NUCLEAR MEDICINE

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JORDANINAN BOARD in NUCLEAR MEDICINE

IODINE ISOTOPES

Most common medical Iodine isotopes

ISOTOPE	HALF LIFE	MODE OF DECAY	TYPE OF RADIATION
I-123	13.27 h	EC	GAMMA
I-124	4,17 d	EC	GAMMA
I-125	59.4	EC	Low x-ray
I-127	STABLE	----	-------
I-131	8.02 d	B	-B , GAMMA

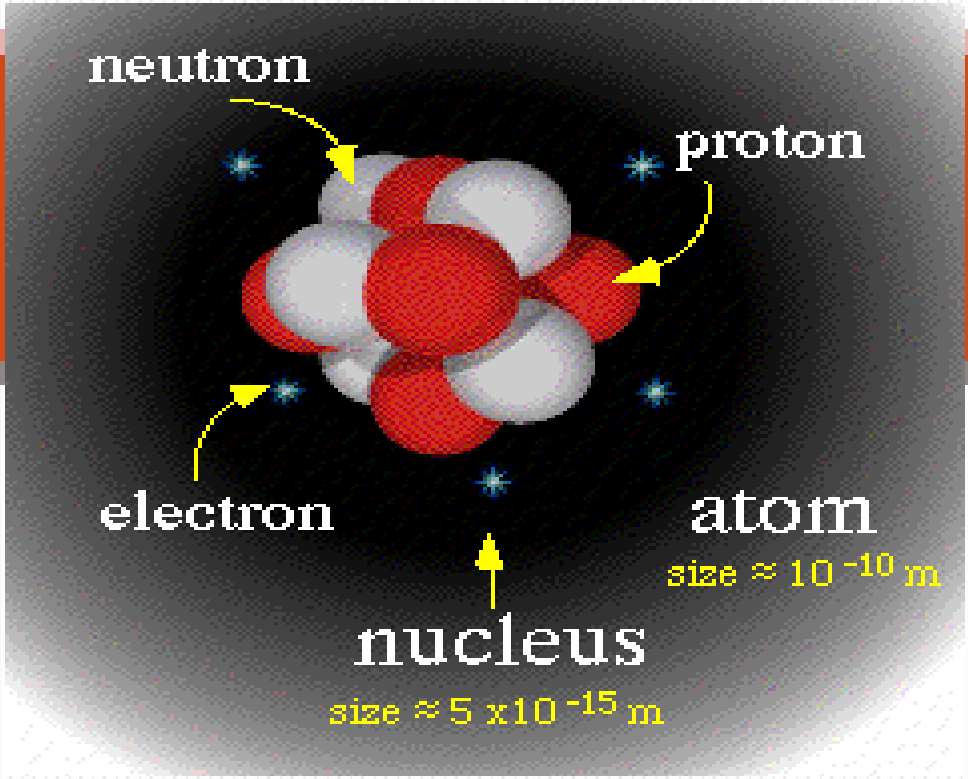
TC-99m isotope

- Isotope is one or two or more forms of the same element having
- the same atomic number (z) ,
- different mass numbers (A) and
- the same chemical properties .

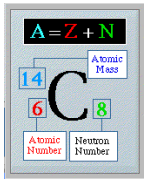
Tc-99m is the most common isotope used in medicine

- Tc-99m
- Half life =6 h
- Mode of decay = isomeric transition IT
- Gamma ray = 140 kev
- Parent is Mo-99
- Generatore mo-99----Tc99m

Nuclear Structure



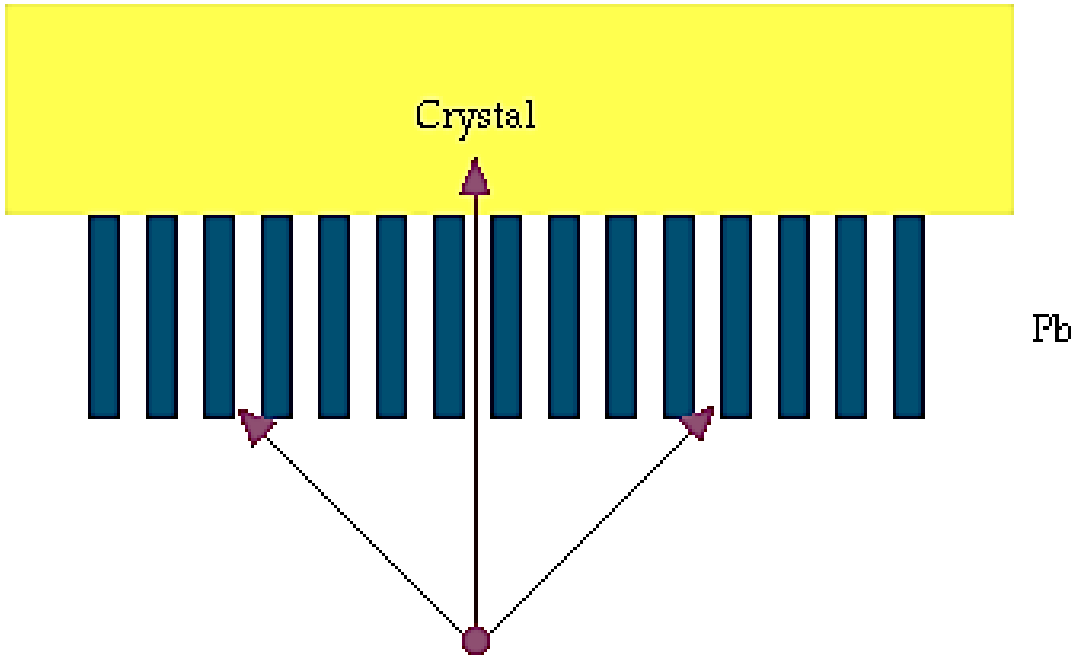
An atom consists of an extremely small, positively charged nucleus surrounded by a cloud of negatively charged electrons. Although typically the nucleus is less than one ten-thousandth the size of the atom, the nucleus contains more than 99.9% of the mass of the atom!

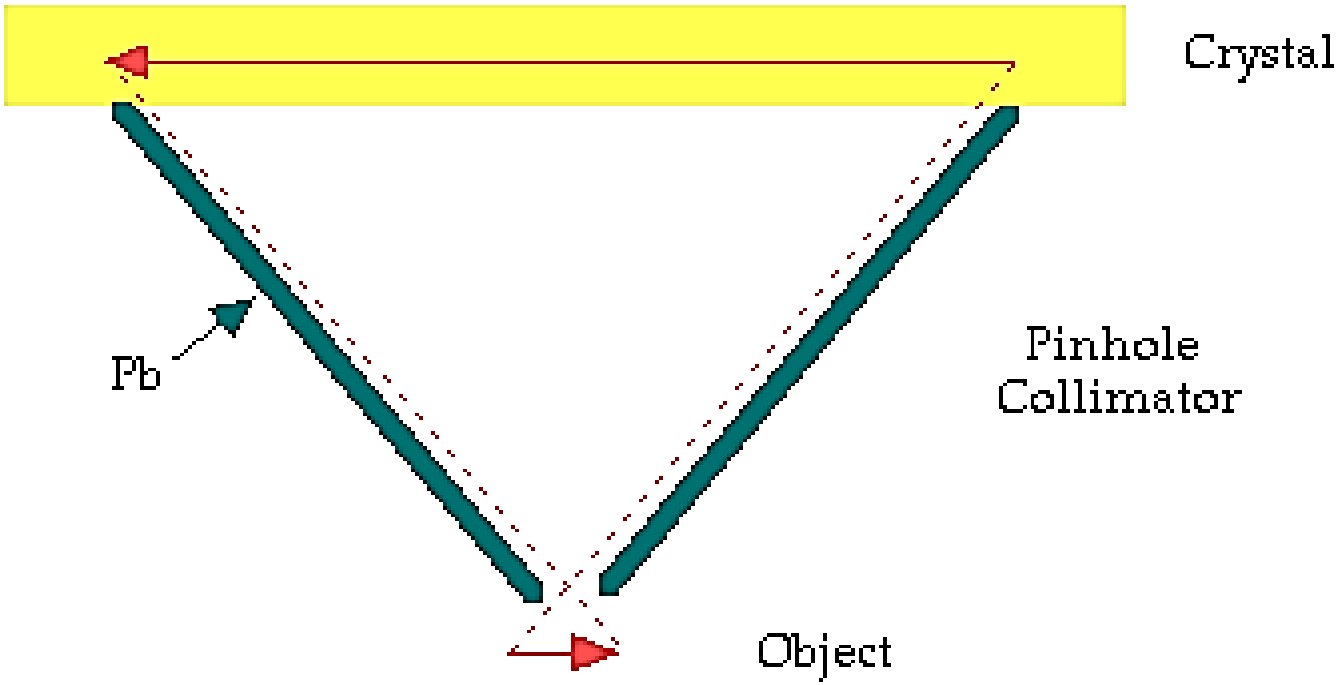


- Nuclei consist of positively charged protons and electrically neutral neutrons held together by the so-called strong or nuclear force.

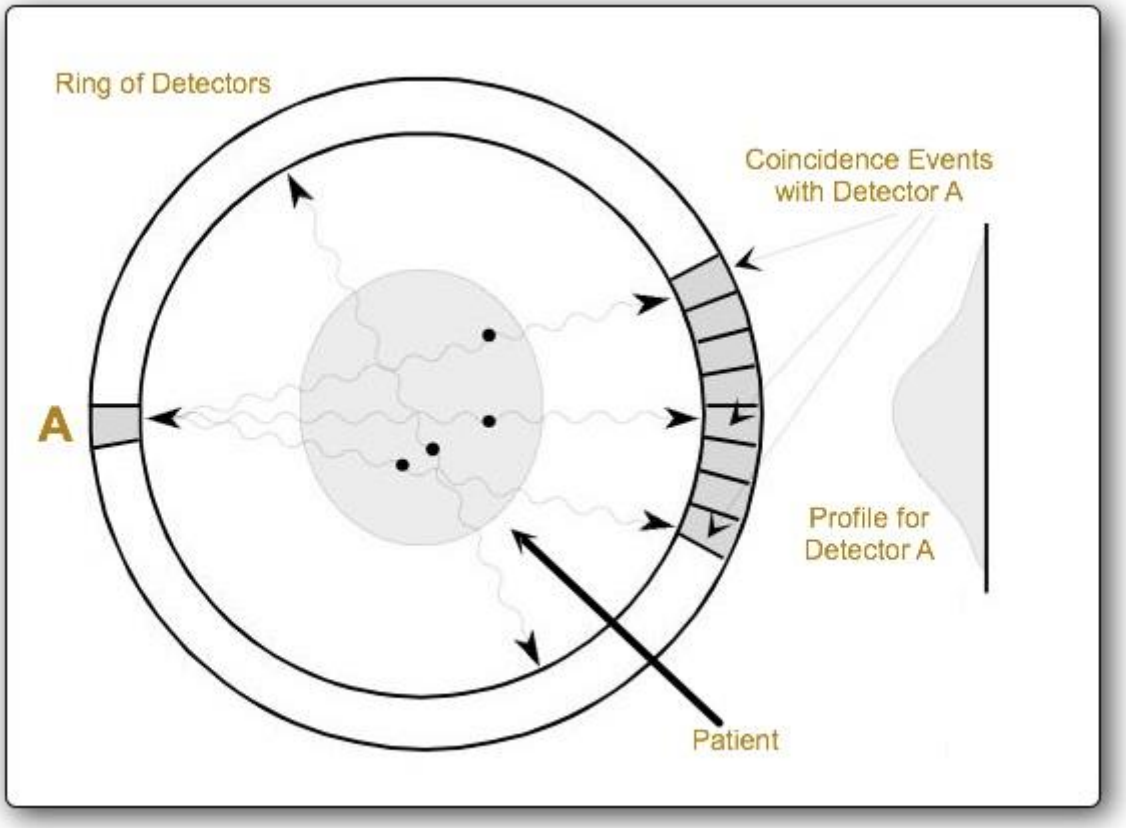
  The number of protons in the nucleus, Z, is called the atomic number. This determines what chemical element the atom is. The number of neutrons in the nucleus is denoted by *N*.

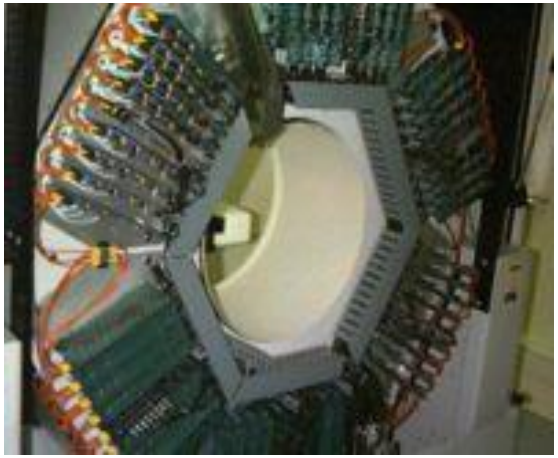
- The atomic mass of the nucleus, *A*, *is* equal to $Z + N$. A given element can have many different isotopes, which differ from one another by the number of neutrons contained in the nuclei.


Crystal
Pb


Crystal
Pb
Pinhole
Collimator
Object

Positron Emission Tomography (PET)





THYROID SCAN

- Definition
- Radiopharmaceuticals
- Indications
- Contraindications
- Imaging

DEFINITION

- Thyroid scanning is a nuclear medicine procedure. As the thyroid gland accumulates radioactive material (usually, radioactive technetium or iodine), the gland produces an image.
- Thyroid scanning is used to determine how active the thyroid is in manufacturing thyroid hormone.
- This can determine whether inflammation of the thyroid gland (thyroiditis) is present.
- It can also detect the presence and degree of overactivity of the gland (hyperthyroidism) or, conversely, it can determine the presence and degree of underactivity of the gland (hypothyroidism).

RADIOPHARMACEUTICALS

- Technetium 99m pertechnetate : Dose 2-6 mci I.V
- Iodine 123 : Dose 100-300uci
- Iodine 131: Doses:
  - uptake 3-5 uci
  - scanning 50-100uci
  - Whole body scan 2-10 mci for ca.thyroid follow up
  - 8-30mci for therapy of hyperthyroidism
  - 50-200 mci as therapy for thyroid carcinoma

Indications

- neck masses
- hypothyroidism
- hyperthyroidism
- ectopic thyroid
- thyroid malignancy
- thyroglossal duct cyst
- benign diffuse goiter
- thyroiditis
- radiation therapy planning

Contraindications

- **Relative contraindications**

-Patients has not discontinued thyroid medication.

-Patients has received iodine contrast for CT scan within 8 weekS

_Drug (amiodaronem.,……)

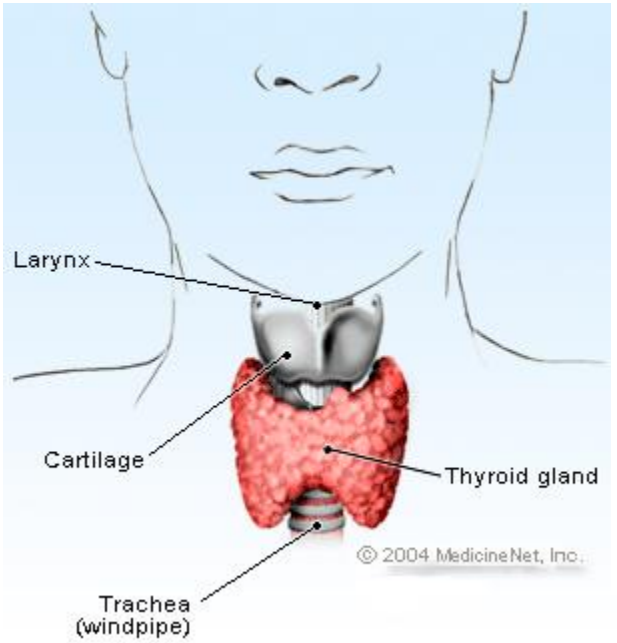
- **Absolute contraindications**

-Pregnant women

-Breastfeeding women until stop feeding.

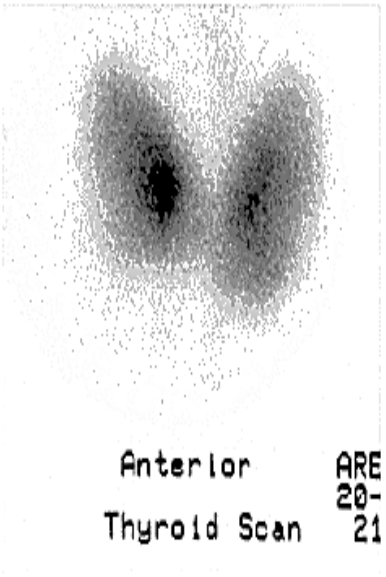
Normal thyroid scan

Anatomy



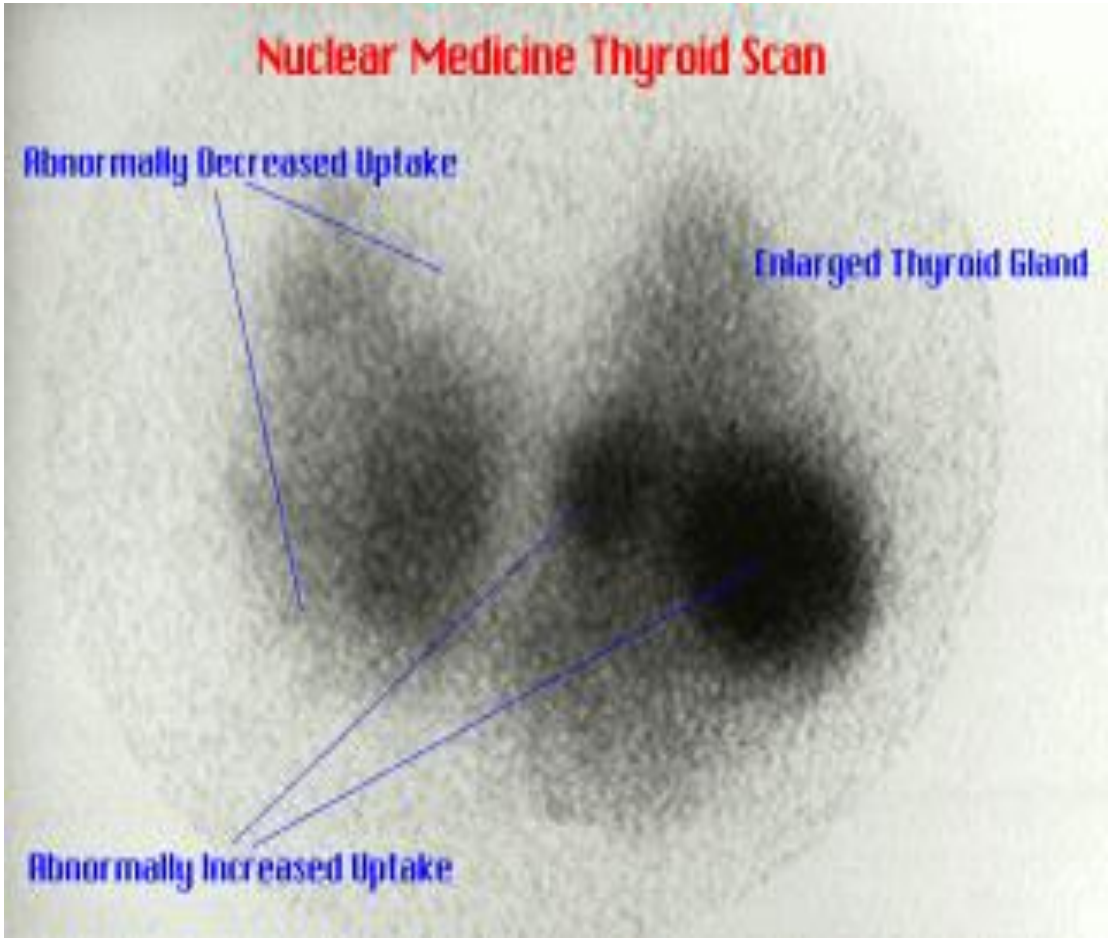
Normal Tc-99m thyroid scan

Two examples of normal thyroid scans

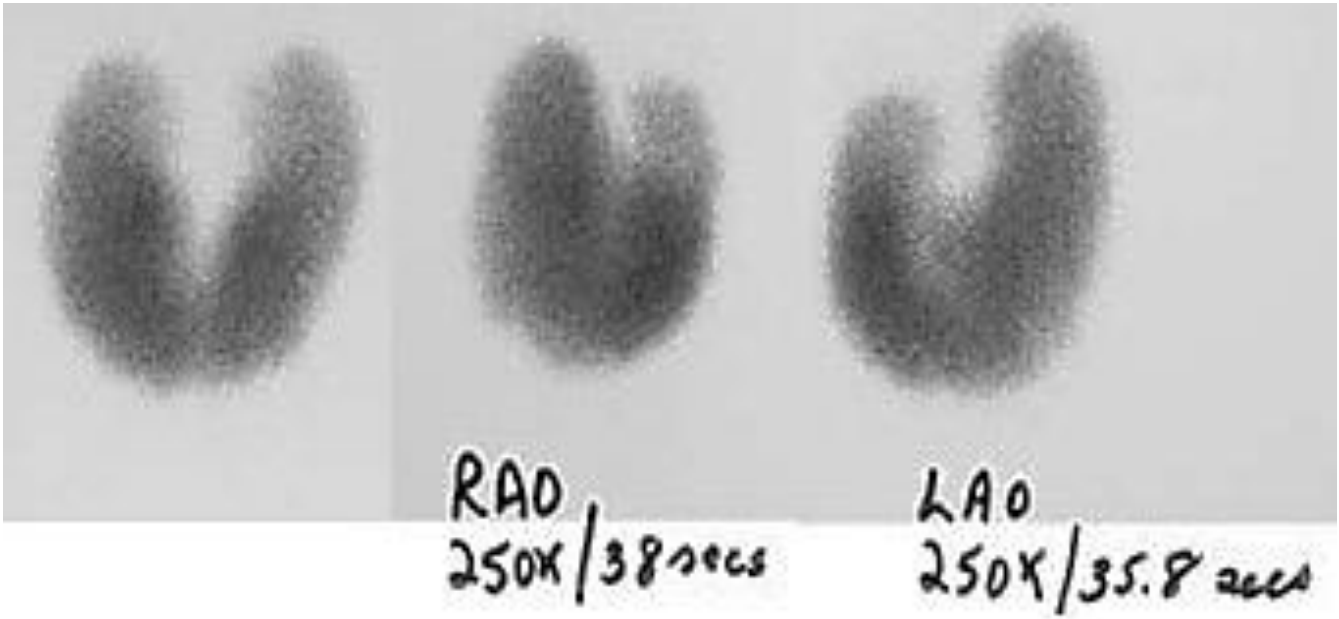


MNG

This Thyroid Scan shows an thyroid gland with areas of both increased as well as decreased uptake of radiotracer

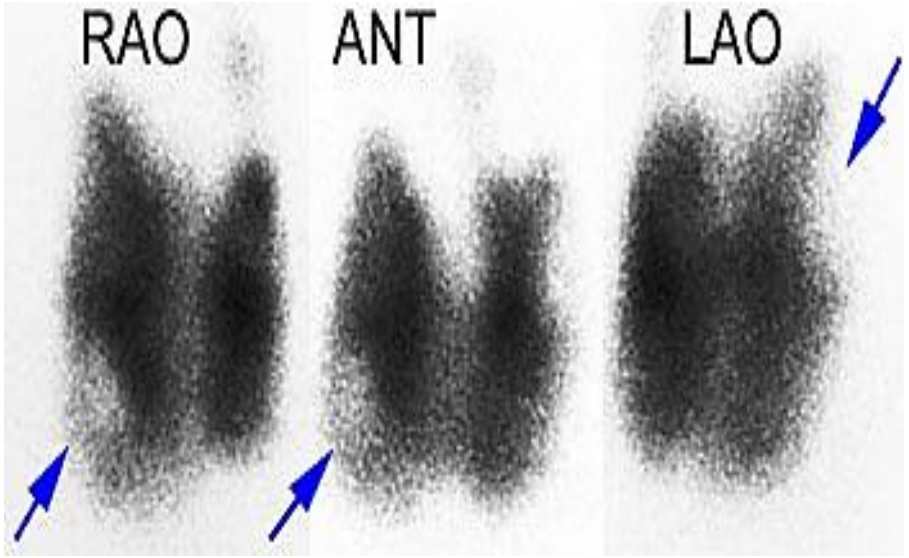


Graves Disease:
Pinhole images from a Tc-99M pertechnetate
(Diffuse Toxic Goiter)



Graves disease and papillary carcinoma

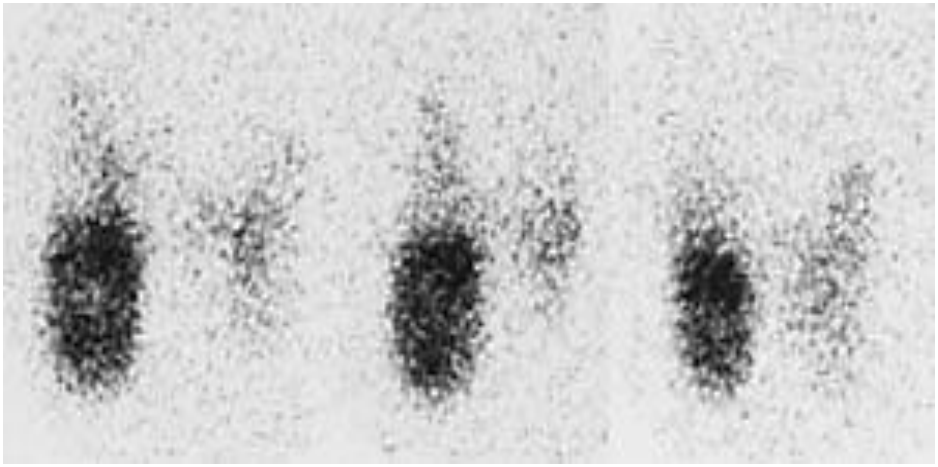
Cold lesions in this case were related to multifocal papillary thyroid carcinoma.



Cold nodule

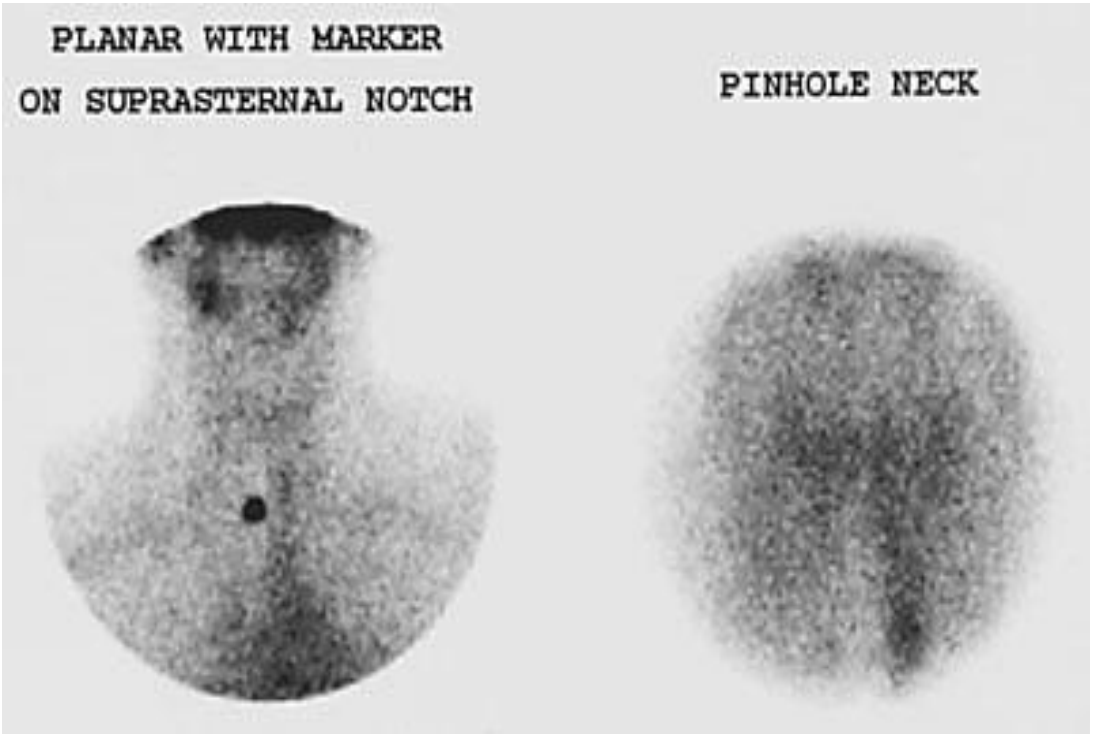
Autonomous Nodule

I-123 scan demonstrate an autonomously functioning nodule within the lower pole of the right lobe of the thyroid gland. The remainder of the thyroid is suppressed by this hyperfunctioning nodule. The patients radioactive iodine uptake was 27%.



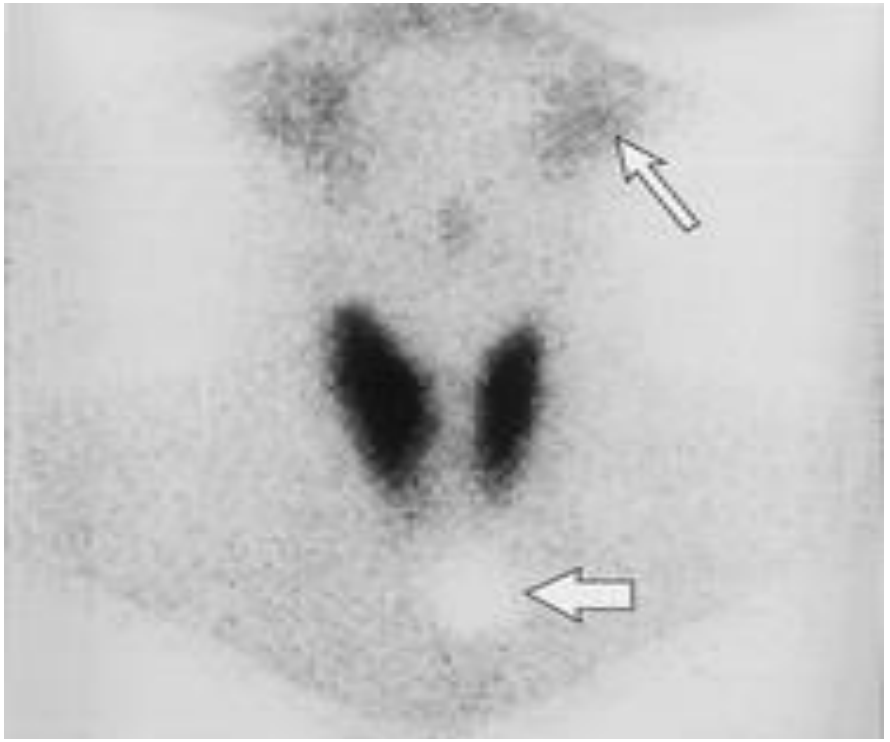
Subacute Thyroiditis

The scan was done to exclude Graves disease. The Tc-99m pertechnetate exam demonstrated no evidence of tracer accumulation in the neck consistent with subacute thyroiditis



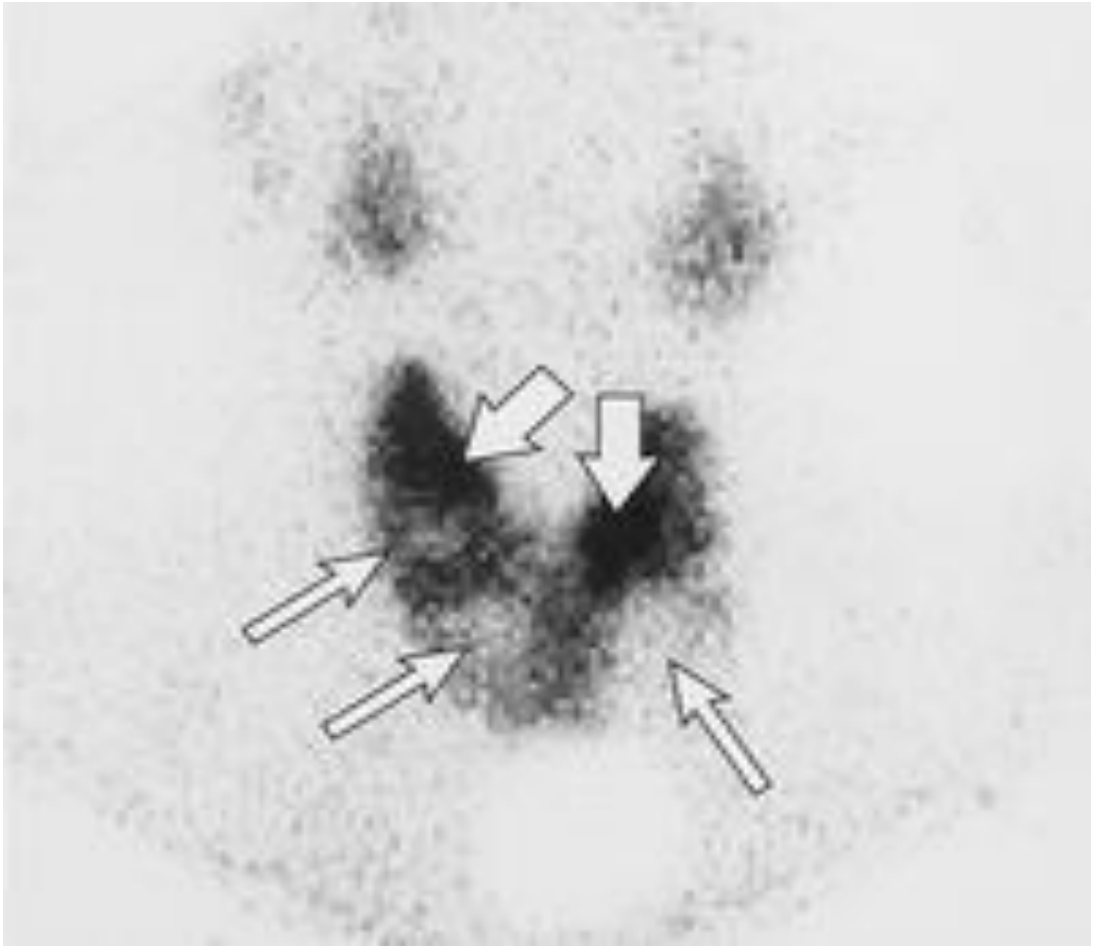
Hashimoto thyroiditis

- Early-stage Hashimoto thyroiditis in a 42-year-old woman who presented with goiter
- The 24-hour RAIU was mildly elevated at 39%.
- (thick arrow) represents the cold sternal marker



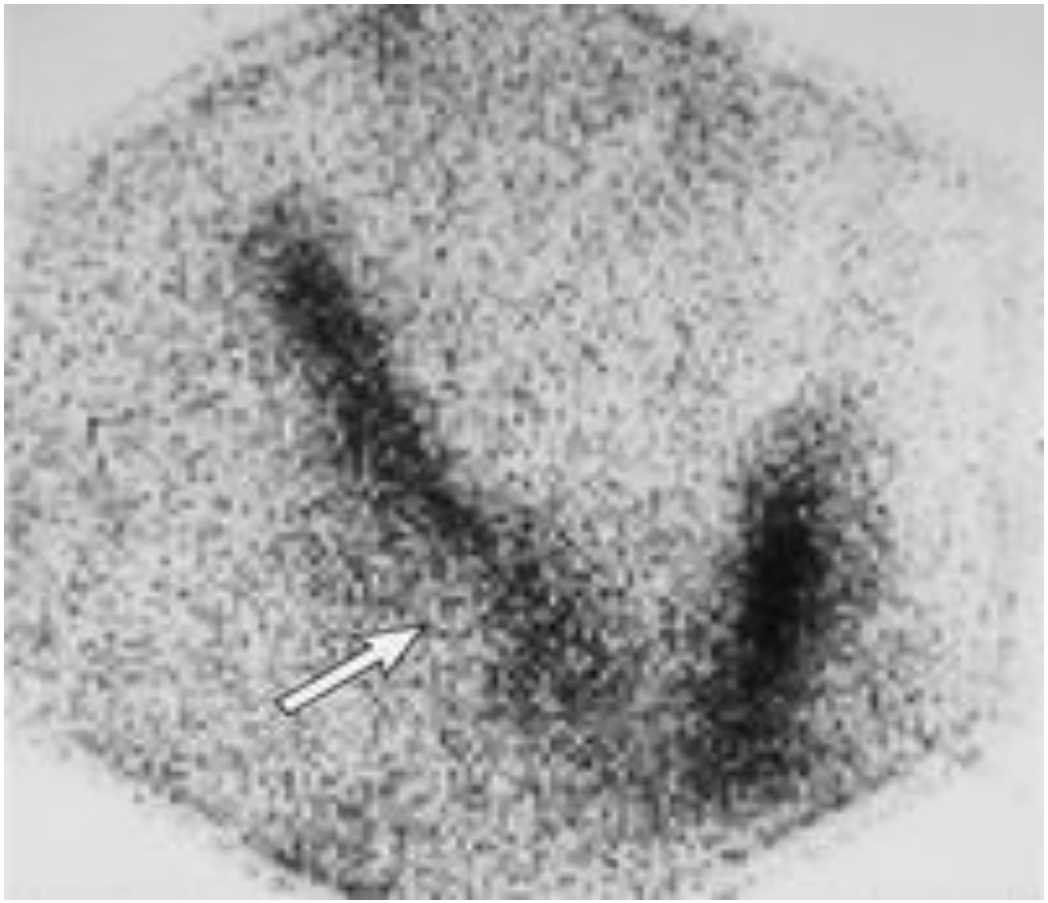
Hashimoto thyroiditis as MNG

Hashimoto thyroiditis manifesting as a multinodular goiter in a 51-year-old man who presented with multiple palpable thyroid nodules.



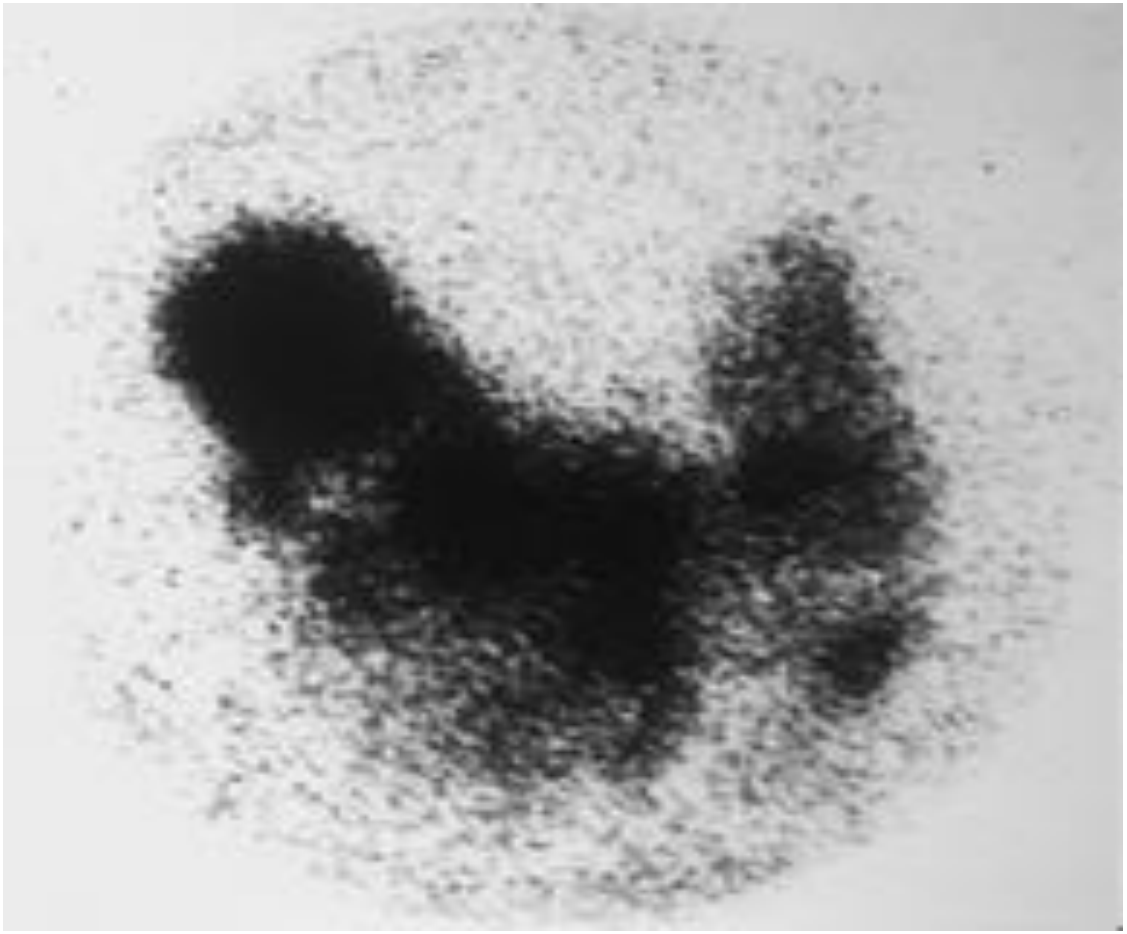
Hashimoto thyroiditis with cold nodule

Hashimoto thyroiditis manifesting as a solitary cold nodule in a 34-year-old woman who complained of a palpable right-sided neck mass of 5 months duration



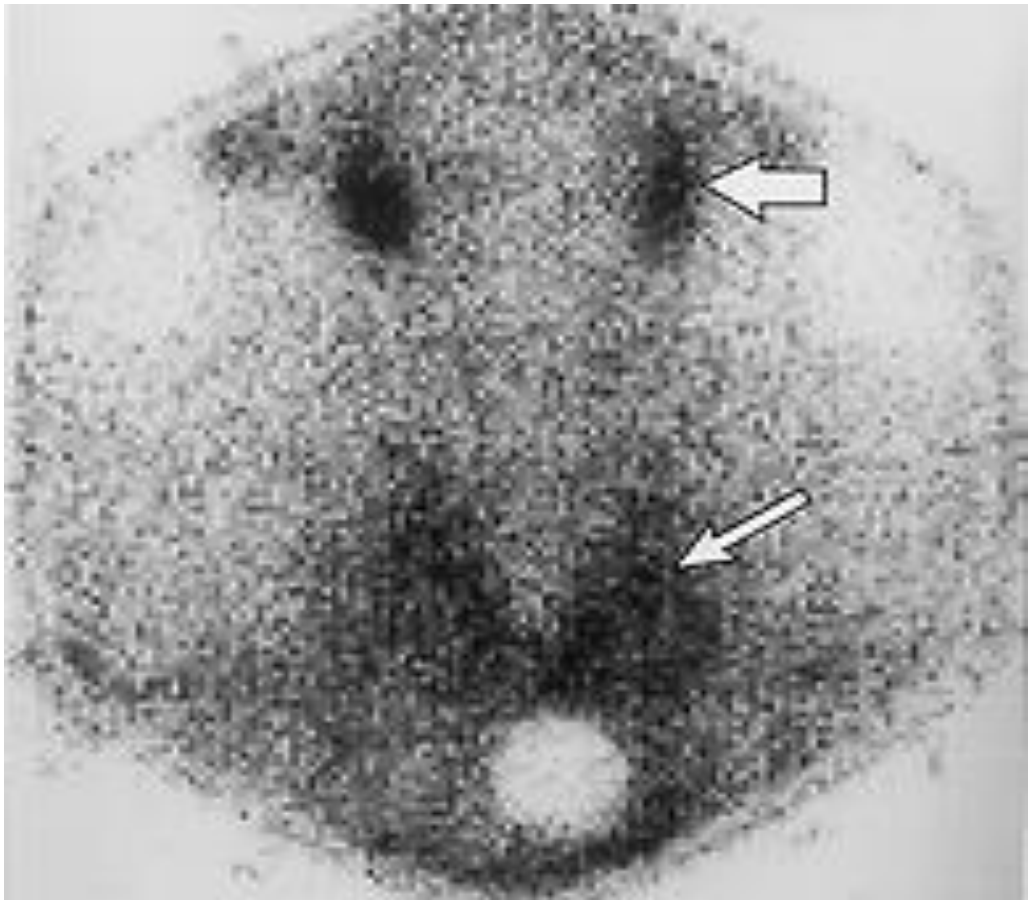
Hashitoxicosis

Hashitoxicosis in a 52-year-old woman



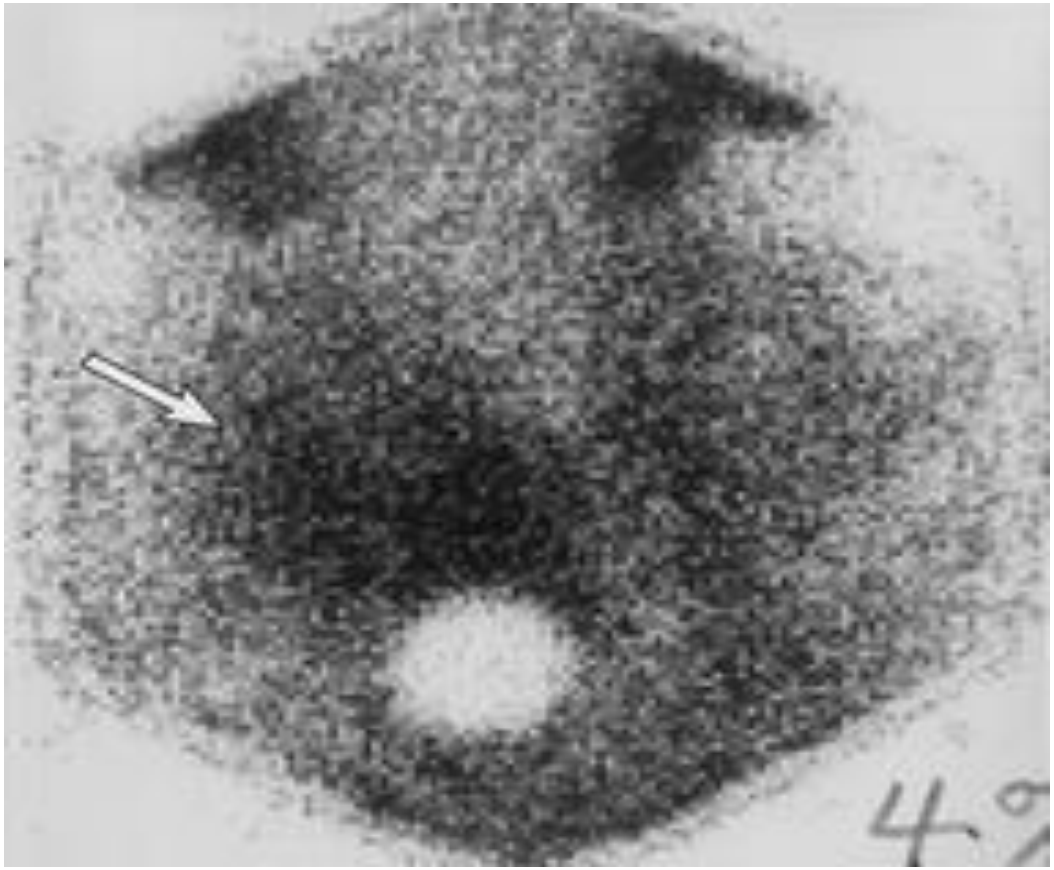
Postpartum thyroiditis

Postpartum thyroiditis in a 27-year-old woman who was experiencing palpitations, nervousness, and insomnia 2 months after giving birth



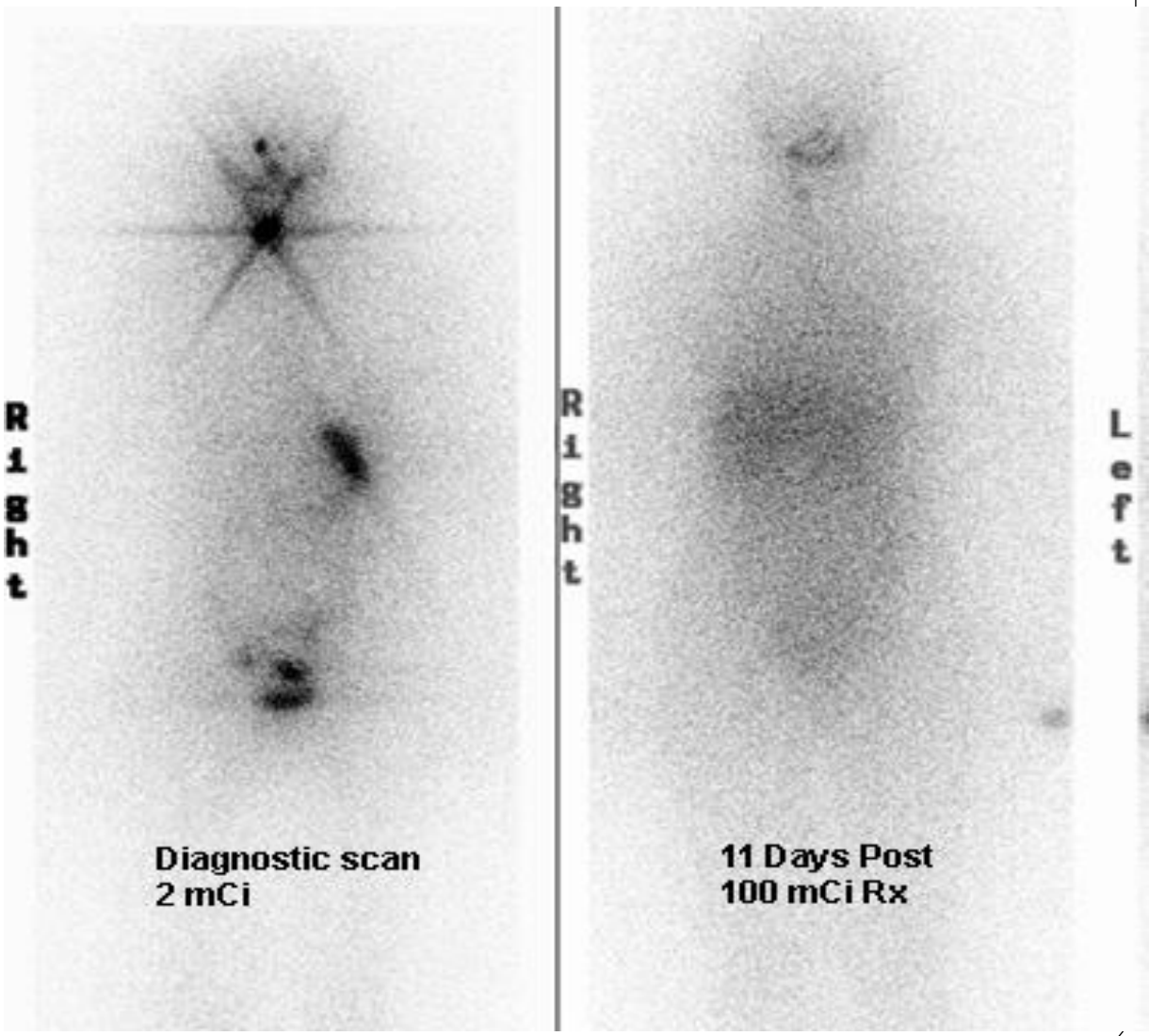
Amiodarone-associated Thyroid Disease

Amiodarone-associated thyroid disease in a 60-year-old man who complained of extreme fatigue, weight gain, and depression.



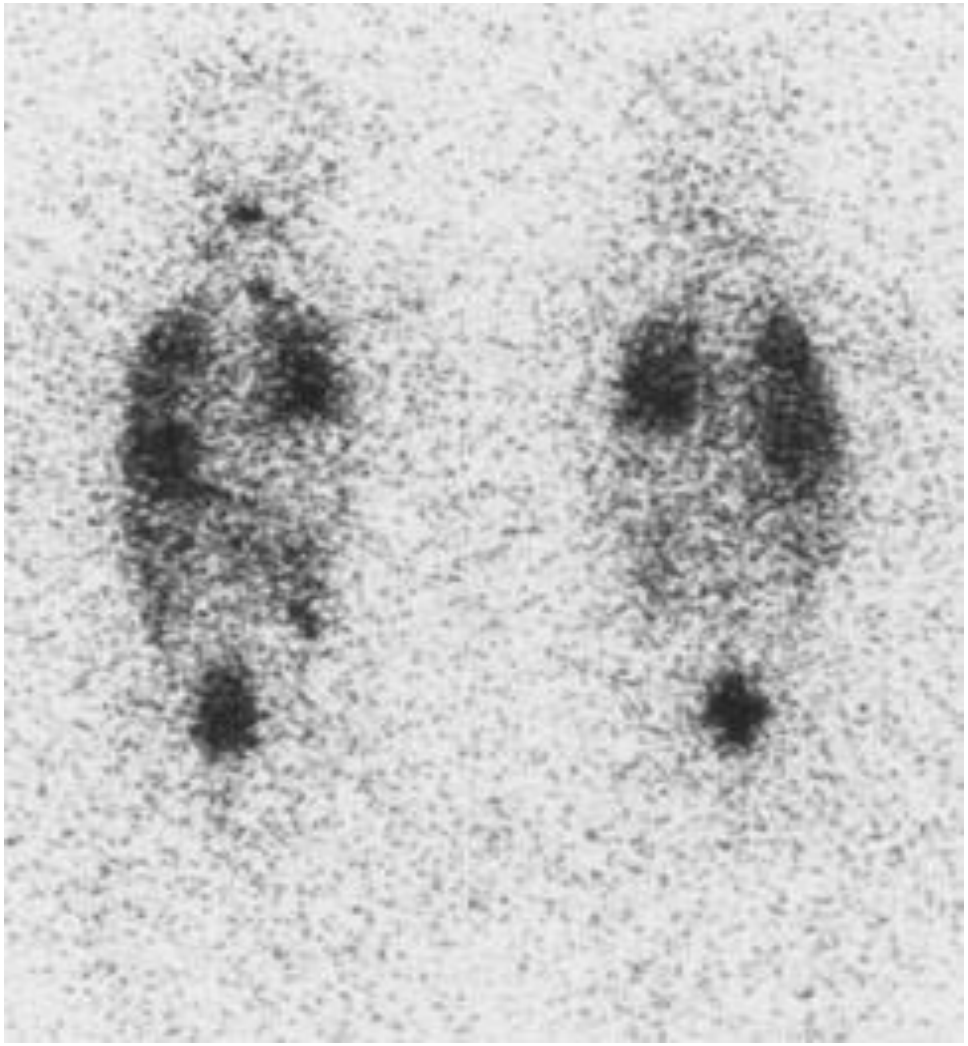
Thyroid Stunning

Diagnostic 2 mCi I-131 scan revealed neck bed activity (oral-pharyngeal, gut, and urinary bladder activity can also be seen). Following treatment with 100 mCi of I-131 the post-therapy scan demonstrated almost no evidence of tracer uptake in the neck indicative of thyroid stunning. Note hepatic activity consistent with breakdown of radiolabeled thyroxine.



Distant Metastatic Disease in Papillary Carcinoma

The I-131 exam demonstrated diffuse pulmonary tracer accumulation consistent with metastatic disease.



BONE SCAN

- Definition
- Radiopharmaceuticals
- Indications
- Images

DEFINTION

- A bone scan is a nuclear imaging test that helps diagnose and track several types of bone disease.
- In many departments, the bone scan is one of the most commonly performed nuclear medicine diagnostic procedure. X-rays, CT scans and MRI examinations evaluate the structure of the bone. In contrast, a bone scan evaluates the functional aspect of the bone diseases.This is very useful in the early diagnosis of a stress fracture when the changes in bone architecture have not taken place yet, but the bone scan is frequently abnormal at that stage.This provides the physician an opportunity to make the diagnosis early, thereby expediting treatment.
- A bone scan is also an important tool for detecting cancer that has spread (metastasized) to the bone from a tumor that started in a different organ, such as the breast or prostate.

Radiopharmaceuticals

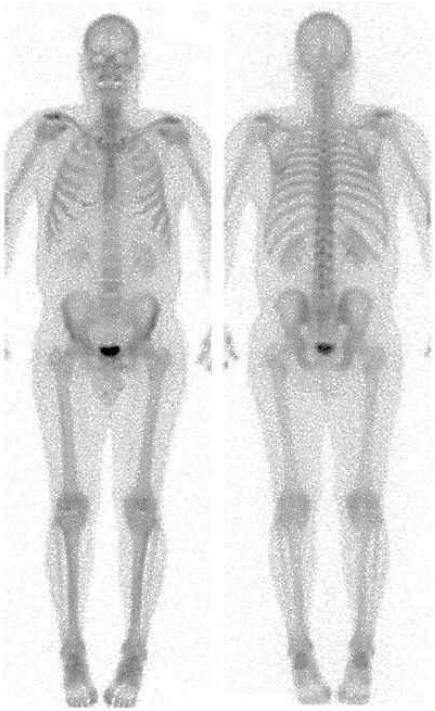
- Tc 99m –MDP (dose:15-20 mci) I.V
- TC99m-HDP (dose: 15-30 mci) I.V

Indications

- Fractures
- Arthritis
- Paget's disease of bone
- Cancer originating in bone
- Cancer that has spread (metastasized) to bone from a different primary site, such as the prostate, lung or breast
- Infection of the joints, joint replacements or bones (osteomyelitis)
- Fibrous dysplasia
- Avascular necrosis or impaired blood supply to bones
- Unexplained bone pain

Normal Bone scan

NORMAL BONE SCAN



Bone scan in breast cancer

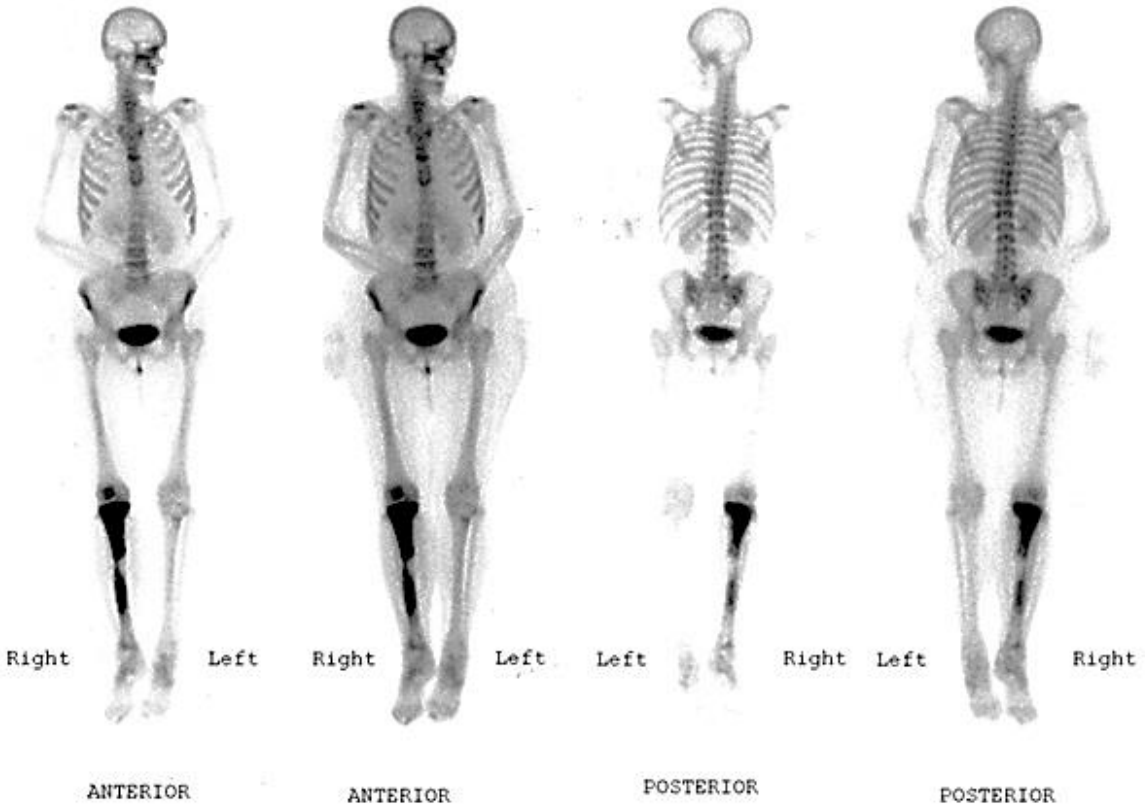
Bone Scan showing scattered focal areas of increased activity involving the spine and pelvis typical for metastatic cancer.

Although this patient is a male, breast cancer in the female would give a similar appearance

A rare presentation of bone metastasis endometrial carcinoma with coexistent osteomyelitis

A62 year-old Female patient.

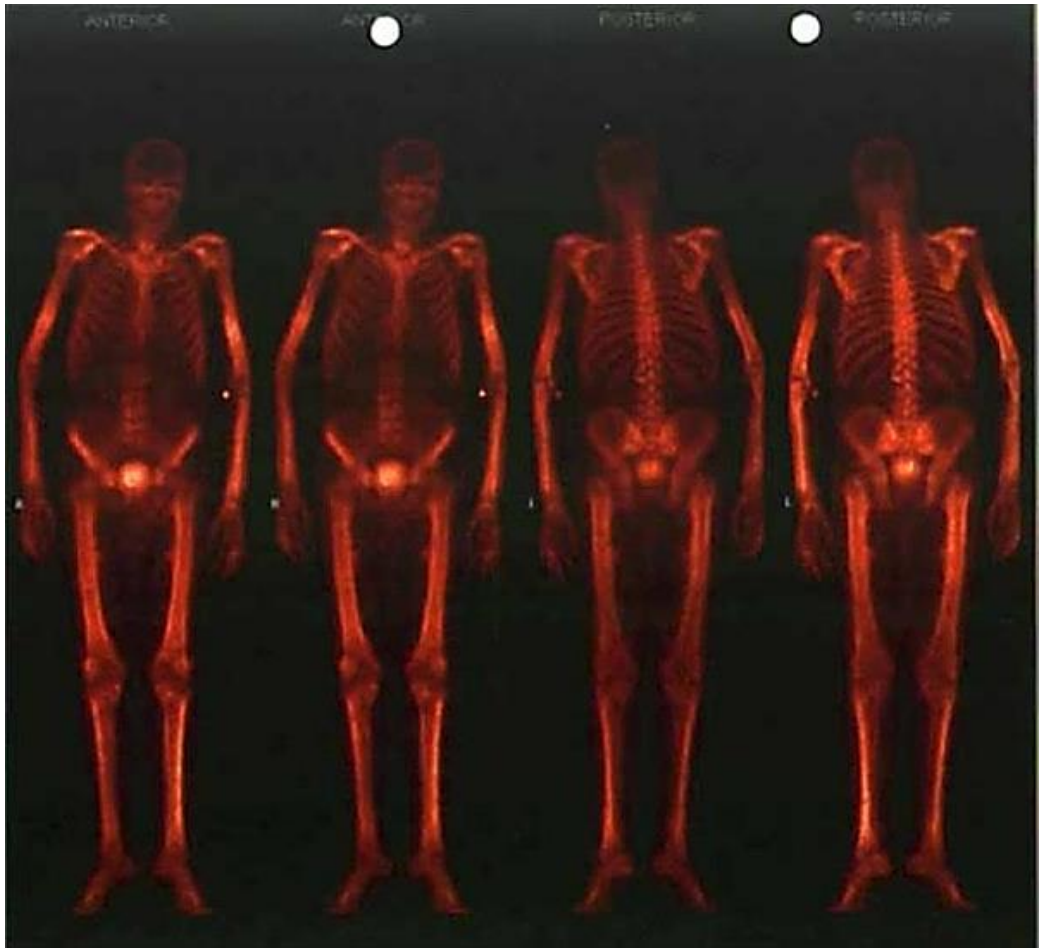
Bone scan revealed an intense hotspot in the right proximal tibia extending well into the distal third of the tibia. There were no other hot spots elsewhere.



Super bone scan prostate carcinoma

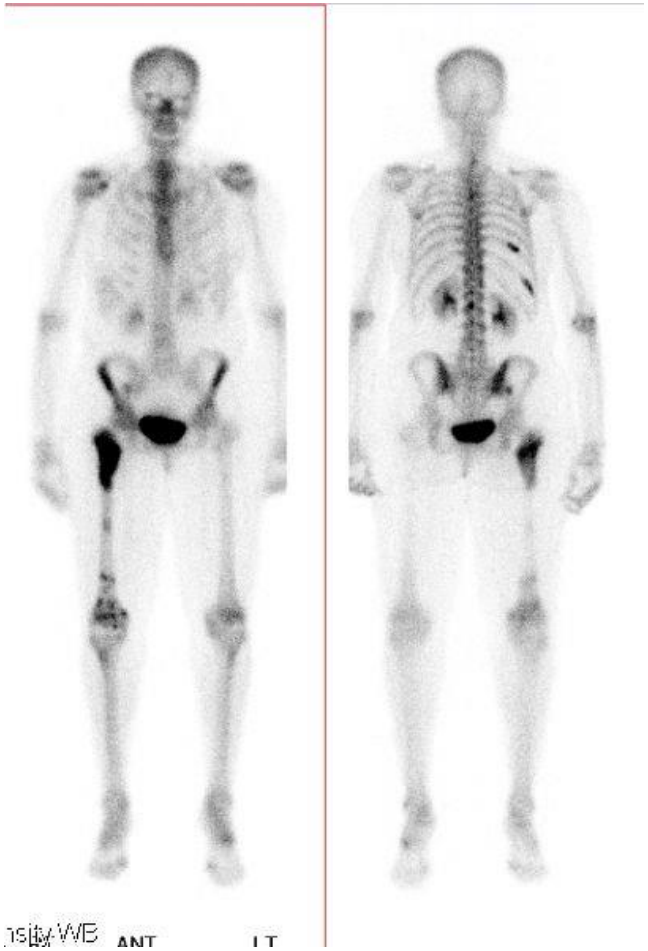
A 81 year old man with prostate adenocarcinoma .

Bone scintigraphy showing diffusely increased uptake throughout the entire skeleton and absent kidney sign .



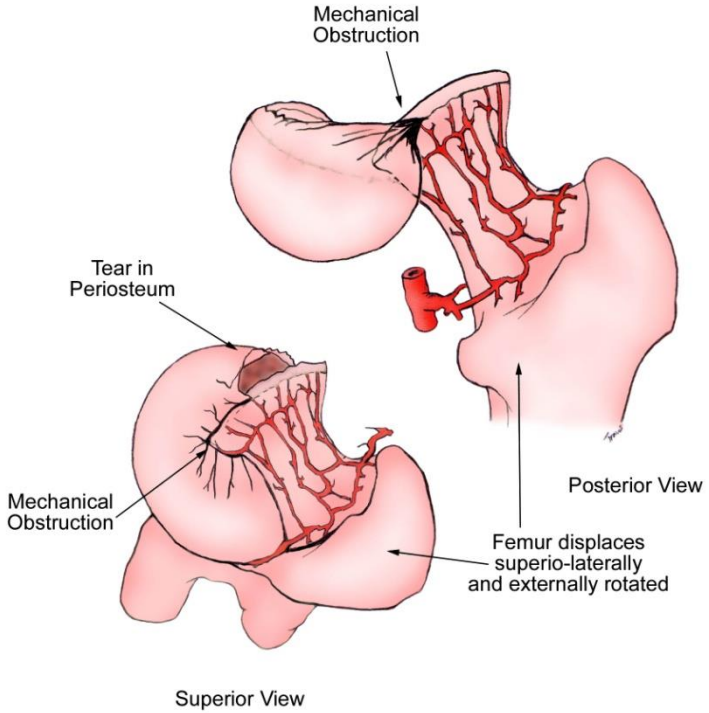
Bone scan in breast cancer

Female patient with multiple bone metastases.

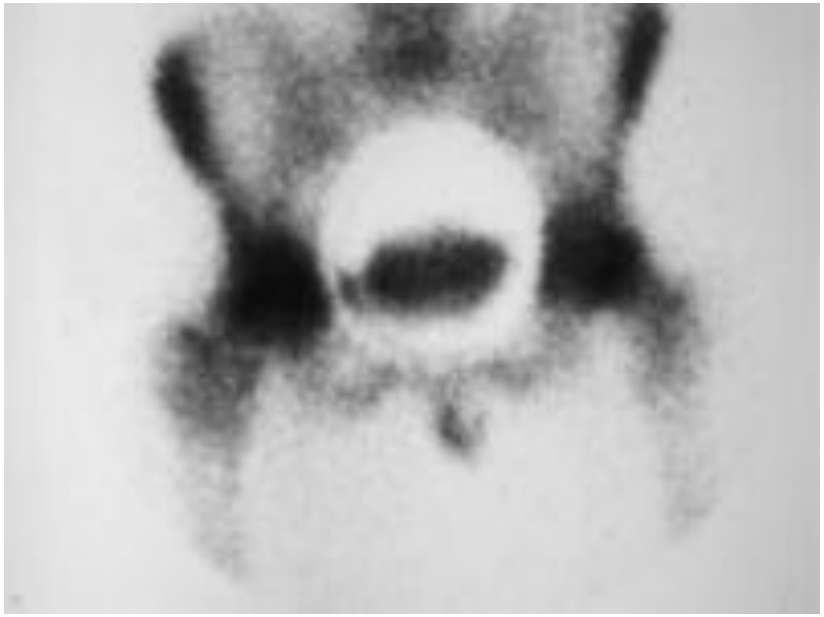


Bone scan in avascular necrosis

Blood supply to the femoral head is compromised by subcapital femoral fractures or slipped capital femoral epiphysis.

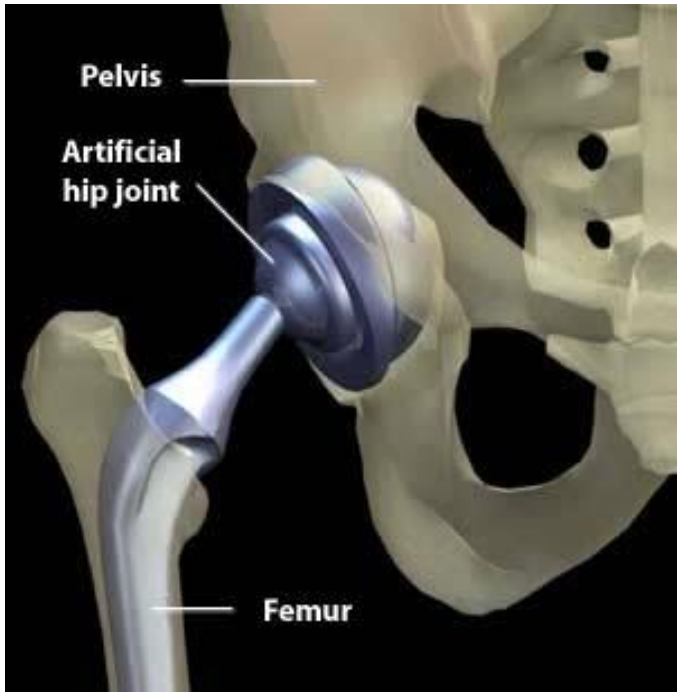


Planar bone scan of the pelvis in a patient with bilateral avascular necrosis of the femoral head



Bone scan in total hip replacement

Total hip joint replacement



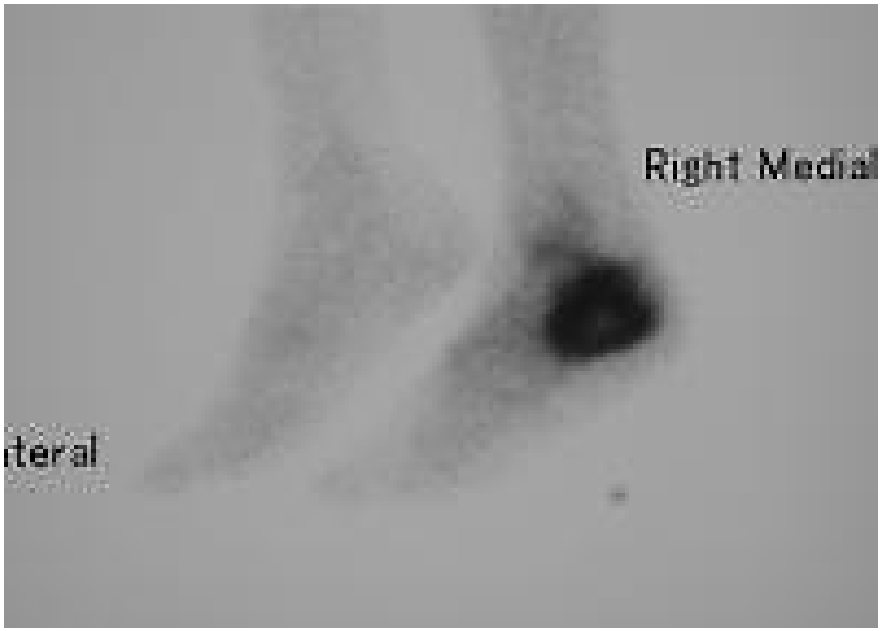
(loosening) :This image shows abnormal tracer uptake at the greater tuberosity, femoral stem, and acetabulum.

Bone scan in Paget's disease

Whole-body bone scan in a patient with polyostotic Paget disease reveals intense uptake of radiopharmaceutical in the femur, pelvis, spine, and proximal right humerus. The cortical discontinuity of the proximal right humerus represents an insufficiency fracture

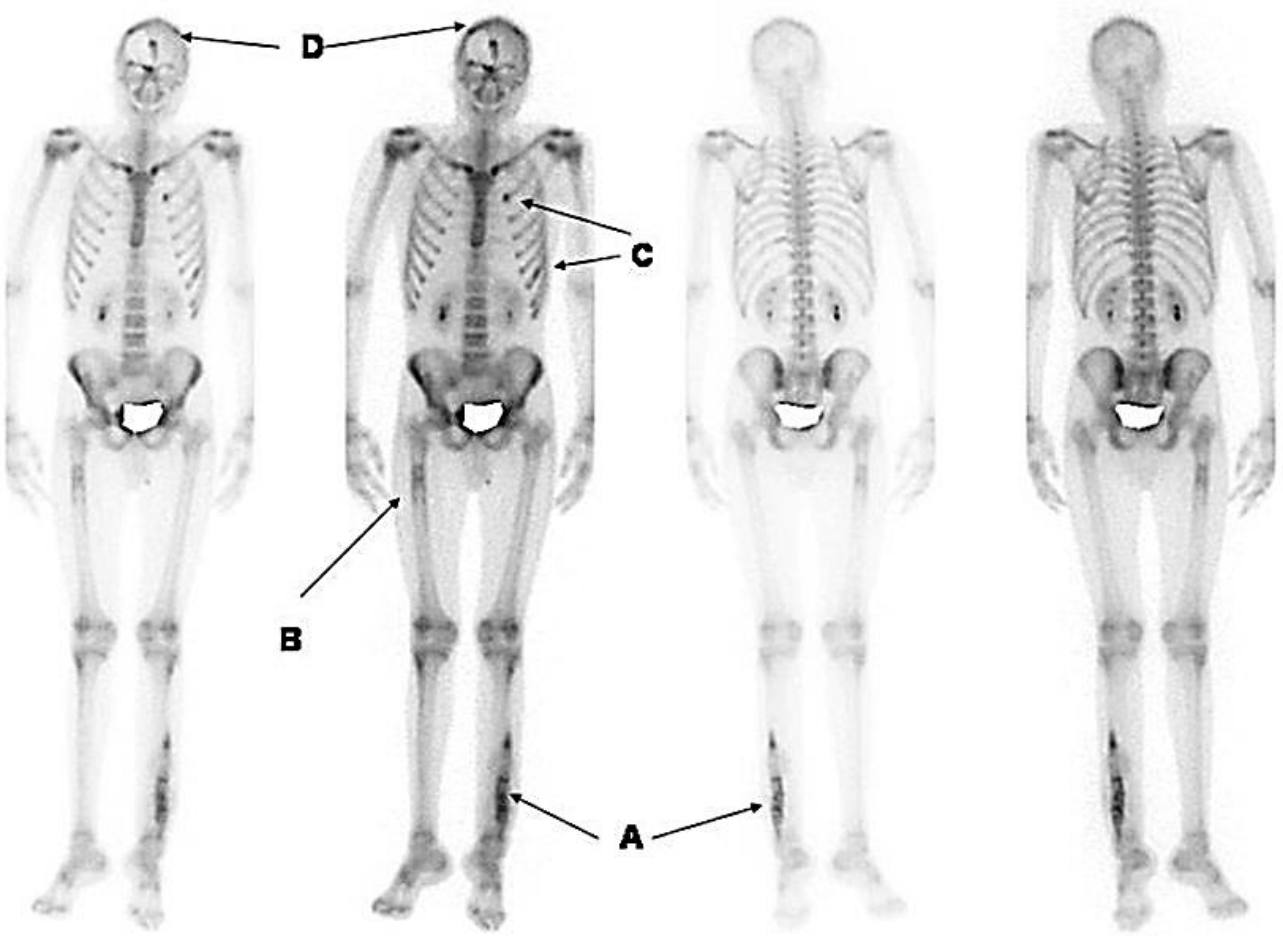
Bone scan in osteosarcoma

Scan shows increase tracer uptake in the calcaneal



Bone scan in oseoid osteoma

Bone scan in Ewing's sarcoma



Renal scintigraphy

- Definition
- Radiopharmaceuticals
- Indications
- Imaging

Definition

- A kidney scan is a nuclear scanning test that is done to evaluate kidney function or appearance.
- Two types of kidney scans can be done:

❖ A cortical scan can be done to look at the shape of the kidneys.

❖ A functional study can be done to measure the amount of time it takes for the tracer to move through the kidney, collect in the urine, and drain into the bladder.

RADIOPHARMACEUTICALS

❖Dynamic imaging

Tc-99m DTPA,Tc-99m MAG3

Dose DTPA 8-15mci I.V

MAG3 5-10mci I.V

Lasix 0.5mg/kg I.V

❖Static imaging

TC-99m DMSA

Dose 2-6mci I.V

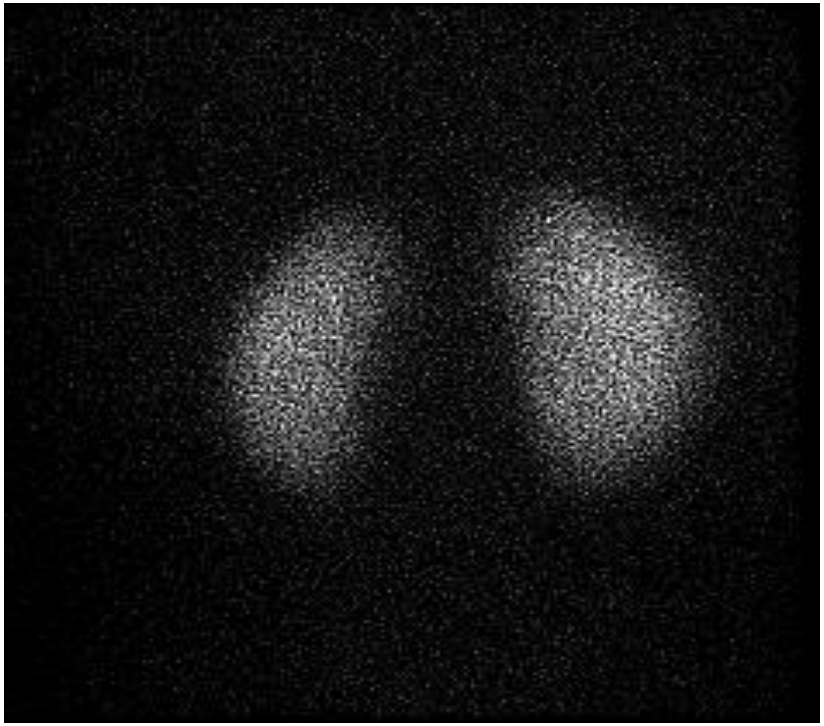
INDICATIONS

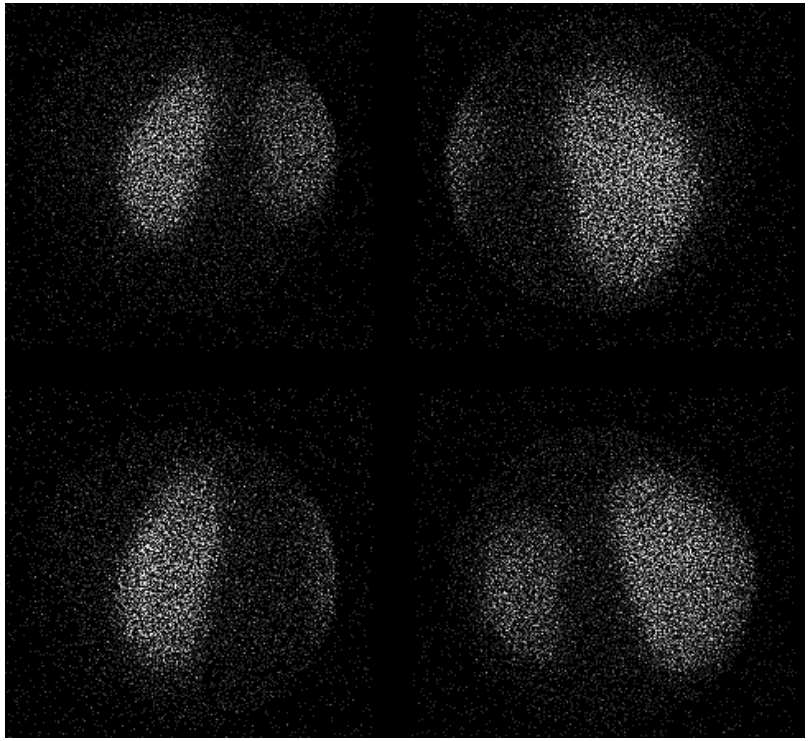
- Individual renal function
- obstructive nephropathy
- renovascular hypertension
- urinary tract infection
- renal transplantation
- Ectopic kidney
- GFR

Normal renal parenchymal imaging study DMSA SCAN

2 year old child being evaluated for renal parenchymal scarring

0.9 mCi Tc-99m DMSA

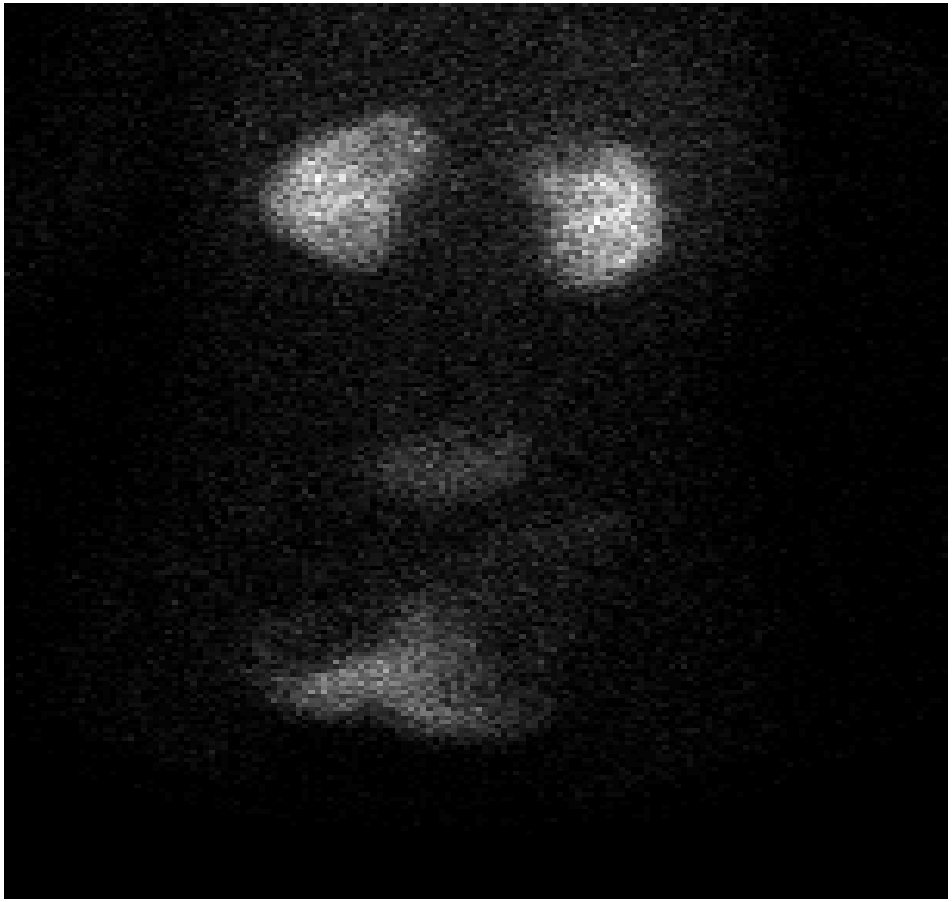




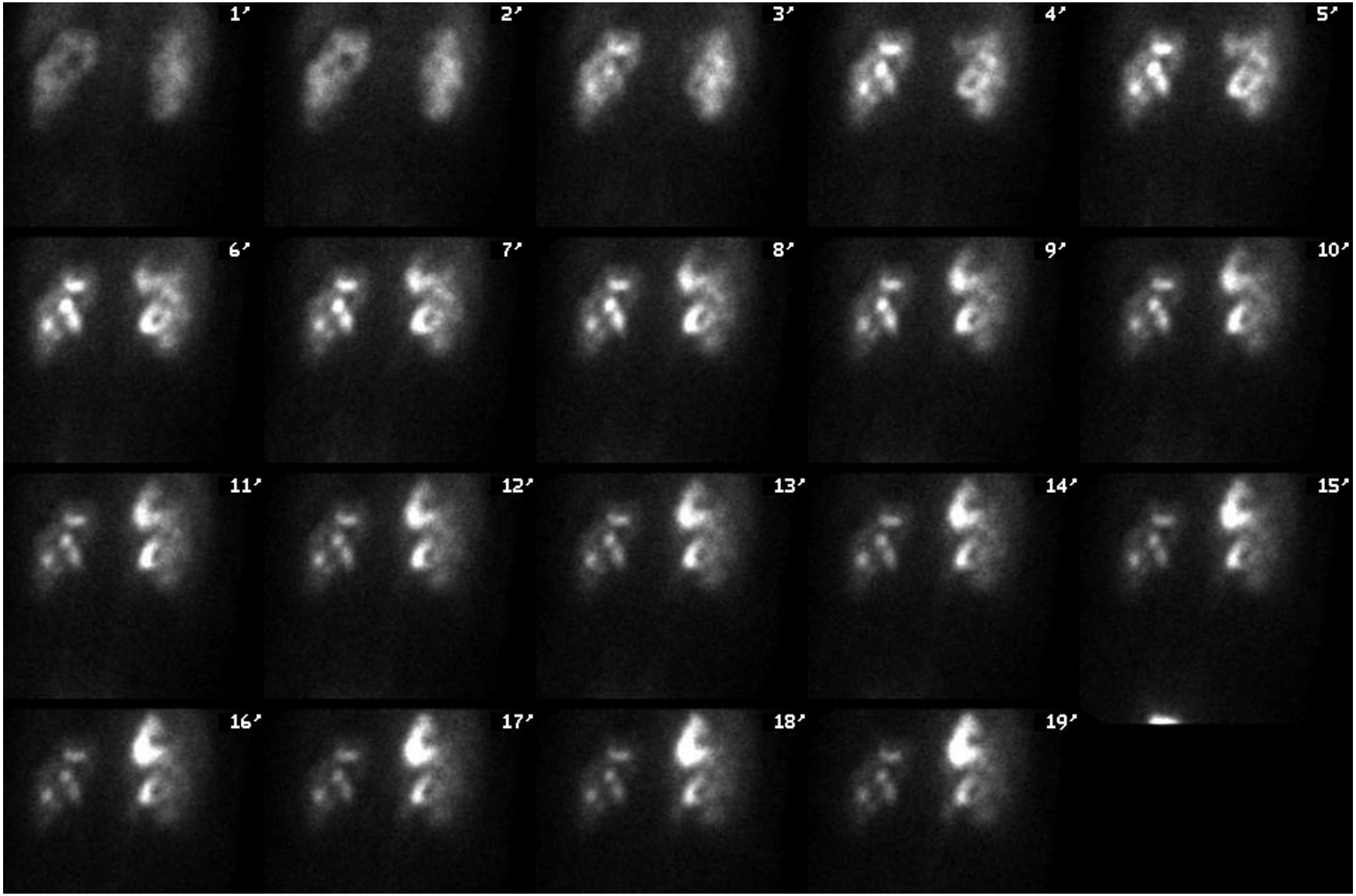
Pyelonephritis (SCAR)

2 year old female with fevers, pyuria, and leukocytosis

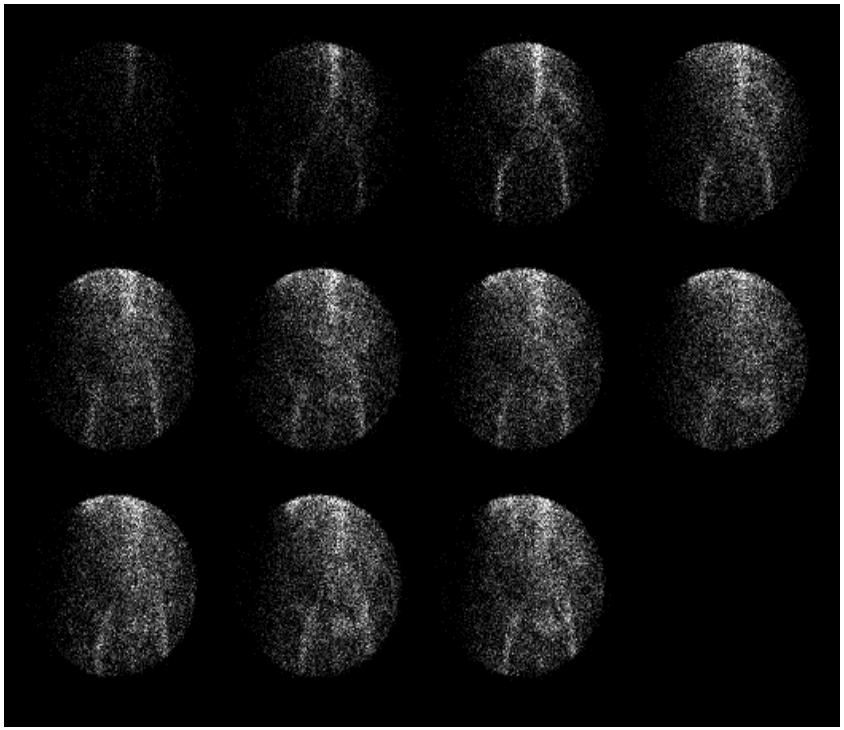
- there is a cortical defect in the upper pole of the right kidney that corresponded to the abnormality on the immediate and static views.

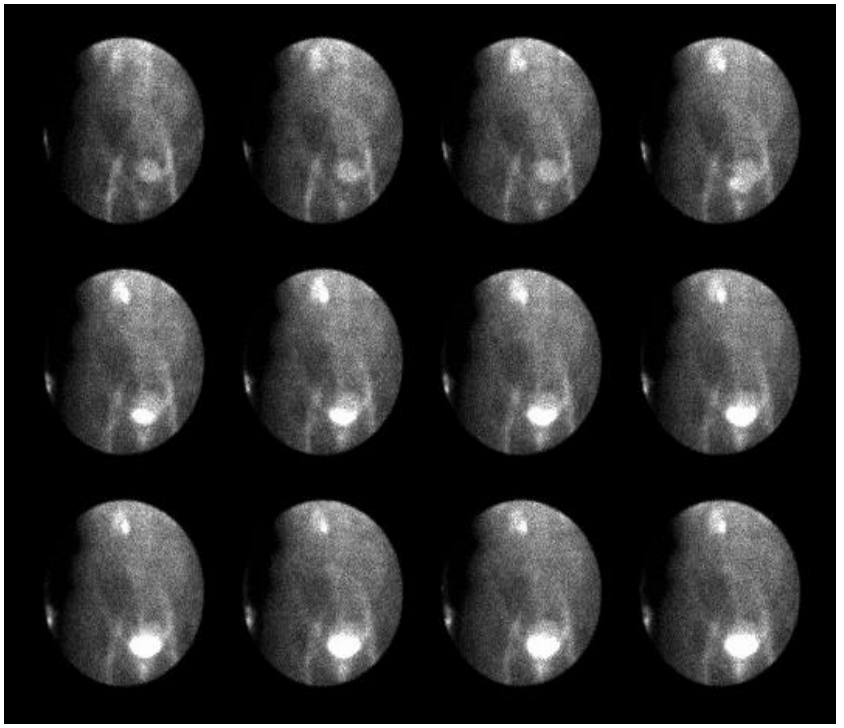


Polycystic kidney disease

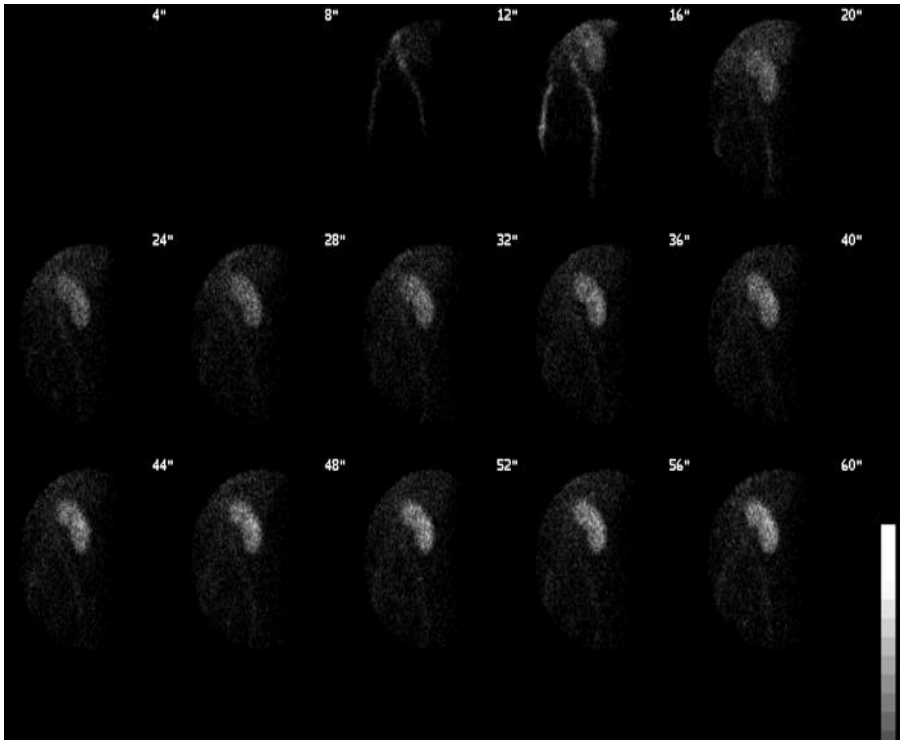


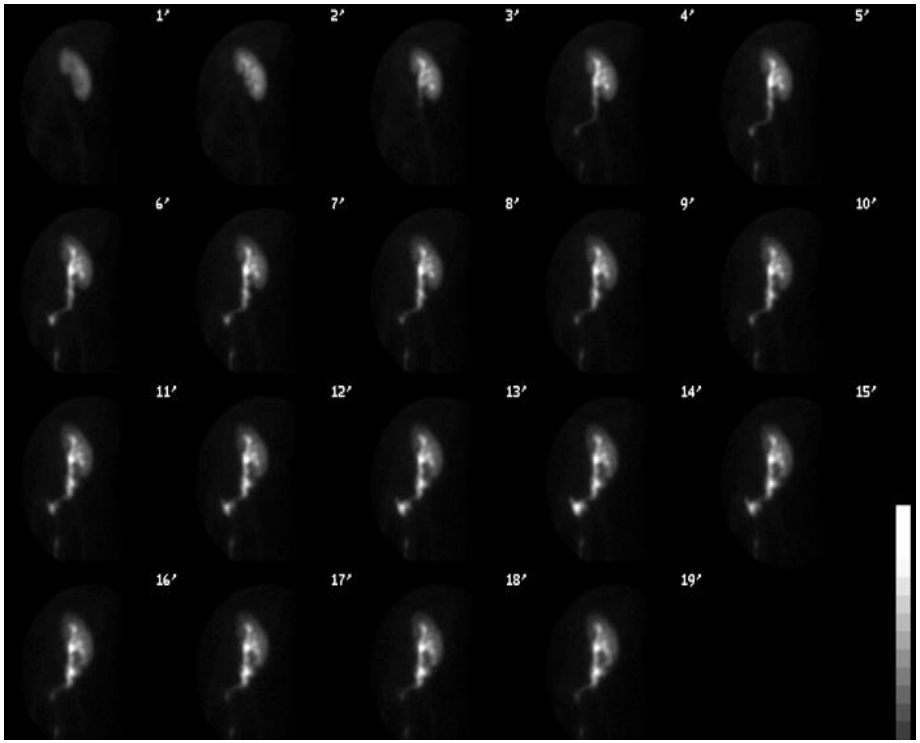
Transplant infarction



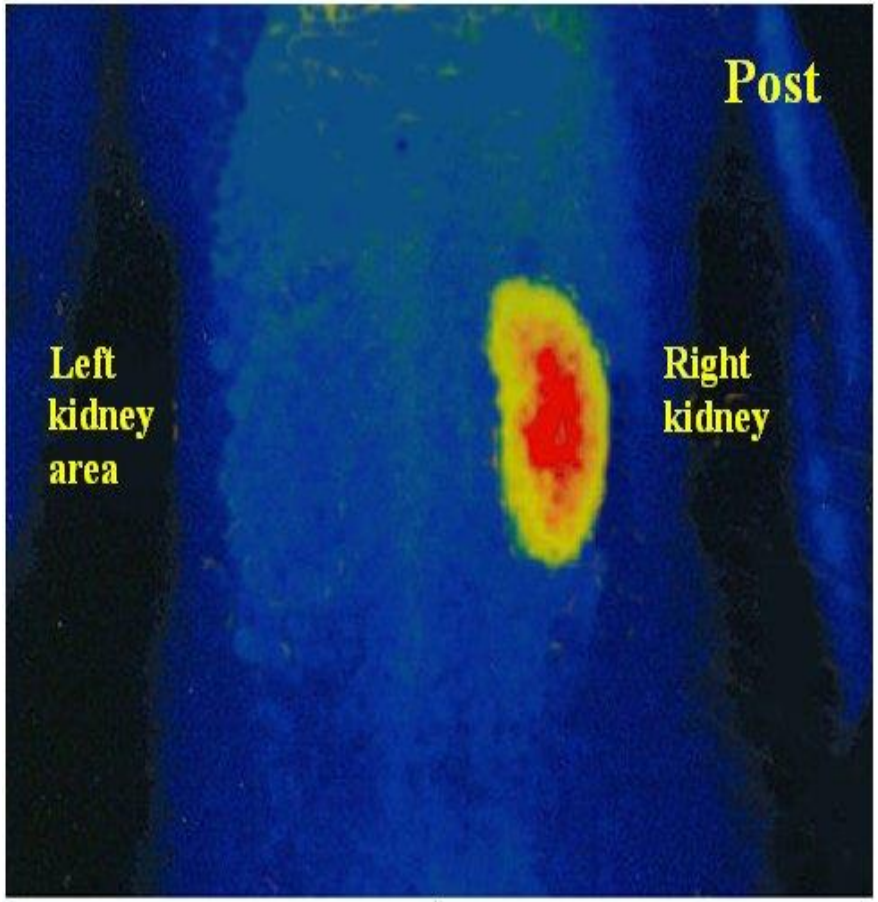


Renal Transplant ATN and Urine Leak

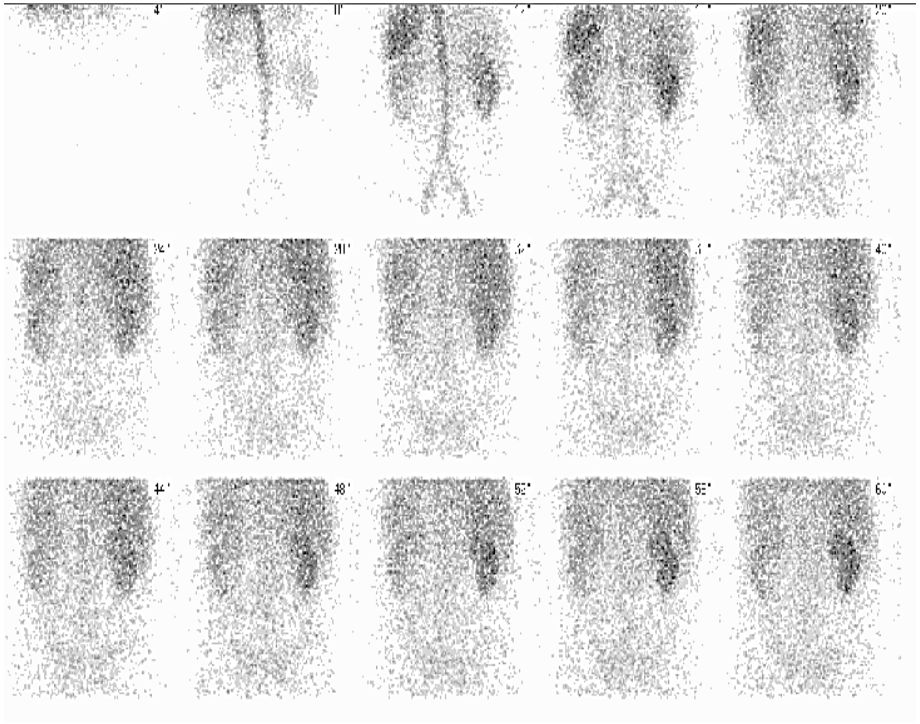


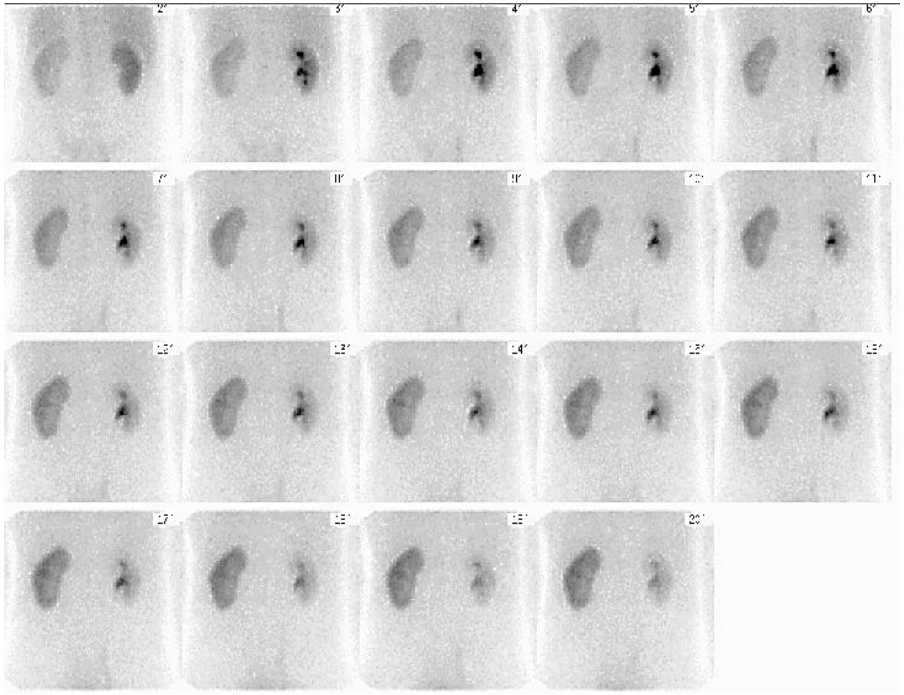


Unilateral renal agenesis revealed by hydronephrosis of contralateral kidney and explored by ^{99m}Tc-DMSA and CT



Acute left renal obstuction

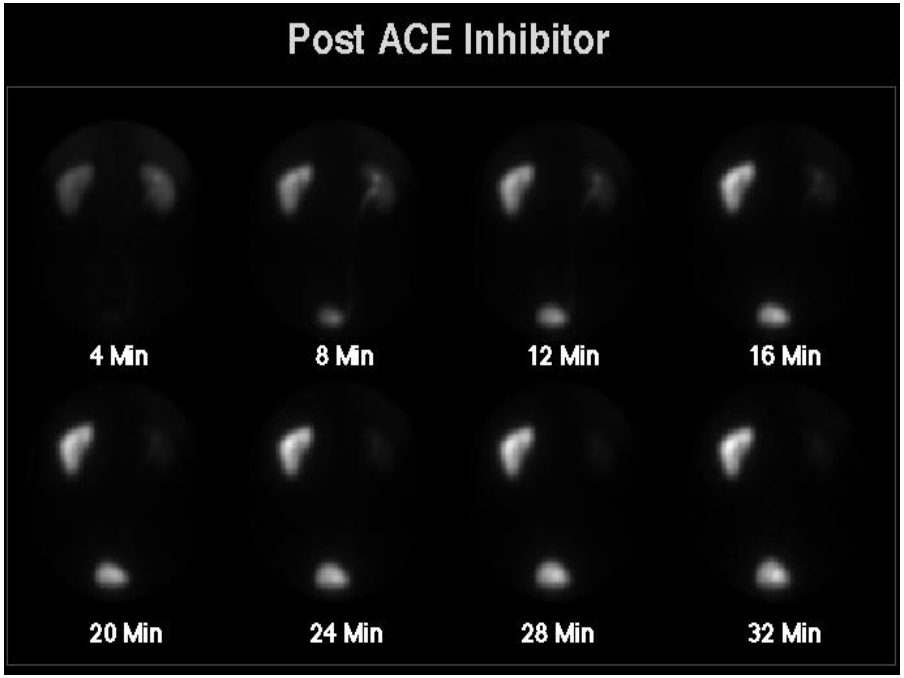


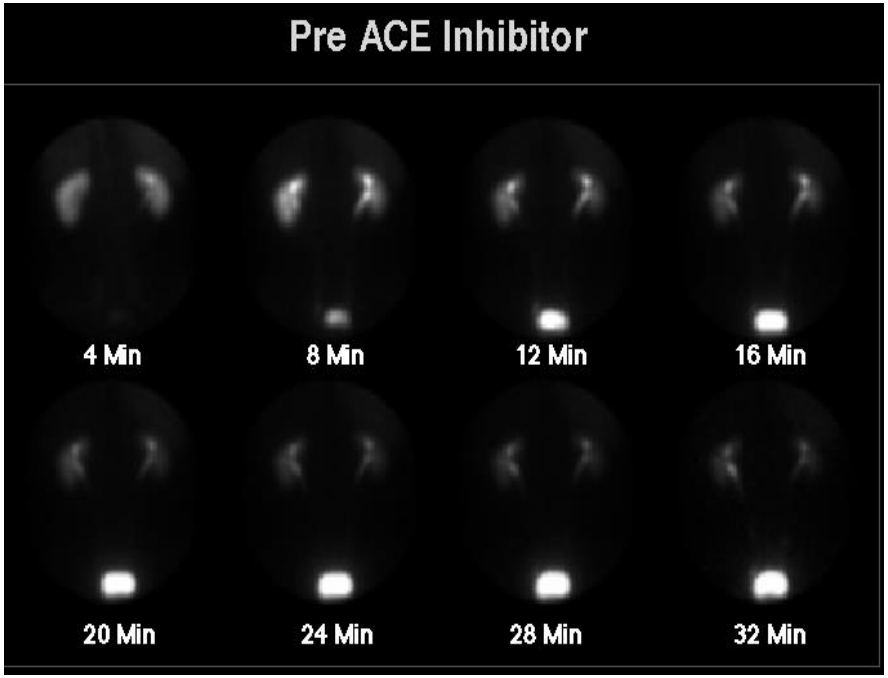


Renal Artery Stenosis

2.5 mg enalapril intravenously over a five minute period followed by administration of Tc-99m MAG3

Tc-99m MAG3





Bone mineral density (BMD)

- Definition
- Indications
- Findings
- Scan

Definition

- The BMD is measured with a dual energy x-ray absorptiometry test (referred to as a DEXA scan).
- The absolute amount of bone as measured by bone mineral density (BMD) testing generally correlates with bone strength and its ability to bear weight.
- By measuring BMD, it is possible to predict fracture risk in the same manner that measuring blood pressure can help predict the risk of stroke.

Indications

- Personal history of fracture as an adult
- Low body weight or thin body stature
- Advanced age
- Use of corticosteroid therapy for more than three months
- Estrogen deficiency at early age
- Lifelong low calcium intake
- Low physical activity
- Alcohol intake
- Thyroid disease

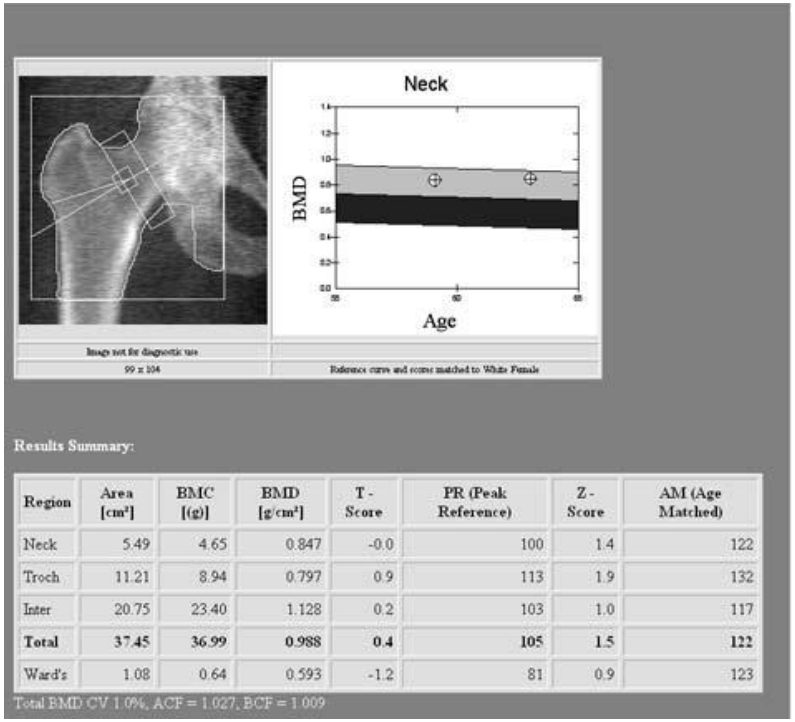
Findings

- **Normal: A bone BMD is considered normal if the T-score is within 1 standard deviation of the normal young adult value. Thus a T-score > -1 is considered a normal result.**
- **Osteopenia(Low bone mass): A BMD defines osteopenia as a T-score between -1 and -2.5. This signifies an increased fracture risk but does not meet the criteria for osteoporosis.**

- **Osteoporosis: A BMD greater than 2.5 standard deviations from the normal (T score less than or equal to -2.5) defines osteoporosis.**

Dexa machine

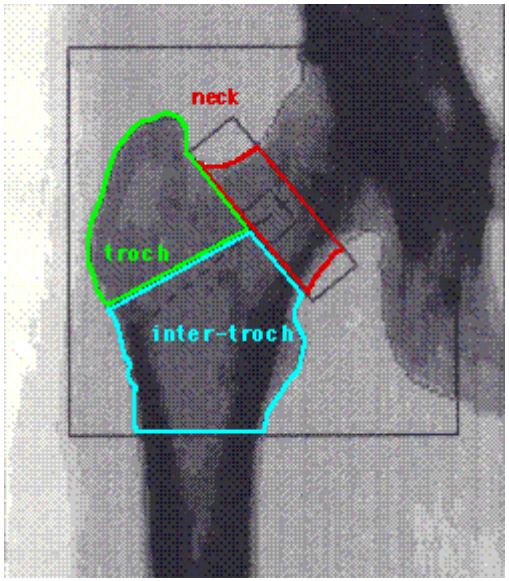
Dexa scan (femural)
neck T-score +1.4
total t-score +1.5



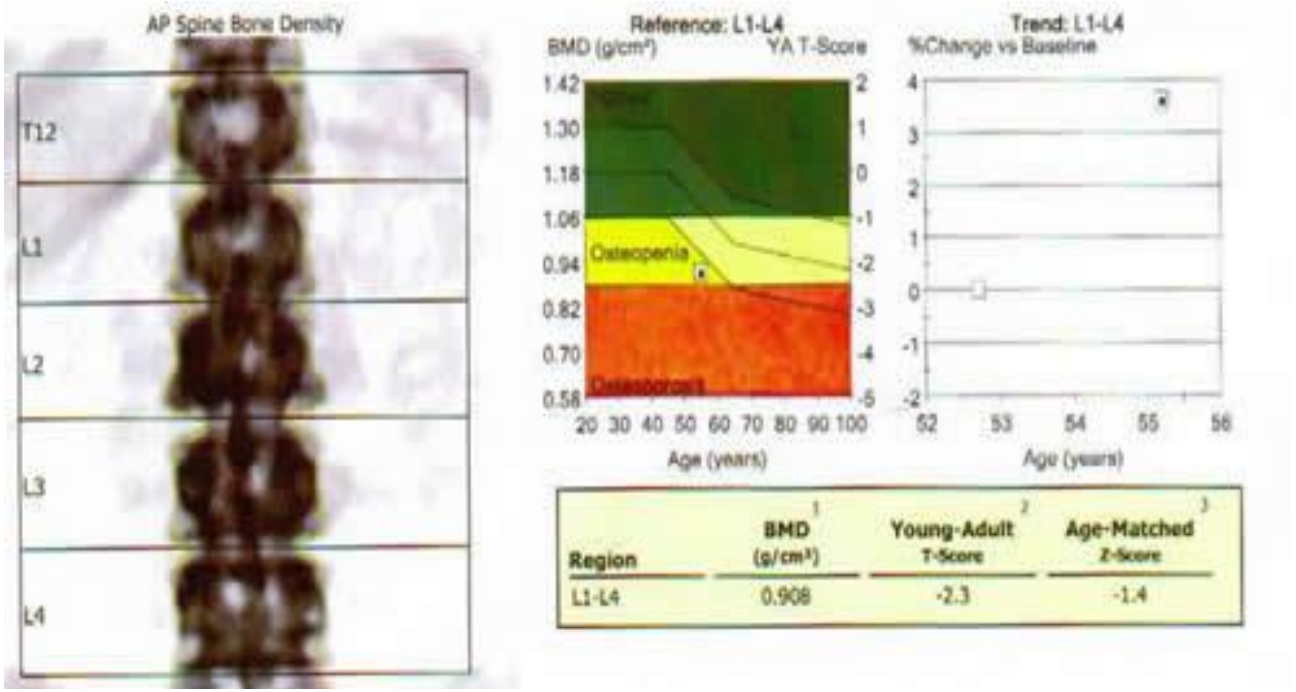
Results Summary:

Region	Area [cm²]	BMC [(g)]	BMD [g/cm²]	T - Score	PR (Peak Reference)	Z - Score	AM (Age Matched)
Neck	5.49	4.65	0.847	-0.0	100	1.4	122
Troch	11.21	8.94	0.797	0.9	113	1.9	132
Inter	20.75	23.40	1.128	0.2	103	1.0	117
Total	**37.45**	**36.99**	**0.988**	**0.4**	**105**	**1.5**	**122**
Ward's	1.08	0.64	0.593	-1.2	81	0.9	123

Total BMD CV 1.0%, ACF = 1.027, BCF = 1.009



Dexa scan (lumbar) T-score -2.3



GENERATOR (1)

6.1.1. Principles of generator operation

A $^{99}Mo/^{99m}Tc$ generator, or 'technetium generator', is a device used to recover and concentrate technetium from ^{99}Mo. A conventional generator consists of an alumina (Al_2O_3) column about the size of a short pencil; associated tubing, valves and filters for extracting technetium; and lead shielding for radiation protection (see Fig. 11.)

The column is loaded with ^{99}Mo at the generator manufacturing facility before shipment to a hospital, radiopharmacy or clinic. The ^{99}Mo in the column decays to technetium with about a 66 hour half-life. About 88.6% of the ^{99}Mo decays to ^{99m}Tc; the remainder decays directly to ^{99}Tc. Technetium is extracted (eluted) by passing a saline solution through the column.

The half-life of ^{99}Mo is about 10 times longer than that of ^{99m}Tc. Approximately 50% of the steady state activity is reached within one ^{99m}Tc half-life and approximately 75% within two half-lives. Therefore, ^{99m}Tc can be

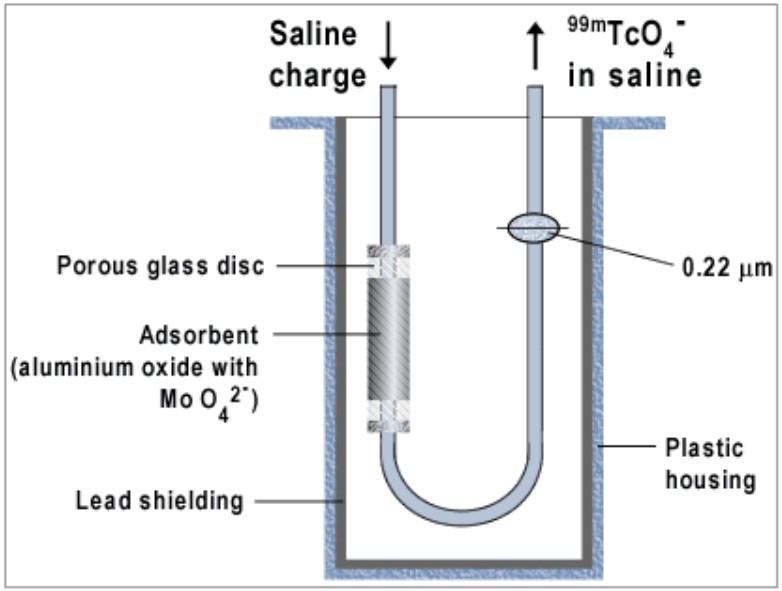
FIG. 11. External and cutaway view of LMI's TechneLite® $^{99}Mo/^{99m}Tc$ generator. Photos used with permission from Lantheus Medical Imaging, Inc. All rights reserved.

GENERATOR (2)

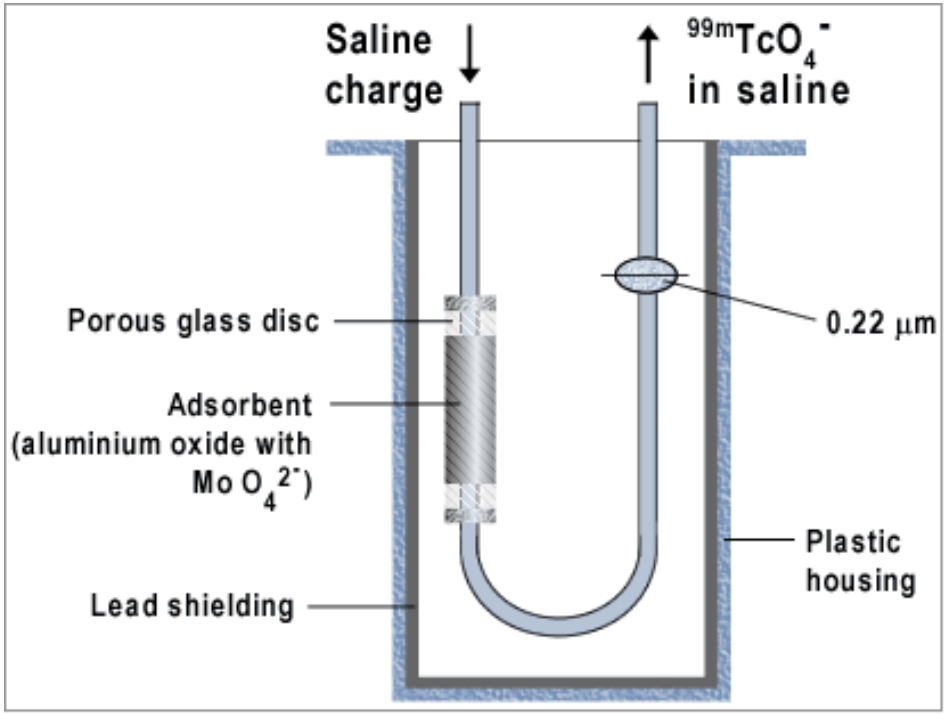
FIG. 13. $^{99}Mo/^{99m}Tc$ generator manufactured by IPEN.

GENERATOR (3)

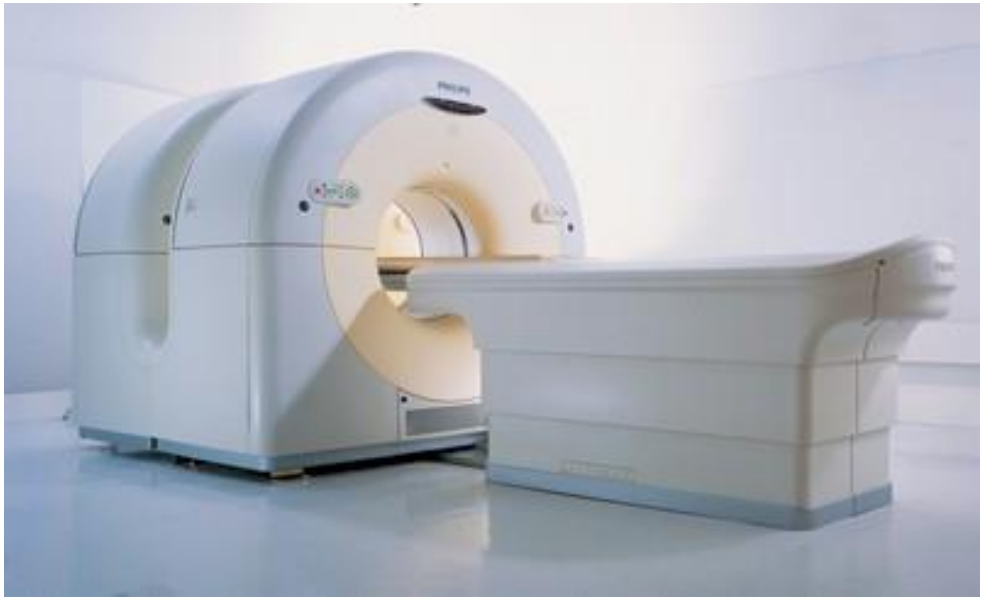
The diagram illustrates the typical components found in a $^{99}Mo \rightarrow {}^{99m}Tc$ radionuclide generator. The design of the individual components will vary by manufacturer but will always allow for the separation and elution of the daughter radionuclide ^{99m}Tc from the parent radionuclide ^{99}Mo. The elution will result in a product that is sterile and free of impurities thus making it immediately suitable for human injection. The components in the typical generator are:



MODULES

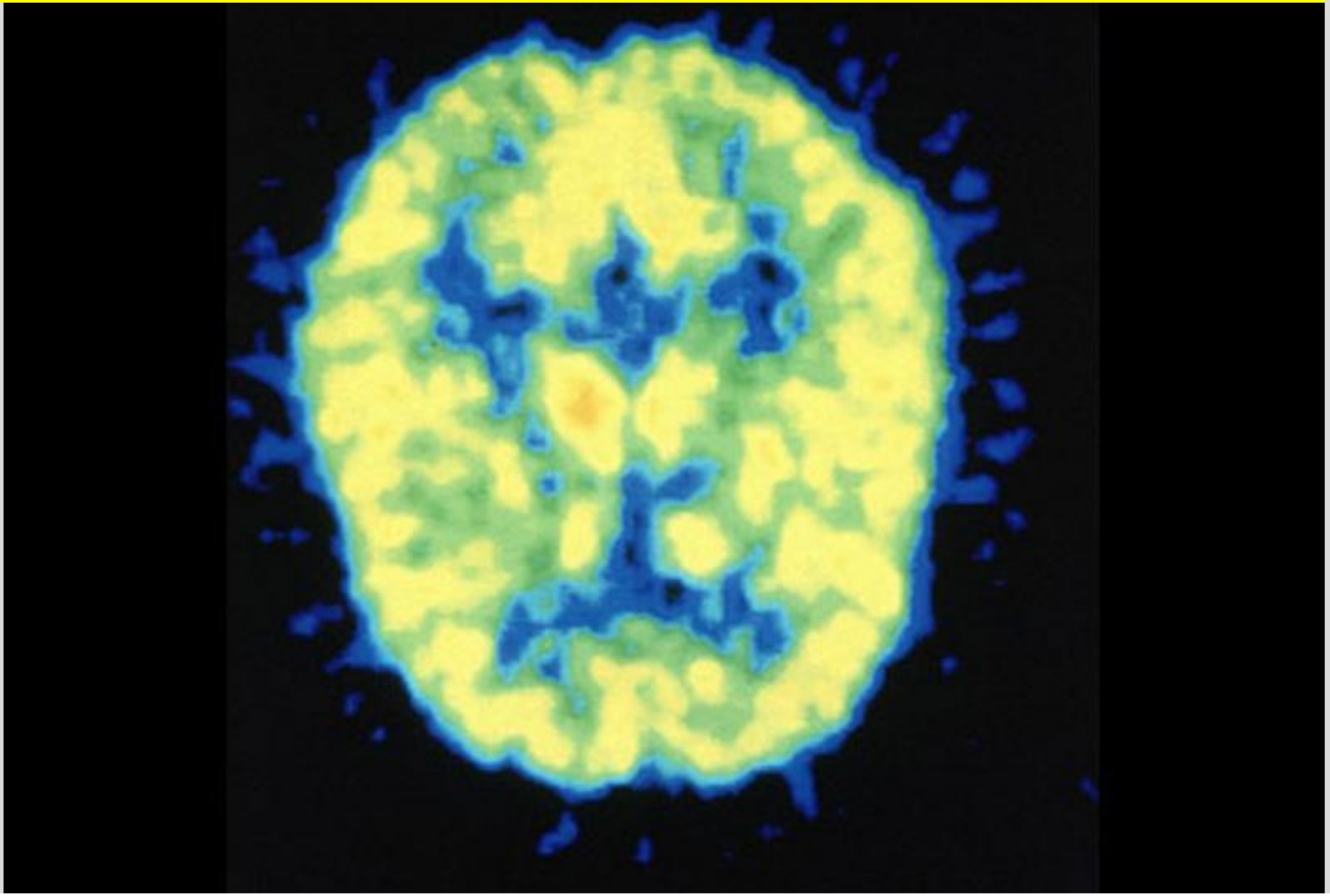

Saline charge
$^{99m}TcO_4^-$ in saline
Porous glass disc
Adsorbent (aluminium oxide with MoO_4^{2-})
Lead shielding
0.22 µm
Plastic housing

POSITRON EMISSION TOMOGRAPHY



A PET scanner in use

COLOUR-ENHANCED PET SCAN OF THE BASAL GANGLIA



This image shows a PET scan of the basal ganglia of a healthy brain. In this case, the scan has been enhanced with colour.

Definition

A positron emission tomography is a nuclear medical imaging technique which produces a three dimensional image of functional processes in the body.

History of PET scan

- The concept of emission and transmission tomography was introduced by David E. Kuhal and Roy Edwards in the late 1950s at the university of Pennsylvania.

- In the 1970s, Tatsuo Ido at the Brookhaven National laboratory was the first to describe the synthesis of 18-F FDG, the most commonly used PET scanning isotope carrier.

- Now there is not one person who developed the PET scan but a whole collection of people have made what it is today.

How does it work...

A short lived radioactive tracer isotope, is injected in to the living subject (usually in to blood circulation) .The tracer is chemically incorporated in to a biologically active molecule.

↓

There is a waiting period while the active molecule becomes concentrated in tissues of interest.

↓

As the radioisotope undergoes positron emission decay (also known as positive beta decay), it emits a positron, an antiparticle of the electron with opposite charge.

↓

After traveling up to a few millimeters the positron encounter an electron.

↓

The encounter annihilates them both, producing a pair of (gamma) photon moving in opposite directions.

↓

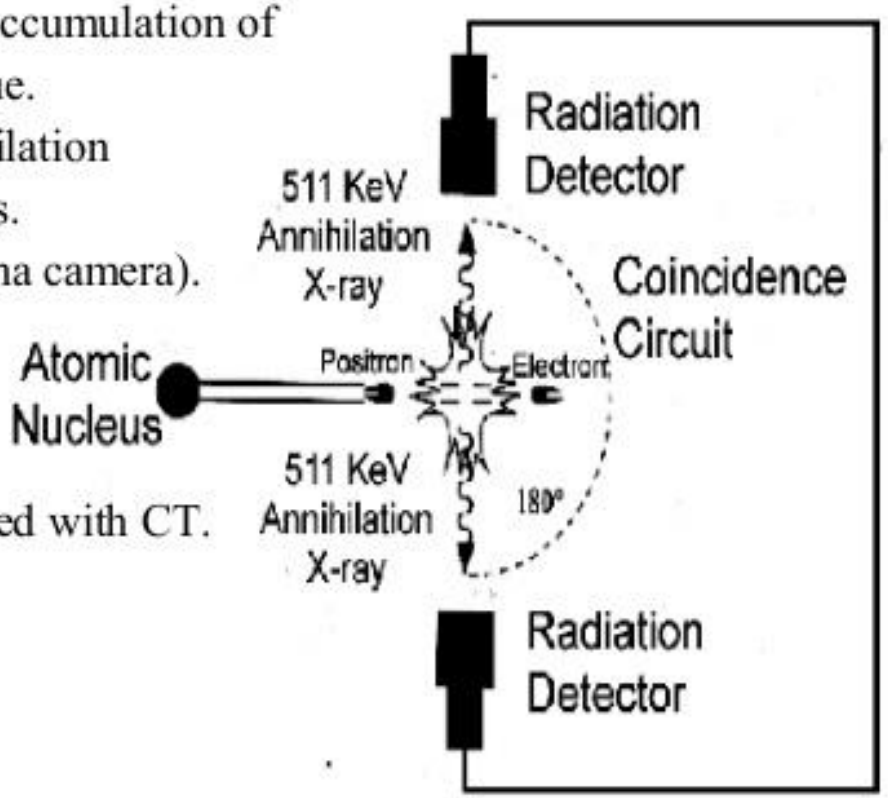
These are detected when they reach scintillator in the scanning device creating a burst of light which is detected by photomultiplier tubes.

↓

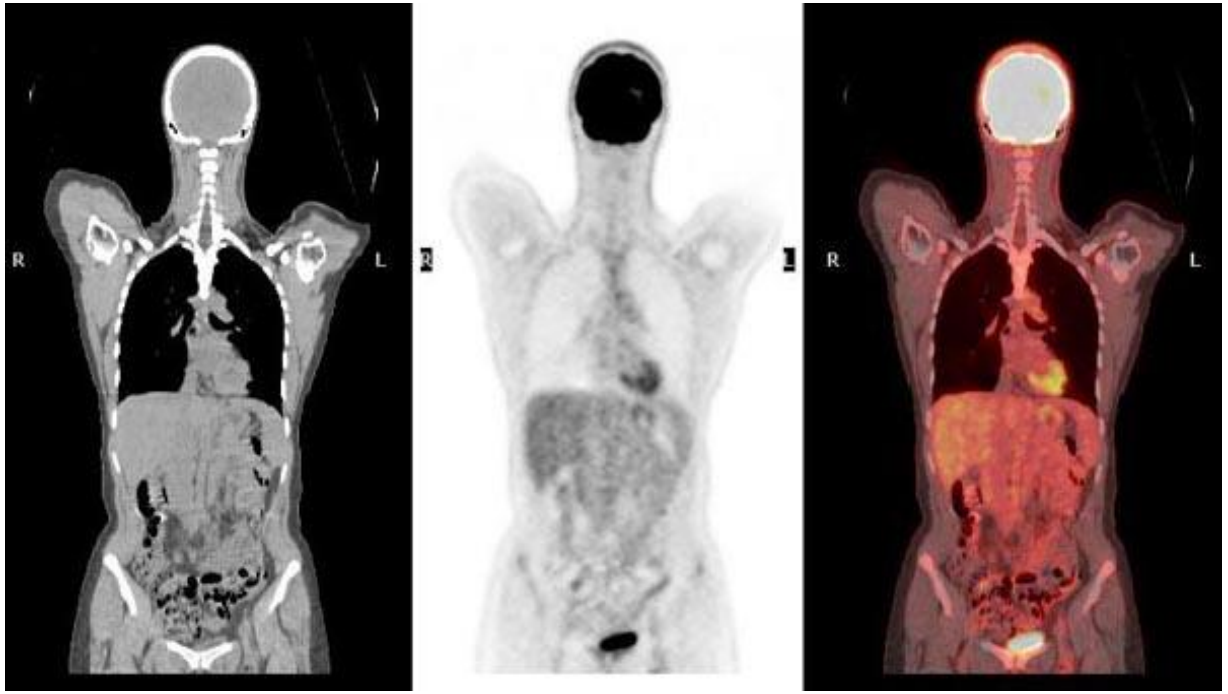
The technicians can then create an image of the parts of your brain, for example which are overactive.

How Does PET Work?

- Administration of radiopharmacon
- Decay of isotope internally, accumulation of radiopharmacon in diseased tissue.
- Electron interaction → annihilation → emission of 2 gamma photons.
- Scintillating detectors (gamma camera).
- Collection and storage of data → reconstruction of 2D distribution map.
- Most scans today are combined with CT.



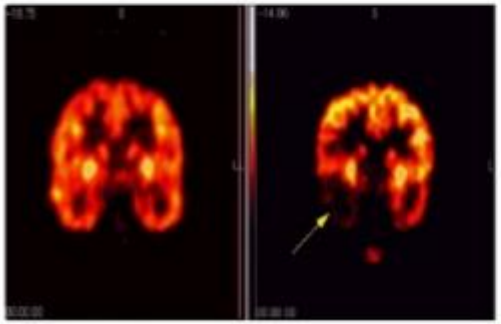
PET SCAN

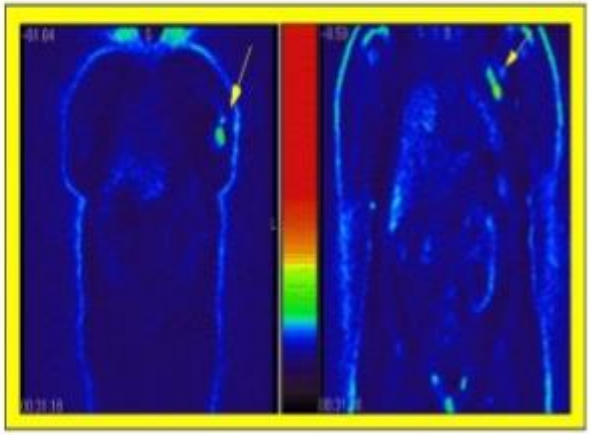


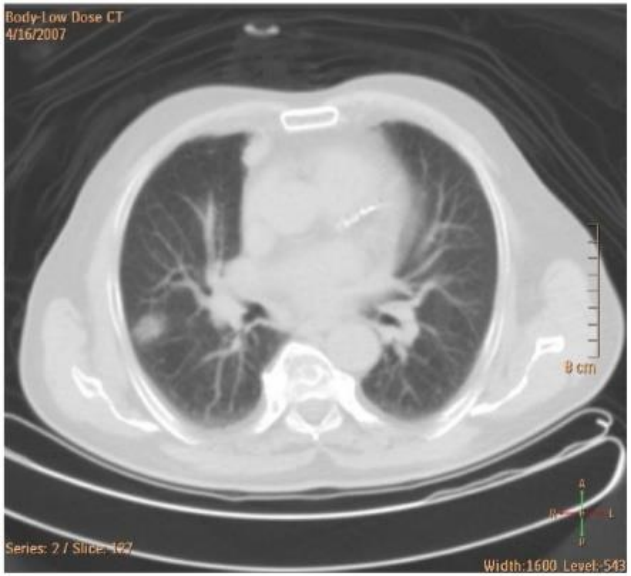
Uses

- Detecting cancer.
- Determining whether a cancer has spread in the body.
- Assess the effectiveness of a treatment plan, such as cancer therapy.
- Determining if a cancer has returned after treatment.
- Determining blood flow to the heart muscle.
- Determining the effects of a heart attack, or myocardial infarction, on areas of the heart.
- Identifying areas of the heart muscle that would benefit from a procedure such as angioplasty or coronary artery bypass surgery (in combination with a myocardial perfusion scan).
- Evaluation brain abnormalities, such as tumors, memory disorders and seizures and other central nervous system disorders.
- To map normal human brain and heart function.

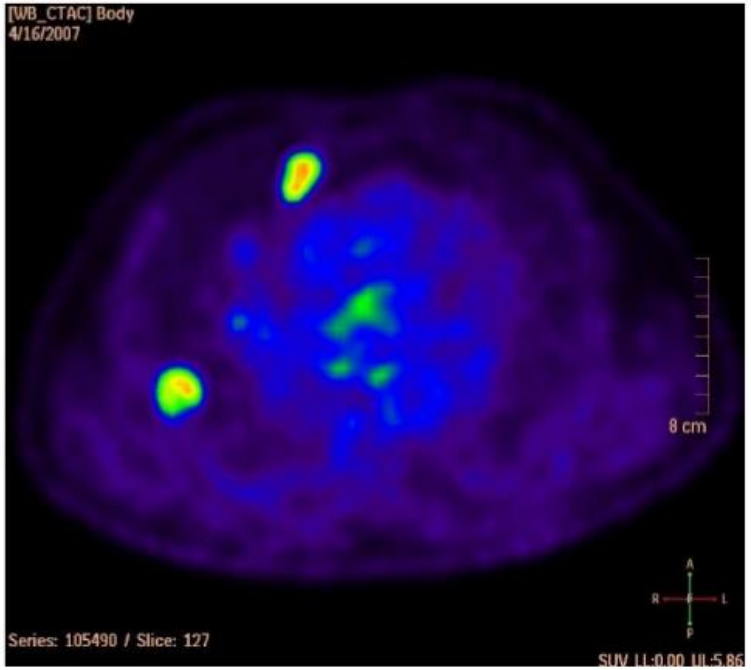
Medical Fields Of Application





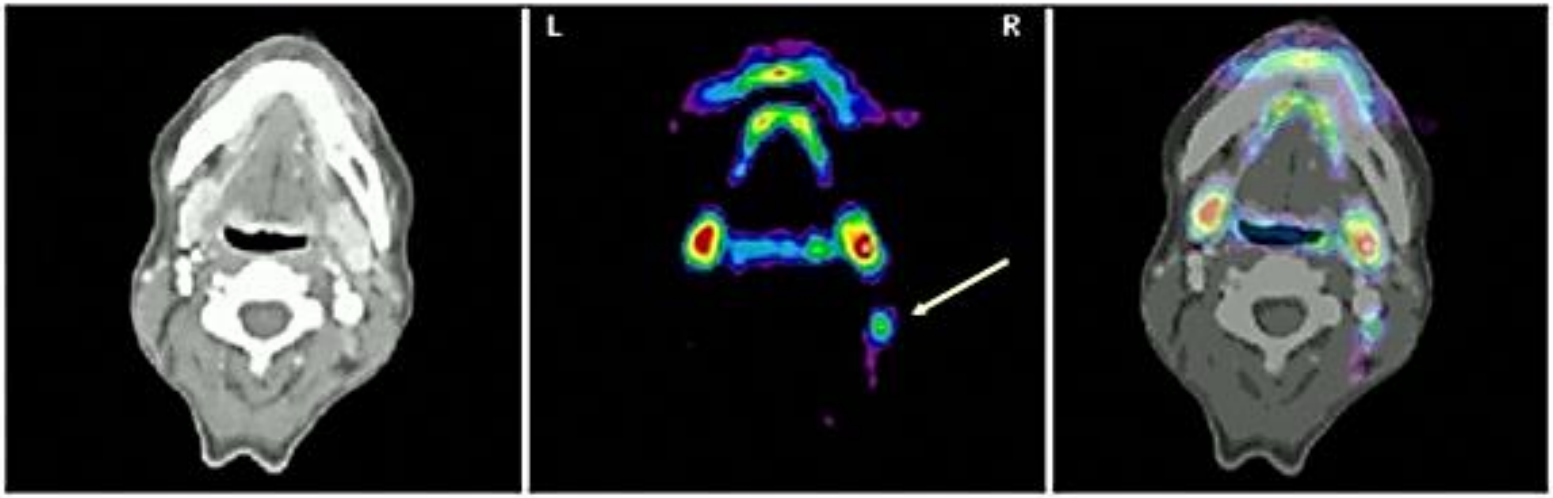


CT scan



PET scan

Metastatic lymph node on the right side of the neck

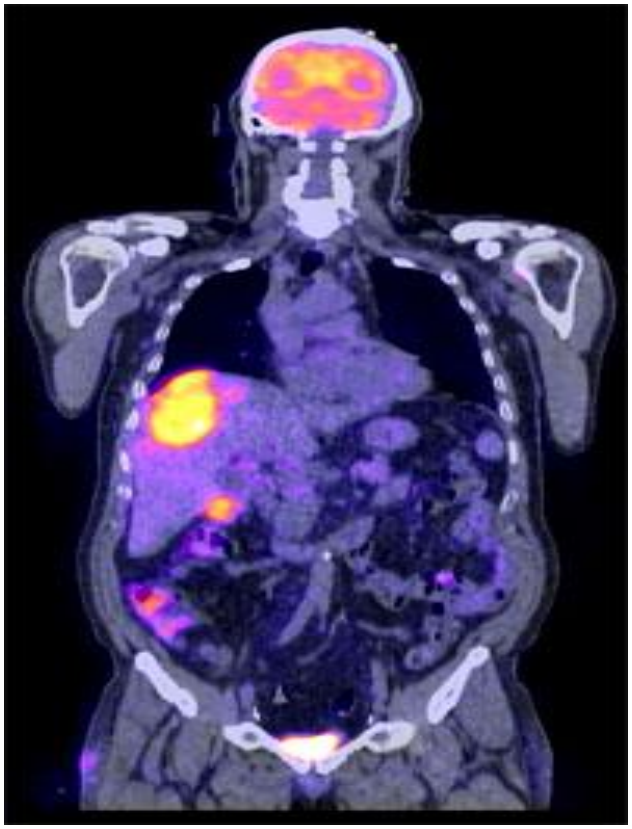


CT [^{11}C]Methionine-PET CT-PET image fusion

Combined PET/CT scanner

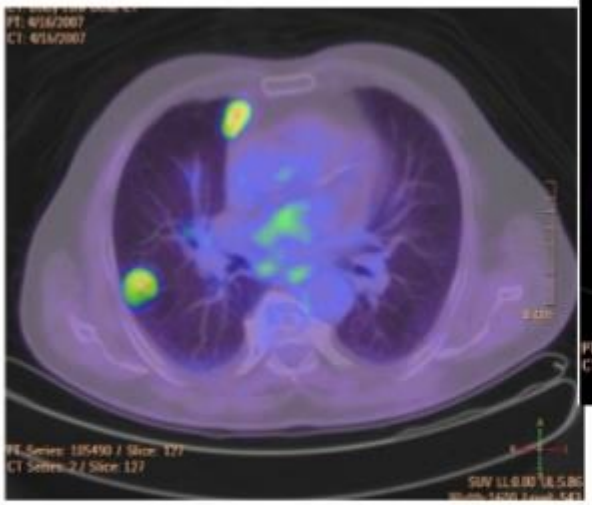
- To detect structure and function simultaneously.
- Greater detail with a higher level of accuracy; because both scans are performed at one time without the patient having to change positions, there is less room for error.
- Greater convenience for the patient who undergoes two exams (CT & PET) at one sitting, rather than at two different times.

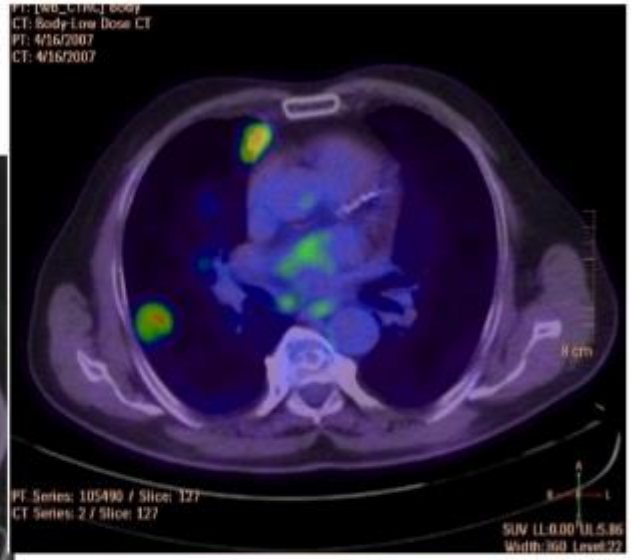
PET/CT FUSION

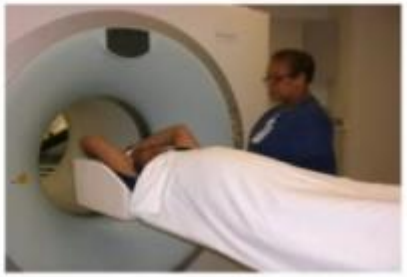


PET/CT FUSION

Fused PET and CT image







Tracer

- Radioisotopes used in PET scans are isotopes of carbon, nitrogen,oxygen,gallium and 18F used as a substitute of hydrogen.

- Only radioactive forms of natural elements that will pass safely through your body and be detected by the scanner.

- The type of scanner used depends on what your doctor wants to measure. For example, if your doctor is looking at the tumor, he might use radio labeled glucose (FDG) and watch how it is metabolized by the tumor.

Cyclotron

- Charged particle accelerator.
- Accelerates charged particles in a cycle path and these particles gain energy.
- Energetic particles then hit a target material get absorbed in to the nucleus, converting the target in to the different species.
- For example, a proton of hydrogen, when hits ^{18}O-water converts it to the ^{18}F-fluoride with emission of a neutron other insignificant subatomic particles to balance the energy equilibrium.

Benefits of PET scan

- The information provided by nuclear medicine examinations is unique and often unattainable using other imaging procedures.
- For many diseases, nuclear medicine scans yield the most useful information needed to make a diagnosis or to determine appropriate treatment, if any.
- Nuclear medicine is less expensive and may yield more precise information than exploratory surgery.
- By identifying changes in the body at the cellular level, PET imaging may detect the early onset of disease before it is evident on other imaging tests such as CT or MRI.

Limitations of PET scan

- Time-consuming.
- The resolution of structures of the body with nuclear medicine may not be as clear as with other imaging techniques, such as CT or MRI.
- PET scanning can give false results if chemical balances within the body are not normal.
- Because the radioactive substance decays quickly and is effective for only a short period of time, it is important for the patient to be on time for the appointment and to receive the radioactive material at the scheduled time.
- A person who is very obese may not fit into the opening of a conventional PET/CT unit.


GOOD
THINGS
ARE GOING
to
Happen


GOOD
LUCK!


GOOD BYE