

Nuclear Oncology

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Radiology Team 429

In this team we used the outlines from the:

Doctor's slides

Lecture notes are in blue and green

427 Radiology team

Diagnostic Imaging –PETER
ARMSTRONG – 6Th Edition

Sorry we don't hold responsibility for any missing information or perhaps – perhaps -wrong material.

We tried our best to present this lecture in the best way, and we hope what we wrote is enough to cover the subjects.

Team Leaders:

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Special Thanks to Najd Al Shamlan

Best Wishes :)

Nuclear Oncology

LEARNING OBJECTIVES

At the end of the lecture you will be able to answer the following questions:

- 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?

What is nuclear oncology ?

- Nuclear Oncology:
the use of isotopes in the diagnosis and treatment of tumors

What are the nuclear medicine tumor imaging methods?

- **Conventional tumor imaging :**
 - Planar: like thyroid scan, 2 planes/dimensions = 2D*
 - SPECT
(Single-photon emission computed tomography)
functional (can not tell the anatomical location of the tracer/
isotopes/ materials injected)
 - SPECT-CT: functional + anatomical
- **Onco PET :**
 - PET (positron emitting tomography):
functional (can not tell the anatomical location of the tracer/isotopes/
materials injected)
 - PET –CT: functional + anatomical

Conventional tumor imaging

Non Specific:

Doesn't define the tumor

Will not characterize the tumor
(taken by many tumors)

1. Gallium 67 citrate (Ga-67)
2. Tc-99m Methylenediphosphonate (Tc-99m MDP)
3. Thallium Chloride 201 (Tl-201)
4. Tc-99m SESTAMIBI

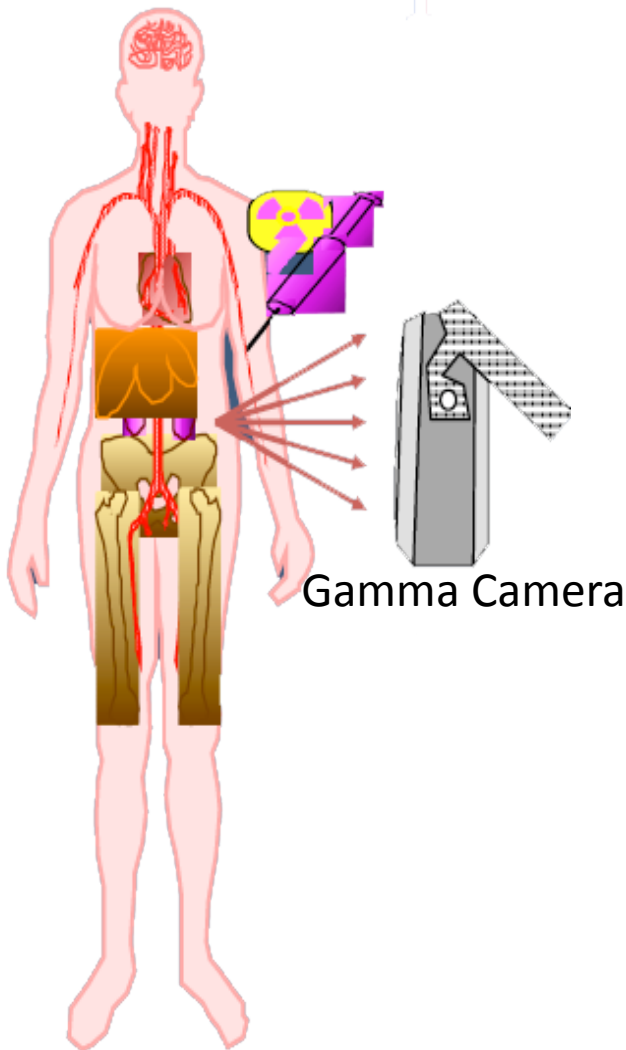
Specific :

Defines the tumor

Characterize the tumor

1. Iodine 131 (I131): specific for thyroid therapy (b/c iodine is metabolized in thyroid)
2. Iodine 123 MIBG(I123 MIBG): thyroid diagnostic use
3. Radiolabelled monoclonal antibodies (MoAB)
4. Receptor imaging : Somatostatin receptors

Nuclear Medicine Procedure



1. Patient is injected with small amount of radioactive material
2. Radiopharmaceutical localizes in patient according to metabolic properties of that drug
3. Radioactivity decays, emitting gamma rays
4. Gamma rays that exit the patient are imaged

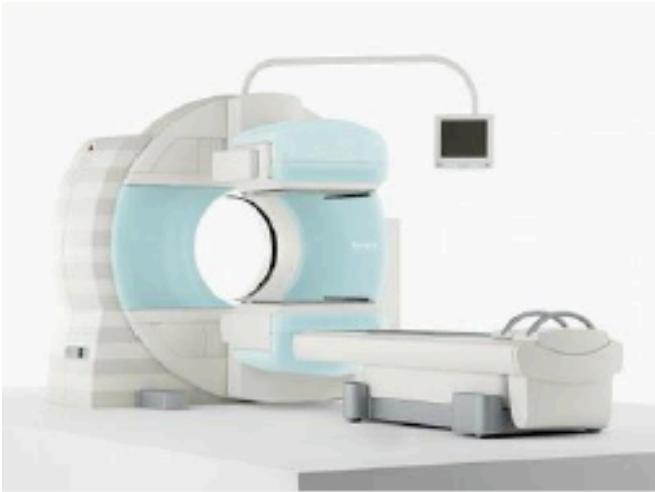
Gamma camera is used only in cases of SPECT and not in PET

Notes:

-Nuclear medicine : radiation comes out of the patient (unlike the radiology) and detected by the machine .

-Radioactive material will go directly to the organ we want to image , so for every organ there is a specific material for it .

NM Imaging Systems



SPECT



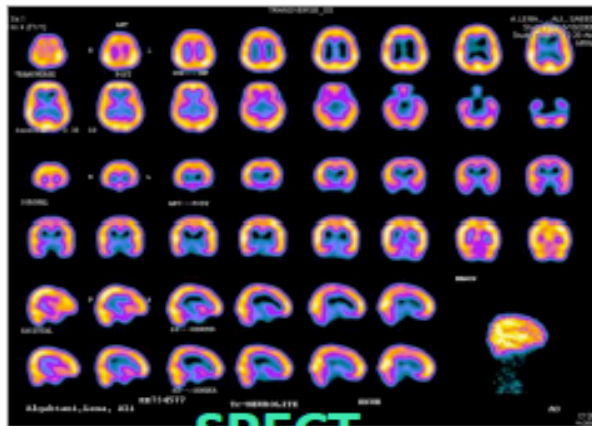
PET CT



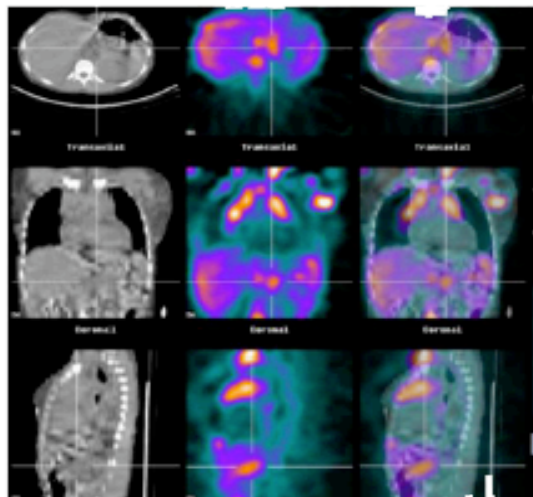
SPECT CT

NM Imaging modalities

- Single Photon Emission Computed Tomography (SPECT) and SPECT CT
- Positron Emission Tomography (PET) and PET CT
- SPECT :depends on blood flow and turnover of tissue .
PET: depends on glucose metabolism by giving the pt glucose labeled w fluorine 18.



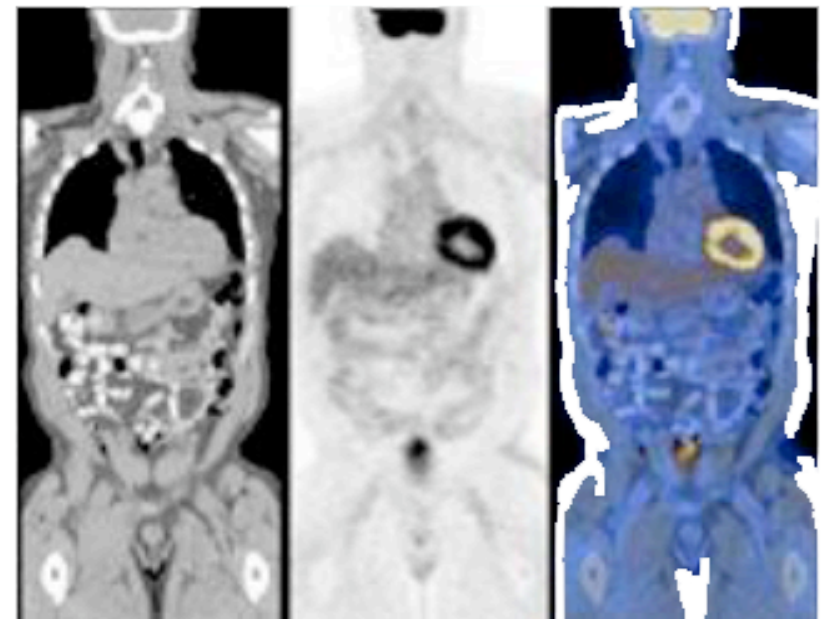
SPECT



SPECT/CT



PET RT Breast CA



PET CT

Tumor Imaging

Numbers beside the radio-active agents' name are important to know

1. **Technetium-99m (Tc-99m) MDP bone scan:** Detection and follow up of bone metastasis
2. **Gallium 67 :** Staging ,Restaging & therapy assessment of HD , NHL , Lung cancer
3. **Thallium 201 :** Tumor viability & tumor seeking. {Tc-99 m Agents (MIBI ,TETRO.).}
4. **In-111 (Tc-99m) Octreotide:** Neuroendocrine tumors
5. **I -123 MIBG :** Neuroendocrine tumor
6. **I -131 :** Lung mets. , thyroid carcinoma and remnants
7. **F18 – FDG : (PET agent)** Staging ,Restaging & therapy assessment of HD , NHL , Lung cancer

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

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

****If u want to look for bone metastasis : order tc-99m MDP bone scan**

Bone Scan In Oncology “Procedure”

- **Agent** : Technitium 99m Methylene DiPhosPhonate (Tc-99m **MDP**)
- **Dose** : 20 mCi for adults and minimum 2 mCi (250 uCi/Kg) for children.
- **Imaging** : Single phase : 3-4 hrs post iv inj.
- **Three phase** : Flow, pool & delayed
- **Specific Instruction** : Well hydration.

The three phases of bone scan:

- Blood flow
- Blood pool
- Uptake phase

Normal Whole Body Bone Scan

8 year old child

How to differentiate children skeleton from adults: MCQ

-Epiphyseal 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)



25 year old adult



Bone Scan In Oncology

1. Metastatic Disease.

2. Primary Bone Tumors :

- Malignant
- Benign

3. Soft tissue tumors :

- Primary
- Metastases

Bone Scan In Oncology

Imaging features

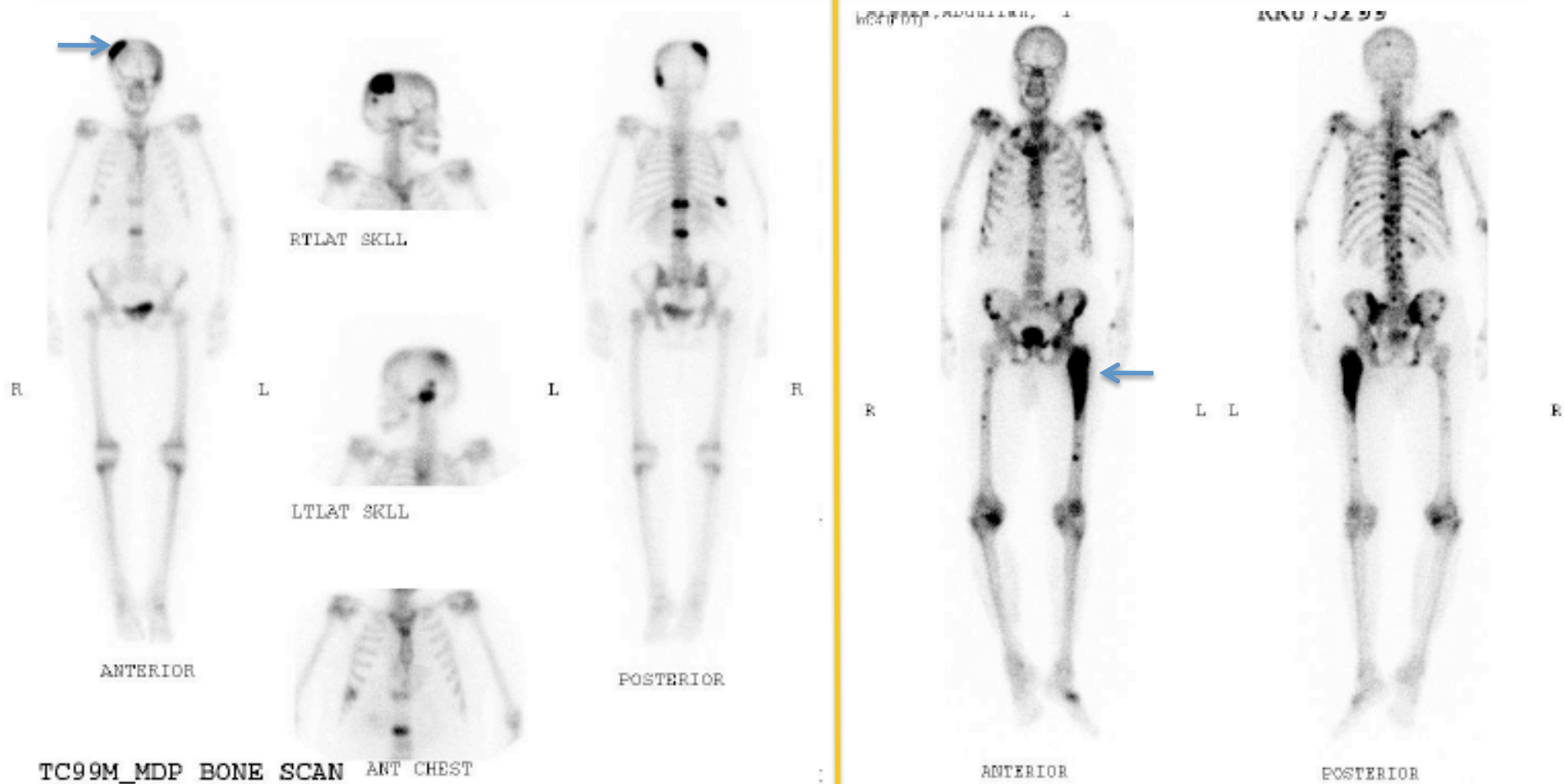
- a. Hot lesions :** *Majority of bone tumors.*
- b. Cold lesions :** *Purely osteolytic tumors (renal cell carcinoma, thyroid cancer, anaplastic tumors).*
- c. Superscan :** *Diffuse increased skeletal uptake with no soft tissue or kidney activity (e.g. CA prostate, breast, ..etc)*
- d. Normal distribution :** *Marrow tumors (e.g. lymphomas, leukemia, multiple myeloma).*
- e. Soft tissue uptake :** *Soft tissue tumors may concentrate the tracer e.g myocardial or brain infarction.*

Bone Scan In Oncology

Indications

1. Diagnosis.
2. Initial staging.
3. Restaging.
4. Asses response to therapy.
5. Therapy planning for patients with primary bone malignancy (e.g. Osteogenic & Ewings sarcoma)

TUMOR STAGING



CA Breast

CA Prostate

Wide Spread bone Metastasis :All the dark spots (hot spots) are metastatic areas to bone

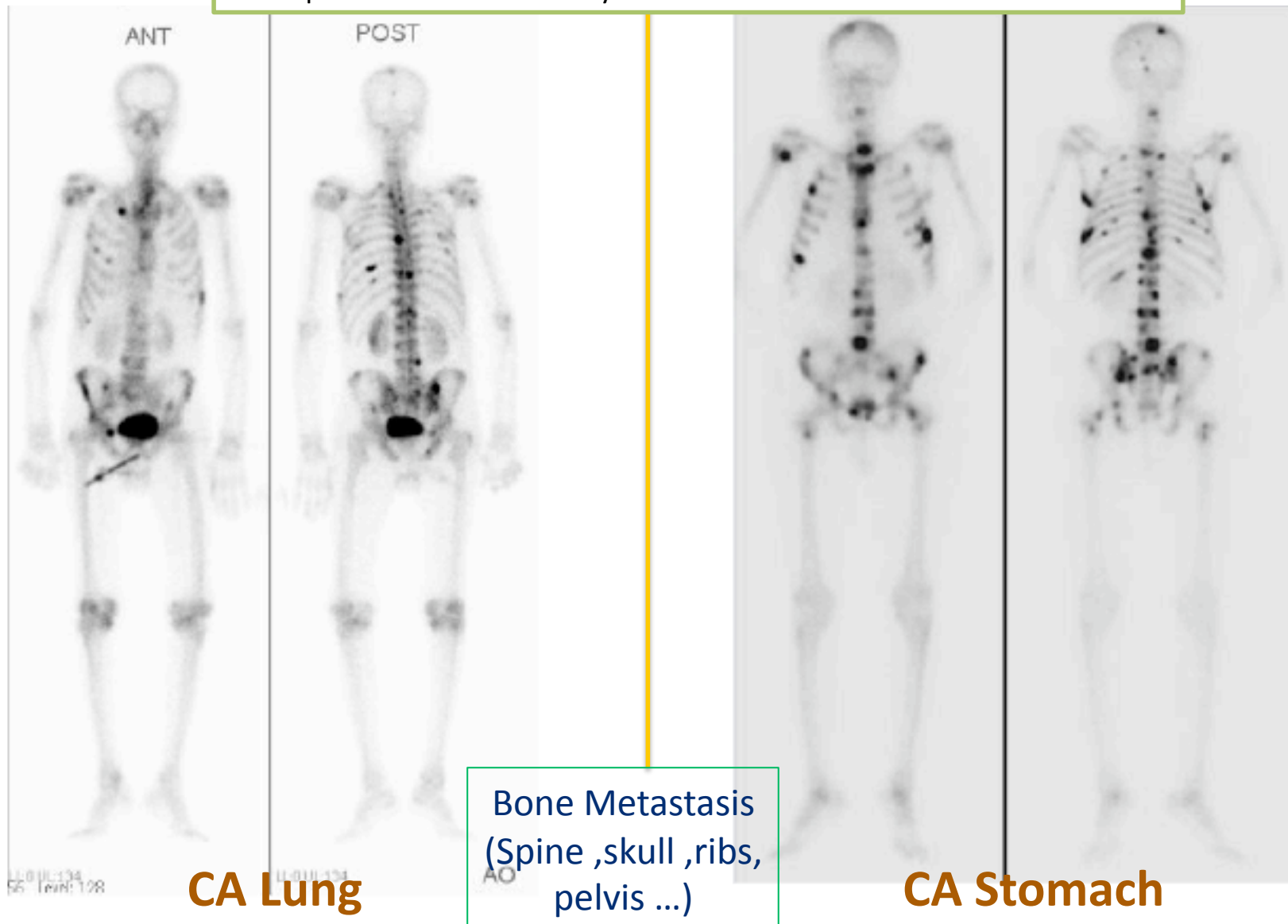
IMP

IMP !

Black areas represent malignant osteoblastic reactions (non-functional proliferation), hence the black color in the bone scan that resembles the epiphyseal plates activity. The type of lesion here is malignant hot lesion (few large areas affected)

TUMOR STAGING

Superscan: scattered malignant areas (wide-spread bone metastasis) that take up all the tracer → kidneys and bladder are not visible



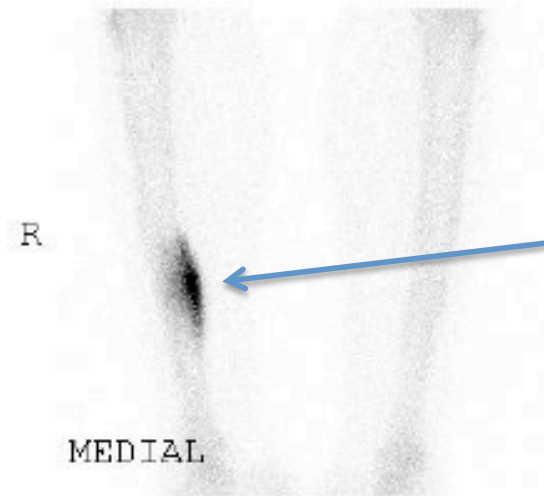
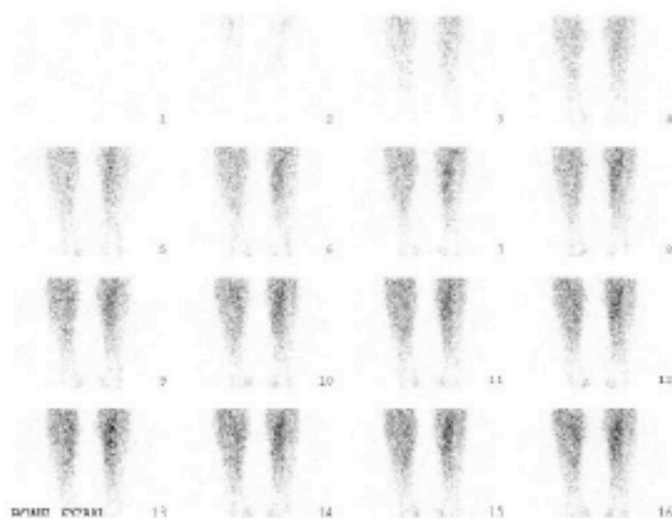
Bone Scan In Bone Tumors

Osteoid Osteoma

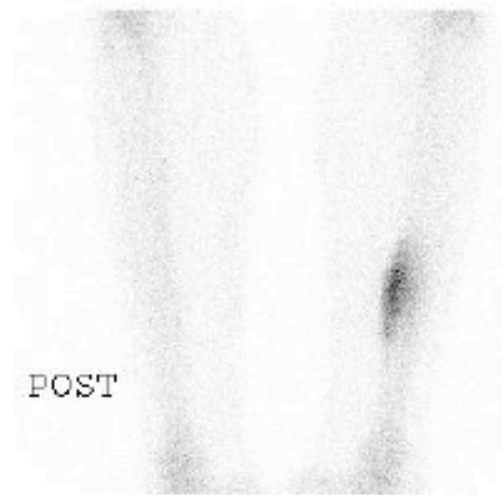
Young patient

Here
3 phase bone
scan:

1-blood
flow(angiogram)
2-Tissue phase
3- delayed image



MEDIAL



POST

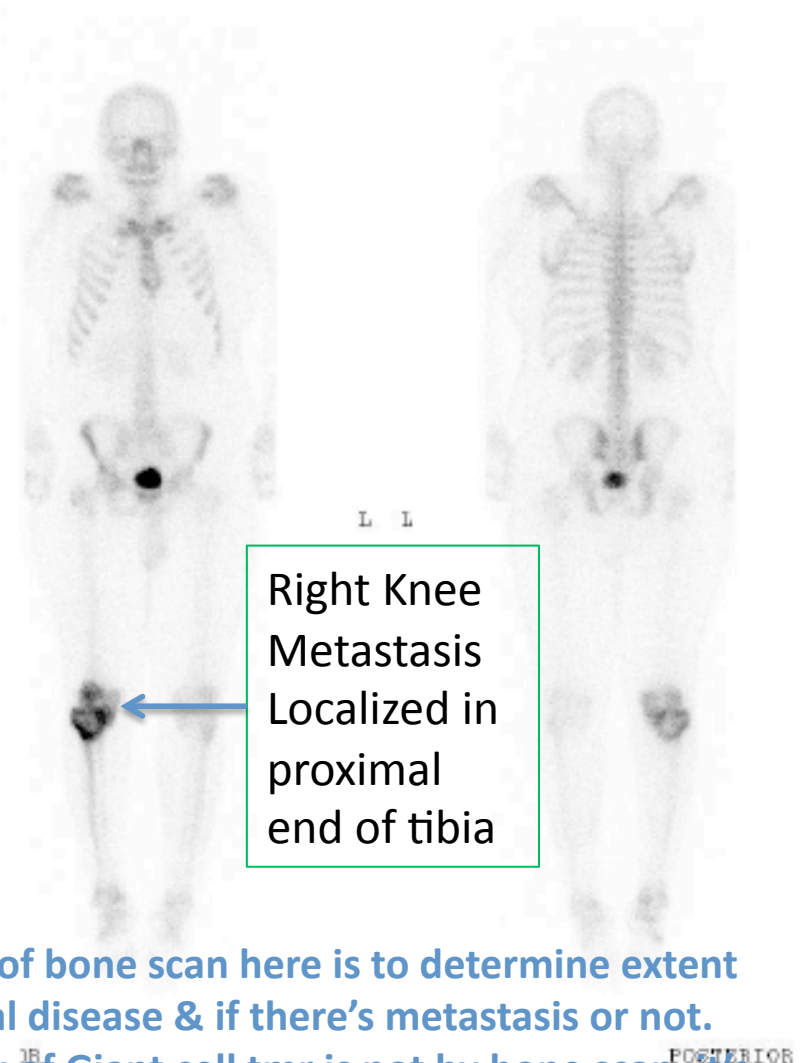
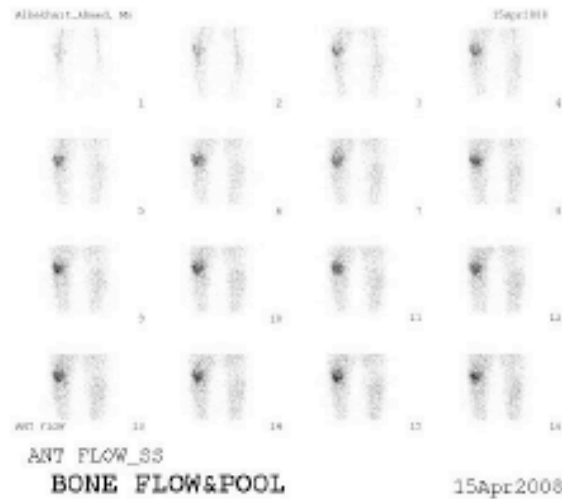
C128
W256

Tracer uptake
In the
Rt tibia
with
increase
in blood
flow

Note

- Best technique in diagnosing bone tumors is MRI, while bone scans are used to detect metastasis.
- However, in Osteoid Osteoma, the best technique in diagnosing is bone scan

Giant Cell Tumor



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 tmr is not by bone scan, it's by conventional radiogram and MRI

Notes

- 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

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



Gallium 67 Citrate (Ga-67)

- Non specific for infection-inflammation and tumors
- **Mechanism** : Binds to transferrin, transferrin is largely found in the liver and bone marrow
- **Excretion**: Kidneys and large bowel
- **Dose** :5-10 mCi
- **Imaging** : 24-72 hours post-injection
- **Tumors** : Lymphoma, bronchogenic carcinoma , malignant melanoma , hepatoma

Gallium 67 Citrate (Ga-67)

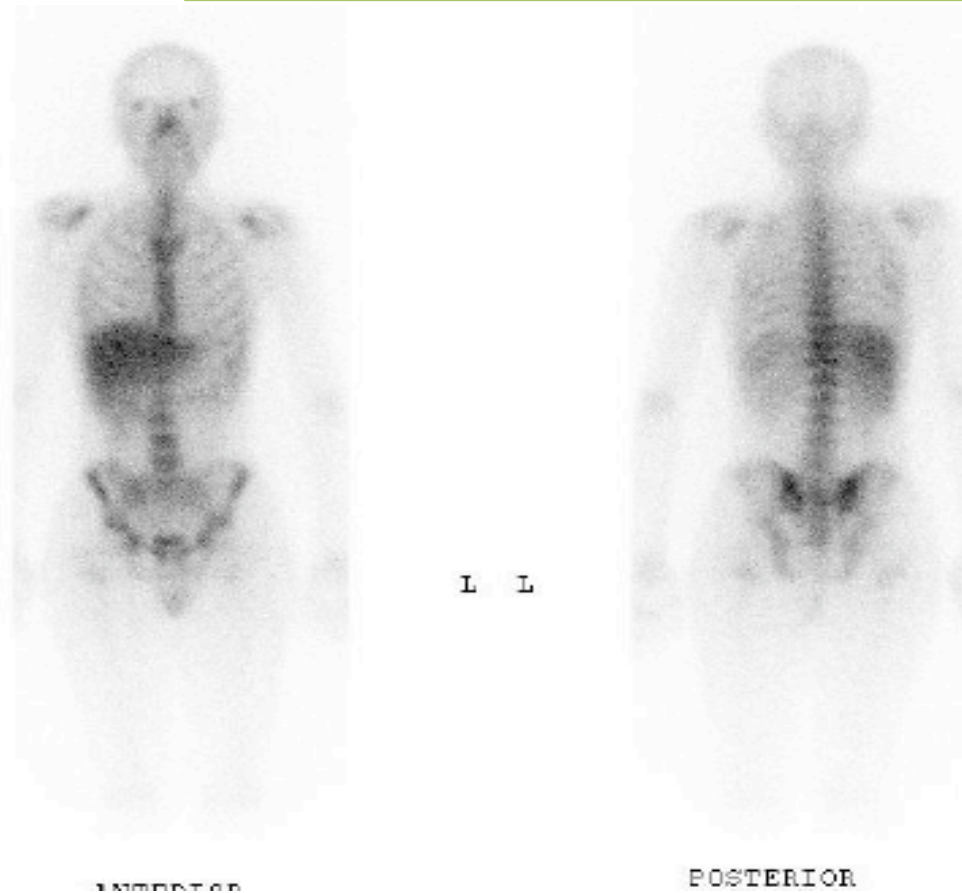
Lymphoma

USE in:

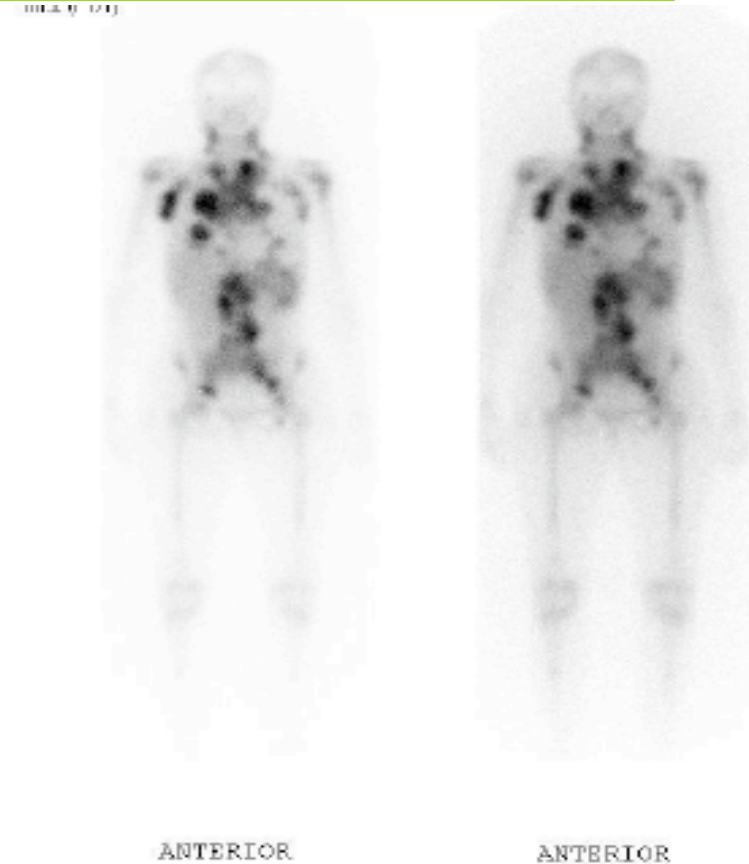
- Staging
- Follow up and monitoring of therapy
- Detection of tumor recurrence
- Differentiate post-therapy changes : tissue necrosis and fibrosis from local recurrence.
- Lymphomas are best diagnosed by: PET + other nuclear imaging (Ga-67) (post-therapy scan)

Gallium Scan in Lymphomas

Black spots = diseased lymph nodes
If lymph nodes above and under the diaphragm are affected = bad sign

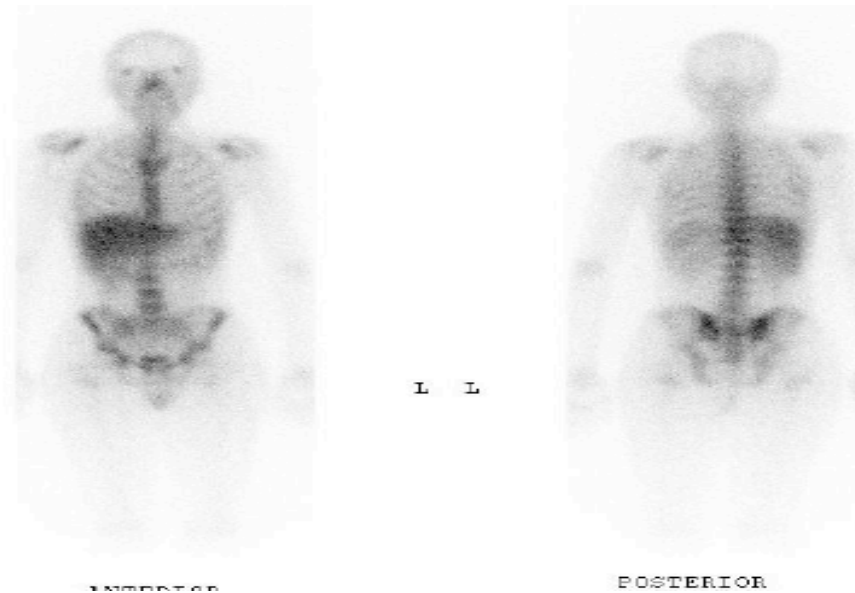


Normal Gallium Scan



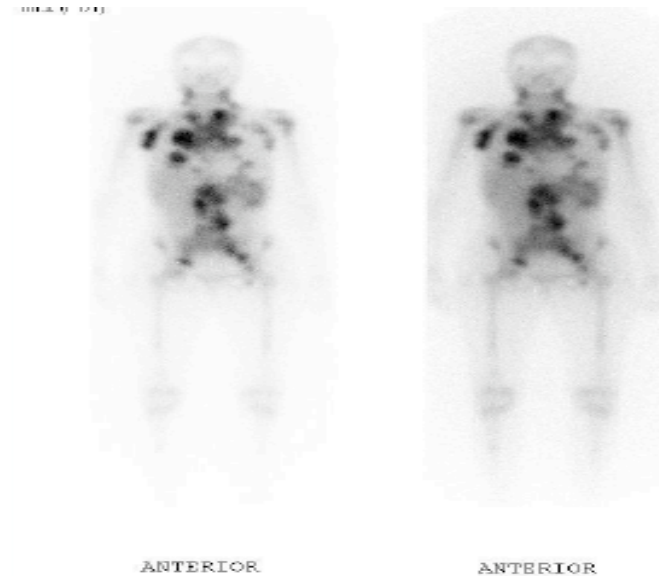
Ga-67 Scan is useful in initial evaluation and monitoring response to treatment in HD and NHL

Comments on the previous slide :



In the normal : as the Ga binds to transferrin it will be more up-taken by the liver and bone marrow because transferrin is concentrated in them

THERE ARE HOT SPOTS (THE DARK SPOTS)

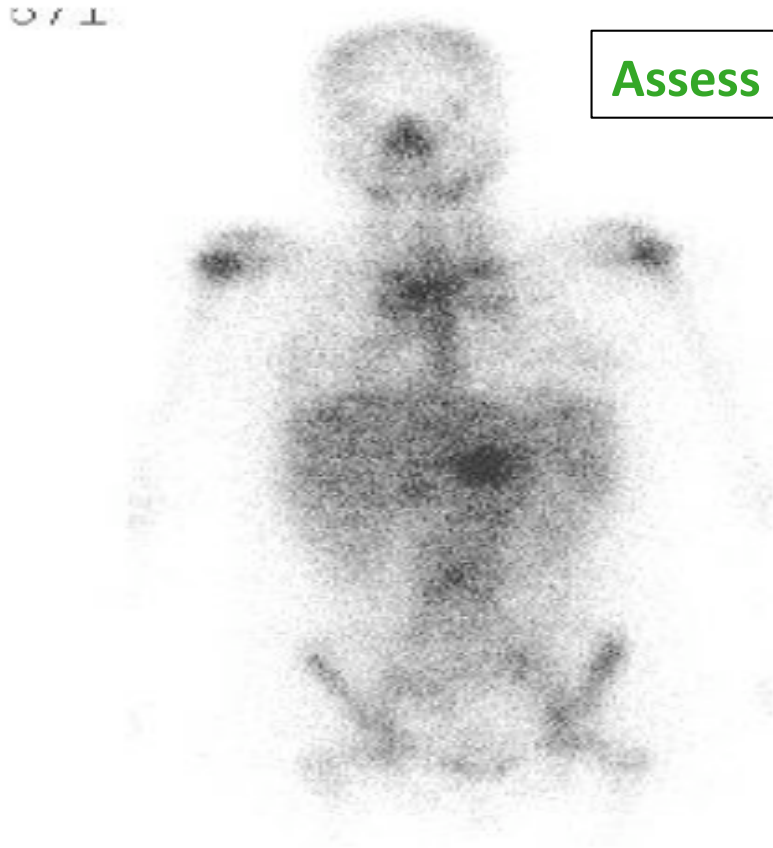


- Multiple focal areas , where there is increase uptake in the cervical area ,mediastenum ,hilum, axilla and abdomen (actively form of patient with lymphoma)
- Lymph node normally should not be seen because they are small in size and minimal Ga found in them , but if they are inflamed , you may see them.

Ga-67 Scan In Lymphoma

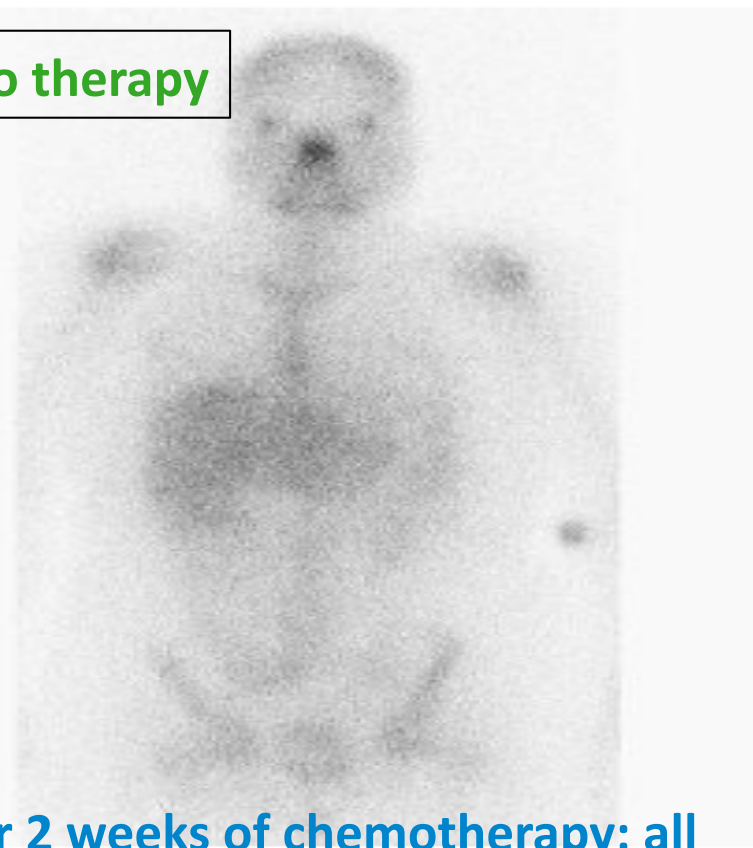
Prediction of response to therapy Normalization

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



Prior to therapy : there is increased uptake in the mediastinum and epigastric lymph nodes

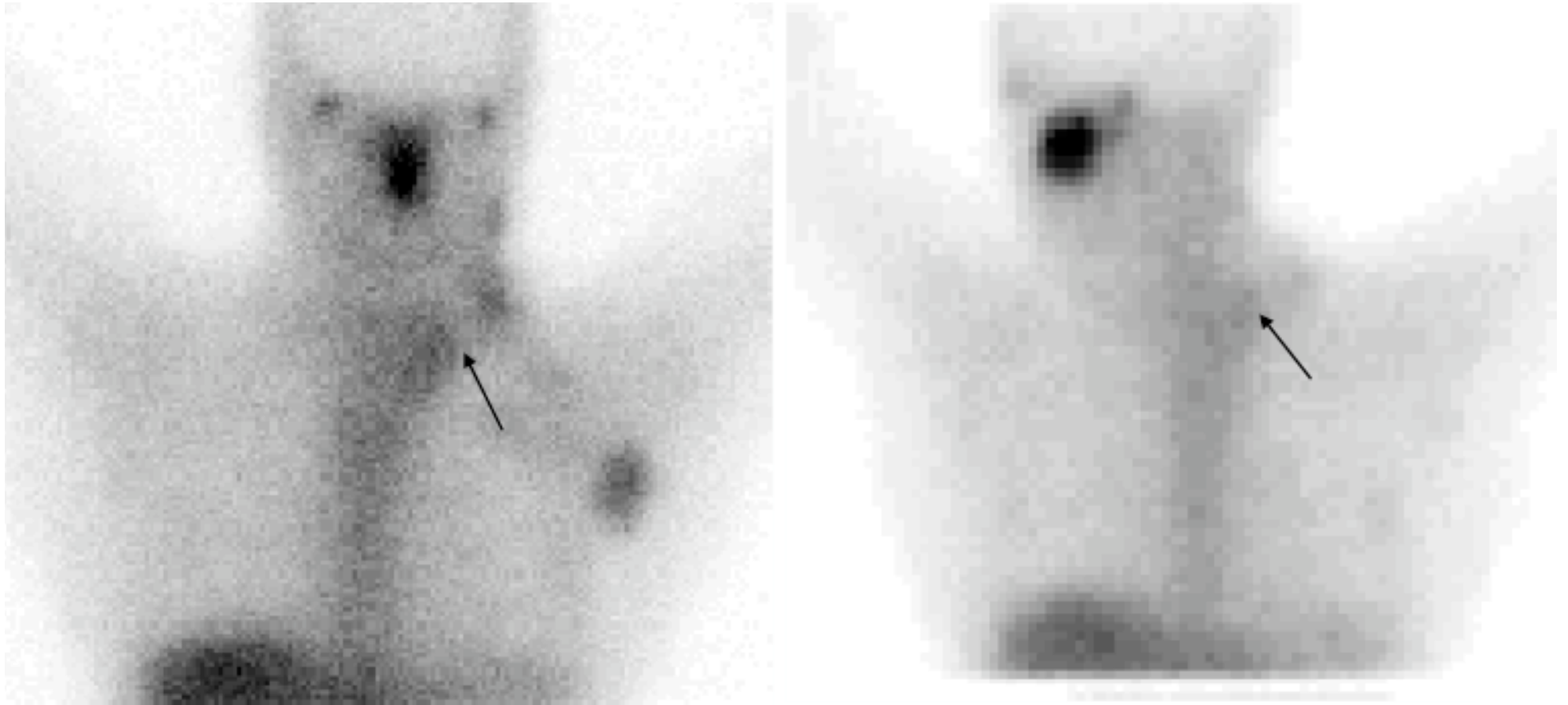
Assess the response to therapy



After 2 weeks of chemotherapy: all previous up taking areas are disappeared indicating excellent response to chemotherapy. Complete cure.

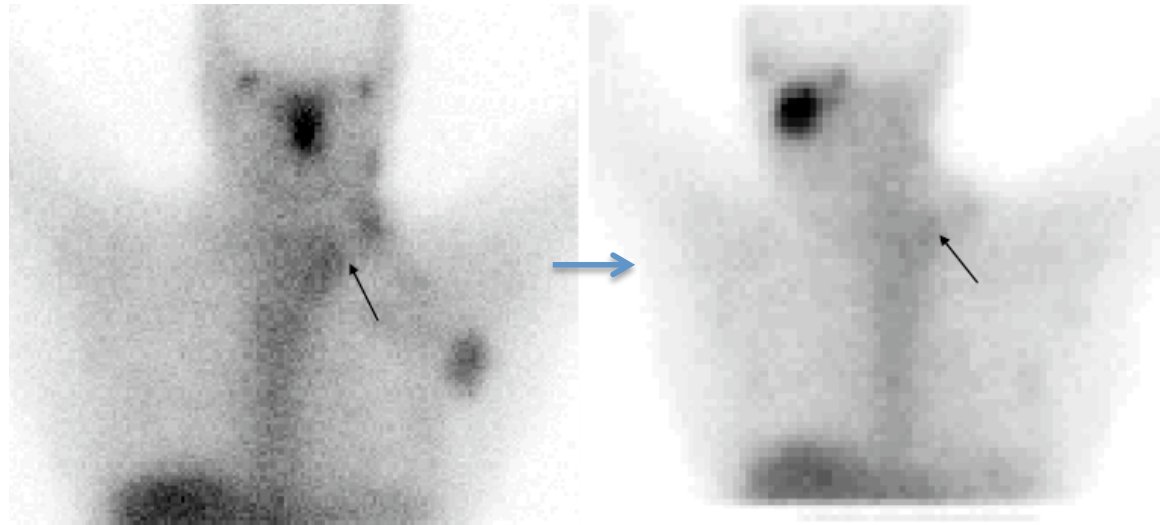
Ga-67 Scan In Lymphoma

Prediction of outcome



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

Comments on the prev. slide:



-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

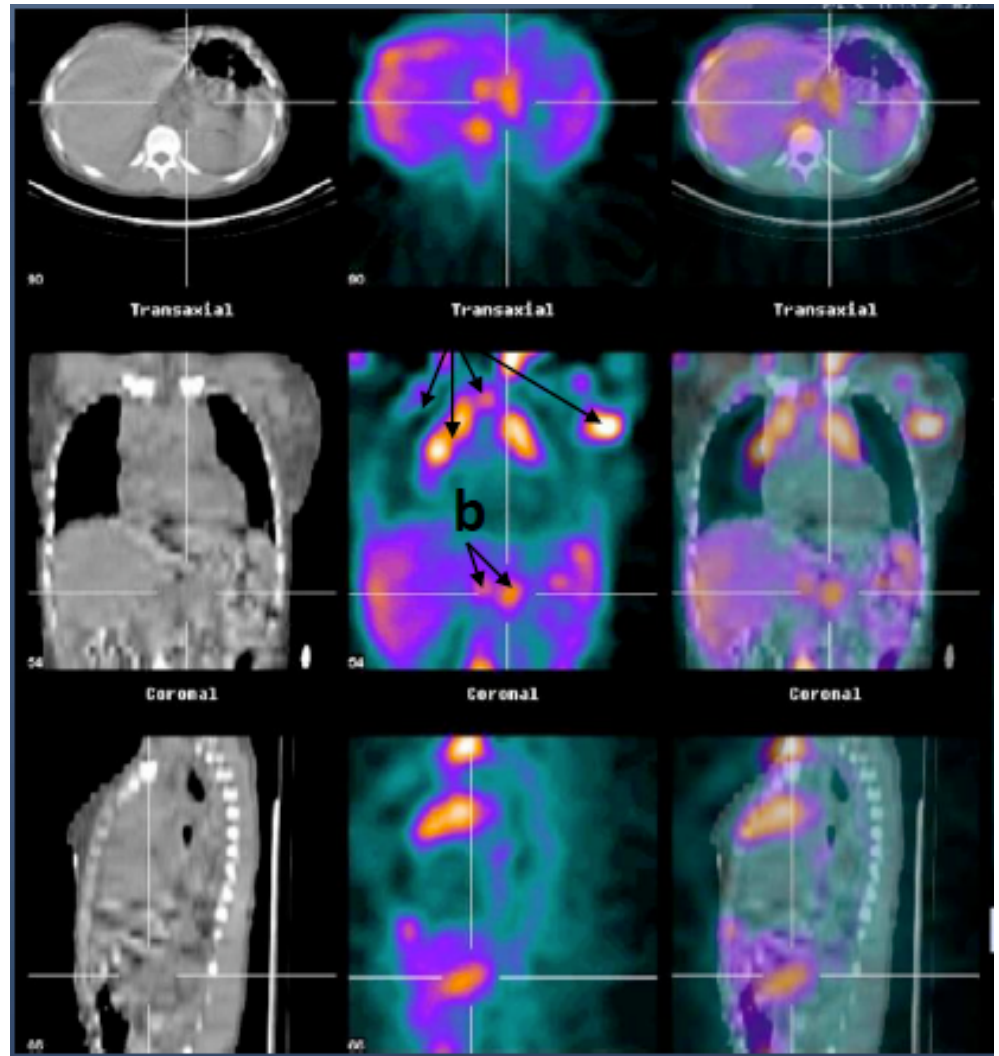
-When we want to assess the response to the chemotherapy , we either say :

1-Complete response : where the uptake disappear

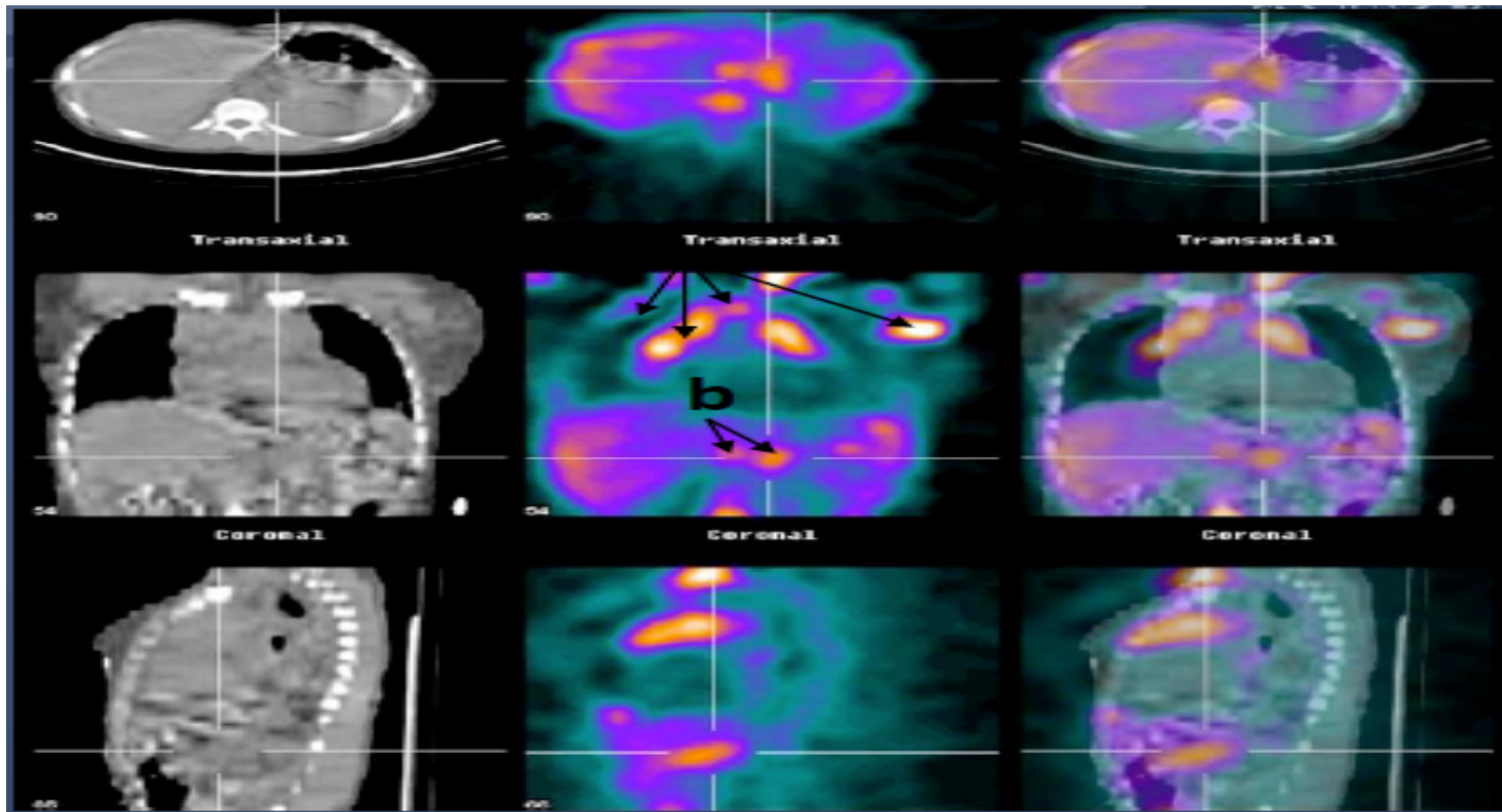
2-No response : when there is uptake of Ga even if it is a little uptake we do not say "partial uptake" only response or no response. And in this case oncologist will give more aggressive chemotherapy

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 subdiaphragmatic disease and excluding bowel activity



Comments on prev. slide : Ga SPECT/CT



1-CT

2- SPECT

3- Fusion(CT+SPECT)

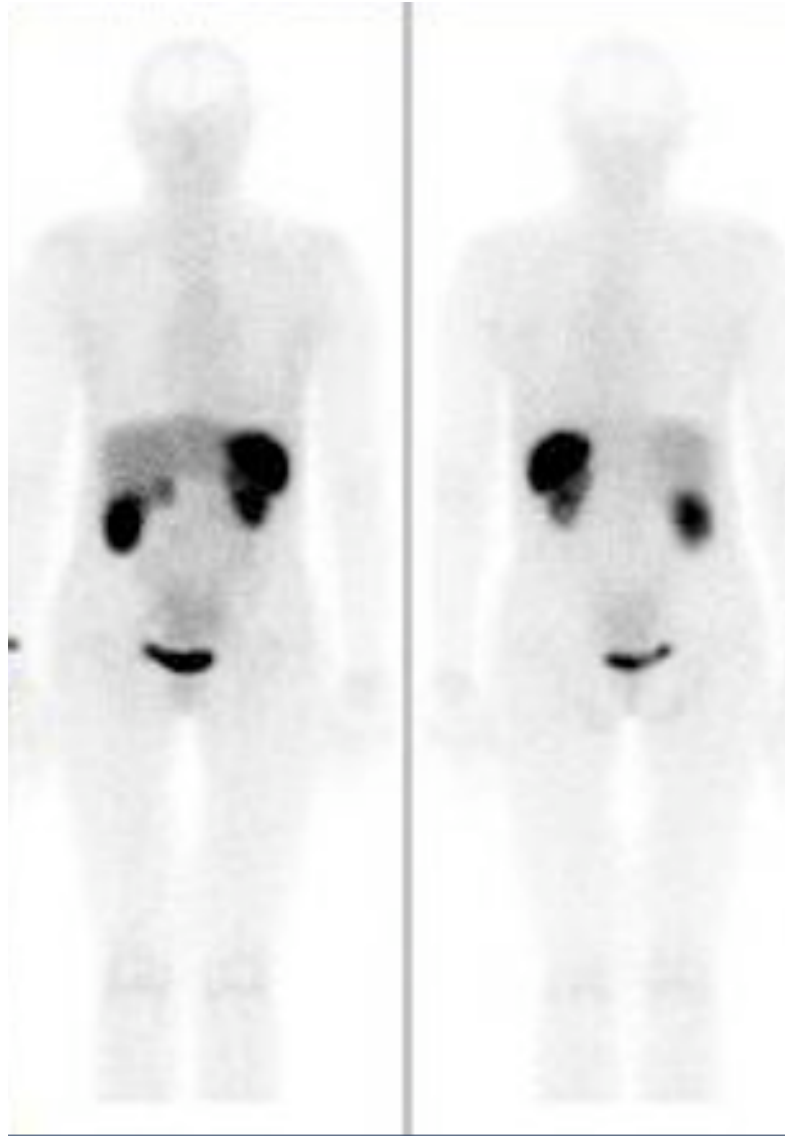
- First CT scan is done, then SPECT . After that the computer will fuse both images in order to tell you which group of lymph nodes is affected.
- CT is used to improve the localization of uptake that seen in nuclear scan

Neuroendocrine Tumors

-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
NORMAL STUDY**



In - 111 octreoscan

Insulinoma

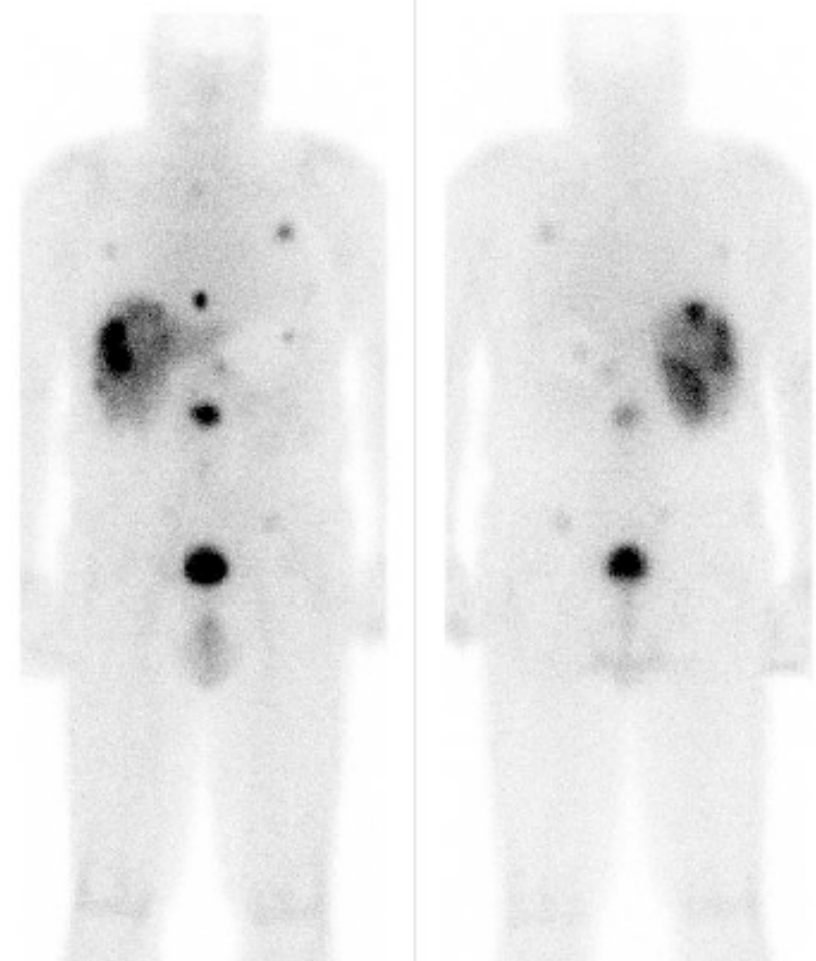
Clinical History

- The patient is a 66-ys male with insulinoma,
- Now being evaluated for evidence of recurrent and/or metastatic disease (liver, abdomen, lung, mediastinum)

Findings :

- Multiple lung, mediastinum , liver and abdominal metastases

4 HR OCTREOTIDE



I123 MIBG Scan

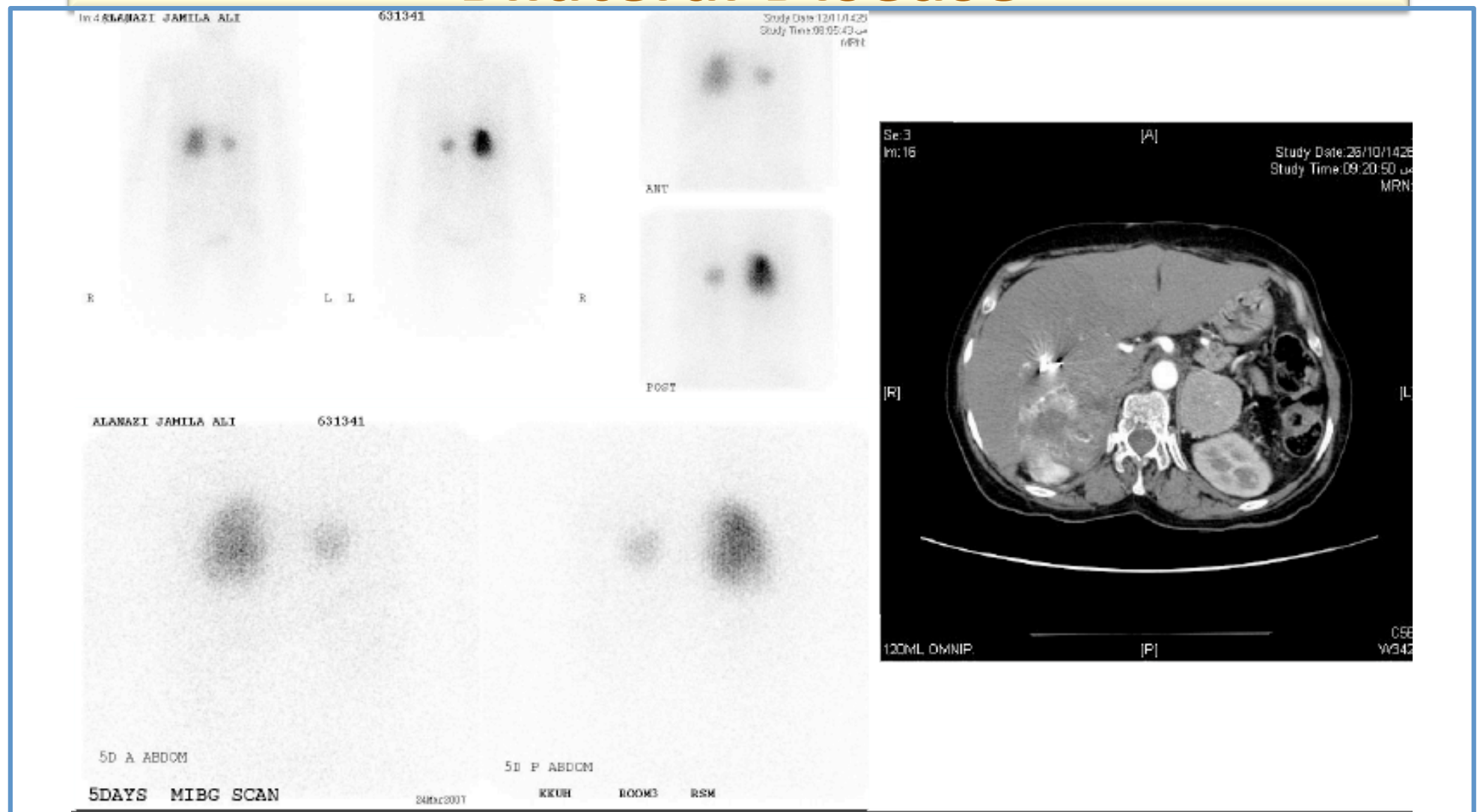
MIBG : Meta Iodo Benzyl Guanidine

- 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

1. Pheochromocytoma
2. Paraganglioma
3. Insulinoma
4. Neuroblastoma
5. Medullary thyroid carcinoma
6. Carcinoid tumors
7. Chatecolamines-producing tumors

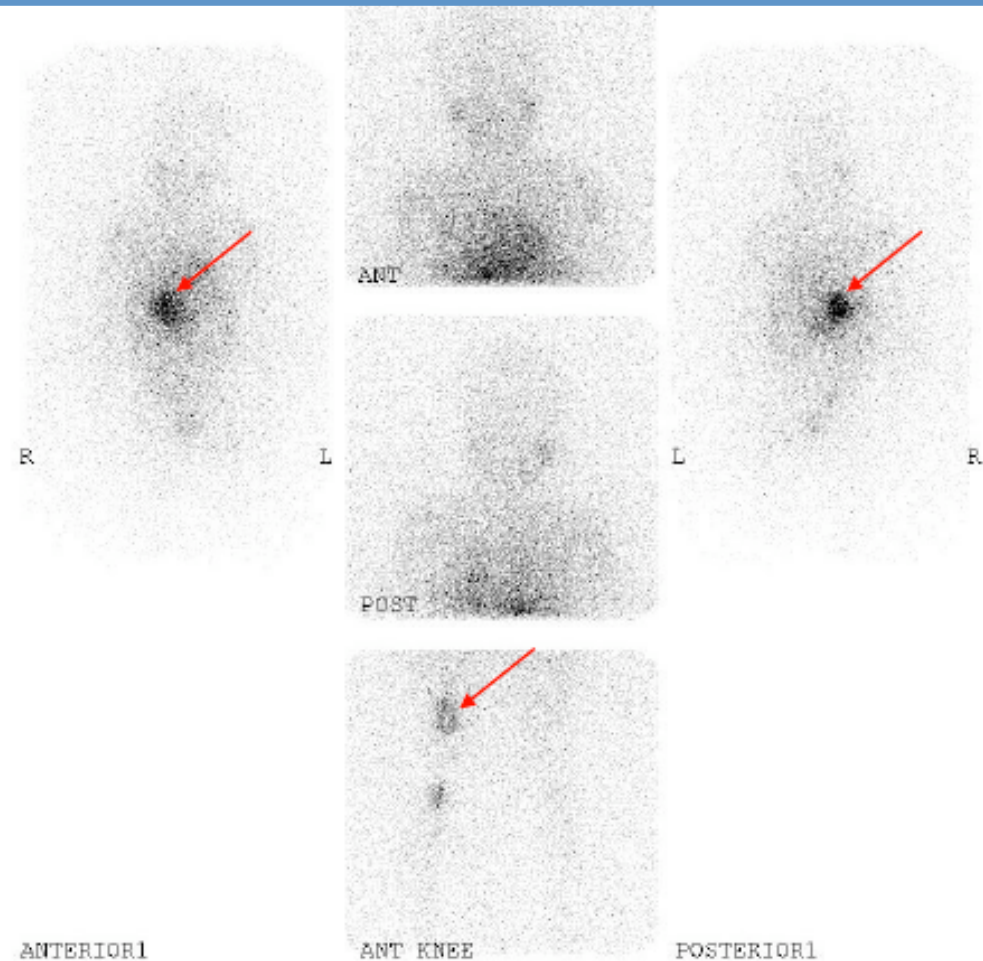
MIBG In Pheochromocytoma Bilateral Disease



patient with bilateral pheochromocytoma

I131 MIBG Total body scan

Primary neuroblastoma /bone mets



With distant metastasis to the bone in right femur and tibia

THYROID METASTASES STUDY

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

- **Indications**
 - Detection and localization of persistent or recurrent local or distant functioning thyroid cancer
- **Patient Preparation**
 - Stimulation of potentially functioning thyroid tissue:
 - A. Inject recombinant human thyrotropin on 2 consecutive days and administer the iodine on the third day .
 - B. Withdraw thyroid replacement hormones : 1. Thyroxine (T-4) for at least 4 weeks.
2. Triiodothyronine (T-3) for at least 10 days. • The patient must not have had i.v iodinated contrast material (IVP, CT with contrast, myelogram, angiogram) for at least 3 weeks .
 - The patient should be NPO for at least 4 hours prior to radiopharmaceutical administration and for at least 1 hour afterwards .
- **Tracer , Dose, & Technique of Administration**

Radiopharmaceutical: Oral administration

 - a. I-123 as sodium iodide : 2 mCi
 - b. I-131 as sodium iodide : 2-10 mCi

} IMP
- **Imaging using Gamma camera : Whole body scan**

Comments on prev. slide :

Thyroid metastasis :

-If the patient have thyroid cancer , you want to search for distant metastasis , you can use :

I123,I 131 for body scan.

-Preparation : stop thyroxin treatment for 4 weeks.

-And the patient is imaged 24-48 hours later

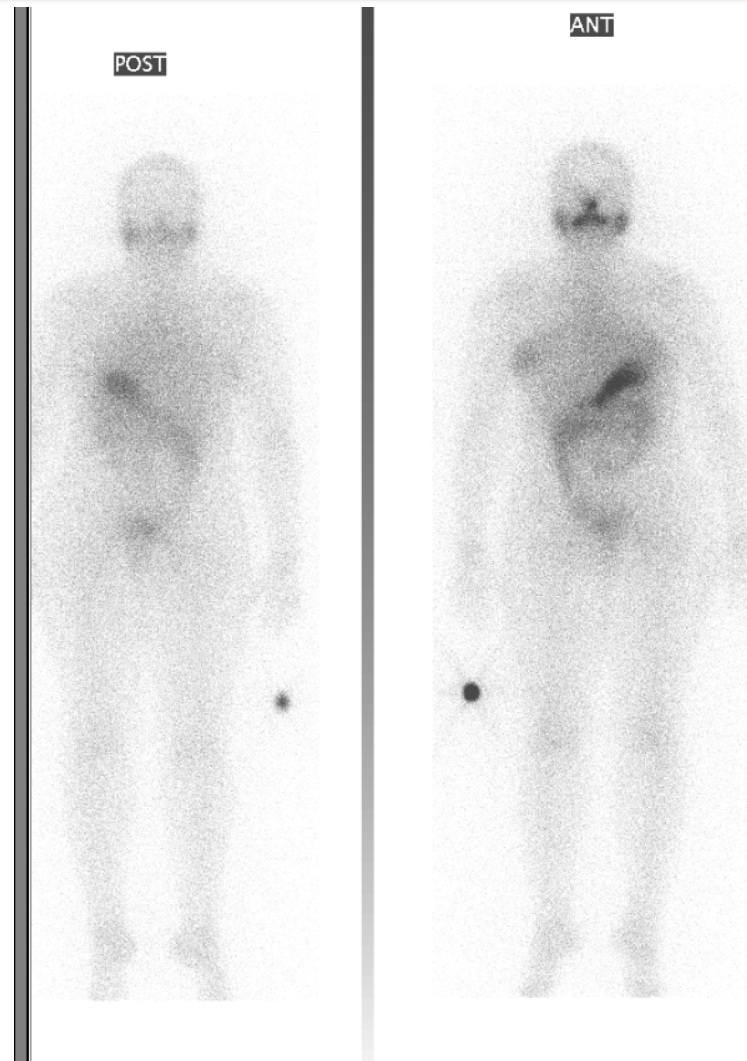
IMP MCQ:

I-131 can also treat tumors if given in high doses

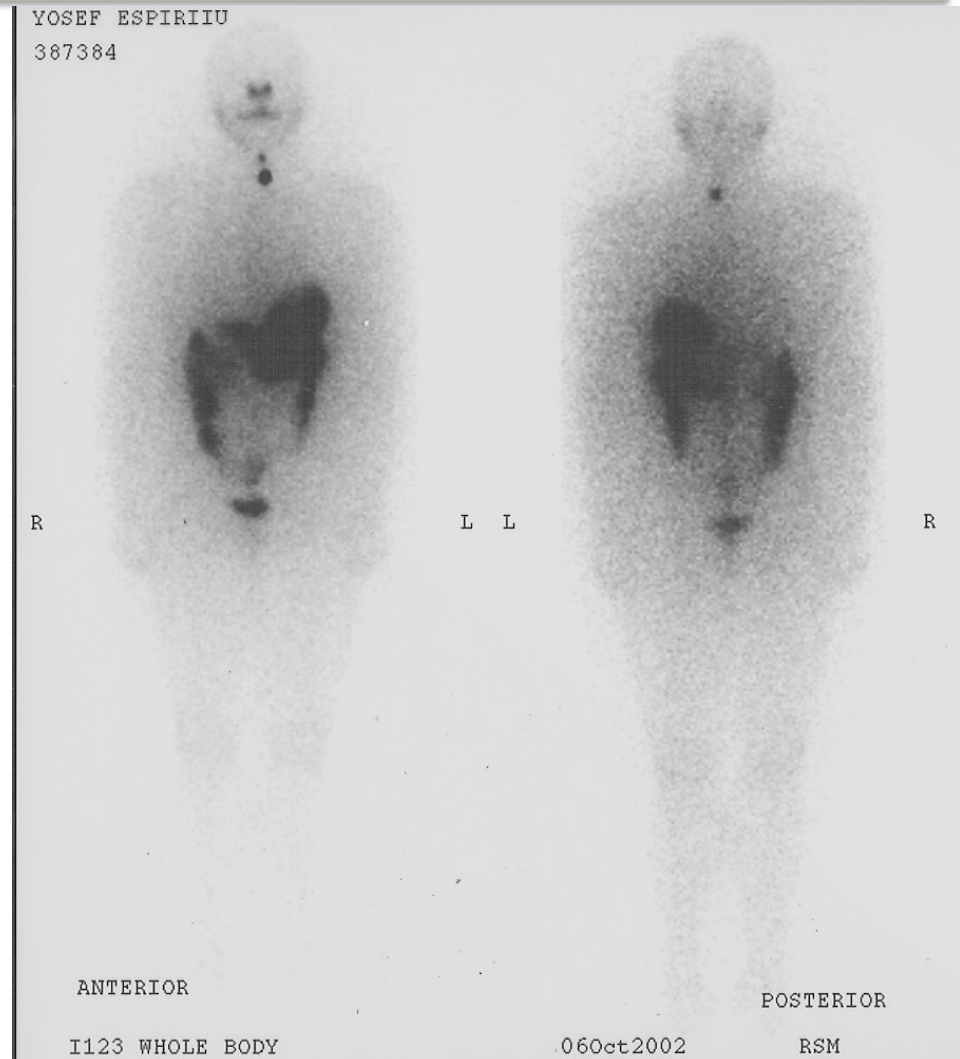
The cause is the I-131 contain beta “ waves or molecule *

Thyroid Cancer

I-123 WB Scan



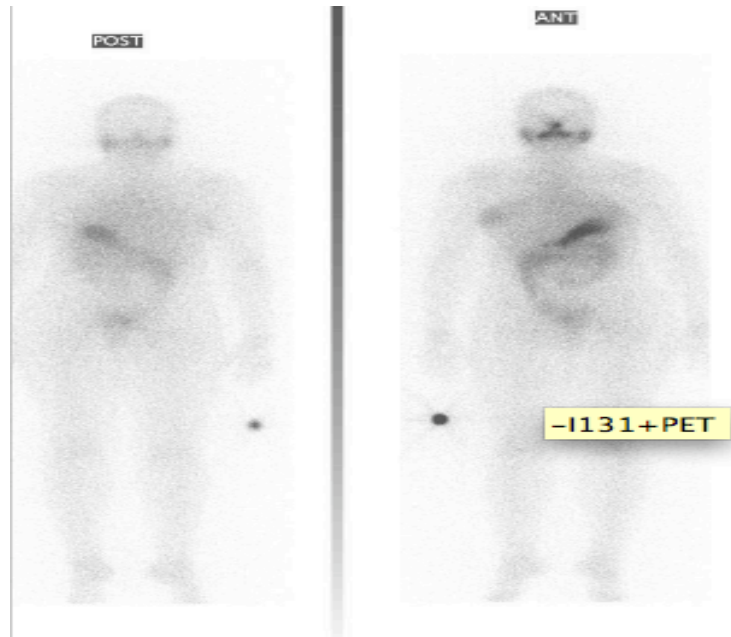
Negative I-123 WB Scan



I-123 WB Scan : Post operative Thyroid remnants

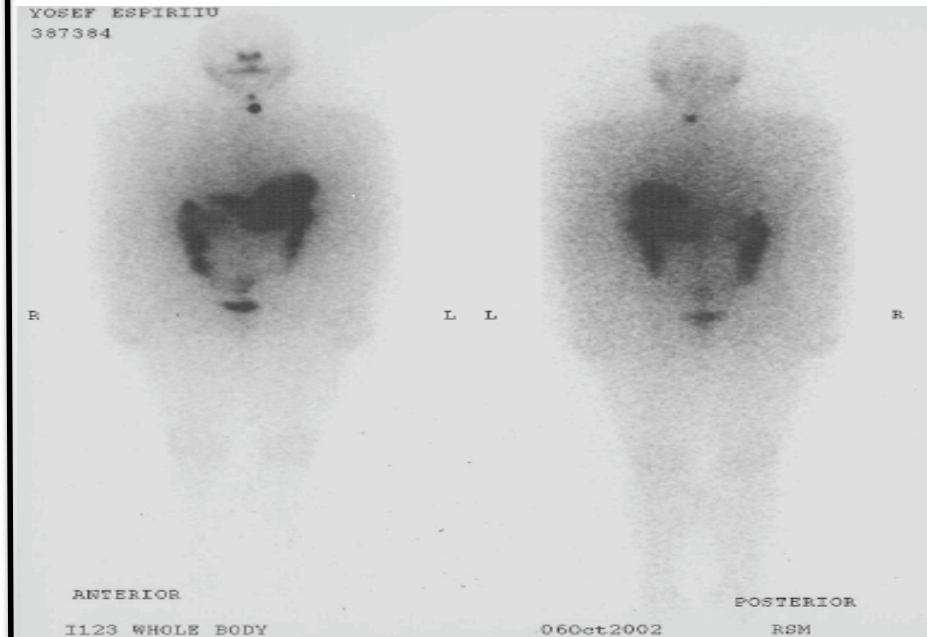
Comments on prev. slide :

**Negative I-123 WB Scan
complete cure of thyroid cancer**



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**

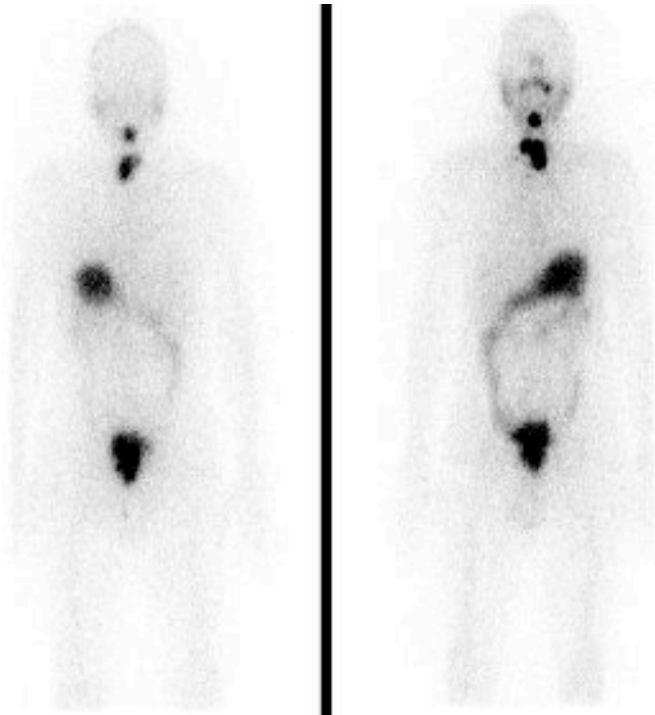


-Post surgery scan for thyroid cancer
-showing remnant of the thyroid . -These remnants are treated by radioactive iodine 131. This I 131 will go to these remnant and destroy them without damaging the surrounding tissues.

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

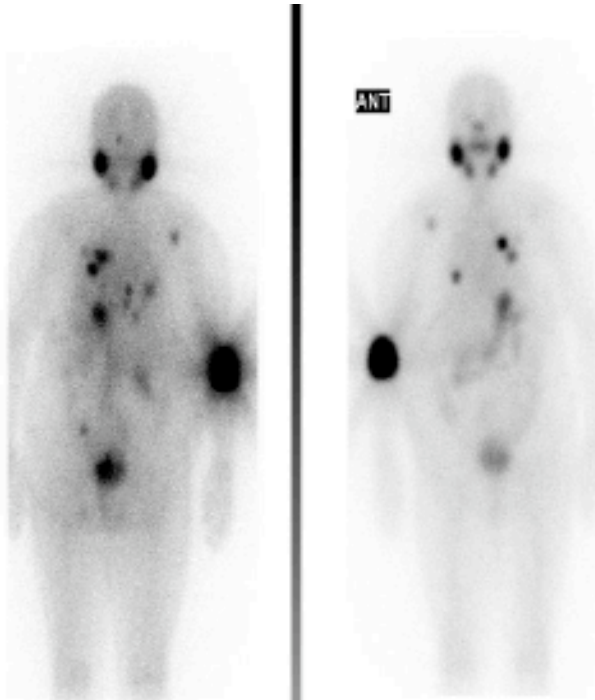
THYROID METASTASES STUDY

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



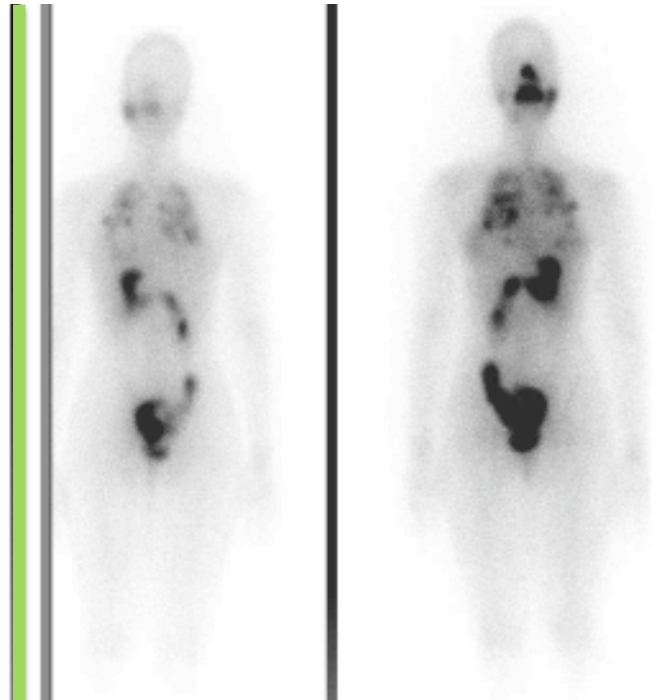
Local Recurrence

patient with multiple recurrence in the thyroid and thyroglossal duct



Bone Metastases

lung and bone metastasis

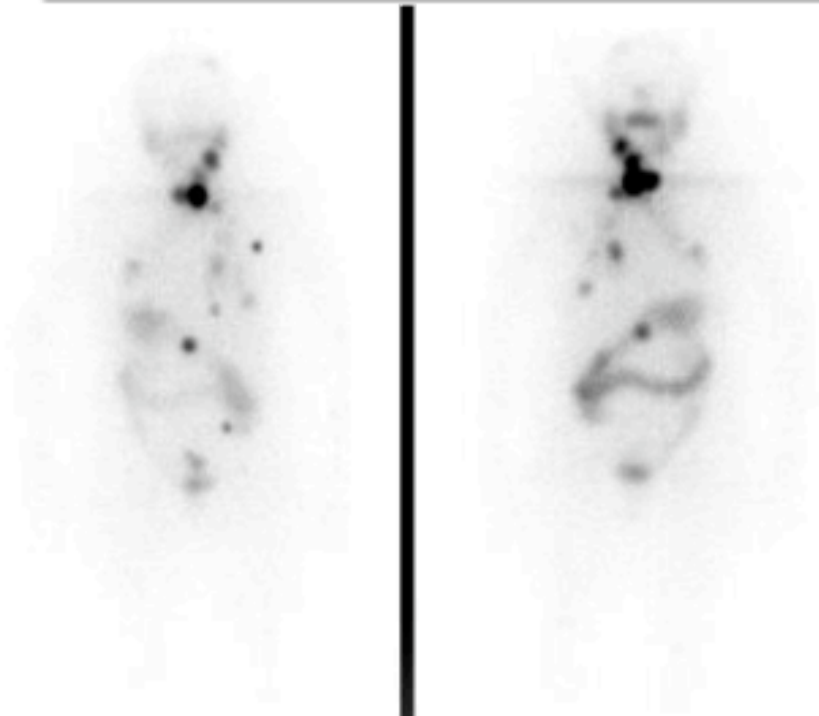


Lung Metastases

diffuse lung metastasis.
-Lung and bone metastasis can be treated by I131

Thyroid Cancer I-131

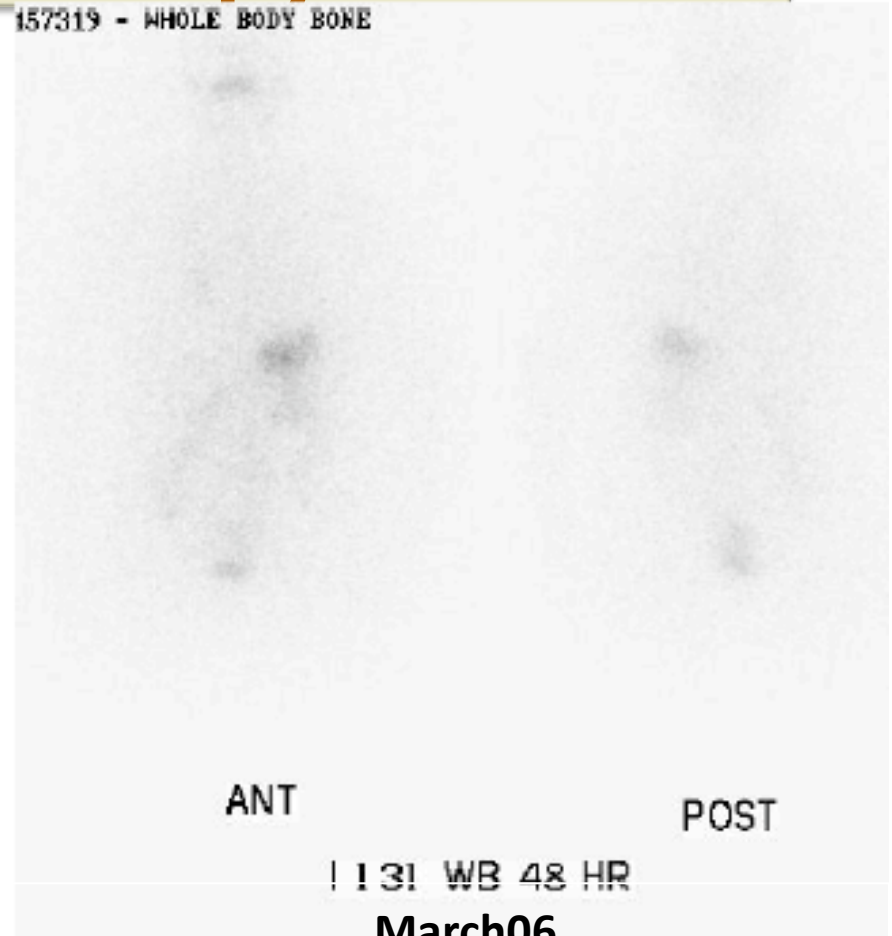
Pre & Post therapy



Dec04

A patient with multiple ;local and distant metastasis .

157319 - WHOLE BODY BONE



I 131 WB 48 HR

March06

Same paient was treated by I 131 and the scan 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.

Fusion of functional image obtained from PET with anatomical image obtained with CT scan.

PET : How it is performed...?

- **Positron emitters (e.g. F18)** labeled 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. Anihilation 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.

Positrons are positive electrons
Fluorine-18 (**F-18**)
Fluorodeoxyglucose (FDG)

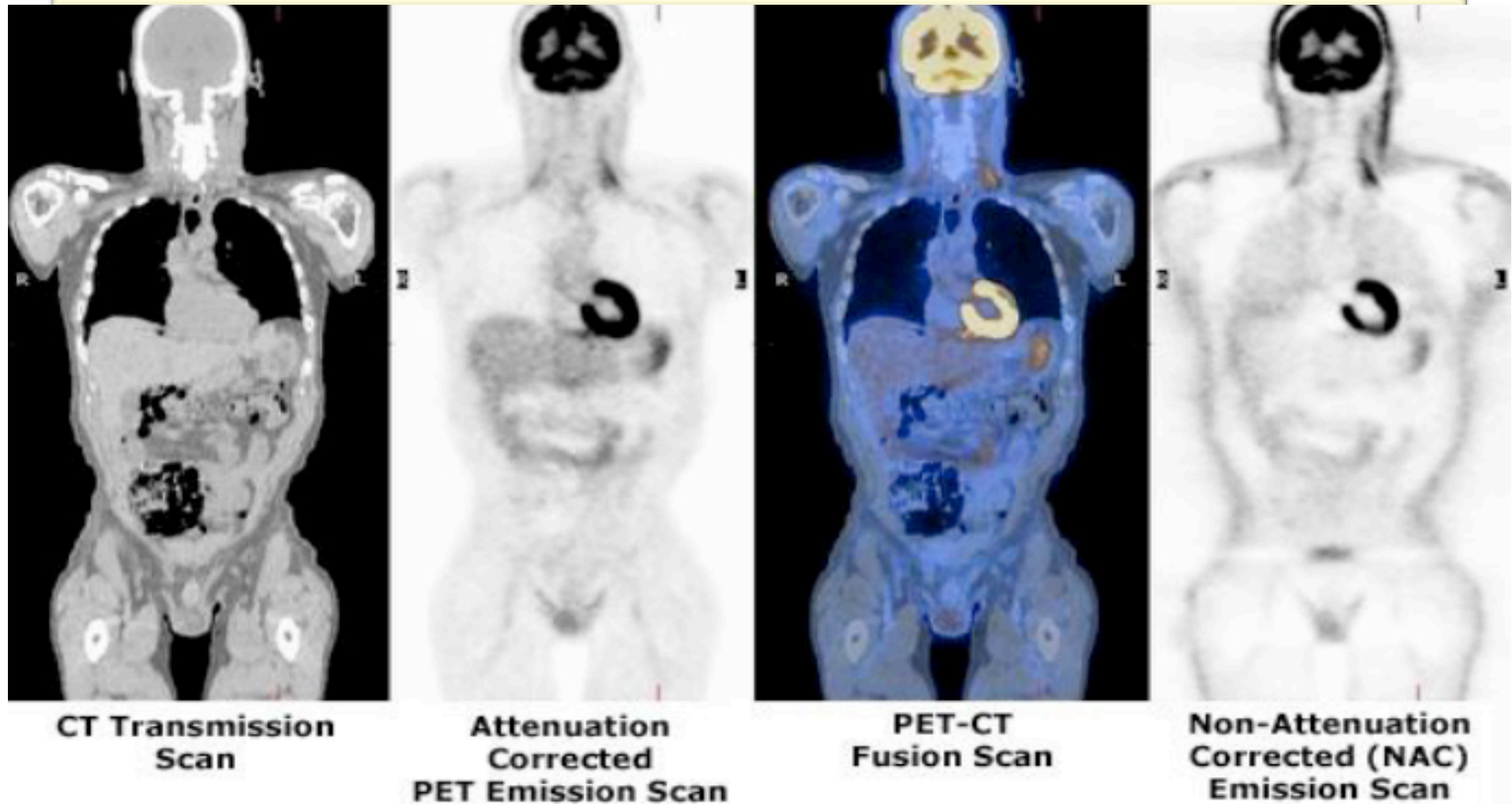
Comments on prev. slide :

How PET is performed ?

-Using of F18 labeled with glucose that is the main source of energy in tumor, so when there is high glycolysis by tumor , it will concentrate more F18 than the surrounding tissues and will appear as increased glucose consumption at that area.

-F18 emitting 1 type of radiation called positron , so image will be obtained called PET.

PET CT



PET CT = PET + CT = Function + Form

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

Positron Emitting Isotopes

Cyclotron produced isotopes:

Isotopes :

- **Oxygen-15**
- **Nitrogen-13**
- **Carbon-11**
- **Fluorine-18** (most commonly used in oncology)

T/2

2 minutes

10 minutes

20 minutes

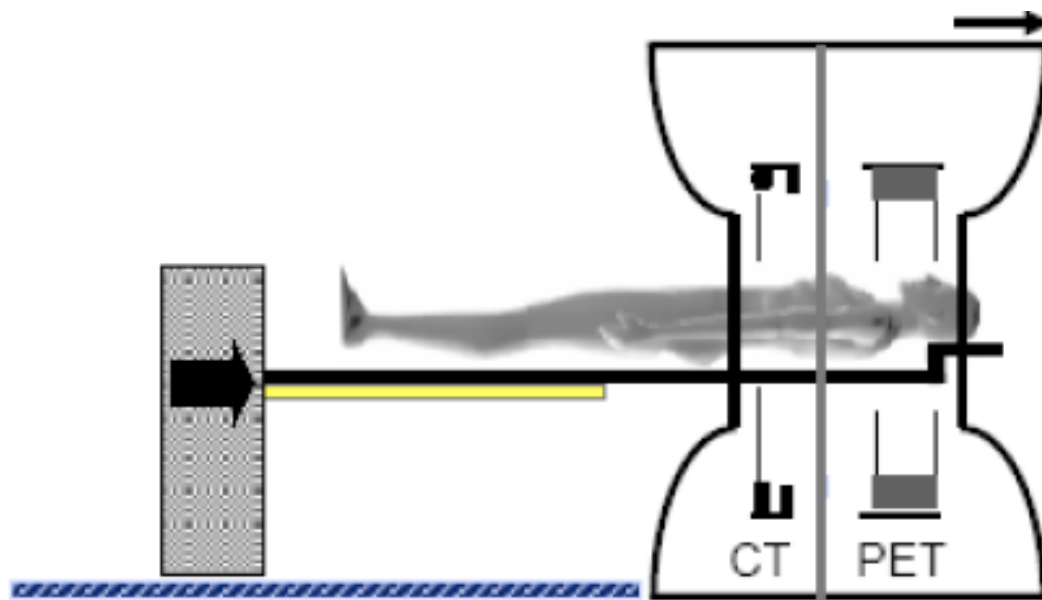
110 minutes

The main isotope here is F18

FDG PET CT : Procedure

- **Fasting** : 4 – 6 hours
- **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)

PET CT IMAGING PROTOCOL



CT then PET

FDG in Oncology

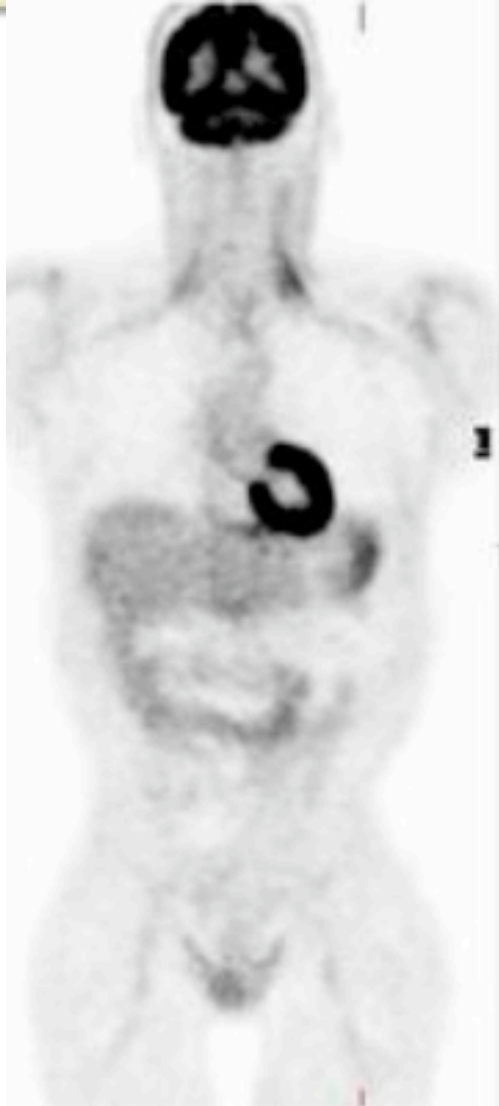
Tumors do not have a blood tumor barrier

- 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

FDG PET



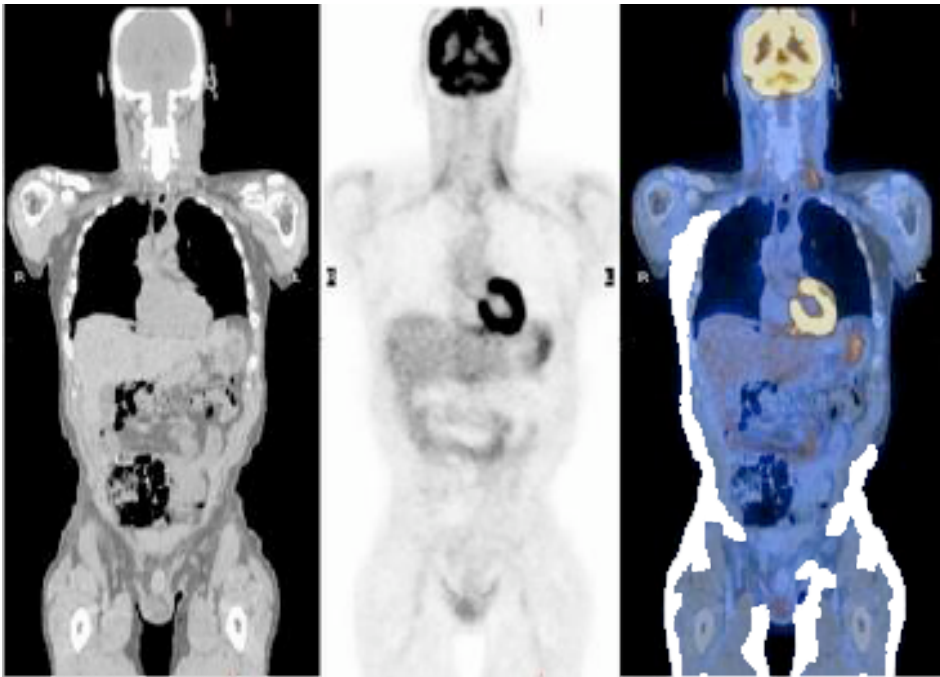
FDG PET : Normal

The spots here are lymph nodes but we can't know their exact area except w the help of CT

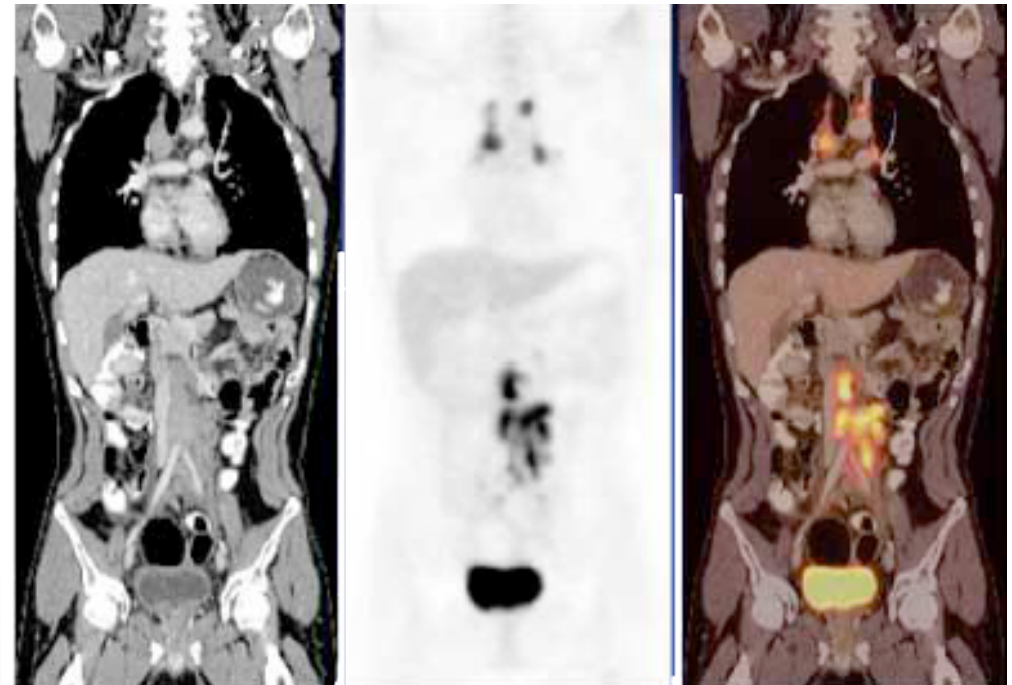


FDG PET : Staging of NHL

FDG PET-CT



FDG PET-CT Normal

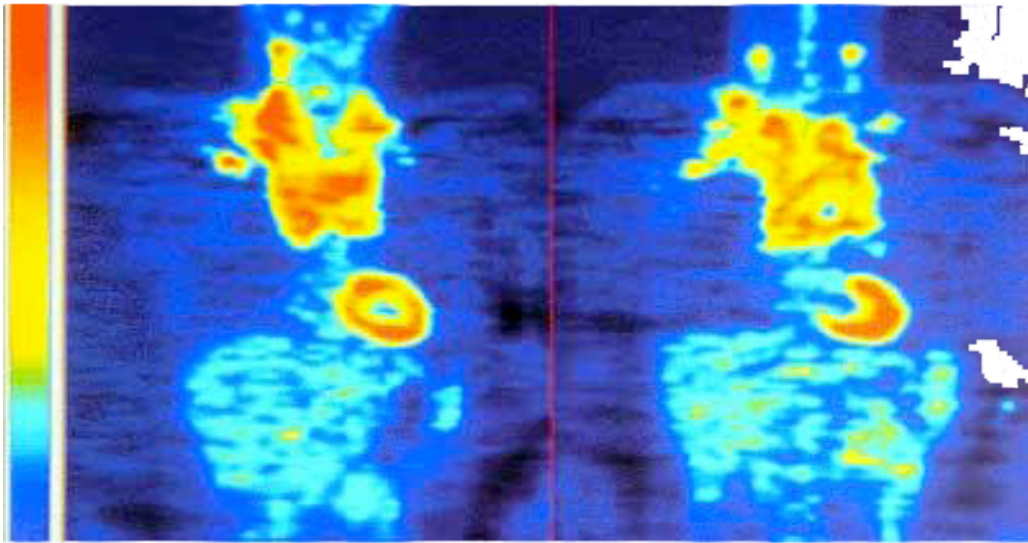


FDG PET-CT
Staging Of Lymphoma

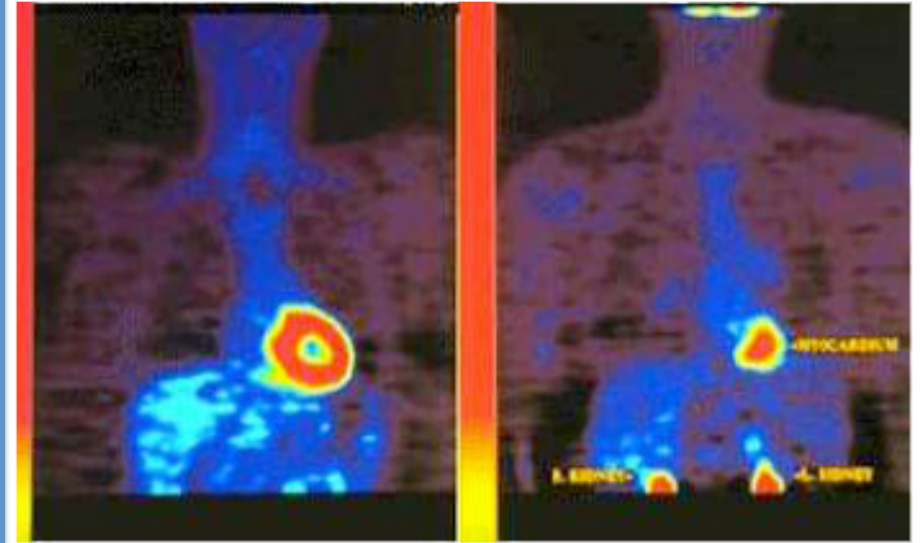
Assessment of therapy response

FDG PET in HD

The hottest uptake is Red ,and the least uptake is yellow



Baseline

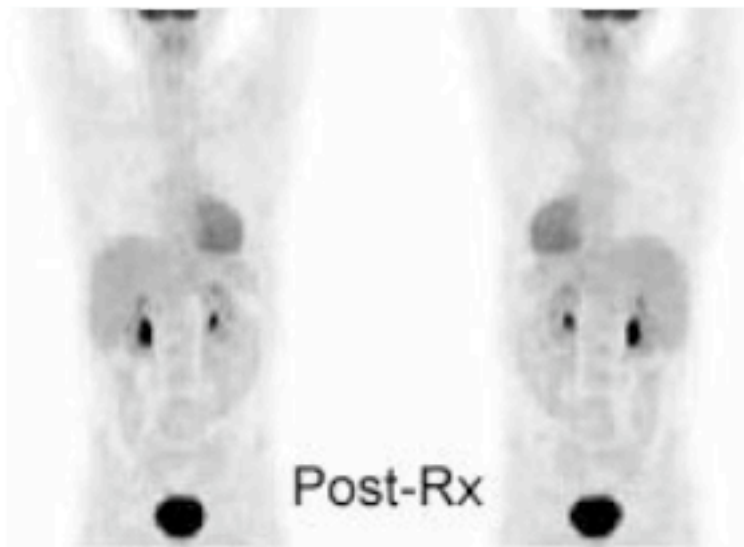
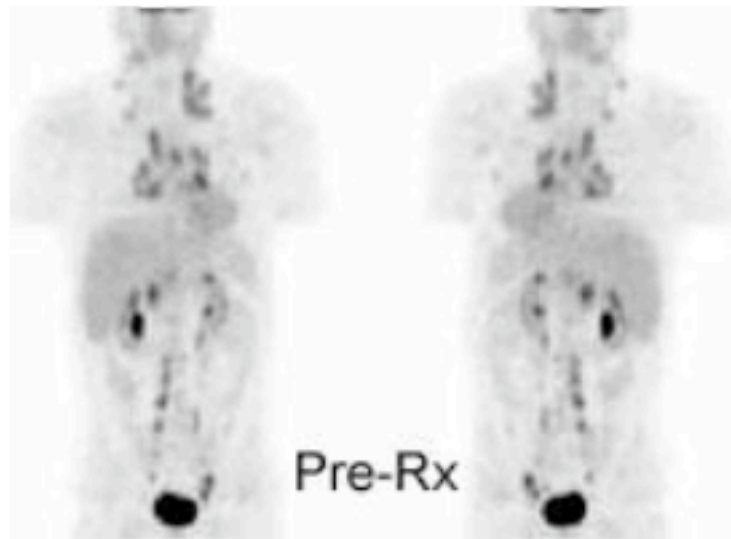


Post therapy

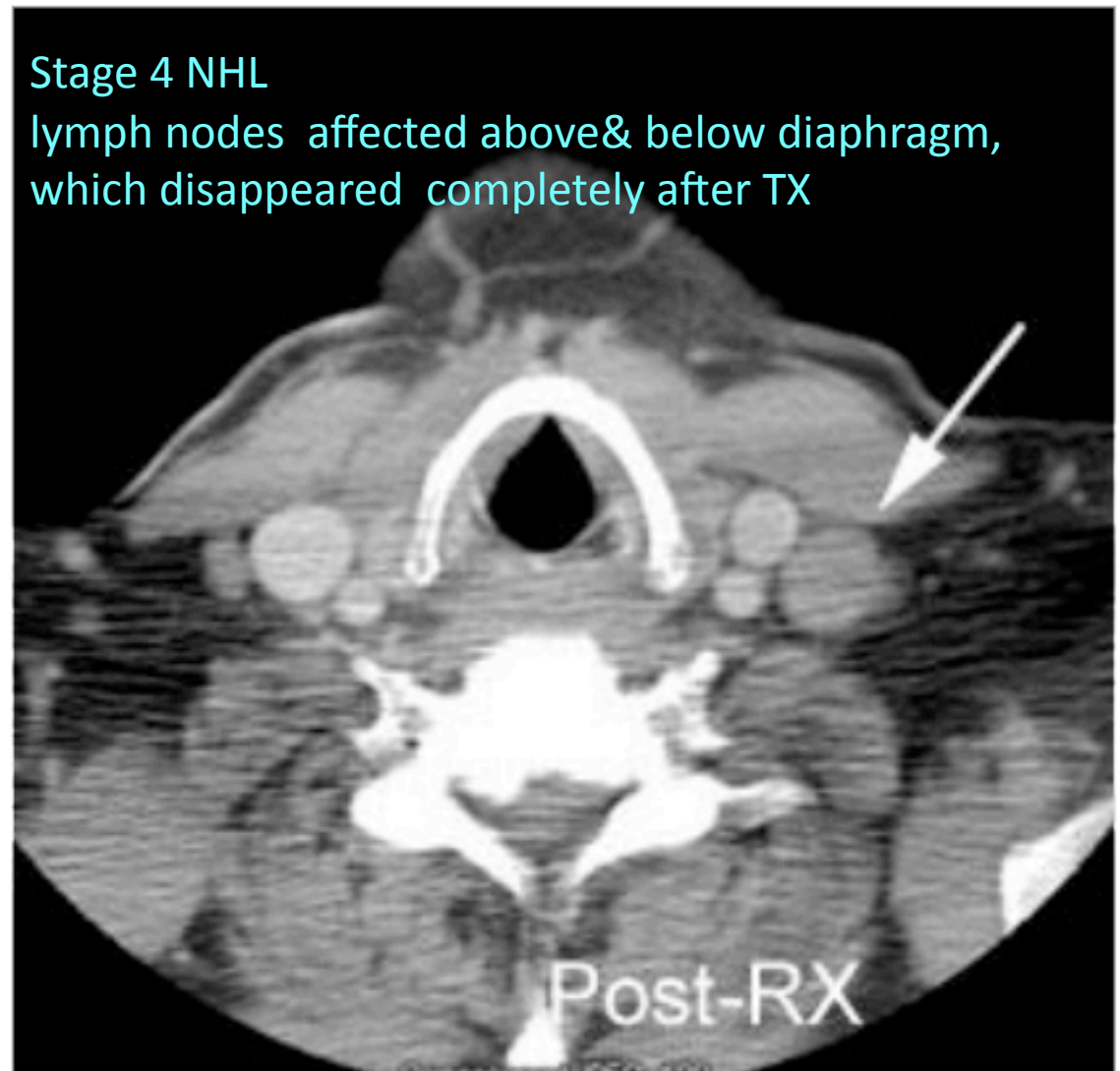
- A 22 years old male patient with Hodgkin's lymphoma.
- Six months after chemotherapy, CT scan showed bilateral hilar abnormalities.
- FDG-PET scan did not show any activity in described CT changes (clearance of mediastinal lymph nodes after therapy).

FDG in Non-Hodgkin's lymphoma

Response to therapy



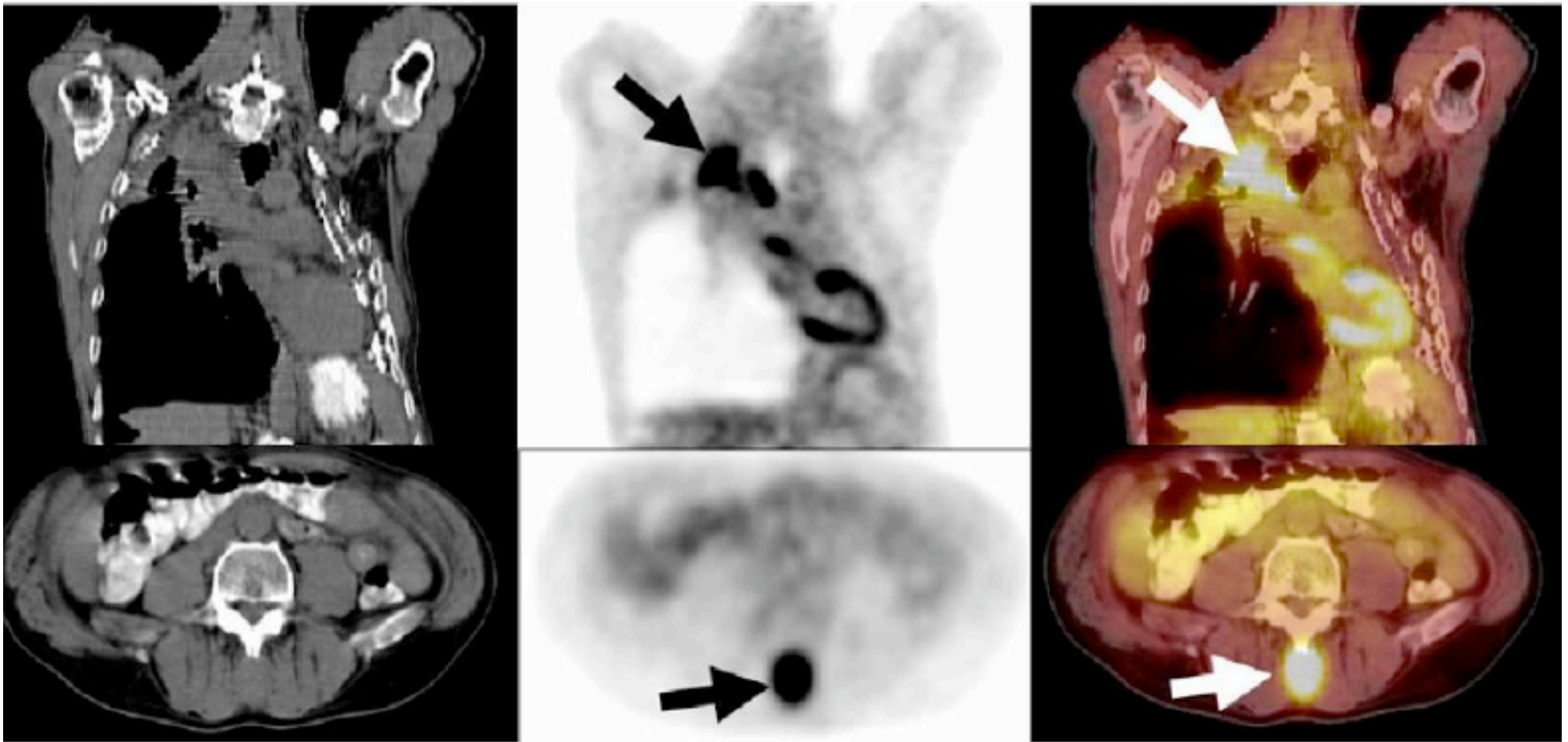
Stage 4 NHL
lymph nodes affected above & below diaphragm,
which disappeared completely after TX



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



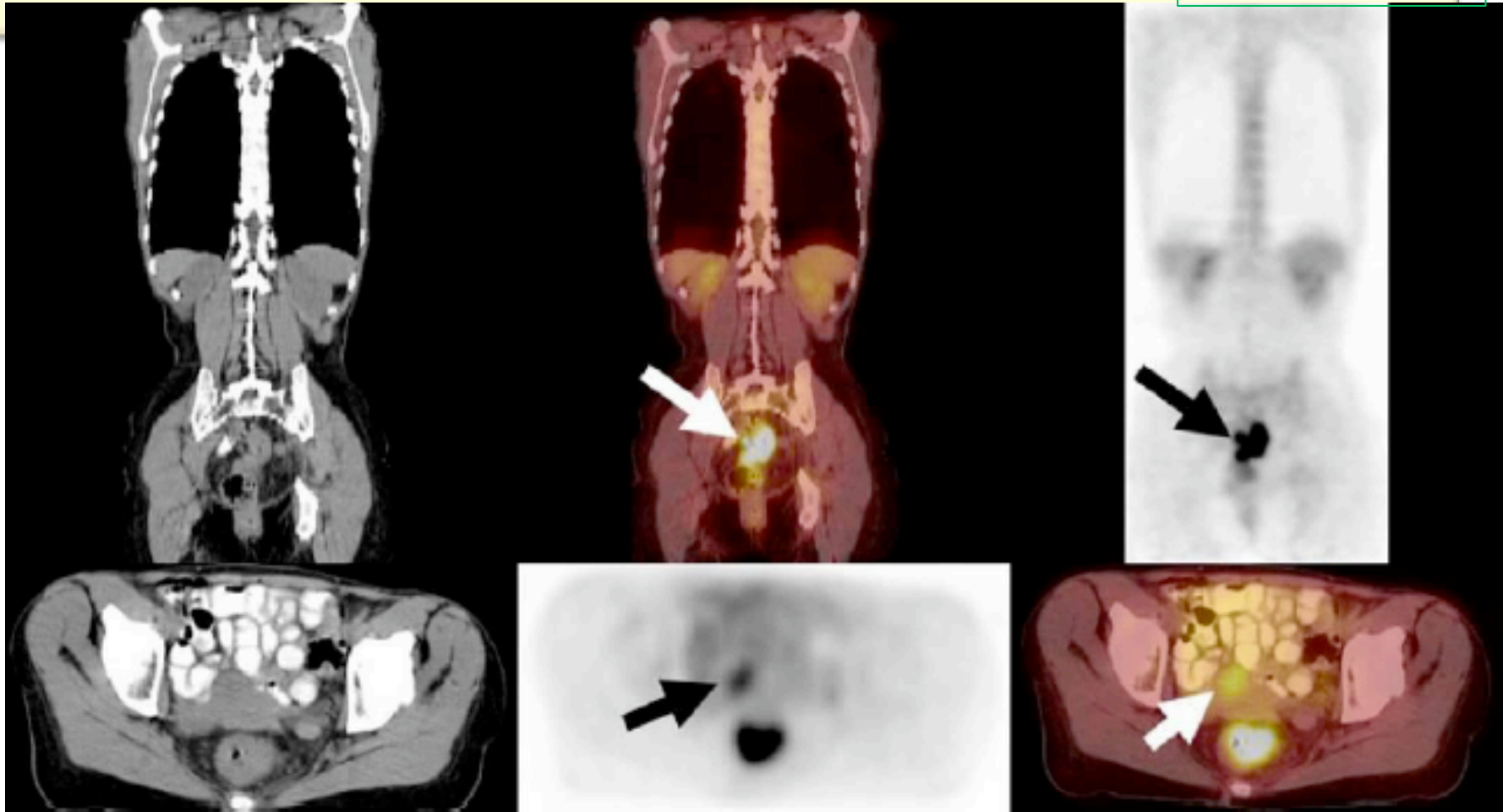
FDG avid soft tissue mass associated with a destructive L5 spinous process consistent with metastatic deposit (arrow).

FDG PET CT IN Solitary Pulmonary Nodule (SPN)

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

Pet CT CA Rectum

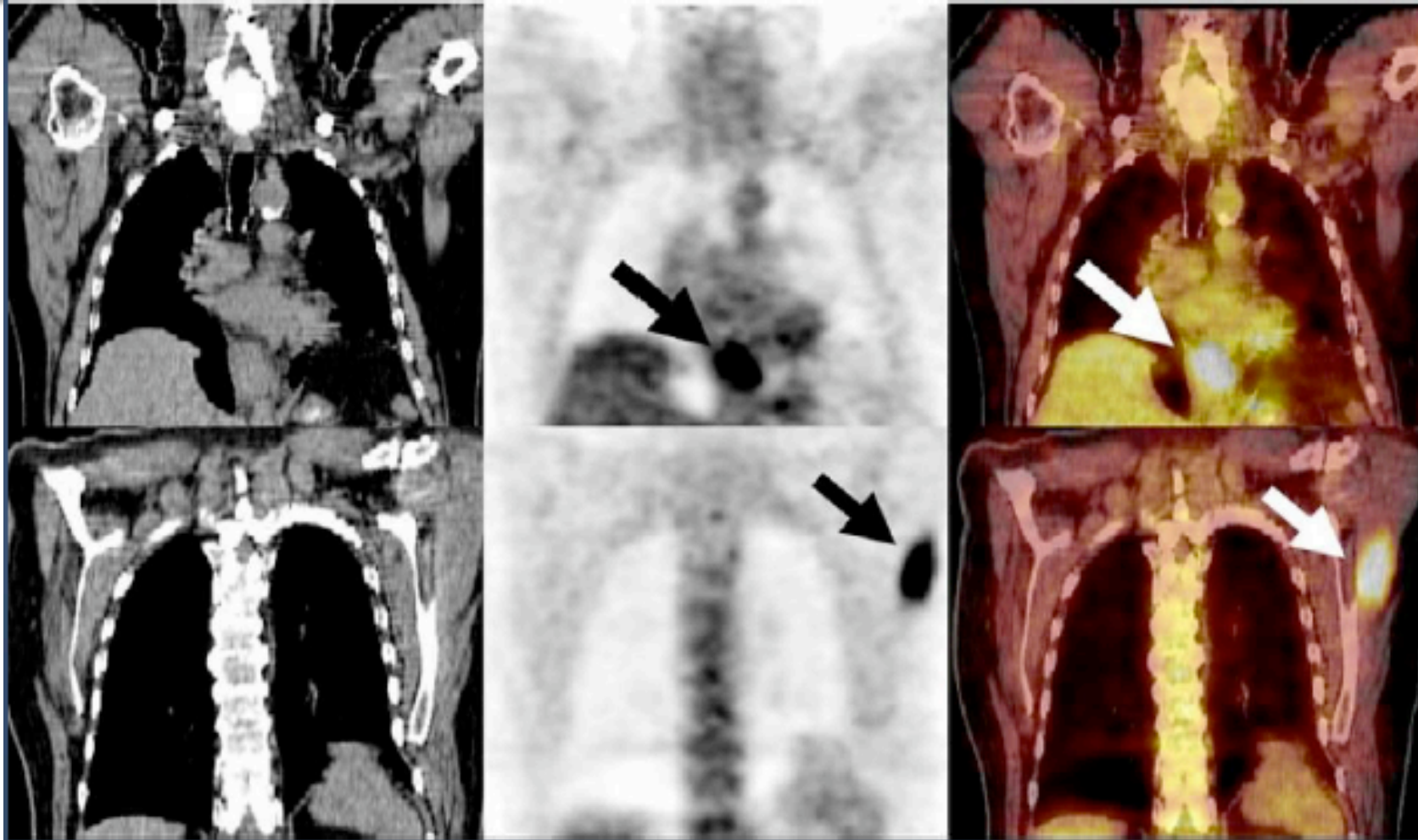
-Staging and
monitoring Tx
-No metastasis



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.

CA Esophagus

No metastasis



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.

Indications of PET CT

Cancer	Indications
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, 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

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.

Radionuclide Therapy

Agent	Indication	Dose
1. I131	Thyroid cancer	100-200 mCi
2. 131 MIBG	Neuroblastoma	100-300 mCi
3. Strontium-89	Bone metastasis	40-60uCi/kg
4. Sm-153-EDTMP	Bone mts.	1.0 mCi per kg
5. Phosphorus- 32	Polycythaemia Rubra Vera	2.3mCi/m ²
6. Y-90-Ibritumomab Tiuxetan [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).

Teaching Points

Objectives of NM tumor imaging

- Diagnosis
- Staging
- Guiding biopsy
- Follow up and therapy monitoring
- Detection of recurrence.
- Functional
- Sensitive
- Whole body evaluation
- Specific: Some tumors
- Targeted therapy

Reference book and the relevant page numbers..

- **Nuclear Medicine: The Requisites, Third Edition (Requisites in Radiology) [Hardcover]**

Harvey A. Ziessman MD, Janis P. O'Malley MD, James H. Thrall MD

Relevant Pages :

**Oncology : 264-274 , 279 -283 ,302 -345 ,
119-133 , 109 -112 ,296 -299**

