RADIOLOGY
TEAM 435

Nuclear medicine in oncology

[Color index: Important ★ | Notes | Extra | Editing file]

● 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?

● Resources:

- Slides & notes 435
- 434 team

● Done by:

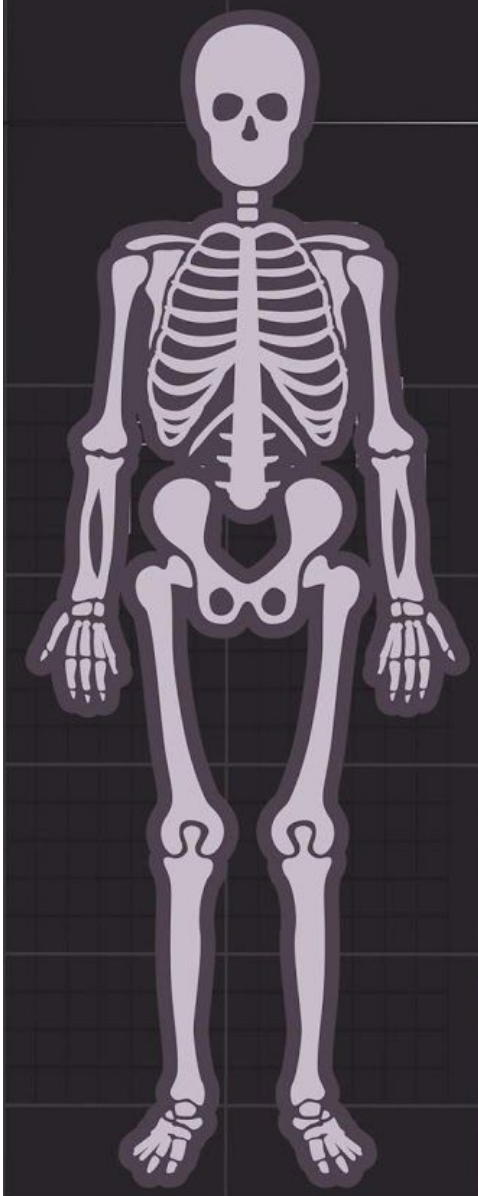
- Faisal Alqahtani
- Ahmed Alrwaly
- Abdullah Alshonaifi

● Team Leader:

- Amjad Alduhaish
- Mohammed Alsahil

- Revised by:

- Luluh Alzeghayer



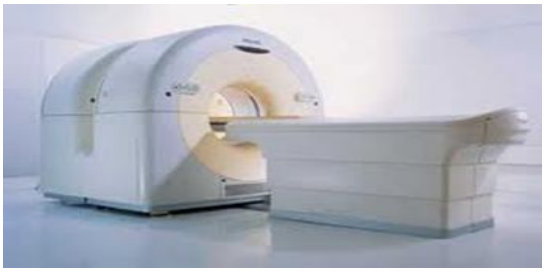
Recall

❖ Nuclear Medicine Procedure:

- Isotopes show Function Not structure.
- 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?

1) Conventional tumor imaging : ● Planar : 2D ● SPECT : 3D SPECT-CT :3D (Function and anatomy)	 PLANAR / SPECT	 SPECT CT

2) Onco PET : ● PET : 3D ● PET –CT : 3D (Function and anatomy)	 PET CT

• The machine that detects 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 emission tomography because 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.

★ Note: F-18 is the gold standard radiotracer used for tumor imaging.

- PET ISOTOPE, used for pet imaging “positron emitting tomography”
- The most commonly used now 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
- Oxygen-15 and Carbon 11 for research purposes .

Tumor imaging

❖ Tumor Metabolic properties:

1) Increased vascularization
2) Increased capillary permeability
3) Newly proliferated capillaries
4) Increased blood flow
5) Increased Metabolically active cells (most of tumors consuming glucose. As they label the Fluorine 18 with glucose and inject the patient if there is any tumor anywhere it will capture Fluorine 18 glucose and appear as spots on the scan).
6) Increased energy demand

❖ Tumor Specific useful properties:

1) High density of some common receptors
2) Expression of several specific receptors
3) Expression of some specific tumor antigens

→ All these properties could be used for imaging and therapy

Tumor Non-specific Diagnostic radiopharmaceuticals	Tumor Specific Diagnostic radiopharmaceuticals
- Demonstrate tumor sites but are not specific for malignancy - There are agents which are taken by tumor but they don't tell what is the type so 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	- Binds directly to special tumor antigens or receptors or are accumulated by special metabolic pathway - 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 epinephrine analog it will go to neuroendocrine tissue
PET or PET-CT ● F-18 FDG – anaerobic metabolism	PET or PET/CT: ● Gallium -68 – octreotide analogues (Ga68 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	Planar, 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 In111, I-123/131 or Tc-99m

❖ Therapeutic radiopharmaceuticals: (only **I-131: Thyroid cancer** is important for the exam)

A. Non-specific: 1) Sr-89, Sm-153, Re-189

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

B. Specific: ★ 1) **I-131: Thyroid cancer**, as specific diagnostic if tumor significantly accumulates. Specific I 131 for thyroid cancer I 131 MIBG for neuroblastoma.

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

NM Imaging modalities

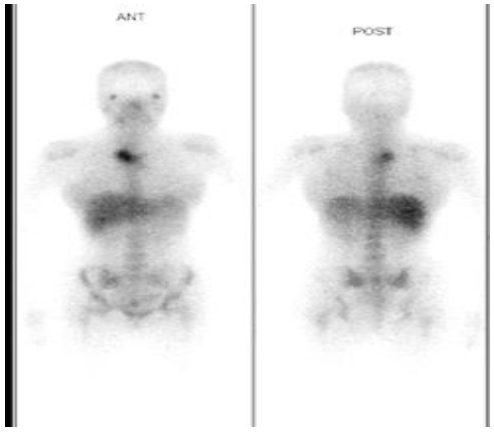
1) Planar Imaging

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

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

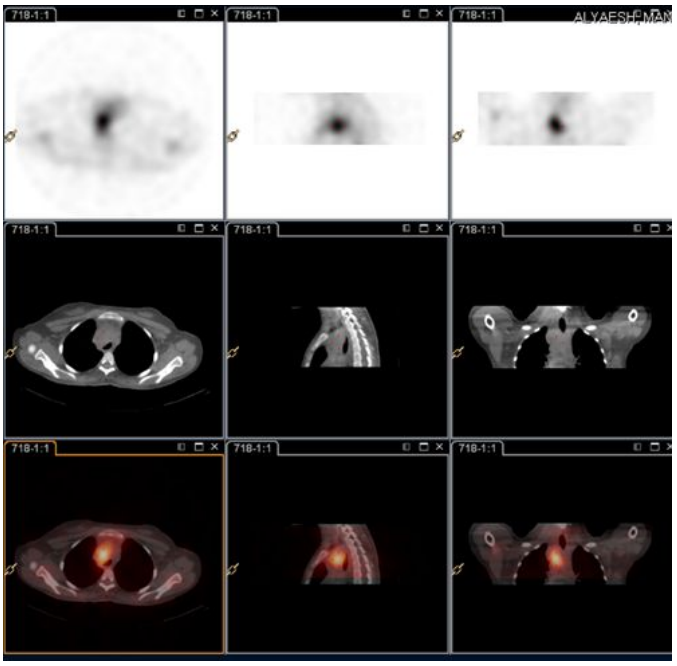
Only SPECT without CT

It can tell us if there is any abnormal uptake of the tracer



Whole Body Gallium Scan : Planar Image

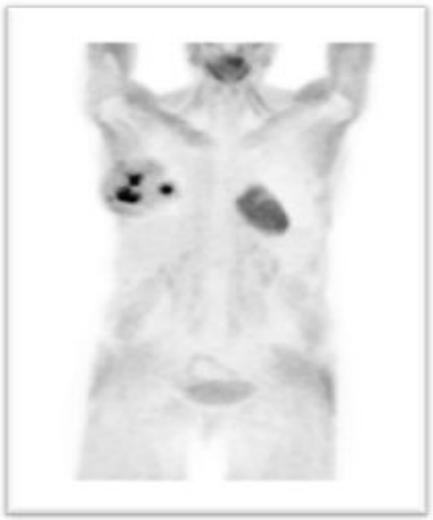
Gallium scan in patient with lymphoma, you can't tell whether it's in the bone or hilum in mediastinum b/c it's 2D image



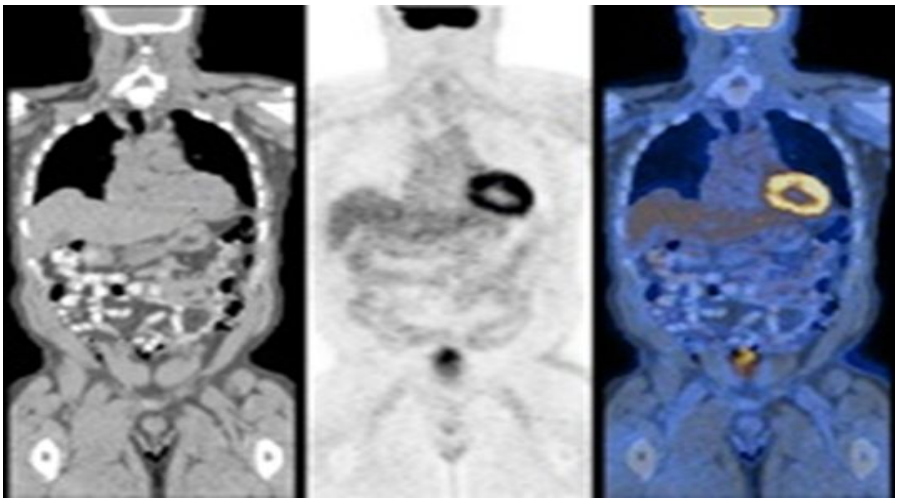
SPECT/CT

- In SPECT image it's 3D
- SPECT image,shows a clear lesion in the mediastinum "behind sternum".
- In SPECT image help to locate the abnormality

Positron Emission Tomography (PET) and PET CT



PET



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

- here, we gave the patient glucose labeled with a radioactive material which was F18, to see any area with high glucose turnover like muscles.
- PET is 2D planar "longitudinal and transverse" there is abnormal uptake in Rt breast "consistent breast Ca"
- PET/CT is 3D "coronal image" 1 st image CT, 2 nd PET, 3 rd PET+ CT

❖ Role for Nuclear Medicine In Oncology:

1. Diagnosis: Specific or non-specific
2. Staging: Important for proper therapy
3. Follow-up: Early detection of recurrence
4. Treatment: Specific or non-specific

Tumor Imaging :

The doctor said: 2 MCQs questions may come in the exam from the below:

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 with FDG or thallium scan, 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 cancer patients "solid tumors").

Bone scan:

we don't want you to know how exactly does it work however, it worth to know that it takes from 3-4 h to be done

primary bone tumors can be detected by cross-sectional images so why do we do a bone scan ? to look for distant metastasis.

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.

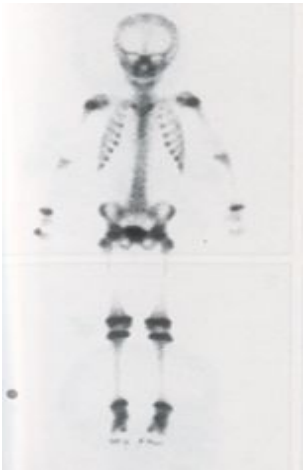
Procedure "Not imp"	Indications
- **Radiopharmaceuticals**: Technetium 99m Methylene DiPhosPhonate (Tc-99m MDP) **- Tissue accumulation depends on** 1) blood flow 2) capillary permeability 3) metabolic activity of osteoblasts and osteoclasts 4) mineral turnover - **Dose**: 500 to 800 MBq (Megabequerel) / 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	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

❖ Imaging features:

The doctor said: 2 MCQs questions may come in the exam from the below:

1) **Hot lesions:** Majority of bone tumors. Majority of hot lesions are bone tumors except trauma and infections. the 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 tissue or kidney activity (e.g. CA prostate ,breast ,lung,colon..etc). After inject radioactive material, there is widespread bone metastasis or the tracer will be taken by metastasis.
★ 4) **Normal distributio**n : Marrow tumors (e.g. lymphomas, leukemia, multiple myeloma). Normal bc the dis is inside the bone	5).**Soft tissue uptake** : Soft tissue tumors may concentrate the tracer.	6) **Flare phenomeno**n: increased number of lesions in the case of effective therapy

Normal Whole Body Bone Scan:



8 year old child
very hot growth plates

25 year old adult

- 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:

there is no metastases below the knee or elbow because there is no red bone marrow there, except for some lung cancers.

★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.

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:

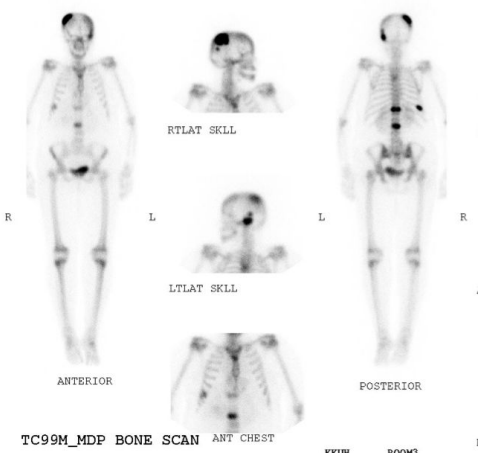
•In early stage superior to x-ray.

•In advanced stage both have high sensitivity.

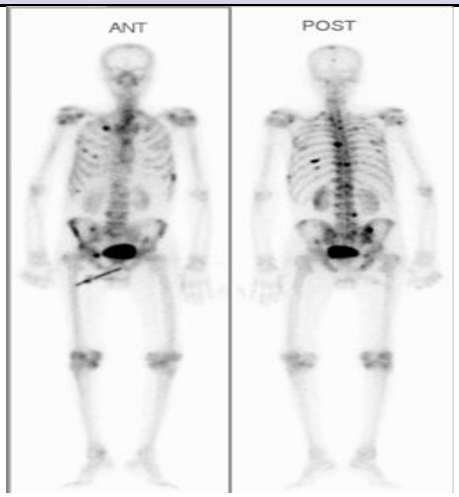
•The accuracy of bone scan not known because of the lack of reference standard.

•The sensitivity is agreed to be 90% or more.

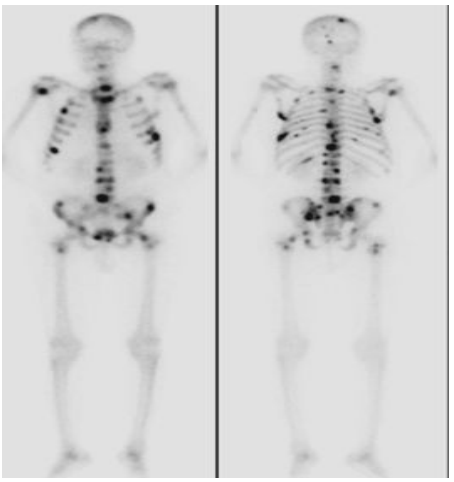
Tumor Staging



Ca Breast



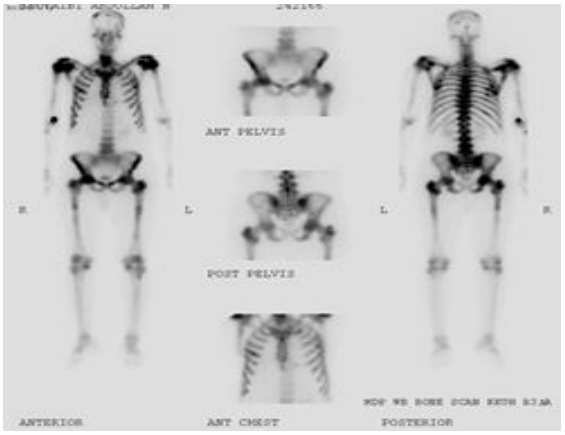
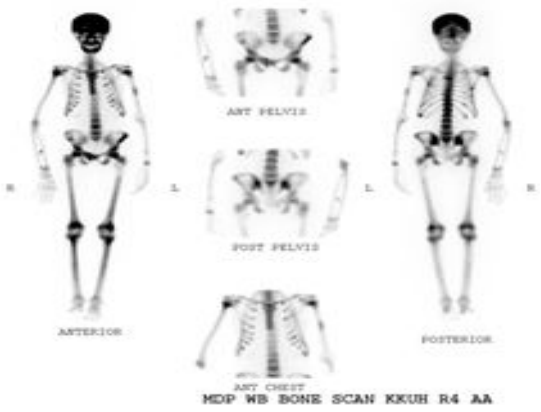
CA LUNG



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) :MCQ 1 or 2

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:**	*pic(a). Bone metastases :* "limited to axial region" Prostate, breast, lung, bladder and lymphoma. *pic(b). Non tumor causes:* "metabolic bone dis" HPT, osteomalacia, Pagets disease, and fibrous dysplasia
Important clues:	In metabolic bone disease the calvarium and long bones are involved unlike in bone metastases.
Images:	 

a) Prostate cancer **b) HPT (hyperparathyroidism)**

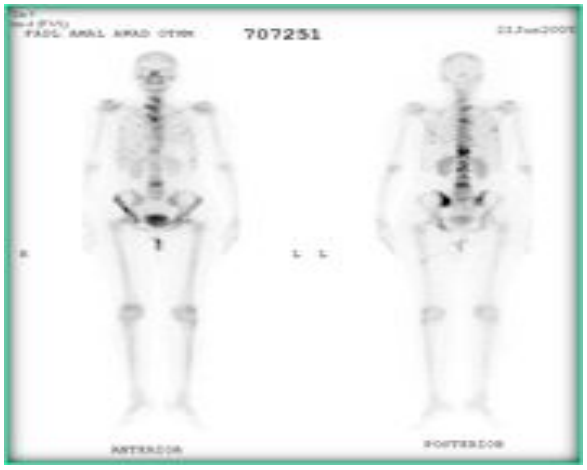
How to differentiate benign from metastatic superscan? Osteocalcin usually affect whole skeleton involve axial and extremities While the metastatic confined in axial "central" skeleton

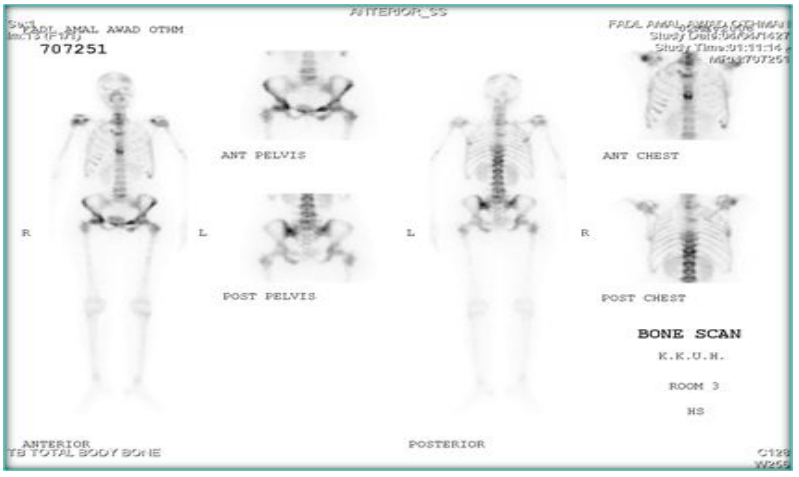
Pure Lytic Lesions:

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 osteoblastic 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.

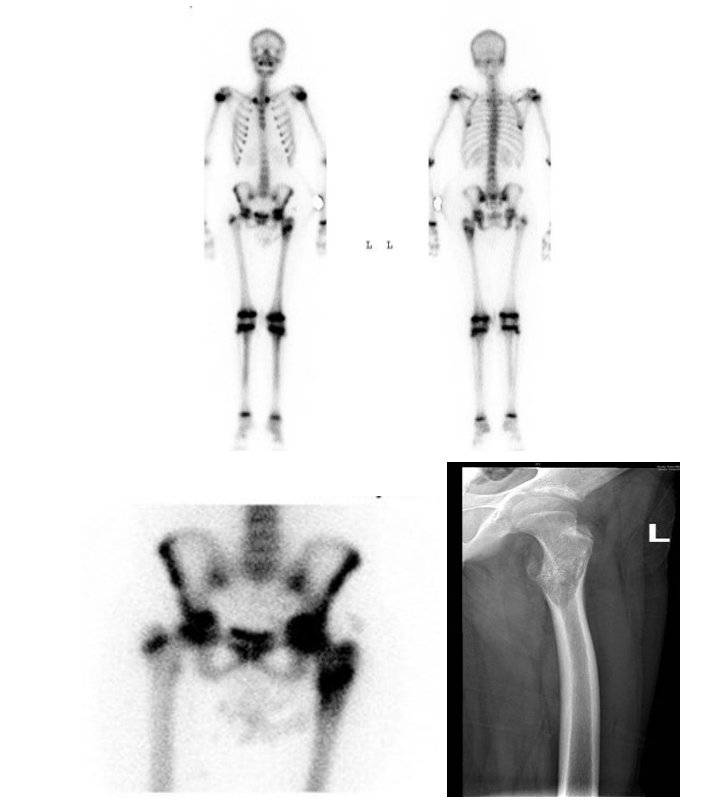
Many patients are referred for radiotherapy, if we see bone scan immediately after radiotherapy due to hyperaemia there will be increase uptake but after 3-6 months there will be decrease uptake.

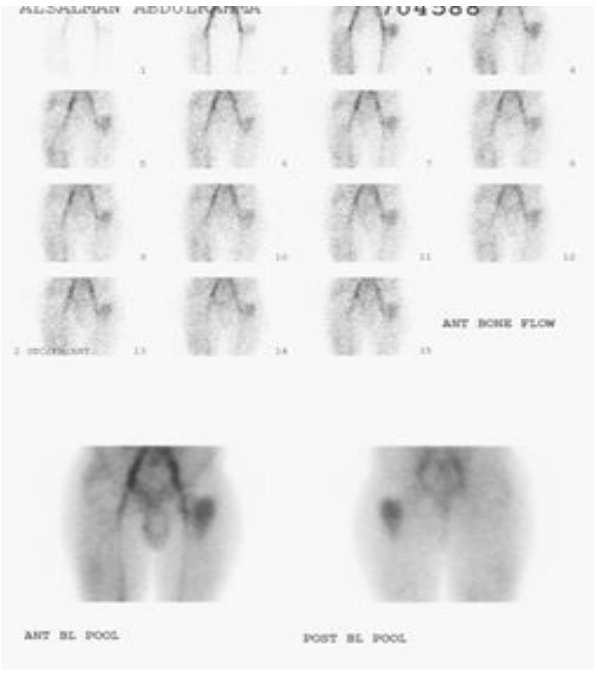
Why?

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

Bone Tumor:

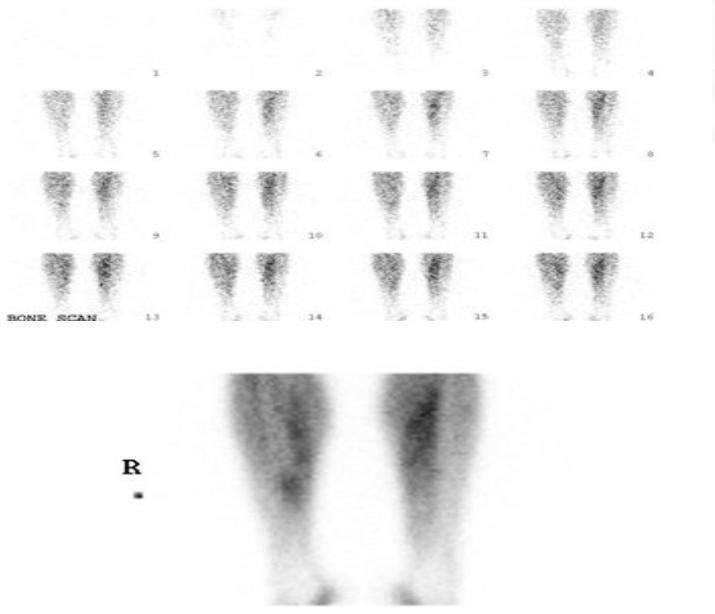
1) ★Ewing's Sarcoma (primary bone tumor) :

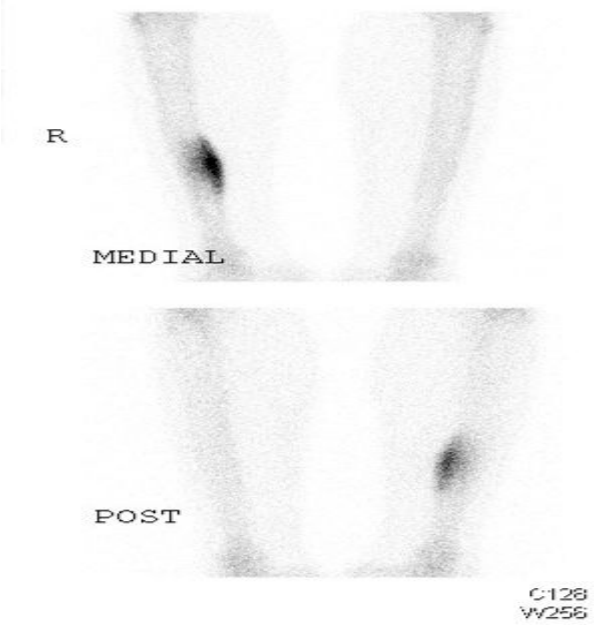




- This called 3 phases bone scan : it shows blood flow, blood pool and delayed image
- The primary diagnosis of bone tumor is radiology. Why they do bone scan? To determine the local extant and to search for distant metastasis
- In this patient the tumor is confined to proximal left femur but rest of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

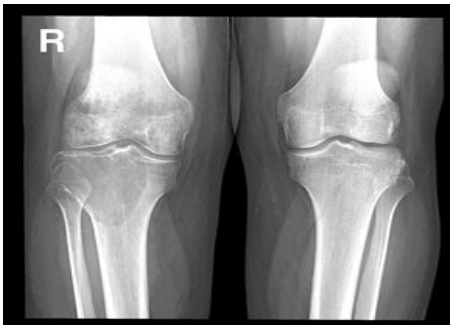
2) Osteoid Osteoma:

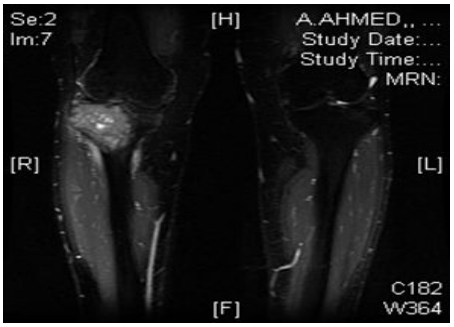


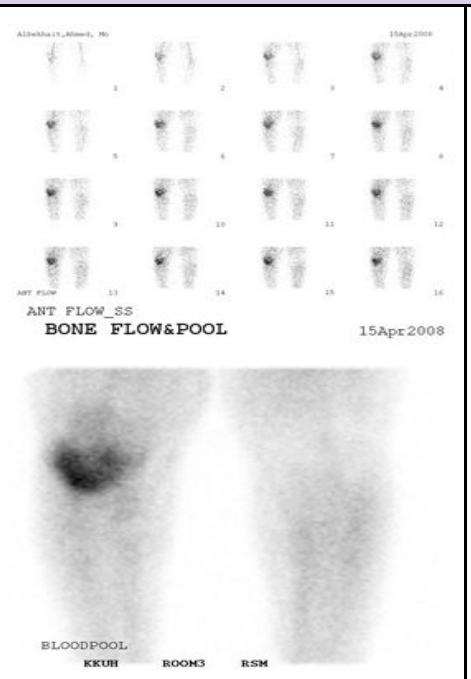


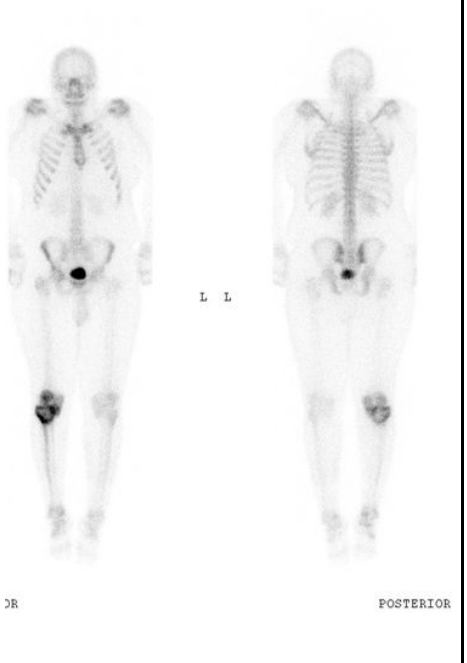
- The bone scan is very sensitive with patient with Osteoid Osteoma
- It's benign tumor usually affect children, "wake up during night b/c of pain once you give aspirin the pain is relieved" the bone scan in this case very useful to confirm the diagnosis
- This is the shape of 3 phase bone scan, treat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

3) Giant Cell Tumor:



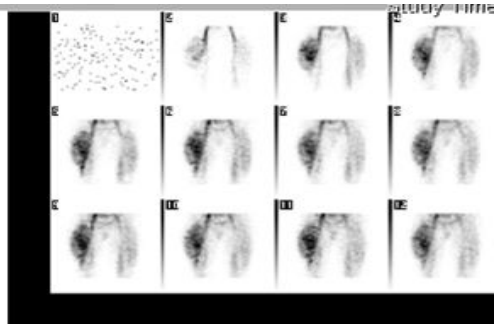


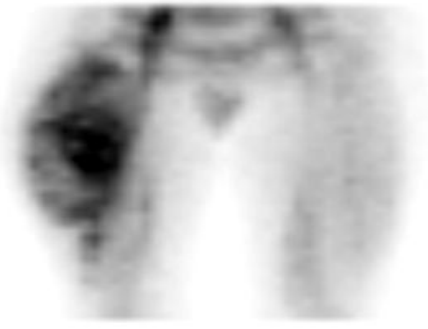


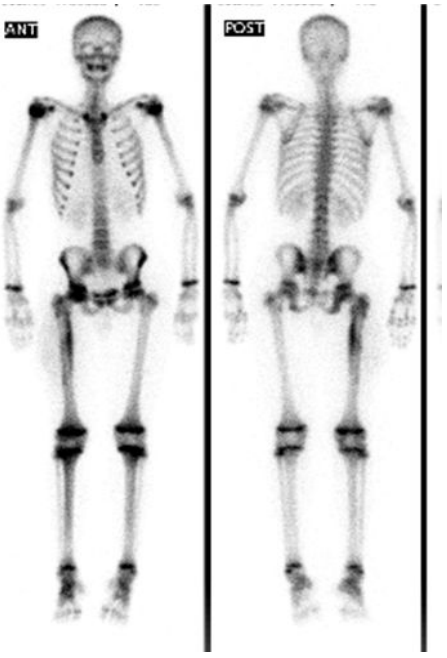


- Also this is 3 phases show increase vascularity, blood pool, increased hyperemia
- And increase uptake in single proximal right tibia with no distant metastasis
- So the main diagnosis by MRI but they want to scan the whole skeleton by bone scan to tell whether there is distant metastasis or not.

4) 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 is the underlying bone invaded or not and is there any metastasis

Gallium 67 (Ga-67) scan:

★ **used for staging & response to treatment**

Properties

Introduced in seventies of 20th century for lymphomas

1) Mechanisms of accumulation	–Tumour viability –Blood flow –Capillary permeability –Lymphatic drainage –Binds to Transferrin receptors on the tumour cells.
2) Nonspecific for infection-inflammation and tumors	
3) 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: the gold standard material is fluorine 18 however, gallium is still used "it is the FDG of the poor"

Clinical indications:-->	• Lymphoma • Lung cancer • Melanoma • Hepatoma
Normal Ga-67 scan:--> Normal scan	• Accumulates in bone marrow and liver. • Splenic uptake is variable. • The kidneys are usually visualized, and 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.

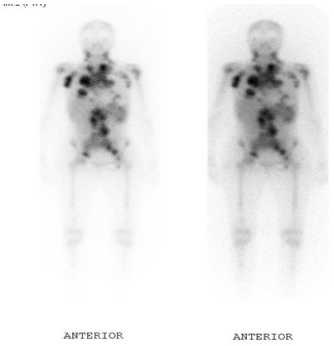
Shows liver and bone marrow because Ga is iron analogue: GA attaches to Ferritin, so where ever the concentration of Ferritin is higher it will appear on the scan (Liver, Bone, spleen).

★Gallium Scan in Lymphomas:

1- Staging
2- Follow up and monitoring of therapy
3- Detection of tumor recurrence
4- Differentiate post-therapy changes: tissue necrosis and fibrosis from local recurrence.

★Pic: stage 4, (=above and below diaphragm with spleen involvement).

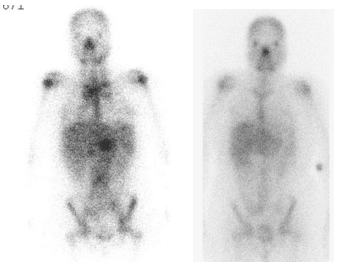
- stage three same but without organ involved



→ 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

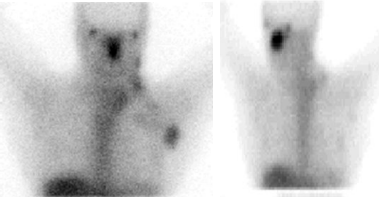
- Baseline Ga scan, they start chemotherapy after the 1 st course they repeat the Ga scan if the patient responded to Ga it means the chemotherapy is effective and they will continue on it
- In this patient you can see there was hot spot in mediastinum after 1 course has good response



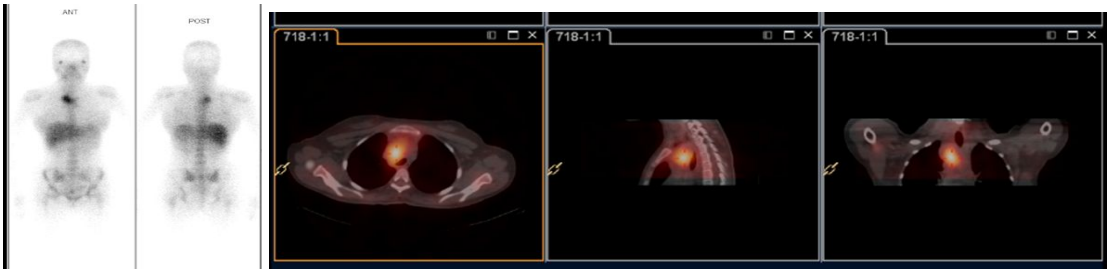
has good response

→ Prediction of outcome:

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



Gallium Scan NHL (Planar Vs SPECT CT):

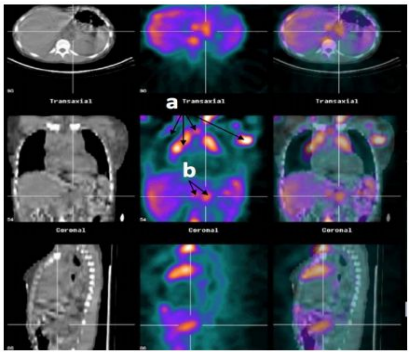


- PET CT very important for localization of abnormal uptake.
- As in this patient shows abnormal uptake in anterior mediastinum

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.

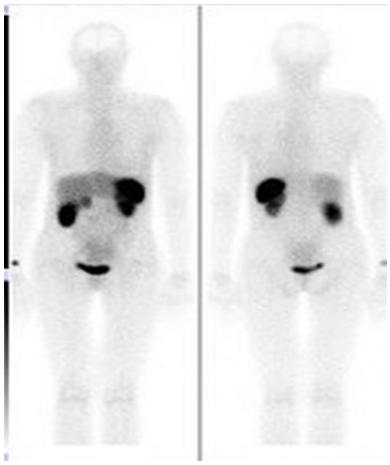
The para-aortic lymph node uptake (b) combined with CT findings allowed the diagnosis of **<u>subdiaphragmatic disease</u>** and excluding bowel activity



Neuroendocrine Tumors

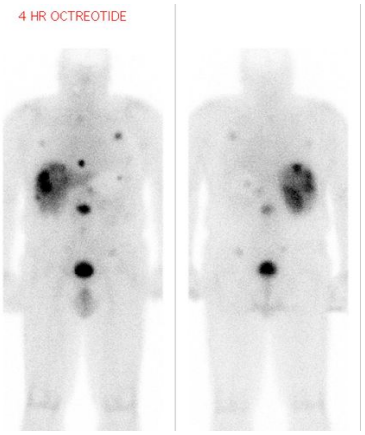
- In-111 octreoscan.
- I-123 MIBG Scan.

★Somatostatin Receptor Imaging / Indium-111 Octreoscan:



NORMAL STUDY

This how indium looks , the normal distribution will show 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 White spots are neuroendocrine tumors, metastases from the insulinoma.there is mets but still considered benign

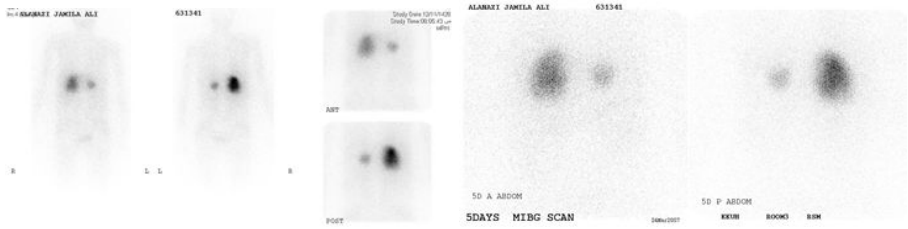
I-123 MIBG Scan:

- 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:

1) Pheochromocytoma 2) Paraganglioma 3)Insulinoma 4) Neuroblastoma 5) Medullary thyroid carcinoma 6) Carcinoid tumors

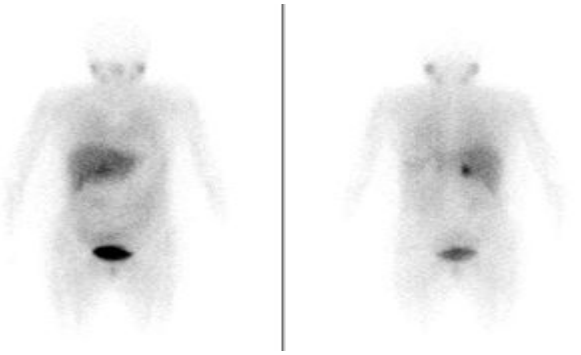
★MIBG In Pheochromocytoma (Bilateral Disease)

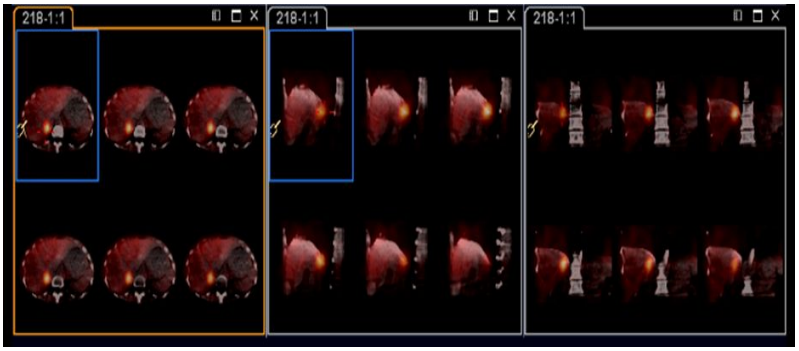


Bilateral adrenal masses.
The bilateral abnormal uptake represent bilateral Pheochromocytoma.

★Pheochromocytoma (Planar Vs SPECT CT):

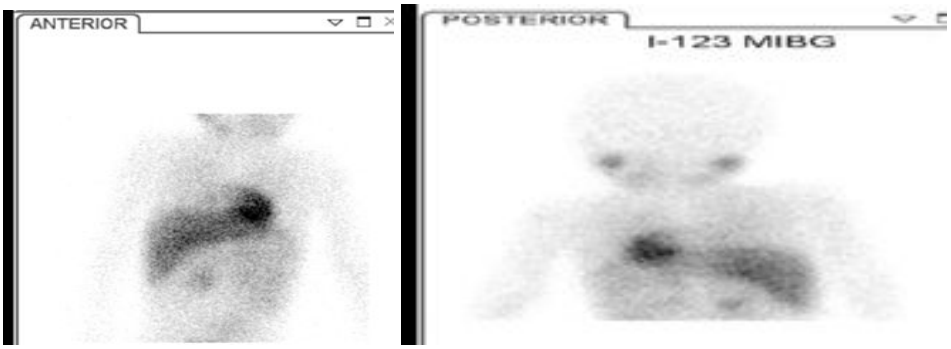
A 41 years old female patient is with 2ndary hypertension. Right adrenal mass? **Pheochromocytoma**

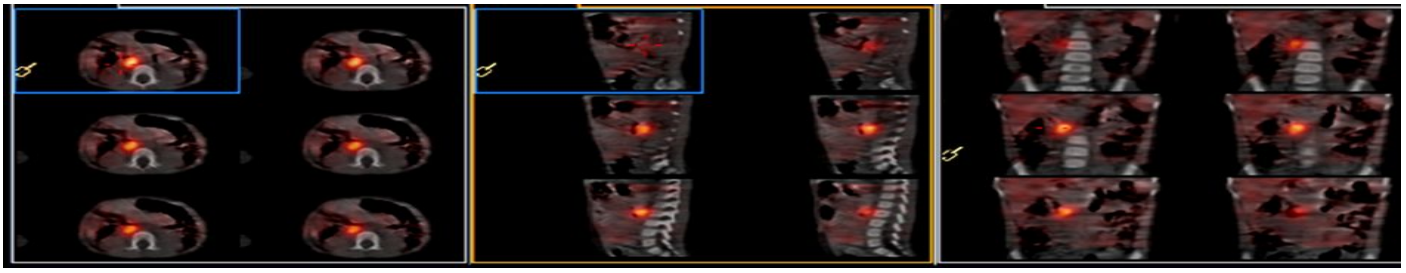




Suspected PCC with abnormal uptake below the liver.
SPECT CT shows that its close to the spine and its Para-spinal just superior to the kidney and that's represent right PCC.

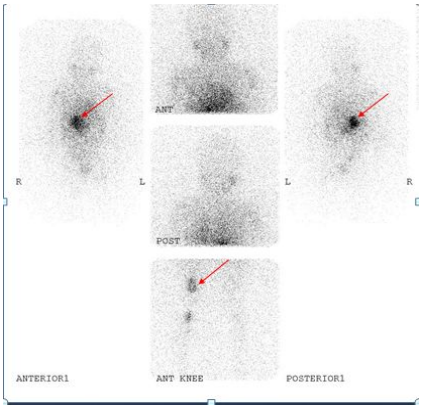
Neuroblastoma (Planar Vs SPECT CT): "without distant mets"





- Common tumor in children under 5 yrs and MIBG is used for initial staging and diagnosis.
- SPECT CT: it was in the Para-spinal area
- All neurogenic tumors are close to the spine why? In embryo all the sympathetic chain extend from the base of the tongue to the urinary bladder around the spine that's why all are in the para-spinal area. only the primary mass in the abdomen anterior to the spine

I 131 MIBG Total body scan: (1ry neuroblastoma /bone metastases)

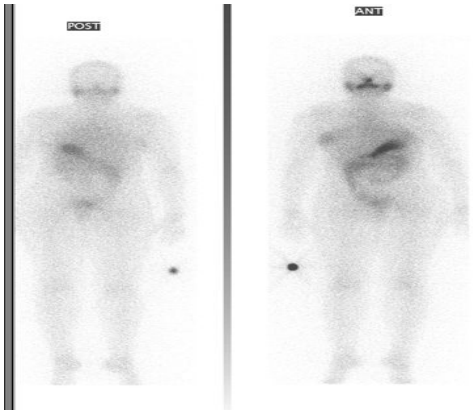


THYROID METASTASES STUDY (I-123 or I-131 as Sodium Iodide):

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 → for Dx b. I-131 as sodium iodide : 2-10 mCi → higher dose for therapy 100-200 mci
Imaging using Gamma camera :	**Whole body scan**

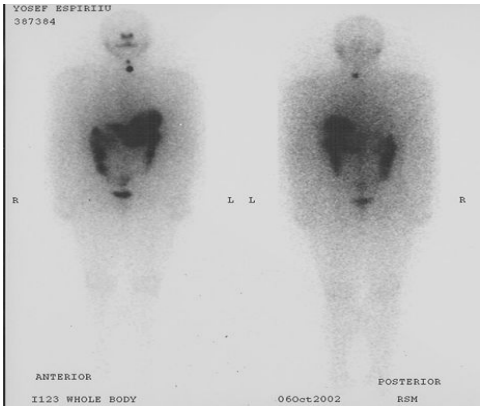
I-123 or I-131 are tumor specific agent spastically for thyroid cancer. I-123 used for diagnosis, I-131 treatment of thyroid cancer and metasets because its beta emitting

Thyroid Cancer I-123 WB Scan



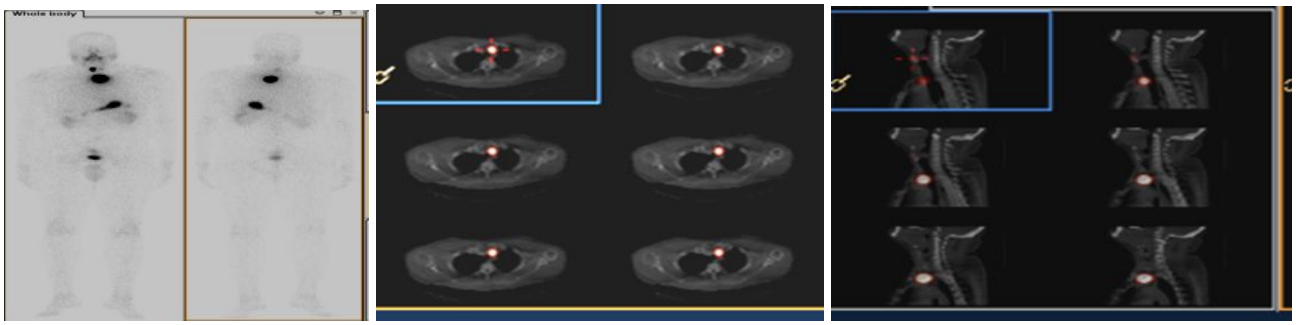
Negative I-123 WB Scan

The surgery went very well ,there is no thyroid remnant in the thyroid neck. if there's remnant give p. I 131



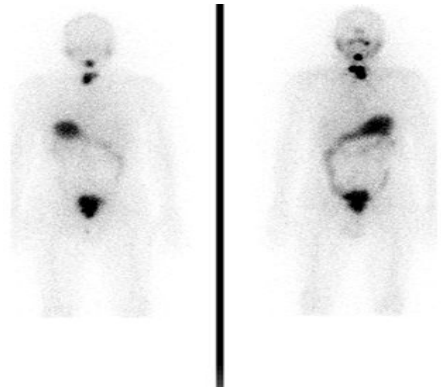
I-123 WB Scan : Post operative Thyroid remnants

I-123 WB Scan (Post operative Thyroid remnants) Planar vs SPECT CT

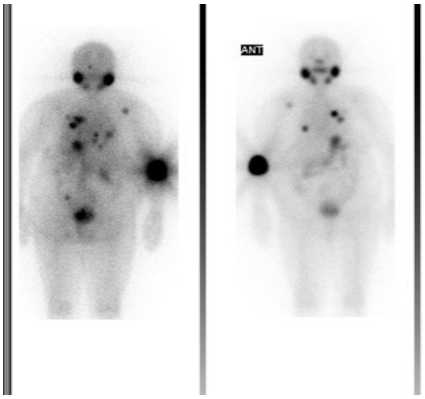


Had thyroid remnant in thyroid bed the surgery was not complete so give him I-131 to treat him, if there are large rement do surgery again

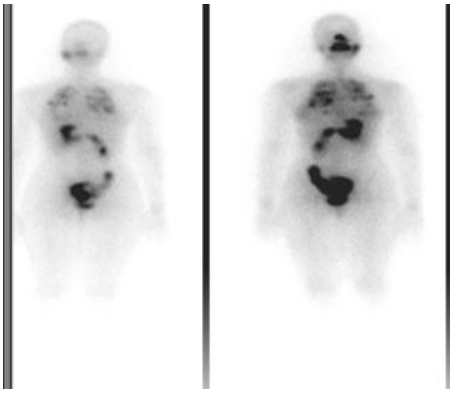
★THYROID METASTASES STUDY (I-123 or I-131 as Sodium Iodide): (MCQ):



Local Recurrence



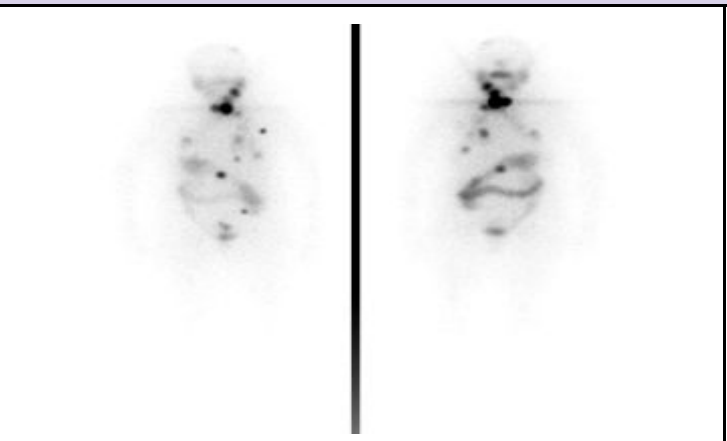
Bone Metastases on ribs



Lung Metastases

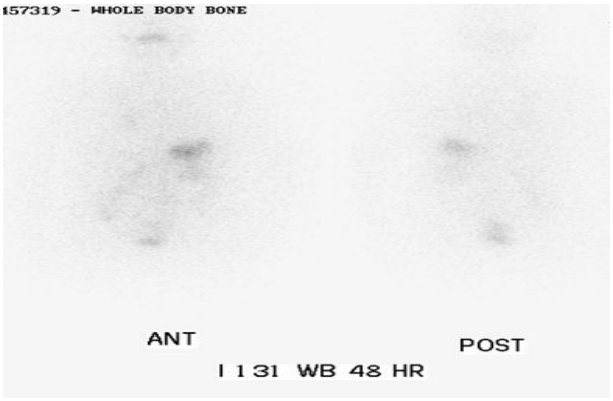
Tumors from thyroid are of 2 types differentiated and undifferentiated. The differentiated are from follicular (hematological spread so it go to all places of the body), papillary (local spread via lymph node). This patient is having wide spread follicular. In the middle pic the black in his hand is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

Thyroid Cancer(I-131 Pre & Post therapy):



december 04

wide spread metastasis local bone lung

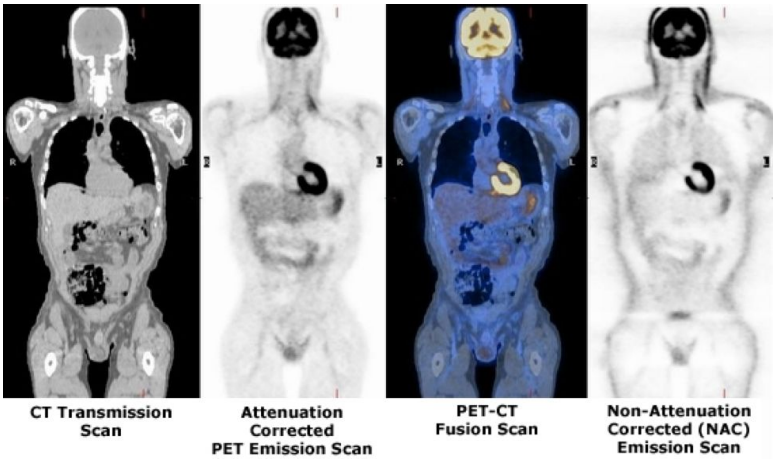


march 06 (recovery)

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

PET CT = PET + CT = Function + Form



★The most commonly used agent is Fluorine 18 with t/2 under 110 min and Gallium 68 t/2 68min.

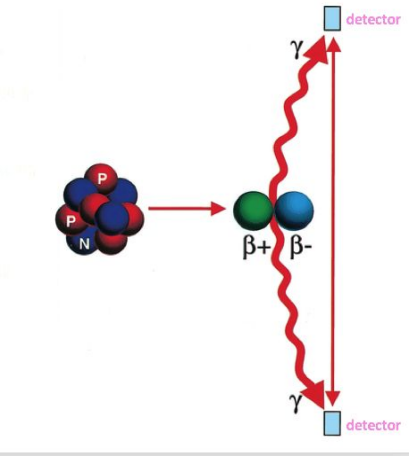
Normal distribution of FDG happens in the brain, where the main source of energy is glucose.

بالنسبة للقلب نخلي المريض يصوم عشان نجوّع التومر وياخذ القلوكوز لما نعطيه، بينما النورمال تشيو بيعتمد الفاتي أسيد

❖ PET: How it is performed ?

(in PET rays move in two direction, while in SPECT rays move in multi direction)

- **Positron emitters (e.g. F18)** labelled with biologically active natural compounds such as oxygen, carbon or glucose are given 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 SCANNER giving an image of the normal and abnormal distribution of tracer in the body



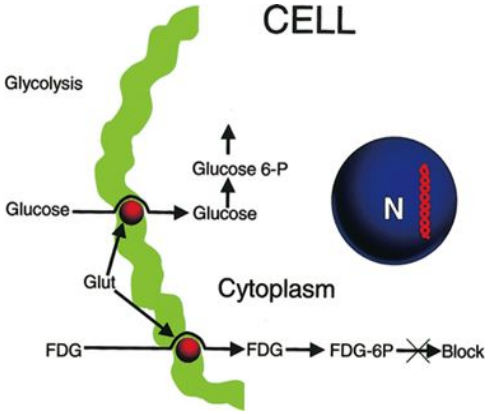
Positron Emitting Isotopes

Cyclotron produced isotopes		Generator produced isotopes			
isotope	**T/2**	**parent**	**T/2**	**daughter**	**T/2**
oxygen-15	2 min	Strontium-82	25 days	Rubidium-82	75 sec
nitrogen-13	10 min	Zin-62	9.3 hrs	Copper-62	10 min
carbon-11	20 min	Germanium-68	288 days	Gallium-68	68 min
fluorine-18	**110 min**				

MCQ :A question about half life of the fluorine-18 .

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

- FDG is a glucose analogue used to assess glucose metabolism.
- FDG transported from intravascular space to the cells by the same mechanism as the glucose.
- In the cell, hexoKinase acts on both <u>FDG and glucose to form:</u>
  - FDG-6-phosphatase (FDG-6-PO4-)
  - Glucose-6-phosphatase.
- FDG-6-PO4- can't 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***

❖ FDG : Normal distribution:

if we know the normal we can know the abnormal

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

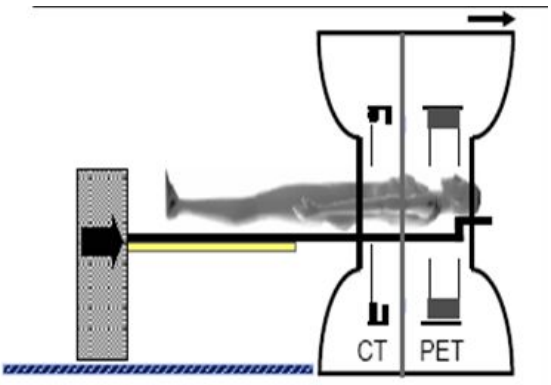
•Recurrence vs post-operative changes (limitations with FDG)

•Monitoring response to therapy

PET CT

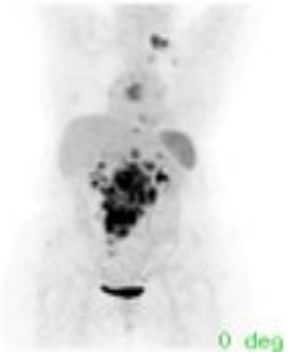
❖ F18 FDG IMAGING PROTOCOL:

- 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)



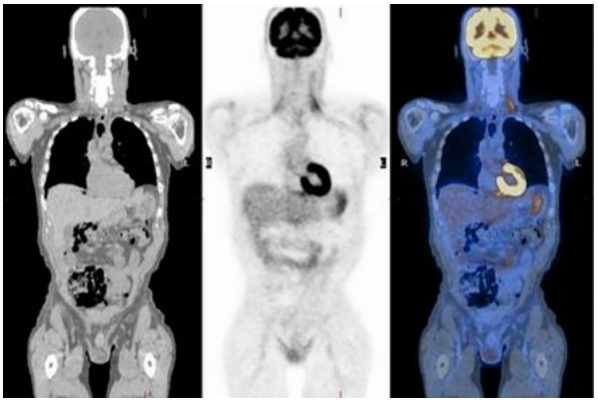
FDG PET

Normal

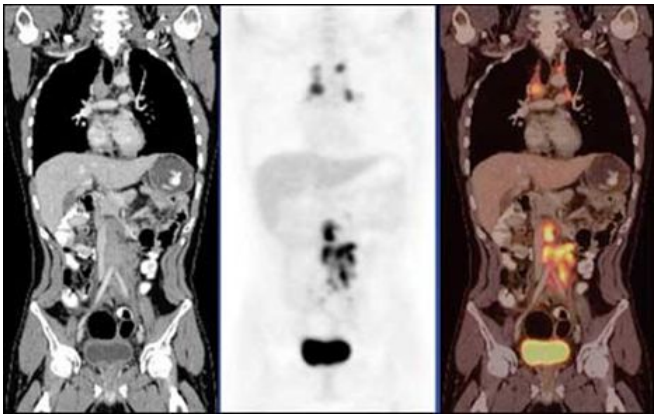


Staging of NHL "stage 4"
the dark spots show increase in glucose metabolism below and above diaphragm with organ involvement so this is stage 4 lymphoma

FDG PET-CT

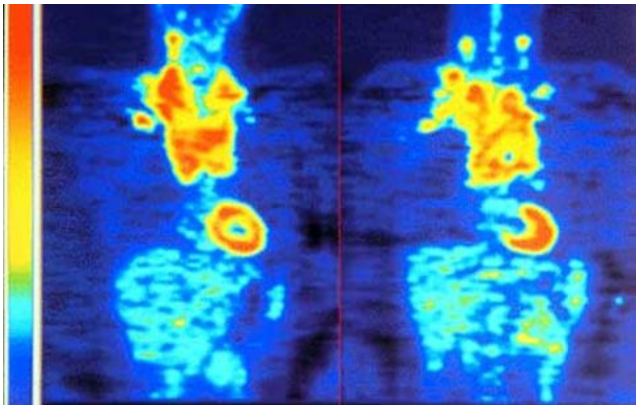


Normal
here we do CT and PET and combine them together

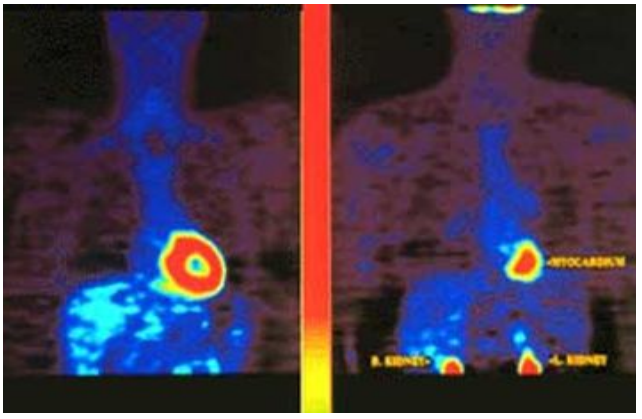


Staging Of Lymphoma "stage 3"

Assessment of therapy response FDG PET in HD



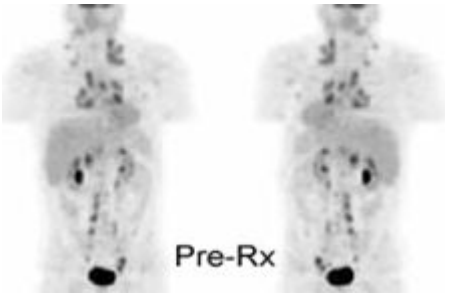
Baseline

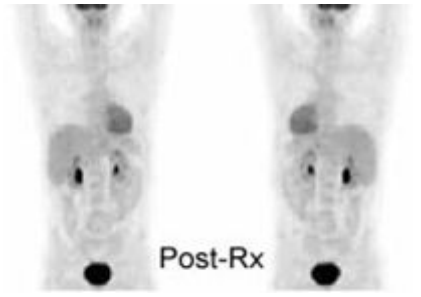


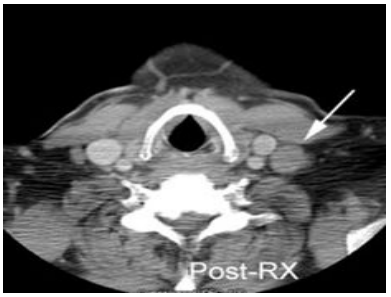
post therapy

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. Baseline therapy shows hilar uptake, post therapy shows complete resolution of abnormal glucose metabolism.

FDG in Non-Hodgkin's lymphoma Response to therapy "very good response to treatment"



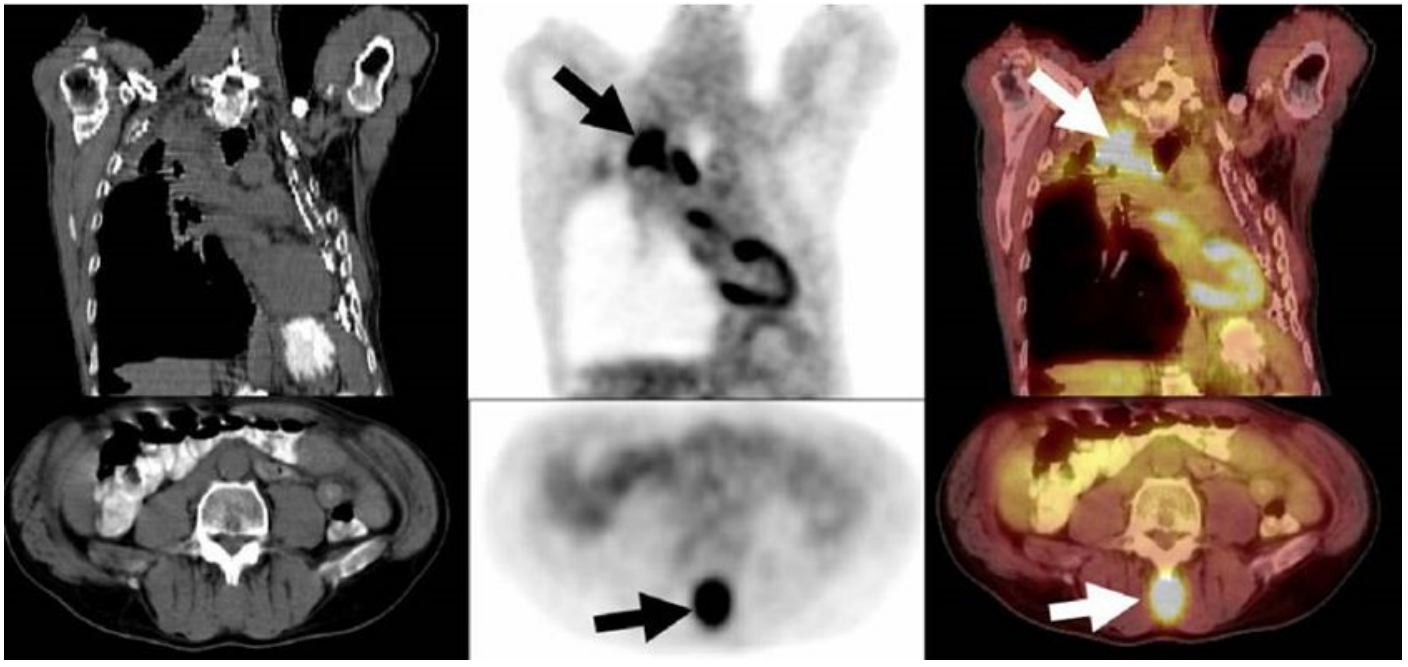




post therapy show complete resolution of abnormal glucose metabolism. (continue the same chemo RX)

PET CT In Lymphoma		
	Sensitivity (%)	**Specificity (%)**
CT	61	89
FDG-PET	78	98
FDG-PET and CT	91	99
FDG-PET/CT	96	99

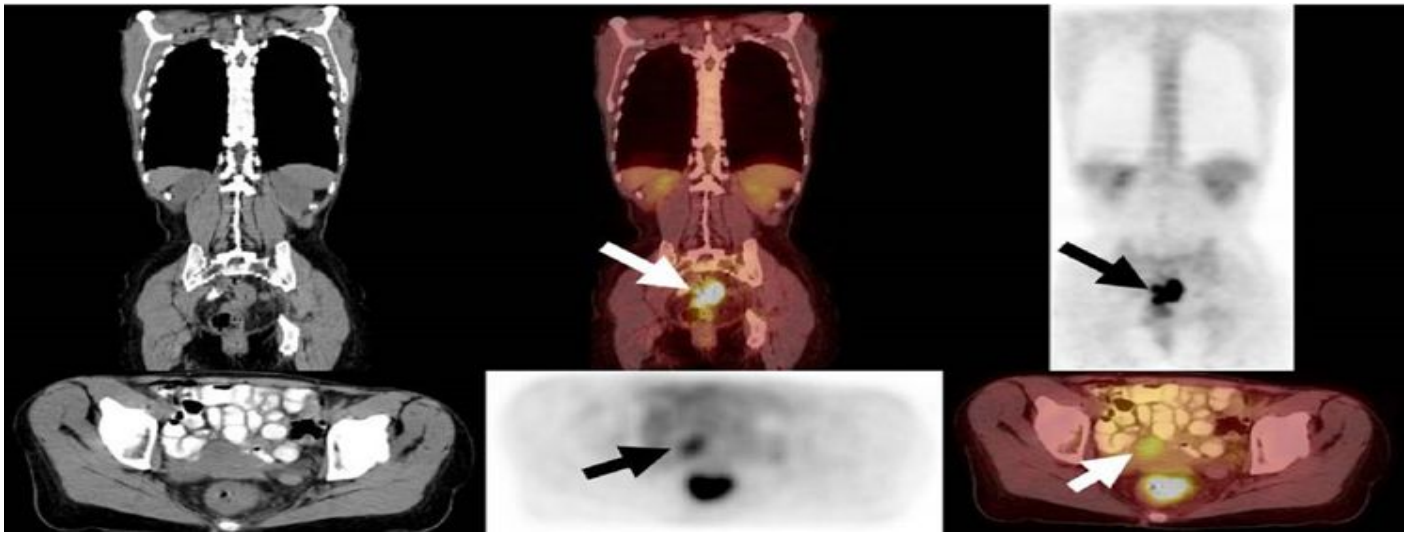
PET CT Lung Cancer Staging



FDG avid soft tissue mass associated with a destructive L5 spinous process consistent with metastatic deposit (arrow). see the metastasis to the spine. PET for local, Dx, following

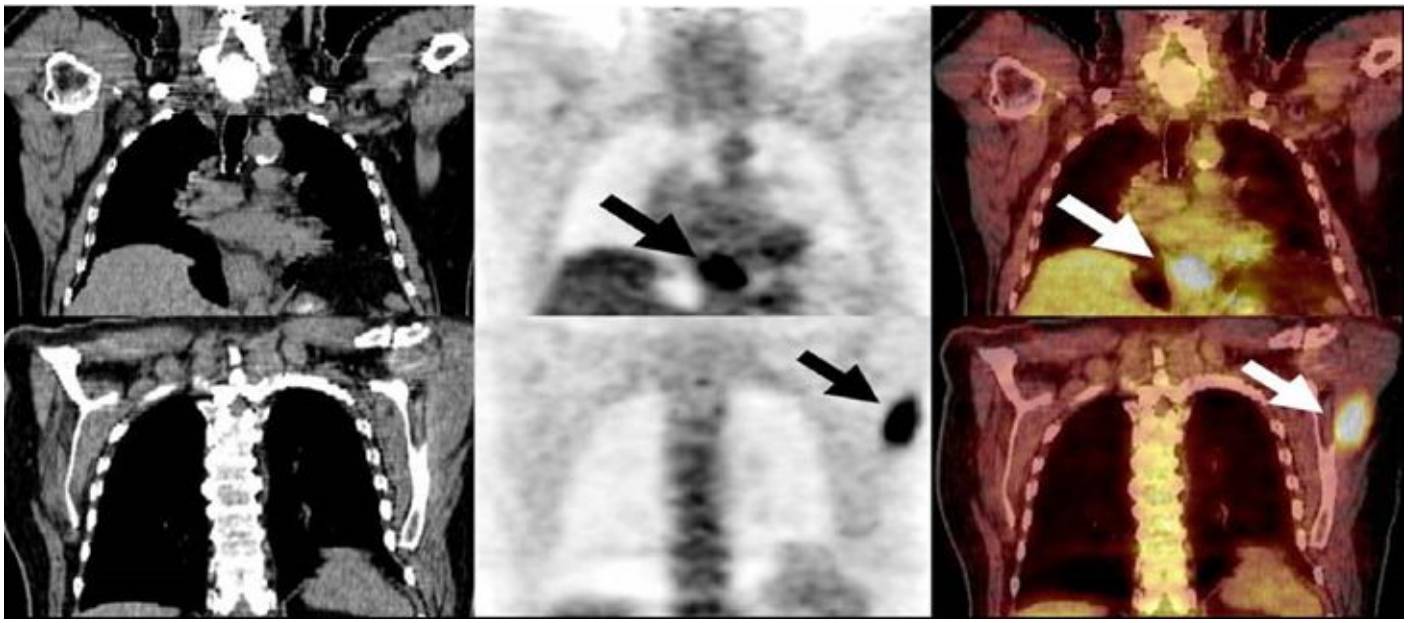
FDG PET CT in Solitary Pulmonary Nodule (SPN):
Sensitivity : 82 – 100 %
Specificity : 67 – 100 %

CA Rectum Staging



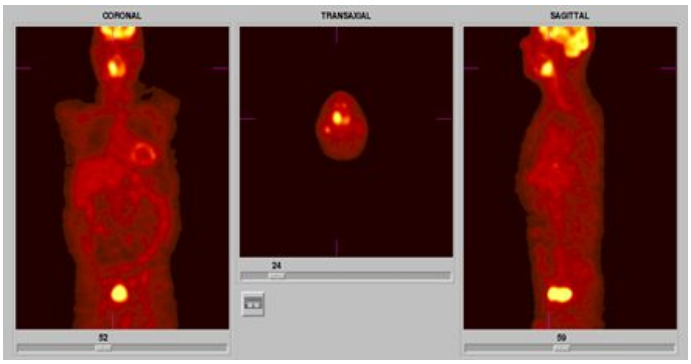
A 57-year-old woman presented with pain and constipation and colonoscopy revealed an obstructing rectal mass. A staging FDG-PET/CT demonstrated intense FDG avidity in a circumscribed mass-like thickening of the proximal rectum (arrows in top row images) and a focus of mild metabolic activity anterior 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. the importance of PET CT is that you can screen all the body for distant metastasis whether in soft tissue or in bone or in liver

CA Esophagus Staging

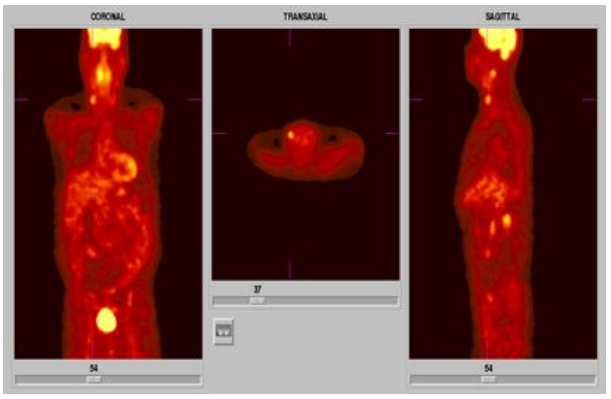


Based on FDG-PET/CT results the clinical management of this patient was changed from surgical resection of the primary tumor to combined chemo-radiation therapy.

FDG PET Tumor of unknown origin



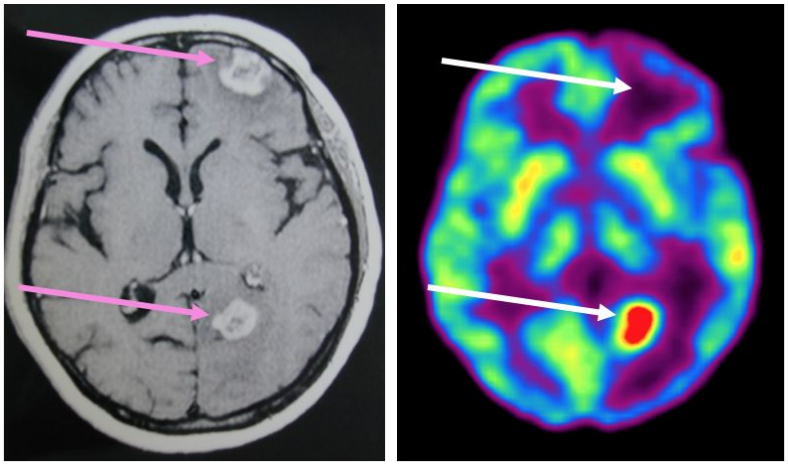
Pharyngeal cancer.
the only way to confirm the diagnosis through a biopsy (it could be lymphoma)



Metastatic involvement of neck lymph nodes

★FDG PET – brain tumor post therapy

Two foci on CT, only one viable tumor



In brain 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. which one of them is a viable tumor and which is fibrotic? The one that appear on PET is a viable tumor while the other is non-viable and don't need therapy. so on CT alone it won't differentiate viable tumor from fibrosis.

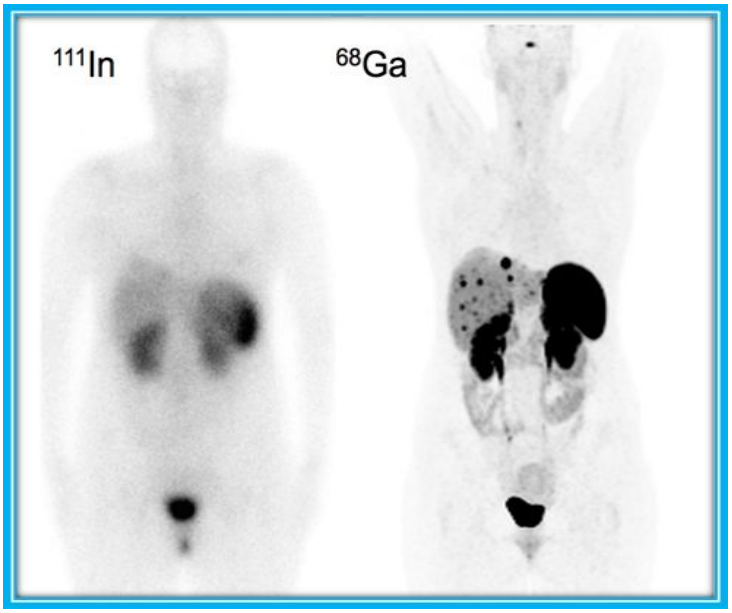
Indications of PET CT (MCQ)	
Breast Cancer*	Staging*, restaging*, and monitoring response to therapy*
Colorectal Cancer	Diagnosis*, staging* and restaging*
Esophageal Cancer	Diagnosis*, staging* and restaging*
Head & Neck Cancers (excluding CNS and thyroid)	Diagnosis*, staging* and restaging*
Lung Cancer (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)
Indications	Tumours with high expression of receptors of somatostatin (neuroendocrine): 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 while the technetium or indian octreotide scan the patient go 2 consecutive days	

Normal Distribution 68Ga-DOTA peptide PET/CT	**Ga-68 DOTANOC PET**	
		
Normal tracer uptake is seen in the pituitary, salivary glands, thyroid, liver, spleen, adrenals, pancreas, kidneys, ureters, and bladder	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

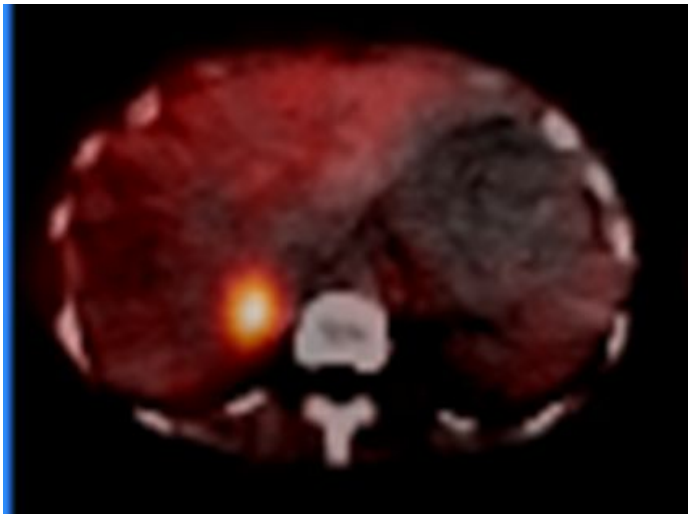


Carcinoid tumor : Positive 68Ga-DOTA-NOC and Negative 111In-Octreoscan.

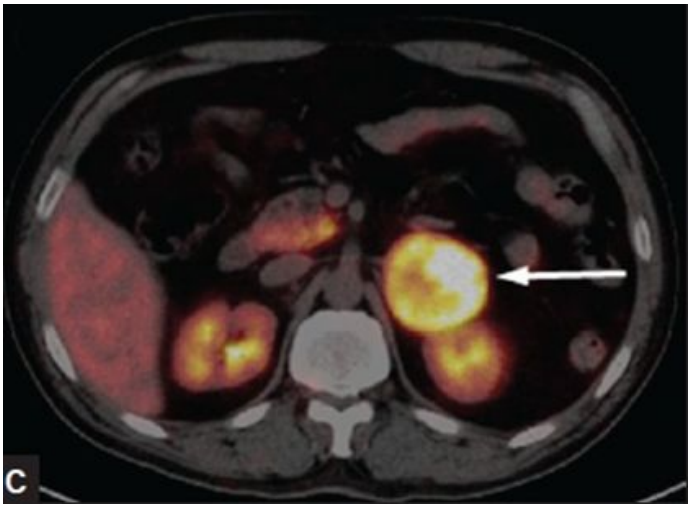
^{68}Ga DOTA-NOC Findings: Multiple metastatic lesions in the liver. (The pituitary also expresses somatostatin receptors and is visualized in the 68Ga PET image, along with normal uptake in the spleen, kidneys, and bladder.)

Indication of ^{68}Ga DOTA-NOC: The 68Ga PET scan was performed because the patient's symptoms were inconsistent with the 111In-Octreoscan findings.
This gallium is 68 its PET agent the other gallium is 67 (SPECT) they are different.
Ga-68 is much more sensitive than In-111 in detecting neuroendocrine tumors.

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 but beta stay confined to the tissue of the person.

Radionuclide Therapy		
Agent	**indication**	**dose (don't memorize it)**
★ **I-131**	Thyroid cancer	100-200 mCi
131 MIBG	Neuroblastoma	100-300 mCi
Strontium-89	Bone metastasis	40-60 uCi/k
Sm-153-EDTMP	Bone metastasis	1.0 mCi per Kg
Phosphorus-32	Polycythemia	2.3 mCi/m2
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 exacerbated 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.