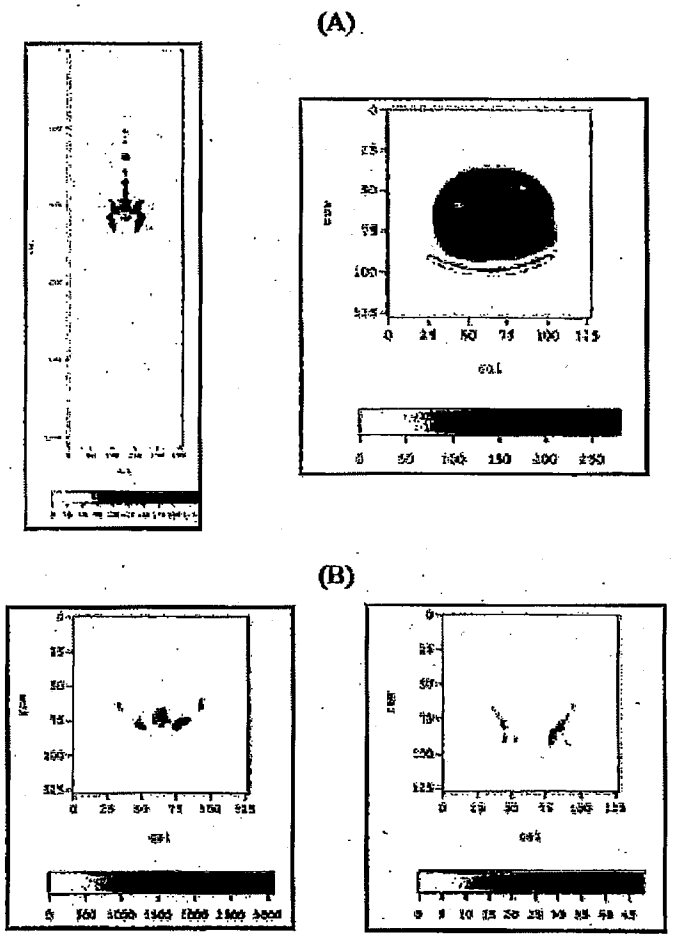

FIG. 16. Sequential steps in the elaboration of the SPECT/CT images obtained after administration of ^{153}Sm-EDTMP given for bone pain palliation purposes in a patient with hormone-refractory prostate cancer. (A) Outline of skeletal uptake of the bone-seeking radiopharmaceutical as derived from an automatic edge-recognition software applied on the planar 24 h whole body scan (left panel). The right panel shows the CT density-reconstructed map acquired at the pelvis. (B) Reconstructed SPECT map (left panel) and tomography of the 3-D dosimetry map in Gy (right panel).

4.5. Radiation dose of CT from SPECT/CT

The radiation absorbed dose delivered to the patient from the use of CT in SPECT/CT study is difficult to measure because of many factors involved, but the CT Dose Index (CTDI) based on scan parameters can be calculated, and represents an index of radiation dose to a standard phantom. The CT scanners generally provide an X ray tube current modulation function that makes uniform image quality and dose for various patient sizes [185]. The system will automatically increase or decrease the tube current (mA) when the user selects a reference effective mA in response to changes in diameter or tissue density of the patient. The effective mA includes the tube current, rotation speed, and pitch used for the scan. The user-selected

scan parameters that affect patient dose in CT examinations are effective mA, kVp, detector collimation setting (affecting the width of the radiation beam in table-travel direction), beam-shaping filter associated with the scan type (body or head), and number of scans over the same section of the body. If the dose distribution from the centre to the edge of the phantom as well as the pitch used in the scan is taken into account, a term called CTDIvol can be used to represent the dose index to the volume of the phantom. The radiation dose is energy absorbed per unit mass. The CTDIvol associated with a single CT scan covering one SPECT bed position is the same as the CTDIvol for a CT scan covering two non-overlapped SPECT bed positions if the same CT scan parameters are used. However, there is a factor of two variation in the radiation risk to the patient between these two cases. The CTDIvol in milli-Gray (mGy) is multiplied by the length of the CT scan in cm, to yield the dose-length product (DLP). Once the DLP is determined, an effective dose can be estimated using conversion factors for the relative radiosensitivity of the organs within the range of the scan. Some CT scanners save the CDTIvol and DLP values for a specific patient scan at the end of the examination. If there are multiple CT scans of the same region of the patient, each scan adds to the radiation dose and risk.

The effective dose and CTDIvol values from typical CT scans to the chest and abdomen have been calculated [186], and they are 4 mSv and 8 mGy, respectively. The value to the head and neck are 4 mSv and 10–20 mGy, respectively. These doses are for one SPECT bed position, relating to a 39 cm CT scan length, acquired using a fixed technique at the reference mA. Doses can be scaled linearly with the actual scan effective mA for the patient study. In case of a CT for a two-bed SPECT/CT, the appropriate effective dose values are added together. A planning CT view is obtained prior to determining the scan extent and location with low (about 20) mA for the postero-anterior projection and with the beam direction such that the beam enters the table prior to passing through the patient. These measures ensure an adequate planning view with the lowest dose to the patient, which is about the same as for a single view of the chest X ray.

5. FURTHER DEVELOPMENT OF SPECT/CT WITH NEW RADIOPHARMACEUTICALS

There is a continuous interest to label biologically important drugs or agents with easily available and cheaper isotopes than PET tracers, such as ^{99m}Tc labelled tracers (Table 1) for SPECT/CT to diagnose, differentiate, and stage cancers and also to evaluate as well as to predict therapeutic responses. L,L-ethylenedicystein, the most successful example of N_2S_2 chelates, can be labelled with ^{99m}Tc with high radiochemical purity, and the preparation remains stable for several hours [187]. Reliable molecular imaging that: assesses cellular targets at low cost, treatment response more rapidly, provides a good differential diagnosis, predicts correctly therapeutic response and allows for better radiation dosimetry for internal radiotherapy, would be very valuable.

6. CT TRAINING IMAGING FOR NUCLEAR PHYSICIANS AND TECHNOLOGISTS

The Societies of Nuclear Medicine, Computed Body Tomography and Magnetic Resonance, and the American College of Radiology have recently agreed that only properly trained qualified physicians should interpret PET/CT images [189]. The issue of training nuclear physicians to interpret the CT images produced by SPECT/CT devices is similar to that for

PET/CT. In this regard, earning 100 hours of CT continuing medical education credits and interpreting 500 CT cases under the supervision of qualified diagnostic radiologists were recommended. The CT cases should include reasonable numbers of head and neck, chest, abdomen and pelvis examinations. According to these recommendations, both radiology and nuclear medicine residents are required to interpret SPECT/CT images.

TABLE 1. SPECIFIC RADIOTRACERS [187, 188]

Character of cancer cells	Compounds
Cellular growth	^{99m}Tc-deoxyglucose ^{99m}Tc-guanine
Hypoxia	^{99m}Tc-metronidazole
Angiogenesis	^{99m}Tc-endostatin ^{99m}Tc-bevacizumab (against VEGF receptor)
Apoptosis	^{99m}Tc-annexin-V
Hormones	^{99m}Tc-estradiol

SPECT/CT and PET/CT present therefore similar practical issues regarding education, training and certification of nuclear medicine technologists to become properly qualified and competent to perform the CT portion of the study. The American Registry of Radiologic Technologists has adapted its CT certification examination and has allowed certified or registered nuclear medicine technologists who have met the required prerequisites to take this examination.

Nevertheless, the choice of the optimal way to achieve adequate training for interpreting multimodality imaging examinations will differ between countries owing to differences in infrastructure and legislation. The European Association of Nuclear Medicine (EANM) and the European Society of Radiology (ESR) have agreed to work together to produce a common position paper regarding multimodality imaging systems [190, 191]. Both organizations recognize the importance of coordinating working practices for multimodality imaging and that undertaking the nuclear medicine and radiology components of imaging with hybrid systems requires different skills. Training should be properly structured and comprehensive and should be conducted in accredited training centres. It should incorporate the principles and all modalities of both specialties to allow the trainee to acquire a full understanding of the possibilities and difficulties of each technique and its medical background, and provide the basis for participating in the evolution of multimodality imaging. Refresher type courses can prepare for specific training or refresh knowledge, but cannot replace appropriate on site training. It is not acceptable for training to be focused on a single technique.

Three different training models have been proposed [190]:

- Comprehensive training in both specialties, clinical radiology and nuclear medicine, in those countries where it is possible for the individual to practice both specialties and where such dual specialty training can be obtained. Such training gives the trainee the possibility of ultimately practicing in one or both of the specialties and of billing appropriately. The duration of the entire training programme in both specialties would most likely be neither politically nor economically acceptable in many European countries.

- An adequate period of training in the other specialty in addition to full training in the primary specialty. This model would facilitate acquisition by nuclear medicine specialists or radiologists of the necessary training in the other specialty after having completed full training in their primarily chosen specialty. Such adjusted additional training programme should be defined to provide a broad foundation of knowledge in the second specialty and should not be confined to a single technique such as CT or SPECT or a single clinical application. For nuclear medicine specialists, besides relevant radioprotection issues, training will include the physical principles and practical clinical skills of CT imaging. For radiologists, besides relevant radioprotection issues, training will include knowledge of radiopharmacy and radiotracer biokinetics and the physical principles and practical skills of SPECT. Training needs not to include therapeutic interventional radiology or radionuclide therapy. The core of the additional training would be dedicated to hybrid imaging. For radiologists, part of the nuclear medicine component should be undertaken during the fourth and fifth year of training. Maintenance of radiology skills during this time would be mandatory. For nuclear medicine specialists, part of the radiology component should be undertaken during the fourth and fifth years of training. Maintenance of nuclear medicine skills during this time would be mandatory. The remaining part of the training would then be obtained with an additional year fully dedicated to the second specialty, giving a total of 6 years' training for both specialties. The exact duration of the training is subject to local regulations, which may vary from country to country. Nonetheless, the general time scale as outlined in this option should be considered as the model. Such additional training will lead to a special competency certification.

- Potential future integration of training: an incorporated training in nuclear medicine and radiology taking the form of a cross-over or integrated training programme, where both specialties agree and recognize a training curriculum which encompasses the principles of all imaging modalities of both specialties. The curricula of both specialties would be adapted to include knowledge of anatomy, cell biology, genetics and physiology as well as the normal requirements of the physical basis of all imaging modalities and patient safety.

Each country should establish a training schedule that ensures the accomplishment of appropriate education in both specialties, bearing in mind that this cannot be achieved by merely performing a certain number of studies with one or the other technique. Only thorough training will give the necessary insight into anatomical and functional aspects of the various modalities, their interpretation with respect to patient-tailored treatment and risk assessment, and finally the further development and refinement of multimodality imaging.

During the interim period while these training models are set up, the nuclear medicine specialist would manage and report the nuclear medicine component of the examination and the radiologist would manage and report the anatomical and pathological component, with consultation between the two specialists to combine the data into a final diagnosis. Each specialist would provide a report with regard to the part of the study that he/she is directly responsible for. The benefit of this strategy is that those fully trained in the specific modalities would interpret the images jointly, thus providing a high-quality result. At a practical level this concept requires careful organization, cooperation and discussion between nuclear medicine and clinical radiology specialists.

7. REFERRAL CRITERIA FOR SPECT/CT

Local logistics and availability of different medical specialties dictate how diagnostic algorithms are applied in the clinical routine when patients are referred for diagnosis and/or characterization of their disease, and in particular to SPECT/CT. These examinations should be performed with the purpose of, whenever possible, avoiding the use of invasive procedures, when surgery is contemplated as part of treatment, or prior to adopting mini-invasive approaches. Clearly, a combined imaging technique such as SPECT/CT provides all the morpho-functional information enabling the surgeon to plan the surgical approach most suited to the individual patient. Referring clinicians have learned to regard radionuclide studies as useful tests that may confirm a suspected clinical diagnosis and characterize disease processes with information that can be relevant to treatment of the disease. This review has been designed to provide a summary of a methodological radionuclide based approach, SPECT/CT, a still evolving procedure with the final goal of enhancing diagnostic information and guiding therapy. It includes the methodology, analysis and estimation of usefulness of these examinations with an emphasis on more recently published data. Based on this review and on the experience accumulated by each centre represented in this panel of experts, referral criteria for a SPECT/CT examination can briefly be summarized in the indications that follow.

Indication to perform a SPECT/CT examination can be raised on primarily clinical ground. Such indications include:

- High suspicion for active disease, or known structural pathology, as SPECT/CT may localize multiple sites and define extent of disease;
- Planning treatment (medical, surgical, or radiation therapy);
- Monitoring response to treatment.

In some other cases, indication can also originate on the basis of data from previous anatomic imaging, including situations such as:

- Abnormal structural findings of equivocal functional significance, either at diagnosis or post-treatment;
- Absence of overt structural pathology in the presence of high clinical suspicion.

It is sometimes necessary to clarify inconclusive results of prior functional imaging (usually planar scintigraphy), showing foci of increased radiotracer uptake of unclear localization and clinical significance. Inconclusive scintigraphic studies can be due to tracer-related factors (because of poor physical characteristics, high target-specificity with paucity of non-target anatomic landmarks, physiologic bio-distribution with the lesion close to excretion sites). Alternatively, inconclusive radionuclide imaging can be due to patient/disease-related factors, such as complex regional anatomy or anatomic distortion post-treatment (surgical and/or radiation therapy).

Finally, emphasis should be placed on the use of the CT component of a SPECT/CT examination for correcting, on a patient-specific basis, the single photon emission data for attenuation and scatter. This is crucial for proper estimation of radioactivity concentration in specific organs/tissues on a volumetric basis.

8. CONCLUDING REMARKS

In summary, a high quality SPECT/CT study requires a reliable, well functioning hybrid scanner which has met acceptance testing criteria and which is regularly monitored for quality of performance. The study must be designed to answer the specific question asked by the referring physician, and the patient must be appropriately educated and compliant with the preparations for the scan, including fasting if so indicated. The technical staff must be well trained to perform and monitor both components of the study according to a well defined protocol. The acquisition and processing protocols must be carefully followed. The images must be reviewed for technical and diagnostic quality before the patient leaves the department. Finally, the images must be interpreted by skilled readers who are well aware of the clinical history of the patient, using workstations that allow integrated viewing of the functional and anatomic data. In this way, a high quality study will provide useful diagnostic information for further clinical management and patient care. As the quality of SPECT/CT devices improves, it is expected that new applications will emerge.

The impact on reader confidence and increased credibility with referring clinicians is an important add-on feature for SPECT/CT. The concept of incremental confidence is difficult to quantify. It is clear that evaluating the impact of combined SPECT/CT remains a subjective process. While nuclear medicine physicians interpret a study, referring clinicians often remain in doubt because of the difficulties visualizing the location of the finding on scintigraphy alone. Correlation with CT data through precise image registration makes the interpretation of high signal-to-background functional images, combined with better anatomic information, less dependant upon individual expertise. Thus, SPECT/CT results in more meaningful communication with referring physicians, as the hybrid imaging study interpretation is more credible to the clinician who is able to see the location of the functional, tracer-avid focus.

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CONTRIBUTORS TO DRAFTING AND REVIEW

Mariani, G.	University of Pisa Medical School, Regional Center of Nuclear Medicine, Italy
Flotats, A.	Autonomous University of Barcelona, Nuclear Medicine Department, Spain
Israel, O.	Rambam Medical Center, Department of Nuclear Medicine, Israel
Kim, E.E.	MD Anderson Cancer Center, University of Texas, United States of America
Kuwert, T.	Universitätsklinikum Erlangen, Nuklearmedizinische Klinik, Germany

Consultants Meeting on Recent Advances on SPECT/CT,
Vienna, Austria, 25–27 June 2007

EXHIBIT 6

CURRICULUM VITAE

W. LANE DUVALL, MD, FACC

Date of preparation: July 1, 2013

GENERAL INFORMATION

Birth date:	November 17, 1971
Birth place:	Lubbock, Texas
Citizenship:	U.S.A.
Home Address:	35 Walbridge Road West Hartford, CT 06119
Home Phone:	(860) 503-3537
Cellular Phone:	(917) 456-2586
Home E-mail Address:	lane.duvall@gmail.com
Business Address:	Hartford Hospital Nuclear Cardiology 80 Seymour Street Hartford, CT 06102
Business Phone:	(860) 545-5517
Business Fax:	(860) 545-5631
Business E-mail Address:	lane.duvall@hhchealth.org

ACADEMIC APPOINTMENTS

2004-06 Instructor Department of Medicine, Mount Sinai Medical Center

2004-11 Assistant Director of the Cardiac Care Unit, Mount Sinai Medical Center

2006-10 Associate Director of the Cardiology Fellowship Training Program, Mount Sinai Medical Center

2006-11 Assistant Professor Department of Medicine, Mount Sinai Medical Center

2011- Associate Professor Department of Medicine, Mount Sinai Medical Center

2013- Director Nuclear Cardiology, Hartford Hospital

HOSPITAL APPOINTMENTS

2006-13 Mount Sinai Hospital Pharmacy and Therapeutics Committee

2008-13 Mount Sinai Heart Performance Improvement Committee

2013- Hartford Hospital Radiation Safety Committee

EDUCATION

1990-94	***Princeton University*** Princeton, New Jersey Major in Molecular Biology Minor in Engineering Biology	B.A. Cum Laude, Phi Beta Kappa
1994-98	***Yale University School of Medicine*** New Haven, Connecticut	M.D.

POSTDOCTORAL TRAINING

1998-99 Intern, Internal Medicine
Duke University Medical Center, Durham, N.C.

1999-01 Resident, Internal Medicine
Duke University Medical Center, Durham, N.C.

2000-01 Assistant Chief Resident
Duke University Medical Center, Durham, N.C.

2001-04 Fellow, Cardiovascular Disease
Mount Sinai Medical Center, New York, N.Y.

CERTIFICATION

2001 American Board of Internal Medicine
Diplomat in Internal Medicine
Certificate No. 203082

2004 American Board of Internal Medicine
Diplomat in Cardiovascular Disease
Certificate No. 203082

2004 Nuclear Cardiology
Diplomat in Nuclear Cardiology
Certificate No. 3283

2005 Level III Echocardiography
Training July 2001 – January 2005

2005 Level III Nuclear Cardiology
Training July 2001 – January 2005

LICENSURE

1998 State of North Carolina
Graduate Medical Training License No. 82801
Expired 2001

2001- State of New York
License No. 220964
Date of issue: 2001
Date of last registration: 2012

2013- State of Connecticut
License No. 51946

2013- State of Connecticut Controlled Substance Registration
License No. 54313

2001- Drug Enforcement Agency
DEA No. BD7324762

HONORS AND AWARDS

2003 Mount Sinai Physician of the Year Nominee

2005 Recognition for Commitment to Excellence in Patient Care Mount Sinai Hospital

2009 Elected Fellow of the American College of Cardiology

2010 Best Clinical Imaging Paper in the Journal of Nuclear Cardiology 2009-2010 for "The Prognosis of a Normal Stress-Only Tc-99m Myocardial Perfusion Imaging Study"

2010 Department of Medicine Excellence in Teaching Award

2011 Best Clinical Imaging Paper in the Journal of Nuclear Cardiology 2010-2011 for "Reduced Isotope Dose with Rapid SPECT MPI Imaging: Initial Experience with a CZT SPECT Camera"

PROFESSIONAL MEMBERSHIPS

1994-04 American Medical Association

2001- American College of Cardiology

2007- American Heart Association

2012- American Society of Echocardiography

GRANT SUPPORT

2007-08 American Society of Echocardiography $25,000
Cardiovascular Sonographer Research Award
"A standardized technician facilitated protocol for use in V-V optimization of biventricular pacemakers for cardiac resynchronization therapy"

2007-08 St Jude Medical
DETECT Study CRD#405 $25,000
"Comparison of St Jude's Quick-Opt V-V optimization system with conventional echocardiographic measures used in V-V optimization"

PUBLICATIONS

PEER REVIEWED REPORTS

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12. Duvall WL, Croft LB, Godiwala T, Ginsberg E, George T, Henzlova M. Reduced Isotope Dose with Rapid SPECT MPI Imaging: Initial Experience with a CZT SPECT Camera. *J Nuc Cardiol* 2010; 17: 1009-1014.

13. Chow E, Hermann L, Duvall WL. Iatrogenic Claudication from a Vascular Closure Device after Cardiac Catheterization. *West J Emerg Med* 2010; 11: 512-513.

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19. Duvall WL, Hiensch RJ, Levine EJ, Croft LB, Henzlova MJ. The Prognosis of a Normal Tl-201 Stress-Only SPECT MPI Study. *J Nuc Cardiol* 2012. 19: 914-921. (Epub Jul 20, 2012)

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REVIEW ARTICLES

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2. Duvall WL. Cardiovascular Disease in Women. *The Mount Sinai Journal of Medicine* 2003; 70: 293-305.

3. Duvall WL and Vorchheimer D. Multi-bed Vascular Disease and Atherothrombosis: Scope of the Problem. *Journal of Thrombosis and Thrombolysis* 2004; 17: 51-61.

4. Duvall WL. Endothelial Dysfunction and Antioxidants. *The Mount Sinai Journal of Medicine* 2005; 72: 71-80.

5. Duvall WL. Antithrombotic Therapy. *Cur Mol Med* 2006; 6: 603-619.

6. Henzlova MJ and Duvall WL. The Future of SEPCT MPI: Time and Dose Reduction. *J Nuc Cardiol* 2011. *J Nuc Cardiol* 2011; 18: 580-587.

7. Harrison S, Harrison M, Duvall WL. Stress Myocardial Perfusion Imaging in the Emergency Department. *Cur Cardiol Rev* 2012; 8: 116-122.

8. Slomka P, Dey D, Duvall WL, Henzlova MJ, Kaufman P, Berman DS, Germano G. Advances in Nuclear Cardiac Instrumentation with a View Towards Reduced Radiation Exposure. *Cur Card Reports* 2012; 14: 208-216.

BOOK CHAPTERS

1. Duvall WL and Vorchheimer D. Antithrombotic Therapy During the Acute Phase. *Atherothrombosis and Coronary Artery Disease,* 2nd Ed. Fuster V, Topol EJ, and Nabel EG, eds. Philadelphia, Lippincott William & Wilkins, 2005.

2. Duvall WL and Vorchheimer D. Antithrombotic Therapy Post Discharge. *Atherothrombosis and Coronary Artery Disease,* 2nd Ed. Fuster V, Topol EJ, and Nabel EG, eds. Philadelphia, Lippincott William & Wilkins, 2005.

3. Duvall WL, Vorchheimer D, and Fuster V. Thrombosis and Antithrombotic Therapy. *Hurst's The Heart*, 11th Ed. Fuster V *et al*, eds. Philadelphia, McGraw-Hill, 2004.

4. Duvall WL and Fischer A. Atrio-ventricular, Intraventricular, and Interventricular Dyssynchrony. *Textbook of Non-Invasive Cardiovascular Imaging*, 1st Ed. Garcia MJ ed. Lippincott, Williams, & Wilkins, 2009.

5. Henzlova MJ and Duvall WL. SPECT Radionuclide Myocardial Perfusion Imaging Protocols. *Nuclear Cardiology: Practical Applications*, 2nd Ed. Heller G and Hendel R, eds. McGraw-Hill, 2010.

6. Harrison M and Duvall WL. Valvular Heart Disease. *Handbook of Hospital Medicine*, 1st Ed. Klotman P, Kathuria N, and Dunn A, eds. World Scientific, 2012.

7. Harrison M and Duvall WL. Basic Valvular Echocardiography. *Bedside Ultrasound in Critical Care Medicine*, 1st Ed. Oropello J and Manasia T, eds. Springer, planned publication 2013.

ABSTRACTS

1. Duvall WL, Restifo KM, Moscovitz HC, Kiskaddon RT. The cost effectiveness of non-contrast helical computed tomography compared to intravenous pyelography in the initial evaluation of flank pain in the emergency department. *Academic Emergency Medicine* 1996; 3: 547 (Abstract).

2. Wakabayashi T, Travin MI, Antonopoulos G, *et al.* The effect of attenuation correction (AC) on the interpretation of stress myocardial perfusion imaging (MPI). *J Nuc Cardiol* 2003; 10: S18 (Abstract).

3. Duvall WL, Henzlova MJ, Croft LB, Goldman ME. Comparison between evaluation of left ventricular size and function by gated SPECT and hand carried ultrasound. *J Nuc Cardiol* 2003; 10: S26 (Abstract).

4. Duvall WL, Croft LB, Einstein AJ, *et al.* SPECT myocardial perfusion imaging in the morbidly obese: Image quality and hemodynamic response to pharmacological stress. *J Nuc Cardiol* 2004; 11: S16-17 (Abstract).

5. Duvall WL, Croft LB, Corriel JS, *et al.* SPECT myocardial perfusion imaging in the morbidly obese: Prognosis and diagnostic value. *J Nuc Cardiol* 2004; 11: S17 (Abstract).

6. Duvall WL, Sealove BA, Vilca R, Sharma SK, Kim MC. The safety of percutaneous coronary interventions prior to noncardiac surgery. *Circulation* 2004; 110 (Supplement): III-383 (Abstract).

7. Duvall WL, Croft LB, Pungoti C, Henzlova MJ. Does attenuation correction improve the interpretation of MPI in patients with LBBB? *J Nuc Cardiol* 2005; 12: S102 (Abstract).

8. Chalfoun NT, Fleischut P, Maddox TM, Duvall WL, Henzlova MJ. Stress only Tc-99m gated MIBI SPECT imaging: prognosis of a normal study. *J Nuc Cardiol* 2006; 13: S2 (Abstract).

9. Belanger AR, Croft LB, Duvall WL, Henzlova MJ. Determinants of the hemodynamic response to coronary vasodilators. *J Nuc Cardiol* 2006; 13: S3 (Abstract).

10. Duvall WL, Sealove B, Pungoti C, *et al.* Demand ischemia is the predominant etiology of perioperative myocardial infarction: Implications for perioperative risk stratification. *JACC* 2007; 49 (Supplement): 239A (Abstract).

11. Spektor G, Waller AH, Daraban N, Duvall WL, *et al.* Comparison of 64-slice computed tomography coronary angiography, radionuclide myocardial perfusion imaging and stress echocardiogram in the detection of significant coronary artery stenosis. *JACC* 2007; 49 (Supplement): 142A (Abstract).

12. Duvall WL, Hansalia RJ, Buckley S, *et al.* Advantage of optimizing V-V timing in CRT devices using three-dimensional echocardiography and aortic velocity time integral. *Heart Rhythm* 2007; 4 (Supplement): S387 (Abstract).

13. Duvall WL, Pungoti C, and Henzlova M. The need for risk reclassification due to the presence of pre-clinical disease in patients with positive ECG response to exercise and normal myocardial perfusion during stress. *J Nuc Cardiol* 2007; 14: S130 (Abstract).

14. Fischer A, Hansalia RJ, and Duvall WL. Lack of predictors of optimal RV-LV delay as established by three dimensional echocardiography and aortic velocity time intergrals. *J Cardiovasc Electrophysiol* 2007; 18: S32 (Abstract).

15. Duvall WL, Razzouk L, Chalfoun NT, and Henzlova MJ. The prognosis of a normal stress-only SPECT myocardial perfusion imaging study. *Circulation* 2007; 116 (Supplement): II-376 (Abstract).

16. Duvall W, Beniaminovitz A, Buckley S, *et al.* Poor reproducibility of echocardiographic measures of mechanical dyssynchrony in cardiac resynchronization therapy. *JACC* 2008; 51 (Supplement): A133-A134 (Abstract).

17. Nair AP, Hansalia R, Beniaminovitz A, *et al.* Velocity vector imaging accurately quantifies left ventricular mechanical dyssynchrony. *Heart Rhythm* 2008; 5 (Supplement): S280 (Abstract).

18. Duvall W, Krishnan M, Mann M, *et al.* The safety of Definity echocardiographic contrast. *J Am Society of Echocardiography* 2008; 21: 572 (Abstract).

19. Sweeny JM, Mozes J, Croft L et al. The utility of repeat SPECT myocardial perfusion imaging in patients with end stage liver disease. *J Nuc Cardiol* 2008; 15: S36-37 (Abstract).

20. Duvall W, Wijetunga M, Klein T, *et al.* The prognosis of normal stress-only SPECT myocardial perfusion imaging studies. *JACC* 2009; 53: A287 (Abstract).

21. Nelson BP, Parekh S, Hermann L, *et al.* Ultrasound lung comets and brain natriuretic peptide in acute dyspnea. *J Ultraound Med* 2009; 28: s43 (Abstract).

22. Wijetunga M, Duvall L, Klein T, *et al.* Clinical use of stress-first SPECT myocardial perfusion imaging studies in an emergency department chest pain unit. *Eur Heart J* 2009; 11 (Supplement B): S15. (Abstract).

23. Klein T, Duvall L, Wijetunga M, *et al.* Positive predictive value of stress-first SPECT myocardial perfusion imaging. *Eur Heart J* 2009; 11 (Supplement B): S17. (Abstract). (Abstract) ICNC-9 Barcelona.

24. Duvall L, Wijetunga M, Klein T, *et al.* The prognosis of normal stress-only SPECT myocardial perfusion imaging studies. *Eur Heart J* 2009; 11 (Supplement B): S92. (Abstract).

25. Hermann L, Weingart S, Yoon Y, *et al.* Typical angina is not predictive of the presence of inducible cardiac ischemia in emergency department chest pain patients. *Ann Emerg Med* 2009; 54: S8 (Abstract).

26. Duvall W, Wijetunga M, Hansalia R, *et al.* Advantage of optimizing V-V timing in cardiac resynchronization therapy devices. *Heart Rhythm* 2009; 6 (Supplement): S446 (Abstract).

27. Bander J, Krasner A, Duvall W, *et al.* Validation of real-time 3D echo derived volume/time curves by magnetic resonance imaging. *J Am Soc Echo* 2009; 22: 571 (Abstract).

28. Duvall W, Croft L, Buckley S, *et al.* Left ventricular dysfunction of aging despite preserved LVEF detected by 3D echocardiography. *Circulation* 2009; 120: s391 (Abstract).

29. Duvall W, Croft L, Zucker A, et al. Can Doppler echocardiography define diastolic heart failure? *Circulation* 2009; 120: s363 (Abstract).

30. Hansalia R, Duvall W, Buckely S, *et al.* A comparison of cardiac resynchronization therapy optimization using Quick Opt and echocardiographic parameters. *J Card Failure* 2009; 15: s59 (Abstract).

31. Duvall W, Croft L, Buckley S, *et al.* Left ventricular systolic and diastolic interdependence demonstrated by left ventricular emptying and filling rates. *JACC* 2010; 55: A89 (Abstract).

32. Duvall W, Croft L, Godiwala T, *et al.* Reduced isotope dose and rapid imaging SPECT MPI with excellent image quality. *JACC* 2010; 55: A90 (Abstract).

33. Croft L, McLaughlin M, Bander J, *et al.* First documentation of cardiac dysfunction following exposure to the world trade center disaster. *JACC* 2010; 55: A86 (Abstract).

34. Ginsberg E, Duvall W, *et al.* Reduced Isotope Dose and Imaging Time with High Speed CZT SPECT Camera. *JNC* 2010; 17: 741 (Abstract).

35. Hiensch R, Duvall W, *et al.* Relationship of Hemodynamic Changes After Dipyridamole, Adenosine, and Regadenoson Administration and Body Weight. (Abstract) *JNC* 2010; 17: 739 (Abstract).

36. Duvall W, Sweeny J, *et al.* Comparison of High Speed CZT SPECT MPI to Coronary Angiography. *Circulation* 2010; 122: A18672. (Abstract).

37. Duvall W, Levine A, Baber U, *et al.* Effective Evaluation of Patients in an Emergency Department Chest Pain Unit with Myocardial Perfusion Imaging. *Eur Heart J* 2011; 13 (Supplement A): A49. (Abstract).

38. Duvall W, Sweeny J, Croft L, *et al.* Comparison of High Efficiency CZT SPECT MPI to Coronary Angiography. *Eur Heart J* 2011; 13 (Supplement A): A80-81. (Abstract).

39. Duvall W, Levine E, Baber U, *et al.* Effective Evaluation of Patients in an Emergency Department Chest Pain Unit with Myocardial Perfusion Imaging. *JACC* 2011; 57: E749 (Abstract).

40. Krasner A, Bander J, Duvall W, *et al.* Real-Time 3D Echo Generated Volume/Time Curves: Comparison to Magnetic Resonance Imaging and Interobserver Correlation. *JACC* 2011; 57: E857. (Abstract).

41. Hiensch R, Duvall W, Croft L, Henzlova M. Normal Tl-201 Stress-Only SPECT MPI. *J Nuc Cardiol* 2011; 18: 771-772. (Abstract).

42. Duvall W, Baber U, Levine E, *et al.* A Model for Determination of the Appropriateness of a Stress-First Tc-99m SPECT MPI. *J Nuc Cardiol* 2011; 18: 778-779. (Abstract).

43. Guma K, Duvall W, Kamen J, et al. Reduction in Occupational Radiation Exposure Using a CZT Camera for Myocardial Perfusion Imaging. *JACC* 2012; 59: E1317 (Abstract).

44. Duvall W, Levine E, Moonthungal S, *et al.* A Protocol for the Provisional Use of Perfusion Imaging in Exercise Stress. *J Nuc Cardiol* 2012; 19: 833. (Abstract).

45. Duvall W, Slomka P, Gerlach J, *et al.* Automated Quantification of High-Efficiency CZT SPECT MPI Compared to Clinical Interpretation. *J Nuc Cardiol* 2012; 19: 840. (Abstract).

46. Duvall W, Naib T, Greco G, *et al.* Cost Savings Associated with the Use of Selective Stress-Only and CZT SPECT Myocardial Perfusion Imaging. *J Nuc Cardiol* 2012; 19: 863. (Abstract).

47. Duvall W, Savino J, Levine E, *et al.* Radiation Dose and Downstream Testing from Coronary CT Angiography (CTA) versus SPECT Myocardial Perfusion Imaging (MPI) for the Evaluation of Chest Pain in the Emergency Department (ED). *Circulation* 2012, 126: A17862. (Abstract).

48. Henzlova M, Songy B, Jager PL, *et al.* Diversity of High-Efficiency CZT SPECT Tc-99m Imaging Protocols: Results of an International Survey. *J Nuc Cardiol* 2013; 20: S8 (Abstract).

49. Henzlova M, Levine EJ, Moonthungal S, *et al.* A Protocol for the Provisional Use of Perfusion Imaging with Exercise Stress Testing. *J Nuc Cardiol* 2013; 20: S9 (Abstract).

50. Henzlova M, Savino J, Levine EJ, *et al.* Radiation Dose and Downstream Testing from Coronary CT Angiography Compared to Stress Testing Using High-Efficiency SPECT MPI for the Evaluation of Chest Pain in the Emergency Department. *J Nuc Cardiol* 2013; 20: S71 (Abstract).

51. Henzlova M, Naib T, Greco G, *et al.* Cost Savings Associated with the Use of Selective Stress-Only and CZT SPECT Myocardial Perfusion Imaging. *J Nuc Cardiol* 2013; 20: S57 (Abstract).

52. Henzlova M, Savino J, Levine E, *et al.* Comparative Effectiveness of Coronary CT Angiography Versus Stress Testing Using High-Efficiency SPECT Myocardial Perfusion Imaging and Stress-Only Imaging in the Emergency Department. *JACC* 2013, 61: E847. (Abstract).

53. Savino JA, Duvall WL, Levine EJ, *et al.* Prospective Evaluation of the Provisional Use of Perfusion Imaging with Exercise Stress in the Emergency Department. *J Nuc Cardiol* 2013; 20: 670 (Abstract).

54. Levine EJ, Savino JA, Duvall WL, *et al.* Clinical Outcomes of Stress-First Myocardial Perfusion Imaging Studies. *J Nuc Cardiol* 2013; 20: 682-683 (Abstract).

55. Guma KA, Duvall WL, Fernandes V, *et al.* Initial Experience with SPECT Gated Blood Pool Scans Using a High-Efficiency SPECT Camera. *J Nuc Cardiol* 2013; 20: 659-660 (Abstract).

EDITORIALS

1. Duvall WL and Nash IS. Exercise, Physical Fitness, and Longevity. *Hurst's The Heart* Online Edition, The McGraw-Hill Companies. 2002.

2. Duvall WL and Nash IS. Too Thin or Not Too Thin (WARIS II). *Hurst's The Heart* Online Edition, The McGraw-Hill Companies. 2002.

3. Hansalia RJ, Duvall WL, and Mehta D. Predicting and Optimizing Response to Cardiac Resynchronization Therapy Beyond QRS Duration: Expanding Role of Echocardiography. *Indian Heart J* 2007; 59: 207-210.

4. Henzlova MJ, Croft LB, and Duvall WL. Stress-Only Imaging: Faster, Cheaper, Less Radiation. So What's the Hold Up? J Nucl Cardiol 2012. Nov 15 (Epub ahead of print)

INVITED CONTRIBUTIONS

1. Author of Monthly Column "New Therapy Update" in *Cardiovascular Reviews & Reports*

January 2003	Zetia (ezetimibe)
February 2003	Remodulin (treprostinil sodium)
March 2003	Inspra (eplerenone)
April 2003	Tevetan (eprosartan mesylate)
May 2003	InnoPran XL (propranolol hydrochloride)
June 2003	Coreg (carvedilol)
July 2003	Cypher (sirolimus-eluting coronary stent)

August 2003	Lescol XL (fluvastatin sodium)
September 2003	Cardizem LA (diltiazem hydrochloride)
October 2003	Pavigard PAC (buffered aspirin and pravastatin sodium)
Nov/Dec 2003	Crestor (rosuvastatin calcium)
Jan/Feb 2004	Contak System (cardiac resynchronization therapy defibrillator)
March/April 2004	Influenza Vaccine
May/June 2004	Caduet (amlodipine besylate/atorvastatin calcium)
July/Aug 2004	Taxus (paclitaxel-eluting coronary stent)
Sept/Oct 2004	Vytorin (ezetimibe/simvastatin)
Nov/Dec 2004	Exanta (ximelagatran)

INVITED LECTURES/PRESENTATIONS

2004 Medicine Grand Rounds
April 4th - Morbidity and Mortality Review on Balloon Aortic Valvuloplasty

2006 Cardiology Grand Rounds
April 17th - Update on Nuclear Cardiology Research

2006 Cardiology Grand Rounds
June 19th - Update on Mitral Valve Disease

2006 CV-MAP National Faculty
Cardio**V**ascular Issues in **M**anaging **A**rthritis **P**ain CME Program

2006 Cardiology Grand Rounds
October 9th – Cardiac Resynchronization Therapy

2011 Cardiology Grand Rounds
April 18th – Nuclear Cardiology 2011

2012 Hospital Medicine Grand Rounds
February 9th – Stress Testing

2012 Cardiology Grand Rounds
October 22nd – Nuclear Cardiology Update

RESEARCH EXPERIENCE

1994 ***Princeton Senior Thesis***
"Reverse Transcription-Polymerase Chain Reaction for the Detection of *LacZ* mRNA In Enhancer Trap Transformant Strains of *Polysphondylium pallidum*"

1998 ***Yale M.D. Thesis***

"The Cost Effectiveness of Non-contrast Helical Computed Tomography Compared to Intravenous Pyelography in the Initial Evaluation of Flank Pain in the Emergency Department"

- April 1996 - Oral Presentation at Society of Academic Emergency Medicine Annual Meeting in Denver, CO
- April 1996 - Abstract Published in *Academic Emergency Medicine* 1996; 3: 547
- October 1996 - Oral Presentation at American College of Physicians Connecticut Chapter Annual Meeting

CLINICAL TRIALS

2004-06 ***CVT 5132 Trial***

"A Phase III, Randomized, Double-Blind Study of Intravenous CVT-3146 vs. Adenoscan in Patients Undergoing Stress Myocardial Perfusion Imaging"

- Site Co-Investigator for Multicenter Study

2005-08 ***GE MIBG 312 Heart Failure Study***

"Open-Label, Multicentre, Phase 3 Study Evaluating the Prognostic Usefulness of ^{123}I-mIBG Scintigraphy for Identifying Subjects with Heart Failure who will Experience an Adverse Cardiac Event"

- Site Co-Investigator for Multicenter Study

2006- ***Genzyme Niemann Pick Type B Enzyme Replacement Study***

"Phase 1 Clinical Trial of Enzyme Replacement in Niemann Pick Disease"

- Cardiology Primary Investigator for Study

2006-07 ***King VISION 305 Study***

"Vasodilator Induced Stress in Concordance with Adenosine, a Phase III, Randomized, Double-Blind Multi-Center Study"

- Site Primary Investigator for Multicenter Study

2007-08 ***Molecular Insight MIP-BP23 Study***

"Open-Label, Phase 2 Study of the Safety and Efficacy of B-Methyl-P-^{123}I-Iodophenyl-Pentadeconoic Acid (Iodofiltic Acid I 123) for Identification of Ischemic Myocardium Using Single Photon Emission Computed Tomography (SPECT) in Adults with Symptoms Consistent with Acute Coronary Syndrome (ACS)"

- Site Co-Investigator for Multicenter Study

2010- ***Genzyme GZGD03109 Study***

"A Phase 3, Randomized, Multi-Center, Multi-National, Double-Blind Study to Evaluate the Efficacy, Safety, and Pharmacokinetics of Once Daily versus Twice Daily Dosing of Genz-112638 in Patients with Gaucher Disease Type 1 who have Demonstrated Clinical Stability on a Twice Daily Dose of Genz-112638"

- Cardiology Co-Investigator for Study

2010- ***Genzyme GZGD02507 Study***

"A Phase 3, Randomized, Double-Blind, Placebo-Controlled, Multi-Center Study Confirming the Efficacy and Safety of Genz-112638 in Patients with Gaucher Disease Type 1"

• Cardiology Co-Investigator for Study

2011-12 ***GE 078-101 Study***

"An Open-Label, Multicenter, Proof of Concept, Phase 2 Study Evaluating the Results of Tc99m-Maraciclatide Scintigraphy in subjects with Diabetes Mellitus and Heart Failure with Preserved Left Ventricular Ejection Fraction"

• Site Co-Investigator for Multicenter Study

2011- ***BMS 747158-301 Study***

"A Phase 3, Open-Label, Multicenter Study for the Assessment of Myocardial Perfusion Using Positron Emission Tomography Imaging of Flurpiridaz F-18 Injection in Patients with Suspected or Known Coronary Artery Disease"

• Site Co-Investigator for Multicenter Study

2012- ***Synageva BioPharma Corp. Study***

"An Open Label, Multicenter Extension Study to Evaluate the Long-Term Safety, Tolerability and Efficacy of SBC-102 in Adult Subjects with Liver Dysfunction Due to Acid Lipase Deficiency who Previously Received Treatment in Study LAL-CL01"

• Site Co-Investigator for Multicenter Study

2013- ***TURBULENCE Study***

"Clinical Evaluation of the Cadence® Device in Detection of Coronary Artery Disease"

• Site Co-Investigator for Multicenter Study

INTERESTS

Sailing, mountain biking, ice hockey

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

April Mann, BA, CNMT, NCT, RT (N)
Curriculum Vitae

Home Address: 47 Hadley Village Road, South Hadley, MA 01075

Business Address: Hartford Hospital
80 Seymour Street
Hartford, Connecticut 06102

Home Telephone: (413) 533-6158
Business Telephone: (860) 545-5531
Fax: (860) 545-5631

E-mail Address: april.mann@hhchealth.org (work)
aprilmann423@gmail.com (home)

Previous name used: Schaarschmidt

Education

Springfield Technical Community College, Springfield, Massachusetts
Associates of Science Degree, Nuclear Medicine Technology 1989

Elms College, Chicopee, Massachusetts.
Bachelors Degree of Arts, Health Care Management 2002

BayPath College, Longmeadow, Massachusetts
MBA, Entrepreneurial Thinking and Innovative Practices – pending completion 2013

Awards

John W. Turner Award, Springfield Technical Community College May 1988

1st Place, Cardiovascular Council Award, Technologist Papers, 47th Annual Society of Nuclear Medicine Meeting, St. Louis, Missouri, June 2000.

2nd Place, Cardiovascular Council Award, Technologist Papers, 47th Annual Society of Nuclear Medicine Meeting, St. Louis, Missouri, June 2000.

2nd Place, Cardiovascular Council Award, Technologist Papers, 48th Annual Society of Nuclear Medicine Meeting, Toronto, Canada, June 2001.

Fellowship Award, Society of Nuclear Medicine Technologist Section, 49th Annual Society of Nuclear Medicine Meeting, Los Angeles, California June 2002.

Service Award, New England Chapter Society of Nuclear Medicine Technologist Section, 35 Annual Spring Symposium, New England Chapter Technologist Section, Braintree, Massachusetts, March 2004.

Fellowship Award, American Society of Nuclear Cardiology January 2006

Affiliations and Certifications

Society of Nuclear Medicine and Molecular Imaging *(since 1993)*
New England Chapter, Society of Nuclear Medicine *(since 1993)*
American Society of Nuclear Cardiology *(since, 1996)*
Nuclear Medicine Technology Certification Board (*1989*) *#012417*
American Registry of Radiological Technology (Nuclear Medicine) *(1989) #236554*
Nuclear Cardiology Technologist, NMTCB *(2001) #C80004*
Basic Life Support (Healthcare Provider)
Alpha Sigma Lambda National Honor Society *(inducted April 2002)*
Honored Lifetime Member, Strathmore's Who's Who *(inducted edition 2003- 2004)*

Experience

1989-1990	**Charlotte Hungerford Hospital**, Torrington, Connecticut Staff Technologist, Nuclear Medicine Laboratory
1990- 1991	**Providence Hospital**, Holyoke, Massachusetts Clinical Supervisor, Nuclear Medicine Laboratory
1991-1994	**Hartford Hospital,** Hartford, Connecticut Staff Technologist, Clinical Nuclear Medicine
1992- 2000	**Hartford Hospital**, Hartford Connecticut Clinical Instructor, Springfield Technical Community College, Springfield Massachusetts
1994-1996	**Hartford Hospital**, Hartford, Connecticut Staff Technologist, Nuclear Cardiology Laboratory
1996- 2000	**Hartford Hospital**, Hartford, Connecticut Clinical Supervisor, Nuclear Cardiology Laboratory
2000-2001	**Hartford Hospital**, Hartford, Connecticut Manager, Nuclear Cardiology Laboratory

2001- 2008	**Hartford Hospital**, Hartford, Connecticut Manager, Non-Invasive Cardiology
2008 – 2009	**Hartford Hospital**, Hartford, Connecticut Manager, Non-Invasive Cardiology and Clinical Nuclear Medicine
2009- present	**Hartford Hospital**, Hartford, Connecticut Manager, Non-Invasive Cardiology

Appointments

1996- 1998	Grassroots Chairperson, Greater Hartford Area. Technologist Section, New England Chapter, Society of Nuclear Medicine.
1997- 2000	Co-Editor, Technologists' Section, Journal of Nuclear Cardiology
1997- 2001	Membership Committee, American Society of Nuclear Cardiology
1997- 2004	Technologist Committee, American Society of Nuclear Cardiology
1997 – 2004	Socio-Economic Affairs Committee, Technologist Section, Society of Nuclear Medicine (Chair, 2001-2003)
1997 – 2004	Nuclear Cardiology Committee, Technologist Section, Society of Nuclear Medicine (Chair 2000-2001)
1997 -1998	Co-Chair, Spring Symposium Committee, New England Chapter Technologist Section, Society of Nuclear Medicine
1997 - 1999	Item-Writer, American Registry of Radiologic Technologists
1998 – 2004	Scientific and Teaching Committee, Technologist Section, Society of Nuclear Medicine (2003 –2004 Continuing Education Vice-Chair)
1998 – 2000	Continuing Education Committee, Technologist Section, Society of Nuclear Medicine
1998 - 1999	President-elect, New England Chapter, Technologist Section, Society of Nuclear Medicine
1998 - 1999	Chair, Spring Symposium Committee, New England Chapter Technologist Section, Society of Nuclear Medicine
1998 - 1999	4th ASNC Tutorial Committee, American Society of Nuclear Cardiology

1999 – 2000	President, New England Chapter, Technologist Section, Society of Nuclear Medicine
1999 – 2000	Chair, New Millennium Subcommittee, Socio-Economic Affairs Committee, Technologist Section, Society of Nuclear Medicine
1999 – 2000	Membership Committee, Technologist Section, Society of Nuclear Medicine
1999 – 2004	Strategic Planning Committee, Technologist Section, Society of Nuclear Medicine
1999 – 2002	Awards Committee, Technologist Section, Society of Nuclear Medicine
1999 – 2000	Chapter Presidents Committee, Technologist Section, Society of Nuclear Medicine
1999 - 2004	Leadership and Mentoring Committee, Technologist Section, Society of Nuclear Medicine
1999 - 2000	5th ASNC Symposium and Scientific Session, American Society of Nuclear Cardiology
1999 – 2006	Board of Directors, Cardiovascular Council, Society of Nuclear Medicine (Secretary/Treasurer 2002- 2004) (Secretary 2004 – 2006)
1999 – 2001	Nuclear Medicine Week Subcommittee, Technologist Section, Society of Nuclear Medicine
2000 – 2001	Section Editor, Technologists' Section, Journal of Nuclear Cardiology
2000 - 2001	Immediate Past President, New England Chapter Technologist Section, Society of Nuclear Medicine
2000 – 2001	Chair, Nominating Committee, New England Chapter, Society of Nuclear Medicine
2000 – 2003	Service Award Committee, New England Chapter, Society of Nuclear Medicine (Chair 2000 – 2001)
2000 – present	Past Presidents Council, New England Chapter, Society of Nuclear Medicine (Chair 2000 – 2001)
2000 - 2001	Executive Board Member at Large, Technologist Section, Society of Nuclear Medicine.

2000 – 2008	Publications Committee, Technologist Section, Society of Nuclear Medicine.
2000 – 2001	Academic Affairs Committee, Technologist Section, Society of Nuclear Medicine
2000 – present	Administrator, New England Chapter, Society of Nuclear Medicine
2000	Member, Coalition for Allied Health Leadership, Health Professions Network, Society of Nuclear Medicine
2000 – 2004	Technologist Advisory Board, Bristol-Myers Squibb Medical Imaging, N. Billerica, Massachusetts
2000 – 2002	Coalition on Allied Health Task Force, Technologist Section, Society of Nuclear Medicine
2000 – present	Application Reviewer, Intersocietal Commission for the Accreditation of Nuclear Medicine Laboratories
2001 – present	Site Inspector, Intersocietal Commission for the Accreditation of Nuclear Medicine Laboratories
2001 – 2003	Allied Health Professionals Committee, American College of Cardiology
2001 – 2004	Finance Committee, Technologist Section, Society of Nuclear Medicine (Chair: 2003 – 2004)
2001 – 2002	Coding and Reimbursement Committee, Society of Nuclear Medicine
2001 – present	Education Committee, American Society of Nuclear Cardiology
2001- 2002	Technologist Task Force, American Society of Nuclear Cardiology
2002 – 2006	Associate Editor, Editorial Board, Journal of Nuclear Medicine Technology
2002 – 2009	Board of Directors, Nuclear Medicine Technology Certification Board (Secretary 2005, Chair-elect 2007, Chair 2008)
2002	Planning Committee, March 2003 Cardiovascular Administrators' Management Conference, American College of Cardiology Administrators, AAMA
2002 – 2004	Government Relations Committee, Committee, American Society of Nuclear Cardiology

2002 – 2003	Audits Committee, Society of Nuclear Medicine
2002 - 2004	Investments Subcommittee of Finance, Society of Nuclear Medicine
2002 – 2003	Membership Committee, Society of Nuclear Medicine
2002 – 2003	Ethics Sub-Committee, Society of Nuclear Medicine
2002 - 2003	8th Annual ASNC Symposium and Scientific Session Committee, American Society of Nuclear Cardiology
2003	Planning Committee, Annual 2003 American Academy of Medical Administrator's Conference Cardiovascular Session, San Antonio, TX.
2002 – present	Co-Program Director, Nuclear Cardiology for the Technologists, American Society of Nuclear Cardiology
2003 – 2004	Executive Board Member (Finance Chair), Society of Nuclear Medicine Technologist Section
2003	Planning Committee, March 2004 Cardiovascular Administrators' Management Conference, American College of Cardiology Administrators, AAMA
2003 - 2004	9th Annual ASNC Symposium and Scientific Session Committee, American Society of Nuclear Cardiology
2003 – 2006	Finance Committee, Society of Nuclear Medicine
2003 – 2006	Scientific Program Committee, Society of Nuclear Medicine
2004 – 2006	Reimbursement Task Force, Society of Nuclear Medicine
2004 – 2006	Program Committee, Society of Nuclear Medicine Technologist Section (Chair-elect 2004-2005, Chair 2005-2006)
2004 – 2006	Advocacy Committee, Society of Nuclear Medicine Technologist Section
2004 – 2006	Task Force on Emerging Technologies Committee, Society of Nuclear Medicine Technologist Section
2004 – 2006	Professional Development Task Force, Society of Nuclear Medicine Technologist Section

2004	Planning Committee, March 2005 Cardiovascular Administrators' Management Conference, American College of Cardiology Administrators, AAMA.
2003 - 2004	10th Annual ASNC Symposium and Scientific Session Committee, American Society of Nuclear Cardiology
2005	Planning Committee, March 2006 Cardiovascular Administrators' Management Conference, American College of Cardiology Administrators, AAMA
2005 – 2010	Board of Directors, Intersocietal Commission of Accredited Nuclear Laboratories
2005 – 2006	Finance Committee, Technologist Section, Society of Nuclear Medicine
2005 - 2006	11th Annual ASNC Symposium and Scientific Session Committee, American Society of Nuclear Cardiology
2005 – 2006	Bylaws Committee, Society of Nuclear Medicine
2005 – 2006	Ethics Committee, Society of Nuclear Medicine
2005 – 2007	PET/CT Technologist Education Task Force (Chair, 2005)
2005 – 2006	Committee on Healthcare Policy, Society of Nuclear Medicine
2005 – 2007	Program Director, Diagnostic and Interventional Symposium for the Cardiac Imaging Professional
2006 – 2009	Board of Directors, American Society of Nuclear Cardiology
2006 – 2008	Publications Committee, Technologist Section Society of Nuclear Medicine
2009 – 2010	Planning Committee, ASNC 2010, American Society of Nuclear Cardiology
2009 – 2011	Steering Committee on Education, American Society of Nuclear Cardiology
2010 – present	Health Policy Resource Group, American Society of Nuclear Cardiology
2010	Task Force on Laboratory Reaccreditation, American Society of Nuclear Cardiology

2010 – present	Finance Committee, Technologist Section Society of Nuclear Medicine and Molecular Imaging (Chair, 2012 – 2013)
2010 – present	Membership Committee, Technologist Section Society of Nuclear Medicine
2010 – present	Executive Committee, New England Chapter Technologist Section, Society of Nuclear Medicine (President-elect, 2010 – 2011, President, 2012 – 2013, Past President 2013 - 2014)
2010 – 2011	Planning Committee, ASNC 2011, American Society of Nuclear Cardiology
2011 – 2012	Planning Committee, ASNC 2012, American Society of Nuclear Cardiology
2012 – present	Finance Committee, Society of Nuclear Medicine and Molecular Imaging
2012 – present	Investments Sub-committee, Society of Nuclear Medicine and Molecular Imaging
2012 – present	Board of Directors, Society of Nuclear Medicine and Molecular Imaging Technologist Section (Finance Chair 2012 – 2013, President-elect 2013 – 2014)
2012 – present	National Council Delegates, Society of Nuclear Medicine and Molecular Imaging Technologist Section (Finance Chair 2012 – 2013, President-elect 2013 – 2014)

Presentations

February 18, 1996	"Gated SPECT Imaging: Perfusion and Clinical Data." 19th Annual Mid-Winter Meeting, New England Chapter, Society of Nuclear Medicine, North Conway, New Hampshire.
April 25, 1996	"Pharmacologic Stress." Annual Respiratory Therapy Symposium, Waterbury, Connecticut
February 16, 1997	"Technical Considerations for Acute Myocardial Perfusion Imaging." 20th Annual Mid-Winter Meeting, New England Chapter, Society of Nuclear Medicine, Jackson, New Hampshire.
September 13, 1997	"Technical Considerations in Image Acquisition." 2nd Annual Tutorial in Nuclear Cardiology, American Society of Nuclear Cardiology, Boston, Massachusetts.
October 25, 1997	"Acute Imaging-Technical Considerations." 11th Northeast Regional Society of Nuclear Medicine Meeting, Rye Brook, New York.

January 17, 1998 "Gated SPECT Imaging for the Technologist." Pharmacologic Stress Imaging 1998: Changing Concepts and Read with the Experts, American Society of Nuclear Cardiology, New York, New York.

February 15, 1998 "Sources of Error in Acquisition of Myocardial Perfusion Imaging- A Case Review." 21st Annual Mid-Winter Meeting, Society of Nuclear Medicine, Jackson, New Hampshire.

April 24, 1998 "Technical Consideration for Acute Myocardial Perfusion Imaging" North Carolina Society of Nuclear Medicine Meeting, Wilmington, North Carolina.

June 09, 1998 "Gated SPECT" 45th Annual Society of Nuclear Medicine Meeting, Toronto, Canada.

August 22, 1998 "Technical Considerations of Image Acquisition in SPECT Myocardial Perfusion Imaging." New Jersey Society of Nuclear Medicine, Teaneck, New Jersey

August 29, 1998 "Gated SPECT Imaging for the Technologist" New England Chapter Technologist Section, Society of Nuclear Medicine, New Hampshire Summer Grassroots Meeting. Yarmouth, Nova Scotia.

September 19, 1998 "Gated SPECT Imaging for the Technologist" New England Chapter Technologist Section, Society of Nuclear Medicine, Vermont Grassroots Meeting. Burlington, Vermont

May 8, 1999 "Gated SPECT Imaging for the Technologist" New England Chapter Technologist Section, Society of Nuclear Medicine, Maine Grassroots Meeting. Augusta, Maine.

June 5, 1999 "Technical Considerations of Image Acquisition in SPECT Myocardial Perfusion Imaging." 46th Annual Society of Nuclear Medicine Meeting, Los Angeles, California.

June 8, 1999 "Laboratory Logistics at Hartford Hospital." 46th Annual Society of Nuclear Medicine Meeting, Los Angeles, California.

November 13, 1999 "Building Blocks of the Technologist Section Society of Nuclear Medicine" New England Chapter, Vermont Grassroots Meeting, Burlington, Vermont.

March 31, 2000 "Nuts and Bolts of Gated SPECT Imaging" 45th Annual Southwest Chapter Society of Nuclear Medicine Meeting. Galveston, Texas

April 1, 2000	"Acute Myocardial Perfusion Imaging" 45th Annual Southwest Chapter, Society of Nuclear Medicine Meeting. Galveston, Texas
April 8, 2000	"Sensitivity, Specificity and Accuracy of Cardiac SPECT" 29th Annual Spring Symposium, Greater New York Chapter Technologist Section, Atlantic City, New Jersey.
May 5, 2000	"Review of AutoQuant™ and Vantage™ Attenuation Correction" ADAC/Du Pont User's Meeting, Tampa, Florida
June 5, 2000	"Correcting Common Artifacts at Hartford Hospital, Nuclear Cardiology Laboratory" 47th Annual Society of Nuclear Medicine Meeting, St. Louis, Missouri.
Sept. 23, 2000	"Acquisition: Challenges and Solutions." 5th Annual American Society of Nuclear Cardiology Symposium and Scientific Session. Chicago, Illinois.
Nov. 4, 2000	"Nuclear Cardiology: Acquisition Challenges and Solutions." 14th Annual Northeast Regional Scientific Meeting. New England and Greater New York Chapter of the Society of Nuclear Medicine. Newport, Rhode Island.
Dec 12, 2000	"Nuclear Cardiology Laboratory Accreditation" DuPont Pharmaceuticals, Al Dente Ristorante, Piscataway, New Jersey
Dec 14, 2000	"Nuclear Cardiology Laboratory Accreditation" Du Pont Pharmaceuticals, High Lawn Pavilion, West Orange, New Jersey
February 10, 2001	"Protocols: Parameters and Technical Considerations" Mid-Winter Meeting Educational Symposium, Society of Nuclear Medicine. Tampa, Florida
February 27, 2001	"Nuclear Cardiology Laboratory Accreditation" Du Pont Pharmaceuticals, The Grande Cafe, Morristown, New Jersey
April 19, 2001	"Technical Consideration for Myocardial Perfusion Imaging" 32nd Annual Spring Symposium, New England Chapter Technologist Section, Society of Nuclear Medicine. Hartford Marriott Farmington, Farmington, Connecticut.
April 20, 2001	"Nuclear Cardiology Laboratory Accreditation" 32nd Annual Spring Symposium, New England Chapter Technologist Section, Society of Nuclear Medicine. Hartford Marriott Farmington, Farmington, Connecticut.

May 5, 2001 "Myocardial Perfusion Imaging: The Good, the Bad and the Ugly." Florida Nuclear Medicine Technologists' Annual Meeting. Wyndham Harbourside, Tampa, Florida.

June 23, 2001 "Mastering the Meeting" Emerging Leaders Conference, 48th Annual Society of Nuclear Medicine Meeting, Toronto, Canada.

June 23, 2001 "Optimizing Display and Interpretation" Nuclear Cardiology 2001: Improving Image Quality – Read with the Experts, 48th Annual Society of Nuclear Medicine Meeting, Toronto, Canada.

October 6, 2001 "Protocols: Parameters and Technical Considerations" North Carolina Nuclear Medicine Technologist Fall Meeting. Raleigh Durham, North Carolina.

October 6, 2001 "Application of Gated SPECT" North Carolina Nuclear Medicine Technologist Fall Meeting. Raleigh Durham, North Carolina.

November 3, 2001 "Myocardial Perfusion Imaging: The Good, the Bad and the Ugly." Continuum 2001: Nuclear cardiology and Latest Updates. Southern Michigan Associates and Technical Affiliates. William Beaumont Hospital, Royal Oak, Michigan.

February 16, 2002 "Nuts and Bolts of Gated SPECT Imaging" Technologist Tutorial American Society of Nuclear Cardiology, Houston Texas.

February 16, 2002 "Stress Testing" Technologist Tutorial American Society of Nuclear Cardiology, Houston Texas.

March 2, 2002 "Nuts and Bolts of Gated SPECT Imaging" Technologist Tutorial American Society of Nuclear Cardiology, George Washington University, Washington, D.C.

March 2, 2002 "Stress Testing" Technologist Tutorial, American Society of Nuclear Cardiology, George Washington University, Washington, D.C.

April 6, 2002 "Nuts and Bolts of Gated SPECT Imaging" Technologist Tutorial, American Society of Nuclear Cardiology, Kansas City, Missouri.

April 6, 2002 "Stress Testing" Technologist Tutorial American Society of Nuclear Cardiology, Kansas City, Missouri.

April 13, 2002 "Choosing the Best Imaging Protocol" Combined Northeast ASNC Working Groups Meeting. New York Marriott Marquis, New York, New York.

May 3, 2002	"Technical Consideration of Myocardial Perfusion Imaging" 31st Annual Spring Symposium, Greater New York Chapter Technologist Section, Society of Nuclear Medicine. Franklin Wyndham Hotel, Philadelphia, Pennsylvania.
May 4, 2002	"Myocardial Perfusion Imaging: the Good the Bad and the Ugly" Florida Nuclear Medicine Technologists 2002 Annual Meeting, Orlando, Florida.
May 15, 2002	"Myocardial Perfusion Imaging: the Good the Bad and the Ugly" Nuclear Medicine Technologist Section of the Society of Nuclear Medicine of Puerto Rico. San Juan, Puerto Rico.
May 16, 2002	"Myocardial Perfusion Imaging: the Good the Bad and the Ugly" Nuclear Medicine Technologist Section of the Society of Nuclear Medicine of Puerto Rico. Ponce, Puerto Rico.
September 12, 2002	"Imaging Protocols and Parameters" Nuclear Cardiology Board Review Coarse, Southeast Chapter Annual Meeting, Orlando, Florida.
September 28, 2002	"Acute Chest Pain Imaging in Your Emergency Department" 7th Annual ASNC Symposium and Scientific Session, Baltimore, Maryland.
October 17, 2002	"Cardiac SPECT Processing: Parameters and Techniques" 27th Annual Nuclear Cardiology Symposium and Workshop. Wyndham Milwaukee Center Hotel, Milwaukee, Wisconsin
October 17, 2002	"Imaging Artifacts and Errors: Challenges and Solutions" 27th Annual Nuclear Cardiology Symposium and Workshop. Wyndham Milwaukee Center Hotel, Milwaukee, Wisconsin.
April 12, 2003	"The Ins and Out's of the NMTCB Nuclear Cardiology Specialty Exam. 34th Annual Spring Symposium, New England Chapter Technologist Section, Society of Nuclear Medicine. Eastland Hotel Portland, Maine.
May 3, 2003	"Identification and Prevention of Common Artifacts in Nuclear Cardiology" 32nd Annual Spring Symposium, Greater New York Chapter Technologist Section, Society of Nuclear Medicine. Wyndham Philadelphia at Franklin Plaza, Philadelphia, Pennsylvania.
May 3, 2003	"The NMTCB Nuclear Cardiology Specialty Exam" 32nd Annual Spring Symposium, Greater New York Chapter Technologist Section, Society of Nuclear Medicine. Wyndham Philadelphia at Franklin Plaza, Philadelphia, Pennsylvania.

May 13, 2003 "Acquisition and Processing of Attenuation Correction from a Technologist Point of View." Philips (ADAC) Users' Meeting on Attenuation Correction. Marriott LaGuardia, New York, New York.

May 17, 2003 "Disease Processes of the Heart" Nuclear Cardiology for the Technologists, American Society of Nuclear Cardiology. Hyatt Arlington, Arlington, Virginia.

May 17, 2003 "Pharmacologic Stress Testing" Nuclear Cardiology for the Technologists, American Society of Nuclear Cardiology. Hyatt Arlington, Arlington, Virginia.

May 18, 2003 "Performing Effective Imaging Protocols" Nuclear Cardiology for the Technologists, American Society of Nuclear Cardiology. Hyatt Arlington, Arlington, Virginia.

May 18, 2003 "Processing Parameters: Techniques and Considerations" Nuclear Cardiology for the Technologists, American Society of Nuclear Cardiology. Hyatt Arlington, Arlington, Virginia.

May 18, 2003 "Overview of Gamma Camera Quality Control" Nuclear Cardiology for the Technologists, American Society of Nuclear Cardiology. Hyatt Arlington, Arlington, Virginia.

June 21, 2003 "Stress Protocols – Exercise versus Pharmacological" 50th Annual Society of Nuclear Medicine Meeting, New Orleans, Louisiana

June 21, 2003 "Read with the Experts – Understanding and Interpreting the Images" 50th Annual Society of Nuclear Medicine Meeting, New Orleans, Louisiana

June 22, 2003 "ICANL Accreditation Workshop" 50th Annual Society of Nuclear Medicine Meeting, New Orleans, Louisiana

June 23, 2003 "Advances in Pharmacologic Stress Myocardial Perfusion Imaging" 50th Annual Society of Nuclear Medicine Meeting, New Orleans, Louisiana

June 23, 2003 "Optimizing Acquisition Parameters and Imaging Protocols" 50th Annual Society of Nuclear Medicine Meeting, New Orleans, Louisiana

June 24, 2003 "The Development of the NMTCB-NCT Specialty Exam" 50th Annual Society of Nuclear Medicine Meeting, New Orleans, Louisiana

September 11, 2003 "Writing: How Do I Begin?" Professional Development Session, 8th Annual symposium and Scientific Session, American Society of Nuclear Cardiology, Indianapolis, Indiana

September 12, 2003 "Artifacts in SPECT Perfusion and Function" Core Session, 8th Annual symposium and Scientific Session, American Society of Nuclear Cardiology, Indianapolis, Indiana

September 12, 2003 "Philips How to Session: Attenuation Correction," 8th Annual symposium and Scientific Session, American Society of Nuclear Cardiology, Indianapolis, Indiana.

October 24, 2003 "Processing Nuclear Cardiology Studies" 28th Annual Nuclear Cardiology Symposium and Workshop. Wyndham Milwaukee Center Hotel, Milwaukee, Wisconsin.

October 24, 2003 "Practicing Nuclear Cardiology" 28th Annual Nuclear Cardiology Symposium and Workshop. Wyndham Milwaukee Center Hotel, Milwaukee, Wisconsin.

December 4, 2003 "Technical Challenges of Myocardial Perfusion Imaging" Bristol-Myers Squibb Medical Imaging, Troy, Wisconsin.

December 14, 2003 "Artifacts in SPECT Perfusion and Function Imaging" King Pharmaceuticals Investigator's Meeting, Loews Miami Beach Florida, Miami, Florida.

March 5, 2004 "Successful Operations of Non-Invasive Cardiology Cardiovascular Administrators' Management Conference, Hotel Intercontinental, New Orleans, Louisiana.

March 14, 2004 "Considerations for Display and Interpretation of Myocardial Perfusion Imaging" Nuclear Medicine/PET Update for Technologists, Opryland Hotel, Nashville, Tennessee.

March 14, 2004 "Considerations for Stress Testing" Nuclear Medicine/PET Update for Technologists, Opryland Hotel, Nashville, Tennessee.

March 27, 2004 "Disease Processes of the Heart" 35 Annual Spring Sympsium, New England Chapter society of Nuclear Medicine Technologist section, Braintree, Massachusetts.

March 28, 2004 "Cardiac Signs & Symptoms" 32nd Annual Spring Symposium, Greater New York Chapter Technologist Section, Society of Nuclear Medicine, Tarrytown, New York.

April 3, 2004 "Overview of Gamma Camera Quality Control" ASNC Affiliated Northeast Combined Nuclear Cardiology Working Groups Meeting. Mystic Marriott Hotel & Spa, Mystic, Connecticut.

April 3, 2004 "Processing Parameters: Techniques and Considerations" Northeast Combined Nuclear Cardiology Working Groups Meeting. Mystic Marriott Hotel & Spa, Mystic, Connecticut.

May 1, 2004 "Disease Processes of the Heart" Nuclear Cardiology for the Technologists, American Society of Nuclear Cardiology, University of Maryland Medical Center, Baltimore, Maryland.

May 1, 2004 "Protocols and Acquisition Considerations" Nuclear Cardiology for the Technologists, American Society of Nuclear Cardiology, University of Maryland Medical Center, Baltimore, Maryland.

May 2, 2004 "Nuclear Cardiology Operations" Nuclear Cardiology for the Technologists, American Society of Nuclear Cardiology, University of Maryland Medical Center, Baltimore, Maryland.

May 5, 2004 "Processing Considerations" Bristol-Myers Squibb Medical Imaging Customer Meeting, Ponce Hilton, Ponce, Puerto Rico

May 6, 2004 "Processing Considerations" Bristol-Myers Squibb Medical Imaging Customer Meeting, San Juan, Puerto Rico.

May 14, 2004 "How to Turn an Abstract into a Poster" Connecticut Chapter, ACP-ASIM Annual Associates Educational Meeting, Hartford Hospital, Hartford, Connecticut.

May 14, 2004 "Navigating Through PowerPoint" Connecticut Chapter, ACP-ASIM Annual Associates Educational Meeting, Hartford Hospital, Hartford, Connecticut.

May 14, 2004 "Tips for Public Speaking" Connecticut Chapter, ACP-ASIM Annual Associates Educational Meeting, Hartford Hospital, Hartford, Connecticut.

June 19, 2004 "Disease Processes of the Heart" 51st Annual Society of Nuclear Medicine Meeting. Philadelphia, Pennsylvania.

September 30, 2004 "Artifacts in Myocardial Perfusion and Function" 9th Annual American Society of Nuclear Cardiology Symposium and Scientific Sessions. New York, New York.

September 30, 2004 "Camera Related Artifacts" 9th Annual American Society of Nuclear Cardiology Symposium and Scientific Sessions. New York, New York.

October 1, 2004 "Cardiac Signs and Symptoms" 9th Annual American Society of Nuclear Cardiology Symposium and Scientific Sessions. New York, New York.

October 12, 2004 "Optimizing SPECT Perfusion and Function Imaging for Diagnosis and Risk Stratification" New England Chapter Grassroots Meeting, Delaney House Holyoke, Massachusetts.

October 30, 2004 "Adapting to Change" 18th Annual Northeast Regional Scientific Sessions. Stamford Marriott, Stamford, Connecticut.

December 3, 2004 "Practical Application of Attenuation Correction Workshop" American College of Cardiology, Gleatcher Center Chicago, Illinois.

December 3, 2004 "PET: Getting Started Workshop" American College of Cardiology, Gleatcher Center Chicago, Illinois.

December 9, 2004 "Optimizing SPECT Perfusion and Function Imaging for Diagnosis and Risk Stratification" In-service, Lawrence General Hospital, Lawrence Massachusetts.

January 29, 2005 "Update on Attenuation Correction" Annual Mid-Winter Meeting, Society of Nuclear Medicine Technologist Section Saddlebrook Resort, Tampa, Florida.

March 6, 2005 "Read with the Experts: Recognizing and Solving Gated SPECT Problems" Annual Scientific Session, American College of Cardiology, Orlando, Florida.

April 16, 2005 "Update on Attenuation Correction" Spring Symposium, New England Chapter Society of Nuclear Medicine. Sheraton, Springfield, Massachusetts.

April 30, 2005 "Processing Considerations" Nuclear Cardiology for the Technologists, American Society of Nuclear Cardiology, University of Maryland Medical Center, Baltimore, Maryland.

April 30, 2005 "Processing Considerations" Nuclear Cardiology for the Technologists, American Society of Nuclear Cardiology, University of Maryland Medical Center, Baltimore, Maryland.

May 1, 2005 "Attenuation Correction" Nuclear Cardiology for the Technologists, American Society of Nuclear Cardiology, University of Maryland Medical Center, Baltimore, Maryland.

May 1, 2005 "Laboratory Accreditation" Nuclear Cardiology for the Technologists, American Society of Nuclear Cardiology, University of Maryland Medical Center, Baltimore, Maryland.

May 9, 2005 "Quality Assurance: What to look for?" 7th International Conference of Nuclear Cardiology European Society of Cardiology, Lisbon, Portugal.

May 10, 2005 "How to Perform Attenuation Correction" 7th International Conference of Nuclear Cardiology, European Society of Cardiology, Lisbon, Portugal.

June 19, 2005 "Identification and Prevention of Common Artifacts in Myocardial Perfusion Imaging" 52nd Annual Society of Nuclear Medicine Meeting. Toronto, Canada.

September 29, 2005 "Tips on Public Speaking" 10th Annual American Society of Nuclear Cardiology Symposium and Scientific Sessions. Seattle, Washington.

November 12, 2005 "Roundtable Discussion: Evaluating and Purchasing New Cardiac Imaging Technologies" 48th Annual American Academy of Medical Administrators Conference, Riviera Hotel & Casino, Las Vegas, Nevada.

February 11, 2006 "Perfusion Imaging: Moving from SPECT to PET" Mid–Winter Symposium, Society of Nuclear Medicine, Tempe, Arizona.

March 9, 2006 "Cardiac Imaging for the Future: Which Way Should I Go?" 17th Annual Cardiovascular Administrators Conference, American College of Cardiovascular Administrators, Sheraton Atlanta Hotel, Atlanta, Georgia

March 11, 2006 "Acquisition and Processing" Practical Applications of Nuclear Cardiology: A Fellows/Residents Tutorial, Sheraton Atlanta Hotel, Atlanta, Georgia.

March 11, 2006 "Acquisition and Processing" Practical Applications of Nuclear Cardiology: A Fellows/Residents Tutorial, Sheraton Atlanta Hotel, Atlanta, Georgia.

April 9, 2006 "Optimizing Acquisition Parameters and Imaging Protocols" Advanced Cardiac Imaging for the Technologist, Society of Nuclear Medicine, Scottsdale Plaza Resort, Scottsdale, Arizona.

April 9, 2006 "Stress Testing for SPECT and PET" Advanced Cardiac Imaging for the Technologist, Society of Nuclear Medicine, Scottsdale Plaza Resort, Scottsdale, Arizona.

April 9, 2006	"Attenuation Correction for SPECT" Advanced Cardiac Imaging for the Technologist, Society of Nuclear Medicine, Scottsdale Plaza Resort, Scottsdale, Arizona.
October 20, 2006	"Technical Considerations for Acquisition Protocols" 31st Annual Nuclear Cardiology Symposium and Workshop, Milwaukee, Wisconsin.
October 20, 2006	"Technical Considerations for Processing" 31st Annual Nuclear Cardiology Symposium and Workshop, Milwaukee, Wisconsin.
July 22, 2006	"Cardiac Part 1" Viva Las Vegas 2006, Pacific Southwest Technologist Chapter, Society of Nuclear Medicine, Las Vegas, Nevada.
July 22, 2006	"Cardiac Part 2" Viva Las Vegas 2006, Pacific Southwest Technologist Chapter, Society of Nuclear Medicine, Las Vegas, Nevada.
April 14, 2007	"Implementing Cardiac PET and PET/CT: Considerations Beyond the Protocols" At the Heart of the Matter: Cardiac PET & PET/CT. Charlotte, North Carolina.
May 5, 2007	"Images: Processing 101" Nuclear Cardiology for the Technologist, American Society of Nuclear Cardiology Chicago, Illinois.
May 5, 2007	"Quality Assurance: Techniques for Excellence and Satisfaction" Nuclear Cardiology for the Technologist, American Society of Nuclear Cardiology Chicago, Illinois.
May 5, 2007	"Attenuation Correction: Principles and Techniques" Nuclear Cardiology for the Technologist, American Society of Nuclear Cardiology Chicago, Illinois.
May 19, 2007	"Implementing Cardiac PET and PET/CT: Considerations Beyond the Protocols" At the Heart of the Matter: Cardiac PET & PET/CT. Dallas, Texas.
April 24, 2009	"Attenuation Correction" Nuclear Cardiology for the Technologist, American Society of Nuclear Cardiology, Chicago, Illinois.
May 3, 2008	"Considerations of Processing" Nuclear Cardiology for the Technologist, American Society of Nuclear Cardiology, Chicago, Illinois.
May 4, 2008	"Attenuation Correction" Nuclear Cardiology for the Technologist, American Society of Nuclear Cardiology, Chicago, Illinois.

May 4, 2008	"Quality Assurance: Techniques for Excellence and Satisfaction" Nuclear Cardiology for the Technologist, American Society of Nuclear Cardiology Chicago, Illinois.
September 12, 2008	"Guidelines: Their Purpose and Place" Annual Scientific Session, American Society of Nuclear Cardiology. Boston, Massachusetts.
October 11, 2008	"Considerations of Processing" Nuclear Cardiology for the Technologist, American Society of Nuclear Cardiology, San Antonio, Texas.
October 12, 2008	"Attenuation Correction" Nuclear Cardiology for the Technologist, American Society of Nuclear Cardiology, San Antonio, Texas.
October 12, 2008	"Quality Assurance: Techniques for Excellence and Satisfaction" Nuclear Cardiology for the Technologist, American Society of Nuclear Cardiology San Antonio, Texas.
April 24, 2009	"PET: Principles and Instrumentation" Cardiac PET Workshop, American Society of Nuclear Cardiology, Fort Lauderdale, Florida
April 24, 2009	"Attenuation Correction" Nuclear Cardiology for the Technologist, American Society of Nuclear Cardiology, Fort Lauderdale, Florida
September 30, 2009	"Indications and Protocols for Myocardial Perfusion" Nuclear Cardiology for the Working Technologist, American Society of Nuclear Cardiology, Minneapolis, Minnesota.
September 30, 2009	"Pharmaceutical Classifications" Nuclear Cardiology for the Working Technologist, American Society of Nuclear Cardiology, Minneapolis, Minnesota.
October 1, 2009	"MPI and Patient Management/Outcomes" Nuclear Cardiology for the Working Technologist, American Society of Nuclear Cardiology, Minneapolis, Minnesota.
October 1, 2009	"Basic PET Imaging" Nuclear Cardiology for the Working Technologist, American Society of Nuclear Cardiology, Minneapolis, Minnesota.
October 2, 2009	"Acquisition (Protocols, Parameters and Artifacts)" ASNC 2009, American Society of Nuclear Cardiology, Minneapolis, Minnesota.
October 2, 2009	"Appropriate Use Criteria and the Role of the Technologist" ASNC 2009, American Society of Nuclear Cardiology, Minneapolis, Minnesota.

October 2, 2009	"Nuclear Jeopardy" ASNC 2009, American Society of Nuclear Cardiology, Minneapolis, Minnesota.
October 3, 2009	"F-18 Agents in Cardiology: Practical Concerns," ASNC 2009, American Society of Nuclear Cardiology, Minneapolis, Minnesota.
April 10, 2010	"Cardiac PET: 2010," New England Chapter Society of Nuclear Medicine Technologist Section Spring Symposium, Plymouth, Massachusetts.
May 14, 2010	"Diseases of the Heart," Nuclear Cardiology for the Technologists 2010, American Society of Nuclear Cardiology, Chicago, Illinois.
May 15, 2010	"How Do I Fix Attenuation?" Nuclear Cardiology for the Technologists 2010, American Society of Nuclear Cardiology, Chicago, Illinois.
May 16, 2010	"Blood Flow Imaging," Nuclear Cardiology for the Technologists 2010, American Society of Nuclear Cardiology, Chicago, Illinois.
May 16, 2010	"Laboratory Considerations for Cardiac PET: Are they different than SPECT?" Nuclear Cardiology for the Technologists 2010, American Society of Nuclear Cardiology, Chicago, Illinois.
June 7, 2010	"Cardiac PET: 2010," Society of Nuclear Medicine Annual Meeting, Salt Lake City, Utah.
September 22, 2010	"MPI and Patient Management/Outcomes- Is This Useful?" Nuclear Cardiology for the Working Technologists, ASNC 2010, American Society of Nuclear Cardiology, Philadelphia, Pennsylvania.
September 22, 2010	"Reconstruction Processing and Filters-Does it Affect My Images?" Nuclear Cardiology for the Working Technologists, ASNC 2010, American Society of Nuclear Cardiology, Philadelphia, Pennsylvania.
September 22, 2010	"Exercise Stress Testing Protocols and End Points" Nuclear Cardiology for the Working Technologists, ASNC 2010, American Society of Nuclear Cardiology, Philadelphia, Pennsylvania.
September 23, 2010	Basic PET Imaging Nuclear Cardiology for the Working Technologists, ASNC 2010, American Society of Nuclear Cardiology, Philadelphia, Pennsylvania.
September 23, 2010	Nuclear Cardiology for the Working Technologists, ASNC 2010, American Society of Nuclear Cardiology, Philadelphia, Pennsylvania.

September 23, 2010 "*MPI and Patient Management/Outcomes – Is This Useful*?" Nuclear Cardiology for Nurses and Nurse Practitioners, ASNC 2010, American Society of Nuclear Cardiology, Philadelphia, Pennsylvania.

September 24, 2010 "Achieving Adequate Count Statistics: Sizing Up the Individual Patient" ASNC 2010, American Society of Nuclear Cardiology, Philadelphia, Pennsylvania.

September 25, 2010 "PET Imaging: How Does This Work?" ASNC 2010, American Society of Nuclear Cardiology, Philadelphia, Pennsylvania.

September 25, 2010 "Laboratory Considerations: What's so different?" ASNC 2010, American Society of Nuclear Cardiology, Philadelphia, Pennsylvania.

September 25, 2010 "Nuclear Cardiology Jeopardy *Part I: Basic Science"* ASNC 2010, American Society of Nuclear Cardiology, Philadelphia, Pennsylvania.

PUBLICATIONS

Abstracts

1. White MP, McMahon M, Russell A, Mascitelli VA, Heller GV. Clinical Comparison of Circular vs. Non-circular Orbit Using Tc-99m Myocardial SPECT Imaging. *J Nucl Med Tech* 1995; 36:263

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

Work Experience

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

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

May 1997	**Executive Vice President & Chief Financial Officer**
To April 2013	**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	**Vice President, Finance and Chief Financial Officer**
To May 1997	**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	**Senior Vice President, Finance**
To April 1996	**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;

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.

EXHIBIT 7

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

Vault

IN REPLY REFER TO
T:EO: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 8

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, 2013** and may be revoked for cause at any time.
Dated at Hartford, Connecticut, January 1, 2012.

Satellites:

West Hartford Surgery Center, 65 Memorial Road, Suite 500, West Hartford
Duncaster Primary Care Satellite, 40 Loeffler Road, Bloomfield
Hartford Hospital, 505 Willard Avenue, Bldg. 3, Newington
*Hartford Marathon Medical Tent, Bushnell Park, at the Finish Line, Hartford
*Hartford Marathon Medical Tent, Bushnell Park, East of the Carousel, Hartford
*Hartford Marathon Medical Tent, Steele Road and Asylum Street, West Hartford

License Revised to Reflect:
*Added (3) Satellites for the Hartford Marathon. Effective for (1) day 10/12/13.

Jewel Mullen, MD, MPH, MPA
Commissioner

EXHIBIT 9

Hartford Hospital

A Hartford HealthCare Partner

CONSTRUCTION BID SET
FEB. 15, 2013

H.H. NUCLEAR SPEC/CT
SOUTH BUILDING - 2ND FLOOR
80 SEYMOUR STREET
HARTFORD, CT

LIST OF DRAWINGS

● NEW OR REVISED ISSUE
○ NOT ISSUED

			DATE ISSUED (02/15/13)	REMARKS
COVWE	A-001	COVER SHEET – DRAWING LIST – GENERAL NOTES – CODE DATA	●	
	A-002	FIRE STOPPING AND WALL TYPE DETAILS	●	
ARCHITECTURAL	A-110	PROPOSED FLOOR PLAN (1st. FLOOR LEVEL)	●	
	AD-120	DEMOLITION FLOOR PLAN (2nd. FLOOR LEVEL)	●	
	A-120	PROPOSED FLOOR PLAN (2ND. FLOOR LEVEL)	●	
	A-720	REFLECTED CEILING PLAN (2ND. FLOOR LEVEL)	●	
	A-800	INTERIOR ELEVATIONS, MILLWORK & SECTIONS	●	
	FF-120	EQUIPMENT FURNITURE PLAN (2ND. FLOOR LEVEL)	●	
	FF-121	FINISH TREATMENT PLAN (2ND. FLOOR LEVEL)	●	
SIEMENS	CS	COVER SHEET	●	
	A-101	ARCHITECTURAL EQUIPMENT PLAN – LEGEND – NOTES	●	
	A-102	SAFETY/SERVICE CLEARANCE PLAN – NOTES	●	
	S-101	STRUCTURAL FLOOR PLAN-NOTES-MOUNTING DETAILS	●	
	S-102	PREPARATION/PROCEDURE FOR FLOOR LEVELING AND FLATTENING	●	
	E-101	ELECTRICAL RACEWAY PLAN – DIMENSION PLAN – NOTES	●	
	E-102	POWER SCHEDULE – SYMBOLS – NOTES	●	
STRUCTURAL	S-100	STRUCTURAL MODIFICATION AT 1ST & 2ND FLOOR FRAMING	●	
FIRE PROT. & PLUMBING	FP-100	FIRE PROTECTION DEMO & PROPOSED FLOOR PLANS (2nd. FLOOR LEVEL)	●	
	FP-200	FIRE PROTECTION ABBREVIATIONS, NOTES, LEGENDS, DETAILS & SPECS	●	
	P-100	PLUMBING DEMOLITION & PROPOSED FLOOR PLANS (2nd. FLOOR LEVEL)	●	
	P-200	PLUMBING ABBREVIATIONS, NOTES, LEGENDS, DETAILS & SCHEDULES	●	
	P-300	PLUMBING SPECIFICATIONS	●	
HVAC	M-100	MECHANICAL DEMOLITION & PROPOSED FLOOR PLANS (2nd. FLOOR LEVEL)	●	
	M-200	MECHANICAL ABBREVIATIONS, NOTES, LEGENDS, DETAILS & SCHEDULES	●	
	M-300	MECHANICAL SPECIFICATIONS	●	
ELECTRICAL	E-100	ELECTRICAL DEMOLITION & PROPOSED FLOOR PLANS (2nd. FLOOR LEVEL)	●	
	E-200	ELECTRICAL DEMOLITION & PROPOSED FLOOR PLANS (2nd. FLOOR LEVEL)	●	
	E-300	ELECTRICAL ABBREVIATIONS, NOTES, LEGENDS, DETAILS & SCHEDULES	●	

SYMBOLS

- FIRST FLOOR PLAN — SCALE: 1/4"=1'-0" — DETAIL NAME
- SECTION CUT
- DETAIL
- DOOR NUMBER
- WINDOW NUMBER
- ROOM NUMBER
- ELEVATION MARK
- FINISH BASE TAG
- FINISH CARPET TAG
- FINISH PAINT TAG
- FINISH WALL TAG

GENERAL NOTES

1. DO NOT SCALE DRAWINGS. USE DIMENSIONS.
2. GENERAL CONTRACTOR TO FIELD VERIFY ALL DIMENSIONS AND CONDITIONS AND SHALL BE RESPONSIBLE FOR SAME.
3. ALL INTERIOR DIMENSIONS ARE TO FINISHED FACE OF GYPSUM WALL BOARD (GWB) PARTITIONS.
4. PROVIDE WOOD BLOCKING IN ALL DRYWALL PARTITIONS AS REQUIRED TO ANCHOR HANDRAILS, SHELVING, WALL CABINETS, TOILET ACCESSORIES, GRAB BARS, MISC. ACCESSORIES AND TRIPS.
5. THESE DOCUMENTS ARE THE SOLE PROPERTY OF THE ARCHITECT AND SHALL NOT BE USED FOR CONSTRUCTION ON ANY OTHER SITE WITHOUT WRITTEN PERMISSION OF THE ARCHITECT.
6. GENERAL CONTRACTOR IS RESPONSIBLE FOR ADHERING TO THE FULL SET OF CONTRACT DOCUMENTS, WHICH INCLUDES THIS SET OF DRAWINGS AND SPECIFICATIONS. DOCUMENTS SHALL BE USED AS A WHOLE AT ALL TIMES. CONTRACTOR SHALL REPORT ANY DISCREPANCIES OR CONFLICTS BETWEEN DRAWINGS AND SPECS. TO THE ARCHITECT.

CODE DATA

MODEL CODE REVIEW BASED UPON INTERNATIONAL BUILDING CODE CROSS-REFERENCED WITH LIFE SAFETY, ADA, STATE HEALTH, ETC.

APPLICABLE CODES

A. 2005 International Building Code Portion of The 2005 State Building Code State of Connecticut + 2005 Amendments
B. International Mechanical Code / 2003
C. National Electrical Code / 2005
D. International Plumbing Code / 2003
E. ICC/ANSI A117.1 / 2003 Accessible and Usable Buildings and Facilities
F. ADA (Americans with Disabilities Act)
G. International Energy Conservation Code / 2004
H. International Fuel Gas Code / 2003
I. Guidelines for Design and Construction of Hospitals and Health Care Facilities / Chapters 8 / 2010
J. Connecticut Public Health Code 2006 (Rev. 10-13-09) Long Term Hospitals
K. Connecticut Fire Safety Code Guide Book 2005
International Fire Code / 2003, NFPA 1 Uniform Fire Code / 2003, NFPA 101 Life Safety Code / 2003, 2005 Amendment
L. NFPA 99 Health Care Facilities / 2002
M. UL Vol. 1, 2 and 3 / 2003
N. OSHA 2003
O. Town and Local Ordinances
P. NFPA 10 Fire Alarm

I.	USE GROUP USE GROUP - NFPA 101	I - 2 INSTITUTIONAL
II.	CONSTRUCTION CLASSIFICATION-	2 A PROTECTED NONCOMBUSTIBLE
III.	SPRINKLERS	FULLY SPRINKLERED
IV.	INTERIOR FINISHES	ALL FINISHES SHALL BE CLASS I IN ACCORDANCE W/ SECT. (7-10 & 8-8.) OF THE LIFE SAFETY CODE.

REVISIONS

CONSULTANTS

H.H. NUCLEAR SPEC/CT
SOUTH BUILDING - 2ND FLOOR
80 SEYMOUR STREET
HARTFORD, CT

Hartford Hospital
A Hartford HealthCare Partner

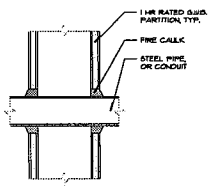
COVER SHEET - DRAWING LIST - GENERAL NOTES - CODE DATA

MBH ARCHITECTURE

DATE ISSUED:	02/15/2013
SCALE:	1/4" = 1'-0"
PROJECT NUMBER:	12193
DRAWN BY:	PEW

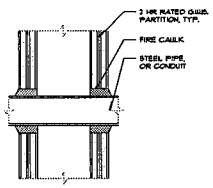
A-001

000180 (12/05/13)



1 HR PENETRATION - U.L. SYSTEM NO. W-L-1091

1



2 HR PENETRATION - U.L. SYSTEM NO. W-L-1091

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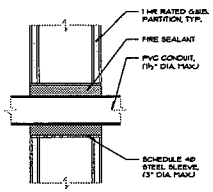

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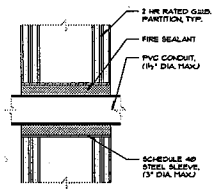

2 HR PENETRATION - U.L. SYSTEM NO. W-L-2053

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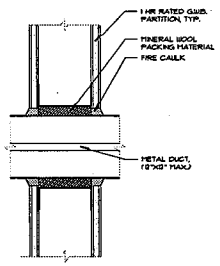
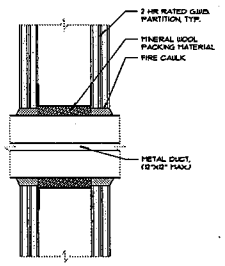


1 HR DUCT PENETRATION - U.L. SYSTEM NO. W-L-2097

5



2 HR DUCT PENETRATION - U.L. SYSTEM NO. W-L-2097

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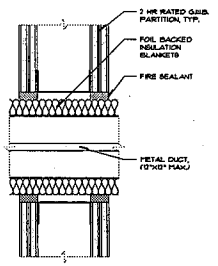
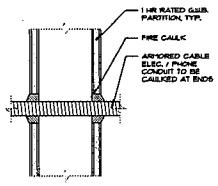


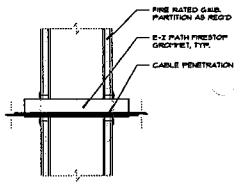
2 HR MULTI-DUCT PENETRATION - U.L. SYSTEM NO. W-L-2099

7



1 HR PENETRATION - U.L. SYSTEM NO. W-L-3015

8



0-4 HR FIRESTOP SLEEVE - U.L. SYSTEM NO. UL-1479

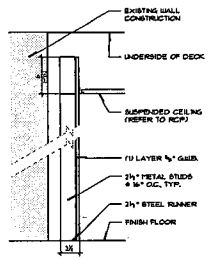
9

NOTES:

1. ALL FIRESTOPPING/SEALING OF ALL PENETRATIONS SHALL BE PERFORMED BY A SINGLE FIRESTOPPING CONTRACTOR.
2. DETAILS ARE PROVIDED FOR GENERAL INFORMATION. WHEN REFERENCED IN ADDITION WITH THE INFORMATION PROVIDED IN SPECIFICATION SECTION 07840 THE PROPER FIRE RATING WILL BE ACHIEVED. FOR ALL VARIATIONS IN SIZE OR CONDITIONS REFER TO FIRE RESISTANCE DIRECTORY VOLUME 2A & 2B

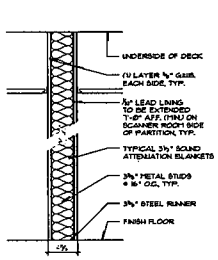
1 FIRE STOPPING DETAILS

SCALE: 1 1/2"=1'-0"



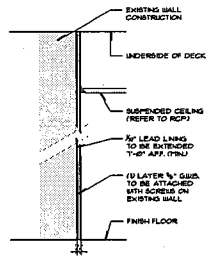
NON-RATED FURRING WALL

1



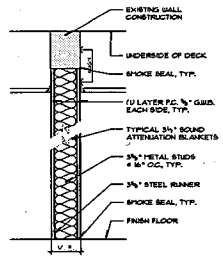
NON-RATED LEAD LINED PARTITION WALL

2



NON-RATED / NON-BEARING LEAD LINED WALL

3



20' RATED PARTITION WALL TO RESIST THE PASSAGE OF SMOKE

4

2 PARTITION WALL TYPES

SCALE: 1 1/2"=1'-0"

GENERAL PARTITION TYPE NOTES:

1. CONSTRUCTION OF RATED PARTITIONS SHALL BE IN ACCORDANCE WITH MANUFACTURER'S SPECIFICATIONS TO MEET ALL REQUIREMENTS OF THE LISTING AGENCY REFERENCED IN THE DRAWINGS AND SPECIFICATIONS.
2. PROVIDE WATER RESISTANT GYPSUM WALLBOARD AT ALL "WET" ROOMS UNLESS OTHERWISE NOTED.
3. USE FIRE RATED GYPSUM WALL BOARD AS RECOMMENDED BY LISTING AGENCY AT ALL SMOKE AND FIRE RATED PARTITIONS.
4. 1 LAYER OF G.W.B. IS NOT NECESSARY AT INTERIOR OF ALL CHASE WALLS THAT ARE NOT RATED.
5. HOLD ALL G.W.B. ½" OFF OF ALL CONCRETE SLAB FLOORS TYPICAL UNLESS OTHERWISE NOTED.

REVISIONS

CONSULTANTS

H.H. NUCLEAR SPEC/CT
SOUTH BUILDING - 2ND FLOOR
80 SEYMOUR STREET
HARTFORD, CT

Hartford Hospital
A Hartford HealthCare Partner

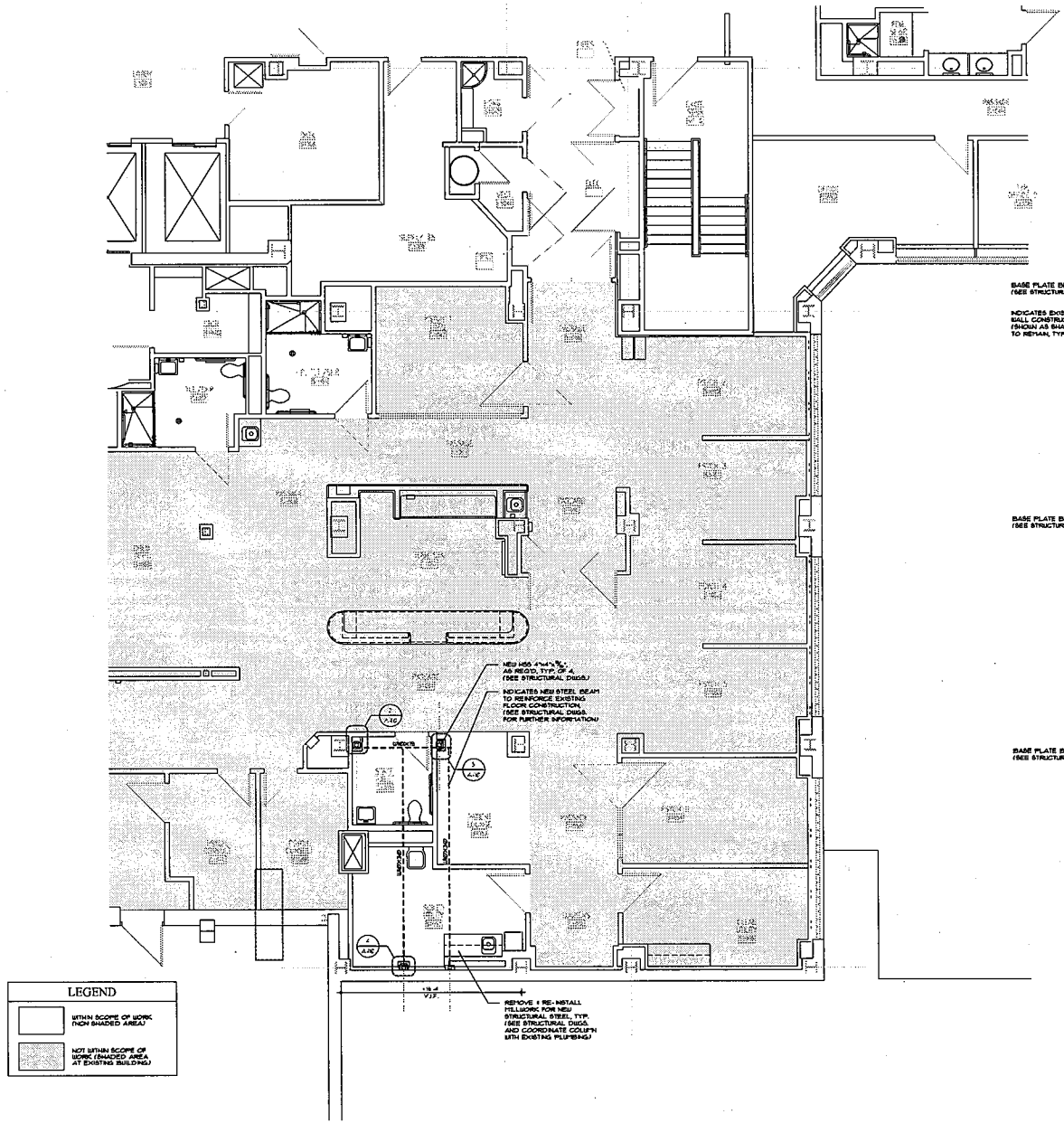
FIRE STOPPING/U.L. DETAILS/WALL TYPES

MBH ARCHITECTURE

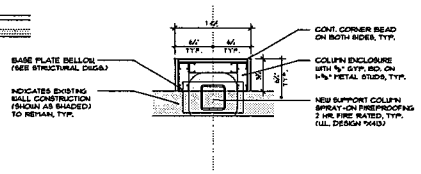
DATE ISSUED:	02/15/13
SCALE:	1 1/2" = 1'-0"
PROJECT NUMBER:	12193
DRAWN BY:	PAW

A-002

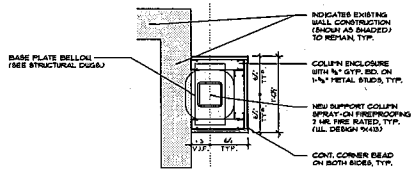
000181 (12/05/13)



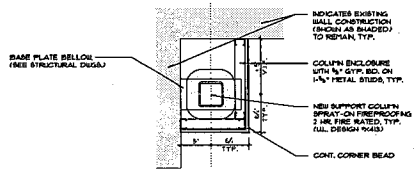
1 PROPOSED FLOOR PLAN (1st. FLOOR LEVEL)
SCALE: 1/4"=1'-0"



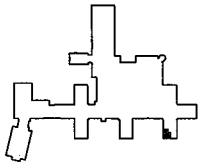
4 COLUMN PLAN DETAIL
SCALE: 1 1/2"=1'-0"



3 COLUMN PLAN DETAIL
SCALE: 1 1/2"=1'-0"



2 COLUMN PLAN DETAIL
SCALE: 1 1/2"=1'-0"



KEY PLAN

REVISIONS

CONSULTANTS

H.H. NUCLEAR SPEC/CT
SOUTH BUILDING - 2ND FLOOR
80 SEYMOUR STREET
HARTFORD, CT

Hartford Hospital
A Hartford HealthCare Partner

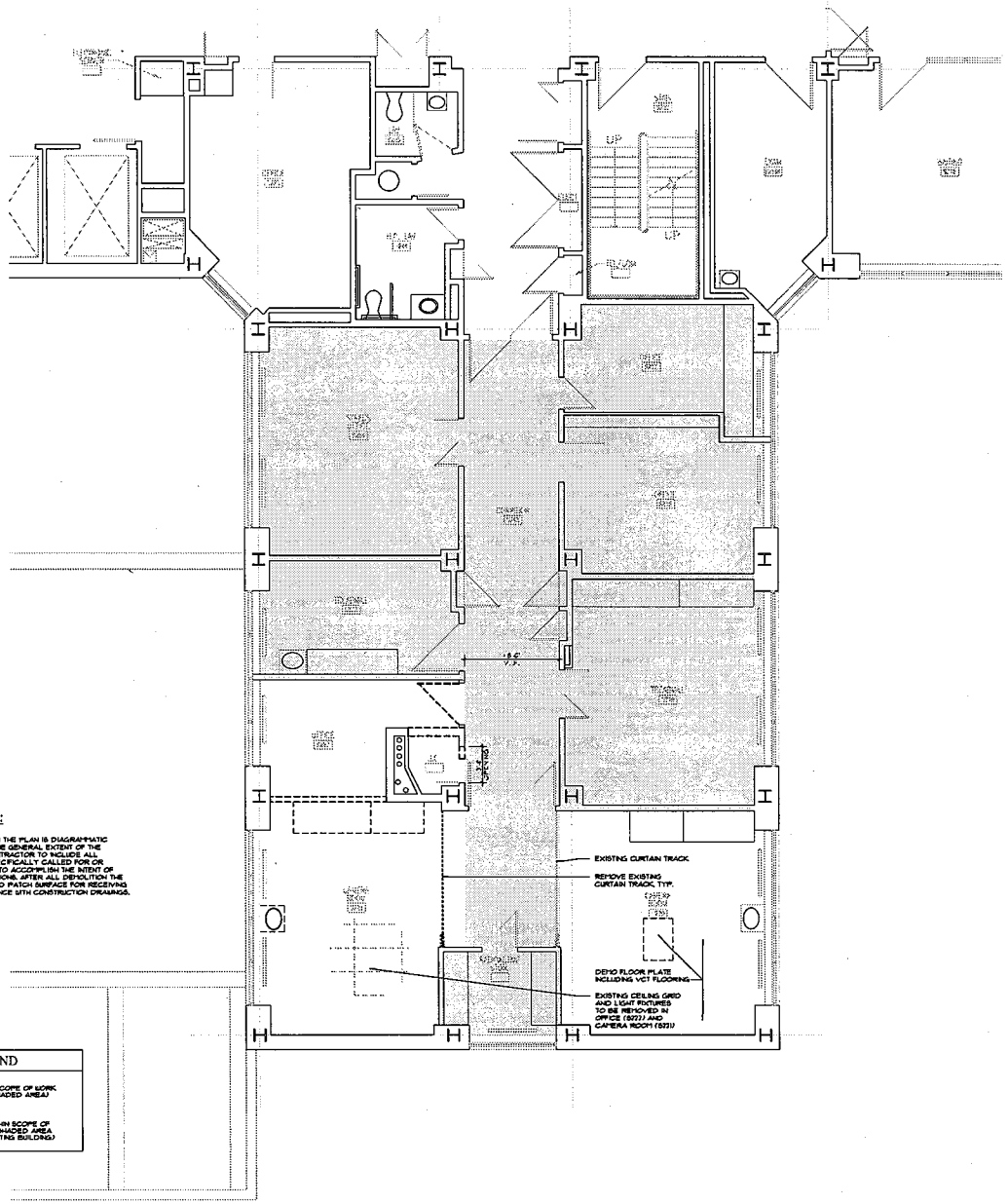
PROPOSED FLOOR PLAN (1st. FLOOR LEVEL)

MBH ARCHITECTURE

DATE ISSUED:	02/15/2013
SCALE:	AS NOTED
PROJECT NUMBER:	12191
DRAWN BY:	PKH

A-110

000182 (12/05/13)



DEMOLITION LEGEND:

- INDICATES EXISTING WALL CONSTRUCTION TO REMAIN
- INDICATES EXISTING WALL CONSTRUCTION TO BE REMOVED
- REMOVE EXISTING DOOR AND FRAME ASSEMBLY (REFERENCE DRAWING NOTE FOR SCOPE OF WORK)
- REMOVE EXISTING BUILDING ELEMENT
- EXISTING DOOR AND FRAME ASSEMBLY TO REMAIN
- EXISTING BUILDING ELEMENT TO REMAIN

DEMOLITION NOTES:

1. EXACT SCOPE OF WORK MUST BE COORDINATED IN FIELD BETWEEN ARCHITECT AND GENERAL CONTRACTOR TO DETERMINE LOCATION AND AMOUNT OF DEMOLITION WORK TO BE PERFORMED.
2. CONTRACTOR SHALL VERIFY ALL CONDITIONS IN FIELD, REPORT ANY AND ALL DISCREPANCIES BETWEEN THE PLANS AND ACTUAL FIELD CONDITIONS TO ARCHITECT BEFORE PROCEEDING WITH WORK.
3. CONTRACTOR SHALL CLEAN ANY AREA OUTSIDE THE CONTRACT LIMIT THAT BECOMES DIRTY AS A RESULT OF DEMOLITION WORK.
4. ALL EXISTING FLOORS, WALLS, WINDOWS, DOORS, FRAMES, CASEWORK, PLUMBING FIXTURES, ETC. TO BE REMOVED WILL BE REPRESENTED BY DASHED LINES. (COORDINATE WITH NEW CONSTRUCTION PLANS FOR EXTENT AND LOCATION OF NEW CONSTRUCTION).
5. CONTRACTOR SHALL LEAVE ALL AREAS UNDER NEW CONSTRUCTION BROOM CLEAN AT THE COMPLETION OF EACH WORK DAY.
6. PROTECT ALL EXISTING SURFACES SCHEDULED TO REMAIN DURING ALL PHASES OF CONSTRUCTION.
7. CONTRACTOR TO BE RESPONSIBLE FOR ALL PENETRATIONS OF EXISTING MATERIALS AND STRUCTURES NECESSARY FOR UTILITIES, MECHANICAL, ELECTRICAL, PLUMBING WORK, ETC. AND SHALL MAINTAIN APPROPRIATE HOURLY RATINGS, STRUCTURAL INTEGRITY AND WEATHER TIGHT CONSTRUCTION.
8. REFER TO 'FEP' DRAWINGS FOR ALL MECHANICAL, ELECTRICAL AND PLUMBING DEMOLITION.
9. PROVIDE TEMPORARY STRUCTURAL SUPPORT AND ENCLOSURE AS REQUIRED TO MAINTAIN INTEGRITY OF EXISTING BUILDING DURING ALL DEMOLITION WORK.
10. CONTRACTOR MUST REFER TO THE CIVIL DRAWINGS FOR ALL OTHER ADDITIONAL DEMOLITION WORK RELATED TO THIS RENOVATION PROJECT, INCLUDING - BUT NOT LIMITED TO- ANY UTILITIES TO BE PROVIDED FOR THIS BUILDING.
11. CONTRACTOR SHALL ENSURE THAT THE REQUIRED TEMPORARY MEANS OF EGRESS AND ACCESS TO BE KEPT FREE AND CLEAR AT ALL TIMES OF CONSTRUCTION EQUIPMENT AND DEBRIS THROUGHOUT THE CONSTRUCTION PROCESS AS REQUIRED.
12. CONTRACTOR SHALL REMOVE ALL DEMOLITION DEBRIS OFF SITE LEGALLY.
13. ALL DEMOLITION WORK SHALL BE PERFORMED IN ACCORDANCE WITH APPLIANCE CODES, REGULATIONS AND ORDINANCES OF LOCAL AND FEDERAL AUTHORITIES.

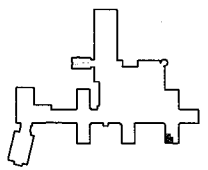
GENERAL NOTE:

THE DEMOLITION SHOWN ON THE PLAN IS DIAGRAMMATIC AND INTENDED TO SHOW THE GENERAL EXTENT OF THE WORK ONLY. GENERAL CONTRACTOR TO INCLUDE ALL DEMOLITION - WHETHER SPECIFICALLY CALLED FOR OR NOT - THAT IS NECESSARY TO ACCOMPLISH THE INTENT OF THE PLAN AND SPECIFICATIONS. AFTER ALL DEMOLITION THE CONTRACTOR TO PREP AND PATCH SURFACE FOR RECEIVING NEW FINISHES IN ACCORDANCE WITH CONSTRUCTION DRAWINGS.

LEGEND

- WITHIN SCOPE OF WORK (NON SHADED AREA)
- NOT WITHIN SCOPE OF WORK (SHADED AREA AT EXISTING BUILDING)

1 DEMOLITION FLOOR PLAN (2nd. FLOOR LEVEL)
SCALE: 1/4"=1'-0"



KEY PLAN

REVISIONS

CONSULTANTS

H.H. NUCLEAR SPEC/CT
SOUTH BUILDING - 2ND FLOOR
80 SEYMOUR STREET
HARTFORD, CT

Hartford Hospital
A Hartford HealthCare Partner

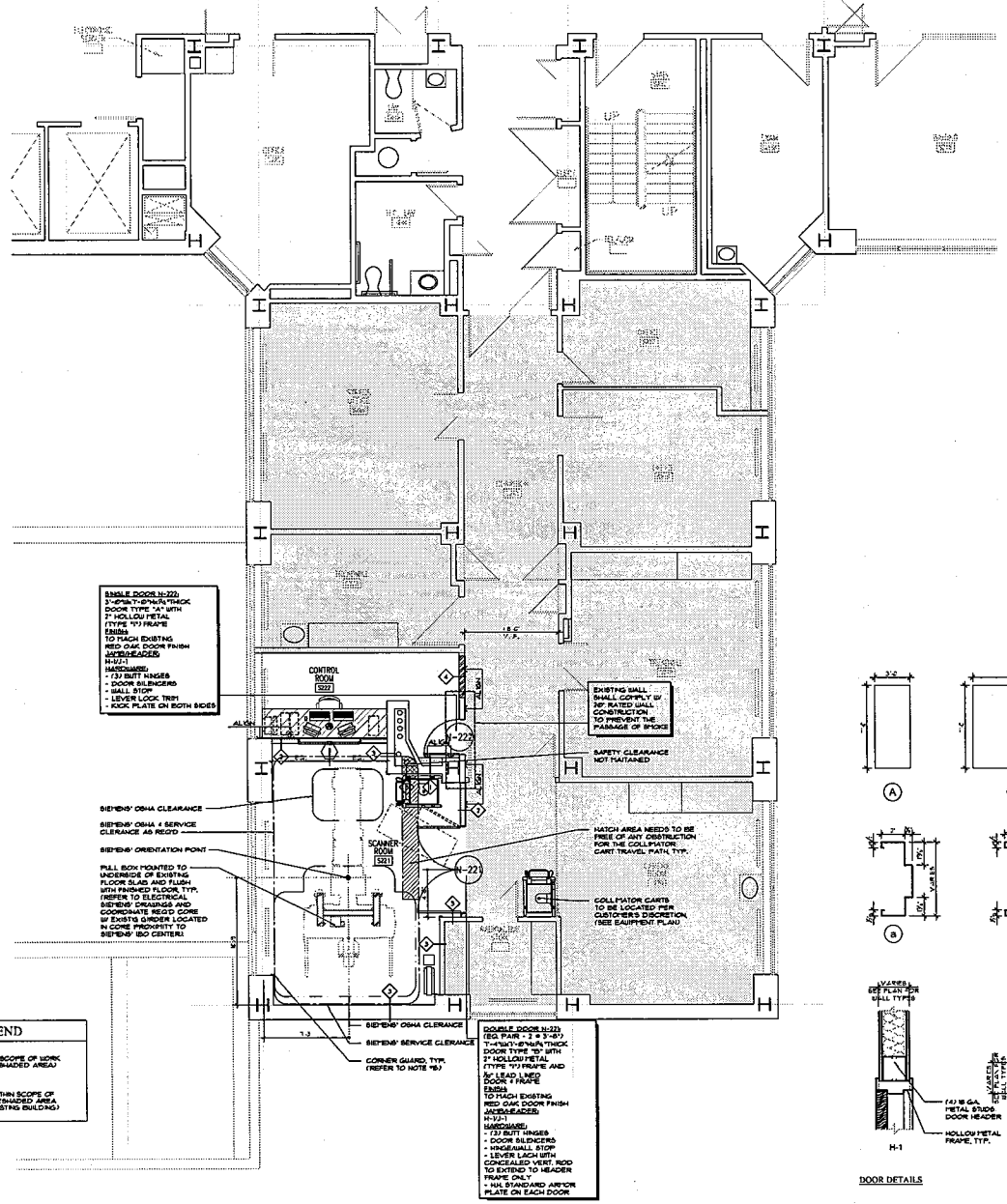
DEMOLITION FLOOR PLAN (2nd. FLOOR LEVEL)

MBH ARCHITECTURE

DATE ISSUED:	02/15/2013
SCALE:	AS NOTED
PROJECT NUMBER:	12191
DRAWN BY:	PKM

AD-120

000183 (12/05/13)



LEGEND

- WITHIN SCOPE OF WORK (NON SHADED AREA)
- NOT WITHIN SCOPE OF WORK (SHADED AREA AT EXISTING BUILDING)

1 PROPOSED FLOOR PLAN (2nd. FLOOR LEVEL)
SCALE: 1/4"=1'-0"

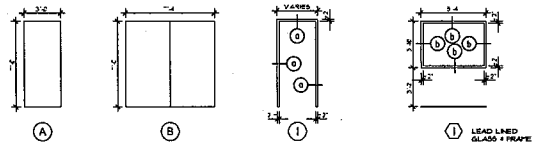
WALL LEGEND:

REFER TO WALL TYPES ON SHEET A-602 FOR DETAILED NEW WALL CONSTRUCTION AND UL DESIGN REQUIREMENTS.

- EXISTING WALL CONSTRUCTION
- NEW NON-RATED PARTITION WALL
- NEW 1HR RATED PARTITION WALL (TO PREVENT PASSAGE OF SMOKE) AT ALL LOCATIONS WHERE EXISTING WALL OCCURS IN PROPOSED NEW 1HR RATED PARTITION TO PREVENT THE PASSAGE OF SMOKE. EXISTING WALL SHALL REMAIN AND BE UPGRADED TO COMPLY WITH NEWLY PROPOSED RATING REQUIREMENT.

FLOOR PLAN NOTES:

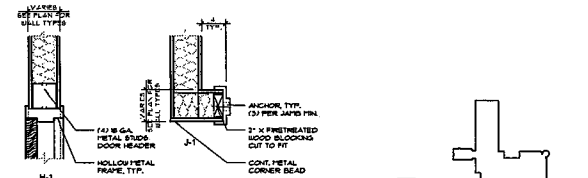
1. CONTRACTOR SHALL VERIFY ALL CONDITIONS IN FIELD, REPORT ANY AND ALL DISCREPANCIES BETWEEN THE PLANS AND ACTUAL FIELD CONDITIONS TO ARCHITECT BEFORE PROCEEDING WITH WORK.
2. CONTRACTOR IS RESPONSIBLE FOR ALL PATCHING AND REPAIRING OF FINISH SURFACES DUE TO PENETRATIONS OF EXISTING MATERIALS AND STRUCTURES NECESSARY FOR NEW UTILITIES, MECHANICAL, ELECTRICAL AND PLUMBING WORK.
3. CONTRACTOR TO REPAIR AND PATCH ALL EXISTING WALL, FLOOR AND CEILING SURFACES AS REQ'D TO ACHIEVE THE FINISH PLAN.
4. ALL INTERIOR DIMENSIONS ARE TO THE FINISH FACE OF WALL (—#.) OR FROM CENTERLINE OF COLUMN (—).
5. ALL EXTERIOR DIMENSIONS ARE FROM THE FACE OF STUD TO FACE OF STUDS WHICH ALIGN WITH THE FACE OF FOUNDATION WALL (—#.) OR FROM CENTERLINE OF WINDOW OPENING (—#.).
6. REFER TO A-600 SHEET SERIES FOR INTERIOR ELEVATIONS AND MILLWORK SECTIONS & DETAILS.
7. NEW MILLWORK IS DESIGNATED WITH A HATCH PATTERN (REFER TO MILLWORK DWGS.)
8. CORRIDORS AND RATED WALL ASSEMBLIES SHALL BE CONSTRUCTED IN A MANNER TO PREVENT THE PASSAGE OF SMOKE AND SEAL ALL PENETRATIONS WITH UL APPROVED SMOKE PREVENTIVE SEALANT.
9. MATCH EXISTING ADJACENT CONSTRUCTION WHERE EXISTING INTERIOR OR EXTERIOR DOORS, WINDOWS AND OPENINGS ARE BEING INFILLED.
11. CONTRACTOR IS RESPONSIBLE FOR RECONSTRUCTING ANY EXISTING MECHANICAL SHAFT OR FLUE THAT MUST BE OPENED IN ORDER TO PERFORM ANY AND ALL REQUIRED MECHANICAL ADDITION WORK. (FIRE RATINGS MUST COMPLY WITH ALL CODES AS REQ'D.)
10. CONTRACTOR IS RESPONSIBLE FOR ENSURING A WATER TIGHT BUILDING WHICH INCLUDES - BUT NOT LIMITED- TO ALL FLASHING AND SEALING AROUND ALL EXTERIOR DOOR AND WINDOW OPENINGS AND WHERE DISSIMILAR MATERIALS ABUT.
12. CONTRACTOR SHALL ALSO FOLLOW ALL MANUFACTURER'S INSTRUCTIONS, REQUIREMENTS AND RECOMMENDATIONS.
13. PROVIDE AND INSTALL CORNER GUARD WITH END WALL CAPS AS SHOWN ON PLAN (L).



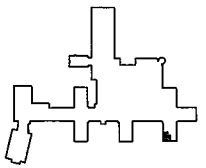
DOOR GENERAL NOTES

1. ALL DOORS TO MATCH FACILITY'S RED OAK FINISH IN THIS AREA.
2. ALL KEYING + DOOR HARDWARE SELECTIONS ARE TO BE VERIFIED BY OWNER.
3. CONTRACTOR SHALL VERIFY ALL REQUIRED DOOR RATING.
4. ALL DOOR CLOSURES TO BE MOUNTED ON INSIDE OF ALL ROOMS.

ALL DOOR CLOSERS REQUIRE DELAYED ACTION.



DOOR DETAILS



KEY PLAN

REVISIONS

CONSULTANTS

H.H. NUCLEAR SPEC/CT
SOUTH BUILDING - 2ND FLOOR
80 SEYMOUR STREET
HARTFORD, CT

Hartford Hospital
A Hartford HealthCare Partner

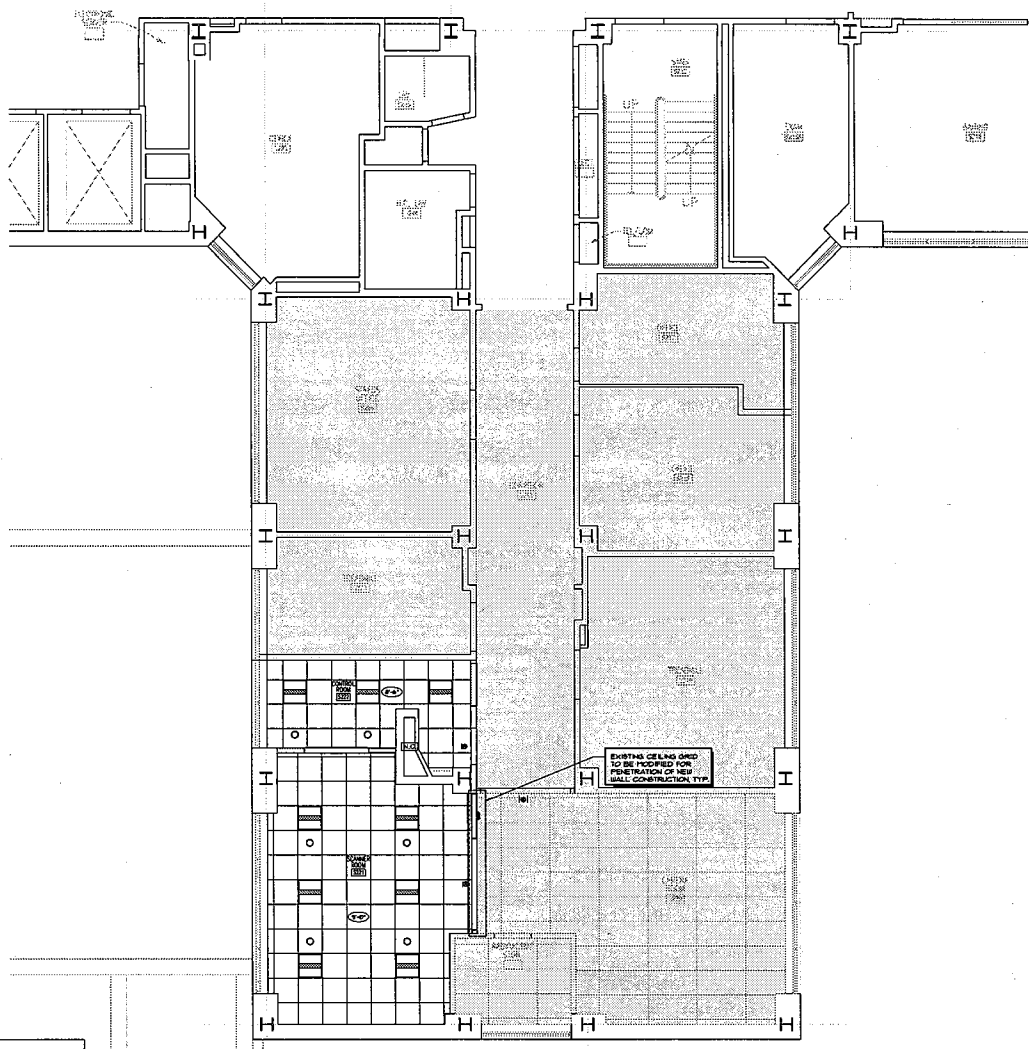
PROPOSED FLOOR PLAN (2nd. FLOOR LEVEL)

MPH ARCHITECTURE

DATE ISSUED:	02/15/2013
SCALE:	AS NOTED
PROJECT NUMBER:	12191
DRAWN BY:	PKM

A-120

000184 (12/05/13)



WITHIN SCOPE OF WORK (NON SHADED AREA)

NOT WITHIN SCOPE OF WORK (SHADED AREA AT EXISTING BUILDING)

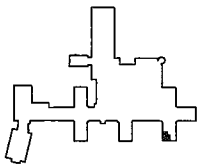
1 REFLECTED CEILING PLAN (2nd. FLOOR LEVEL)
SCALE: 1/4"=1'-0"

LIGHT FIXTURES AND LEGEND:

- 6" RECESSED HALOGEN DOWNLIGHT FIXTURE
- RECESSED 2'X2' FLUORESCENT LIGHT FIXTURE WITH BASKET
- EMERGENCY LIGHT (IF REQ'D)
- DOORWAY EXIT SIGN
- DIRECTIONAL EXIT SIGN
- F-4* CEILING HEIGHT
- GYPSUM CEILING
- N.C. NO CEILING

REFLECTED CEILING NOTES:

1. THIS DRAWING IS FOR FIXTURE LOCATION ONLY. (REFER TO ALL MECHANICAL AND ELECTRICAL DRAWINGS FOR DETAILED LIGHT FIXTURE DESCRIPTIONS AND ADDITIONAL CEILING RELATED WORK AND NOTIFY THE ARCHITECT/ENGINEER FOR ANY CONFLICTS PRIOR TO INSTALLATION.)
2. ALL ACOUSTICAL HUNG CEILING SHALL BE SUSPENDED FROM THE STRUCTURE ABOVE AS DETAILED AND SHOWN ON PLAN, UNLESS OTHERWISE NOTED.
3. CONTRACTOR TO COORDINATE INSTALLATION OF LIGHT FIXTURES WITH ALL NEW DUCT AND PLUMBING CONDITIONS AND NOTIFY THE ARCHITECT/ENGINEER FOR ANY CONFLICTS PRIOR TO INSTALLATION.
4. PROVIDE GYPSUM BOARD CEILING AT ALL LOCATIONS DESIGNATED WITH HATCH PATTERN.
5. PROVIDE ACOUSTICAL HUNG CEILING AS SHOWN AND DESIGNATED ON PLAN WITH HATCH PATTERN. CEILING GRID IS TO BE CENTERED IN ROOMS, OR AS SHOWN ON PLAN. CONTACT ARCHITECT FOR ANY QUESTIONS REGARDING DIMENSIONS.
6. REFER TO FLOOR PLANS FOR ALL WALL TYPES AND UL RATINGS.
7. PROVIDE CURTAIN AND TRACK AS SHOWN ON PLAN. (- - - - - -).
8. COORDINATE EXTENT OF ALL UNDER CABINET AND COUNTER LIGHTING WITH CASEWORK DETAILS.
9. CONTRACTOR TO COORDINATE LOCATION OF SPRINKLER HEADS WITH LOCATIONS OF ALL CEILINGS, LIGHTS AND DIFFUSERS.
10. COORDINATE SPRINKLER HEAD COVERAGE TO MEET REQ'MTS FOR FIRE PROTECTION WITH M.E.P. DRAWINGS AS WELL AS WITH LAY-OUT OF LIGHTS AND CEILINGS. MAKE ARCHITECT AND ENGINEER AWARE FOR ANY CONFLICTS THAT MAY ALTER THE DESIGN OR CHANGE THE EXISTING LAY-OUT.
11. ALL CEILINGS TO BE INSTALLED AT 9'-0" AFF, UNLESS OTHERWISE NOTED ON PLAN.



KEY PLAN

REVISIONS

CONSULTANTS

H.H. NUCLEAR SPEC/CT
SOUTH BUILDING - 2ND FLOOR
80 SEYMOUR STREET
HARTFORD, CT

Hartford Hospital
A Hartford HealthCare Partner

REFLECTED CEILING PLAN (2nd. FLOOR LEVEL)

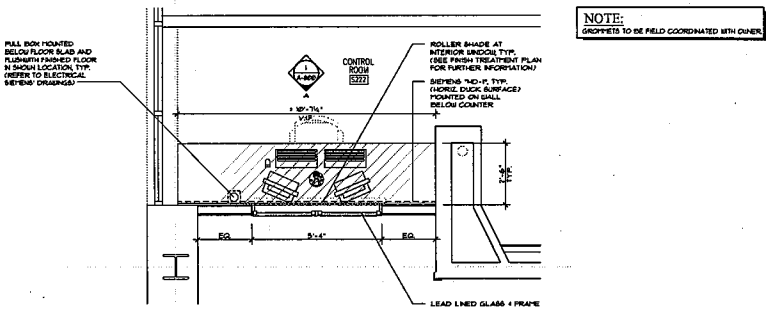
MBH ARCHITECTURE

DATE ISSUED:	02/15/2013
SCALE:	AS NOTED
PROJECT NUMBER:	12191
DRAWN BY:	PKH

A-720

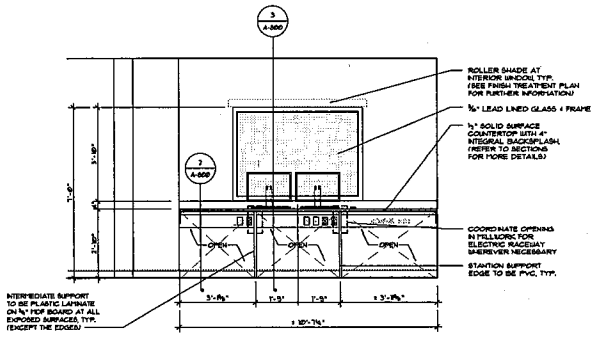
000185 (12/05/13)

NOTE:
GROMMETS TO BE FIELD COORDINATED WITH OWNER.

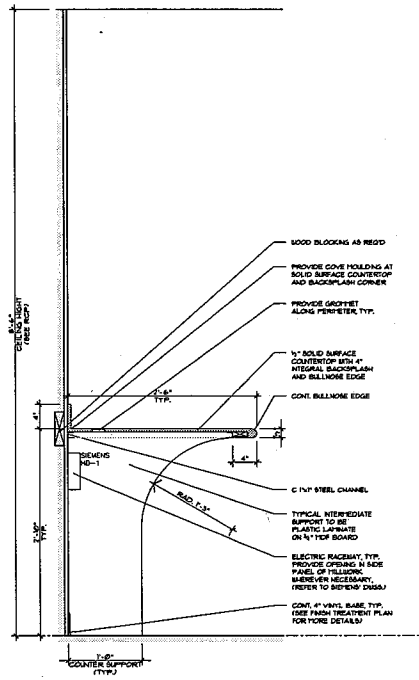


1 CONTROL ROOM FLOOR PLAN, INTERIOR ELEVATIONS & SECTION

SCALE: 1/2" = 1'-0"

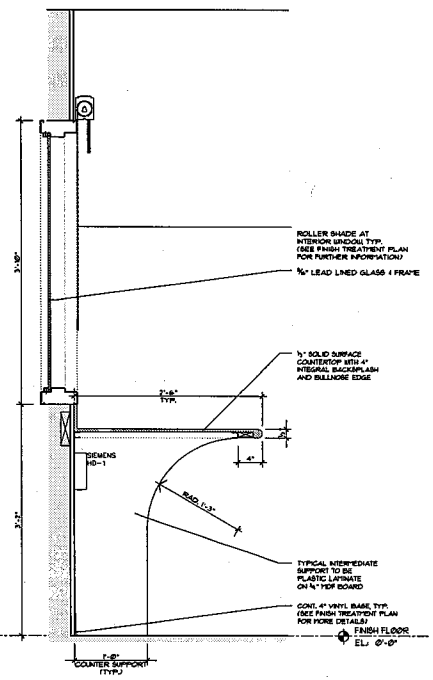


ELEVATION A



2 OPEN WORKSPACE

SCALE: 1 1/2" = 1'-0"



3 OPEN WORKSPACE

SCALE: 1 1/2" = 1'-0"

REVISIONS

CONSULTANTS

H.H. NUCLEAR SPEC/CT
SOUTH BUILDING - 2ND FLOOR
80 SEYMOUR STREET
HARTFORD, CT

Hartford Hospital
A Hartford HealthCare Partner

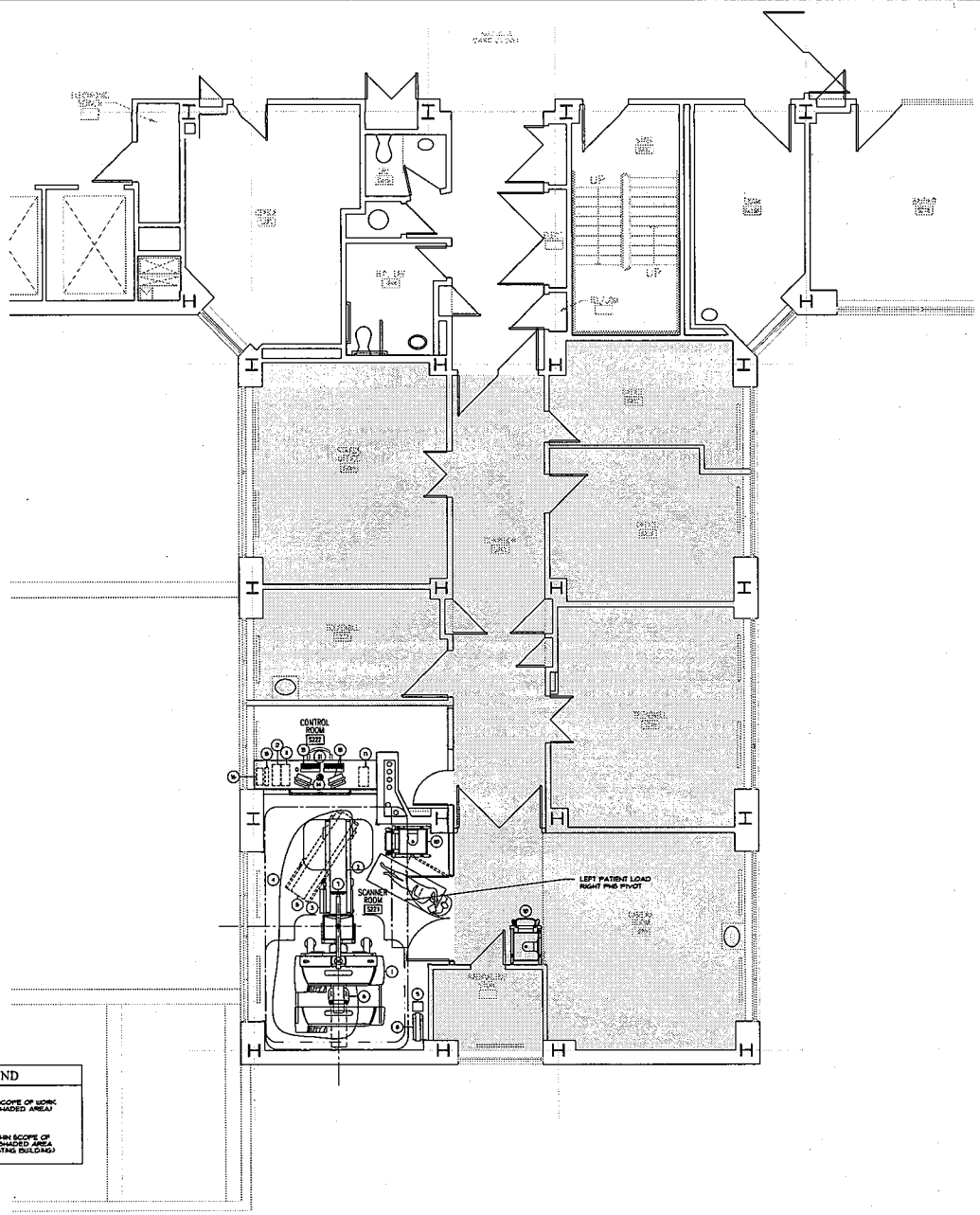
INTERIOR ELEVATIONS, MILLWORK & SECTIONS

MBH ARCHITECTURE

DATE ISSUED:	02/15/13
SCALE:	AS NOTED
PROJECT NUMBER:	12181
DRAWN BY:	PKH

A-800

000186 (12/05/13)



LEGEND

- WITHIN SCOPE OF WORK (NON SHADED AREA)
- NOT WITHIN SCOPE OF WORK (SHADED AREA AT EXISTING BUILDING)

1 EQUIPMENT/FURNITURE PLAN (2nd. FLOOR LEVEL)
SCALE: 1/4"=1'-0"

EQUIPMENT LIST

ITEM #	ITEM DESCRIPTION	H.H.'S VENDOR SUPPLIED INSTALL	H.H. SUPPLIED/ INSTALLED	G.C. SUPPLIED/ INSTALLED	H.H. SUPPLIED G.C. INSTALLED
	SIEMENS EQUIPMENT				
1	SYMBIA T, GANTRY W/ COLLIMATORS	●			
2	FRONT PHS	●			
3	AUTOMATIC COLLIMATOR CHANGER: -ACC WITH ACC-				
	PRODUCTIVITY PACKAGE	●			
4	PHS CABLE ON THE FLOOR STANDARD	●			
5	PHS STANDARD PIVOT	●			
6	REAR PHS WITH SMAC	●			
7	PATIENT BOOM SWING ARM	●			
8	UPS FOR SPECT GANTRY	●			
9	TRANSFORMER REQUIRED WITH UPS FOR SPECT (SPS)	●			
10	COLLIMATOR CART (EMPTY)				
11	IMAGE CONSTRUCTION SYSTEM FOR SYMBIA MI (ACQUISITION) WORKPLACE	●			
12	IMAGE RECONSTRUCTION SYSTEM FOR SYMBIA MI (ACQUISITION) WORKPLACE	●			
13	CONTROL AND KEYBOARD	●			
14	18" MONITOR	●			
15	SYMBIA MI (ACQUISITION) WORKPLACE UPS FOR IMS	●			
	(VERTICAL)STANDARD COMPONENT	●			
16	UPS 5KVT/C CAM	●			
17	SYMBIA NETWORKPLACE CPU	●			
18	SYMBIA NETWORKPLACE KEYBOARD AND MONITOR	●			
19		●			
20					
	H.H. EQUIPMENT				
21	COUNTER HEIGHT TASK CHAIR		●		
22					
23					

KEY PLAN

REVISIONS

CONSULTANTS

H.H. NUCLEAR SPEC/CT
SOUTH BUILDING - 2ND FLOOR
80 SEYMOUR STREET
HARTFORD, CT

Hartford Hospital
A Hartford HealthCare Partner

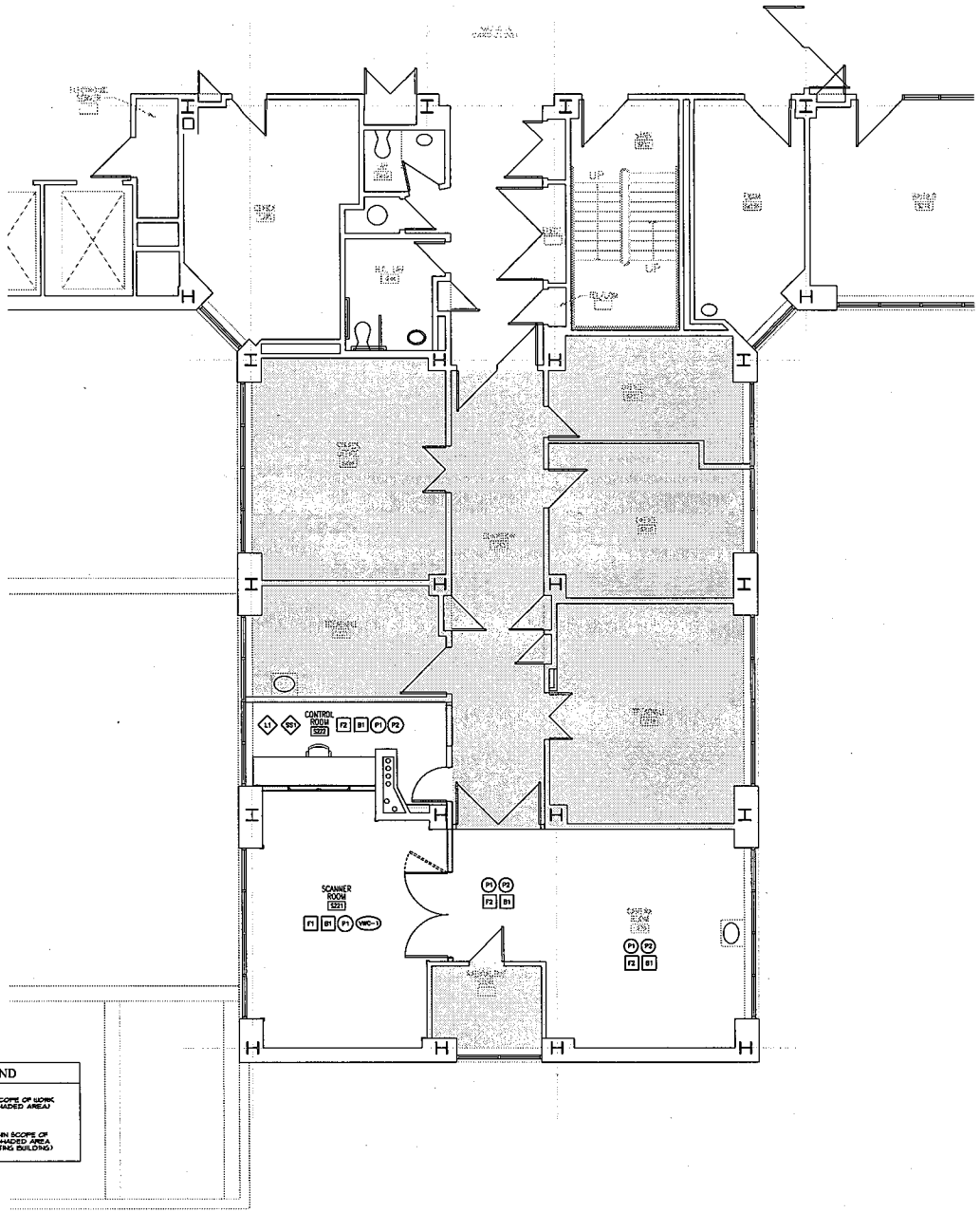
EQUIPMENT/FURNITURE PLAN (2nd. FLOOR PLAN)

MBH ARCHITECTURE

DATE ISSUED:	02/15/2013
SCALE:	AS NOTED
PROJECT NUMBER:	12193
DRAWN BY:	PKH

FF-120

000187 (12/05/13)



WALL FINISH LEGEND

- P1 — TRIM PAINTS (SEMI-GLOSS)
  BENJAMIN MOORE
  INTERIOR READY MIX
  COLOR: WHITE DOVE OC-17
- P2 — WALL PAINT (EGGSHELL)
  BENJAMIN MOORE
  INTERIOR READY MIX
  COLOR: FRENCH WHITE 1093
- VWC-1 — VINYL WALL COVERING
  ARC COM
  PATTERN: MONTECO
  COLOR: ACW-51084, TAUPE #4

FLOOR FINISH LEGEND

- F1 — RESILIENT FLOORING
  ALTRO FLOORING
  CS LINE
  COLOR: CS 5520
- F2 — MANNINGTON
  BRUSHWORKS
  COLOR: 707 CANVAS
- B1 — WALL BASE
  JOHNSONITE
  4" VINYL COVE BASE
  COLOR: 49 BEIGE

MILLWORK SURFACES

- L1 — PLASTIC LAMINATES
  NEVAMAR (SUPPORTS)
  P: CHAMPAGNE TEXTURED
  C: S20037
- SS1 — SOLID SURFACING
  (COUNTERTOPS, BACKSPLASH & EDGE DETAIL)
  CORIAN
  COLOR: SAVANNAH

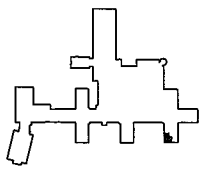
FINISH TREATMENT PLAN NOTES:

1. ALL DOORS TO MATCH EXISTING RED OAK STAIN IN CORRIDORS.
2. NEW EXTERIOR WINDOW SHADES @ ALL ROOMS IN HIGHLIGHTED AREA OF WORK. SHADE TO BE AS FOLLOUS:
   HUNTER DOUGLAS, B-EERSEAVE, 4400- PET ALABASTER, 3% OPENNESS
3. NEW INTERIOR WINDOW SHADES TO BE AS FOLLOUS.
   HUNTER DOUGLAS, B-EERSEAVE, 4400-PET ALABASTER, 3% OPENNESS.
   VERIFY MATERIAL WITH OUNER PRIOR TO ORDERING.

LEGEND

- WITHIN SCOPE OF WORK (NON SHADED AREA)
- NOT WITHIN SCOPE OF WORK (SHADED AREA AT EXISTING BUILDING)

1 FINISH TREATMENT PLAN (2nd. FLOOR LEVEL)
SCALE: 1/4"=1'-0"



KEY PLAN

REVISIONS

CONSULTANTS

H.H. NUCLEAR SPEC/CT
SOUTH BUILDING - 2ND FLOOR
80 SEYMOUR STREET
HARTFORD, CT

Hartford Hospital
A Hartford HealthCare Partner

FINISH TREATMENT PLAN (2ND. FLOOR LEVEL)

MBH ARCHITECTURE

DATE ISSUED:	02/15/2013
SCALE:	AS NOTED
PROJECT NUMBER:	12191
DRAWN BY:	PKH

FF-121

000188 (12/05/13)

EXHIBIT 10

SIEMENS

Siemens Medical Solutions USA, Inc.
51 Valley Stream Parkway, Malvern, PA 19355
Fax: (781) 203-6025

SIEMENS REPRESENTATIVE
John Hubbard - (603) 801-4879

Customer Number: 0000006646

Date: 9/10/2012

HARTFORD HOSPITAL
80 SEYMOUR ST
HARTFORD, CT 06102

Siemens Medical Solutions USA, Inc. is pleased to submit the following quotation for the products and services described herein at the stated prices and terms, subject to your acceptance of the terms and conditions on the face and back hereof, and on any attachment hereto.

Table of Contents **Page**

Proposal valid until 10/25/2012

Siemens is pleased to offer the Productivity package at no charge with Quote #1-3S3AHV contingent upon a signed 4 year gold level service contract for your Symbia S Series. This offer is only available to qualified purchasers and is limited to a set number of offers. This offer expires on the date indicated in this quote.

Accepted and Agreed to by:

Siemens Medical Solutions USA, Inc.

By (sign): _____
Name: John Hubbard
Title: Product Sales Executive
Date: _____

HARTFORD HOSPITAL

By (sign): _____
Name: _____
Title: _____
Date: _____

All pages of the signed proposal must be returned to Siemens to process the order - Thank you.

SIEMENS

Siemens Medical Solutions USA, Inc.
51 Valley Stream Parkway, Malvern, PA 19355
Fax: (781) 203-6025

SIEMENS REPRESENTATIVE
John Hubbard - (603) 801-4879

Quote Nr:	**1-3S3AHV Rev. 1**
Terms of Payment:	00% Down, 80% Delivery, 20% Installation Free On Board: Destination
Purchasing Agreement:	MedAssets-BL MedAssets-BL terms and conditions apply to Quote Nr 1-3S3AHV

Symbia T

All items listed below are included for this system:

Qty	Part No.	Item Description
1	14415085	**Symbia_T** The Symbia T is built on TruePoint SPECT•CT technology, for the seamless integration of two equal modalities. The True Integration of state-of-the-art SPECT and high quality dual slice CT gives this system full functionality for all SPECT-only or SPECT•CT applications in Oncology, Neurology, and routine Cardiology. True Clarity from the ultra fast dual slice spiral CT maximizes confidence in precise Attenuation Correction and Anatomical Mapping and Diagnostic CT within a SPECT/CT study. The True Efficiency of the single patient bed and gantry, together with work flow improvements, achieves high throughput in all modes.
1	08719218	**Room Prep Kit Symbia T/T2 (US/CA)** Room preparation kit for U.S. sites with two components to bring power from wall to Symbia T or Symbia T2 Input power box with 50 amp fuse Junction box
2	07833283	**Symbia 3/8" Hi-Res. Det. /Tub Asm.**
1	10182856	**Detector Support with Caudal Tilt** Caudal and cephalic tilt on Detector 2 allows for precise positioning of static and dynamic acquisitions.
2	07835494	**Low_Energy_Hi_Res Collimator Symbia** Low energy (140 keV), high resolution, parallel hole collimator · AUTOFORM Technology · 148,000 hexagonal holes · Sensitivity: 202 cpm/microCurie · Geometric Resolution: 6.4 mm · Weight: 70 lbs (31.8 kg) Includes drawer for collimator cart
1	14414929	**IQ-SPECT** Innovative fast cardiac imaging solution that provides intelligent reduction of SPECT acquisition time for nuclear cardiology applications to four minutes.
1	10273911	**Productivity Package** Productivity package includes the integrated collimator changer, the automatic collimator exchanger, and the automatic quality control option. Integrated Collimator Changer Innovative collimator exchange system that is mounted beneath the patient bed. Saves time and effort when changing the most frequently used collimators. Holds two sets of low or medium energy collimators. Automatic Collimator Exchange Fully automated changing of collimators within the integrated collimator changer. Collimator removal or exchange is initiated with the touch of one button on the patient positioning monitor. Automatic Quality Control Option Gd-153 line and Co-57 point sources housed in the patient bed will be extended at customer scheduled times to perform daily, weekly, and monthly quality control procedures without manual intervention.
1	10413528	**AQC Web Based Training**
1	10273917	**AutoQC Source Registration Kit** Source registration kit for Symbia Automatic Quality Control option.
1	10273914	**AutoQC source kit** Gd-153 line and Co-57 point source for the automatic quality control option.

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Qty	Part No.	Item Description
1	10183566	**Internal ECG for Symbia** Symbia Internal ECG gate provides ECG triggering to nuclear subsystem for nuclear cardiology examinations. In addition, for Symbia T2, T6, and T16 cameras the internal ECG gate provides ECG triggering to the CT subsystem for CT applications that require ECG gating. The ECG gate is built into the Symbia patient bed and is controlled by the Symbia acquisition station. The leads connect near the head of the patient bed and travel with patient, never interfering with scanning. ECG waveform is displayed on the touch-screen PPM.
1	08418407	**Hand Controller Symbia_SPECT_CT** All motorized motions of the patient bed, gantry and detectors are controlled from the ergonomically designed hand controller which can be plugged into either side of the gantry.
1	07830909	**Remote Diagnostic Services** Remote Diagnostic Services. A broadband connection is required for full remote diagnostic functionality and optimal system uptime.
1	10097270	**MI University** Molecular Imaging University (MI-U) is a comprehensive resource for clinical educational materials in PET/CT and SPECT/CT (www.mi-university.com). MI University demonstrates the benefit of hybrid imaging and where it influences patient management. The license is valid for 1 year and includes the rights to set up accounts for other users that are related to the customer facility.
1	08719374	**English Symbia T Lang Kit**
1	10412858	**Symbia T Series US Installation** Mechanical installation of the Symbia T Series camera system including complete system assembly and alignment, system startup, calibrations, and performance verification to factory specifications.
1	14415032	**First User** The first user provides a singler user license to operate Symbia.net as a workplace solution.
1	14415058	**Monitor, 19" LCD DICOM** The 19" DICOM Calibrated LCD monitor is designed to meet the demanding requirements of medical imaging. The display features high contrast even under high ambient light conditions that can be encountered in nuclear medicine viewing environments. The gamma curve is exactly matched to CIE/DICOM recommendation, enhancing the ability to display both color and gray scale images. Light output stability is ensured by continuous backlight control throughout the display's lifetime.
1	14415036	**SPECT/CT Processing** Processing software package that provides advanced SPECT/CT Reconstruction, image fusion capabilities, volumetric analysis for tumor imaging, image manipulation tools, as well as cardiac and other organ-based SPECT processing.
1	14415205	**Cardiology Engine SPEC.CT 4DM** The Cardiology Engine SPECT.CT Corridor4DM assists in the diagnosis and quantitative assessment of coronary artery disease by enabling the visualization of SPECT studies as well as quantified perfusion assessment.
1	10182980	**English Corridor4DM Lang Kit**
1	08419207	**English MI WP Lang Kit** The language kit includes: e.soft Getting Started Manual, e.soft User Notes and customer letter.
1	14415195	**4 Quadrant Phantom for Symbia S / T** A 4 quadrant 2.0-2.5.30.3.5 mm standard pattern slightly modified for use with the e.cam and Symbia Imaging Systems
1	10119031	**UPS for SPECT Camera Systems** Uninterruptible power supply option that provides 10 minutes of back up power to the SPECT gantry enabling the proper shut down in the event of a power loss. Also provides noise filtering and transient suppression. Specifications:5.0 KVA Input configuration: 200-240 VAC, 50/60 Hz, L6-30P Output configuration: 208 VAC, L6-30R
1	05245316	**UPS for e.soft/c.cam (60 Hz)** Uninterruptable power supply option that provides 10 minutes of back up power enabling the proper shut down of the system in the event of a power loss.

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Fax: (781) 203-6025

SIEMENS REPRESENTATIVE
John Hubbard - (603) 801-4879

Qty	Part No.	Item Description
1	MI_SPEC_INITIAL_32	**Initial onsite training 32 hrs** Up to (32) hours of on-site clinical education training, scheduled consecutively (Monday - Friday) during standard business hours for a maximum of (4) imaging professionals. Training will cover agenda items on the ASRT approved checklist. Uptime Clinical Education phone support is provided during the warranty period for specified posted hours. This educational offering must be completed (12) months from install end date. If training is not completed within the applicable time period, Siemens obligation to provide the training will expire without refund.
1	MI_SPEC_FLWUP_32	**MI_SYMB_FOLLOWUP** Up to (32) hours of follow-up on-site clinical education training, scheduled consecutively (Monday - Friday) during standard business hours for a maximum of (4) imaging professionals. Uptime Clinical Education phone support is provided during the warranty period for specified posted hours. This educational offering must be completed (12) months from install end date. If training is not completed within the applicable time period, Siemens obligation to provide the training will expire without refund.
1	MI_SPEC_INT_BCLS	**Basic syngo Class** Tuition for (1) imaging professional to attend a Siemens Classroom Course at Siemens Training Center. The objectives of this class are to introduce the user interface of the common syngo platform and instructions on building protocols, demonstration of software functions, and hands-on sessions. This class includes lunch, economy airfare, and lodging for (1) imaging professional. All arrangements must be arranged through Siemens designated travel agency. This educational offering must be completed (12) months from install end date. If training is not completed within the applicable time period, Siemens obligation to provide the training will expire without refund.
1	MI_SPEC_INT_BCLST	**Basic SymbiaT Class** Tuition for (1) imaging professional to attend a Siemens Classroom Course at Siemens Training Center. The objectives of this class are to introduce the user interface of the common syngo platform and instructions on building protocols, demonstration of software functions, and hands-on sessions. This class includes lunch, economy airfare, and lodging for (1) imaging professional. All arrangements must be arranged through Siemens designated travel agency. This educational offering must be completed (12) months from install end date. If training is not completed within the applicable time period, Siemens obligation to provide the training will expire without refund.
1	MI_SPEC_CTCRSTR	**CT Cross Trainer (Printed Self Study)** CT Cross Trainer printed self study materials for (1) imaging professional. These materials will provide the user with basic CT knowledge by testing the participant periodically. Successful completion of the self study program will provide the participant with CE credits. CT Cross Trainer printed self study materials for (1) imaging professional. These materials will provide the user with basic CT knowledge by testing the participant periodically. Successful completion of the self study program will provide the participant with CE credits. This educational offering must be completed (12) months from install end date. If training is not completed within the applicable time period, Siemens obligation to provide the training will expire without refund.
6	MI_SPEC_CTCRSTR	**CT Cross Trainer (Printed Self Study)** CT Cross Trainer printed self study materials for (1) imaging professional. These materials will provide the user with basic CT knowledge by testing the participant periodically. Successful completion of the self study program will provide the participant with CE credits. CT Cross Trainer printed self study materials for (1) imaging professional. These materials will provide the user with basic CT knowledge by testing the participant periodically. Successful completion of the self study program will provide the participant with CE credits. This educational offering must be completed (12) months from install end date. If training is not completed within the applicable time period, Siemens obligation to provide the training will expire without refund.
1	MI_SPECT_PM	**MI SPECT Project Management** A Siemens Project Manager (PM) will be the single point of contact for the implementation of your Siemen's equipment. The assigned PM will work with the customer's facilities management, architect or building contractor to assist you in ensuring that your site is ready for installation. Your PM will provide initial and final drawings and will coordinate the scheduling of the equipment, installation, and rigging, as well as the initiation of on-site clinical education.
1	MI_SPEC_ADD_16	**Additional onsite training 16 hours** Up to (16) hours of on-site clinical education training, scheduled consecutively (Monday - Friday) during standard business hours for a maximum of (4) imaging professionals. Training will cover agenda items on the ASRT approved checklist if applicable. This educational offering must be completed (12) months from date of purchase order. If training is not completed within the applicable time period, Siemens obligation to provide the training will expire without refund.
1	ACRPHANTOM464	**464 ACR Accreditation CT Phantom**

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Qty	Part No.	Item Description
1	14414937	**Symbia.net** Symbia.net is an economical solution for reading of SPECT and SPECT•CT studies. The system can be optionally configured with full MI processing capabilities. The Symbia.net can be configured as a client-server system by adding the Server Management option. PET functionality is available on multi-seat systems.
2	07835452	**Medium Energy Collimator Symbia** Medium energy (300 keV), parallel hole collimator · 14,000 hexagonal holes · Sensitivity: 310 cpm/microCurie · Geometric Resolution 10.8 mm · Weight: 161 lbs (73.2 kg) Includes drawer for collimator cart
2	07835445	**High Energy Collimator Symbia.** High energy (364 keV), parallel hole collimator · 8,000 hexagonal holes · Sensitivity: 147 cpm/microCurie · Geometric Resolution 13.2 mm · Weight: 321 lbs (149.9 kg) Includes drawer for collimator cart
2	08717873	**Symbia Collimator Cart** The collimator cart combines manual collimator insertion with fully automatic collimator clamping and allows collimator exchange to occur without removing the bed. The cart is designed to hold two sets of collimators (or one set of collimators and one pinhole collimator)
1	MISYS_PP_SER_OF	**PP offset w / POS Gold Service contract**
1	NMSYS_ADDL_RIGGING	**Additional Rigging NMSYS $1,500**

System Total: $481,500

FINANCING: The equipment listed above may be financed through Siemens. Ask us about our full range of financial products that can be tailored to meet your business and cash flow requirements. For further information, please contact your local Sales Representative.

ACCESSORIES: Don't forget to ask us about our line of OEM imaging accessories to complete your purchase. All accessories can be purchased or financed as part of this order. To purchase accessories directly or to receive our accessories catalog, please call us directly at 1-888-222-9944 ext. 7 or contact your local Sales Representative.

COMPLIANCE: Compliance with legal and internal regulations is an integral part of all business processes at Siemens. Possible infringements can be reported to our Helpdesk "Tell us" function at www.siemens.com/tell-us.

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Siemens Medical Solutions USA, Inc. General Terms and Conditions

1. GENERAL

1.1 Contract Terms. These terms and conditions constitute an integral part of any contract between Seller and Purchaser identified on the first page hereof and shall govern the sale of the products identified in such contract ("Products"). Seller shall not be bound by, and specifically objects to, any terms, conditions or other provisions which are different from or in addition to the provisions of this Agreement (even if provided to Seller concurrently with this Agreement), unless Seller specifically agrees to any such provision in a writing signed by Seller. Neither Seller's lack of objection to any such terms, nor delivery of the Products or provision of any services hereunder, shall constitute the agreement of Seller to any such terms. Purchaser acknowledges that this is a commercial and not a consumer transaction.

1.2 Acceptance. Purchaser shall be deemed to have assented to, and to have waived any objection to, this Agreement upon the earliest to occur of any of the following: Purchaser's completion or execution of this Agreement; Purchaser's acceptance of all or any part of the Products; Purchaser's issuance of a purchase order for any Products identified on Seller's quotation or proposal; or delivery of the Products to the common carrier for shipment pursuant hereto.

1.3 Refurbished/Used Products. For Products identified on this Agreement as used or refurbished Products, these Products have been previously owned and used. When delivered to Purchaser, the Products may have received mechanical, electrical and/or cosmetic reconditioning, as needed, and will comply with the manufacturer's specifications. Since pre-owned Products may be offered simultaneously to several customers, the sale of such Products to Purchaser cannot be guaranteed and is subject to continuing availability at the time Purchaser accepts Seller's offer to sell the Products. If the Products are no longer available, Seller will use its best efforts to identify other products in its inventory that may be suitable for purchase by Purchaser, and if substitute products are not acceptable to Purchaser, then Seller will cancel the order and refund to Purchaser any deposits previously paid. The warranty period for any used or refurbished Products will be separately stated on the quotation.

1.4 Third Party Products. If this Agreement includes the sale of third party products not manufactured by Seller, then Purchaser agrees and acknowledges that (a) Purchaser has made the selection of these products on its own, (b) the products are being acquired by Seller solely at the request of and for the benefit of Purchaser, in order to eliminate the need for Purchaser to issue a separate purchase order to the manufacturer of the products, (c) no representation, warranty or guarantee has been made by Seller with respect to the products, (d) the obligation of Purchaser to pay Seller for the products is absolute and unconditional, (e) Purchaser will indemnify and hold Seller harmless from and against any and all claims, regardless of the form of action, related to, resulting from or caused by the products or any work or service provided by the manufacturer of the products or any other party, (f) use of the products may be subject to Purchaser's agreement to comply with any software licensing terms imposed by the manufacturer, as well as any applicable laws, rule and regulations; and (g) the manufacturer, and not Seller, is solely responsible for any required installation, testing, validation, tracking, product recall, warranty service, maintenance, support, and complaint handling, as well as any other applicable FDA regulatory requirements, and the Purchaser will look solely to the manufacturer regarding these services and will assert no claim against Seller with respect to these products.

2. PRICES

2.1 Quotations. Unless otherwise agreed to in writing or set forth in the quotation, all prices quoted by Seller are based on U.S. dollars, and include standard and customary packaging. F.O.B. terms are set forth in Section 6.2 hereof. Domestic prices apply only to purchasers located in, and who will use the Products in, the U.S. International prices apply to all purchasers located outside of, or who will use or ship or facilitate shipment of the Products outside of, the U.S. Unless otherwise stated, the quotation shall only be valid for forty-five (45) days from the date of the quotation.

2.2 Delay in Acceptance of Delivery. Should the agreed delivery date be postponed by Purchaser, Seller shall have the right to deliver the Products to storage at Purchaser's risk and expense, and payments due upon delivery shall become due when Seller is ready to deliver.

2.3 Escalation. Unless otherwise agreed to in writing, except as to Products to be delivered within six (6) months of Seller's acceptance of Purchaser's order, Seller reserves the right to increase its prices to those in effect at the time of shipment.

3. TAXES

3.1 Any sales, use or manufacturer's tax which may be imposed upon the sale or use of Products, or any property tax levied after readiness to ship, or any excise tax, license or similar fee required under this transaction, shall be in addition to the quoted prices and shall be paid by Purchaser. Notwithstanding the foregoing, Seller agrees to honor any valid exemption certificate provided by Purchaser.

4. TERMS OF PAYMENT; DEFAULT

4.1 Payments; Due Date. Unless otherwise set forth in the quotation, Seller's payment terms are as follows: an initial deposit of 10% of the purchase price for each Product is due upon submission of the purchase order, an additional 80% of the purchase price is due upon delivery of each Product, and the final 10% of the purchase price is due upon completion of installation or when the Products are available for first patient use, whichever occurs first. Unless otherwise agreed, all payments other than the initial deposit are due net thirty (30) days from the date of invoice. Seller shall have no obligation to complete installation until the payment due upon delivery is received. All amounts payable pursuant to this Agreement are denominated in United States dollars, and Purchaser shall pay all such amount in lawful money of the United States. Partial shipments shall be billed as made, and payments for such shipments will be made in accordance with the foregoing payment terms.

4.2 Late Payment. A service charge of 1½% per month, not to exceed the maximum rate allowed by law, shall be made on any portion of Purchaser's outstanding balance which is not paid within thirty (30) days after invoice date, which charge shall be determined and compounded on a daily basis from the due date until the date paid. Payment of such service charge shall not excuse or cure Purchaser's breach or default for late payment.

4.3 Payment of Lesser Amount. If Purchaser pays, or Seller otherwise receives, a lesser amount than the full amount provided for under this Agreement, such payment or receipt shall not constitute or be construed other than as on account of the earliest amount due Seller. Seller may accept any check or payment in any amount without prejudice to Seller's right to recover the balance of the amount due or to pursue any other right or remedy. No endorsement or statement on any check or payment or in any letter accompanying a check or payment or elsewhere shall constitute or be construed as an accord or satisfaction.

4.4 Where Payment Due Upon Installation or Completion. Should any terms of payment provide for either full or partial payment upon completion of installation or thereafter, and completion of installation is delayed for any reason for which Seller is not responsible, then the Products shall be deemed installed upon delivery and the balance of payments shall be due no later than thirty (30) days from the delivery date regardless of the actual installation date.

4.5 Default; Termination. Each of the following shall constitute an event of default under this Agreement: (i) a failure by Purchaser to make any payment due Seller within ten (10) days of receipt of written notice of non-payment from Seller; (ii) a failure by Purchaser to perform any other obligation under this Agreement within thirty (30) days of receipt of written notice from Seller; (iii) a default by Purchaser under any other obligation to or agreement with Seller or Siemens Financial Services, Inc., or any assignee of the foregoing (e.g., a promissory note, lease, rental agreement, license agreement or purchase contract); or (iv) the commencement of any insolvency, bankruptcy or similar proceedings by or against Purchaser (including any assignment by Purchaser for the benefit of creditors). Upon the occurrence of any event of default, at Seller's election: (a) the entire amount of any indebtedness and obligation due Seller under this Agreement and interest thereon shall become immediately due and payable without notice, demand, or period of grace; (b) Seller may suspend the performance of any of Seller's obligations hereunder, including, but not limited to, obligations relating to delivery, installation and warranty services; (c) Purchaser shall put Seller in possession of the Products upon demand; (d) Seller may enter any premises where the Products are located and take possession of the Products without notice or demand and without legal proceedings; (e) at the request of Seller, Purchaser shall assemble the Products and make them available to Seller at a place designated by Seller which is reasonable and convenient to all parties; (f) Seller may sell or otherwise dispose of all or any part of the Products and apply the proceeds thereof against any indebtedness or obligation of Purchaser under this Agreement (Purchaser agrees that a period of 10 days from the time notice is sent to Purchaser shall be a reasonable period of notification of sale or other disposition of the Products by or for Seller); (g) if this Agreement or any indebtedness or obligation of Purchaser under this Agreement is referred to an attorney for collection or realization, Purchaser shall pay to Seller all costs of collection and realization (including, without limitation, a reasonable sum for attorneys' fees, expenses of title search, all court costs and other legal expenses) incurred thereby; and (h) Purchaser shall pay any deficiency remaining after collection of or realization by Seller on the Products. In addition, Seller may terminate this Agreement upon written notice to Purchaser

in the event that Purchaser is not approved for credit or upon the occurrence of any material adverse change in the financial condition or business operations of Purchaser.

4.6 Financing. Notwithstanding any arrangement that Purchaser may make for the financing of the purchase price of the Products, the parties agree that any such financing arrangement shall have no effect on the Purchaser's payment obligations under this Agreement, including but not limited to Sections 4.1 and 4.2 above.

5. EXPORT TERMS

5.1 Unless other arrangements have been made, payment on export orders shall be made by irrevocable confirmed letter of credit, payable in U.S. dollars against Seller's invoice and standard shipping documents. Such letter of credit shall be in an amount equal to the full purchase price of the Products and shall be established in a U.S. bank acceptable to Seller. Purchaser shall procure all necessary permits and licenses for shipment and compliance with any governmental regulations concerning control of final destination of Products.

5.2 Purchaser acknowledges that Seller is required to comply with applicable export laws and regulations relating to the sale, exportation, transfer, assignment, disposal and usage of the Products provided under this Agreement, including any export license requirements. Purchaser agrees that such Products shall not at any time directly or indirectly be used, exported, sold, transferred, assigned or otherwise disposed of in a manner which will result in non-compliance with such applicable export laws and regulations. It shall be a condition of the continuing performance by Seller of its obligations hereunder that compliance with such export laws and regulations be maintained at all times. **PURCHASER AGREES TO INDEMNIFY, DEFEND AND HOLD SELLER HARMLESS FROM ANY AND ALL COSTS, LIABILITIES, PENALTIES, SANCTIONS AND FINES RELATED TO NON-COMPLIANCE WITH APPLICABLE EXPORT LAWS AND REGULATIONS.** If Purchaser purchases a Product at the domestic price and exports such Product, or transfers such Product to a third party for export, outside of the U.S., Purchaser shall pay to Seller the difference between the domestic price and the international retail price of such Product pursuant to the payment terms set forth herein. Purchaser shall deliver to Seller, upon Seller's request, written assurance regarding compliance with this section in form and content acceptable to Seller.

6. DELIVERY, RISK OF LOSS

6.1 Delivery Date. Delivery and installation dates will be established by mutual agreement of the parties. Seller shall make every reasonable effort to meet the agreed upon delivery date(s), but shall not be liable for any failure to meet such date(s). Partial shipments may be made.

6.2 Risk of Loss; Title Transfer. Unless otherwise agreed to in writing, the following shall apply:

(a) For Products that do not require installation by Seller, and for options and add-on products purchased subsequent to delivery and installation of Products purchased under this Agreement, delivery shall be complete upon transfer of possession to common carrier, F.O.B. Shipping Point, whereupon title to and all risk of loss, damage to or destruction of the Products shall pass to Purchaser.

(b) For Products that require installation by Seller, delivery shall be complete upon delivery of the Products to Purchaser's designated site, F.O.B. Destination; title to and all risk of loss, damage to or destruction of such Products shall pass to Purchaser upon completion of the installation.

(c) All freight charges and other transportation, packing and insurance costs, license fees, custom duties and other similar charges shall be the sole responsibility of Purchaser unless included in the purchase price or otherwise agreed to in writing by Seller. In the event of any loss or damage to any of the Products during shipment, Seller and Purchaser shall cooperate in making a claim against the carrier.

7. SECURITY INTEREST/FILING

7.1 Purchaser grants to Seller a security interest in the Products (and all accessories and replacements thereto and all proceeds thereof) until payment in full by Purchaser and satisfaction of all other obligations of Purchaser hereunder. Purchaser hereby (i) authorizes Seller to file (and Purchaser shall promptly execute, if requested by Seller) and (ii) irrevocably appoints Seller its agent and attorney-in-fact to execute in the name of Purchaser and file, with such authorities and at such locations as Seller may deem appropriate, any Uniform Commercial Code financing statements with respect to the Products and/or this Agreement. Purchaser further represents and covenants that (a) it will keep the Products in good order and repair until the purchase price has been paid in full, (b) it will promptly pay all taxes and assessments upon the Products or the use thereof, (c) it will not attempt to transfer any interest in the Products until the purchase price has been paid in full, and (d) it is solvent and financially capable of paying the full purchase price for the Products.

8. CHANGES, CANCELLATION, AND RETURN

8.1 Orders accepted by Seller are not subject to change except upon Seller's written agreement.

8.2 Orders accepted by Seller are noncancellable by Purchaser except upon Seller's written consent and payment by Purchaser of a cancellation charge equal to 10% of the price of the affected Products, plus any shipping, insurance, inspection and refurbishment charges; the cost of providing any training, education, site evaluation or other services completed by Seller; and any return, cancellation or restocking fees with respect to any Third Party Products ordered by Seller on behalf of Purchaser. Seller may retain any payments received from Purchaser up to the amount of the cancellation charge. In no event can an order be cancelled by Purchaser or Products be returned to Seller after shipment.

8.3 Seller shall have the right to change the manufacture and/or design of its Products if, in the judgment of Seller, such change does not alter the general function of the Products.

9. FORCE MAJEURE

9.1 Seller shall not be liable for any loss or damage for delay in delivery, inability to install or any other failure to perform due to causes beyond its reasonable control including, but not limited to, acts of government or compliance with any governmental rules or regulations, acts of God or the public, war, civil commotion, blockades, embargoes, calamities, floods, fires, earthquakes, explosions, storms, strikes, lockouts, labor disputes, or unavailability of labor, raw materials, power or supplies. Should such a delay occur, Seller may reasonably extend delivery or production schedules or, at its option, cancel the order in whole or part without liability other than to return any unearned deposit or prepayment.

10. WARRANTY

10.1 Seller warrants that the Products manufactured by Seller and sold hereunder shall be free from defects in material or workmanship under normal use and service for the warranty period. The final assembled Products shall be new although they may include certain used, reworked or refurbished parts and components (e.g., circuit boards) that comply with performance and reliability specifications and controls. Seller's obligation under this warranty is limited, at Seller's option, to the repair or replacement of the Product or any part thereof. Unless otherwise set forth in the Product Warranty attached hereto and incorporated herein by reference, the warranty period shall commence upon the earlier of the date that the Products have been installed in accordance with Section 12.6 hereof (which date shall be confirmed in writing by Seller) or first patient use, and shall continue for 12 consecutive months. Seller makes no warranty for any Products made by persons other than Seller or its affiliates, and Purchaser's sole warranty therefor, if any, is the original manufacturer's warranty, which Seller agrees to pass on to Purchaser, as applicable. The warranty provided by Seller under this Section 10 extends only to the original Purchaser, unless the Purchaser obtains the Seller's prior written consent with respect to any sale or other transfer of the Equipment during the term of the warranty.

10.2 No warranty extended by Seller shall apply to any Products which have been damaged by fire, accident, misuse, abuse, negligence, improper application or alteration or by a force majeure occurrence as described in Section 9 hereof or by the Purchaser's failure to operate the Products in accordance with the manufacturer's instructions or to maintain the recommended operating environment and line conditions; which are defective due to unauthorized attempts to repair, relocate, maintain, service, add to or modify the Products by the Purchaser or any third party or due to the attachment and/or use of non-Seller supplied parts, equipment or software without Seller's prior written approval; which failed due to causes from within non-Seller supplied equipment, parts or software including, but not limited to, problems with the Purchaser's network; or which have been damaged from the use of operating supplies or consumable parts not approved by Seller. In addition, there is no warranty coverage for any transducer or probe failure due to events such as cracking from high impact drops, cable rupture from rolling equipment over the cable, delamination from cleaning with inappropriate solutions, or TEE bite marks. Seller's obligation under this warranty is limited to the repair or replacement, at Seller's option, of defective parts. Seller may effectuate such repair at Purchaser's facility, and Purchaser shall furnish Seller safe and sufficient access for such repair. Repair or replacement may be with parts or products that are new, used or refurbished. Repairs or replacements shall not interrupt, extend or prolong the term of the warranty. Purchaser shall, upon Seller's request, return the noncomplying Product or part to Seller with all transportation charges prepaid, but shall not return any Product or part to Seller without Seller's prior written authorization. Purchaser shall pay Seller its normal charges for service and parts for any inspection, repair or replacement that falls outside the warranty set forth in Section 10.1. Seller's warranty does not apply to consumable materials, disposables, supplies, accessories and collateral equipment, except as specifically stated in writing or as otherwise set

forth in the Product Warranty attached hereto and incorporated herein by reference, nor to products or parts thereof supplied by Purchaser.

10.3 This warranty is made on condition that immediate written notice of any noncompliance be given to Seller and Seller's inspection reveals that Purchaser's claim is covered under the terms of the warranty (i.e., that the noncompliance is due to traceable defects in original materials and/or workmanship).

10.4 Purchaser shall provide Seller with both on-site and remote access to the Products. The remote access shall be provided through the Purchaser's network as is reasonably necessary for Seller to provide warranty services under this Agreement. Remote access will be established through a broadband internet-based connection to either a Purchaser owned or Seller provided secure end-point. The method of connection will be a Peer-to-Peer VPN IPsec tunnel (non-client based) with specific inbound and outbound port requirements.

10.5 Warranty service will be provided without charge during Seller's regular working hours (8:30-5:00), Monday through Friday, except Seller's recognized holidays. If Purchaser requires that service be performed outside these hours, such service can be made available at an additional charge, at Seller's then current rates. The obligations of Seller described in this section are Seller's only obligations and Purchaser's sole and exclusive remedy for a breach of product warranty.

10.6 SELLER MAKES NO WARRANTY OTHER THAN THE ONE SET FORTH HEREIN AND IN THE ATTACHED PRODUCT WARRANTY COVERING THE APPLICABLE PRODUCT CATEGORY. SUCH WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY EXPRESS OR IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR PARTICULAR PURPOSES, AND SUCH CONSTITUTES THE ONLY WARRANTY MADE WITH RESPECT TO THE PRODUCTS AND ANY DEFECT, DEFICIENCY OR NONCONFORMITY IN ANY PRODUCT, SERVICE OR OTHER ITEM FURNISHED UNDER THIS AGREEMENT.

10.7 In the event of any inconsistencies between the terms of this Section 10 and the terms of the attached Product Warranty, the terms of the attached Product Warranty shall prevail.

11. LIMITATION OF LIABILITY

11.1 In no event shall Seller's liability hereunder exceed the actual loss or damage sustained by Purchaser, up to the purchase price of the Products. The foregoing limitation of liability shall not apply to claims for bodily injury or damages to real property or tangible personal property to the extent arising from Seller's negligence or a product defect.

11.2 SELLER SHALL NOT BE LIABLE FOR ANY LOSS OF USE, REVENUE OR ANTICIPATED PROFITS; COST OF SUBSTITUTE PRODUCTS OR SERVICES; LOSS OF STORED, TRANSMITTED OR RECORDED DATA; OR FOR ANY INDIRECT, INCIDENTAL, UNFORESEEN, SPECIAL, PUNITIVE OR CONSEQUENTIAL DAMAGES WHETHER BASED ON CONTRACT, TORT (INCLUDING NEGLIGENCE), STRICT LIABILITY OR ANY OTHER THEORY OR FORM OF ACTION, EVEN IF SELLER HAS BEEN ADVISED OF THE POSSIBILITY THEREOF, ARISING OUT OF OR IN CONNECTION WITH THIS AGREEMENT OR THE SALE OR USE OF THE PRODUCTS. THE FOREGOING IS A SEPARATE, ESSENTIAL TERM OF THIS AGREEMENT AND SHALL BE EFFECTIVE UPON THE FAILURE OF ANY REMEDY, EXCLUSIVE OR NOT.

12. INSTALLATION - ADDITIONAL CHARGES

12.1 General. Unless otherwise expressly stipulated in writing, the Products covered hereby shall be installed by and at the expense of Seller except that Seller shall not provide rigging or site preparation services unless otherwise agreed to in writing by Seller for an additional charge. Seller will not install accessory items such as cabinets, illuminators, darkroom equipment or processors for X-Ray and CT equipment, unless otherwise agreed to in writing by Seller.

12.2 Installation by Seller. If Seller specifies it will install the Products, the following applies: subject to fulfillment of the obligations set forth in Section 12.4 below, Seller shall install the Products and connect them to the requisite safety switches and power lines to be installed by Purchaser. Except as otherwise specified below, if such installation and connection are performed by Seller's technical personnel, prices shown include the cost thereof, provided that the installation and connection can be performed within the Continental United States or Puerto Rico and during normal business hours. Any overtime charges or other special expenses shall be additional charges to the prices shown.

12.3 Trade Unions. In the event that a trade union, or unions, or other local labor conditions prevent Seller from performing the above work with its own employees or contractors, then Purchaser shall either make all required arrangements with the trade union, or unions, to permit Seller to complete the work or shall provide the personnel, at Purchaser's sole cost and expense. Moreover, any additional cost incurred by Seller and related to such labor disputes shall be paid by the Purchaser and Seller's obligations under such circumstances will be limited to providing engineering supervision of installation and connection of the Products to existing wiring.

12.4 Purchaser's Obligations. Purchaser shall, at its expense, provide all proper and necessary labor and materials for plumbing service, carpentry work, conduit wiring, and other preparations required for such installation and connection. All such labor and materials shall be completed and available at the time of delivery of the Products by Seller. Additionally, Purchaser shall provide free access to the installation site and, if necessary, safe and secure space thereon for storage of Products and equipment prior to installation by Seller. Purchaser shall be responsible, at its sole cost and expense, for obtaining all permits, licenses and approvals required by any federal, state or local authorities in connection with the installation and operation of the Products, including but not limited to any certificate of need and zoning variances. Purchaser shall provide a suitable environment for the Products and shall ensure, at its sole cost and expense, that its premises are free of asbestos, hazardous conditions and any concealed, unknown or dangerous conditions and that all site requirements are met. Seller shall delay its work until Purchaser has completed the removal of any asbestos or other hazardous materials or has taken any other precautions and completed any other work required by applicable regulations. Purchaser shall reimburse Seller for any increased costs and expenses incurred by Seller that are the result of or are caused by any such delay. In the event that Seller is requested to supervise the installation of the Products, it remains the Purchaser's responsibility to comply with local regulations. Seller is not an architect and all drawings furnished by Seller are not construction drawings.

12.5 Regulatory Reporting. In the event that any regulatory activity is performed by anyone other than Seller's authorized personnel, then Purchaser shall be responsible for fulfilling any and all reporting requirements.

12.6 Completion of Installation. Installation shall be complete upon the conclusion of final calibration and checkout under Seller's standard procedures to verify that the Products meet applicable written performance specifications. Notwithstanding the foregoing, first use of the Products by Purchaser, its agents or employees for any purpose after delivery shall constitute completion of installation.

13. PATENT, COPYRIGHT AND OTHER INFRINGEMENT CLAIMS

13.1 Infringement by Seller. Seller warrants that the Products manufactured by Seller and sold hereunder do not infringe any U.S. patent or copyright. If Purchaser receives a claim that any such Products, or parts thereof, infringe upon the rights of others under any U.S. patent or copyright, Purchaser shall notify Seller immediately in writing. As to all infringement claims relating to Products or parts manufactured by Seller or one of its affiliates:

(a) Purchaser shall give Seller information, assistance and exclusive authority to evaluate, defend and settle such claims.

(b) Seller shall then, at its own expense, defend or settle such claims, procure for Purchaser the right to use the Products, or remove or modify them to avoid infringement. If none of these alternatives is available on terms reasonable to Seller, then Purchaser shall return the Products to Seller and Seller shall refund to Purchaser the purchase price paid by Purchaser less reasonable depreciation for Purchaser's use of the Products. The foregoing states Seller's entire obligation and liability, and Purchaser's sole remedy, for claims of infringement.

13.2 Infringement by Purchaser. If some or all of the Products sold hereunder are made by Seller pursuant to drawings or specifications furnished by Purchaser, or if Purchaser modifies or combines, operates or uses the Products other than as specified by Seller or with any product, data, software, apparatus or program not provided or approved by Seller, then the indemnity obligation of Seller under Section 13.1 shall be null and void and should a claim be made that such Products infringe the rights of any third party under patent, copyright or otherwise, then Purchaser shall indemnify, defend and hold Seller harmless against any liability or expense, including reasonable attorneys' fees, incurred by Seller in connection therewith.

14. DESIGNS AND TRADE SECRETS; LICENSE; CONFIDENTIALITY

14.1 Any drawings, data, designs, software programs or other technical information supplied by Seller to Purchaser in connection with the sale of the Products are not included in the sale of the Products to Purchaser, shall remain Seller's property and shall at all times be held in confidence by Purchaser. Such information shall not be reproduced or disclosed to others without Seller's prior written consent.

14.2 For all goods purchased hereunder which utilize software for their operation, such "Applications Software" shall be licensed to Purchaser under the terms of Seller's Software License Schedule attached hereto.

14.3 Diagnostic/Maintenance Software is not included under Section 14.2 above, is available only as a special option under a separate Diagnostic Materials License Agreement, and may be subject to a separate licensing fee.
14.4 Seller and Purchaser shall maintain the confidentiality of any information provided or disclosed to the other party relating to the business, customers and/or patients of the disclosing party, as well as this Agreement and its terms (including the pricing and other financial terms under which the Purchaser will be purchasing the Products). Each party shall use reasonable care to protect the confidentiality of the information disclosed, but no less than the degree of care it would use to protect its own confidential information, and shall only disclose the other party's confidential information to its employees and agents having a need to know this information. The obligations of confidentiality set forth herein shall not apply to any information in the public domain at the time of disclosure or that is required to be disclosed by court order or by law.

15. ENGINEERING CHANGES
15.1 Seller makes no representation that engineering changes which may be announced in the future will be suitable for use on, or in connection with, the Products.

16. ASSIGNMENT
16.1 Neither party may assign any rights or obligations under this Agreement without the prior written consent of the other and any attempt to do so shall be void, except that Seller may assign this Agreement without consent to any subsidiary or affiliated company, and may delegate to authorized subcontractors or service suppliers any work to be performed under this Agreement so long as Seller remains liable for the performance of its obligations under this Agreement. This Agreement shall inure to and be binding upon the parties and their respective successors, permitted assigns and legal representatives. Seller shall have no obligations under this Agreement to any assignee of Purchaser that is not approved by Seller in advance.

17. COSTS AND FEES
17.1 In the event that any dispute or difference is brought arising from or relating to this Agreement or the breach, termination or validity thereof, the prevailing party shall be entitled to recover from the other party all reasonable attorneys' fees incurred, together with such other expenses, costs and disbursements as may be allowed by law.

18. MODIFICATION
18.1 This Agreement may not be changed, modified or amended except in writing signed by duly authorized representatives of the parties.

19. GOVERNING LAW; WAIVER OF JURY TRIAL
19.1 This Agreement shall be governed by the laws of the Commonwealth of Pennsylvania.
19.2 EACH OF THE PARTIES EXPRESSLY WAIVES ALL RIGHTS TO A JURY TRIAL IN CONNECTION WITH ANY DISPUTE UNDER THIS AGREEMENT.

20. COST REPORTING
20.1 Purchaser agrees that it will fully and accurately account for and report in all cost reports and otherwise fully and accurately disclose to federal and state health care program payors and fully and accurately reflect where and as appropriate to the applicable reimbursement methodology, all services and other items, including any and all discounts, received from Seller under this Agreement, in compliance with all applicable laws, rules and regulations, including but not limited to the Social Security Act and implementing regulations relating to Medicare, Medicaid and other federal and state health care reimbursement programs.

21. INTEGRATION
21.1 These terms and conditions, including any attachments or other documents incorporated by reference herein, constitute the entire agreement and the complete and exclusive statement of agreement with respect to the subject matter hereof, and supersede any and all prior agreements, understandings and communications between the parties with respect to the Products.

22. SEVERABILITY; HEADINGS
22.1 No provision of this Agreement which may be deemed unenforceable will in any way invalidate any other portion or provision of this Agreement. Section headings are for convenience only and will have no substantive effect.

23. WAIVER
23.1 No failure and no delay in exercising, on the part of any party, any right under this Agreement will operate as a waiver thereof, nor will any single or partial exercise of any right preclude the further exercise of any other right.

24. NOTICES
24.1 Any notice or other communication under this Agreement shall be deemed properly given if given in writing and delivered in person or mailed, properly addressed and stamped with the required postage, to the intended recipient at its address specified on the face hereof. Either party may from time to time change such address by giving the other party notice of such change in accordance with this section.

25. RIGHTS CUMULATIVE
25.1 The rights and remedies afforded to Seller under this Agreement are in addition to, and do not in anyway limit, any other rights or remedies afforded to Seller by any other agreement, by law or otherwise.

26. END USER CERTIFICATION
26.1 Purchaser represents, warrants and covenants that it is acquiring the Products for its own end use and not for reselling, leasing or transferring to a third party (except for lease-back financings).

03/2012 Rev

SIEMENS

Siemens Medical Solutions USA, Inc.
51 Valley Stream Parkway, Malvern, PA 19355
Fax: (781) 203-6025

SIEMENS REPRESENTATIVE
John Hubbard - (603) 801-4879

Software License Schedule
to the Siemens Medical Solutions USA, Inc. General Terms and Conditions

1. DEFINITIONS: The following definitions apply to this Schedule:
"**Agreement**" shall mean the attached (i) Quotation for Products and/or Services including the Terms and Conditions of Sale and applicable schedules; and/or (ii) Software License Agreement describing the software licensed herein and the specific system for which the license is issued.
"**Licensor**" shall mean Siemens Medical Solutions USA, Inc.
"**Licensee**" shall mean the end-user to whom Licensor provides Software or Documentation for its internal use under the Agreement.
"**Software**" shall mean the software described in the attached Agreement, including the following as contained therein: (i) software programs consisting of a series of statements or instructions to be used directly or indirectly in a programmable controller or computer to bring about a certain result and (ii) databases consisting of systemized collections of data to be used or referenced directly or indirectly by a programmed controller or computer. Notwithstanding the foregoing, "Software" does not include "firmware" as such term is conventionally understood. Diagnostic/Maintenance Software also is not included within the scope of the Software licensed under this Schedule, and is available only as a special option under a separate Diagnostic Materials License Agreement and may be subject to a separate licensing fee.
"**Documentation**" shall mean the documents and other supporting materials which are intended to support the use of an associated product, including (but not limited to) instructions, descriptions, flow charts, logic diagrams and listings of the Software, in text or graphic form, on machine readable or printed media.
"**Designated Unit**" shall mean a single control unit or computer identified on the first page of the Agreement, on which Software licensed hereunder may be used by Licensee.
2. SCOPE: The following terms and conditions shall apply to all Software and Documentation provided by Licensor to Licensee under the Agreement (whether included with other products listed in the Agreement or listed separately in the Agreement), together with any updates or revisions thereto which Licensor may provide to Licensee, and all copies thereof, except any Software and/or Documentation licensed directly by Licensor's supplier under a separate end-user license agreement accompanying the Software or the Documentation, in which case Licensee agrees to be bound by that license agreement as a condition to using the Software and/or Documentation. Except as expressly provided herein, and provided that in no event shall the warranties or other obligations of Licensor with respect to such Software or Documentation exceed those set forth in this Schedule, this Schedule shall be subject to the liability limitations and exclusions and other terms and conditions set forth in the Agreement. **ANY USE OF THE SOFTWARE, INCLUDING BUT NOT LIMITED TO USE ON THE DESIGNATED UNIT, WILL CONSTITUTE LICENSEE'S AGREEMENT TO THIS SOFTWARE LICENSE SCHEDULE (OR RATIFICATION OF ANY PREVIOUS CONSENT).**
3. SOFTWARE AND DOCUMENTATION LICENSE: Subject to the payment of any applicable annual license fee(s), whether stated separately or included in the purchase price of another product, and to Licensee's acceptance of all of the obligations set forth herein and to the fulfillment of those obligations, Licensor or, if applicable, its licensor or supplier, hereby grants to Licensee a paid-up, nonexclusive and nontransferable (except as expressly provided in this Schedule) limited license to use the Software provided by Licensor under the Agreement solely for Licensee's own use on the Designated Unit and to use the Documentation in support of Licensee's authorized use of the Software, for the purpose of operating the Designated Unit in accordance with the instructions set forth in the user's manual supplied with the Designated Unit and for no other purpose whatsoever. A separate license is required for each Designated Unit on which the Software is to be used. Licensee may obtain from Licensor one copy of the Software licensed hereunder for backup and archival purposes only as is necessary to support Licensee's own authorized use of the Software, provided that Licensee includes on or in all copies (in any form) all copyright, trade secret or other proprietary notices contained on or in the Software as provided by Licensor. Additional copies of the Documentation may be licensed from Licensor at its then applicable charges. Licensee may make the Software and Documentation (including any copies) available only to its employees and other persons on Licensee's premises to whom such disclosure is necessary to enable Licensee to use the Software or Documentation within the scope of the license provided in this Schedule. If the Software is supplied to any unit or agency of the United States Government other than the Department of Defense, the Software and Documentation are classified as "restricted computer software" and the Government's rights in the Software and Documentation shall be as provided in paragraph (c) (2) of the Commercial Computer Software-Restricted Rights clause in FAR 52.227-19 and any successor laws, rules or regulations thereto. If the Software is supplied to the United States Department of Defense, the Software is classified as "commercial computer software" and the Government is furnished the Software and Documentation with "restricted rights" as defined in paragraph (c) (1) of the Rights in Technical Data and Computer Software clause in DFARS 252.227-7013 and any successor laws, rules or regulations thereto.
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SIEMENS
Siemens Medical Solutions USA, Inc.
51 Valley Stream Parkway, Malvern, PA 19355
Fax: (781) 203-6025

SIEMENS REPRESENTATIVE
John Hubbard - (603) 801-4879

MI Warranty Information

Product	Period of Warranty[1]	Coverage	
(New Systems and "Proven Excellence" Refurbished Systems Only)			
MI-SPECT System or MI-PET System (not including radioactive sources and consumables)	12 month	Full Warranty (parts & labor including ALL CT tubes)	
Post-Warranty (after expiration of system warranty) – Replacement parts only:			
Straton CT tubes	Prorated to a maximum of 160,000 scan-seconds or 12 months whichever occurs first	Prorated credit given to customer against replacement cost	credit percentage = (160,000 – scan-seconds used) / 160,000*100
Dura Akron Q CT tubes	Prorated to a maximum of 120,000 scan-seconds or 12 months whichever occurs first	Prorated credit given to customer against replacement cost	credit percentage = (120,000 – scan-seconds used) / 120,000*100
All other Dura CT tubes	Prorated to a maximum of 130,000 scan-seconds or 12 months whichever occurs first	Prorated credit given to customer against replacement cost	credit percentage = (130,000 – scan-seconds used) / 130,000*100
Spare Parts	6 month	Parts only	
Radioactive Sources	Not covered		
Consumables	Not covered		

Note: Optional extended warranty coverage can be obtained by purchase of a service agreement.

[1] Period of warranty commences from the date of first use or completion of installation, whichever occurs first. In the event the completion of installation is delayed for reasons beyond Siemens' control, the stated Warranty period shall commence 60 days after delivery of equipment.

EXHIBIT 11

12. C (i). Please provide one year of actual results and three years of projections of **Total Facility** revenue, expense and volume statistics without, incremental to and with the CON proposal in the following reporting format:

Total Facility: Description	FY 2012 Actual Results	FY 14 Projected W/out CON	FY 14 Projected Incremental	FY 14 Projected With CON	FY 15 Projected W/out CON	FY 15 Projected Incremental	FY 15 Projected With CON	FY 2016 Projected W/out CON	FY 16 Projected Incremental	FY 16 Projected With CON
NET PATIENT REVENUE										
Non-Government	$421,071,330	$504,994,994		$504,994,994	$521,407,331		$521,407,331	$540,125,854		$540,125,854
Medicare	$381,926,070	$375,474,280		$375,474,280	$387,677,194		$387,677,194	$401,594,805		$401,594,805
Medicaid and Other Medical Assistance	$114,354,648	$111,971,347		$111,971,347	$115,610,416		$115,610,416	$119,760,830		$119,760,830
Other Government	$9,281,003	$6,084,024		$6,084,024	$6,281,755		$6,281,755	$6,507,270		$6,507,270
Total Net Patient Patient Revenue	$926,633,051	$998,524,645	$0	$998,524,645	$1,030,976,696	$0	$1,030,976,696	$1,067,988,759	$0	$1,067,988,759
Other Operating Revenue	$172,515,114	$145,740,012		$145,740,012	$148,727,682		$148,727,682	$154,022,388		$154,022,388
Revenue from Operations	$1,099,148,165	$1,144,264,657	$0	$1,144,264,657	$1,179,704,378	$0	$1,179,704,378	$1,222,011,147	$0	$1,222,011,147
OPERATING EXPENSES										
Salaries and Fringe Benefits	$604,512,881	$606,232,019		$606,232,019	$637,877,330		$637,877,330	$667,857,565		$667,857,565
Professional / Contracted Services	$44,286,457	$51,423,026		$51,423,026	$53,994,177		$53,994,177	$56,693,886		$56,693,886
Supplies and Drugs	$133,308,976	$153,687,097		$153,687,097	$164,445,194		$164,445,194	$175,956,357		$175,956,357
Bad Debts	$22,645,968	$22,740,654		$22,740,654	$23,479,725		$23,479,725	$24,322,647		$24,322,647
Other Operating Expense	$173,935,441	$189,269,610		$189,269,610	$193,055,002		$193,055,002	$196,916,102		$196,916,102
Subtotal	$978,689,723	$1,023,352,406	$0	$1,023,352,406	$1,072,851,429	$0	$1,072,851,429	$1,121,746,558	$0	$1,121,746,558
Depreciation/Amortization	$46,274,726	$45,855,088	$46,710	$45,901,798	$64,731,581	$93,419	$64,825,000	$66,756,581	$93,419	$66,850,000
Interest Expense	$4,517,043	$5,649,775		$5,649,775	$5,483,210		$5,483,210	$5,943,000		$5,943,000
Lease Expense	$17,167,465	$17,960,797		$17,960,797	$18,320,013		$18,320,013	$18,686,413		$18,686,413
Total Operating Expense	$1,046,648,957	$1,092,818,066	$46,710	$1,092,864,776	$1,161,386,233	$93,419	$1,161,479,652	$1,213,132,552	$93,419	$1,213,225,971
Gain/(Loss) from Operations	$52,499,208	$51,446,591	($46,710)	$51,399,881	$18,318,145	($93,419)	$18,224,726	$8,878,595	($93,419)	$8,785,176
Plus: Non-Operating Revenue	$56,285,568	$20,461,000		$20,461,000	$20,461,000		$20,461,000	$20,461,000		$20,461,000
Revenue Over/(Under) Expense	$108,784,776	$71,907,591	($46,710)	$71,860,881	$38,779,145	($93,419)	$38,685,726	$29,339,595	($93,419)	$29,246,176
FTEs	6,033	5872		5872	5872		5872	5,872		5872
	24,679	24,800		24,800	24,900		24,900	25,000		25,000

*Volume Statistics:
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.

EXHIBIT 12

12.C(ii). Please provide **three** years of projections of incremental revenue, expense and volume statistics **attributable to the proposal** in the following reporting format:

Type of Service Description **Cardiac stress tests with and without myocardial perfusion imaging**
Type of Unit Description: **SPECT/CT Nuclear Camera System**
# of Months in Operation 6

FY 2014 **FY Projected Incremental** Total Incremental Expenses: **$46,710**	(1)	(2) Rate	(3) Units	(4) Gross Revenue Col. 2 * Col. 3	(5) Allowances/ Deductions	(6) Charity Care	(7) Bad Debt	(8) Net Revenue Col.4 - Col.5 -Col.6 - Col.7	(9) Operating Expenses Col. 1 Total * Col. 4 / Col. 4 Total	(10) Gain/(Loss) from Operations Col. 8 - Col. 9
Total Facility by Payer Category:										
Medicare				$0				$0	$0	$0
Medicaid		$0		$0				$0	$0	$0
CHAMPUS/TriCare		$0		$0				$0	$0	$0
Total Governmental			0	$0	$0	$0	$0	$0	$0	$0
Commericial Insurers		$0		$0				$0	$0	$0
Uninsured		$0		$0				$0	$0	$0
Total NonGovernment		$0	0	$0	$0	$0	$0	$0	$0	$0
Total All Payers		$0	0	$0	$0	$0	$0	$0	$46,710	($46,710)

12.C(ii). Please provide **three** years of projections of incremental revenue, expense and volume statistics **attributable to the proposal** in the following reporting format:

Type of Service Description: **Cardiac stress tests with and without myocardial perfusion imaging**
Type of Unit Description: **SPECT/CT Nuclear Camera System**
# of Months in Operation: 12

FY 2015 FY Projected Incremental Total Incremental Expenses:	(1) **$93,419**	(2) Rate	(3) Units	(4) Gross Revenue Col. 2 * Col. 3	(5) Allowances/ Deductions	(6) Charity Care	(7) Bad Debt	(8) Net Revenue Col.4 - Col.5 -Col.6 - Col.7	(9) Operating Expenses Col. 1 Total * Col. 4 / Col. 4 Total	(10) Gain/(Loss) from Operations Col. 8 - Col. 9
Total Facility by Payer Category:										
Medicare				$0				$0	$0	$0
Medicaid		$0		$0				$0	$0	$0
CHAMPUS/TriCare		$0		$0				$0	$0	$0
Total Governmental			0	$0	$0	$0	$0	$0	$0	$0
Commericial Insurers		$0		$0				$0	$0	$0
Uninsured		$0		$0				$0	$0	$0
Total NonGovernment		$0	0	$0	$0	$0	$0	$0	$0	$0
Total All Payers		$0	0	$0	$0	$0	$0	$0	$93,419	($93,419)

12.C(ii). Please provide **three** years of projections of incremental revenue, expense and volume statistics **attributable to the proposal** in the following reporting format:

Type of Service Description	**Cardiac stress tests with and without myocardial perfusion imaging**									
Type of Unit Description:	**SPECT/CT Nuclear Camera System**									
# of Months in Operation	12									
FY 2016	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
FY Projected Incremental		Rate	Units	Gross	Allowances	Charity	Bad	Net	Operating	Gain/(Loss)
Total Incremental Expenses:	**$93,419**			Revenue	Deductions	Care	Debt	Revenue	Expenses	from Operations
				Col. 2 * Col. 3				Col.4 - Col.5 -Col.6 - Col.7	Col. 1 Total * Col. 4 / Col. 4 Total	Col. 8 - Col. 9
Total Facility by Payer Category:										
Medicare				$0				$0	$0	$0
Medicaid		$0		$0				$0	$0	$0
CHAMPUS/TriCare		$0		$0				$0	$0	$0
Total Governmental			0	$0	$0	$0	$0	$0	$0	$0
Commericial Insurers		$0		$0				$0	$0	$0
Uninsured		$0		$0				$0	$0	$0
Total NonGovernment		$0	0	$0	$0	$0	$0	$0	$0	$0
Total All Payers		$0	0	$0	$0	$0	$0	$0	$93,419	($93,419)

STATE OF CONNECTICUT

DEPARTMENT OF PUBLIC HEALTH

Office of Health Care Access

December 26, 2013

VIA FAX ONLY

Barbara A. Durdy
Director, Strategic Planning
Hartford Healthcare
181 Patricia Genova Drive
Newington, CT 06111

RE: Certificate of Need Application, Docket Number 13-31878-CON
Hartford Hospital
Acquisition of One SPECT-CT Scanner

Dear Ms. Durdy:

On December 5, 2013, the Office of Health Care Access ("OHCA") received your Certificate of Need ("CON") application filing on behalf of Hartford Hospital ("Applicant") proposing to acquire one Single Photon Emission Computed Tomography-Computed Tomography ("SPECT-CT") scanner, with a total associated cost of $850,000.

OHCA has reviewed the CON application and requests the following additional information pursuant to General Statutes §19a-639a(c).

1. Please revise and resubmit Financial Attachment 1 to include a following:
    a. Add a column with fiscal year 2013 actual results
    b. Please be sure to include any and all financial assumptions related to the Financial Attachment 1

In responding to the questions contained in this letter, please repeat each question before providing your response. Paginate and date your response, i.e., each page in its entirety. Information filed after the initial CON application submission (i.e. completeness response letter, prefile testimony, late file submissions and the like) must be numbered sequentially from the Applicant's document preceding it. Please begin your submission using Page 206 and reference "Docket Number: 13-31878-CON." Submit one (1) original and three (3) hard copies of your response. In addition, please submit a scanned copy of your response, in an Adobe format (.pdf) including all attachments on CD. If available, a copy of the response in MS Word should also be copied to the CD.

Pursuant to Section 19a-639a(c) of the Connecticut General Statutes, you must submit your response to this request for additional information not later than sixty days after the date that this request was transmitted. Therefore, please provide your written responses to OHCA no later than February 24, 2014, otherwise your application will be automatically considered withdrawn. If you have any questions concerning this letter, please feel free to contact me by email or at (860) 418-7007.

Sincerely,

A. Veyberman

Alla Veyberman
Health Care Analyst

****
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****

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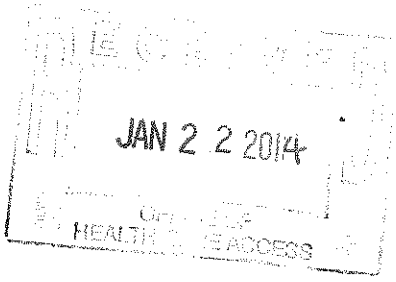
COUNSELORS AT LAW

Joan W. Feldman
Phone: 860-251-5104
Fax: 860-251-5211
Jfeldman@goodwin.com



January 21, 2014

Alla Veyberman
Health Care Analyst
Department of Public Health
Office of Health Care Access
410 Capital Avenue, MS#13 HCA
P.O. Box 340308
Hartford, Connecticut 06134-0308

Re: Certificate of Need Application: Docket Number 13-31878-CON
Hartford Hospital
Acquisition of SPECT/CT Scanner

Dear Ms. Veyberman:

On behalf of Hartford Hospital (the "Applicant"), enclosed please find the original and 3 hard copies of the Applicant's responses to your: (1) Certificate of Need Completeness Letter dated December 26, 2013; and (2) Supplemental Questions Email dated January 16, 2014. As requested, I have also included a CD with a scanned copy of the Applicant's entire response, and electronic versions of any Microsoft Word or Excel documents, as applicable.

Please do not hesitate to contact me at 860-251-5104 if you have any questions.

Sincerely,

Joan W. Feldman

Joan W. Feldman

Enclosures

000209 (1/21/2014)

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Responses to Certificate of Need Completeness Letter dated December 26, 2013

1. Please revise and resubmit Financial Attachment 1 to include the following:

   a. Add a column with fiscal year 2013 actual results

   Please see Exhibit 13 for revised Financial Attachment 1, which includes a column for Fiscal Year 2013 actual results.

   b. Please be sure to include any and all financial assumptions related to the Financial Attachment 1

   We have included any and all financial assumptions related to Financial Attachment 1 as noted below:

   - **Other than the change in depreciation expense due to the replacement of a fully depreciated unit there are no expected changes in revenues and expenses as a result of the acquisition of the replacement unit.**

   - **Depreciation of Fixed Assets to be acquired under this Certificate of Need has been calculated based on expected useful life of the assets as follows:**

	Capital Asset	Depreciable life	Annual Depreciation
Renovation/Construction Costs	**$364,500**	**15**	**$24,300**
Medical Equipment	**$481,500**	**7**	**$68,786**
Furniture	**$4,000**	**12**	**$333**
Totals	**$850,000**		**$93,419**

Responses to Certificate of Need Supplemental Questions of the Completeness Letter dated January 16, 2014

1. Please address the following regarding the hospital's Medicaid population:

   a. Provide evidence as to how the hospital has demonstrated that this proposal will improve the quality, accessibility and cost effectiveness of health care delivery in the region, including but not limited to:

      i. provision of any change in the access to services for Medicaid recipients and indigent persons, and

      There will be no change in access for the patient population served by this proposal, in particular Medicaid patients, except that they will be better served with new and more technologically advanced equipment. The Hospital's payer mix will not change as a result of this proposal and it is inevitable that Medicaid patients will benefit equally as a result of this proposal.

      ii. the impact on the cost effectiveness of providing access to services provided under the Medicaid program.

      As previously mentioned, the Siemens Symbia T SPECT/CT camera is a replacement for a SPECT camera at the end of its useful life which will be removed when the new camera is installed, thus avoiding duplication of equipment. The new SPECT/CT camera will perform the same diagnostic study (myocardial perfusion imaging) as the old SPECT camera it is replacing only with more advanced technology, thereby avoiding duplication of services while providing higher quality more reliable imaging.

2. Provide the hospital'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.

   Hartford Hospital has always served and will continue to serve all patients regardless of ability to pay or type of health insurance. As previously stated, the Hospital's payer mix will go unchanged as a result of this proposal and this proposal is not in any way focused on limiting access to Medicaid or indigent patients.

3. If the Hospital has failed to provide or reduced access to services for Medicaid recipients or indigents persons, demonstrate how the Hospital has done this due to good cause or demonstrate that it was not solely on the basis of differences in reimbursement rates between Medicaid and other health care payers.

   Not applicable.

Exhibit 13

12. C (i). Please provide one year of actual results and three years of projections of **Total Facility** revenue, expense and volume statistics without, incremental to and with the CON proposal in the following reporting format:

Total Facility: Description	FY 2012 Actual Results	FY 2013 Actual Results	FY 14 Projected W/out CON	FY 14 Projected Incremental	FY 14 Projected With CON	FY 15 Projected W/out CON	FY 15 Projected Incremental	FY 15 Projected With CON	FY 2016 Projected W/out CON	FY 16 Projected Incremental	FY 16 Projected With CON
NET PATIENT REVENUE											
Non-Government	$421,071,330	$439,164,968	$504,994,994		$504,994,994	$521,407,331		$521,407,331	$540,125,854		$540,125,854
Medicare	$381,926,070	$376,476,032	$375,474,280		$375,474,280	$387,677,194		$387,677,194	$401,594,805		$401,594,805
Medicaid and Other Medical Assistanc	$114,354,648	$99,237,056	$111,971,347		$111,971,347	$115,610,416		$115,610,416	$119,760,830		$119,760,830
Other Government	$9,281,003	$6,374,332	$6,084,024		$6,084,024	$6,281,755		$6,281,755	$6,507,270		$6,507,270
Total Net Patient Patient Revenue	$926,633,051	$921,252,388	$998,524,645	$0	$998,524,645	$1,030,976,696	$0	$1,030,976,696	$1,067,988,759	$0	$1,067,988,759
Other Operating Revenue	$172,515,114	$163,350,558	$145,740,012		$145,740,012	$148,727,682		$148,727,682	$154,022,388		$154,022,388
Revenue from Operations	$1,099,148,165	$1,084,602,946	$1,144,264,657	$0	$1,144,264,657	$1,179,704,378	$0	$1,179,704,378	$1,222,011,147	$0	$1,222,011,147
OPERATING EXPENSES											
Salaries and Fringe Benefits	$604,512,881	$633,026,330	$606,232,019		$606,232,019	$637,877,330		$637,877,330	$667,857,565		$667,857,565
Professional / Contracted Services	$44,286,457	$49,630,461	$51,423,026		$51,423,026	$53,994,177		$53,994,177	$56,693,886		$56,693,886
Supplies and Drugs	$133,308,976	$166,401,219	$153,687,097		$153,687,097	$164,445,194		$164,445,194	$175,956,357		$175,956,357
Bad Debts	$22,645,968	$17,467,613	$22,740,654		$22,740,654	$23,479,725		$23,479,725	$24,322,647		$24,322,647
Other Operating Expense	$173,935,441	$133,659,193	$189,269,610		$189,269,610	$193,055,002		$193,055,002	$196,916,102		$196,916,102
Subtotal	$978,689,723	$1,000,184,816	$1,023,352,406	$0	$1,023,352,406	$1,072,851,429	$0	$1,072,851,429	$1,121,746,558	$0	$1,121,746,558
Depreciation/Amortization	$46,274,726	$48,796,972	$45,855,088	$46,710	$45,901,798	$64,731,581	$93,419	$64,825,000	$66,756,581	$93,419	$66,850,000
Interest Expense	$4,517,043	$5,704,487	$5,649,775		$5,649,775	$5,483,210		$5,483,210	$5,943,000		$5,943,000
Lease Expense	$17,167,465	$34,920,187	$17,960,797		$17,960,797	$18,320,013		$18,320,013	$18,686,413		$18,686,413
Total Operating Expense	$1,046,648,957	$1,089,606,462	$1,092,818,066	$46,710	$1,092,864,776	$1,161,386,233	$93,419	$1,161,479,652	$1,213,132,552	$93,419	$1,213,225,971
Gain/(Loss) from Operations	$52,499,208	($5,003,516)	$51,446,591	($46,710)	$51,399,881	$18,318,145	($93,419)	$18,224,726	$8,878,595	($93,419)	$8,785,176
Plus: Non-Operating Revenue	$56,285,568	$42,330,877	$20,461,000		$20,461,000	$20,461,000		$20,461,000	$20,461,000		$20,461,000
Revenue Over/(Under) Expense	$108,784,776	$37,327,361	$71,907,591	($46,710)	$71,860,881	$38,779,145	($93,419)	$38,685,726	$29,339,595	($93,419)	$29,246,176
FTEs	6,033	6,125	5,872		5872	5872		5872	5,872		5872

25,000

*Volume Statistics:
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.

Assumptions:
1. Replacement equipment- volumes based on historical utilization