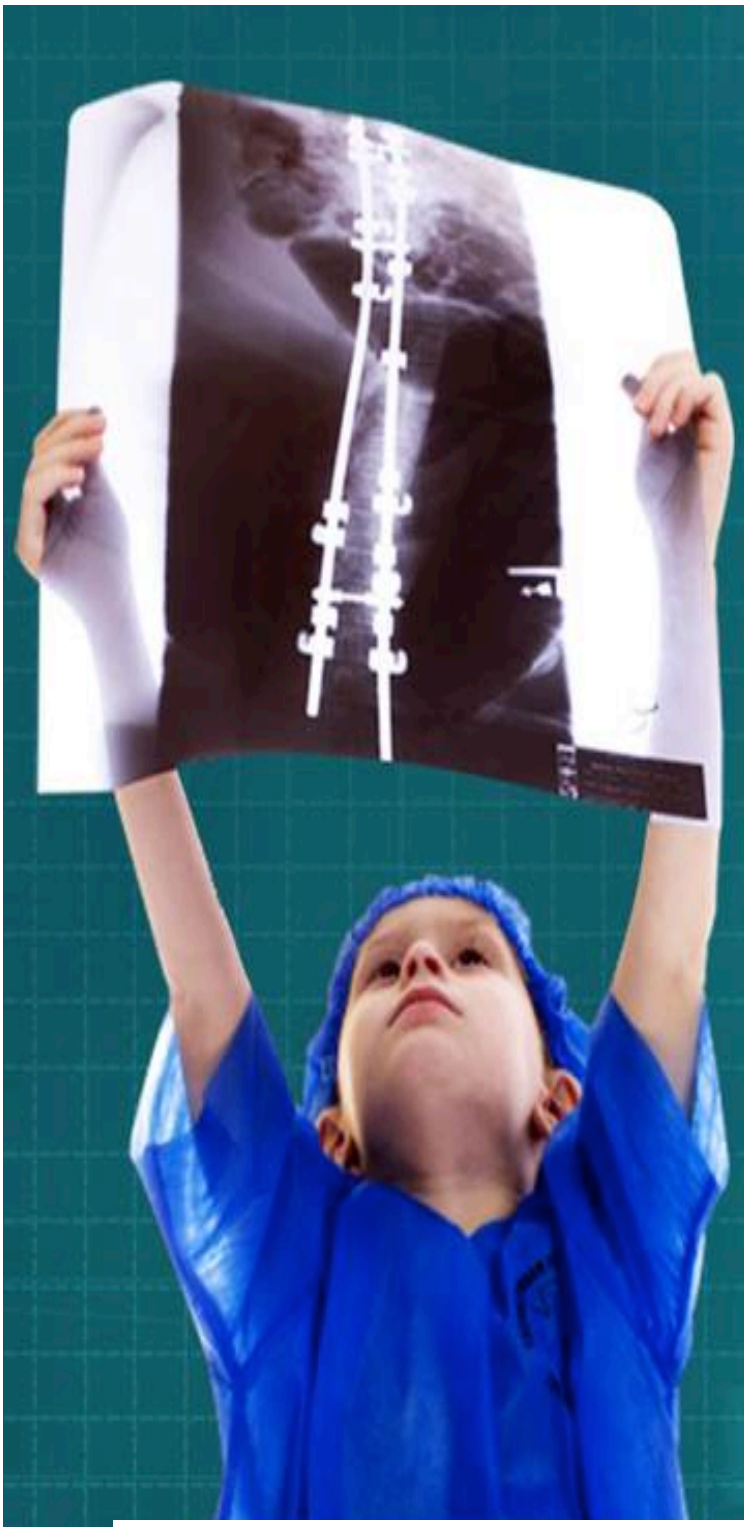

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Radiology Team

Leader: Lama AlShwairikh

Sub-leader: Abdulaziz Almutair

Lecture 5: Nuclear Medicine in Oncology

Done By: Omar Al-Omar

Revised By: Lama AlShwairikh

◆Important ◆Doctor's notes ◆Team's notes

We thank 430 Team for their helpful notes

All the images are from the lecture.

Objectives

What is nuclear oncology?

- The use of isotopes in the diagnosis and treatment of tumors
- In nuclear medicine: the radiation comes out of the patient (unlike radiology) and then it is detected by the machine .
- Nuclear medicine is not radiation therapy!
- Radiation used in nuclear medicine is gamma rays.

What is nuclear medicine? An illustrated introduction
http://www.youtube.com/watch?v=wfPza-R2sAY

Nuclear medicine procedure:

-Patient is injected with small amount of radioactive material (tracer)
-Radiopharmaceutical localizes in patient according to metabolic properties of that drug.
-Radioactivity decays, emitting gamma rays. (The body is the one emitting radiation, not the machine as in x-ray)
-Gamma rays that exit the patient are imaged through gamma camera.

Tumors

Metabolic properties: Each organ has metabolic properties. **E.G.:**

- Increased vascularization.
- Increased capillary permeability.
- Newly proliferated capillaries.
- Increased blood flow.
- Metabolically active cells: Those cells need more glucose and that's why patients start losing weight.
- Increased energy demand.

We use these properties to allow the radioactive material (tracer) to reach the organ of interest.

Tumor cells

IMP: "In tumor imaging we have 2 groups, you should know that, I'll ask you in the exam about it: specific and non-specific agents"

Specific useful properties:

*High density of some common receptors (like neuroendocrine tumors which express somatostatin 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 tracers:

Can go to normal tissue and abnormal tissue.

1•PET or PET-CT (PET: positron emission tomography. They emmit two photons in opposite direction)

F-18 FDG (Fluorine-18 fluorodeoxyglucose) – anaerobic metabolism (Most commonly used. It expresses glucose metabolism by the tumor)

2•Planar, SPECT or SPECT-CT (SPECT: single-photon emission computerized tomography)

- Diphosphonates – bone scan.
- Ga-67 citrate – similar to FDG – localizing agent.
- Tc99m Nanocolloid – bone marrow scan.
- Tc99m MIBI / Thallium 201 – several tumors.

Demonstrate tumor sites but are not specific for malignancy. They don't determine the nature of the tumor. It can be used to see if there is bone metastasis for example.

Tumor specific: go to specific organs. E.g. radioactive iodine goes to the thyroid because the thyroid consumes iodine.

1•PET or PET/CT

2•Planar, SPECT or SPECT/CT

- I-123/131 MIBG for neuroendocrine tumors.
- I-131 for differentiated thyroid carcinomas.
- In-111 or Tc99m octreotide for tumors expressing somatostatin receptors.
- Monoclonal antibodies labelled with In-111, I-123/131 or Tc-99m.

Binds directly to special tumor antigens or receptors or are accumulated by special metabolic pathway.

Therapeutic radiopharmaceuticals (Non-specific and specific)

[90% of nuclear medicine is used in diagnosis, 10% is used in treatment]

1) Non-specific

- Sr-89, Sm-153, Re-189:
  Bone pain palliation (used to treat bone metastasis)

2) Specific

- I-131

Thyroid cancer, as specific diagnostic if tumor significantly accumulates (Only goes to thyroid tissue)

- Y-90

Zevalin – monoclonal antibody for B-cell lymphomas (only goes to there because it's labeled with antibody to B-cell lymphoma)

I: Iodine
In: Indium
Sr: Strontium
Sm: Samarium
Re: Rhenium
Y: Yttrium
Tl: Thallium chloride
Tc: Technitium
Ga: Gallium citrate
F: Fluorine

Physical Properties SPECT Radionuclides:

"You should ONLY know the half-life. Other properties I don't want you to memorize it."

Radionuclide	T/2 physical	Type of radiation	E(kev)
Technitium 99m(Tc-99m)	6 hrs	Gamma	140
Iodine I131	8 days	Gamma/ Beta	364/606
Iodine I123	13.2 hrs	Gamma	159
Gallium Citrate (Ga-67)	78.3 hrs	Gamma	90,190,290
Thallium Chloride 201 (Tl201)	73.1 hrs	X-ray	68-83
Indium 111 (In 111)	2.8 days	Gamma	173,247
Xenon 133	5.2 days	Gamma	81
Kripton 81m	13 secs.	Gamma	190

The doctor only mentioned those 4 in the lecture.

Physical Properties of positron emitting (PET) Radionuclides:

Only know half-life of Fluorine 18 (note that it's in minutes). No need to memorize the others.

Radionuclide	T/2 physical (min)	positron energy	Productivity
Carbon 11	20	0.96	accelerator
Nitrogen-13	10	1.19	accelerator
Oxygn-15	2	1.73	accelerator
Fluorine 18	110	0.635	accelerator
Gallium 68	68	1.9	generator (germanium 68)
Rubidium 82	1.3	3.15	generator (strontium-82)

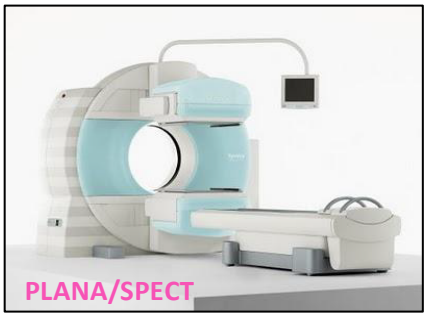
Most commonly used in oncology imaging

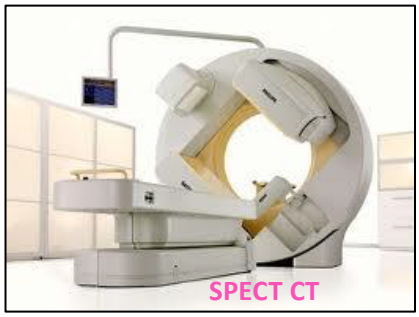
What are the nuclear medicine tumor imaging methods?

1) Conventional tumor imaging:
- Planar.
- SPECT. (Single-photon emission computerized tomography)
- SPECT-CT.

2) Onco PET:
- PET.
- PET –CT.

SPECT-CT and PET-CT are hybrid system, we first do CT for the patient and then we do SPECT or PET.
The CT helps in: anatomical imaging.
The SPECT and PET help in: functional imaging.
So this system is combining anatomical and functional imaging.





Planar imaging:
- All techniques in which MR (Magnetic resonance) images are reconstructed by collecting data from an entire plane but in a wider sense also applicable to all non cross-sectional imaging.
- Types include x-ray, CT, and MRI.

SPECT imaging:

Creates three-dimensional color images of your internal organs that reveal anatomy and physiology.

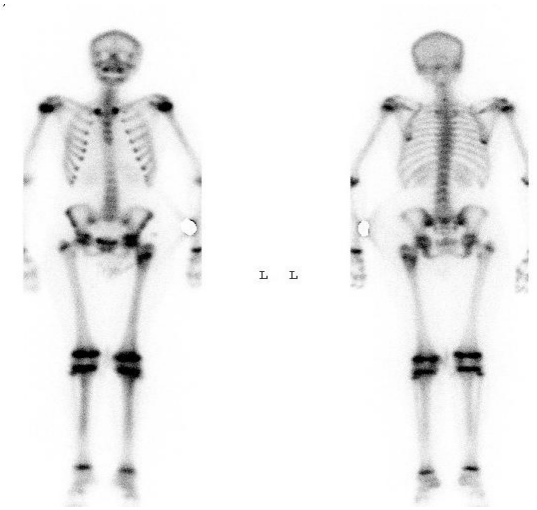
Nuclear Medicine Imaging modalities:

Planar Imaging :

Normal Bone scan

Anterior view

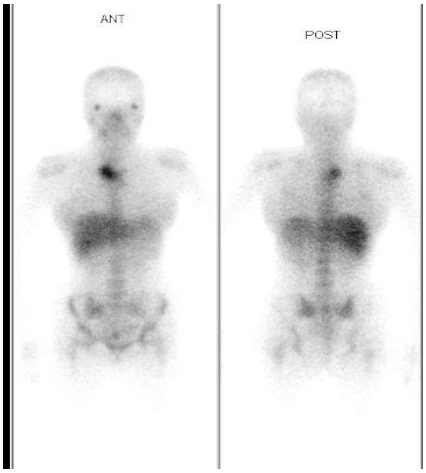
Posterior view



*Always look at symmetry between the left and right sides

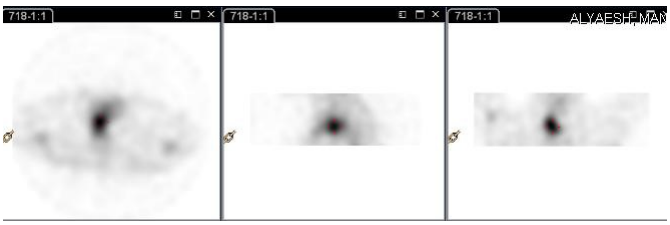
In Planer Imaging, it will give you two dimension (2D) images and you cannot tell where the abnormal uptake is.

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

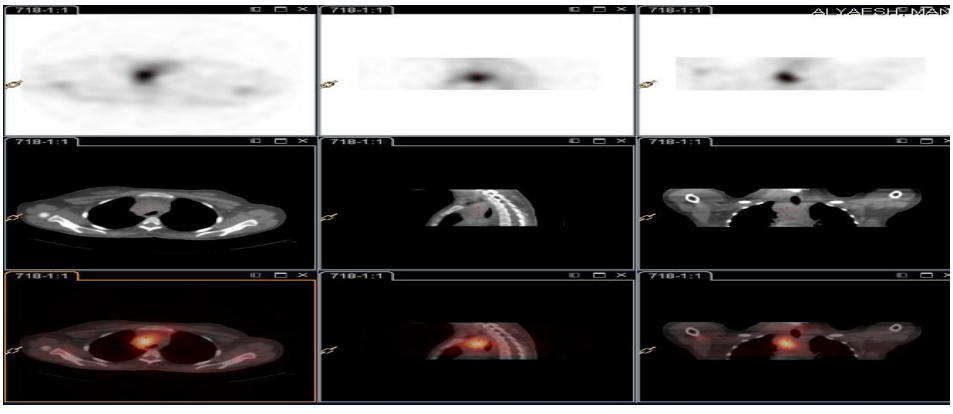


Whole Body Gallium Scan: Planar Image.

Parathyroid adenoma, but we can't tell the exact site.



SPECT



SPECT/CT

Here we can know exactly where the lesion is.

Parathyroid adenoma in anterior mediastinum

Positron Emission Tomography (PET) and PET CT :

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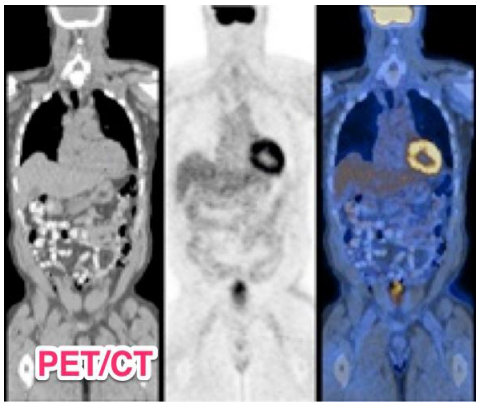
This is a patient with right breast tumor



You can see high glucose consumption in the brain in non-fasting state.

Role for Nuclear Medicine In Oncology

- **Diagnosis**

–Specific or non-specific

- **Staging**

–Important for proper therapy

- **Follow-up**

–Early detection of recurrence

- **Treatment**

–Specific or non-specific

Tumor Imaging: (make sure to memorize the names and numbers)

Non-specific tumor imaging agents:

- **Tc-99m MDP bone scan: Detection and follow up of bone metastasis**

If you want to look for bone metastasis: order tc-99m MDP bone scan, which is a complex organic phosphate labeled with TC-99m, that will be taken up by bones and can be used to visualize the skeleton.

- **Gallium 67: Staging, Restaging & therapy assessment of HD (Hodgkin disease) , 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**

Florin-labeled glucose =Fluoro-2-deoxy-D-glucose (FDG)

F18-FDG: Gold standard for tumor imaging, staging & monitoring of Tx

It's considered the most common agent used in PET scan

It's more specific and sensitive than gallium

It's labeled with glucose, so it's taken by tumor cells and eventually we can localize the tumor

Note: most tumors depend on glucose for their growth!

Specific tumor imaging agents:

- In–111 (TC99m) Octreotide : Neuroendocrine tumors
Examples of neuroendocrine tumors: neuroblastoma, paraganglioma and carcinoid tumors

- I -123 MIBG : Neuroendocrine tumor

- I -131: Lung metastasis. Thyroid carcinoma

Bone scan in oncology (procedure):

- **Radiopharmaceuticals:** Technitium 99m Methylene DiPhosPhonate (Tc-99m MDP)

(Since bone has phosphate, MDP will go there)

- **Dose:** 500 to 800 MBq (Megabequerel) / 15- 20 mCi (millicurie)
- **Imaging:** 2 to 3 hours post-injection – WB + SPECT
- **Potentials of bone scan:** Positivity many months before an abnormality can be detected on X ray (more sensitive than x-ray, because it focuses on changes of function rather than structure of the bone)
- **Tissue accumulation depends on:**
  –blood flow
  –capillary permeability
  –metabolic activity of osteoblasts and osteoclasts
  –mineral turnover

Indications of Bone Scan in Oncology:

1. **Metastatic Disease. (E.g. from lung, breast, prostate, thyroid and renal tumor)**
   - ❖ Diagnosis.
   - ❖ Initial staging.
   - ❖ Restaging.
   - ❖ Assess response to therapy.

2. **Primary Bone Tumors: (Detect the primary tumor and the extent of metastasis if present)**
   - ❖ Malignant or Benign .
   - ❖ Therapy planning for patients with primary bone malignancy (e.g. Osteogenic & Ewings sarcoma)

3. **Soft tissue tumors:**
   - ❖ Primary.
   - ❖ Metastases.

E.g. Some tumors like neuroblastoma can take up MDP.

Imaging features:

A. **Hot lesions:** Majority of bone tumors. (Dark spots)

B. Cold lesions: Purely osteolytic tumors (renal cell carcinoma, thyroid cancer, anaplastic tumors). (Osteoclast is more active than Osteoblast)

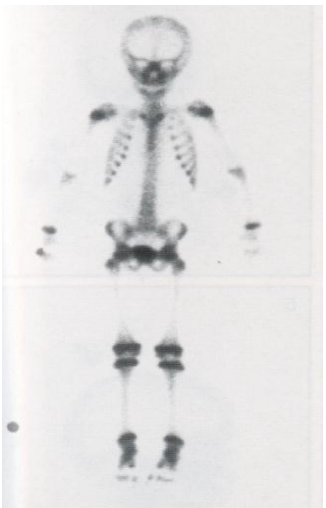
C. Superscan: Diffuse increased skeletal uptake with no soft tissue or kidney activity (e.g. prostate cancer, breast, etc.).
- When you give a tracer, all of it will be up taken
- It's associated with wide spread metastasis

D. Normal distribution: Marrow tumors (e.g. lymphomas, leukemia, multiple myeloma).
- we can have a normal distribution of the tracer , but we might have an underlying pathology in the bone marrow, like in cases of bone marrow tumors because the tracer is distributed superficially not deep

E. Soft tissue up take (E.g. neuroblastoma): Soft tissue tumors may concentrate the tracer
Bone Scan In Metastatic disease Diffuse involvement (Superscan)

F. Flare phenomenon: increased number of lesions in the case of effective therapy

Normal Whole body scan:



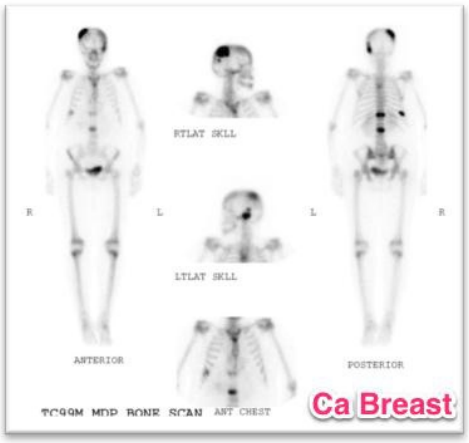
An 8 year old child

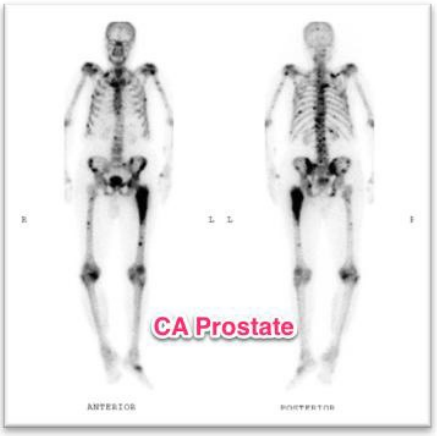
A 25 year old adult

How to differentiate?
- Growth plates in children are Hot (active), while adults have normal uptake.
- Active epiphyseal plates in children bone scans (Black shadowing at each pole of the long bones)

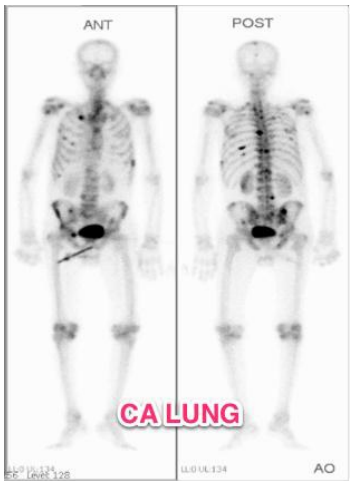
So first know the age of the patient in order not to say an image is abnormal when it's normal.

Examples of tumor staging:





In the CA breast image: Wide Spread of bone Metastasis. In skull, spine and the ribs.
All the dark spots (hot spots) are metastatic areas to bone
*You will not see metastasis below knee or elbow.



With bone metastasis

With bone metastasis

- In the CA lung image: we can see the kidneys of the patient, meaning that the tracer is still being excreted.
- Notice that the kidneys and bladder are not seen in the CA stomach image, indicating superscan lesion with diffused symmetrical wide spread metastasis. Superscan is seen in prostate cancer, breast, lung, bladder and lymphoma.
- CA stomach is common with wide spread bone metastasis (skull, spine, scapula, and multiple ribs)

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 (malignant): Prostate, breast, lung, bladder and lymphoma.

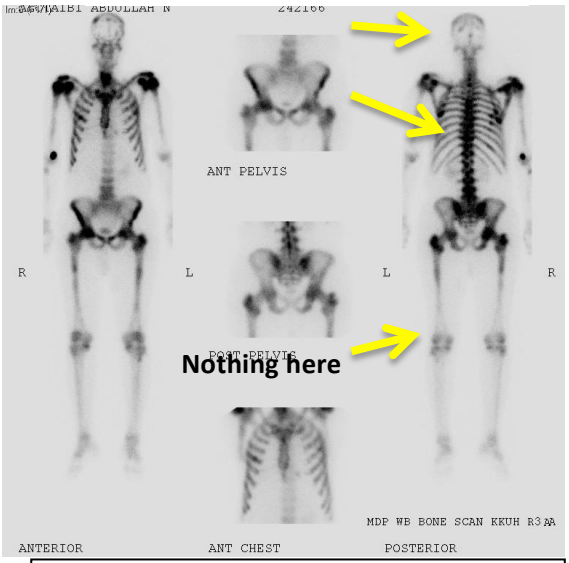
b. Non tumor causes (benign): Hyperparathyroidism, osteomalacia, Pagets disease and fibrous dysplasia

Important clues:

In metabolic bone disease the calvarium and long bones (appendicular bone and skull) are involved unlike metastases where it is confined to the axial skeleton.

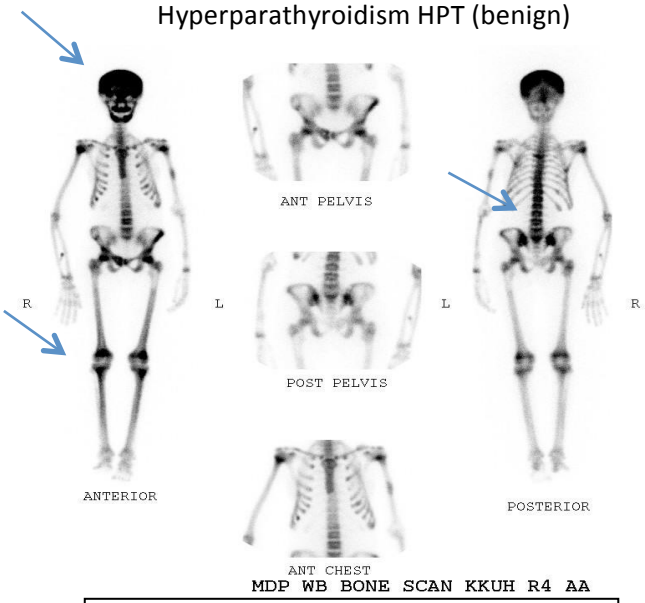
Superscan:

Prostate Cancer (malignant)



Only in axial skeleton with scattered area in the proximal femur

Hyperparathyroidism HPT (benign)



Involvement of both axial and appendicular bones.

Pure Lytic Lesions:

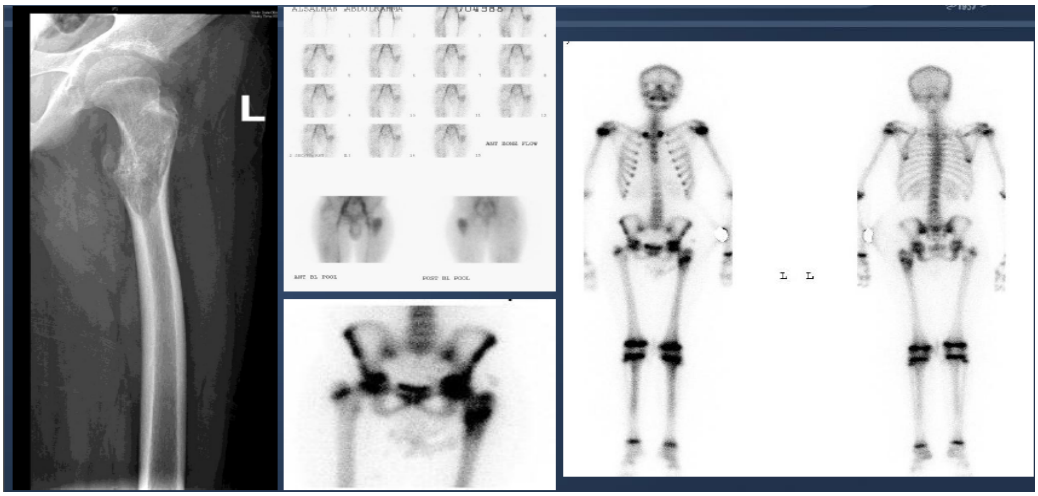
This patient has Renal Cell Carcinoma and you can see **the cold lesions**.

It is a destructive lesion; it doesn't induce an osteoblastic activity.

From its name (Pure Lytic Lesions) easy to remember.

So not all bone metastasis appear as hot lesion.

Ewing's Sarcoma (Primary bone tumor in the proximal end of left femur)



It is diagnosed by radiography and the purpose of doing bone scan is to determine:

1-Extent of primary disease.

2-Metastasis or not.

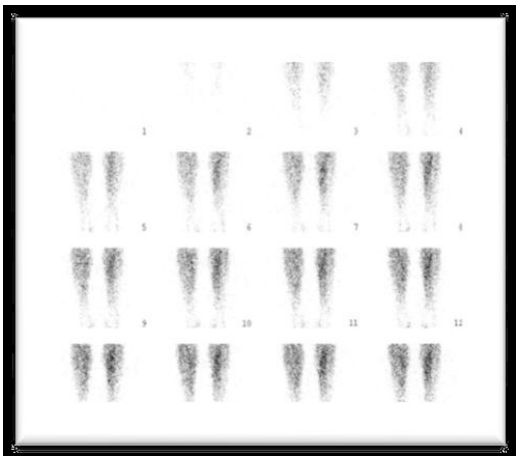
3-Staging and planning therapy.

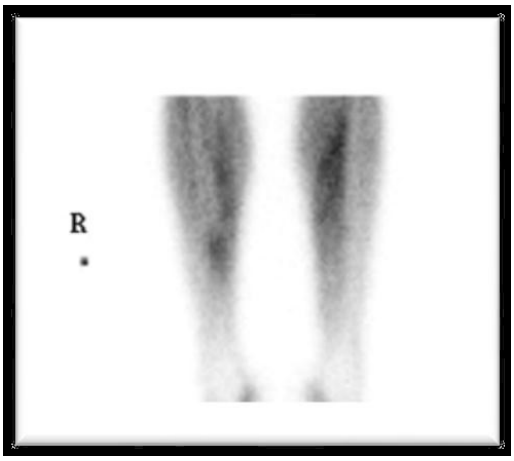
So for useful for diagnosis and staging.

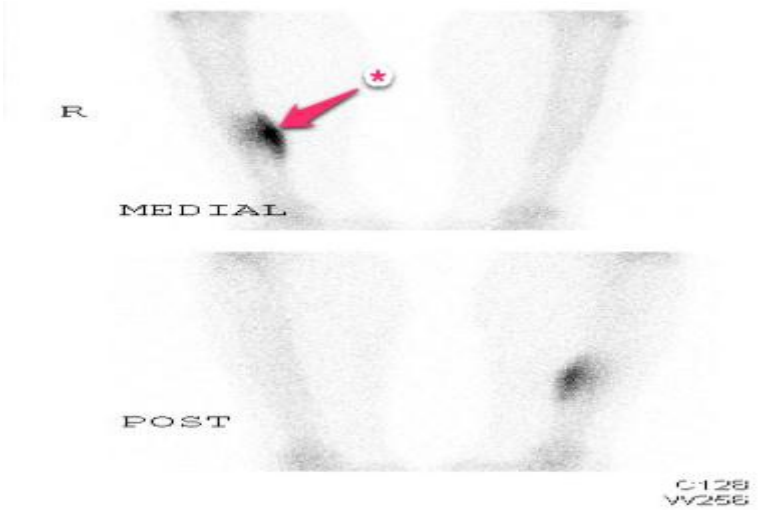
Osteoid Osteoma:

The bone scan is very specific and can be used for diagnosis. It specially affects vertebral region or small bones

- These images were obtained from a patient complaining of leg pain that is relieved by aspirin.
- It's a benign tumor, which affects children and young adult.



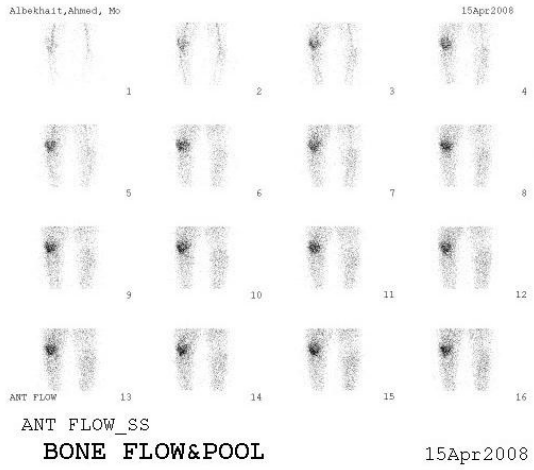


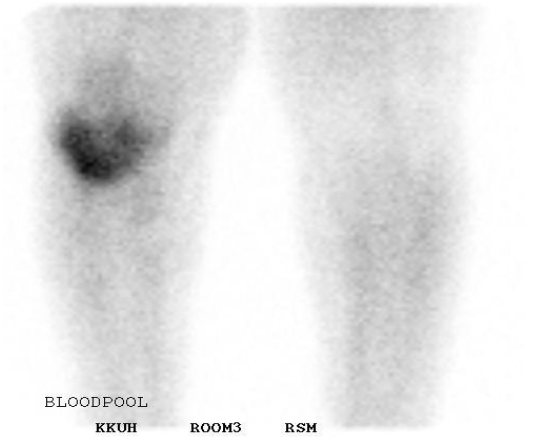


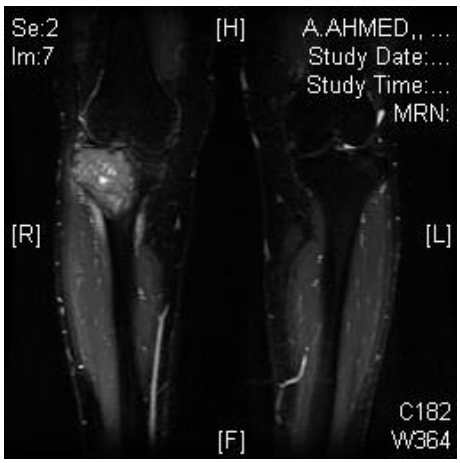
* Tracer uptake in the right tibia with increased blood flow.

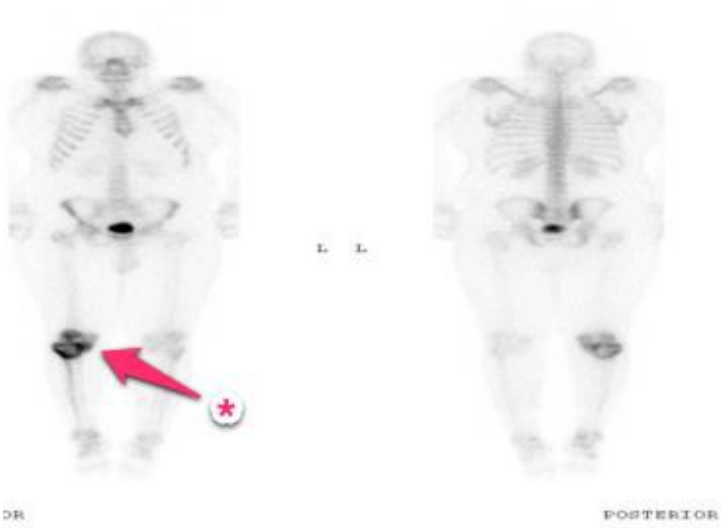
Giant cell tumor:

The bone scan was done to determine the extent of the disease and if distant metastasis is present









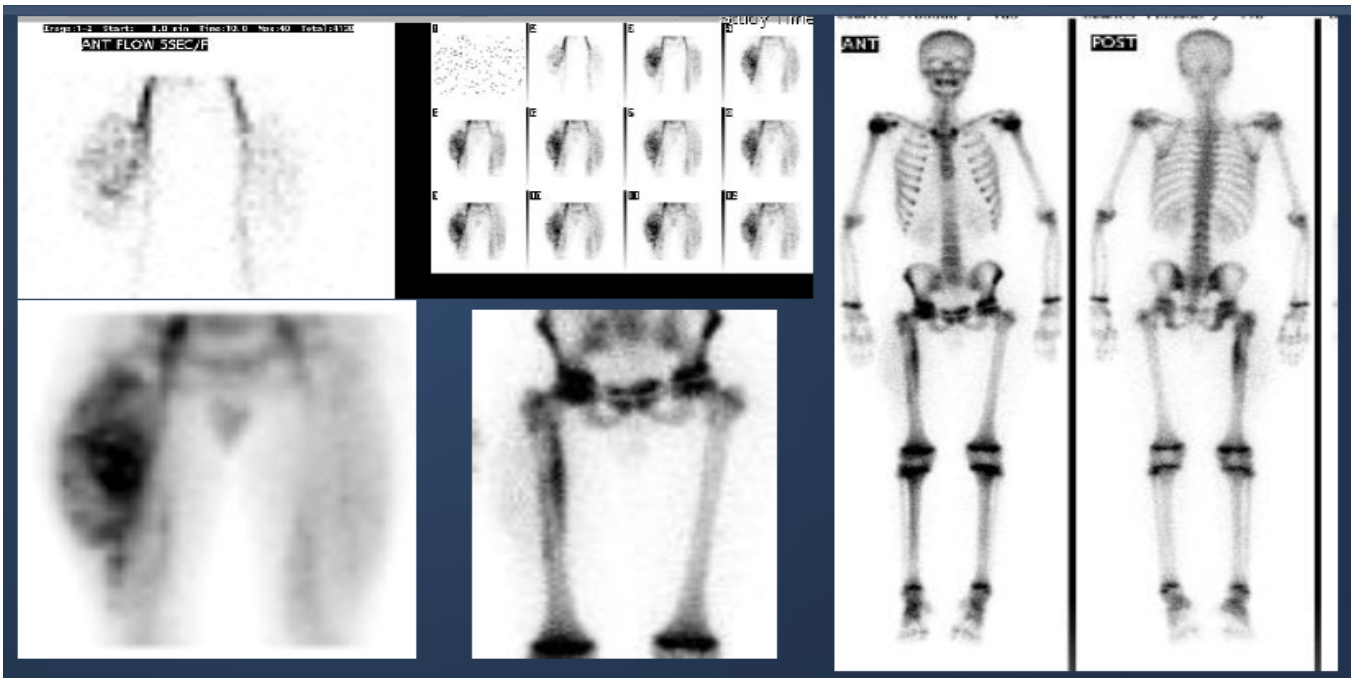
* Right knee metastasis localized in proximal end of tibia

Value of bone scan here is to determine extent of local disease & if there's metastasis or not. 1ry dx of Giant cell tumor is not by bone scan, it's done by conventional radiogram and MRI.

Extra notes for more understanding:

- Giant-cell tumor of the bone (GCTOB) is a relatively uncommon tumor of the bone.
- It is characterized by the presence of multinucleated giant cells (osteoclast-like cells).
- Malignancy in giant cell tumor is not common.
- On x-ray, giant-cell tumors (GCTs) are lytic/lucent lesions that have an epiphyseal location and grow to the articular surface of the involved bone

Soft tissue sarcoma:



The bone scan is requested to see whether there is underlying bone involvement and if distant bone metastasis is present.

Rhabdomyosarcoma (Soft Tissue Sarcoma) is a cancerous (malignant) tumor of the muscles that are attached to the bones. It can occur in many places in the body. The most common sites are the structures of the head and neck, the urogenital tract…etc.

(a) Gallium 67 Citrate (Ga-67):

Mostly for staging

- **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
- **Mechanism:** Binds to transferrin
- **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

Gallium Scan in Lymphomas:

Normal Gallium Scan

Ga-67 Scan is useful in initial evaluation and monitoring response to treatment in HD and NHL

Normal image: Gallium is transported with transferrin after injection. So all the sites with transferrin concentration will show increase gallium uptake; Liver and bone marrow.

In the abnormal image:

- A patient with lymphoma. All the hot spots are lymph nodes, in the abdominal paraaortic region, mediastinum, right axilla and the neck
- The lymphoma is extending above and below the diaphragm so it's considered stage 4 disease.
- Normally lymph nodes shouldn't be seen because they are small.

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

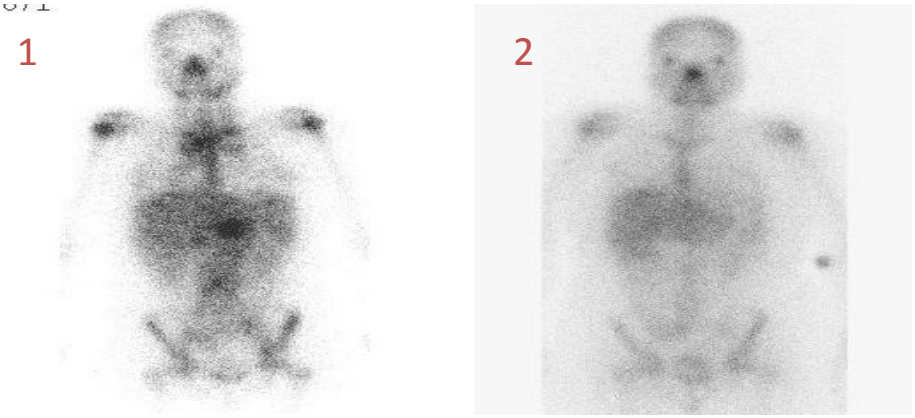
• Lymphoma
• Melanoma
• Lung cancer
• Hepatoma

Gallium 67 Citrate (Ga-67) In Lymphoma:

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

Note: Lymphomas are best diagnosed with PET/CT, but if we don't have the modality like in KKUH, we use other nuclear medicine modalities like: Gallium.

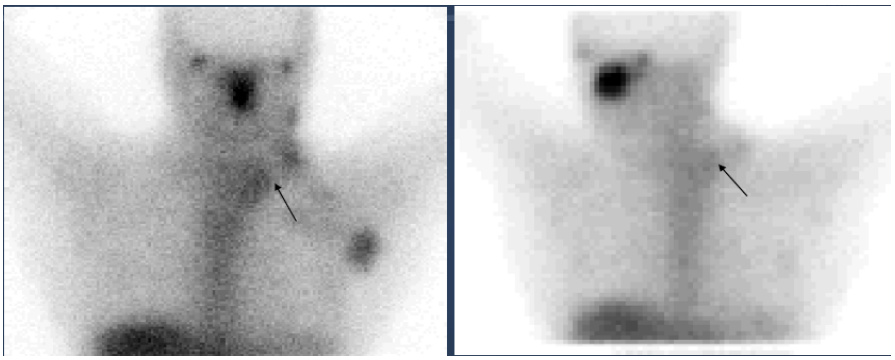
Prediction of response to therapy



A negative scan after one cycle or at mid cycle is associated with a high likelihood of complete response. A positive scan indicates no response to therapy, and will direct you to change the course of therapy.

The first image:
Prior to therapy: there is increased uptake in the mediastinum and epigastric lymph nodes.

The second image:
After course of chemotherapy: excellent response. All previous up take areas have returned to normal



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

Extra information for more understanding:

- Poor response (no response) to therapy because the increased uptake in the cervical region persisted even after the chemotherapy.
- In this case the oncologist will change the regimen of chemotherapy

When we want to assess the response to the chemotherapy, we either says:

1-Complete response: where the uptake disappear

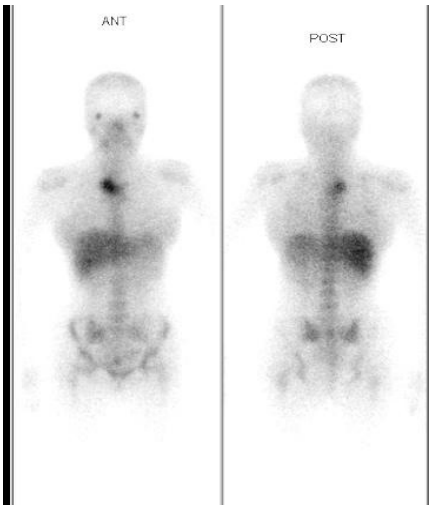
2-No response: when there is uptake of Ga even if it is a little uptake

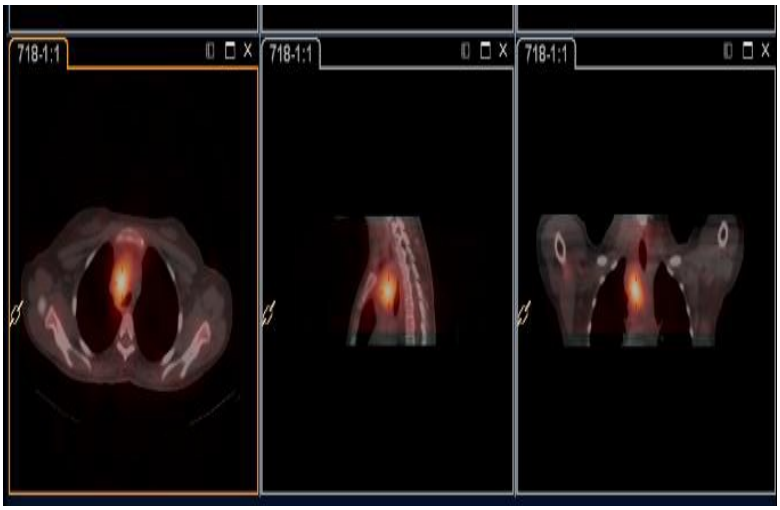
We do not say "partial uptake" only response or no response. And in this case oncologist will give more aggressive chemotherapy

Gallium Scan NHL

A patient with lymphoma

Planar **vs** **SPECT CT**

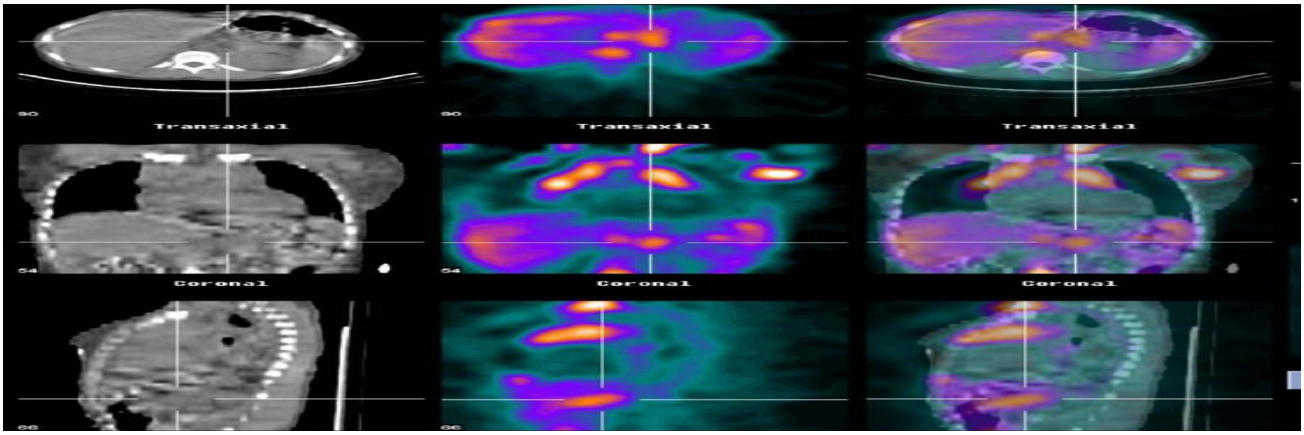




The planar scan shows abnormal uptake in the anterior mediastinum in the upper chest. But we can't know where it is localized exactly.

We did SPECT CT: we can see that it's in the right mediastinum. So this combines the anatomical imaging of CT with functional imaging of SPECT.

(b) 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 sub diaphragmatic disease and excluding bowel activity.

- First CT scan is done, then SPECT . After that the computer will fuse both images in order to tell you which group of lymph nodes is affected.
- CT is used to improve the localizaMon of uptake that seen in nuclear scan

Neuroendocrine tumors:

These tumors can be diagnosed by the following modalities:

- In-111 octreoscan: Somatostatin receptor imaging, absorbed by somatostatin receptors found in sympathetic chain tumors: gastrinoma + inulinoma ..etc

- I123 MIBG Scan: works in the same way but does not need somatostatin receptors to be absorbed by sympathetic chain tumors. You can see the liver, kidneys, spleen and gall bladder

Somatostatin Receptor Imaging (Indium-111 Octreoscan):

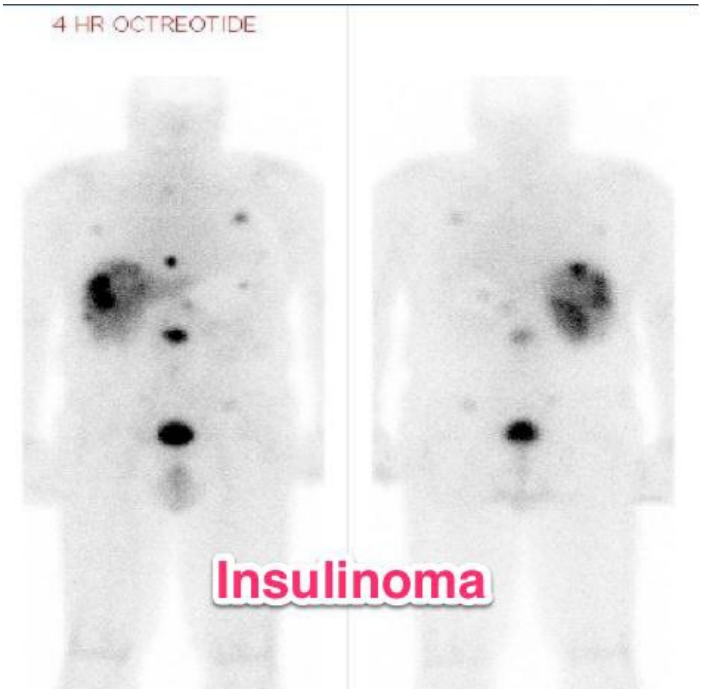
In the normal study:

The tracer is metabolized in the liver.

Spleen has a high somatostatin receptor agent showing very hot area.

Tracer is execrated through kidneys.

You can see the bladder.



Clinical History

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

Findings:

Multiple lung, mediastinum, liver and abdominal metastases.

I123 MIBG Scan:

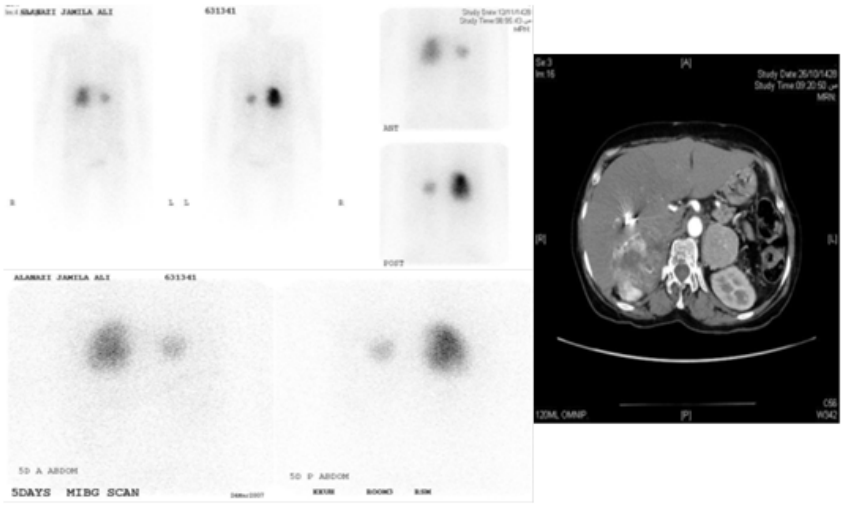
- MIBG : Meta Iodo Benzyl Guanidine
- Is a nor adrenaline analog
- Localizes in adrenergic tissues: catecholamines producing tumors and their metastases.
- Patient preparation: stop drugs interfering with MIBG uptake. Lugols solution to protect thyroid gland

- I123 MIBG Scan indications:

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

MIBG in pheocromocytoma: Bilateral disease

A 41 years old female patient is with 2ndary hypertension. Right adrenal Mass.

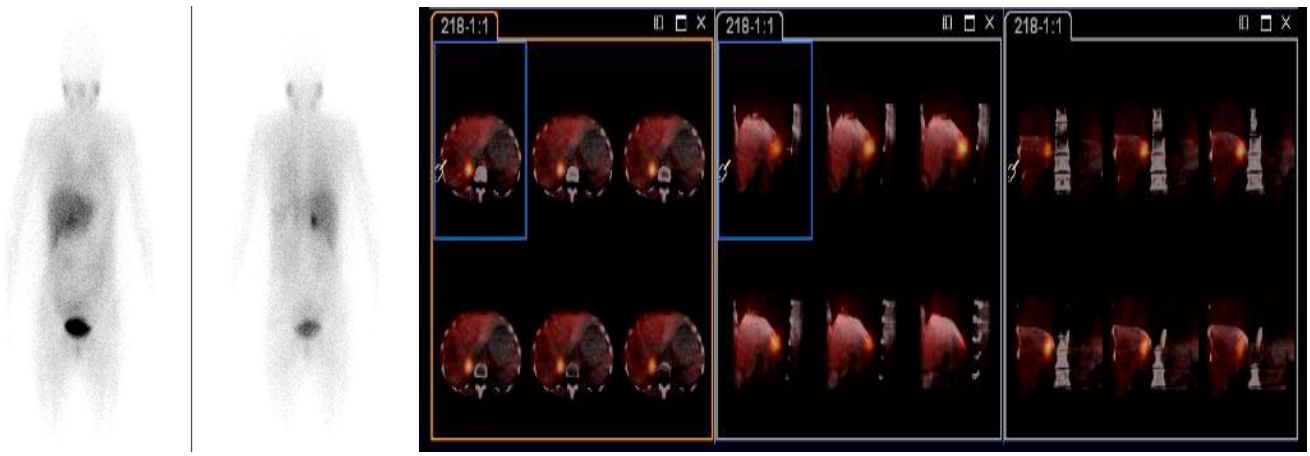


Two lesions in the adrenal gland and we need to know if they are functioning or not so after doing MIBG we found that right adrenal lesion is larger than the left and show increase MIBG uptake.

Diagnosis: Bilateral pheocromocytoma

Pheocromocytoma

Planer **vs** **SPECT CT**

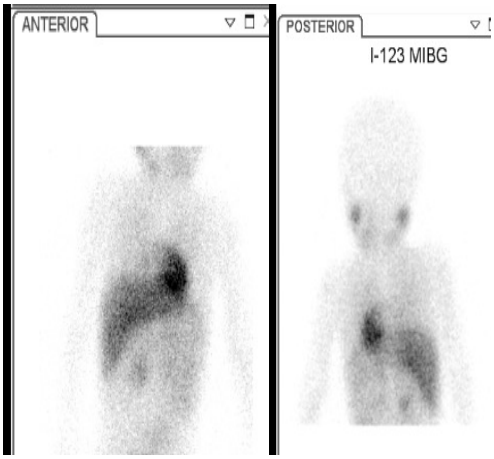


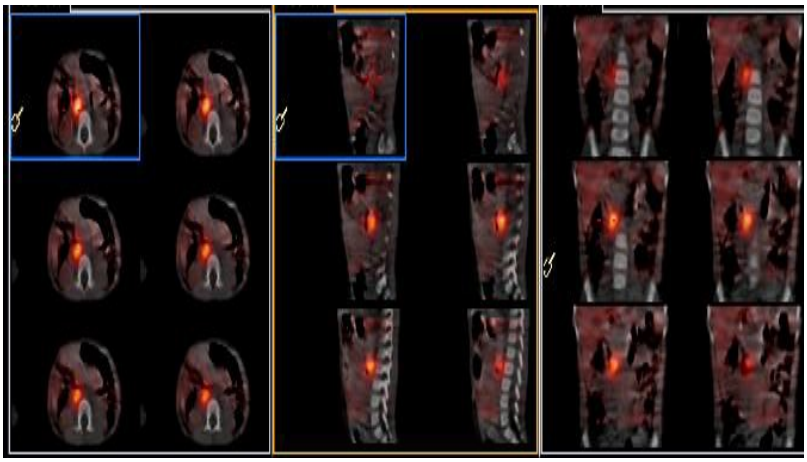
This is another patient with right pheochromocytoma, but the location in planer image was not accurate.

In SPECT CT you can tell it is in the paraspinal region. This represents right pheocromocytoma.

Neuroblastoma

Planer **vs** **SPECT CT**





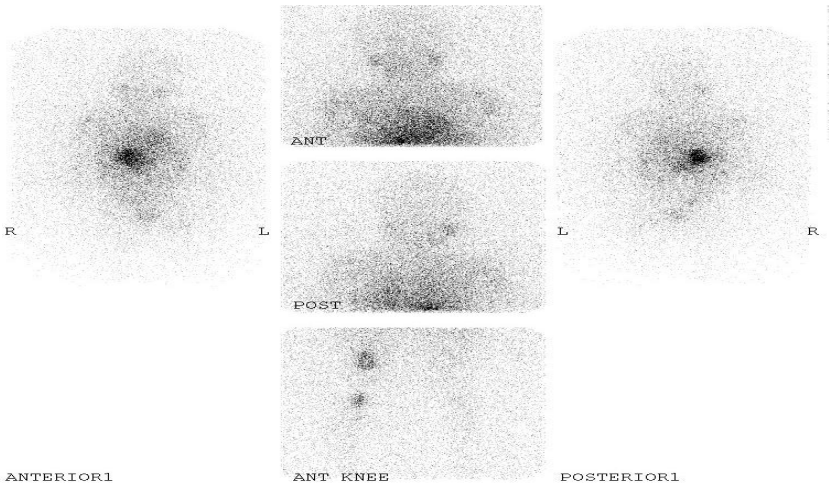
This is a patient with **Neuroblastoma**, we can see the primary tumor in the planer image but we cannot know where is it exactly. But in SPECT CT it shows the accurate location of Neuroblastoma in this child, right paraspinal.

I131 MIBG Total body scan:

Can be usd in staging

1ry Neuroblastoma /bone mets

This is a 1ry neuroblastoma with distant metastasis to the bone in the right femur and tibia.



THYROID METASTASES STUDY: (Important)

(I-123 or I-131 as Sodium Iodide)

I-123 is used for diagnosis. I-131 is used for therapy.

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 diagnostic use) (pure gamma emitter)
b) I-131 as sodium iodide: 2-10 mCi (specific for thyroid therapy) (beta minus emitter)

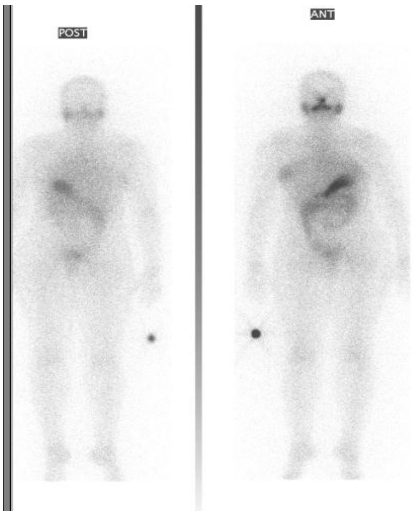
- I-131 can be used as a treatment if given in high doses
- To detect metastasis you can use I-123 (the best), in remote area and if you don't have I-123 you can use I-131.
- Why I-131 can be used in remote area? because it is available, has long half-life and cheap.
- I-123 is very expensive.
- Why I-131 is used for treatment? Because it is Beta minus emitter (B- ray)

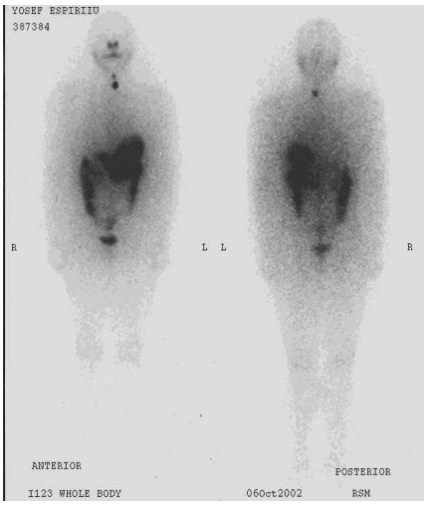
Imaging using Gamma camera: Whole body scan

Thyroid cancer can be differentiated or undifferentiated
Differentiated can be derived from C-cells or parafollicular cells

- Papillary metastasized via lymph nodes
- Follicular is metastasized hematogenously so it can go anywhere throw blood.

Thyroid cancer: I-123 WB scan





Negative I- 123 body scan:
post surgery
showing stomach and colon activity and there are no thyroid remnants

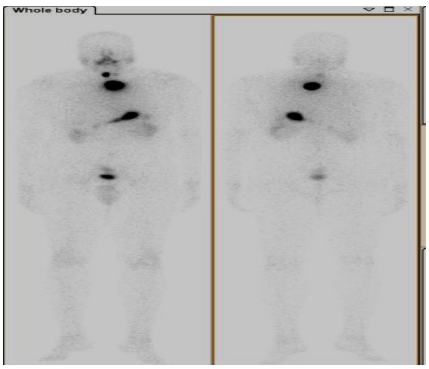
I-123 WB Scan Post-operative Thyroid remnants

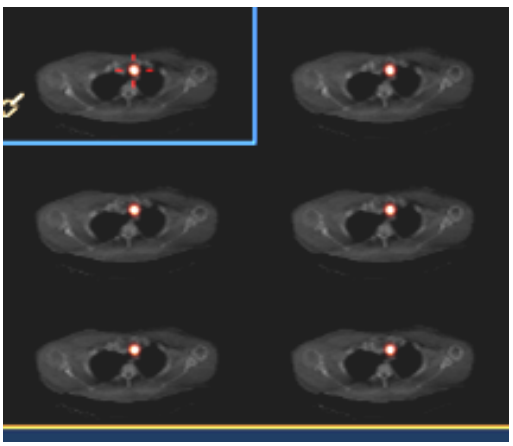
Post- surgery scan for thyroid cancer showing remnant of the thyroid . These remnants are treated by radioactive iodine 131. This I 131 will go to these remnant and destroy them without damaging the surrounding tissues.

N.B. Iodine 131 is used to remove the remnants

I-123 WB Scan
Post-operative Thyroid remnants

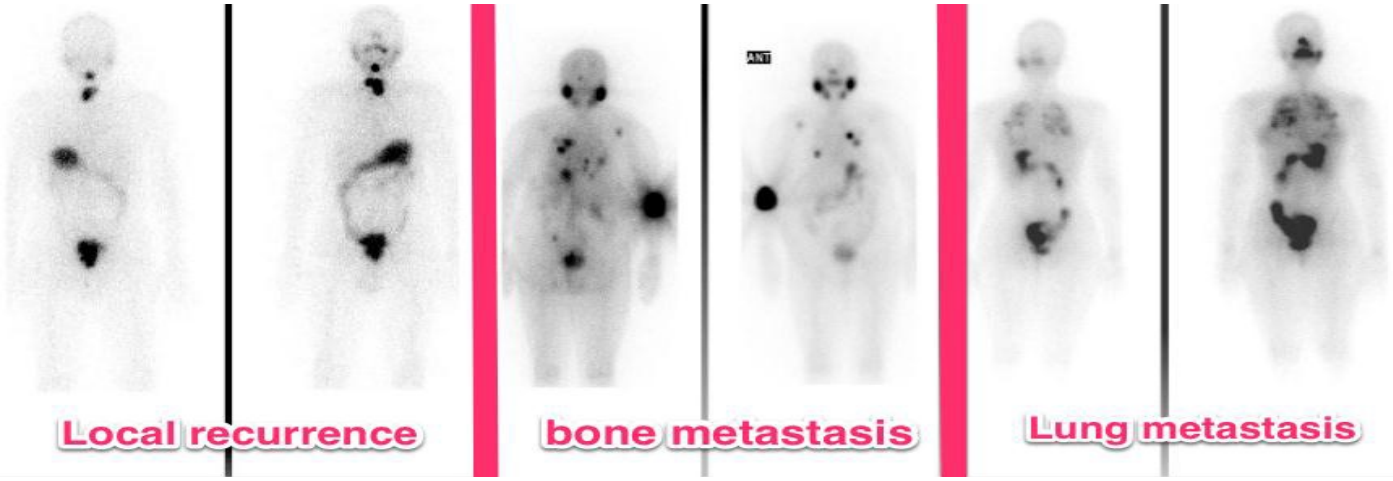
Planer **vs** **SPECT CT**





You cannot know where is exactly the site of the remnant in planer image, but In SPECT CT you can detect exactly where the site of remnant is.

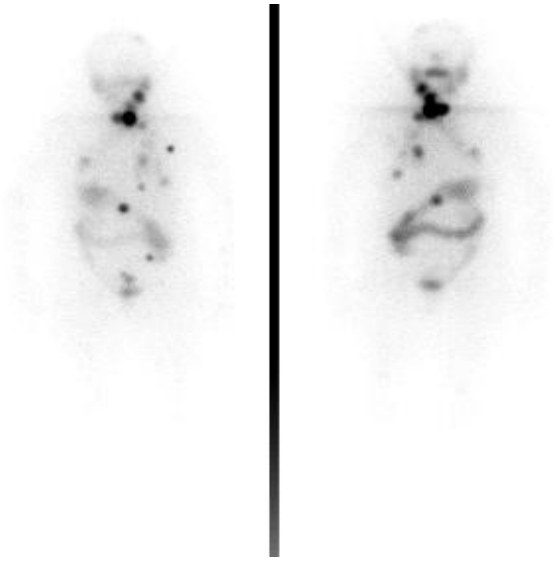
THYROID METASTASES STUDY
(I-123 or I-131 as Sodium Iodide)



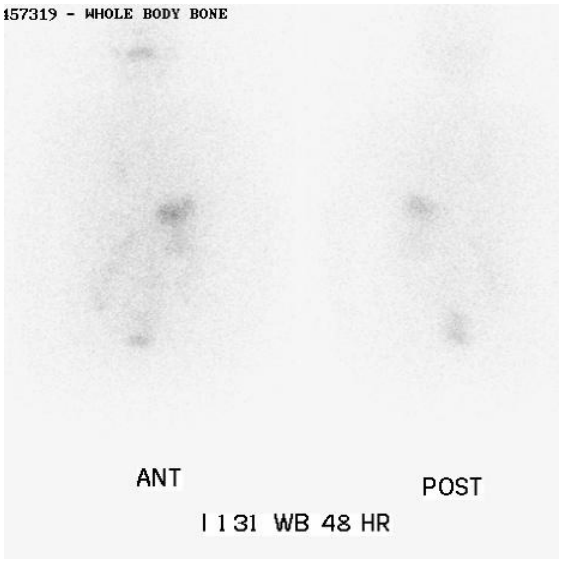
So both agents I-123 and I131 can detect local recurrence, bone metastasis and lung metastasis.
All these metastasis can be treated by I-131.

Remember: we can treat all these patients with I-131

Thyroid metastatic study: (pre and post therapy with I-131)



In 2004, patient with multiple; local and distant metastasis



Same patient was treated by I 131 and the scan was repeated on 2006 and there was complete cleaning of the body without metastasis

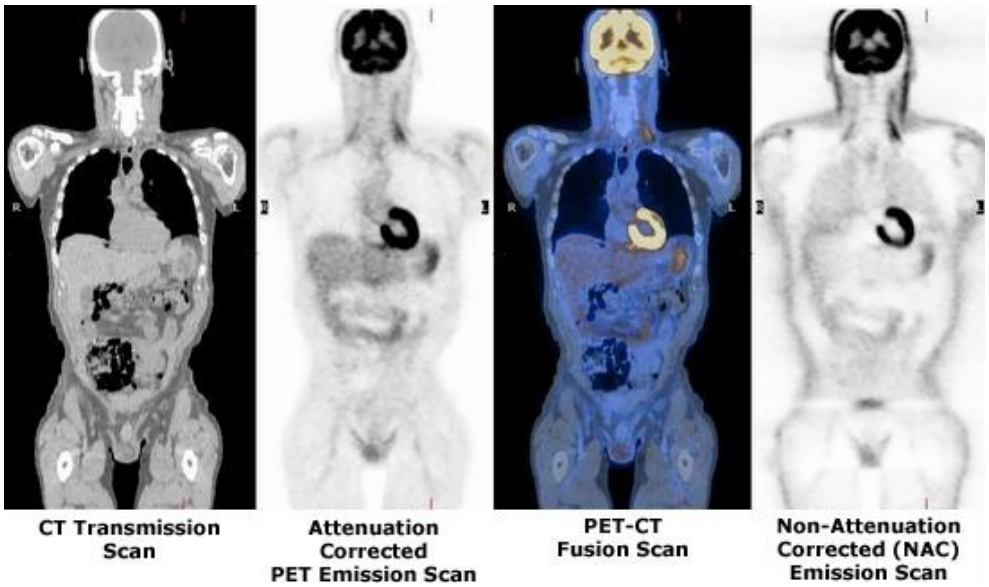
Onco PET (PET and PET CT):

What is 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 = Function + Form**

PET-CT is the first line and golden standard in imaging of tumor & metastasis. Especially fluorine 18 FDG, because most tumors depend on glucose to grow.

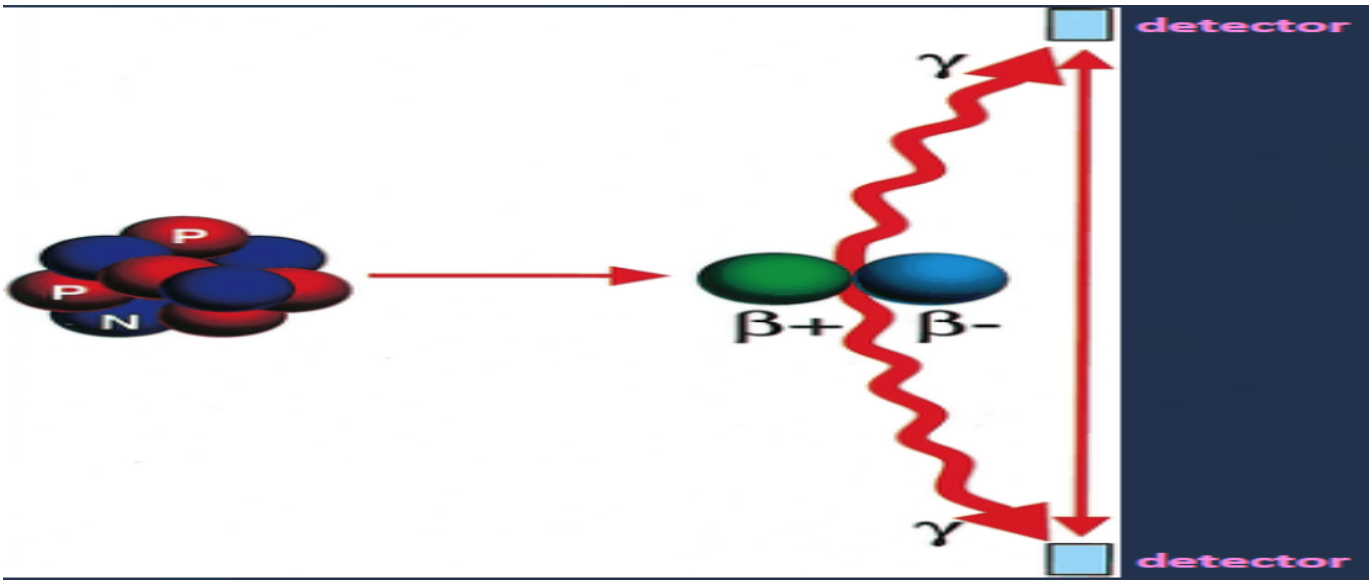


Normal CT scan (brain and heart will appear in the image because their main source of energy is glucose and it will be concentrated in them), hence their viability in F18 (glucose based) PET scan

Two photons are emitted in opposite directions and detected by 2 detectors.

How it is performed?

Positron emitters (e.g. F18) labelled with biologically active natural compounds such as oxygen, carbon or glucose 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:

Isotope	T/2
Oxygen-15	2 min
Nitrogen-13	10 min
Carbon-11	20 min
Fluorine-18	**110 min (main isotope)**

It is the most commonly used

Again, what you need to know is Fluorine-18 and its T-2

FDG (Fludeoxyglucose) in Oncology:

- Tumors do not have a blood tumor barrier(so any tracer we give will reach to the tumor, unlike normal tissues which have blood 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.

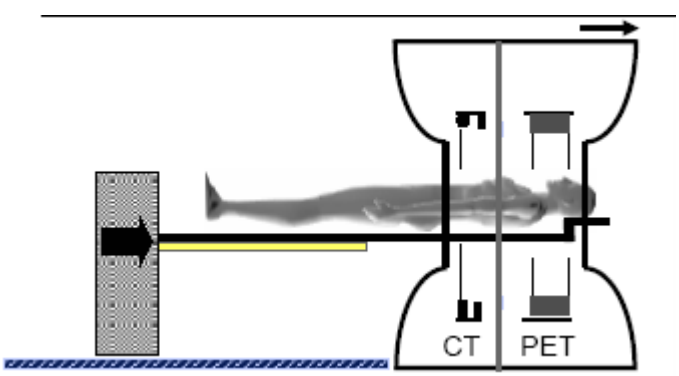
Applications of FDG:

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

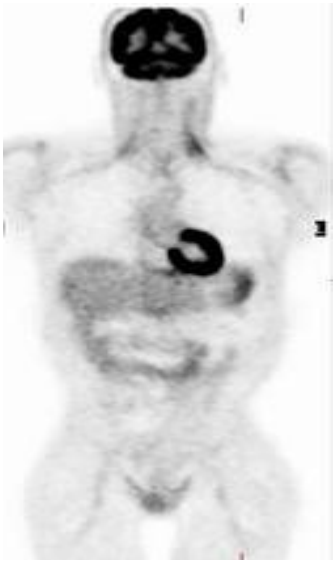
- Notice that: the scan can tell whether the tumor is viable and where there is increase in the uptake glucose labeled material or not .

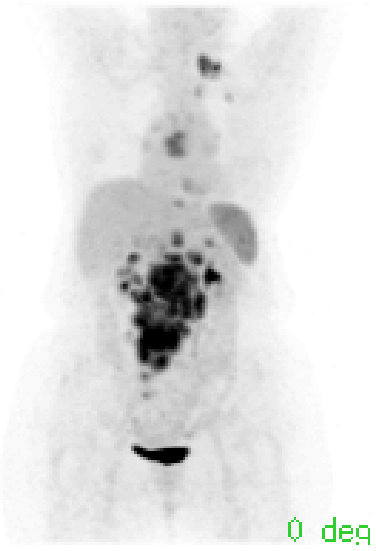
FDG PET CT : Procedure:

- **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:





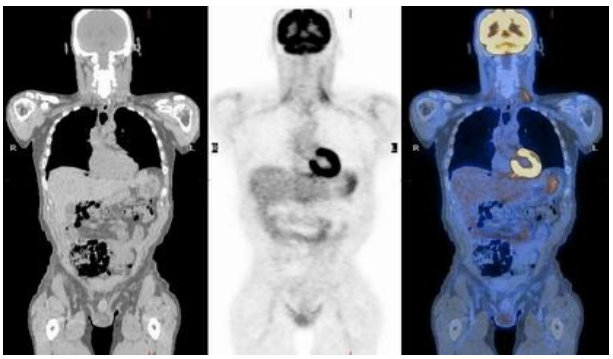
Normal FDG PET

The brain and heart appear black because it depends highly on glucose, so there is increase uptake.

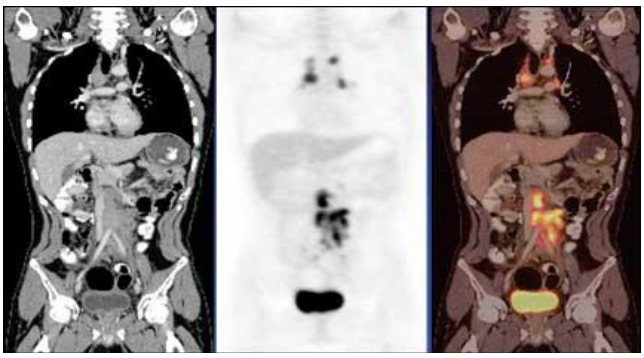
Patient is having NHL(Non-Hodgkin's lymphoma)

There are multiple lesions above and below the diaphragm.
For accurate localization we need SPECT CT.

FDG PET-CT



FDG PET-CT
Normal

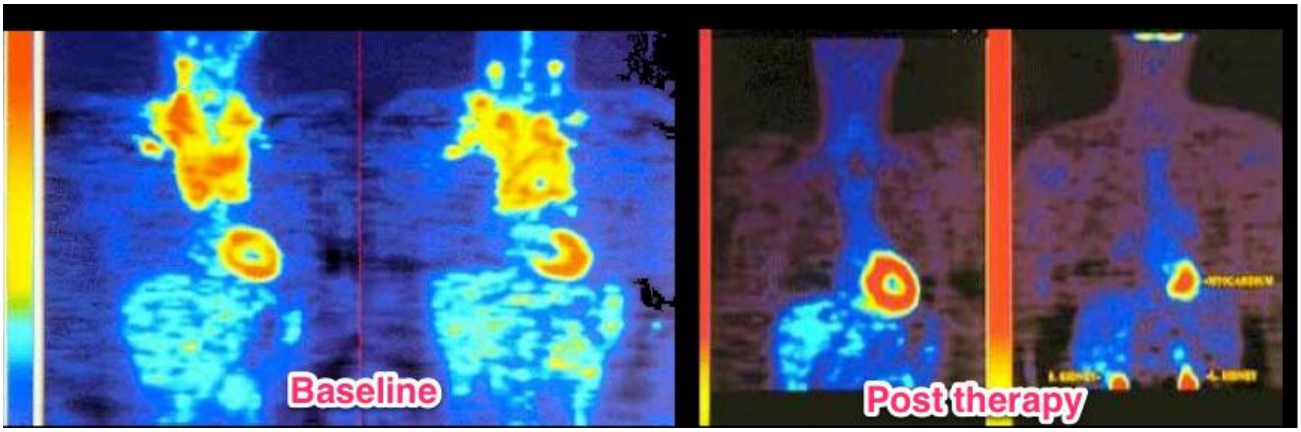


FDG PET-CT
Staging of Lymphoma

You can see abnormal areas with increase glucose metabolism in the chest and abdomen.

Use of FDG PET in the assessment of the therapy response :

FDG PET in Hodgkin disease:

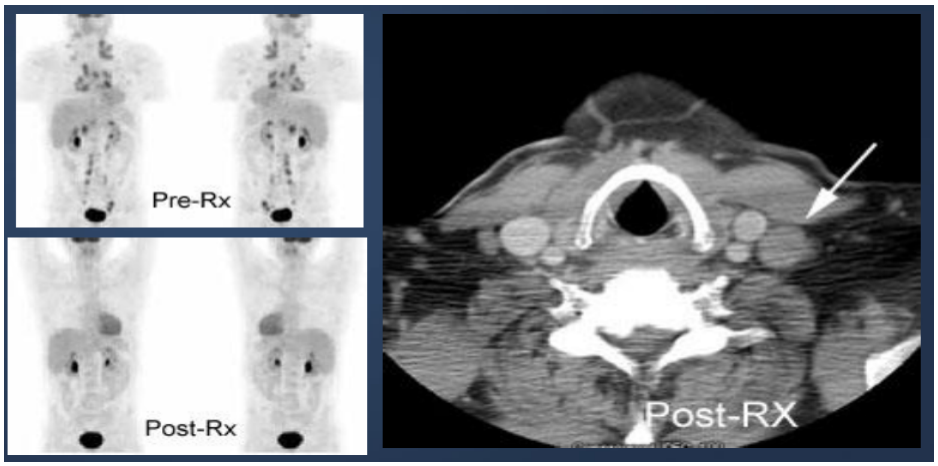


A 22 years old male patient with Hodgkin's lymphoma. Six months after chemotherapy, CT scan showed bilateral hilar abnormalities.

FDG-PET scan did not show any activity in described CT changes(excellent response to the management. There was an excellent clearance of mediastinal lymph nodes after therapy)

Here in the first image you can see abnormal uptake in the neck and in the second image you can see complete disappearance of the disease.

FDG in non-Hodgkin lymphoma:



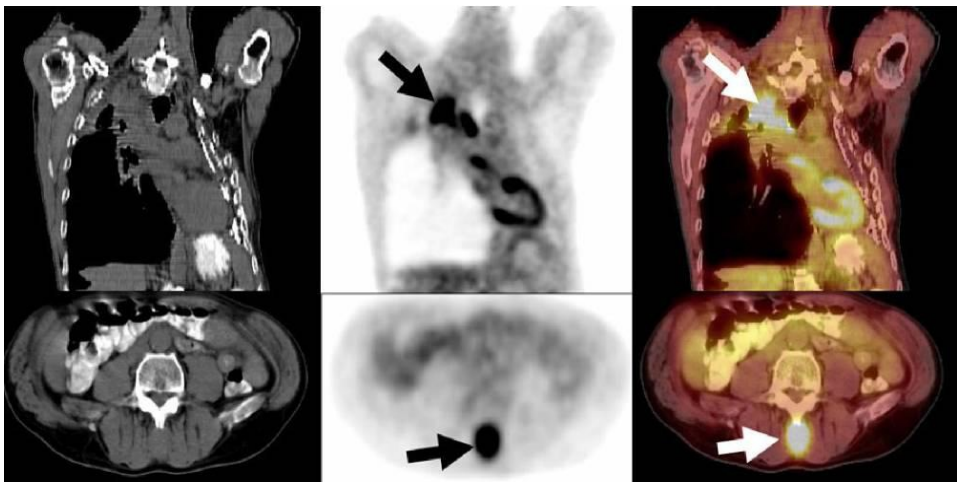
Stage 4 NHL, which showed excellent response to the treatment in the 2nd image .

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 :

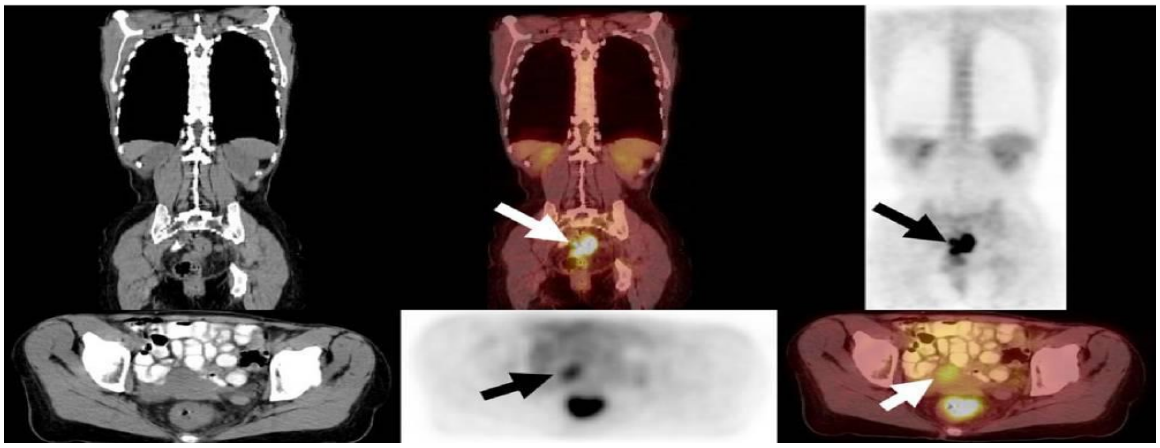
FDG avid soft tissue mass associated with a destructive L5 spinous process consistent with metastatic deposit (arrow).



FDG PET CT IN Solitary Pulmonary Nodule (SPN):

- **Sensitivity : 82 – 100 %**
- **Specificity : 67 – 100 %**

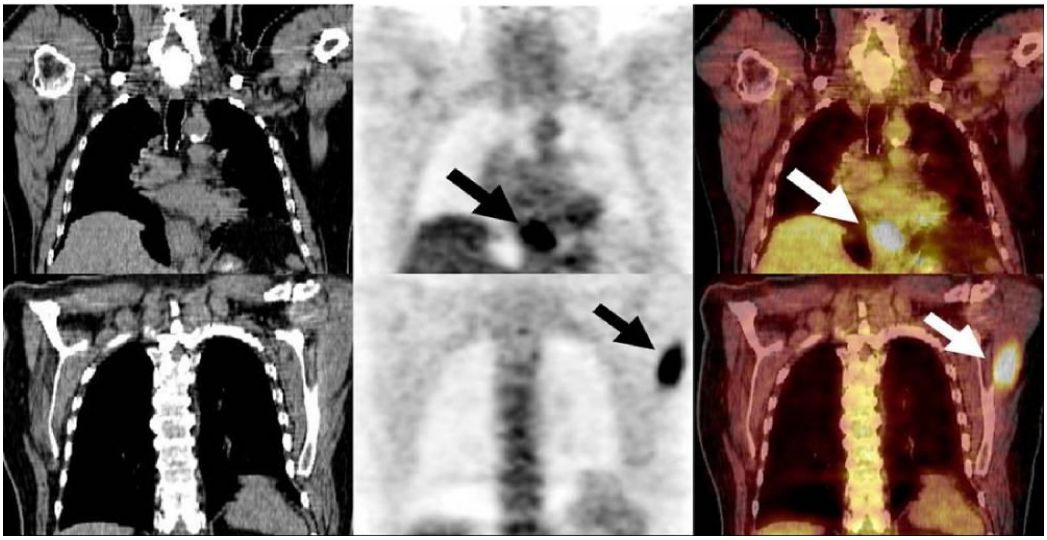
CA Rectum: (PET CT)



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.

Lymph node metastasis.

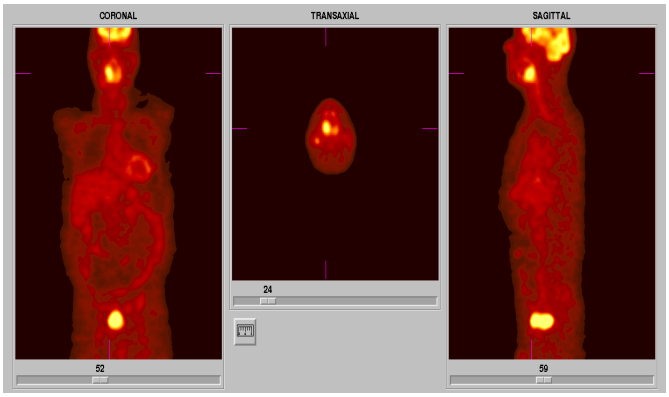
CA of esophegous:



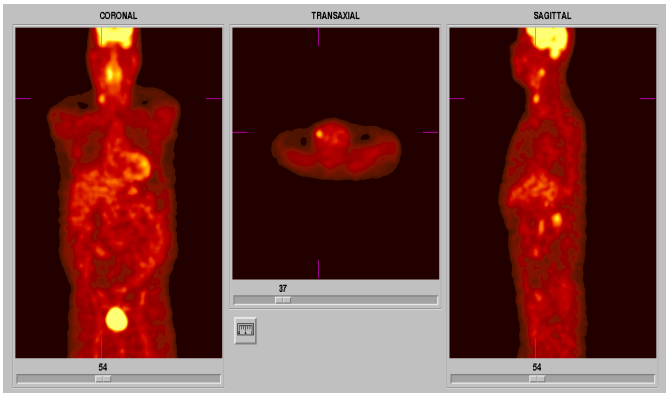
Based on FDG-PET/CT results the clinical management of this patient was changed from surgical resection of the primary tumor to combined chemo-radiation therapy.

Distant metastasis to the scapula.

FDG PET
Tumor of unknown origin

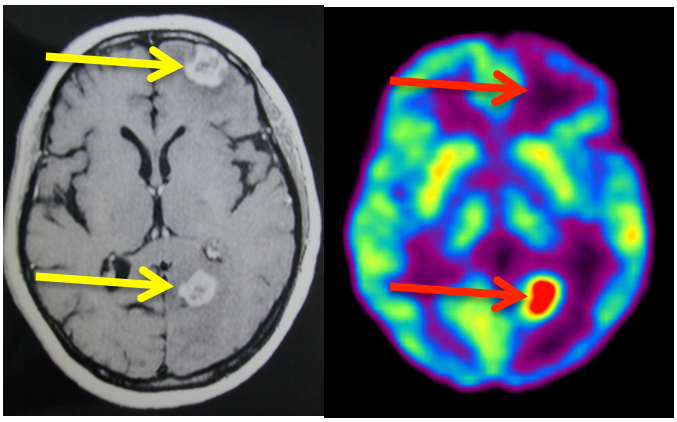


Pharyngeal cancer



Metastatic involvement of neck lymph nodes

FDG PET – brain tumor post therapy



This patient has Brain Tumor and there are 2 lesions, only one lesion was viable and the other one was fibrotic tissue.

On CT: no glucose metabolism → necrosis.

PET: there is glucose uptake → tumor

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

You can keep it for your record. No need to memorize them That's all what he said about this slide

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. Like I-131
4. High target - nontarget ratio so it should be concentrated more in the tumor than other tissue.
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.

AGENT	INDICATION	DOSE
- I131 - 131 MIBG - Strontium-89 - Sm-153 EDTMP - Phosphorus- 32 - Y-90-Ibritumomab Tiuxetan [Zevalin®]	- Thyroid cancer - Neuroblastoma - Bone metastasis - Bone mets - Polycythemia - B-cell NHL	- 100-200 mci - 100-300 mCi - 40-60uCi/kg - mCi per kg - 2.3mCi/m2 - The dose should never exceed 32 - mCi (1,184 MBq).

The doctor only mentioned the agent and indication.

Strontium-89 Therapy for Palliation of Bony Metastases

History :

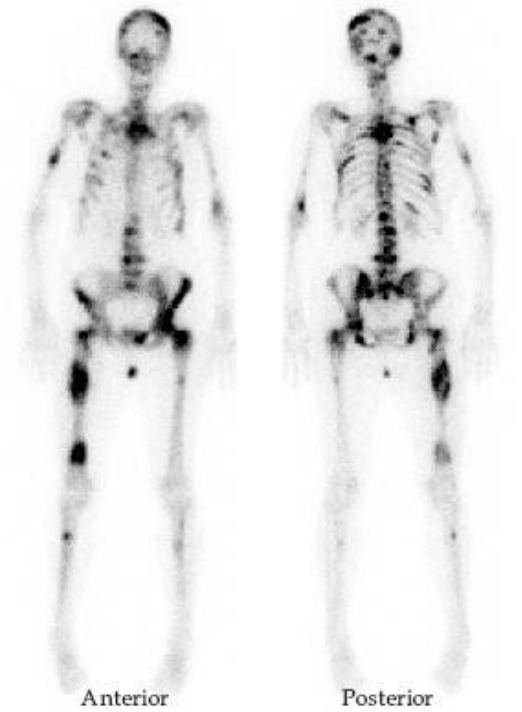
A 65 Ys ,M, with CA prostate and widespread bone metastases and severe bony pain. Admitted for palliative Strontium-89 therapy.

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.



Teaching Points

Nuclear Medicine tumor imaging:

- Diagnosis
- Staging
- Guiding biopsy
- Follow up & therapy monitoring
- Detecting recurrence.

Objectives of Nuclear Medicine tumor imaging:

- Functional
- Sensitive
- Whole body evaluation
- Specific : Some tumors
- Targeted therapy

Tumor Tracers

Specific		Non-specific	
1) PET or PET CT. 2) Planar, SPECT or SPECT-CT		1) PET or PET CT: *F-18 FDG (Gold standard & the most used). T/2: 110 minutes 2) Planar, SPECT or SPECT-CT:	
*I-123/131 MIBG	Neuroendocrine tumors	*Diphosphonates	Bone scan
*I-131	Differentiated thyroid carcinomas	*Ga-67 citrate	Similar to FDG – localizing agent.
*In-111 or Tc99m	Tumors expressing somatostatin receptors	*Tc99m Nanocolloid	Bone marrow scans.
*Monoclonal antibodies labelled with In-111, I-123/131 or Tc-99m.		*Tc99m MIBI / Thallium 201	Several tumors.

Therapeutic radiopharmaceuticals

Specific	Non-specific
I-131: Thyroid cancer, as specific diagnostic if tumor significantly accumulates. Y-90: Zevalin – monoclonal antibody for B-cell lymphomas.	Sr-89, Sm-153, Re-189: Bone pain palliation (used to treat bone metastasis

Tumor Imaging Agents

Specific	Non-specific
In–111 (TC99m) Octreotide: Neuroendocrine tumors I -123 MIBG: Neuroendocrine tumor **I -131:** Lung metastasis. Thyroid carcinoma	Tc-99m MDP bone scan: Detection and follow up of bone metastasis. F-18 FDG & Gallium 67: Staging, Restaging & therapy assessment of lymphoma and CA lung Thallium 201: Tumor viability & tumor seeking.

Notes:

- In metabolic bone disease: the calvarium and long bones (appendicular bone and skull) are involved.
- Bone metastases: confined to the axial skeleton.
- Half-life of radionuclide:
  - Tc-99 m: 6 hours
  - I-131: 8 days (used for therapy)
  - I-123: 13.2 hours (used for diagnosis)
  - Ga-67: 78.3 hours