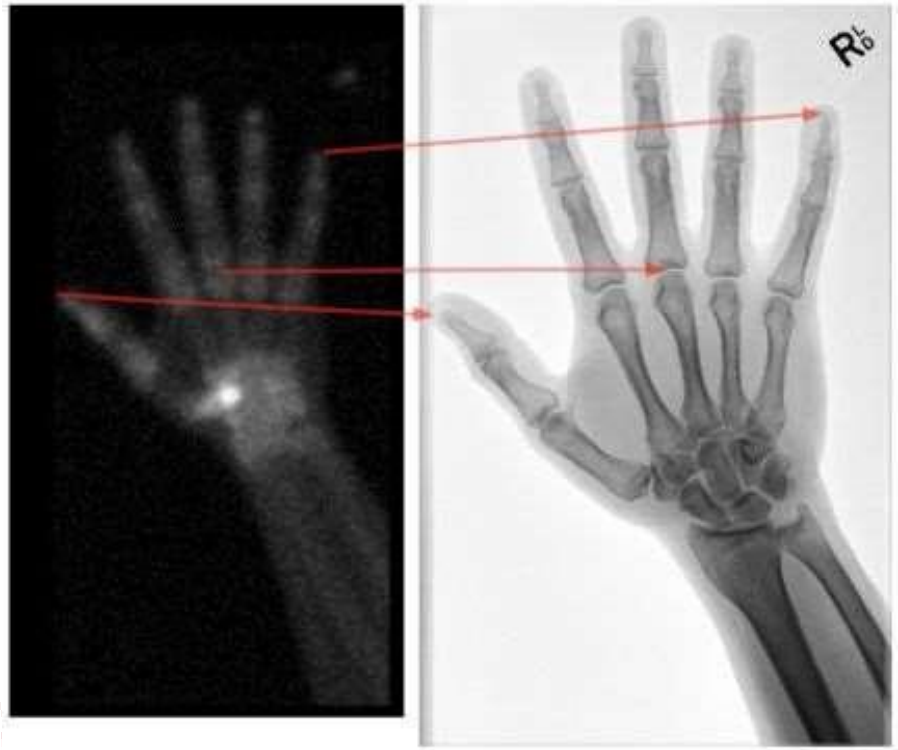
Overview of Nuclear Medicine, PET and SPECT/CT Imaging

MRT Program

Nuclear Medicine vs. Radiography



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Hybrid Imaging





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Nuclear Medicine

Modalities are used in conjunction with one another to provide the patient with the most appropriate diagnosis and treatment options.

This modality evaluates how organs are functioning to help detect pathology.

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-

Radiopharmaceuticals

A major part of nuclear medicine is the preparation and administration of radiopharmaceuticals.

Preparation is done in the radiopharmacy.

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-

A Day in the Life of an NMT

- A nuclear medicine technologist will begin the day in the radiopharmacy where radioactive drugs called radiopharmaceuticals are prepared.



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What are Radiopharmaceuticals?

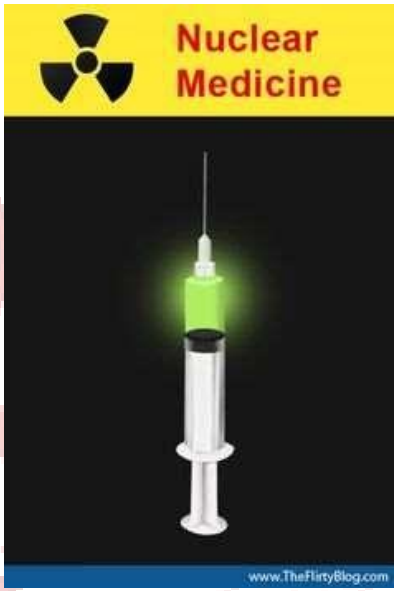
They are made up of two parts:

The drug portion (goes to the source)



Source: Colourbox.com, Rob Byron, Image 6310158

Radioactive isotope (so we can see it)



Source: https://s-media-cache-ak0.pinimg.com/236x/c7/fb/fd/c7fbfd58efbb771bf10195592 2619e27.jpg

A Day in the Life of an NMT (cont'd)
Generating a Radiopharmaceutical

- Nuclear medicine generators are much smaller than the generators we are used to using for our modality.



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- Before radiopharmaceuticals can be administered to a patient, stringent quality control procedures must be performed by technologists.



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A Day in the Life of an NMT (cont'd)

Most often, the technologist injects the radioactive tracer into a vein in the arm. There is no pain or side effects associated with most of these drugs.

Radiopharmaceuticals can also be administered orally or inhaled (depending on the study).

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Radiopharmaceuticals

- Each one is designed to accumulate in a specific organ system depending on what type of exam is being performed





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Most common nuclide used is technetium 99-m (Tc-99m).

Within 24 hours the radiopharmaceutical can be completely voided.

Danger of exposing others is negligible.

What kind of Radiopharmaceutical is used?

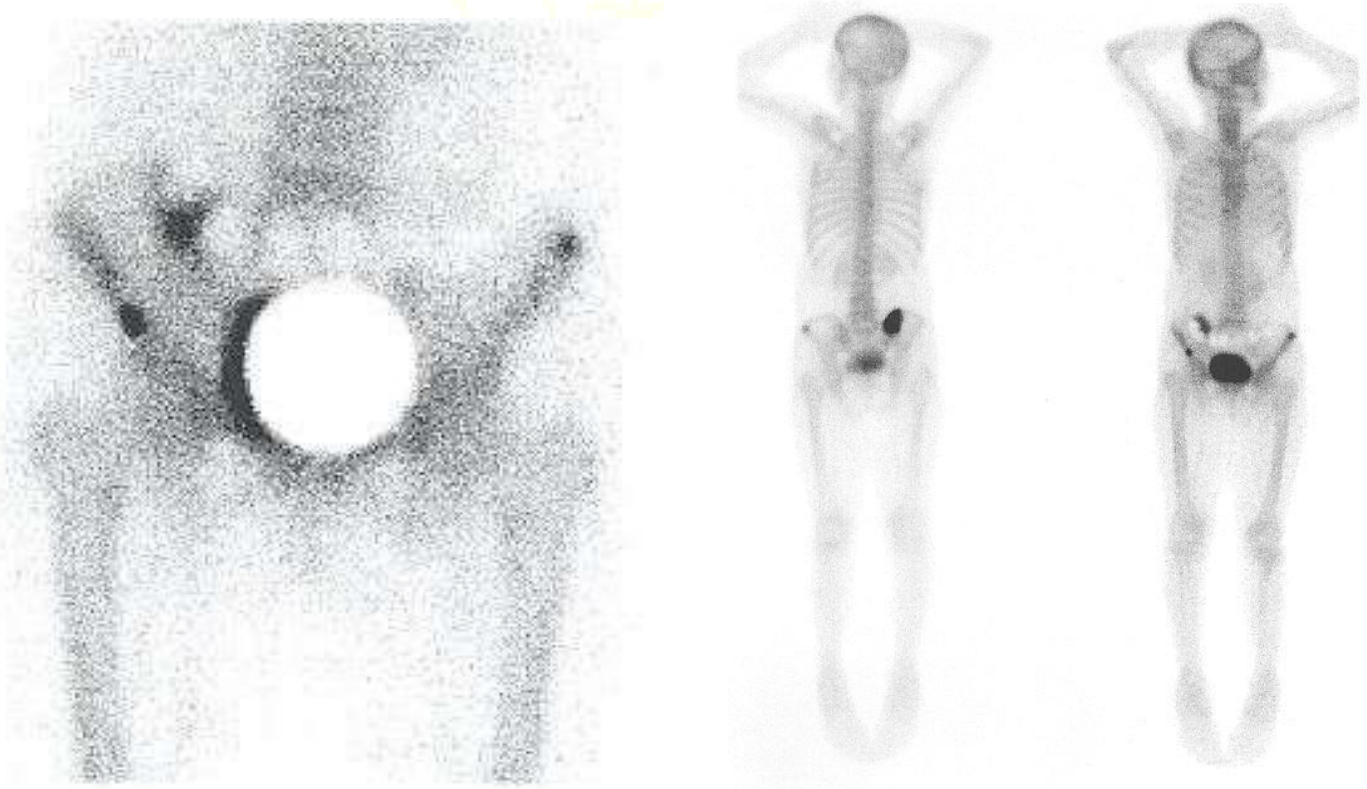
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How do we create images?

- Gamma radiation is emitted from within the patient, as opposed to through the patient.
- Emission of a gamma photon represents the location of the radionuclide within the structure.
- Information emitted is captured by a detector.
- Function is determined by the intensity of the gamma radiation detected.

- Contraindications:
  - No barium for 48 hours
  - No previous NM tests
- Appropriate preparation—fasting, stopping medications.
- Must remove all attenuating artifacts, but patients can stay clothed.
  - Using higher energy photons, so no artifact from clothing.

Barium



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Radiation Exposure (cont'd)

- Exam length: 30 mins to several days
  - Patient comfort is important!
- Test-specific history questions
  - (e.g., broken bones, bone disease, renal disease, surgery to the bones, cancer, etc.)
- Repeats?!?
  - If the patient leaves, cannot come back for a quick repeat. May need to repeat entire procedure/injection.
- NMTs will advise patients who are breastfeeding to modify their feedings accordingly (depends on radiopharmaceutical administered).

Bone Scan



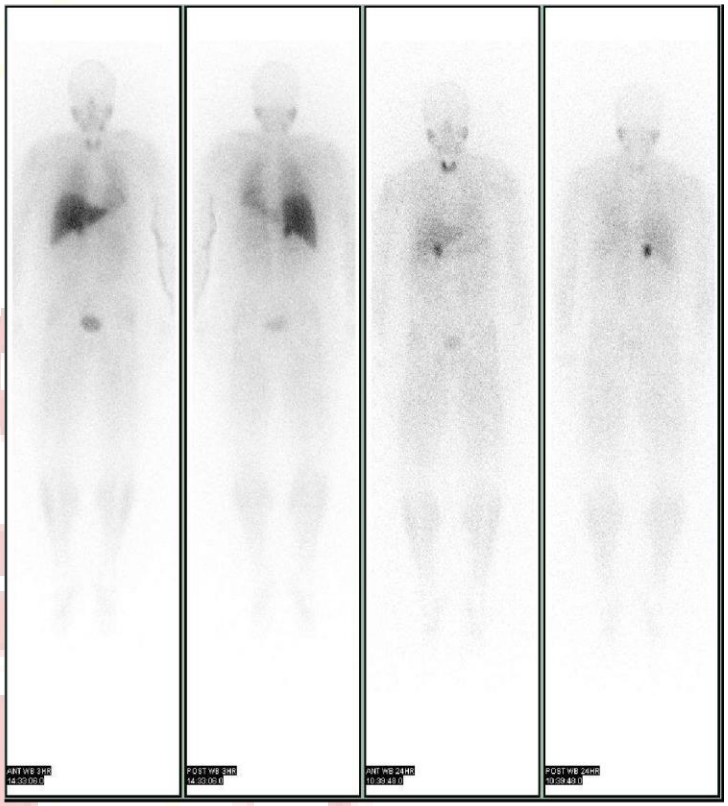
- © Ytrottier, https://commons.wikimedia.org/wiki/Category:Nuclear_medicine#/media/File:SPECT_CT.JPG CC BY-SA 3.0

Image Processing

- After the images are acquired they are computer processed to produce qualitative and quantitative data.
- Pathologies are usually demonstrated by:
  - Hot spots: areas of increased uptake
  - Cold spots: areas of decreased uptake

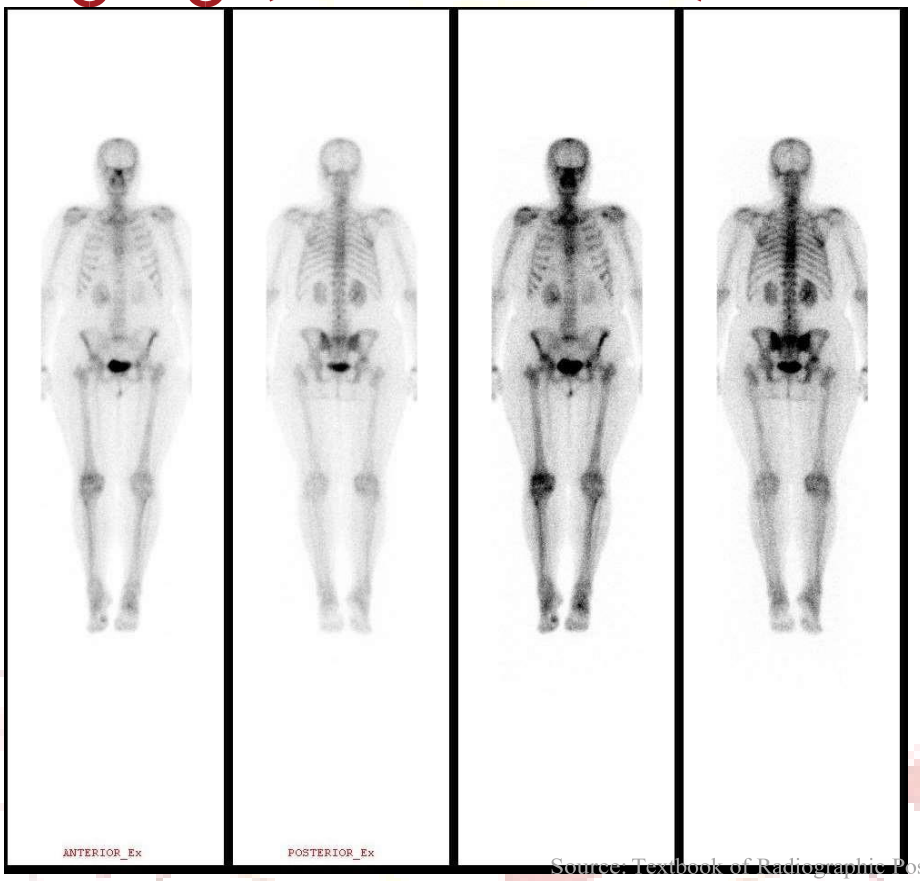
Nuclear Medicine Exams

- A sample of what NMTs have to offer and how x-ray and NMT work together in the diagnostic process.



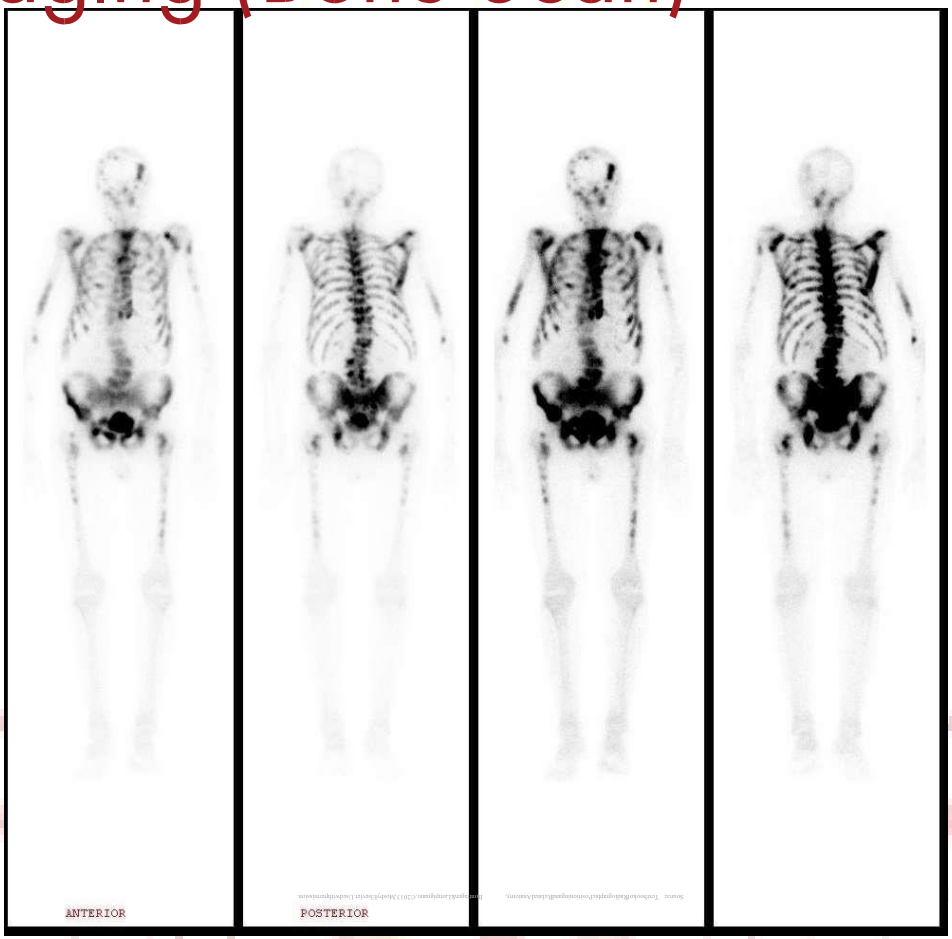
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Skeletal Imaging (Bone Scan)



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Skeletal Imaging (Bone Scan)



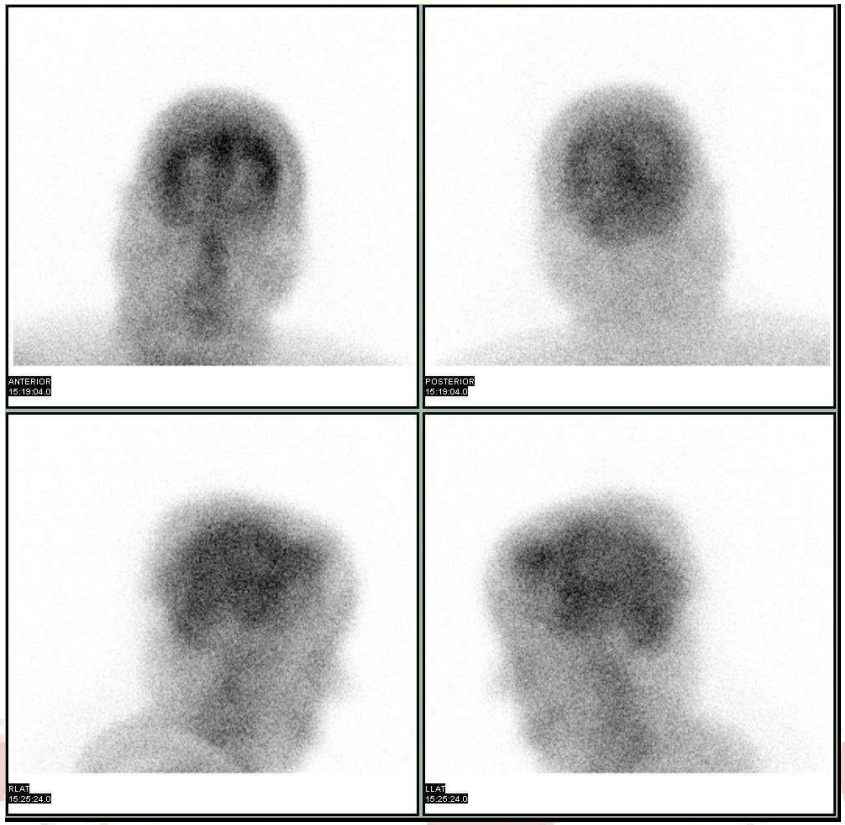
Central Nervous System

- Determines brain viability
- 99m Tc-Bicisate (Neurolite)
- Measures the regional cerebral blood flow to assess if there is sufficient activity to sustain life.
- Diagnostic correlation:
  - EEG



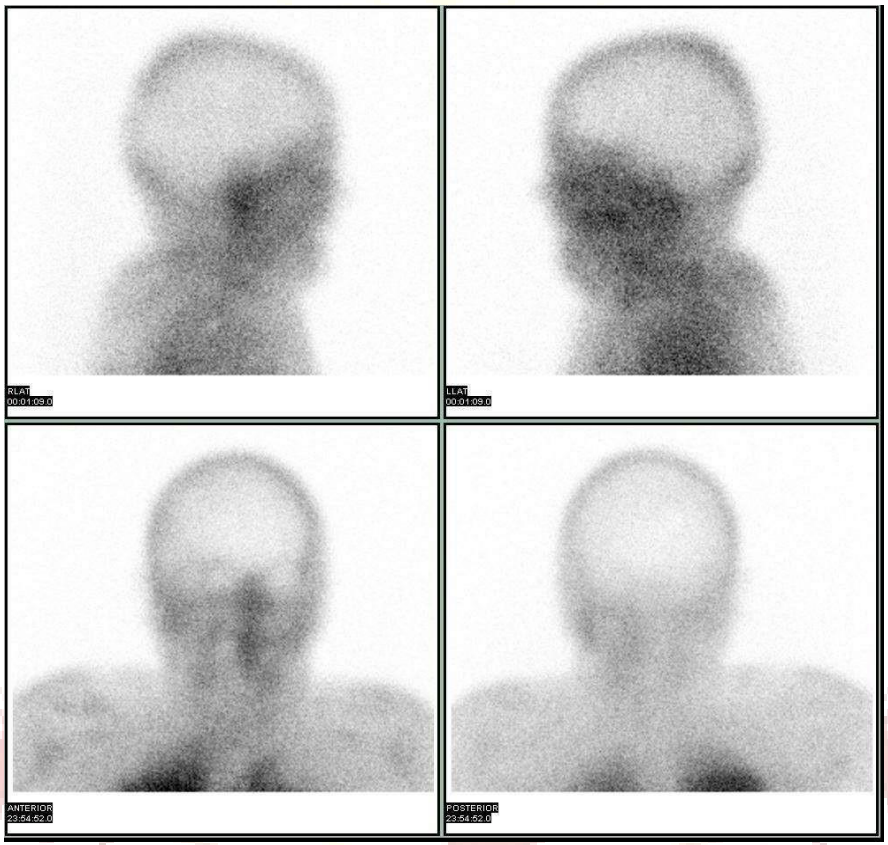
Source: Colourbox.com, Kiyoshi Takahase Segundo, Image #5112966

Central Nervous System (cont'd)



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Central Nervous System (cont'd)

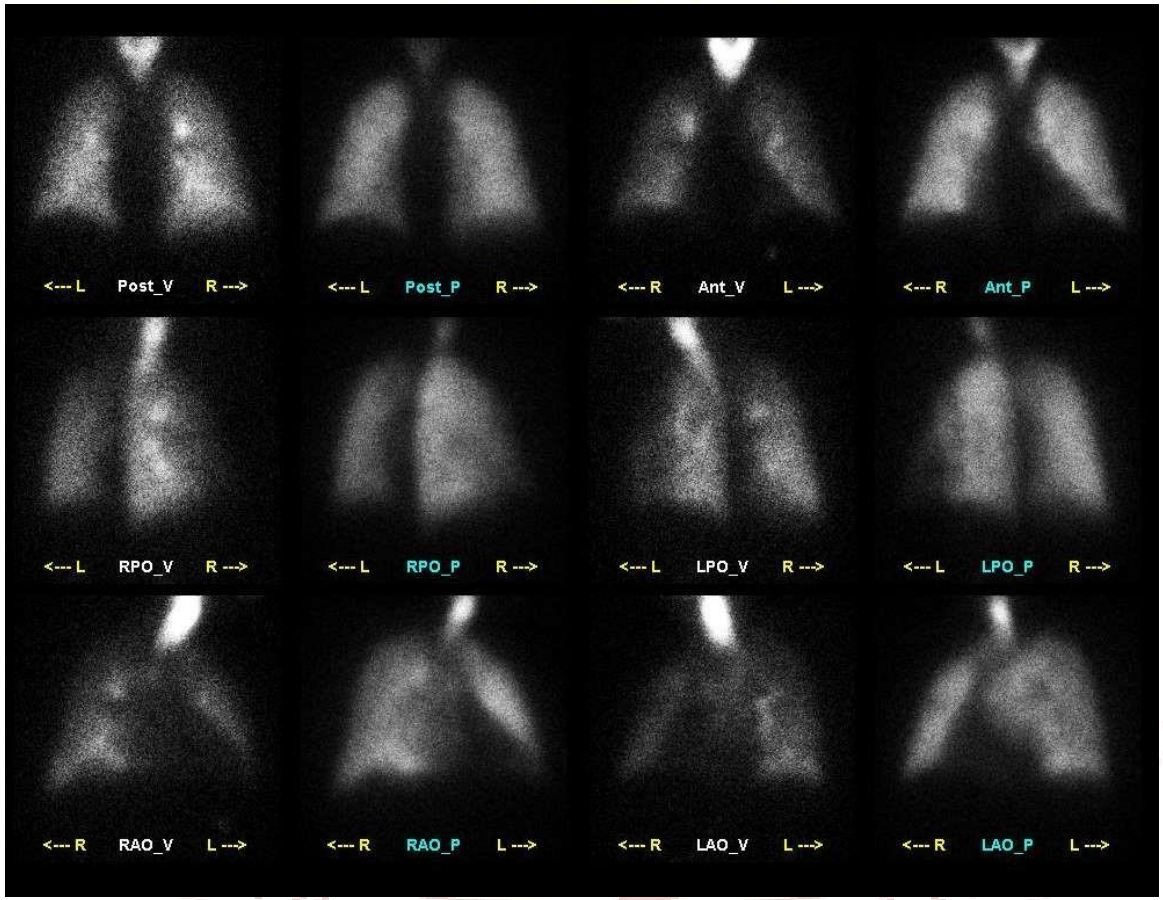


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Pulmonary System

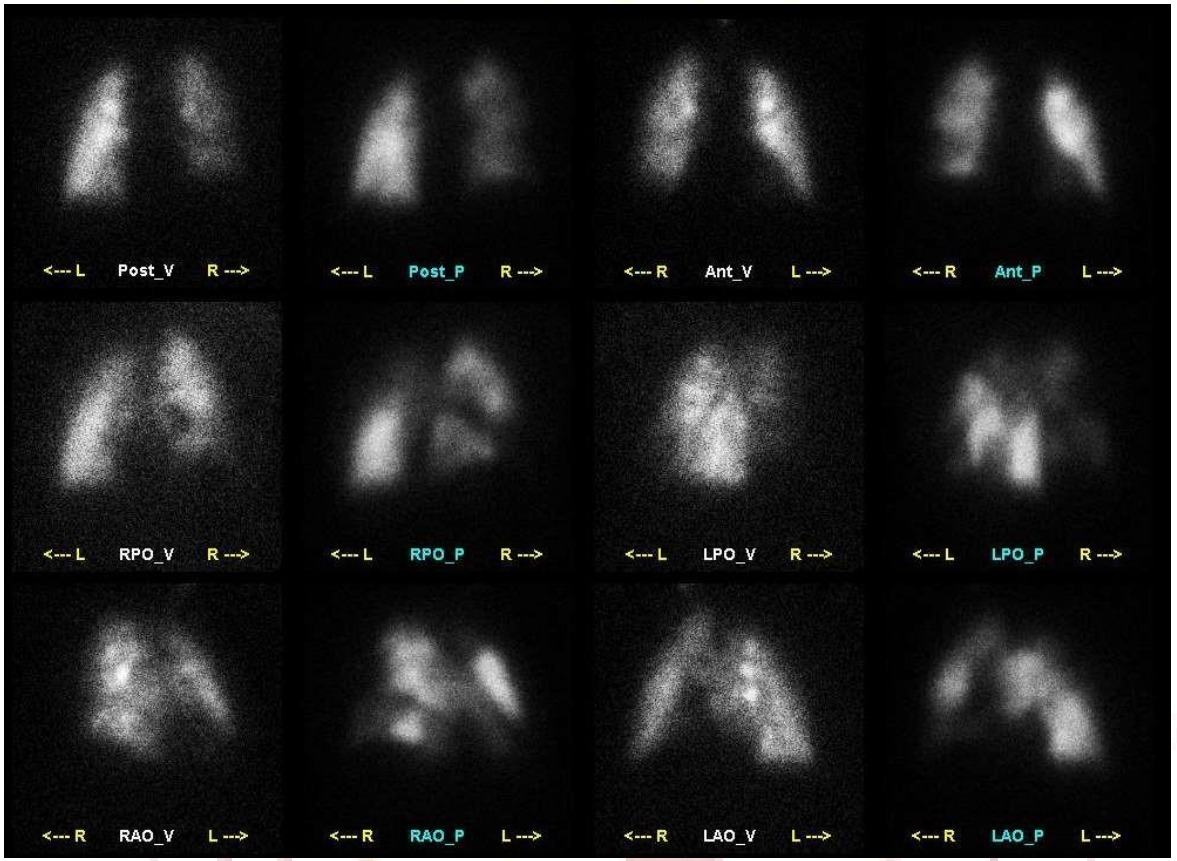
- 99m Tc-DTPA and 99m Tc-MAA
- Used to diagnose Pulmonary Embolism
- Two phases: Ventilation and Perfusion
  - Ventilation: assesses air flow to the lungs by breathing in a radioactive aerosol.
  - Perfusion: assesses blood flow to the lungs by injecting the radioactive tracer intravenously.
- Looking for a "mismatched" defect
- Diagnostic correlation:
  - Chest x-ray, CT, ultrasound (to assess for DVT), MRA

Normal Pulmonary Scan



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Scan with Pulmonary Embolism

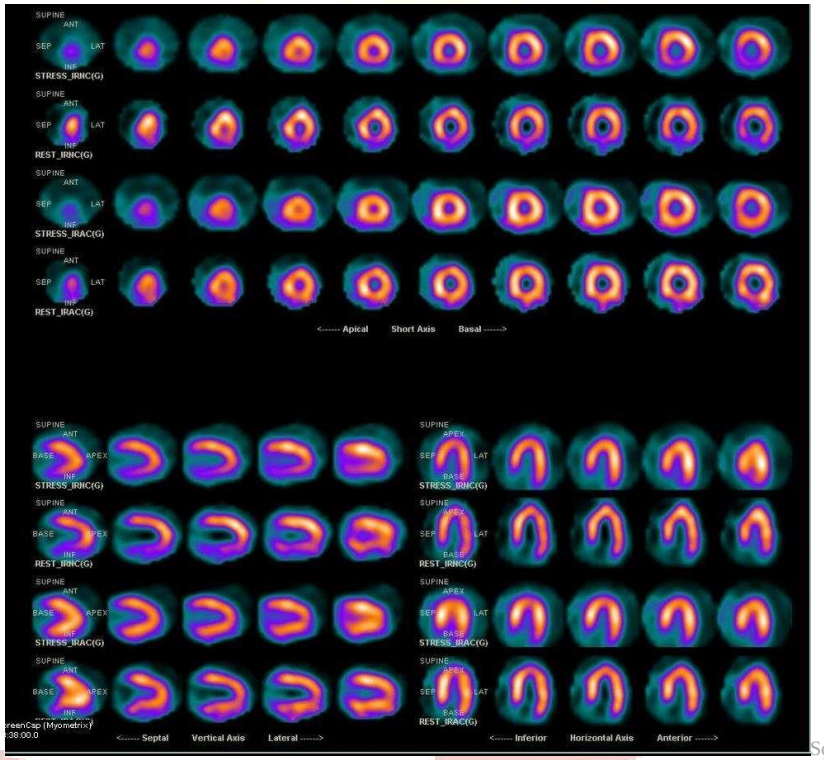


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Myocardial Perfusion Imaging

- Imaging of regional and global myocardial perfusion to aid in the diagnosis and management of coronary artery disease.
- Differentiates between ischemia and infarction
- SPECT/CT
- Diagnostic correlation:
  - Coronary angiography, exercise stress test, echocardiogram, blood test (cardiac enzymes)
- Therapeutic uses: CABG, angioplasty/stent, pacemaker, valve replacement

Stress/Rest Tests



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Cameras

Images can be obtained in multiple formats:

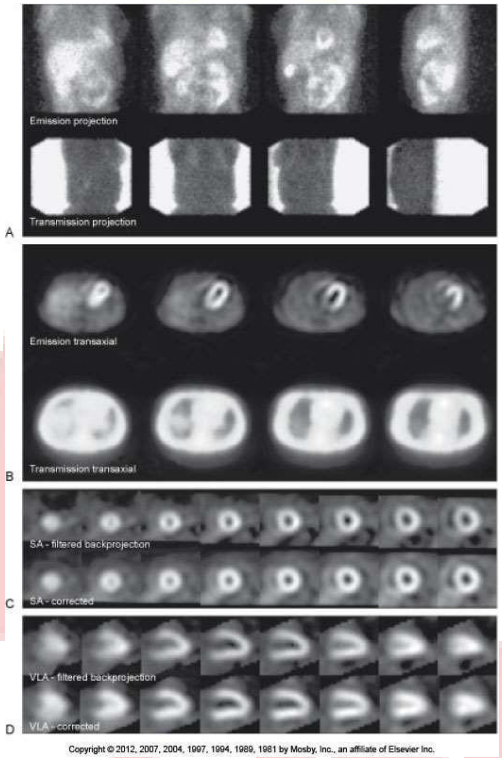
- Planar images
- Dynamic images
- 3-dimensional images

Why are NMTs Performing CT?

- ACMDTT position:
- Nuclear medicine imaging equipment that integrates SPECT imaging with a computed tomography (CT) component that is intended for limited use is now considered to be a principle expectation of practice for nuclear medicine technologists.
  - 1. Nuclear medicine technologists do not require enhanced practice authorization to operate the CT component of hybrid imaging equipment if the included CT component is being utilized, in conjunction with nuclear medicine images, explicitly for the purposes of attenuation correction and anatomical mapping.

- (ACMDTT, retrieved from http://www.acmdtt.com/wp-content/uploads/2014/03/CT-in-the-NM-Environment.pdf)

SPECT Nuclear Imaging



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Computerized Tomography (CT)

- Single Photon Emission Computed Tomography.
- Uses the same radiopharmaceuticals as regular NM tests.
  - No need for special equipment.
- Uses the same cameras as regular nuclear medicine exams.
  - Takes planar images at different angles around patient and they can be reconstructed.

This technology was developed from conventional x-ray.

A tightly collimated beam is swept around the patient with the exposures directed through the patient and measured on the other side.

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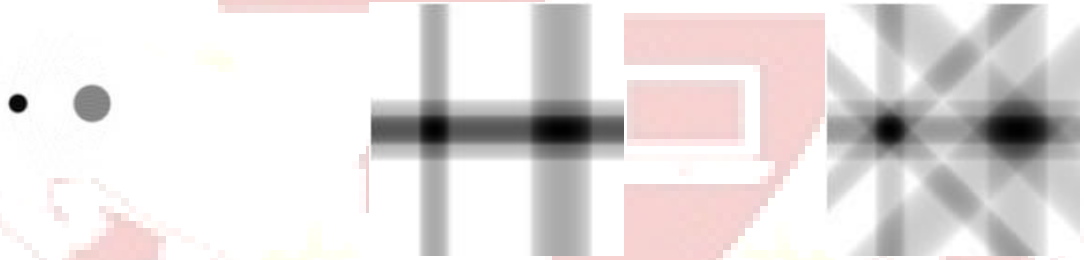
Computerized Tomography (CT)

- Scanning from different angles allows the computer to reconstruct the image to give a cross-section of the anatomy.



Original Structure

One Angle

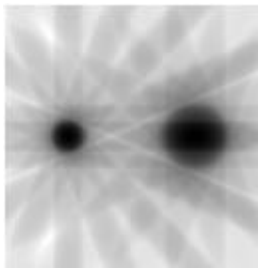


Original structure

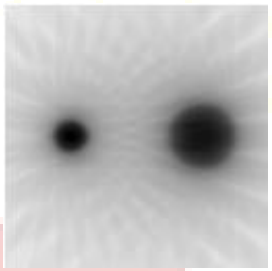
Two angles

Four angles

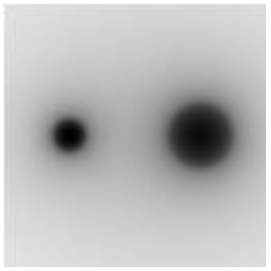
Computerized Tomography (CT) SPECT



Eight angles



Sixteen angles



Thirty-two angles

- Images acquired as cameras/detectors rotate around the patient.
- Planar images are taken and reformatted.
  - Using back projection, the computer will process the data and reconstruct the information into layers/slices.
  - Very similar to CT post processing/reconstruction.

SPECT Advantages over PET

Advantages:

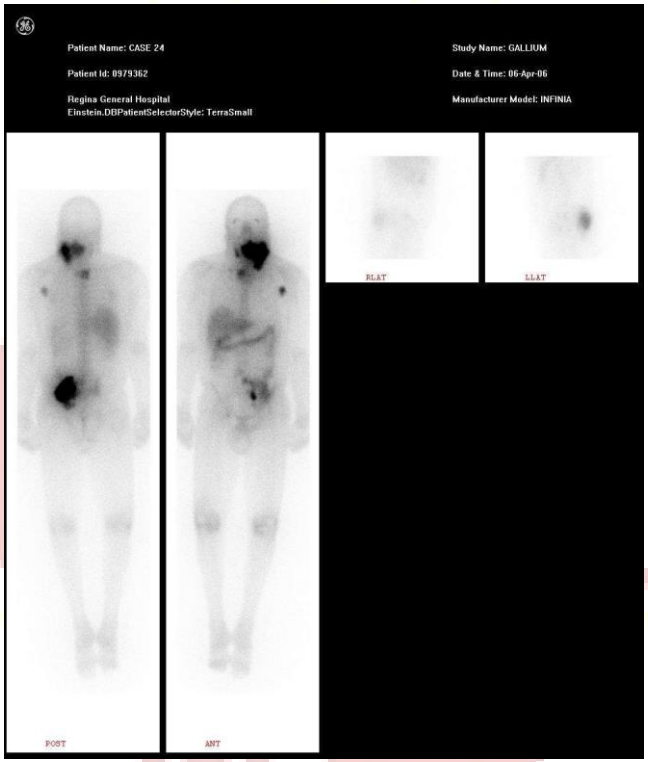
- Require less space and consumables compared to PET
- No cyclotron required
- Operating costs lower

Benefits of Combining CT with NM

- The exponential attenuation law:
  - Gamma rays that originate from deep within a patient will undergo interactions as they travel resulting in a lower detection efficiency of photons.
- CT is one of the methods utilized to determine patient-specific attenuation correction factors.

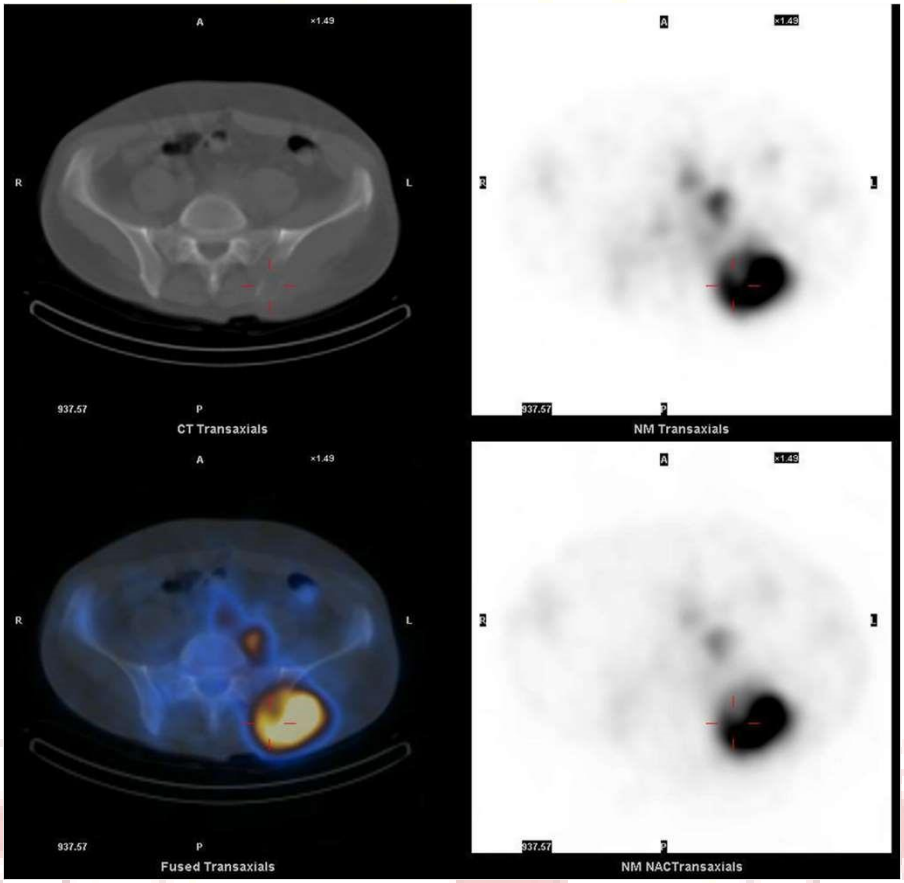
- CT is the method of choice for attenuation correction:
  - Speed
  - Decreased image noise
  - Decreased patient dose
- The CT scan is a non-diagnostic image.
  - The image produced still allows for correlation of anatomical information with the functional information of the nuclear medicine scan.

SPECT



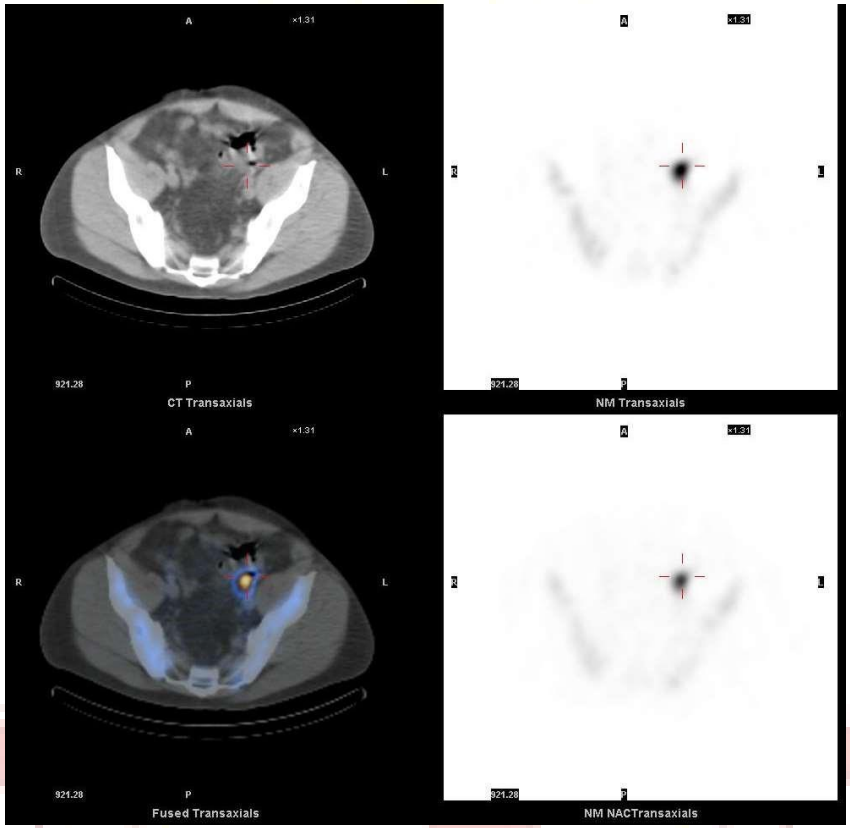
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SPECT/CT



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SPECT/CT (cont'd)



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SPECT/CT Advantages

- Traditionally, injured soldiers in training are given an x-ray and sent back to continue training if an injury is not visible.
- Undiscovered stress injuries then progress and are discovered at a later date as a more serious insufficiency fracture or stress fracture.
- Use of SPECT/CT allows small injuries/fractures to be discovered and treated earlier.

Advantages of SPECT/CT (cont'd)



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Positron Emission Tomography (PET)



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Fluorine-18 Fluorodeoxyglucose

- PET imaging is a form of nuclear medicine imaging.
- Differs from conventional imaging:
  - Requires a cyclotron in close proximity
    - Half life of 2 mins – 1 hour and 50 mins
  - Radiopharmaceuticals have biological significance (nitrogen, fluorine, oxygen and carbon)

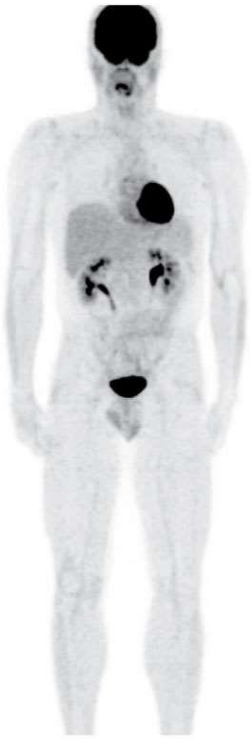
- Most commonly used positron-emitting radiopharmaceutical.
- It is a glucose analog.
- Many tumor cells use large amounts of glucose as an energy source.
- ^{18}F-FDG will be taken up by metabolically active, metastatic sites.

Source: Positioning and Anatomy,

Normal PET Image

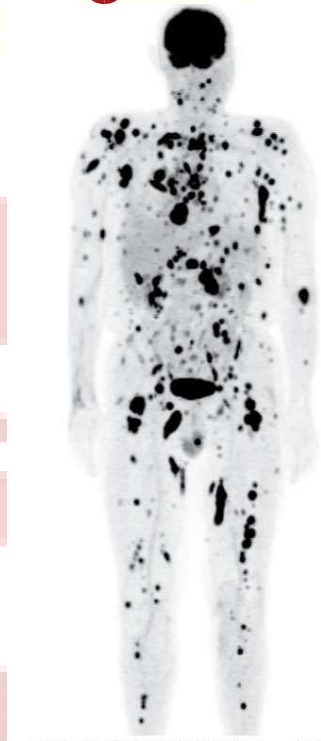
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- Radioactivity accumulates in the brain, pharyngeal constrictors, salivary glands, myocardium, urinary collecting system and bladder.
- Moderate activity appears in the liver, spleen, and testicles.



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Metastases from Malignant Melanoma



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Small Cell Lung Carcinoma PET/CT

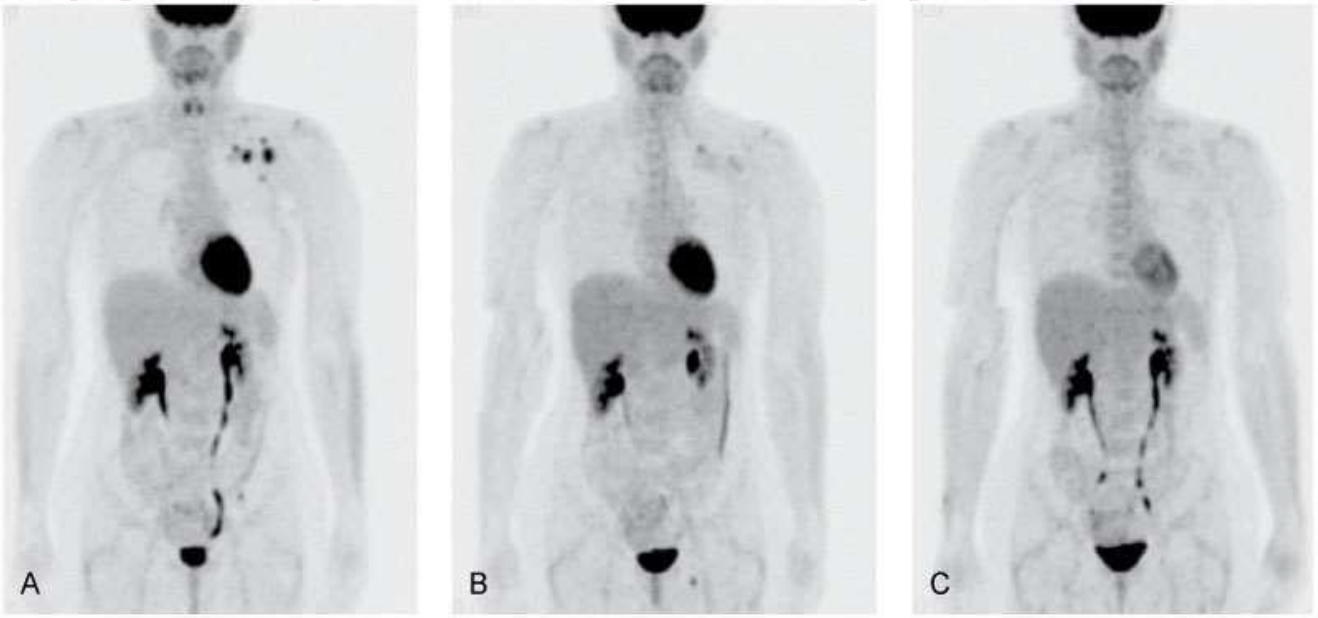
- Large accumulation of FDG in the right hilum and mediastinum.
- Normal activity demonstrated in the liver, spleen, kidneys, ureters and bladder.

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Evaluating Response to PET Therapy



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Nuclear Medicine in Therapy

- PET is also useful in cardiology studies (83Rb) and neuroscience (15O).
  - Brain neurology (Alzheimer's/dementia)
  - Cognitive neuroscience
  - Psychiatry (schizophrenia)
- PET cameras always include a diagnostic CT scanner.
- PET is considered an enhanced practice by the ACMDTT.
- First PET/MR unit installed in Canada in 2012.

When do we use NM?

- Goal in NM is always to keep the dose to the patient as low as possible.
- In some situations, the administration of a radionuclide is given in larger amounts so as to impact the function of the organ.
- Therapy doses are used to decrease function of tissue or nodule—destroy cells.

- Bone scan
  - Survey study of skeletal system
- Genitourinary studies
  - Kidneys – anatomy and function
  - Kidney transplant assessment
- Gastrointestinal studies
  - Anatomy and organ function
  - **Meckel's diverticulum
- Cardiac studies
  - Stress tests
- Thyroid uptake
  - Hyperthyroid or hypothyroid

Hybrid Imaging

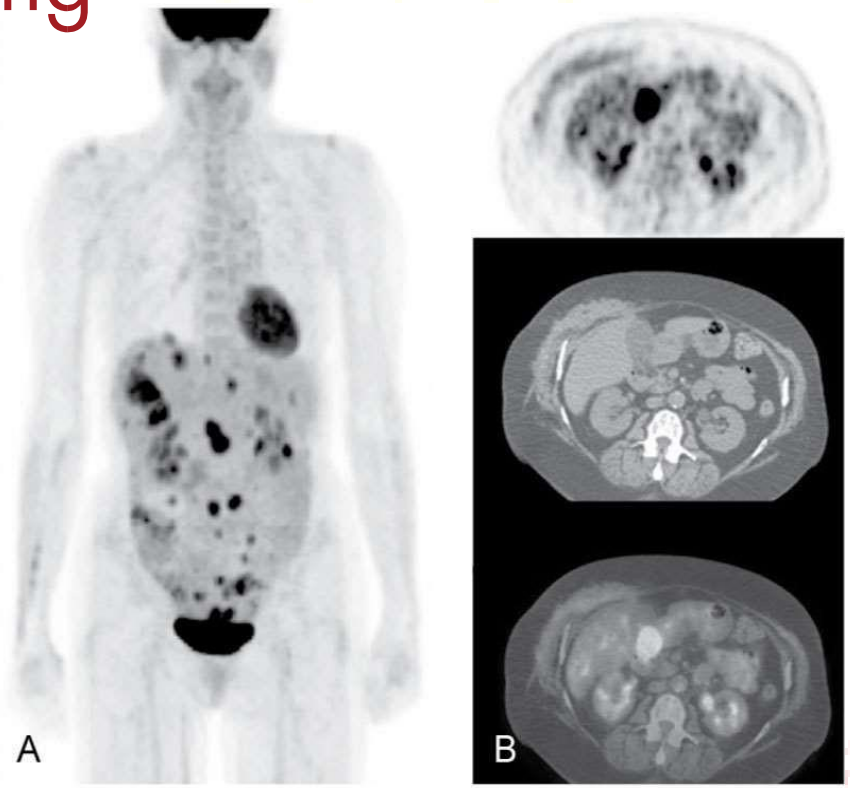


Fig. 13-30. An FDG scan in a patient with ovarian cancer demonstrates extensive hepatic, peritoneal, and pelvis metastases **(A)** and another patient **(B)** with recurrent ovarian cancer with a soft-tissue mass in the pyloric region linked to serosal metastasis. (See Color Plate 12.)

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PET/CT Imaging



Fig. 13-29. An FDG PET/CT on a patient with squamous cell carcinoma of the cervix that shows FDG activity consistent with primary tumor. The PET sagittal scan **(B)** shows the region of tumor uptake above the bladder. The fused PET/CT image **(C)** allows correlation of sites of increased uptake with anatomy. (See Color Plate 11.)

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PET/CT Imaging (cont'd)

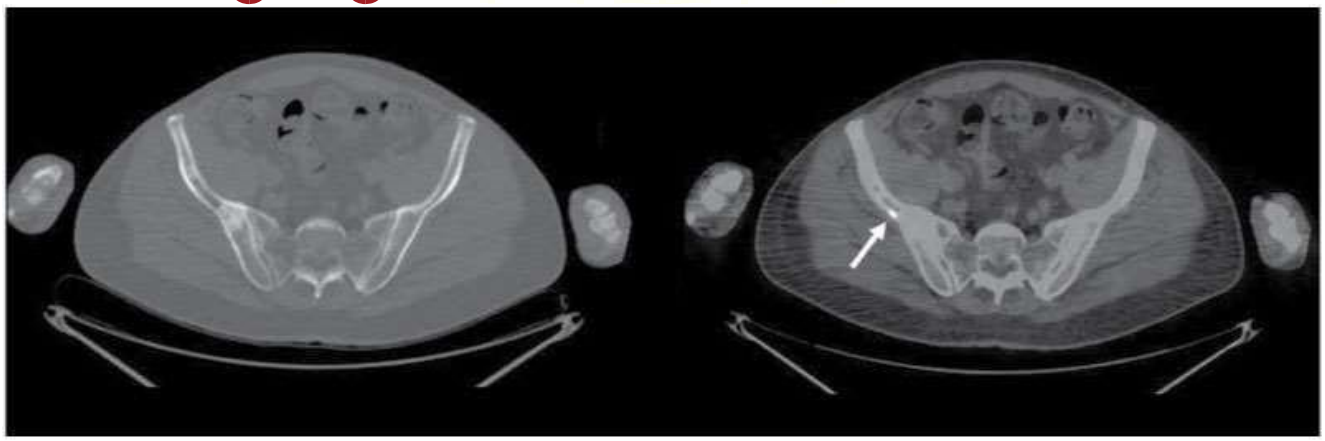


Fig. 13-22. The FDG PET/CT fused image *(right)* in a patient with a history of plasmacytoma post radiotherapy that illustrates recurrent disease within the right ileum. The CT scan is seen on the left. (See Color Plate 10.)

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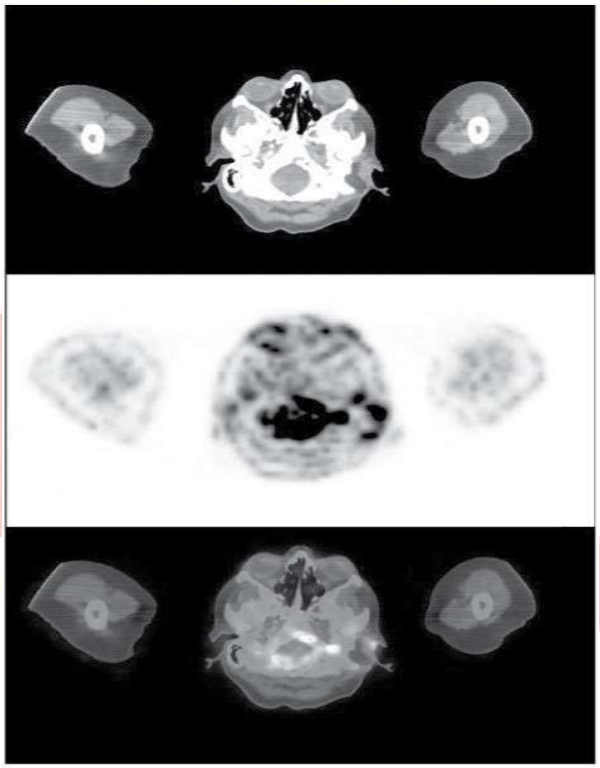


Fig. 13-2. FDG PET/CT scan for a patient with breast cancer illustrating intense activity that has accumulated in the left ear because of chronic otitis media with a mixed infection of multiresistant *Staphylococcus aureus* and an *Aspergillus* species. The upper image is the CT, middle image is the PET scan, and the lower image demonstrates the fused PET scan on the CT. (See Color Plate 5.)

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PET/CT Imaging (cont'd)

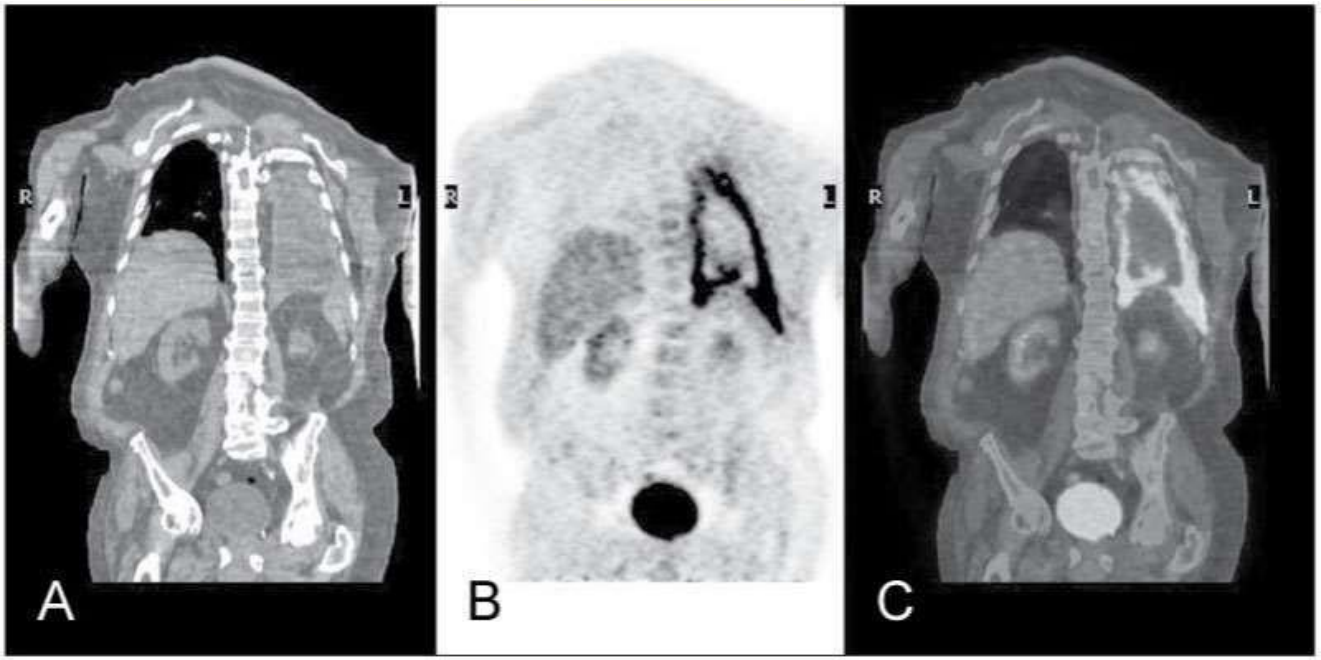


Fig. 13-18. The coronal CT scan **(A)** and FDG scan **(B)** on a patient who was experiencing fever, left chest pain, with known exposure to asbestos diagnosed with mesothelioma. The fused PET/CT scan **(C)** demonstrates the exact location of the intense FDG uptake on the anatomical CT scan. (See Color Plate 9.)

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PET/CT Imaging (cont'd)

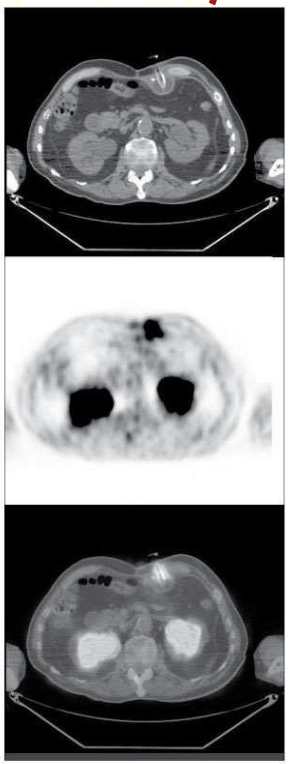


Fig. 13-3. A gastrostomy tube is in place in the abdomen and is seen on the CT scan. The PET scan *(middle)* demonstrates elevated FDG activity along its insertion route and perimeter consistent with inflammation. The fused PET/CT scan is shown at the bottom. (See Color Plate 6.)

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Radiation Exposure

- During the test:
  - Patient must not move!
  - Must be relaxed—good communication helps here.
- Post-procedure:
  - Correlating x-rays needed?
  - No breastfeeding or flying—again, communication is key!

Nuclear Medicine

- Lung scan: 2.2 mSv
- Bone scan: 6.3 mSv
- Renal scan: 2.6 mSv
- GI bleed: 7.8 mSv
- Cardiac rest/stress (2 day protocol: 12.8 mSv
- Biliary (HIDA): 3.1 mSv

X-ray/CT

- Posteroanterior chest: 0.02 mSv
- CT of chest (for PE): 15 mSv
- X-ray of lumbar spine: 1.5 mSv
- Intravenous Urography: 3 mSv
- Small bowel series: 5 mSv
- Coronary Angiography: 16 mSv
- ERCP: 4 mSv