SPECT Imaging

Single-Photon Emission Computed Tomography

FIU | Biomedical Engineering
Florida International University

Group 4

- Christopher Emerson
- Caterina Pette
- Douglas Wright

FIU | Biomedical Engineering
Florida International University

Contents

Advantages

- Provides Physiological Information though Functional Imaging
  - Metabolic Activity
  - Blood Flow
- Intrinsic Lesion Localization though Radiopharmaceutical Use
  - Radio-labeled ligans migrate to specific imaging site
- 3-D Imaging
- Hybrid Imaging Systems provide Increased Spatial Resolution
  - SPECT/CT

http://xa.yimg.com/kq/groups/15914941/74581872/name/EJNMMI-SPECT%25EF%2580%25A2CT-Review.pdf,
"Advantages and disadvantages of PET and SPECT in a busy clinical practice" Timothy M. Bateman, MD

Disadvantages

- Gamma Emissions Harmful due to Ionization Potential
- Non-Hybrid Devices have Poor Spatial Resolution
  - Tissue boundaries are ill-determined
- Long Scan Time
  - Upwards of 30-40 minutes
  - Inconveniences certain patient populations
- Use of Possible Allergens
  - Radiopharmaceuticals could induce allergic reactions
- Intrinsic Reliance on Radiopharmaceuticals
  - Severe supply shortages can halt imaging

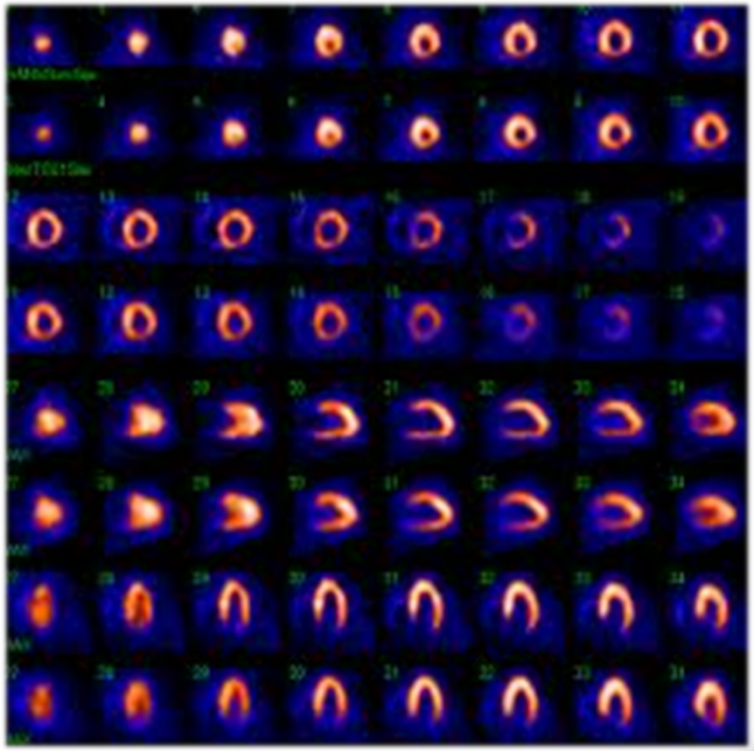
http://www.massgeneral.org/imaging/services/procedure.aspx?id=2255
http://blue.regence.com/trgmedpol/radiology/rad44.html

Medical Applications

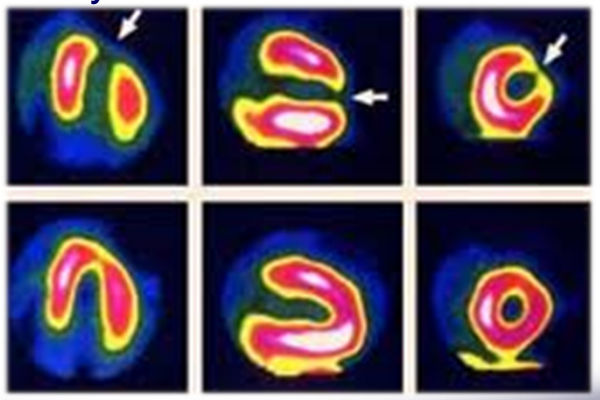
- Myocardial Perfusion Imaging
- Brain Perfusion
- Thyroid Function
- Renal Function
- Bone Imaging
- Myocardial Perfusion Imaging

Myocardial Perfusion Imaging

- Assessment of hemodynamic consequences of Coronary Artery Disease
- Allows for risk stratification and pre-surgical guidance
- Determines ischemic myocardial tissue though rest and stress cardiac studies



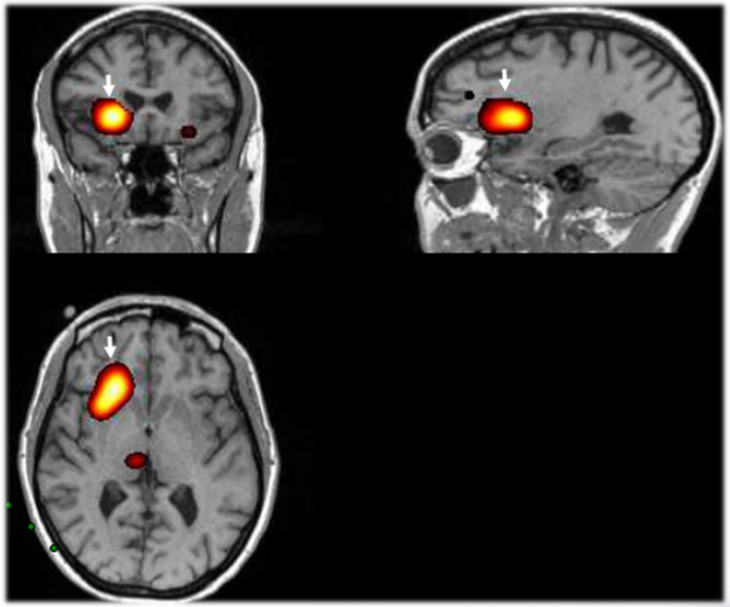
Myocardial Perfusion Scan



http://eradiology.bidmc.harvard.edu/LearningLab/cardio/Furie.pdf

Brain Perfusion

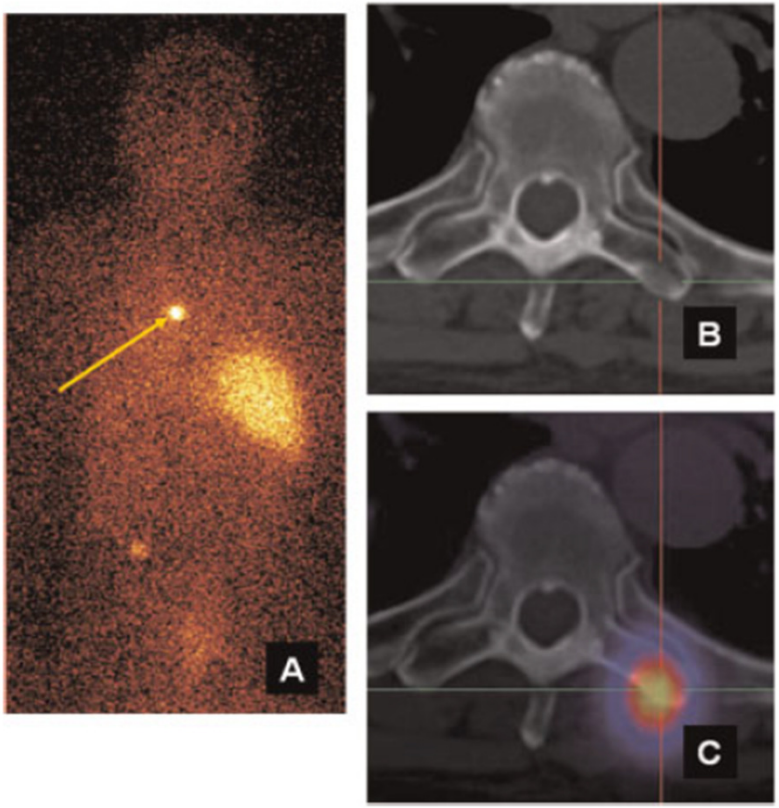
- Pre-surgical localization of epileptic seizure origin
- Technetium-99m labeled ECD or HMPAO injected at time of seizure
  - Localize to region of increased blood flow
- Images during and after seizure are compared to identify seizure origin



http://my.clevelandclinic.org/Documents/Epilepsy_Center/PET%20and%20SPECT%20-%20Wu.pdf

Thyroid Function

- Thyroid tumor causes increased metabolic activity
- Localization achieved through the use of Iodine-123 and Iodine-131
  - Iodine-123: Routine testing for hyperthyroidism and nodules
  - Iodine-131: Whole-body imaging for detection of metastasis
- SPECT-CT shows metastasis is localized in tip of transverse process of the sixth thoracic vertebra

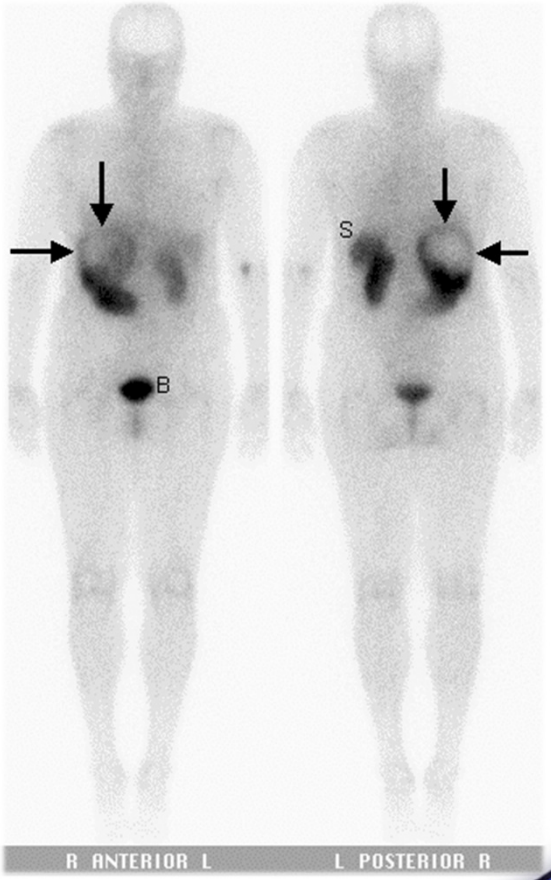


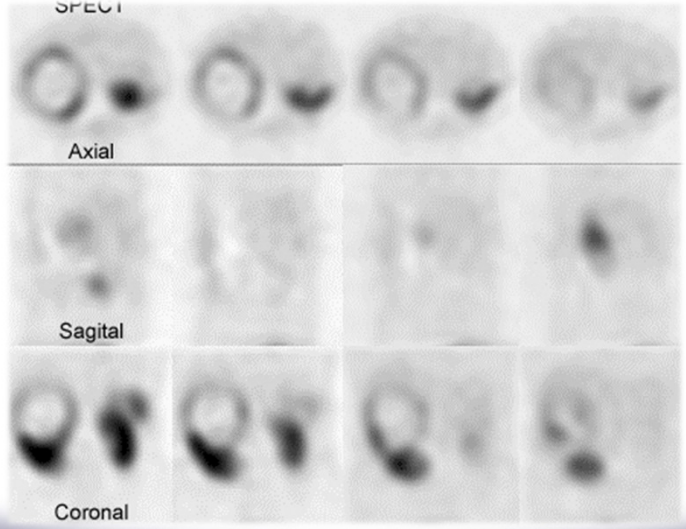
A. Whole-body SPECT
B. Diagnostic CT
C. Fusion Image

http://www.ncbi.nlm.nih.gov/pubmed/1418597

Renal Function

- Renal lesions can result in elevated levels of norepinehprine, epinephrine, dopamine, cathecholamines, and VMA
- Localization achieved through the use of Indium-111 Pentetreotide
- SPECT scans revealed large right suprarenal lesion

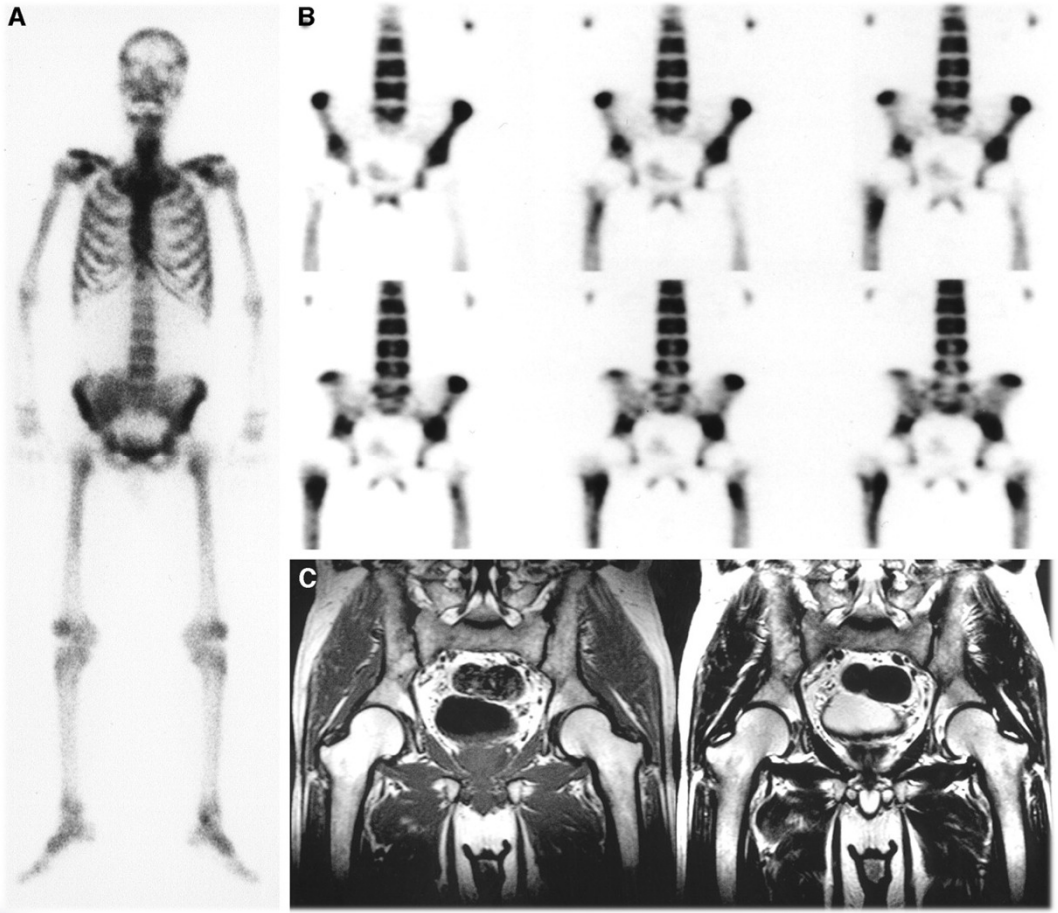




http://www.med.harvard.edu/JPNM/TF00_01/Sept19/WriteUp.html

Bone Imaging

- Early Detection of Osteonecrosis of the Femoral Head



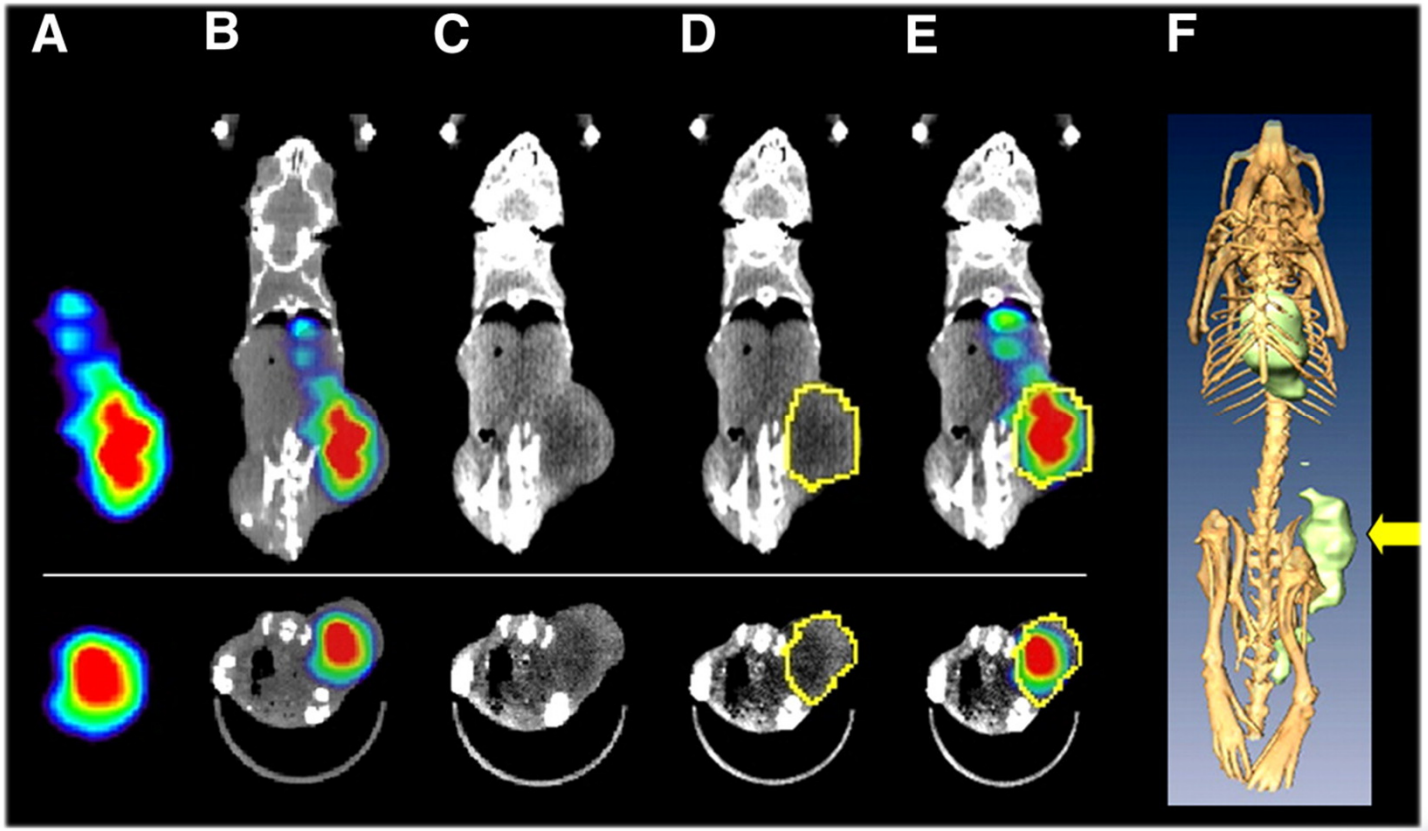
A. Whole-body scintigraphy
B. Bone SPECT
C. MRI Scan

- A & B show “cold” areas in both femoral heads while C shows normal findings

http://jnm.snmjournals.org/content/43/8/1006/F1.expansion.html

Small Animal SPECT & SPECT/CT Imaging

- Used to determine drug efficacy in pre-clinical trials



http://jnm.snmjournals.org/content/49/10/1651/F5.expansion.html

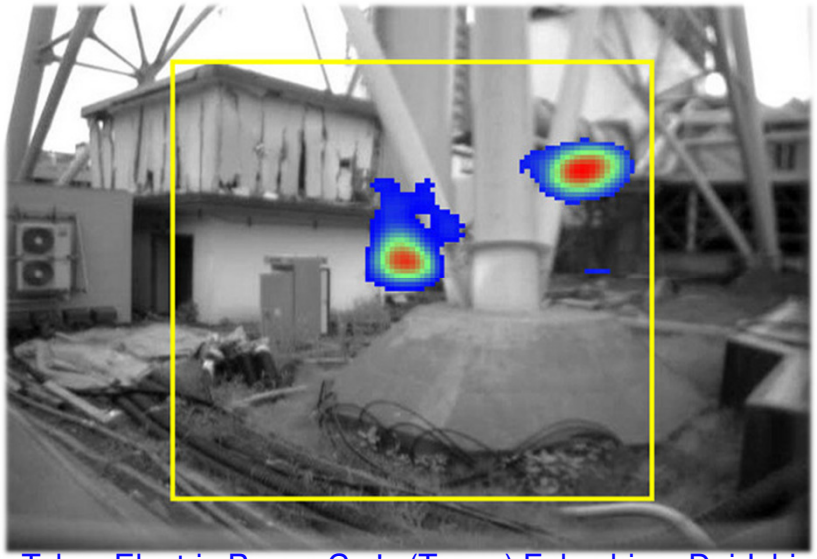
Non-Medical Applications

- Detection of nuclear waste
  - Gamma cameras used to study the environmental behavior of nuclear waste
  - Helps scientists monitor and control the spread of radioactivity
  - Fe(III)-reducing bacteria immobilizes technetium in sediment

http://www.bloomberg.com/news/2011-08-02/tepco-reports-second-deadly-radiation-reading-at-fukushima-plant.html

Non-Medical Applications (cont.)

- Detection of nuclear emission
  - Fukushima Nuclear Power Plant
  - Gamma cameras can be used to image radiation readings of wrecked nuclear power plant
  - A photograph shows a gamma camera image of an area around the main exhaust of Tokyo's nuclear power plant detecting 5 Svt/hr.



Tokyo Electric Power Co.'s (Tepco) Fukushima Dai-Ichi nuclear power station in Fukushima, Japan, on Monday, Aug. 1, 2011.

Soil Sampling

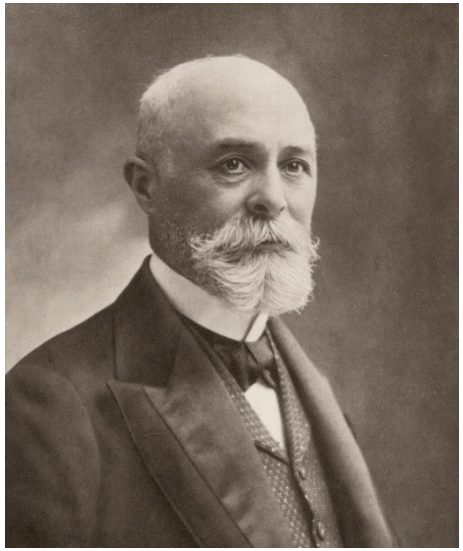
http://www.bloomberg.com/news/2011-08-02/tepco-reports-second-deadly-radiation-reading-at-fukushima-plant.html

History

- < 1950s
- 1950s – 1960s
- 1960s – 1970s
- > 1970s
- Why the Delay?

< 1950s

- 1896 – Antoine-Henri Becquerel discovers Radioactivity
  - Discovered that radiation from Uranium did not need any excitation from an external energy source to emit radiation.
- 1934 – Frederic and Irene Joliot-Curie produce first artificial radionuclide
  - Positron-emitting radionuclide of phosphorous



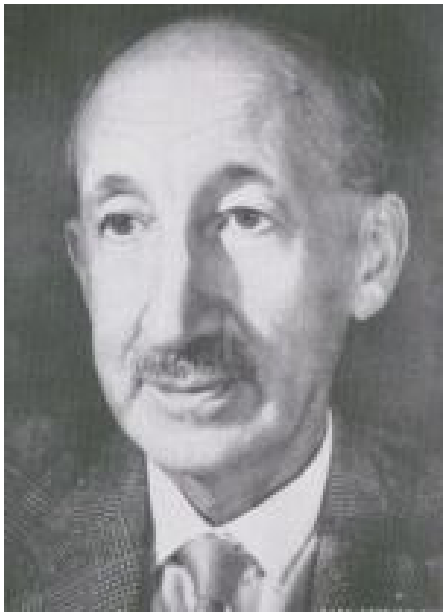
Antoine-Henri Becquerel

Irene Curie and Frederic Joliot

http://www.rtstudents.com/radiology/history-of-radiology.htm
http://www.brainmattersinc.com/forphysicians/historyofspect.html

< 1950s

- 1943 – Gyorgy Hevesy develops radioactive tracers
  - Used to study the metabolic processes in plants and animals
- 1946 – Oak Ridge National Laboratory began production of radionuclides for medical use



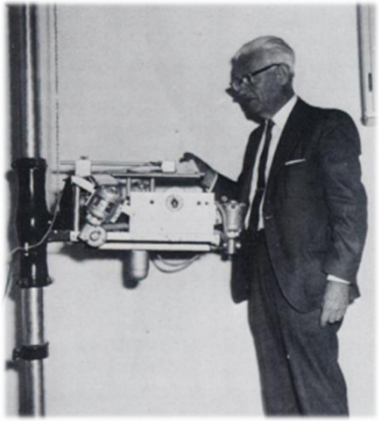
Gyorgy Hevesy

Oak Ridge National Laboratory

http://www.rtstudents.com/radiology/history-of-radiology.htm
http://www.brainmattersinc.com/forphysicians/historyofspect.html

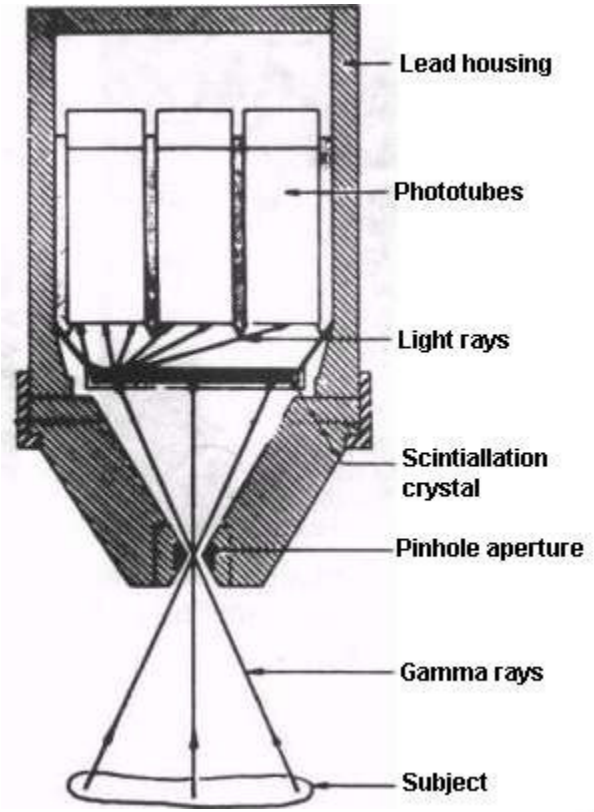
1950s – 1960s

- 1950 – Benedict Cassen assembled the first automated scanning system
  - Motor-driven scintillation detector coupled to a printer
- 1957 – Hal Oscar Anger develops Anger Camera
  - Sodium-Iodine scintillation crystal
  - Vacuum tube photomultipliers



Benedict Cassen

Hal Oscar Anger



http://jnm.snmjournals.org/content/12/8/573.full.pdf
http://www.ncbi.nlm.nih.gov/pubmed/11155815

1960s – 1970s

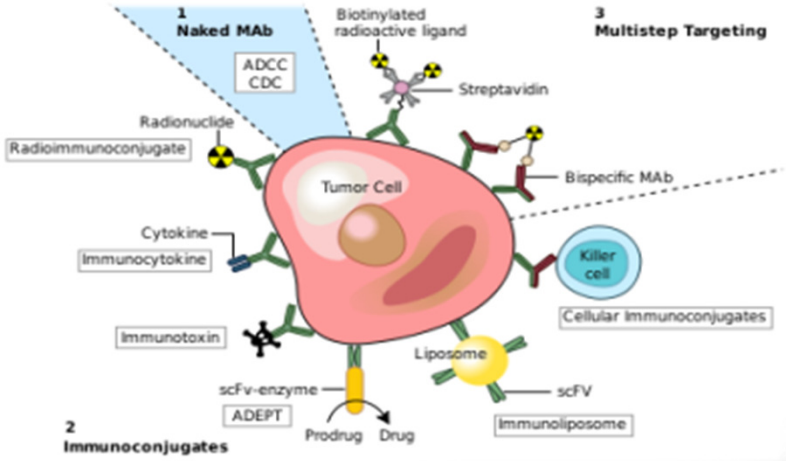
- Development of generator system to produce Technetium-99m
  - Most utilized element in Nuclear Medicine
  - Employed in a wide variety of Nuclear Medicine studies
- Late 1963 – David E. Kuhl and Roy Q. Edwards introduce emission and transmission tomography
  - Later developed into Single Photon Emission Computed Tomography (SPECT)
  - Used 32 photon detectors
  - Images were frequently distorted and not of diagnostic quality

David Edmund Kuhl

http://www.uclimaging.be/ecampus/etu_med/option_2011/opt_2011_3120_mn.pdf
http://www.news-medical.net/health/History-of-Nuclear-Medicine.aspx

> 1970s

- Late 1970s – Most organs of the body could be visualized with nuclear medicine procedures
  - Liver, spleen, brain tumor localization, and gastrointestinal tract
- 1980s – Radiopharmaceuticals were designed for diagnosing heart disease and cancer
- 1980s – Development of Monoclonal Antibodies
  - Act as cell-specific ligans that, when tagged with a radioisotope, localize to a specific region of the body
  - Can detect cancerous cells before anatomical changes occur



http://interactive.snm.org/index.cfm?PageID=1107
http://www.news-medical.net/health/History-of-Nuclear-Medicine.aspx

EXAMPLE RADIONUCLIDES

Isotope	Half-life	Typical radiation	Typical target organs
Phosphorus 32	14.3 days	Beta (1.71 MeV)	Liver
Chromium 51	27.8 days	Gamma (320 KeV)	Red blood cells, urinary
Barium 131	11.6 days	Gamma (54 - 1000 KeV)	Intestinal
Iodine 131	8.1 days	Gamma (80 - 723 KeV)	Thyroid; blood
Technetium 99m	6.0 hr	Gamma (142.7 KeV)	Brain
Xenon 127	36.4 days	Gamma (57 - 375 KeV)	Lung

Why the Delay?

- The development of SPECT was slow due to a number of factors:
  - Image analysis algorithms were not advanced enough
  - Limited number of radionuclides available as tracers
  - Device size limited SPECT use outside of hospitals
  - Physicians were inexperienced reading SPECT images
- Better late than never!
  - Advances in mathematics, innovations in radionuclide and ligand development, and the advent of multi-modality imaging systems laid the foundation for modern SPECT and SPECT/CT devices

http://www.imagingeconomics.com/issues/articles/MI_2004-06_02.asp

Modern Systems

- Leading Device Manufacturers
- Brivo NM 615
- Discovery NM 630
- Discovery NM/CT 670
- Ventri
- Discovery NM 750b

Leading Device Manufacturers

- GE Healthcare

- Siemens Healthcare

SIEMENS
medical

- Philips Healthcare

PHILIPS
sense and simplicity

- Toshiba Medical Systems

TOSHIBA
Leading Innovation

Brivo NM 615

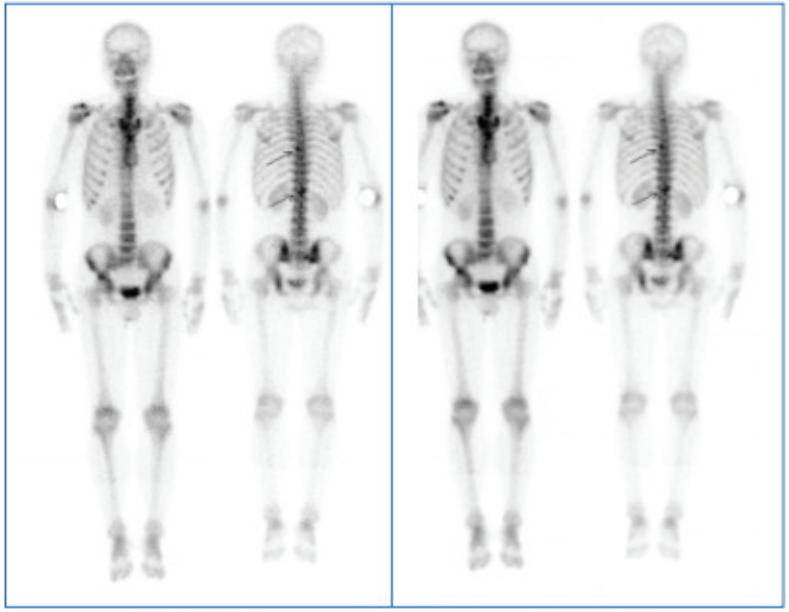
- Single-Headed System
- Thin, Pivoting Gantry
  - 5.12 m x 3.74 m x 2.30 m
  - 500 lb Patient Limit
    - Increases patient population
  - Upright, chair, or stretcher imaging
    - Increases patient comfort
- Elite NXT Detectors
  - Exceptionally High Count Rate
    - 460k counts-per-second
  - SPECT-Optimized Collimators
  - Dose management
    - Reduce time or dose by 50%
- Acquisition time rivals dual-headed systems
- Auto-Body Contouring
  - Infra-red detectors minimize the distance between the patient and the detectors
- Xeleris 3 Workstation

FIU | Biomedical Engineering
Florida International University

http://www3.gehealthcare.com/en/Products/Categories/Nuclear_Medicine/General_Purpose_Cameras/Brivo_NM615
http://www.gehealthcare.com/euru/clinical-education/images/december_newsletter/xeleris_3_460x260.jpg

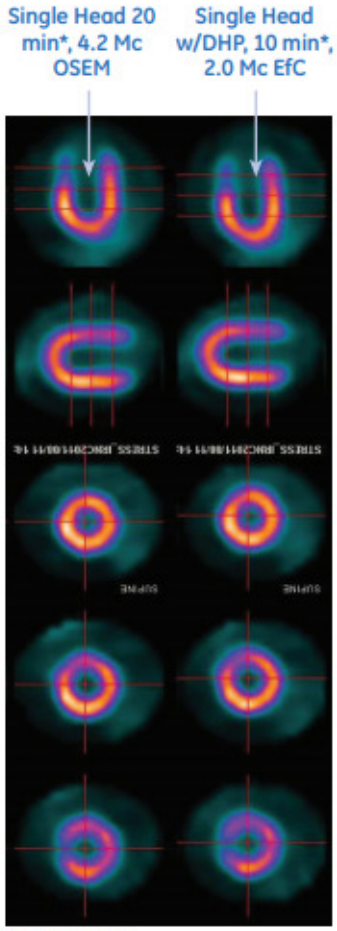
Brivo NM 615

Dual Head Performance Package (DHP)
enables you to cut acquisition time to rival a dual-head system in many common procedures



Single Head
30 min*, Ant then Post
Standard

Single Head
15 min*, Ant then Post
With DHP



*Net scan time

FIU | Biomedical Engineering
Florida International University

http://www3.gehealthcare.com/~/media/Downloads/Product/Product-Categories/Nuclear-Medicine/General-Purpose-Scanners/Brivo-NM615/GEHealthcare-Brochure_Brivo-NM-615.pdf?Parent={83A02FFC-6F7B-48B3-AB0F-AC550678E0B0}

Discovery NM 630

- Upgrade from Brivo NM 615
- Dual-Headed System
  - Cut imaging time or dose in half, again.
  - 180° or 90° Orientations

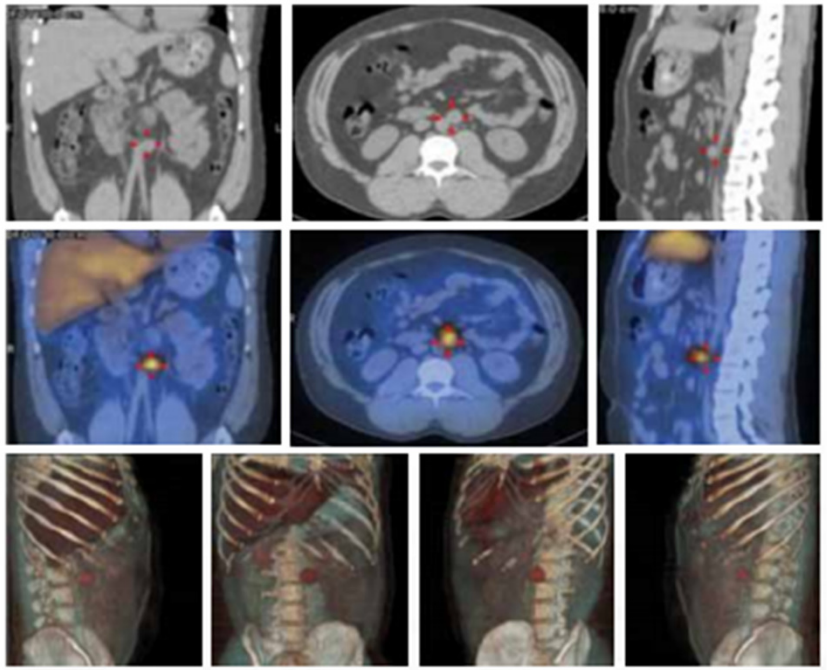
http://www3.gehealthcare.com/en/Products/Categories/Nuclear_Medicine/General_Purpose_Cameras/Discovery_NM_630

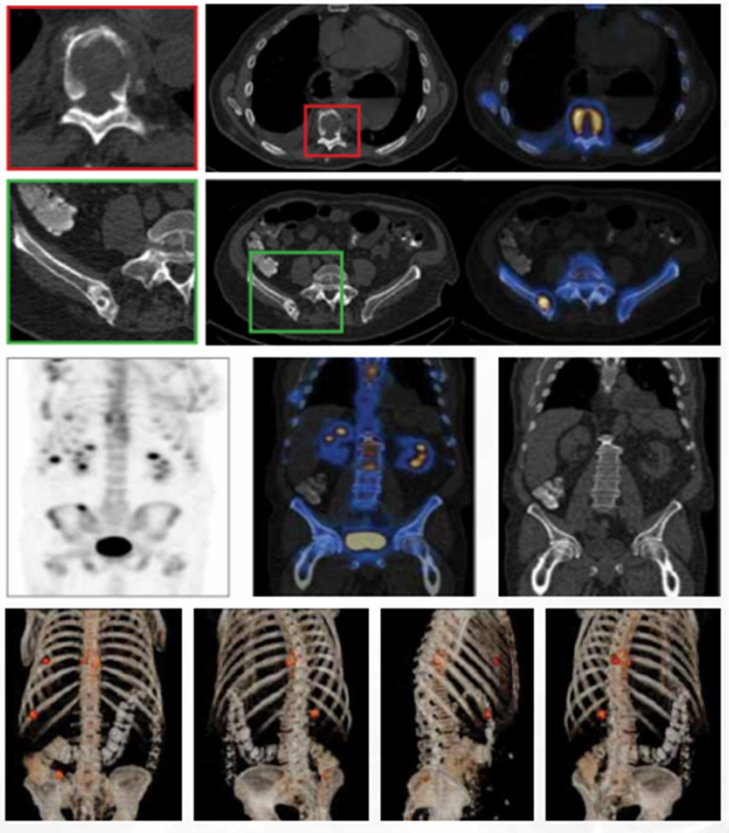
Discovery NM/CT 670

- Upgrade from Discovery NM 630
- IQ Enhance
  - Faster pitch helical scanning
  - Coverage equivalent to 50 slice CT scans with same imaging speed
  - 16-minute bone protocol
- BrightSpeed Elite CT Technology
  - Lower dose but maintained quality

http://www3.gehealthcare.com/en/Products/Categories/Nuclear_Medicine/SPECT-CT_Cameras/Discovery_NM-CT_670

Discovery NM/CT 670





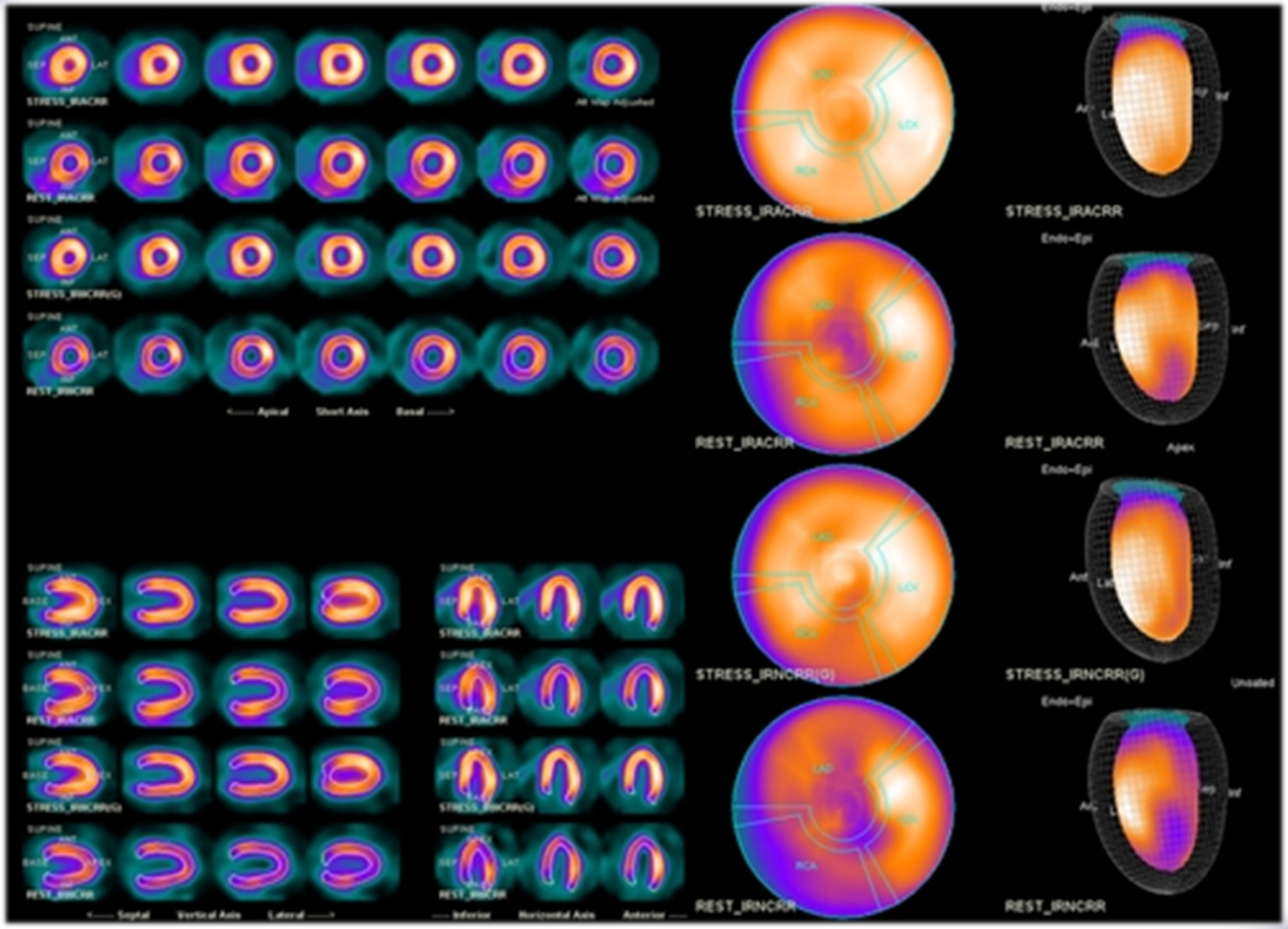
http://www3.gehealthcare.com/~/media/Downloads/Product/Product-Categories/Nuclear-Medicine/SPECT-CT%20Scanners/GEHC-Brochure_%20Discovery_NM-CT-670.pdf?Parent={B5FEFEC2-711D-444A-AB1E-87EA682FB27C}

Ventri

- Originally Designed for Cardiac Imaging
  - Restricted Imaging Range
- Now offers Neurological Imaging
- Smaller Office Footprint
- Less expensive
- Similar Technology as Larger Devices

http://www3.gehealthcare.com/en/Products/Categories/Nuclear_Medicine/Cardiac_Cameras/Ventri

Ventri

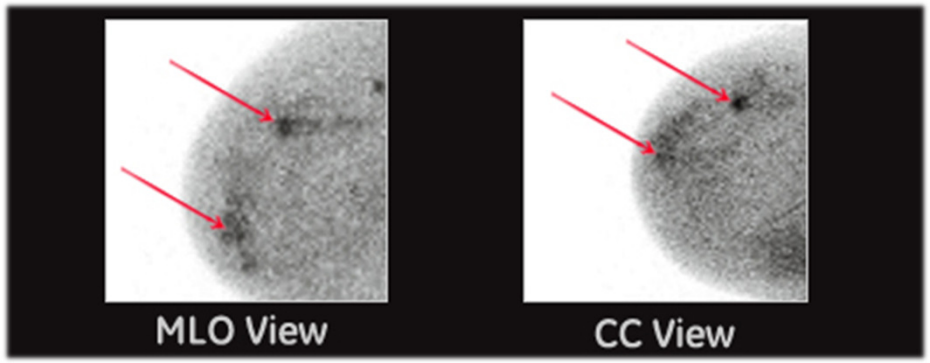


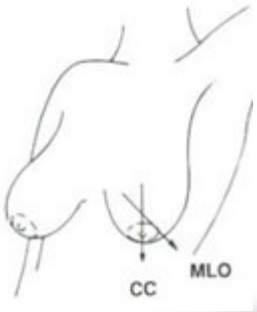
FIU | Biomedical Engineering
Florida International University

http://www3.gehealthcare.com/en/Products/Categories/Nuclear_Medicine/Xeleris_3/Evolution_for_Cardiac

Discovery NM 750b

- Dedicated Breast Imaging
- Solid-state Cadmium Zinc Telluride Detectors
  - 3 times the imaging sensitivity of conventional NaI gamma cameras
- Degradation-free Uniformity across entire Field-of-View
- Overcomes Breast Density challenges
- Single or Dual-Head Configuration



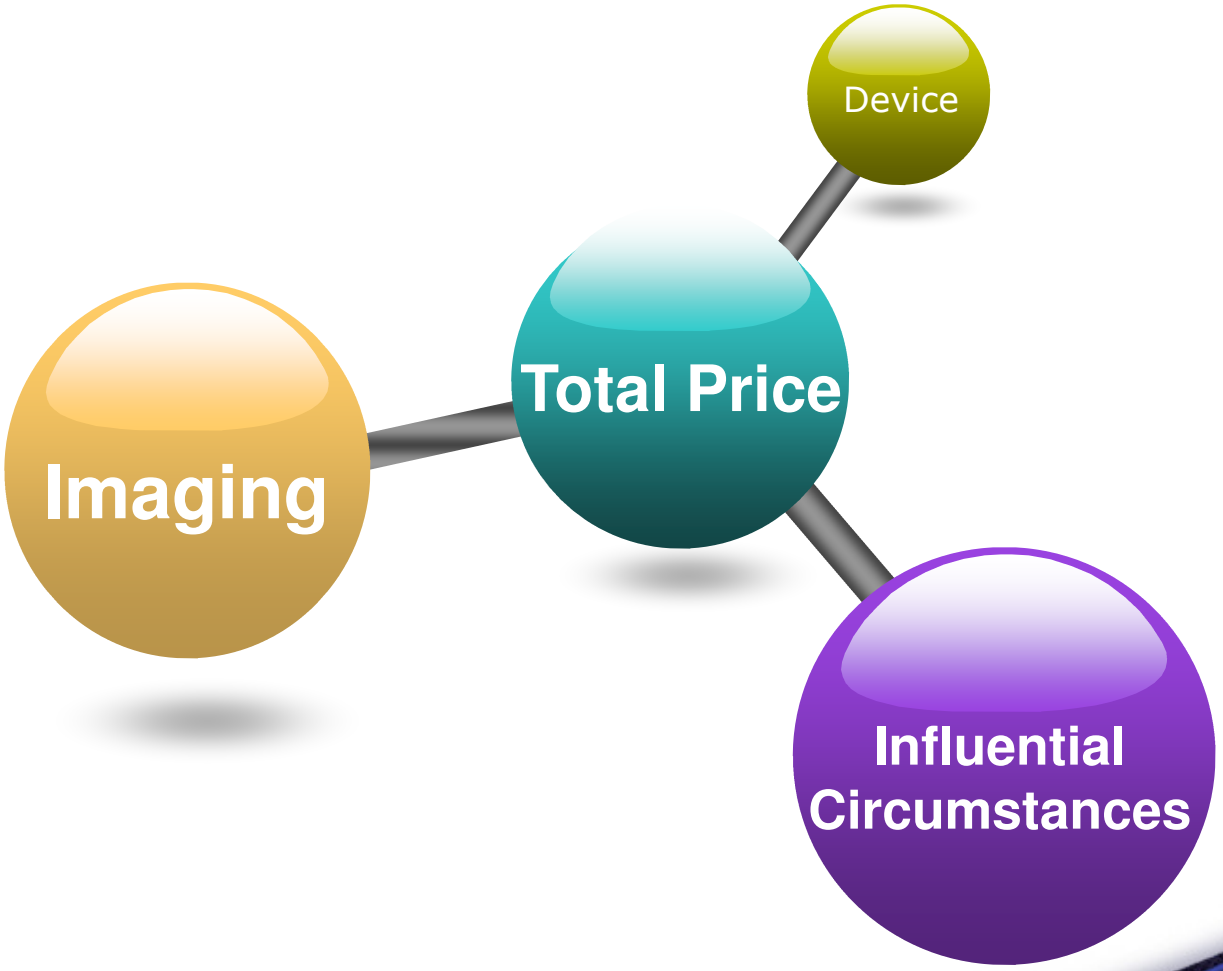


- MLO = Mediolateral Oblique View
- CC = Cranio – Caudal View

FIU | Biomedical Engineering
Florida International University

http://www3.gehealthcare.com/en/Products/Categories/Nuclear_Medicine/Discovery_NM-CT_750b

Pricing



Imaging

- Base Imaging Cost
- Radiopharmaceuticals Used
- Interpretation by Radiologist

Organ	Price
Bone Imaging	Scan: $585.20 Radiopharmaceutical: $62.35
Liver / Spleen Imaging	Scan: $993.30 Radiopharmaceutical: $77.90
Brain Imaging	Scan: $809.75
Renal Imaging	Scan: $996.08
Joint Imaging	Scan: $1016.00
Myocardial Perfusion Imaging	Scan: $2902.00

http://outofpocket.com/OOP/Default.aspx?q=SPECT&cx=015166729515697606531%3a3sy7u0rpz2o&cof=FORID%3a9

Device

- Device Cost
  - Multi-Headed, New : $400,000
  - Multi-Headed, Refurbished: $100,000
- Utility Costs
  - Powering the Device and Control Station
  - Powering the Electronics in the Imaging Suite
- Wages of Employees
  - Radiology Technicians
  - Maintenance Personnel
  - Sanitation Personnel
- Hardware Updates
- Software Updates

http://www.ibh.com/SPECT-ComplexCases.pdf

Influential Circumstances

- Age of Imaging System
  - Recently Purchased
    - Hospital may charge more till it breaks even
  - Post Breaking-Even
    - Hospital may charge less since device has "paid-for-itself"
- Neighboring Hospital Competition
  - Rich Competition
    - May charge less to attract more customers
  - Poor Competition
    - May charge more to capitalize on pseudo-monopoly
- Pending Lawsuits

"One minute she was eyeing her hospital bill, and the next minute..."

U.S. SPECT Statistics

- Imaging Locations and Frequency
- Installed Devices and Patient Waiting Times
- Projected Purchases

Imaging Locations and Frequency

- ~ 17 million Nuclear Medicine procedures performed at 7,230 different sites in 2010
  - Procedure frequency decreased by 0.5% each year from 2007 to 2010
  - 87% of procedures conducted in nonhospital locations are cardiovascular studies
  - 47% of procedures conducted in hospital locations are cardiovascular studies
    - More likely to be conducting other procedures including bone scans, liver, renal, respiratory, infection/abscess, and tumor localization studies.
- 1/3 of Nuclear Imaging sites are physician office locations
  - Includes cardiology offices, multispecialty clinics, and imaging centers
- ~ 25% of imaging sites provide neurology applications
  - Projected to grow to 1/3 of sites by 2013
    - Driven by development of radiopharmaceuticals to address Parkinson's disease

http://184.107.144.35/pressreleases/imv-nuclear-medicine-report-shows-nuclear-medicine-procedure-volume-flat-from-2007-to-2010.html
http://www.auntminnie.com/index.aspx?sec=vdp&sub=def&pag=dis&itemId=96830

Installed Devices and Patient Waiting Times

- Dual-head SPECT installations comprise 64% of the gamma camera installed base
  - Down from 70% in 2008
- SPECT/CT camera installed base increased from 2% of the installed base in 2008 to 9% in 2011
- 69% of the SPECT/CT and SPECT camera installed base are considered to be general purpose
- 31% are dedicated cardiac cameras
- Patient waiting times for nuclear imaging procedures have decreased
  - Waiting times of 1+ days for scheduled outpatient procedures decreased from 77% of the sites in 2003 to 43% of the sites in 2011

http://184.107.144.35/pressreleases/imv-nuclear-medicine-report-shows-nuclear-medicine-procedure-volume-flat-from-2007-to-2010.html
http://www.auntminnie.com/index.aspx?sec=vdp&sub=def&pag=dis&itemId=96830

Projected Purchases

- Estimated replacement time of 12.8 years for a typical gamma camera
  - 85% of purchases are replacements
- 1 in 6 planned camera purchases through 2013 will be from physician offices
  - ~ 50% are Dual-head SPECT cameras
  - 33.33% are SPECT/CT systems
    - Gaining momentum

http://184.107.144.35/pressreleases/imv-nuclear-medicine-report-shows-nuclear-medicine-procedure-volume-flat-from-2007-to-2010.html
http://www.auntminnie.com/index.aspx?sec=vdp&sub=def&pag=dis&itemId=96830


Thank You !
FIU
Biomedical Engineering
Florida International University