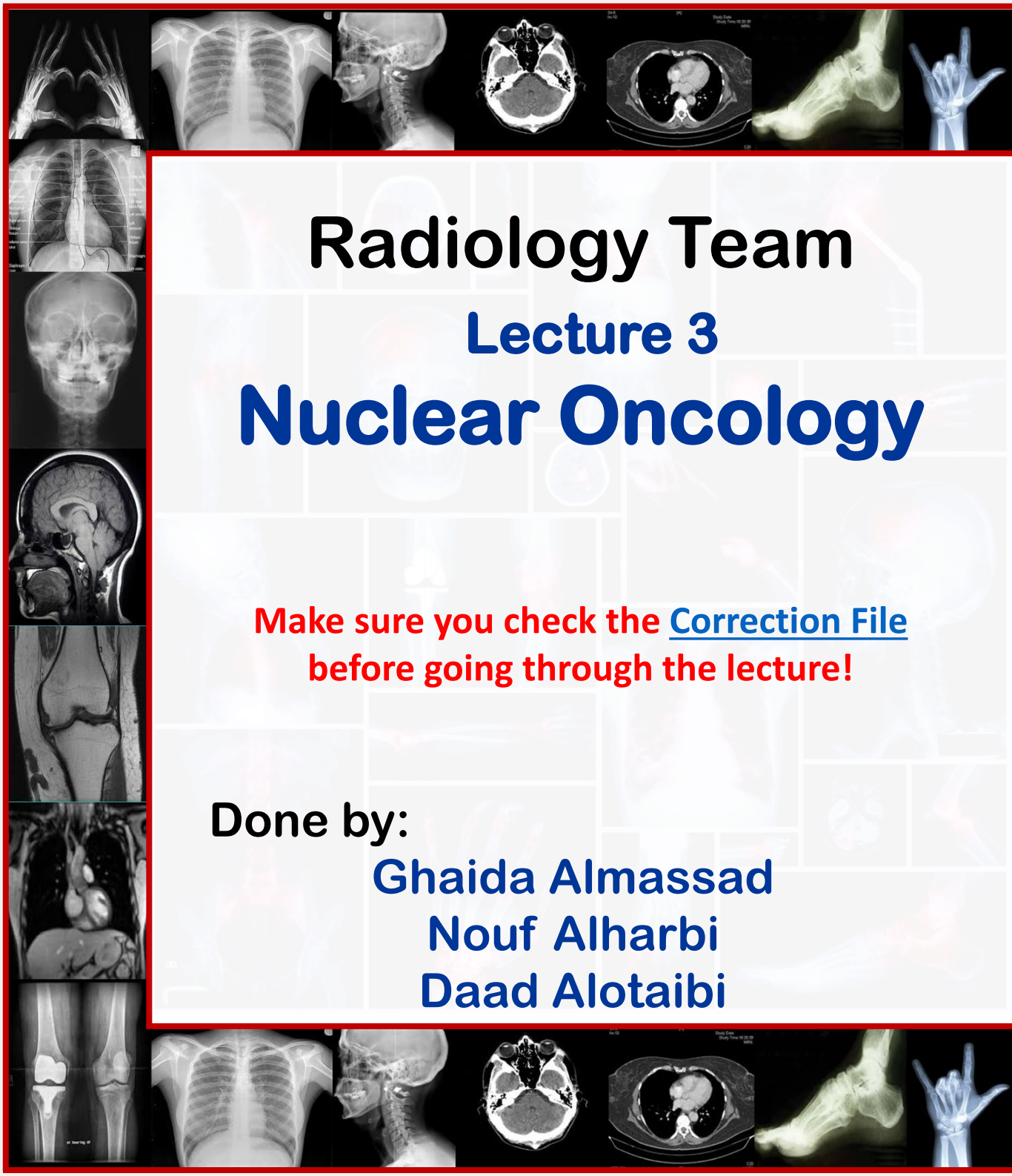
جامعة الملك سعود
King Saud University
1957

RADIOLOGY TEAM 434



Radiology Team

Lecture 3

Nuclear Oncology

Make sure you check the Correction File before going through the lecture!

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Color Index:

• Important • Females' & 432 Teamwork notes • Explanations

LEARNING OBJECTIVES:

•What are the tumor imaging and therapeutic radiopharmaceuticals?

•What are the nuclear medicine tumor imaging methods?

• What are the objectives of tumor imaging?

•What are the potential values of nuclear medicine tumor imaging
methods?

•What is the role of nuclear medicine in the treatment of tumors?

Teaching Points

NM tumor imaging

Functional
Sensitive
Whole body evaluation
Specific : Some tumors

Targeted therapy

Objectives of NM tumor imaging
•Diagnosis
•Staging
•Guiding biopsy
•Follow up and therapy monitoring
•Detection of recurrence.

❖ Nuclear Medicine Procedure:

- **Patient injected** (I.V) most of the time / oral **with small amount of radioactive material.**
- **Radiopharmaceutical localizes in patient according to metabolic properties of that drug.**
- **Radioactivity decays, emitting gamma rays.** radiation coming out of the patient, nuclear machine doesn't emit radiation.
- **Gamma rays that exit the patient are imaged** and detected by Gamma camera.

❖ What are the nuclear medicine tumor imaging methods?

- **The machine that detecting the radiation in nuclear is Gamma camera, there are several types of gamma camera: dual head, triple head, SPECT CT and PET CT**
- **PET CT mainly used for oncology patients**
- **Nuclear called emition tomography, b/c radiation emitted from the patient unlike x-ray which called transmission: x-ray comes through tube into the patient and give an image according to attenuation from patient tissue.**

- Nucular medicine = radiactive material + gamma camera
- For each organ there is a spesific agent " bone >> phsphate "
- Uses is to assessed function , diagnosed , tretment .
- **How to differentiate between radiology and nuclear medicine?**

➢ in nuclear medicine: the machine"gamma camera" is detecting the radiation emitting from the patient

➢ in radiology: the maching will give radiation to the patient

- **Tumors "metabolic properties":**
- -Increased vascularization, Increased capillary permeability, Newly proliferated capillaries, Increased blood flow→Metabolically active"patient will lose weight"→ Increased energy demand.
- Tumor cells "specific useful properties in imaging and therapy":

(1)-High density of some common receptors,
(2)Expression of several specific receptors
(3)Expression of some specific tumor antigenes.

Conventional tumor imaging :

- **Planar : 2D**
- **SPECT : 3D**
- **SPECT-CT :3D (Function and anatomy)**

Onco PET :

- **PET : 3D**
- **PET –CT : 3D (Function and anatomy)**

PLANAR / SPECT

SPECT CT

PET CT

❖ Physical Properties SPECT Radionuclides:

Single Photon Emission Computed Tomography

Radionuclide	T/2 physical	Type of radiation	E (kev)	Uses
Technetium diagnostic	**6 hrs.**	Gamma	140	The most commonly used
Iodine I131 therapeutic	**8 days**	Gamma/Beta	364/606	Used mainly for therapy
Iodine I123 diagnostic	**13.2 hrs.**	Gamma	159	used for diagnosis
Gallium Citrate (Ga-67)	78.3 hrs.	Gamma	90,190,290	used for tumor and infection imaging
Thallium Chloride 201 (T1201)	73.1 hrs.	X-ray	68-83	used for cardiac imaging
Indium 111 (In111)	2.8 days	Gamma	173,247	used for infection imaging
Xenon 133	5.2 days	Gamma	81	used for lung ventilation
Kripton 81m	13 sec.	Gamma	190	

NOTE: Know the half life for the first 3 isotopes only, it's the most commonly used in planner in inventional nuclear medicine.

❖ Physical Properties of positron emitting (PET) Radionuclides:

Positron Emission Tomography

Radionuclide	T/2 physical	Positron energy	Productivity
Carbon 11	20	0.96	accelerator
Nitrogen- 13	10	1.19	accelerator
Oxygen-15	2	1.73	accelerator
Fluorine 18	**110**	0.635	accelerator
Gallium 68	**68**	1.9	Generator
Rubidium 82	1.3	3.15	Generator

*Note: F-18 is the gold standard radiotracer used for tumor imaging together with glucose because

- **PET ISOTOPS, used for pet imaging "positron emitting tomography"**
- **The most commonly used know is Fluorine 18 with T/2 110, labeled with glucose and injected to the oncology patient to image the tumor**
- **The other agents used are Gallium 68 with T/2 68**
- **The other isotopes just for your knowledge**
- **Oxygen-15 and Carbon 11 for research purposes**

Tumor Imaging
Tumor Metabolic properties:

- **Increased vascularization**
- **Increased capillary permeability**
- **Newly proliferated capillaries**
- **Increased blood flow**
- **Increased Metabolically active cells, most of tumors consuming glucose as they label Fluorine 18 with glucose and inject the patient if there is any tumor anywhere it will capture Fluorine18 glucose and appear as spots on the scan.**
- **Increased energy demand**

▪ Tumor Specific useful properties:

- High density of some common receptors
- Expression of several specific receptors
- Expression of some specific tumor antigenes

➢ **All these properties could be used for imaging and therapy**

➢ **Tumor Non-specific Diagnostic radiopharmaceuticals**	**Tumor Specific Diagnostic radiopharmaceuticals**
➢ There are agents which are taking by tumor but they don't tell what is the type. **Called non specific.** ➢ Fluorine 18 labeled with glucose it will go to lymphoma, lung cancer, rectal ca, renal cancer but won't tell weather it's lymphoma or lung ca ➢ Highly sensitive but not specific this is concerning PET e.g. if there is abnormal uptake in hilar area we don't know is it large lymph node or lung tumor. ➢ Same applied in non PET agents "general nuclear medicine" bone scan will tell there is metastasis but from where ? Is it from thyroid or breast won't know	• These can tell which type of tumor so if you used Gallium-68-octereotide or somatostatin receptor it will tell it's neuroendocrine. • Fluorine 18: is it high proliferation rate or not • In General nuclear medicine there are also specific agents • Iodine 123 where it can go? Thyroid. If we label it with material called MIBG > known epinephrin analog it will go to neuroendocrine tissue
PET or PET-CT ➢ F-18 FDG – anaerobic metabolism	PET or PET/CT: ➢ Gallium -68 –octreotide analogues (Ga-68 DOTA): For neuroendocrine tumors ➢ Fluorine -18-fluorodeoxythymidine(F-18-FLT): For tumor proliferation ➢ Fluorine -18-fluoromisonidazole(F-18-FMISO): For tumor hypoxia
Planar, SPECT or SPECT-CT: ➢ Diphosphonates – bone scan ➢ Ga-67 citrate – similar to FDG – localising agent ➢ Tc99m Nanocolloid – bone marrow scan ➢ Tc99m MIBI / Thallium 201 – several tumors	❿Planar, SPECT or SPECT/CT: ❖I-123/131 MIBG for neuroendocrine tumours ❖I-131 for differentiated thyroid carcinomas ❖In-111 or Tc99m octreotide for tumours expressing somatostatin receptors. ❖Monoclonal antibodies labelled with In-111, I-123/131 or Tc-99m

- **Therapeutic radiopharmaceuticals:**

Non-specific

Sr-89, Sm-153, Re-189

Bone pain palliation. Those Given to Wide spread bone metastasis who are not responding to opioid or morphine and alleviate their symptoms

Specific

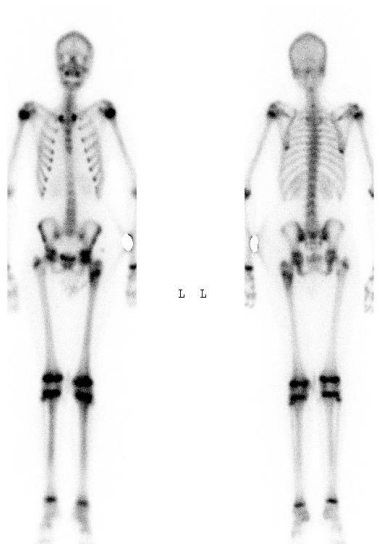
I-131: Thyroid cancer, as specific diagnostic if tumor significantly accumulates.

Specific I 131 for thyroid cancer

I 131 IMBG for neuroblastoma.

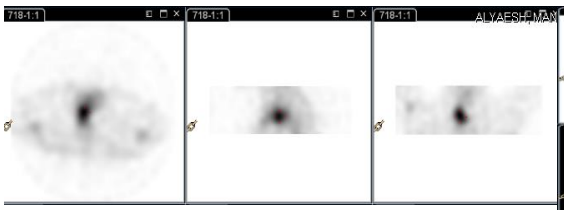
Y-90: Zevalin – monoclonal antibody for B-cell lymphomas

NM Imaging modalities " Planar Imaging ":



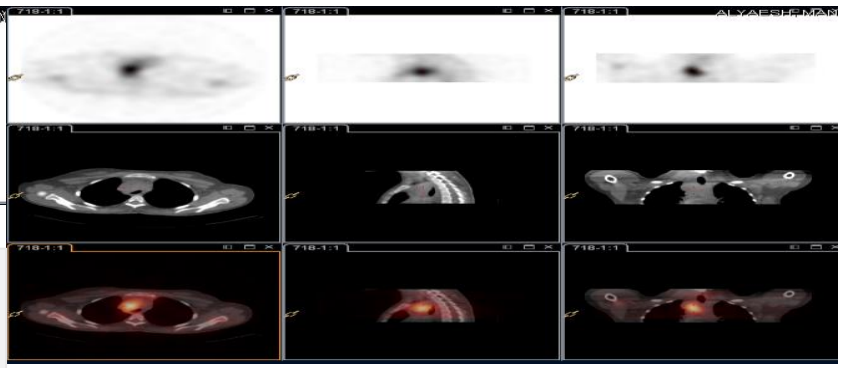
- Planner image means it has 2D
- This is normal bone scan, always look to symmetric between right and left.
- See the costochondral junction, sternoclavicular joint and humorous.
- Then the agent excreted through kidney.
- -If the growth plates look very radioactive->young patient

Single Photon Emission Computed Tomography (SPECT) and SPECT CT:

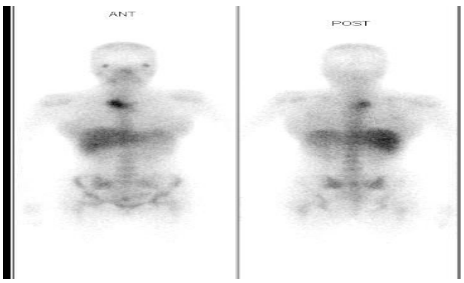


SPECT

Only SPECT without CT, It can tell us if there is any abnormal uptake of the tracer.



SPECT/CT



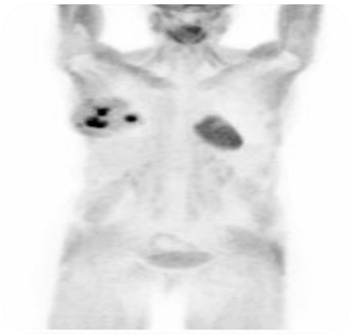
Whole Body Gallium Scan: Planar Image

- In SPECT image it's 3D
- Gallium scan in patient with lymphoma, you can't tell weather it's in the bone or hilum in mediastinum b/c it's 2D image, when they did SPECT image, it's clear in the mediastinum "behind sternum".
- In SPECT image help to locate the abnormality

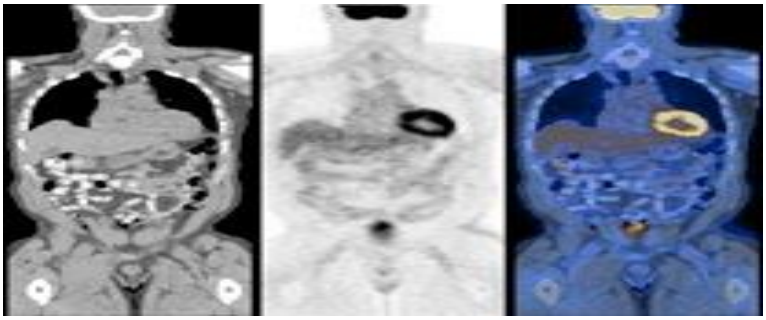
NM Imaging modalities

Positron Emission Tomography (PET) and PET CT

here, we gave the patient glucose labeled with a radioactive material which was F-18, to see any area with high glucose turnover like muscles"



PET



1st-CT 2nd-PET 3rd-PET/CT

- PET is 2D planar "longitudinal and transverse" there is abnormal uptake in Rt breast "consistent breast Ca"
- PET/CT is 3D "coronal image" 1st image CT, 2nd PET, 3rd PET+ CT
- In the left side of PET image this is the heart, which is need Fatty acid for energy but in case of postprandial take it from glucose, this patient wasn't properly fasting " so it shouldn't appear". In oncology patient ask them to fast so all the activity go to tumor not the heart.
- We see brain b/c the main source of energy is glucose.

Role for Nuclear Medicine In Oncology:

- **Diagnosis:** Specific or non-specific. weather it's stage 1,2,3…ect or is there any metastasis.
- **Staging:** Important for proper therapy
- **Follow-up:** Early detection of recurrence
- **Treatment:** Specific or non-pecific. Therapy monitoring (is patient responding or not, or is it make case worse so need to be changed)

Tumor Imaging

Non specific tumor imaging agents	Specific tumor imaging agents
Tc-99m MDP bone scan: Detection and follow up of bone metastasis	**In–111 (TC99m) Octreotide:** Neuroendocrine tumors
Gallium 67: Staging ,Restaging & therapy assessment of HD , NHL , Lung cancer	**I -123 MIBG:** Neuroendocrine tumor
Thallium 201: Tumor viability & tumor seeking {Tc-99 m Agents (MIBI ,TETRO.).}	**I -131: Lung mets. thyroid carcinoma**
F18 – FDG: Staging ,Restaging & therapy assessment of HD , NHL , Lung cancer	--

Some patient on radiotherapy, once you repeat CT image you see abnormality (e.g. fibrosis) is it due to radiotherapy or not?! you have to assess tumor viability either FDG or thallium scan or med scan but mainly the gold standard for tumor imaging is fluorine 18 PET scan (PET scan FDG is the gold standard to evaluate and monitor therapy for patient cancer "solid tumors").

Bone scan:

1."Procedure"

What are the main component of bone ?
Ca, phosphate. If we label one of these agents with radioactive material it will go and stick to the bone and show the skeleton, so the bone scan consist of injecting phosphate compound, technetium MDP and image patient 3 hours after injection

- **Radiopharmaceuticals**

Technitium 99m Methylene DiPhosPhonate (Tc-99m MDP)

- **Tissue accumulation depends on**

–blood flow
–capillary permeability
–metabolic activity of osteoblasts and osteoclasts
–mineral turnover

- **Dose:** 500 to 800 MBq (Megabequerel) / 15- 20 mCi (millicurie)
- **Imaging time:** 2 to 3 hours postinjection – WB + SPECT
- **Potentials of bone scan:** Positivity many months before an abnormality can be detected on X ray

2.Indications

I- Metastatic Disease: Lung cancer, prostate, breast, thyroid, and renal tumours

- Diagnosis.
- Initial staging.
- Restaging.
- Asses response to therapy.

II- Primary Bone Tumors :

- Malignant or Benign
- Therapy planning for patients with primary bone malignancy (e.g. Osteogenic & Ewings sarcoma**)**

III- Soft tissue tumors :

- Primary
- Metastases

Soft can be evaluated by MDP to determine is it primary or secondary

Bone Scan In Oncology
Imaging features (MCQs)

1. Hot lesions : Majority of bone tumors. Majority of hot lesions are bone tumors except trauma and infectionThe history will guide you to know is it tumor or fracture

2.Cold lesions : Purely osteolytic tumors (renal cell carcinoma,

thyroid cancer, anaplastic tumors),radiation therapy

3.Superscan : Diffuse increased skeletal uptake with no soft tissueor kidney activity (e.g. CA prostate ,breast ,lung,colon..etc). After inject radioactive material, there is wide spread bone metastasis or the tracer will be taken by metastasis.

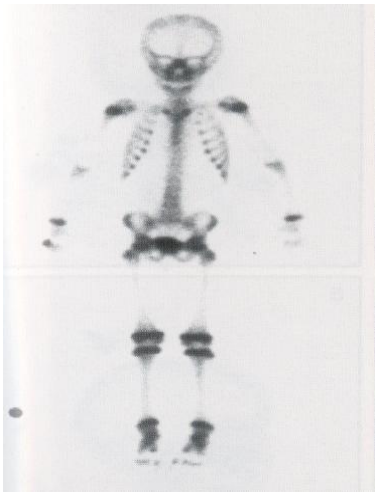
4.Normal distribution : Marrow tumors

(e.g. lymphomas, leukemia, multiple myeloma).

5.Soft tissue uptake : Soft tissue tumors may concentrate the tracer.

6.Flare phenomenon – increased number of lesions in the case of effective therapy

Normal Whole Body Bone Scan:



An 8 year old child

A 25 yrs old adult

- Normal adult bone scan, see … activity epiphysis
- In young patient you can see epiphysis growing
- Remember symmetry between right and left
- If the tumor within the bone marrow and not touch the bone cortex the bone scan will appear normal

Bone Scan : In Metastatic Disease

Access of Nonosseous Tumors To Bone:

Direct Extension.

Retrograde venous flow.

Arterial Circulation (after venous or lymphatic access).

Epithelial Tumors:

Reach red marrow of axial skeleton via venous and arterial flow.

Distribution of red marrow in adult : calvarium, spine , pelvis , and proximal femurs and humerus

90% of metastasis from epithelial tumors are found in red marrow.

Metastatic Foci:

Grows in red marrow space.

The surrounding bone remodels through osteoclastic (resorption) and osteoblastic (deposition) activity.

The relative balance between resorption and deposition determine whether the lesion is hot (sclerotic) , cold (lytic) or mixed pattern.

The tracer does not concentrate in the metastatic foci (cancerous tissue) but in the surrounding reactive bone.

Bone Scan : In Metastatic Disease

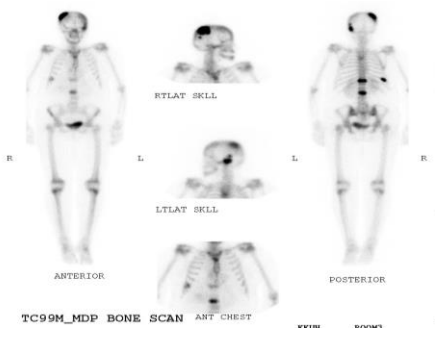
Scan Patterns:

- Solitary lesions.
- Multiple focal lesions.
- Diffuse involvement (Superscan).
- Photon deficient lesions (cold lesions).
- Flare phenomenon.
- Normal (false negative).
- Soft tissue lesions (tracer uptake in tumor).

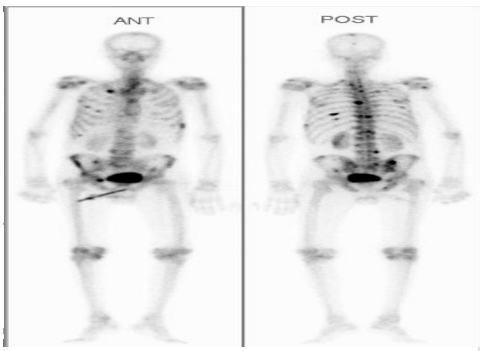
Sensitivity:

- In early stage superior to x-ray.
- In advanced stage both have high sensitivity.
- The accuracy of bone scan not known because of the lack of reference standard.
- The sensitivity is agreed to be 90% or more.

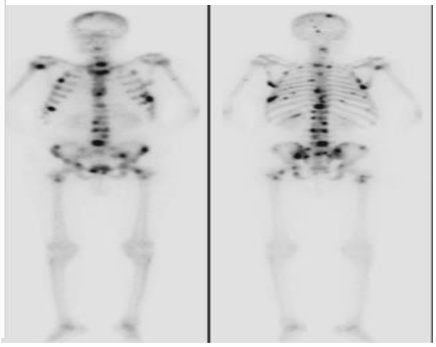
• TUMOR STAGING:



Ca Breast



CA LUNG



CA STOMACH

- All metastasis appear similar in bone scan, so it's sensitive to detect the bone metastasis but not specific.
- Metastasis will be confined to red marrow which is located in axial skeleton, proximal femur and humorous

Bone Scan In Metastatic Disease Diffuse involvement (Superscan)

Definition: Bone scan with diffuse symmetrical increased uptake and almost absence of soft tissue activity, lack of kidney activity and bone uptake seen in blood pool images.

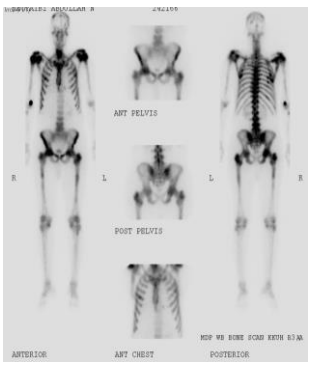
Causes:

a. Bone metastases: Prostate, breast, lung, bladder and lymphoma.

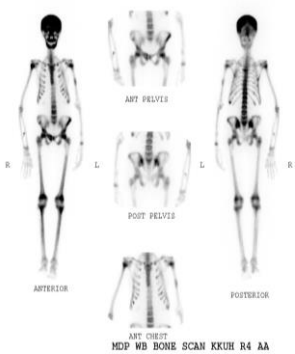
b. Non tumor causes: HPT, osteomalacia, Pagets disease and fibrous dysplasia

Important clues:

In metabolic bone disease the calvarium and long bones are involved unlike in bone metastases.



CA Prostate

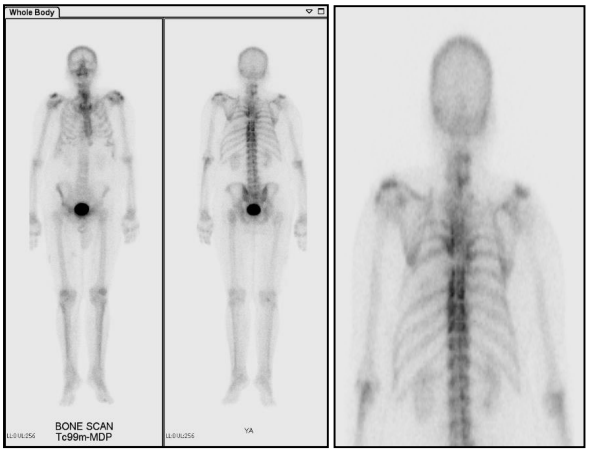


HPT: hyperparathyroidism

How to differentiate benign from metastatic superscan?

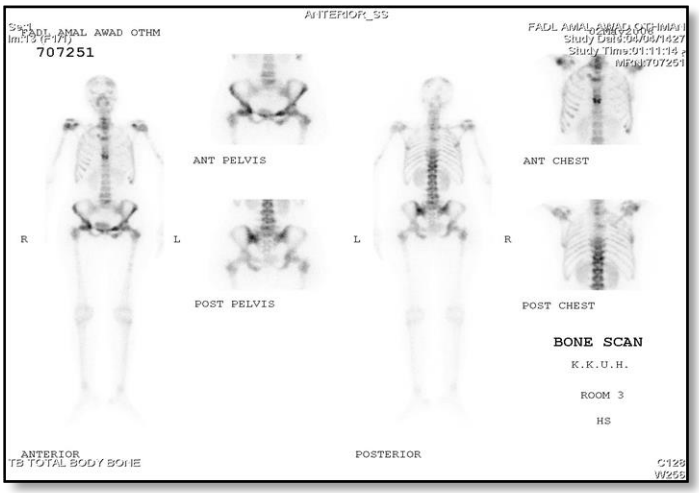
Osteocalcin usually affect whole skeleton involve axial and extremities While the metastatic confined in axial "central" skeleton

Pure Lytic Lesions



- Some tumor considered as pure.. As RCC, anaplastic tumor Don't induce osteoblastic activity to show increase uptake
- Metastasis has 2 types: lytic, osteoblastic or mixed
- In this patient you see affected vertebrae, it's pure lytic metastasis.
- In pure lytic lesions osteoblastic activity decreases " no osteoblstic activity"

Bone Scan: Radiation Effects



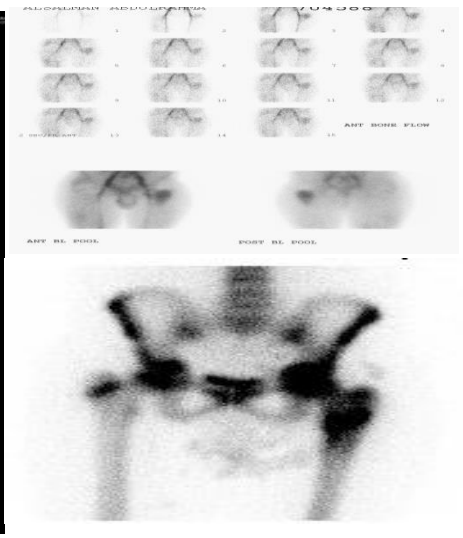
- **Hours following radiation** : Increased uptake due to increased blood flow and vascular permeability.
- **3-6 months post radiation** : Decreased uptake due to microvascular injury. Dose related (>2000 rads).
- **Following Radiotherapy** : Spontaneous ribs fracture may occur.

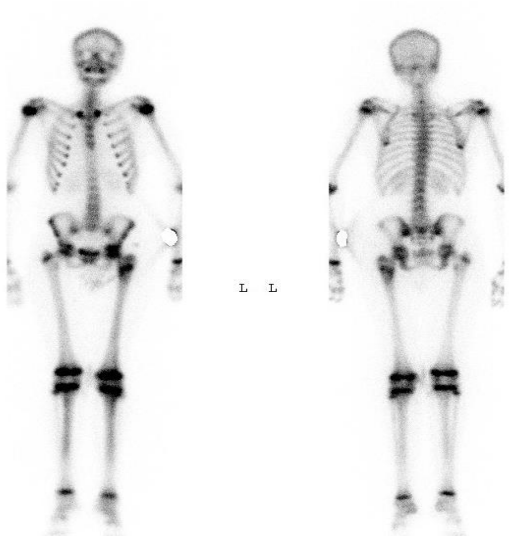
Many patient refferd for radiotherapy, if we see bone scan immediately after radiotherapy due to hyperemia there will be increase uptake but after 3-6 months there will be decrease uptake.

Why?

B/c there will be microvascular injury and the material which injected won't reach site of radiotherapy.

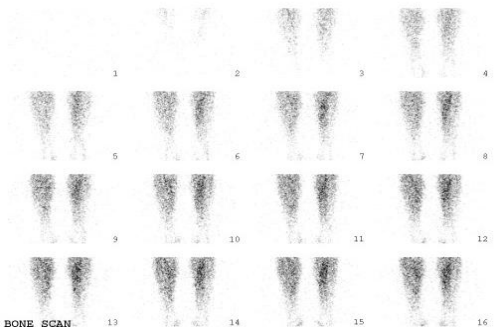
Ewing's Sarcoma (primary bone tumor) :

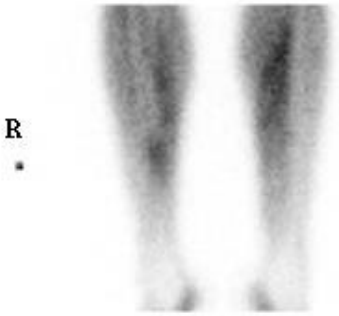




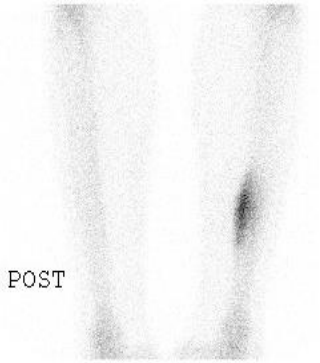
- This called **3 phases** bone scan : it shows blood flow, blood pool and delayed image
- The primary diagnosis of bone tumor is radiology. **Why they do bone scan?** To determine the local extant and to search for distant metastasis
- In this patient the tumor is confined to **proximal** left femur but rest of skeleton is clear there is local tumor and there is no metastasis

Bone Scan In Bone Tumors: (Osteoid Osteoma)

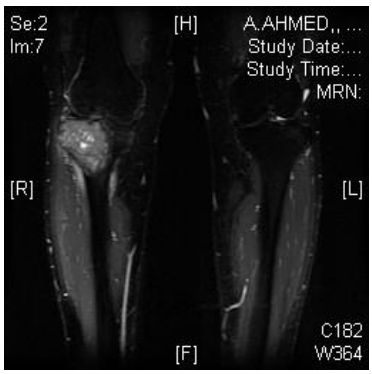


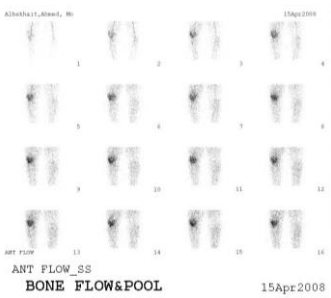


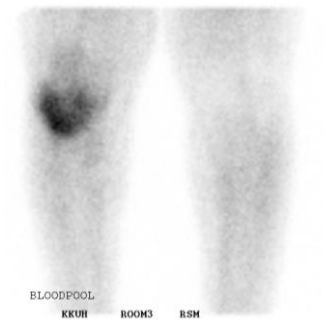
- The bone scan is very sensitive with patient with **Osteoid Osteoma**
- It's benign tumor usually affect children, "wake up during night b/c of pain once you give aspirin the pain is relieved" the bone scan in this case very useful to confirm the diagnosis
- This is the shape of 3 phase bone scan

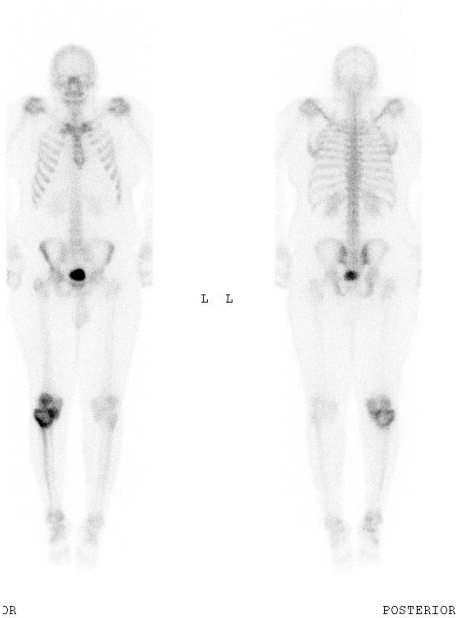


Giant Cell Tumor:



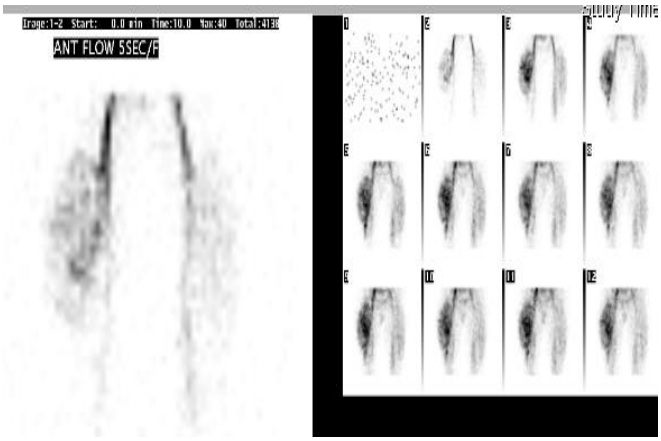


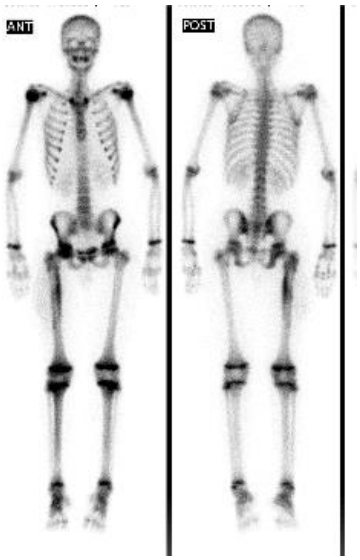




- Also this is 3 phases show increase vascularity, blood pool, increased hyperemia
- And increase uptake in **proximal right tibia** with no distant metastasis
- So the main diagnosis by MRI but they want to scan the whole skeleton by bone scan to tell weather there is distant metastasis or not.

Soft Tissue Sarcoma:





- Clinically rare suspected
- 3 phases bone scan: increase vascularity, hyperemia but the underlying bone Is not affected
- In soft tissue tumor the main point of bone scan to check **does the underlying bone invaded or not** and **is there any metastasis**

Gallium 67 (Ga-67) scan

Properties: Introduced in seventies of 20th century for lymphomas

•Mechanisms of accumulation

–Tumour viability
–Blood flow
–Capillary permeability
–Lymphatic drainage
–Binds to Transferrin receptors on the tumour cells

•Non specific for infection-inflamation and tumors

•Excretion: Kidneys and large bowel

Imaging Protocol:

➢**Patient preparation** : Laxatives for bowel preparation post injection, nothing else

➢**Several weeks post tumor therapy (FN)**

Radiation therapy and chemotherapy can alter the normal pattern of gallium distribution

➢**180 MBq (4-5 mCi) is usually administered**

Imaging follows after 48 – 72 hours

WB + SPECT/SPECT CT, midium-energy collimator

NOTE: They won't use it anymore b/c the gold standard material is **fluorine 18**

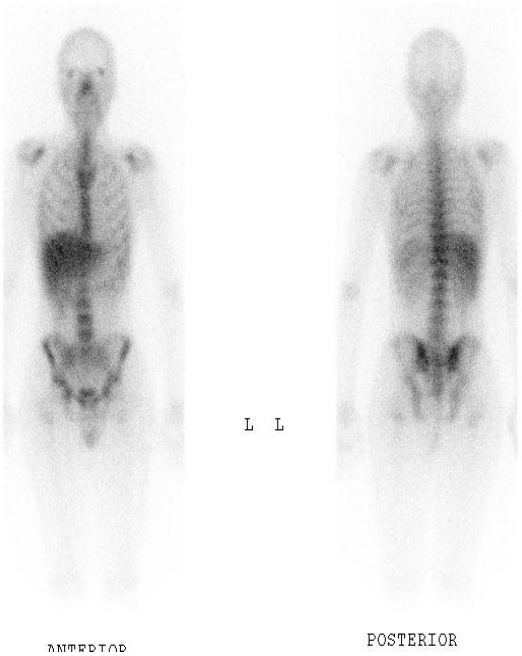
Normal Ga-67 scan:

Normal scan

- Accumulates in bone marrow and liver.
- Splenic uptake is variable.
- The kidneys are usually visualized and also lacrimal, salivary, nasopharyngeal and genital activity is often present.
- Female breasts can be visualized, but accumulation is physiologically symmetrical
- Radioactivity is commonly seen in the colon

Clinical indications

- Lymphoma
- Melanoma
- Lung cancer
- Hepatoma

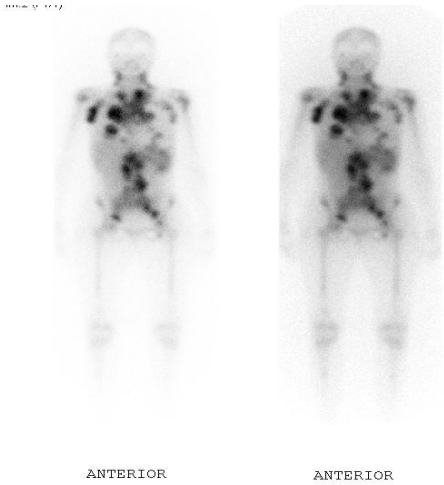


Shows liver and bone marrow b/c Ga is iron analog?

After give it to patient will go to arae with high iron deposite where is it ? In liver and BM

Gallium Scan in Lymphomas

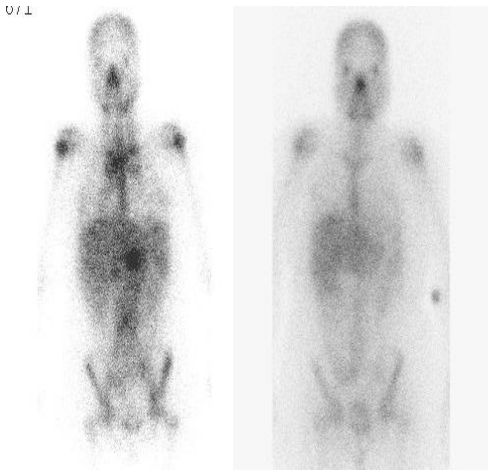
- Staging
- Follow up and monitoring of therapy
- Detection of tumor recurrence
- Differentiate postherapy changes : tissue necrosis and fibrosis from local recurrence.



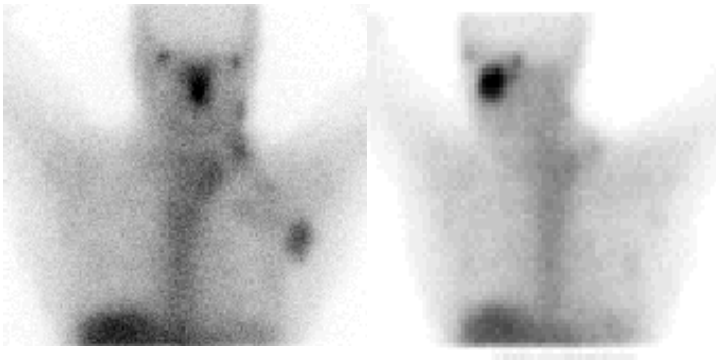
Prediction of response to therapy:

Normalization of a positive pre-therapy scan :
A negative scan after one cycle or at mid cycle is associated with a high likelihood of complete response.

- Baseline Ga scan, they start chemotherapy after the 1st course they repeat Ga scan if patient responded to Ga it means the chemo effective and they will continue on it
- In this patient you can see there was hot spot in mediastinum after 1 course has good response



Prediction of outcome:



Residual gallium uptake after treatment is a poor prognostic sign, indicates viable tumor and treatment should be modified.

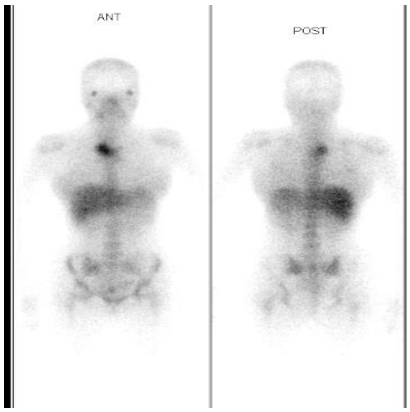
In this patient the response wasn't good, so need to shift to another chemo therapy. What applies here applied in PET, do baseline PET scan give chemo therapy and then repeat the PET after 1st course, patient responded eveyone is happy ☺ if not shift to other chemotherapy

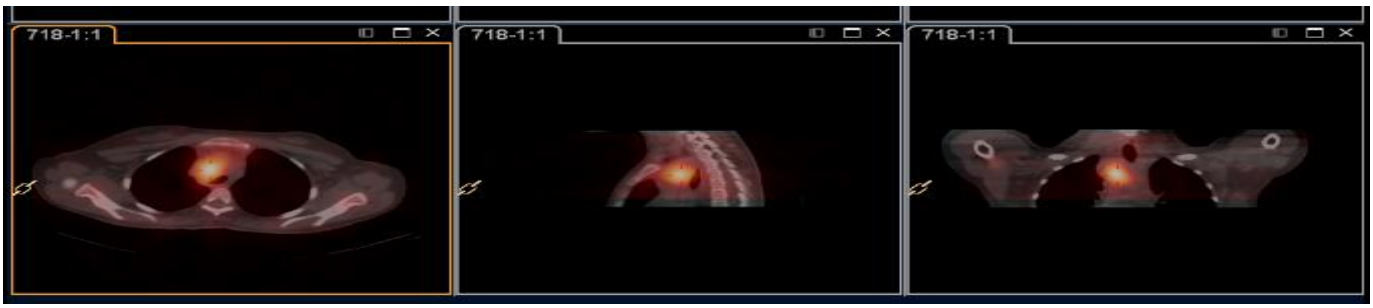
Gallium Scan in Lymphomas

Gallium Scan NHL:

Planar Vs SPECT CT

- PET CT very important for localization of abnormal uptake.
- As in this patient shows abnormal uptake in anterior mediastinum

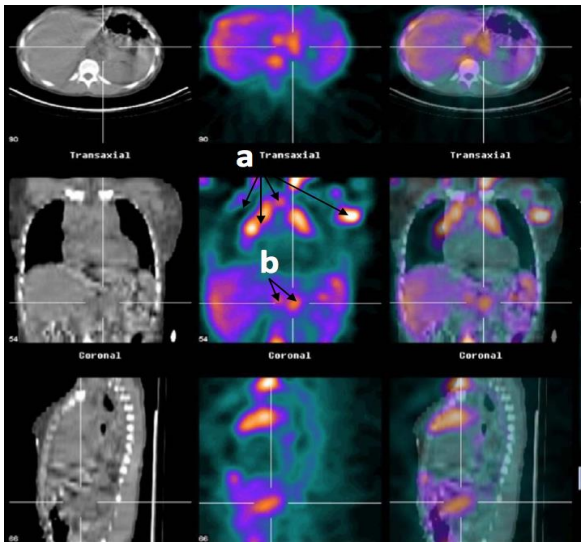




Ga-67 SPECT/CT: Staging HD:

Abnormal Ga uptake (a) in supraclavicular, axillary, Paratracheal , parahilar and para-aortic lymph nodes and in the spleen, at lesion sites corresponding to those observed on CT.

The para-aortic lymph node uptake (b) combined with CT findings allowed the diagnosis of **<u>subdiaphragmatic disease</u>** and excluding bowel activity.



- For patient with Hodgkin lymphoma CT/SPECT/ SPECT-CT
- CT used to localized abnormal uptake in SPECT

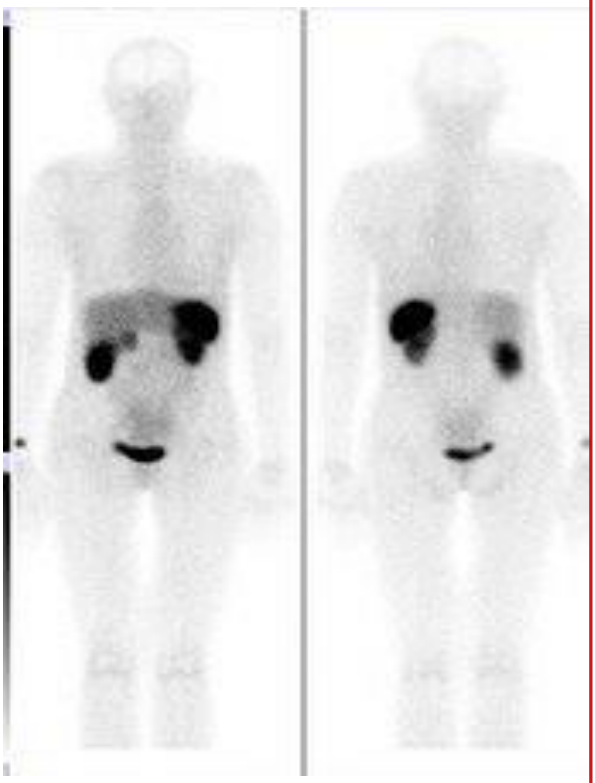
Neuroendocrine Tumors

In-111 octreoscan.

I123 MIBG Scan.

Somatostatin Receptor Imaging
Indium-111 Octreoscan

NORMAL STUDY



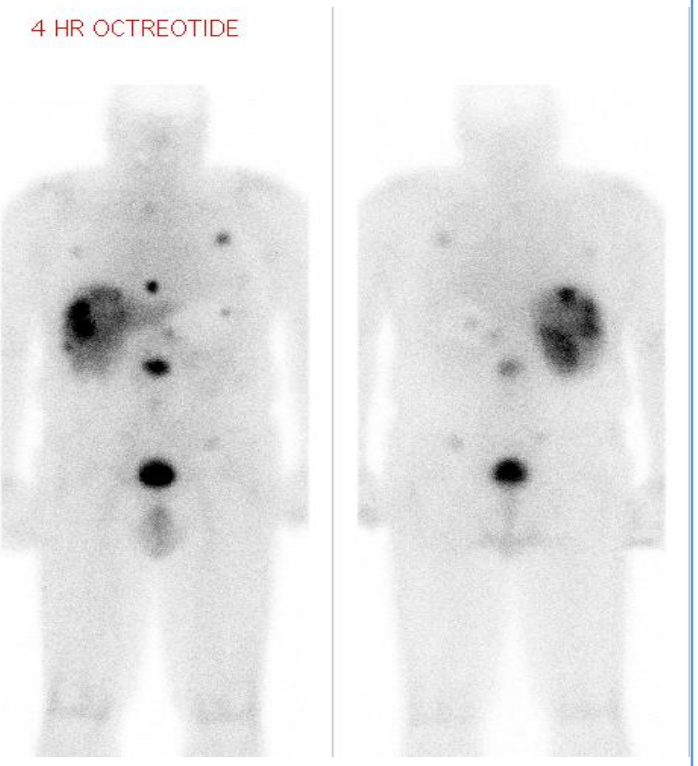
This how indium looks

Normal distribution will

see liver, spleen, kidneys

and urinary bladder

Insulinoma



Clinical History

The patient is a 66-ys male with insulinoma, now being evaluated for evidence of recurrent and/or metastatic disease.

Findings :

Multiple lung, mediastinum , liver and abdominal metastases

all these Wight spots are neuroendocrine tumors, metastases from the insulinoma.

I123 MIBG Scan

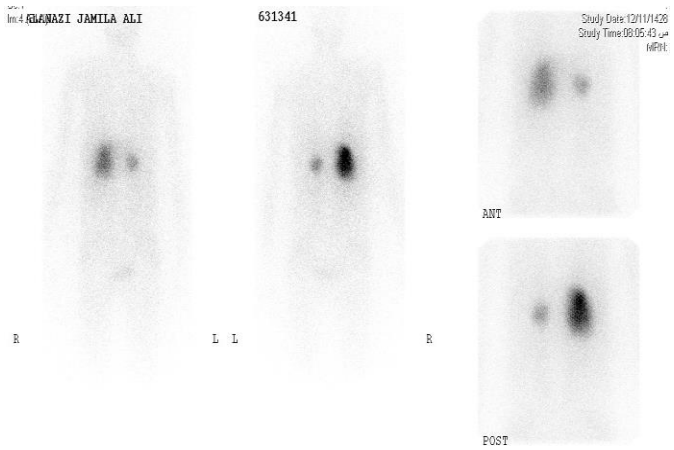
•MIBG : Meta Iodo Benzyl Guanidine
•Is a nor-adrenaline analog
•Localizes in **adrenergic tissues**: **catecholamines producing tumors** and their metastases.
•**Patient preparation:** stop drugs interfering with MIBG uptake. Lugols solution to protect thyroid gland

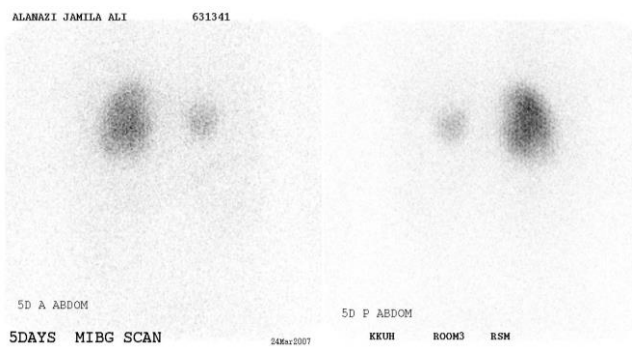
Indications

•Pheochromocytoma
•Paraganglioma
•Insulinoma
•Neuroblastoma
•Medullary thyroid carcinoma
•Carcinoid tumors

MIBG In Pheochromocytoma

Bilateral Disease





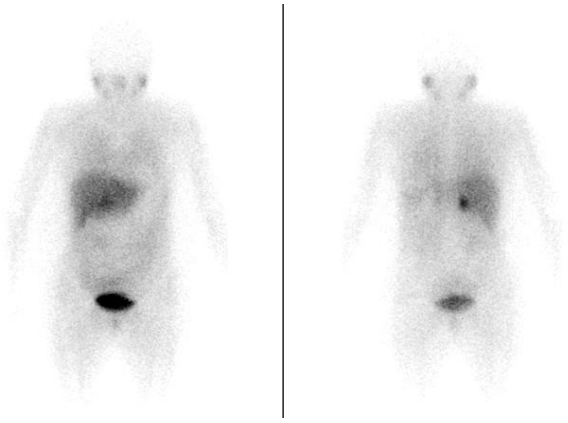
Bilateral adrenal masses.

The bilateral abnormal uptake represent bilateral Pheochromocytoma.

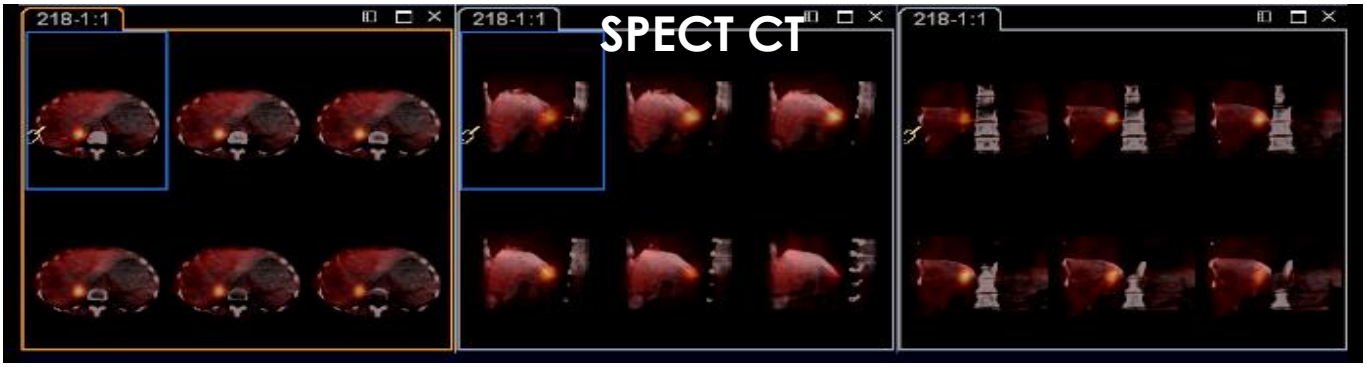
Pheochromocytoma

A 41 years old female patient is with 2ndary hypertension. Right adrenal mass.
Pheochromocytoma?

Suspected PCC with abnormal uptake below the liver , post and ant image. SPECT CT shows that its close to the spine and its Para-spinal just superior to the kidney and that's represent right PCC.



Planar

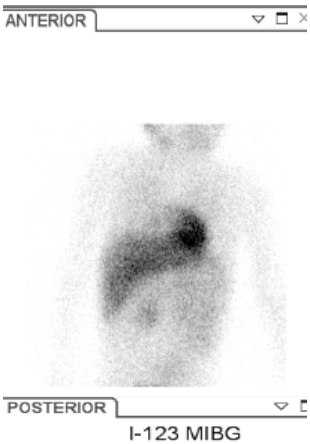


Neuroblasoma

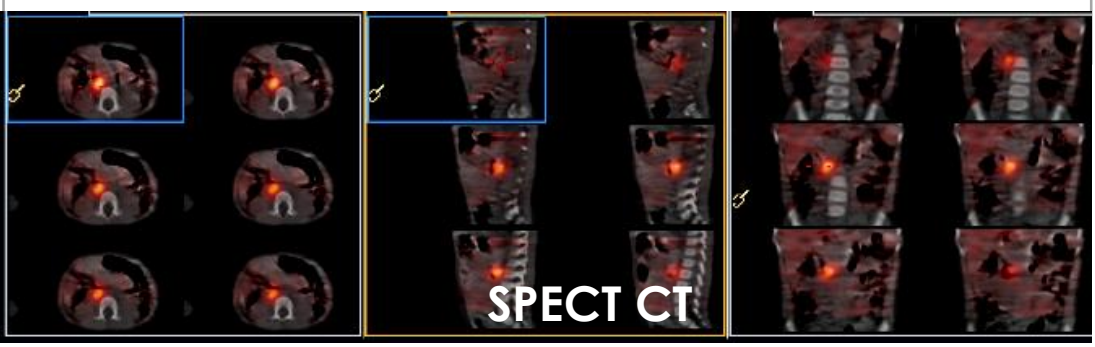
Common tumor in children under 5 yrs and MIGB is used for initial staging and diagnosis. this patient area of faint uptake. SPECT CT it was in the Para-spinal aria
All neuronic tumors are close to the spine why? In embryo all the sympathetic chine extend from the base of the tongue to the urinary bladder around the spin that's why all are in the para-spinal area.

only the primary mas in the abdomen anterior to the spine

Planar

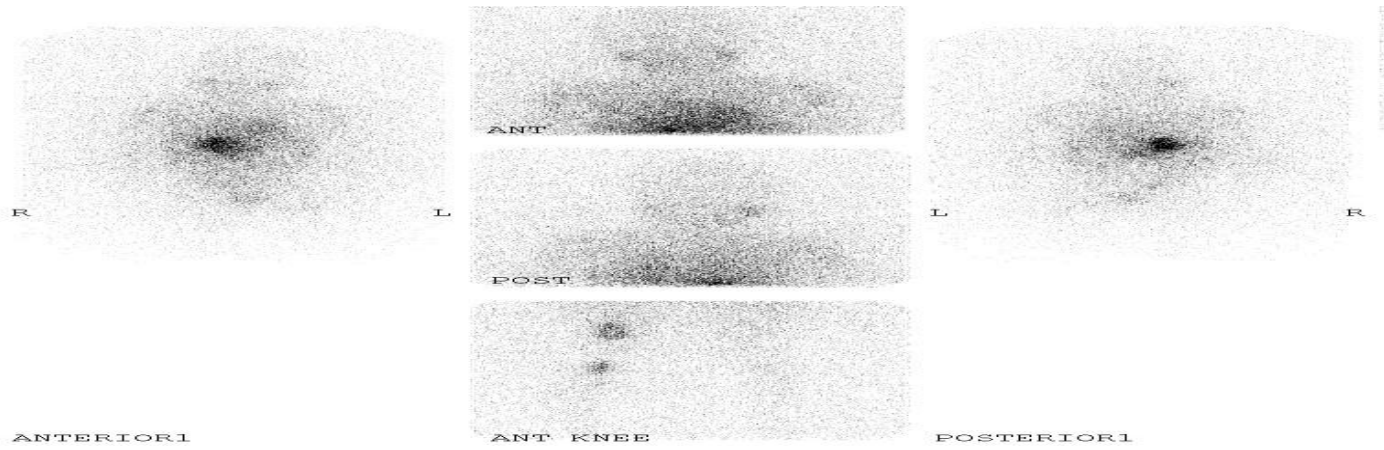


I-123 MIBG



I131 MIBG Total body scan
1ry neuroblastoma /bone metastases

MIBG is used to diagnose primary neuroblastoma and to detect distant metastasis.
At King Fisal they treat NP metastasis in children with I131MIBG.



THYROID METASTASES STUDY
(I-123 or I-131 as Sodium Iodide)

Indications

• Detection and localization of persistent or recurrent local or distant functioning thyroid cancer

Patient Preparation

• Stimulation of potentially functioning thyroid tissue:

A. Inject recombinant human thyrotropin on 2 consecutive days and administer the iodine on the third day .

B. Withdraw thyroid replacement hormones :

1. Thyroxine (T-4) for at least 4 weeks.
2. Triiodothyronine (T-3) for at least 10 days.

• The patient must not have had i.v iodinated contrast material (IVP, CT with contrast, myelogram, angiogram) for at least 3 weeks .

• The patient should be NPO for at least 4 hours prior to radiopharmaceutical administration and for at least 1 hour afterwards .

Tracer , Dose, & Technique of Administration

• Radiopharmaceutical: Oral administration

a. I-123 as sodium iodide : 2 mCi

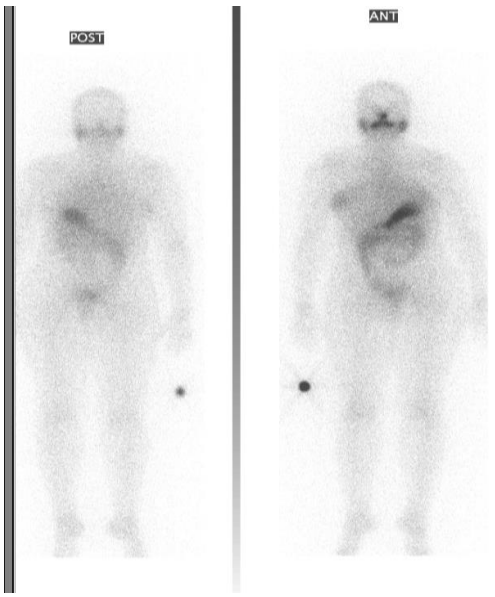
b. I-131 as sodium iodide : 2-10 mCi

Imaging using Gamma camera : Whole body scan

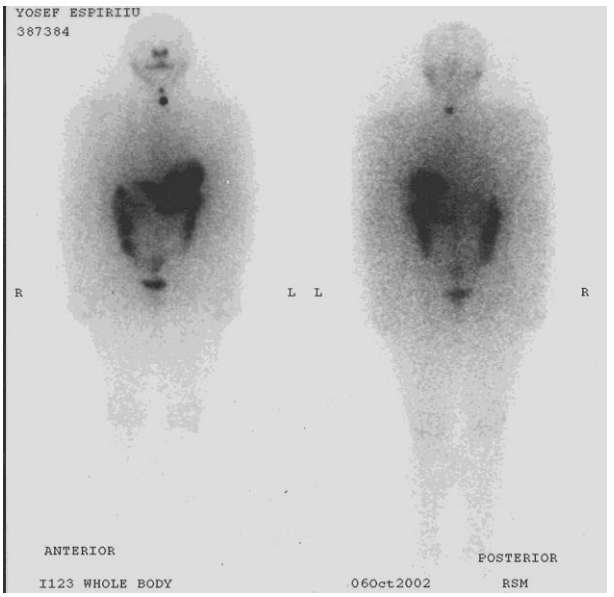
I-123 or I-131 are tumor specific agent spastically for thyroid cancer. **I-123 used for diagnosis, I-131 treatment of thyroid cancer and metasets** because its beta emetine

Thyroid Cancer

I-123 WB Scan



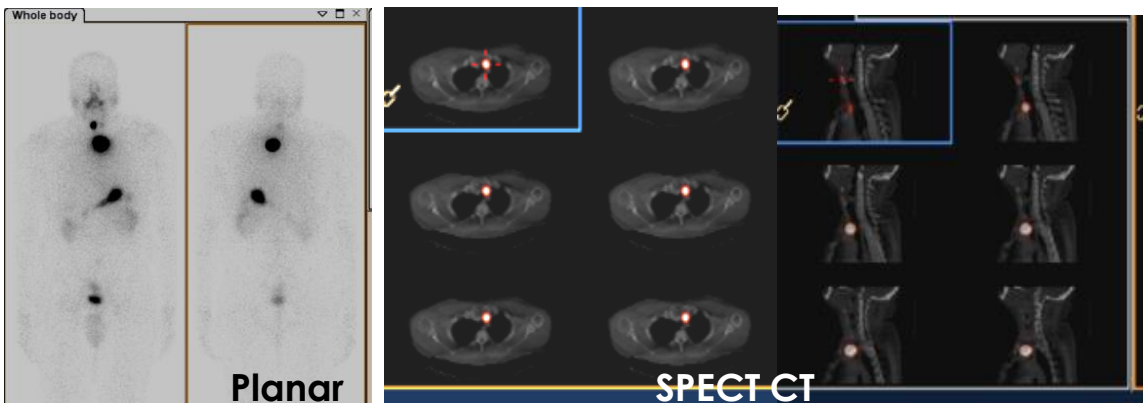
Negative I-123 WB Scan



I-123 WB Scan : Post operative Thyroid remnants

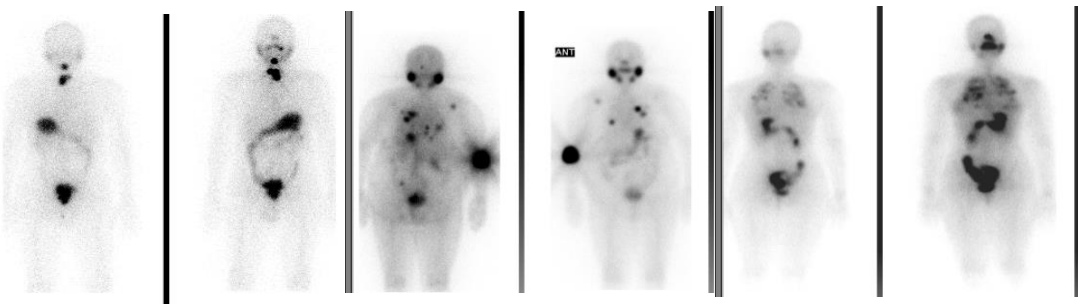
The surgery went very well ,there is no thyroid remnant in the thyroid neck.

I-123 WB Scan
Post operative Thyroid remnants



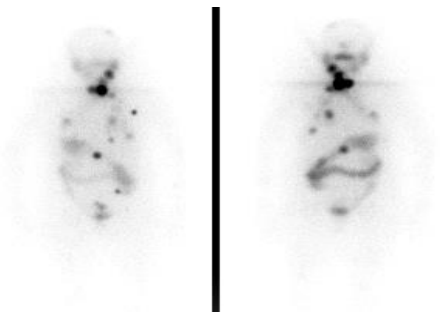
Had thyroid remnant in thyroid bed the surgery was not complete so give **him I-131to treat him**. so any remnant after sugary treat by I-131, alone for thyroid treatment and graves and with MIBG for neuroblastoma. Every patient with have SPECT-CT to determine wither this is remnant in the thyroid bed or metastasis ,,, this is heard to treat surgically you have to give him i131,, usually not using chemotherapy unless in anaplastic.

THYROID METASTASES STUDY
(I-123 or I-131 as Sodium Iodide)

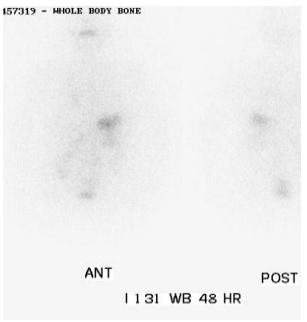


Local Recurrence Bone Metastases Lung Metastases

Tumors from thyroid are of 2 types differentiated and undifferentiated. The differentiated are from follicular(hematological spread so it go to all pleases of the body), papillary (local spared via lymph node). This patent is having wide spread follicular. In the middle pic the black in his hand is due to injection sight.



Dec04



March06

Thyroid Cancer
I-131 Pre & Post therapy

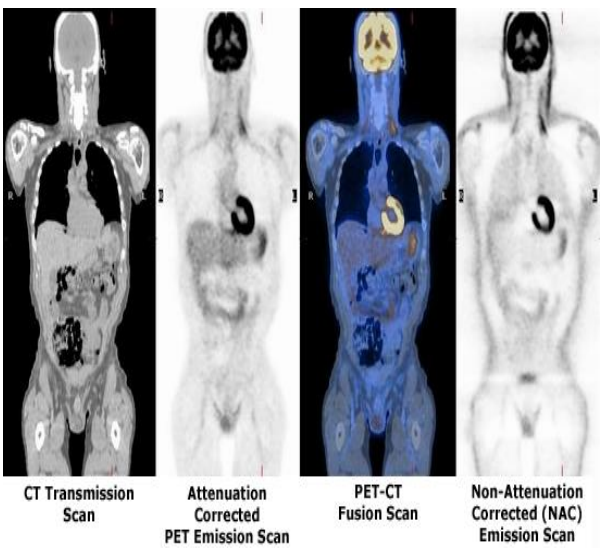
- Dec04-Pre therapy wide spread metastasis local bone lung.
- March06- Post I-131 full recovery.

What is PET – CT?

Oncology PET (PET and PET CT)

- **PET**: Positron Emission Tomography.
- **CT**: Computerized Tomography.
- **PET-CT** is the fusion of functional and anatomic information acquired almost simultaneously from which we are able to visualize form and function.

The most commonly used agent is **Flurien18** with t\2 under 110 min and **Gallium68** t\2 68min. Normal destitution of FDG happens in the brain, where the main source of energy is glucose. part in the fast early stage depend on the fatty acid (postprandial in the heart)and is the liver with little bowl activity.



CT Transmission Scan | Attenuation Corrected PET Emission Scan | PET-CT Fusion Scan | Non-Attenuation Corrected (NAC) Emission Scan

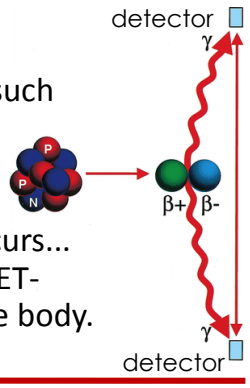
PET CT = PET + CT = Function + Form

How PET is performed?

-Positron emitters (e.g. F18) labelled with biologically active natural compounds such as oxygen, carbon or glucose give intravenously and reacting in the body identically to their non-radioactive counterparts.

-Positrons are emitted from F18 and react with tissue electrons.....Anhillation occurs...

-Two photons 511 kev each in opposite direction are emitted and detected by PET-SCANNERgiving an image of the normal and abnormal distribution of tracer in the body.



FDG : Fluoro-2-deoxy-D-Glucose Uptake Mechanism

FDG is a glucose analogue used to asses glucose metabolism.

FDG transported from intravascular space to the cells by the same mechanism as the glucose.

In the cell, hexoKinase acts on both FDG and glucose to form:

- FDG-6-phosphatase (FDG-6-PO4-)
- Glucose-6-phosphatase.

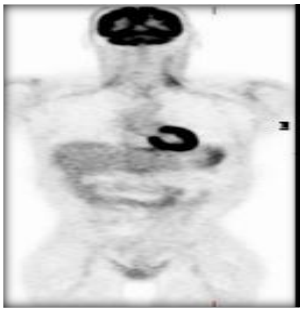
FDG-6-PO4- cannot progress further into glucose metabolism and remains trapped intracellularly in proportion to glycolitic rate of the cell.

In tumors, there is high rate of glycolysis compared to normal cells as well as higher level of hexoKinase. FDG is labeled with F18

Positron Emitting Isotopes

I Cyclotron produced isotopes:		II Generator produced isotopes:			
Isotope	T/2	Parent	T/2	Daughter	T/2
Oxygen-15	2min	Strontium-82	25 day	Rubidium-82	75sec
Nitrogen-13	10 min	Zin-62	9.3 h	Copper-62	10 min
Carbon-11	20 min	Germanium-68	288 day	Gallium-68	68 min
Fluorine-18	110 min				

FDG : Normal distribution



Brain & heart →High uptake

Liver→ Less uptake

Kidneys→ Unlike glucose, FDG is excreted with urine

GI→ Mild clearance, faintly seen

Muscles→ Low, increase with exercise

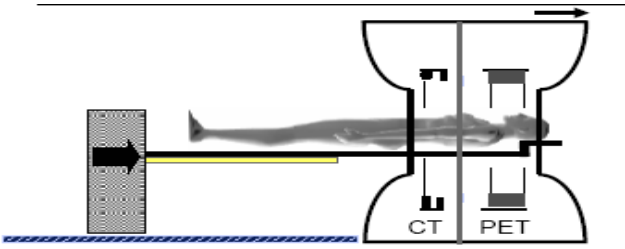
FDG in Oncology

- Tumors do not have a blood tumor barrier
- FDG transport into tumors occurs at a higher rate than in the surrounding normal tissues.
- FDG is de-phosphorylated and can then leave the cell.
- The de-phosphorylation occurs at a slower rate in tumors.

Applications of FDG

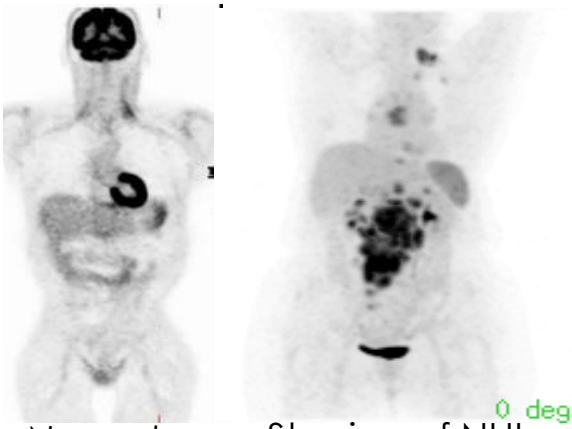
- Locating unknown primaries
- Differentiation of tumor from normal tissue
- Pre-operative staging of disease (lung, breast, colorectal, melanoma, H&N, pancreas)
- Recurrence vs necrosis
- Recurrence vs post-operative changes (limitations with FDG)
- Monitoring response to therapy

PET CT
F18 FDG IMAGING PROTOCOL



Fasting : 4 – 6 hours
Dose : Inject 10 mCi F18 FDG
Wait (uptake phase): 45 -60 min then scan
Scanning time : 30 min to complete PET CT study
SUV : Standard uptake value (N:0.5-2.5 and Tumors > 3.0)

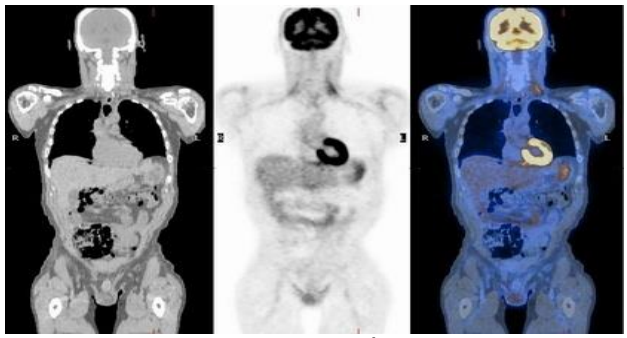
FDG PET



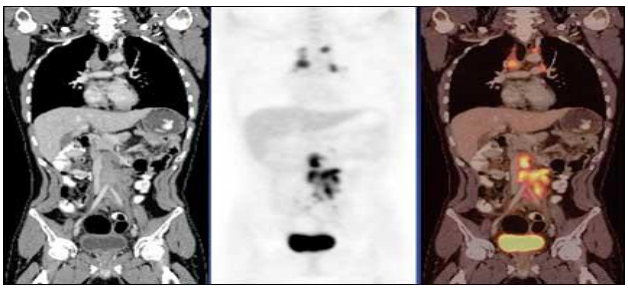
Normal Staging of NHL

All these dark spots show increase in glucose metabolism below and above diaphragm so this is stage 4 lymphoma

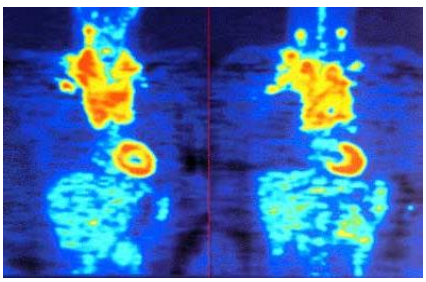
FDG PET-CT



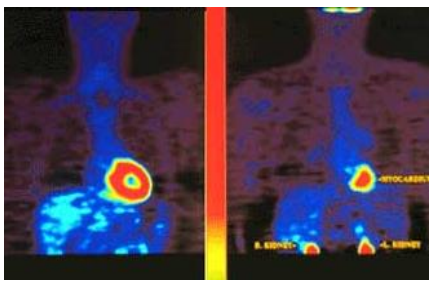
Normal



Staging Of Lymphoma



Baseline



Post therapy

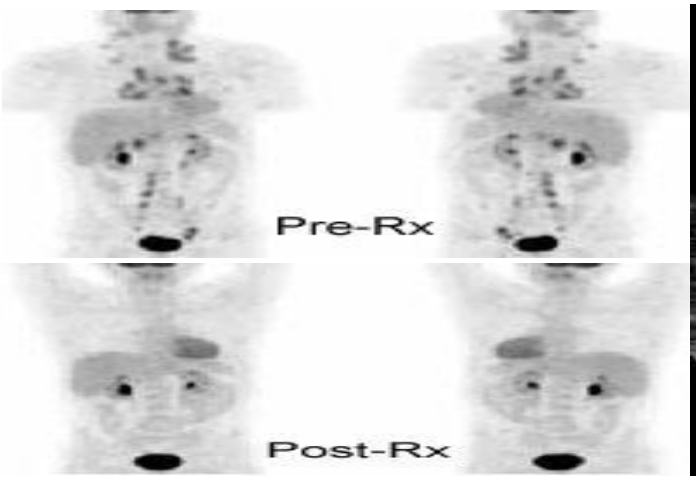
Assessment of therapy response FDG PET in HD

A 22 years old male patient with Hodgkin's lymphoma. Six months after chemotherapy, CT scan showed bilateral hilar abnormalities. FDG-PET scan did not show any activity in described CT changes.

It is used to monitor therapy this is baseline therapy ,hilar uptake , post therapy show complete resolution of abnormal glucose metabolism

FDG in Non-Hodgkin's lymphoma
Response to therapy

This is after therapy the patient responded and we can include him in the coerce of chemotherapy.



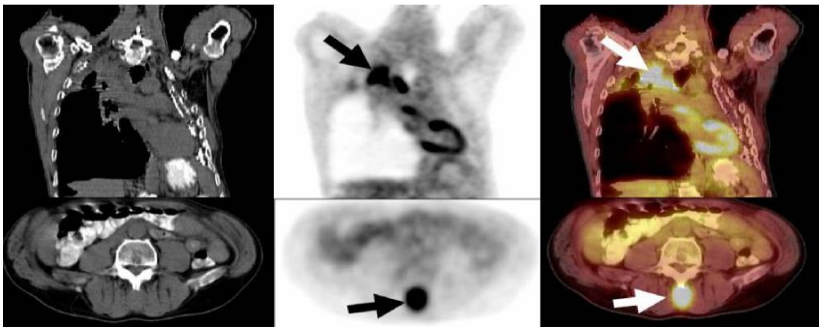
IPET-CT ts very sensitive and highly specific. **FDG-PET/CT** more sensitive and specific than CT alone in lymphoma

PET CT In Lymphoma

PET CT Lung Cancer Staging

<u>FDG PET CT in Solitary Pulmonary Nodule (SPN)</u>
Sensitivity : 82 – 100 %
Specificity : 67 – 100 %

	sensitivity	Specificity
CT	61	89
FDG-PET	78	98
FDG-PET and CT	91	99
PDG-PET/CT	96	99



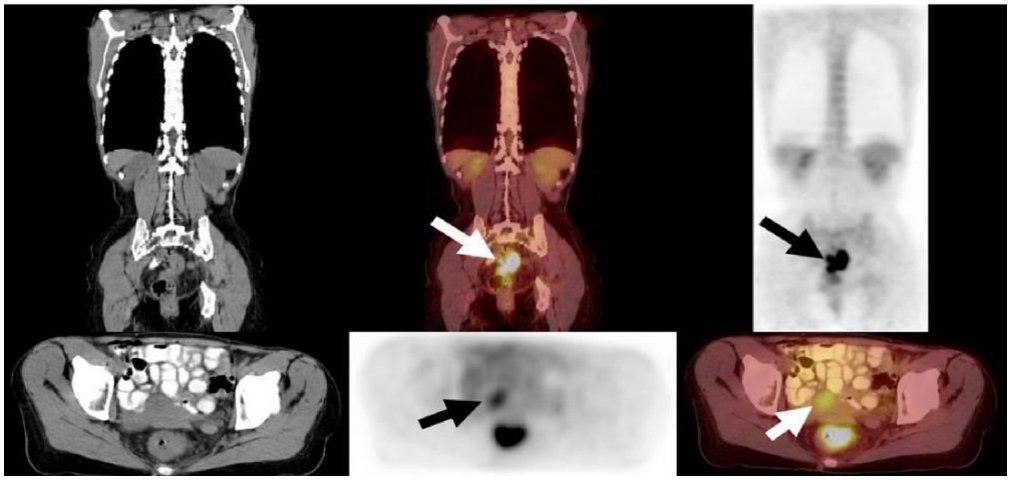
FDG avid soft tissue mass associated with a destructive L5 spinous process consistent with metastatic deposit (arrow).

Patient with lung cancer and metastasis

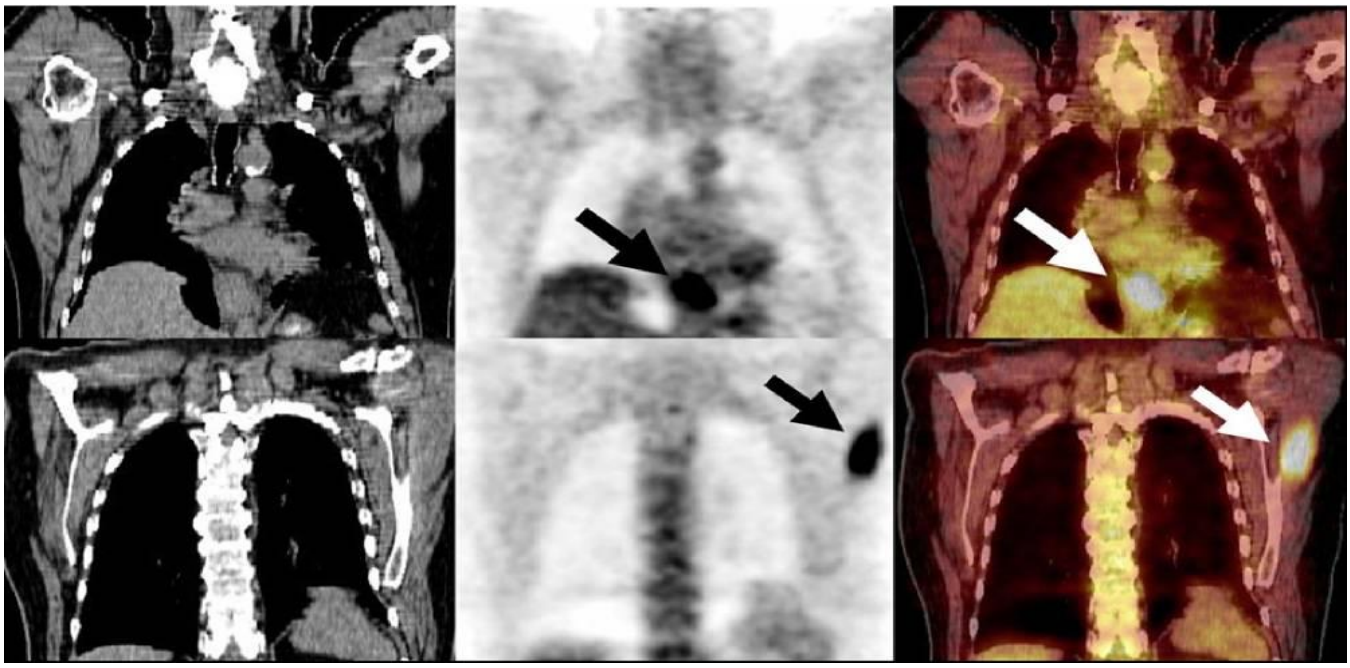
CA Rectum Staging

A 57-year-old woman presented with pain and constipation and colonoscopy revealed an obstructing rectal mass. A staging FDG-PET/CT demonstrated intense FDG avidity in a circumscribed mass-like thickening of the proximal rectum (arrows in top row images) and a focus of mild metabolic activity anterior to the rectum (bottom row arrow) which was not avid as the rectal malignancy. This was located within the uterus as seen on CT images (bottom row), and was subsequently shown to be a uterine fibroid on other imaging studies.

Patient with CA rectum and metastasis as will. the importance of PET CT is that you can screen all the body for distant metastasis wither in soft tissue or in bone or in liver

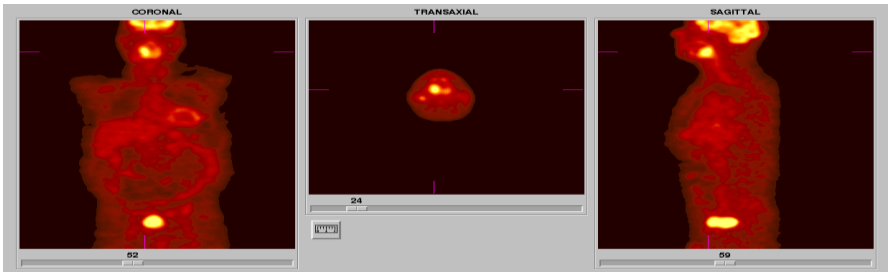


CA Esophagus Staging

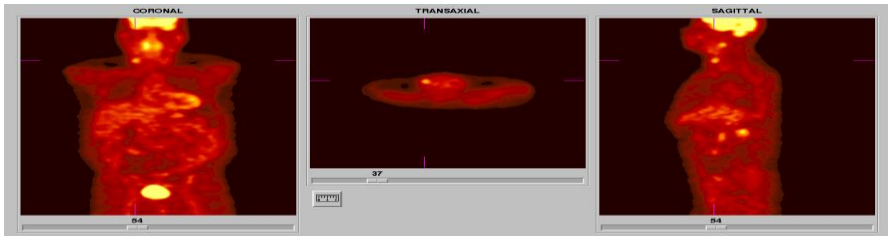


Based on FDG-PET/CT results the clinical management of this patient was changed from surgical resection of the primary tumor to combined chemo-radiation therapy.

FDG PET
Tumor of unknown origin



Pharyngeal cancer



Metastatic involvement of neck lymph nodes

this is a patient with unknown primary origin they suspect primary bone tumor so one of the indications of PET-CT is to search for primary tumors and this patient is find to have nasopharyngeal

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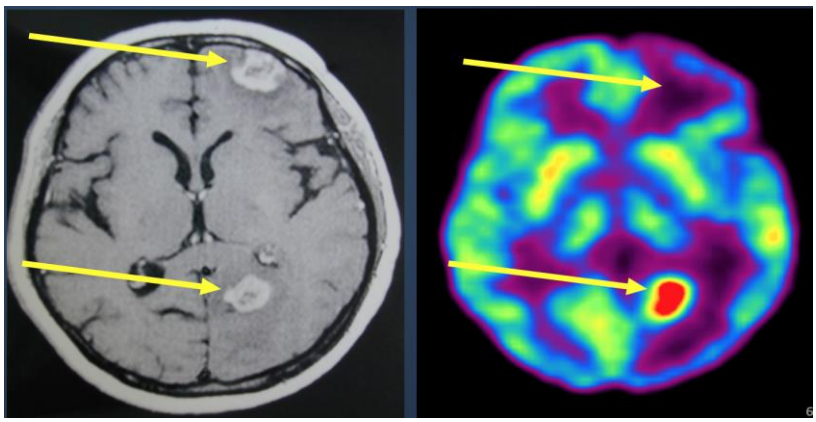
FDG PET – brain tumor post therapy

Two foci on CT, only one viable tumor



In brane tumors the PET-CT is used to evaluate the pre-therapy and after the therapy they repeat CT and there is fibrotic tissue here and there.

witch one of theme is viral and witch is fibrotic? This one is viral because it contain mucosa will the other is non-viral and don't need therapy

Indications of PET CT

Breast Cancer*	Staging*, restaging*, and monitoring response to therapy*
Colorectal Cancer	Diagnosis*, staging* and restaging*
Esophageal Cancer	Diagnosis*, staging* and restaging*
Head & Neck Cancers (excluding CNS and thyroid)	Diagnosis*, staging* and restaging*
Lung Cancer (Non-Small Cell)	Diagnosis*, staging* and restaging*
Lymphoma	Diagnosis*, staging* and restaging*
Melanoma (Excludes evaluation of regional nodes)	Diagnosis*, staging* and restaging*
Solitary Pulmonary Nodule	Characterization of indeterminate single pulmonary nodule
Thyroid Cancer*	Restaging
Cervical Cancer*	Staging as an adjunct to conventional imaging

Somatostatin receptor PET tracers
Ga-68 DOTANOC

Radiopharmaceutical: DOTANOC , DOTATOC or DOTATATE is labeled with Ga-68

Dose: 3-5 mCi given intravenously.

PET Imaging time: 45-60 min postinjection

Clinical value: higher lesion detection rate than is achieved with (18)F-fluorodihydroxyphenyl-l-alanine PET, somatostatin receptor SPECT, CT, or MR imaging.

Sensitivity: 70-100% (depends on density of somatostatin receptors in the tumor)

CONT…

Indications: Tumours with high expression of receptors of somatostatin
1. Gastroenteropancreatic tumours (e.g. carcinoids,gastrinoma, insulinoma, glucagonoma, VIPoma, etc.),
2. Sympathoadrenal system tumours (phaeochromocytoma, paraganglioma, neuroblastoma, ganglioneuroma)
3. Medullary thyroid carcinoma
4. Pituitary adenoma
5. Medulloblastoma
6. Merkel cell carcinoma
7. Small-cell lung cancer (mainly primary tumours)
8. Meningioma

Ga-68 DOTANOC Used for neuroendocrine tumors. its sensitivity can reach 100% and its specificity as will. Used as the technician agent. the advantage of Ga-68 DOTANOC that you can finish the scan in 4h will the technitian or indian obturatetoid scan the patient go 2 consecutive days.

Normal Distribution 68Ga-DOTA peptide PET/CT

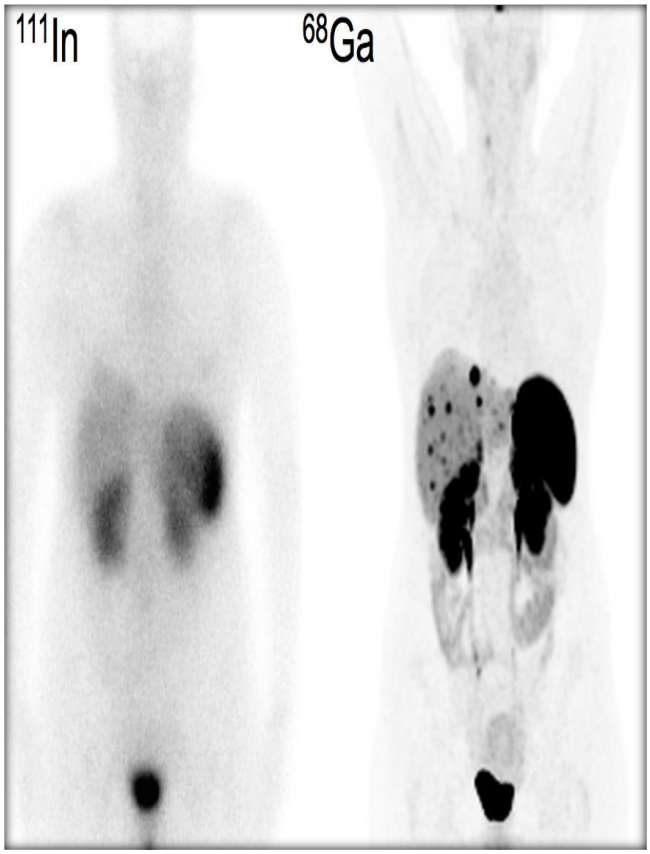
Normal tracer uptake is seen in the pituitary, salivary glands, thyroid, liver, spleen, adrenals, pancreas, kidneys, ureters, and bladder

Ga-68 DOTANOC PET

NET with multiple metastatic disease confined to the liver and abdominal cavity

NET with extensive metastatic lesions throughout the body (to Lung liver and lymph nodes)

Ga-68 DOTANOC PET superior to In- 111 Octreoscan



Ga-68 is much more sensitive than In-111 in detecting neuroendocrine tumors .

Carcinoid tumor :
Positive ^{68}Ga-DOTA-NOC and Negative ^{111}In-Octreoscan.

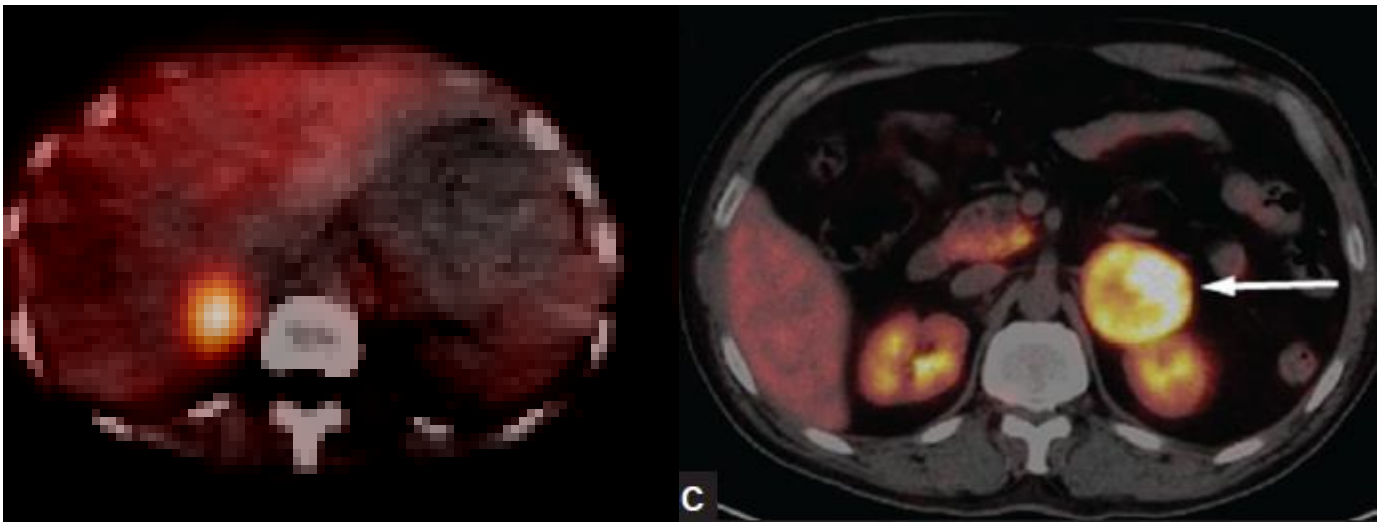
^{68}Ga DOTA-NOC Findings:
Multiple metastatic lesions in the liver. (The pituitary also expresses somatostatin receptors and is visualized in the ^{68}Ga PET image, along with normal uptake in the spleen, kidneys, and bladder.)

Indication of ^{68}Ga DOTA-NOC: The ^{68}Ga PET scan was performed because the patient's symptoms were inconsistent with the ^{111}In-Octreoscan findings.

This glaun is 68 its PET agent the other galun is 67 they are different

Pheochromocytoma
Ga68 DOTANOC superior to MIBG

SPECT CT - I123 MIBG **PET CT Ga68 DOTANOC**



in oncology the ga68 is superior to other agents in neuroendocrine tumors.

Radionuclide Therapy
Properties of the Ideal Therapeutic Radiopharmaceutical

1. Pure beta minus emitter
2. Medium/high energy (>1 meV).
3. Effective half-life = moderately long, e.g., days.
4. High target:nontarget ratio
5. Minimal radiation dose to patient and Nuclear Medicine personnel
6. Patient Safety
7. Inexpensive, readily available radiopharmaceutical.
8. Simple preparation and quality control if manufactured in house.

Nuclear medicine is used for diagnosis and for therapy . the most important for therapy should be **beta emitter**, not gamma radiation because it goes ,outside the body and the room bout beta stay confined to the tissue of the person.

Radionuclide Therapy

Agent	Indication	Dose
I131	Thyroid cancer	100-200 mCi
131 MIBG	Neuroblastoma	100-300 mCi
Strontium-89	Bone metastasis	40-60 uCi/kg
Sm-153-EDTMP	Bone metastasis	1.0 mCi per Kg
Phosphorus-32	Polycythemia	2.3 mCi/m^2
Y-90Ibritumomab Tiuxeten [[Zevalin®]	B-cell NHL > Platelet count > 150,000 cells/mL: 0.4 mCi/kg > Platelet count 100,000-150,000 cells/mL	0.3 mCi/kg The dose should never exceed 32 mCi (1,184 MBq)

Strontium-89 Therapy for Palliation of Bony Metastases

History :

A 65 Ys ,M, with CA prostate and widespread bone metastases and severe bony pain.

Admitted for palliative Strontium-89 therapy.

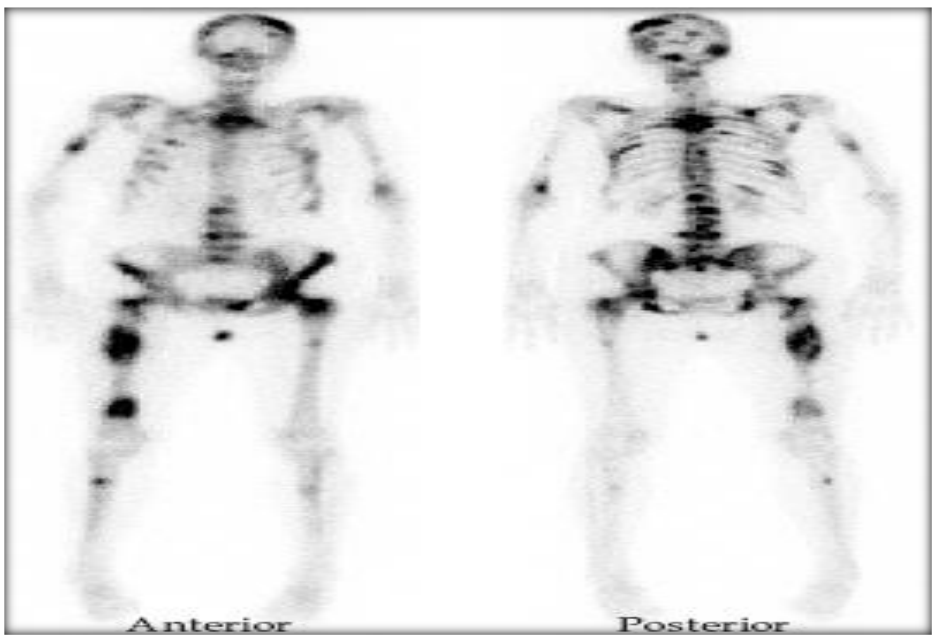
Procedure :

Bone metastases was confirmed by bone scan.

The patient was given 40 mCi of Strontium-89 I.V.according to body weight of the patient.

The patient experienced one day of exacerpated pain which was controlled by opiates but the following day showed gradual pain relieve.

Not responding to morphine or any other analgesics so give him Strontium-89 .He will not cure but all pain will subside.



Don’t Forget !

SUMMARY of the radionuclides:

Non specific tumor imaging agents:

- Tc-99m MDP bone scan: Detection and follow up of bone metastasis
- Gallium 67 : Staging ,Restaging & therapy assessment of HD , NHL , Lung cancer
- Thallium 201 : Tumor viability & tumor seeking.

{Tc-99 m Agents (MIBI ,TETRO.).}

- F18 – FDG : Staging ,Restaging & therapy assessment of HD , NHL , Lung cancer

Specific tumorimaging agents:

- In–111 (TC99m) Octreotide : Neuroendocrine tumors
- I -123 MIBG : Neuroendocrine tumor
- I -131 : Lung mets. thyroid carcinoma