

# Nuclear Oncology



**Saleh Othman , MD**

A. Prof.& Consultant Nuclear Medicine  
King Khalid University Hospital & School Of Medicine  
King Saud University

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# 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 are the nuclear medicine tumor imaging methods?



- **Conventional tumor imaging :**
  - Planar
  - SPECT
  - SPECT-CT
  
- **Onco PET :**
  - PET
  - PET -CT

# Conventional tumor imaging



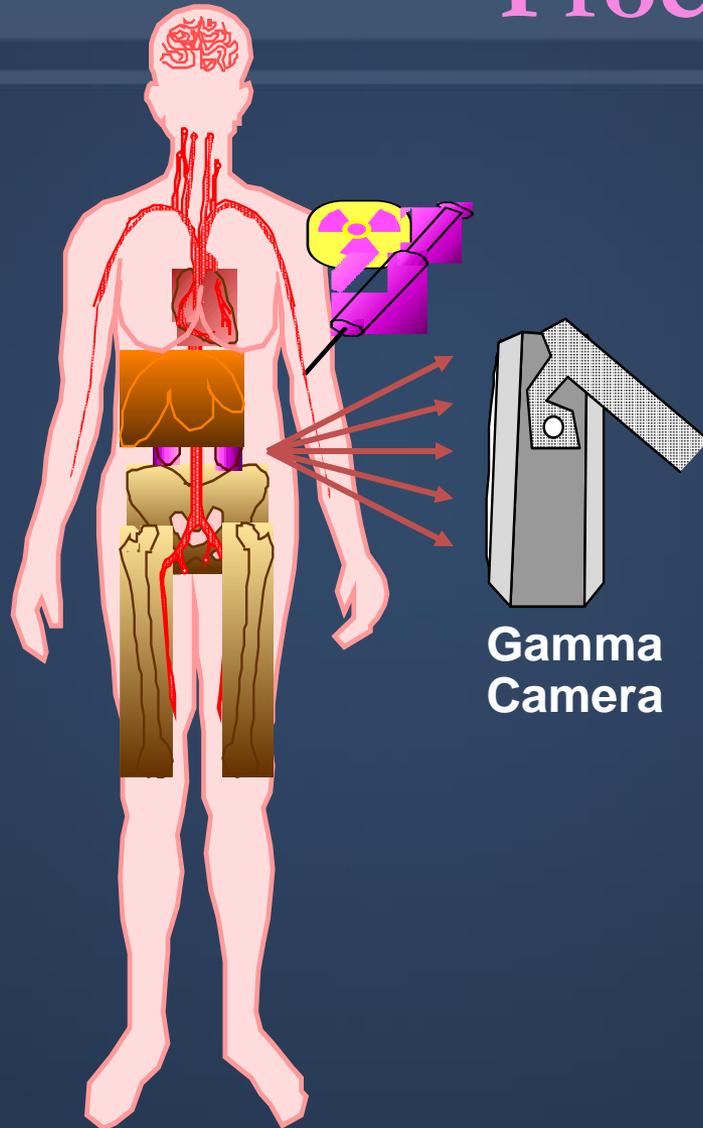
## Non Specific

- Gallium 67 citrate (Ga-67 )
- Tc-99m Methylendiphosphonate (Tc-99m MDP)
- Thallium Chloride 201 (Tl-201)
- Tc-99m SESTAMIBI

## Specific

- Iodine 131 (I131)
- Iodine 123 MIBG(I123 MIBG)
- Radiolabelled monoclonal antibodies (MoAB)
- Receptor imaging : Somatostatin receptors

# Nuclear Medicine Procedure



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

# NM Imaging Systems



**SPECT**



**PET CT**

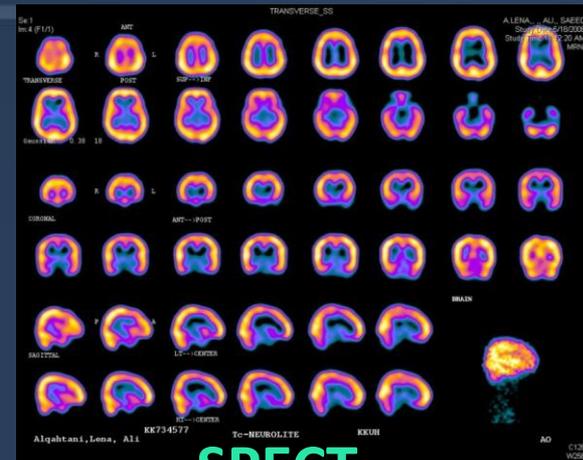


**SPECT CT**

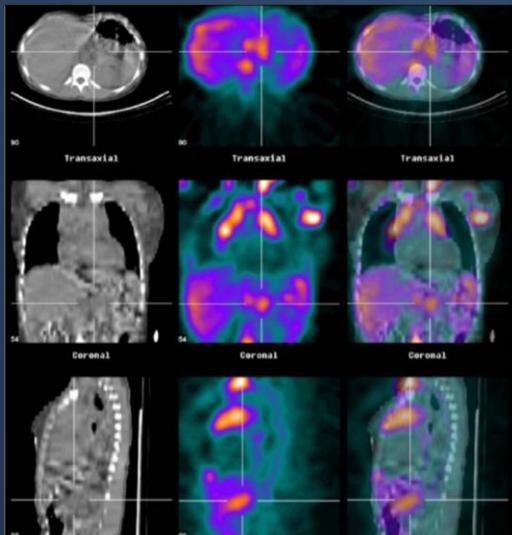
# NM Imaging modalities

Single Photon Emission Computed Tomography (SPECT) and SPECT CT

Positron Emission Tomography (PET) and PET CT



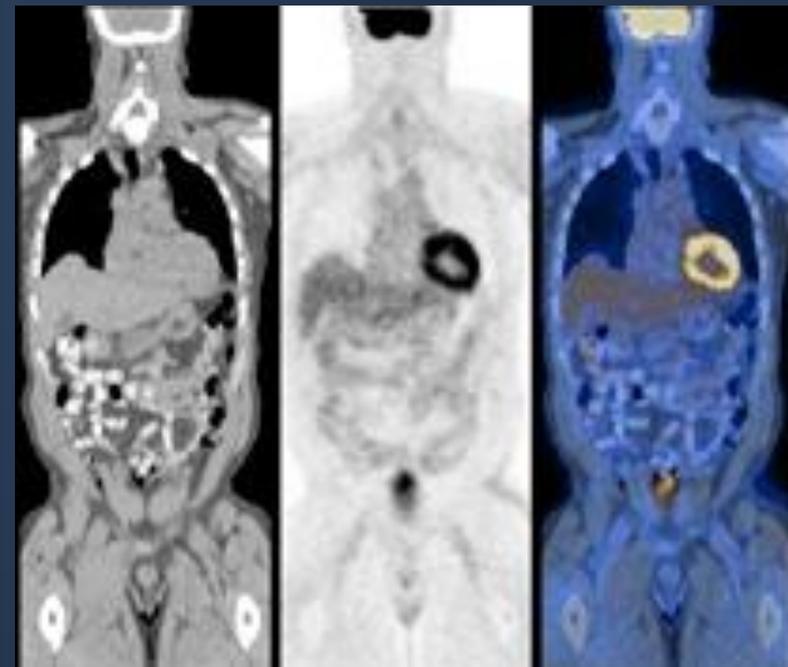
SPECT



SPECT/CT



PET



PET/CT

# Tumor Imaging



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

# 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.



# Normal Whole Body Bone Scan



An 8 year old child

A 25 yrs old adult

# Bone Scan In Oncology



- **Metastatic Disease.**
- **Primary Bone Tumors :**
  - Malignant**
  - Benign**
- **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.

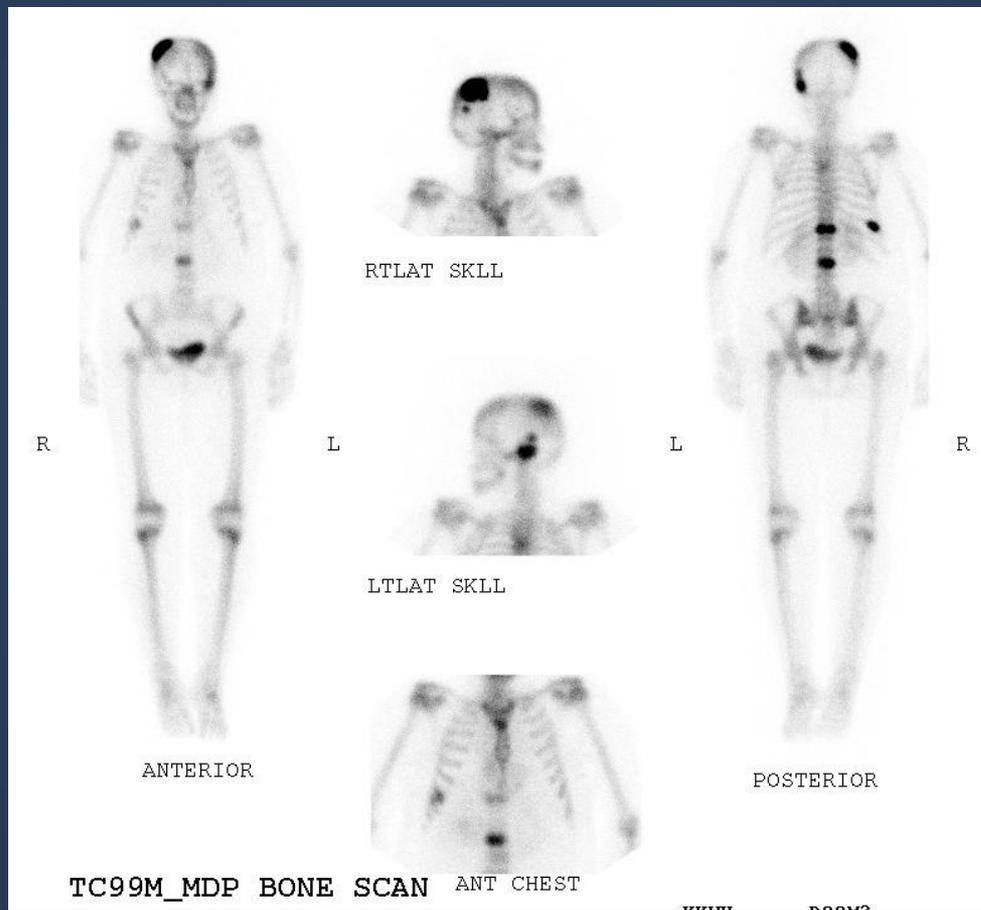
# Bone Scan In Oncology

## Indications

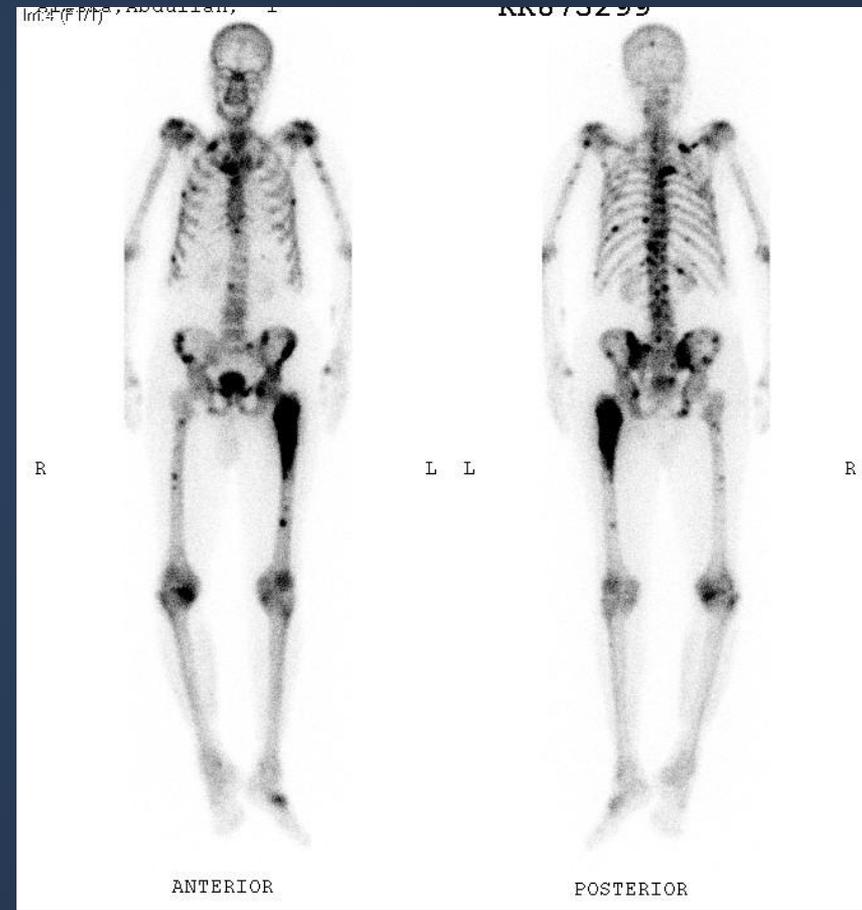


- **Diagnosis.**
- **Initial staging.**
- **Restaging.**
- **Asses response to therapy.**
- **Therapy planning for patients with primary bone malignancy ( e.g. Osteogenic & Ewings sarcoma)**

# TUMOR STAGING

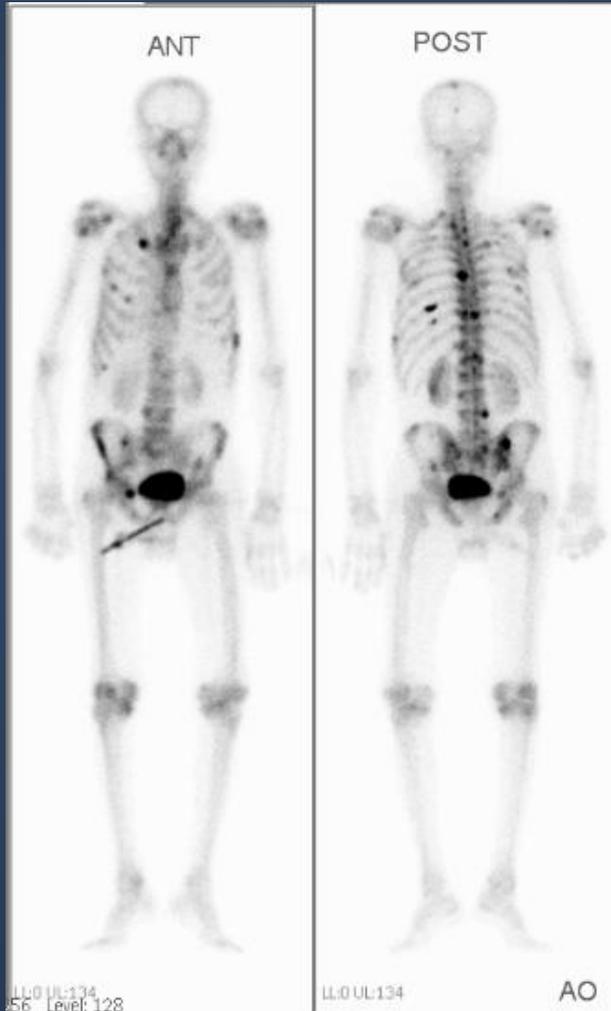


Ca Breast

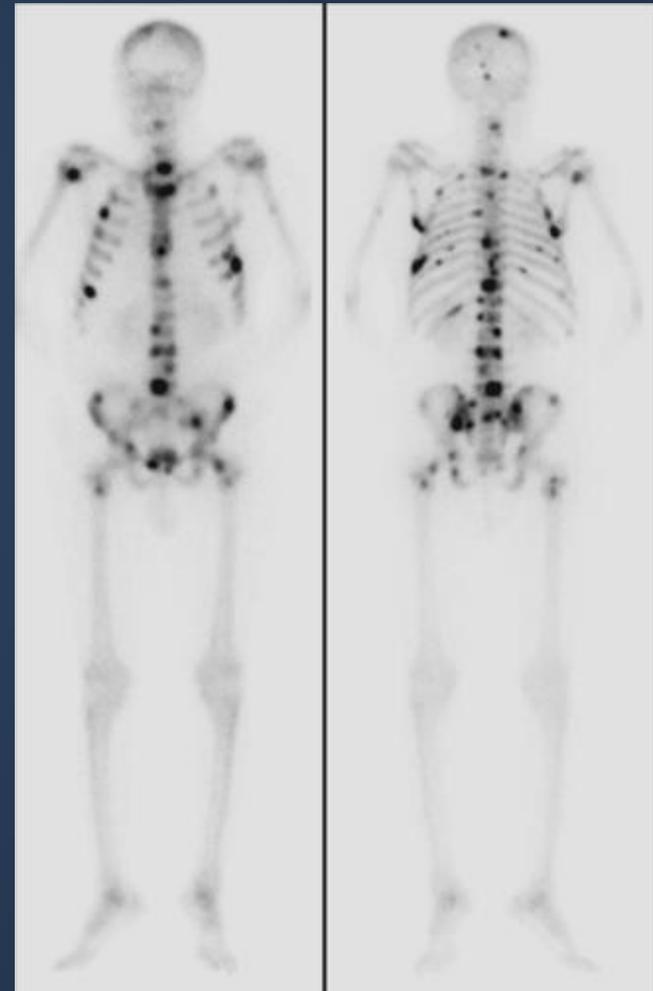


CA Prostate

# TUMOR STAGING



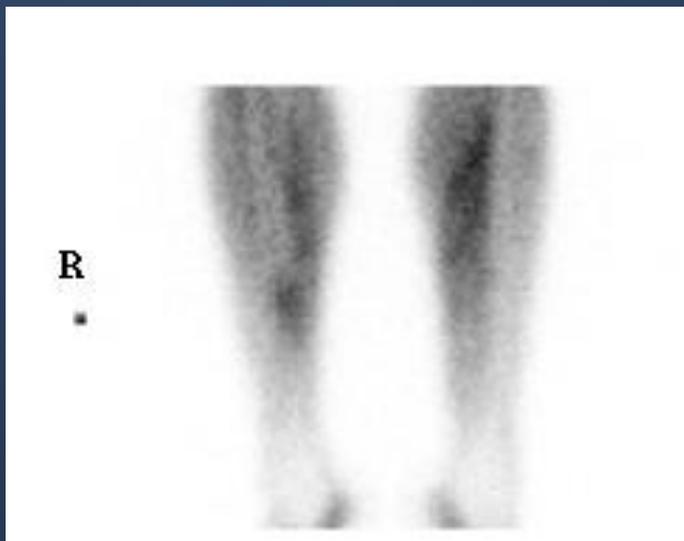
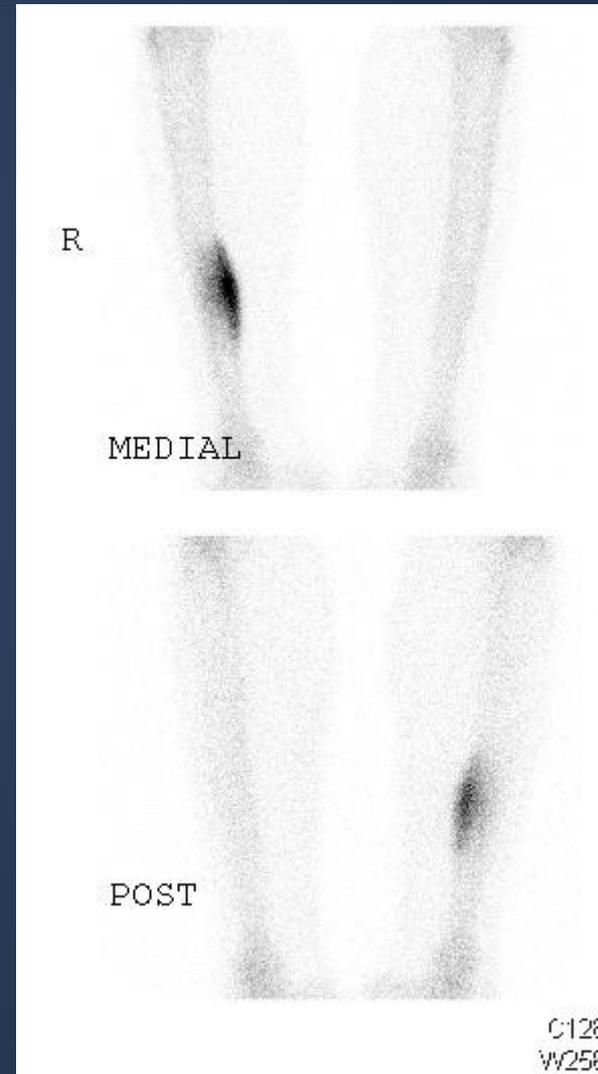
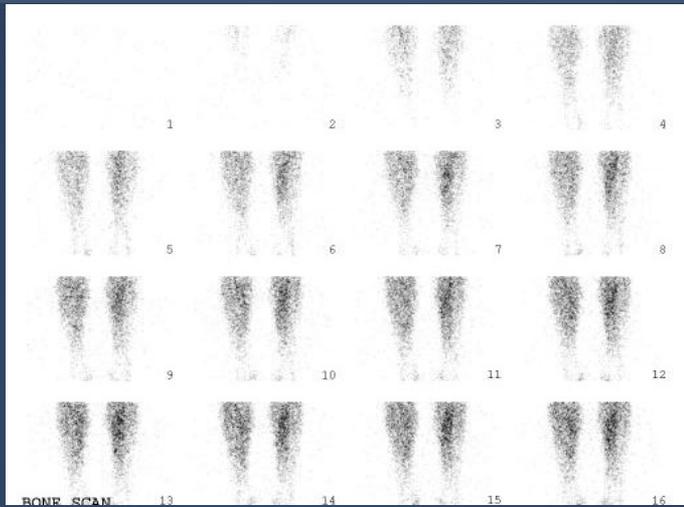
CA LUNG



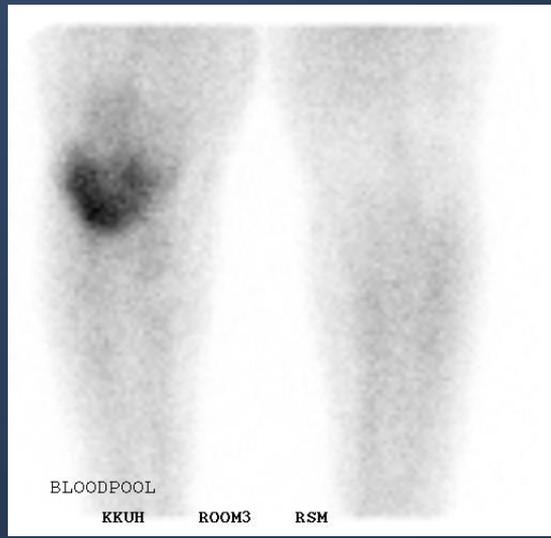
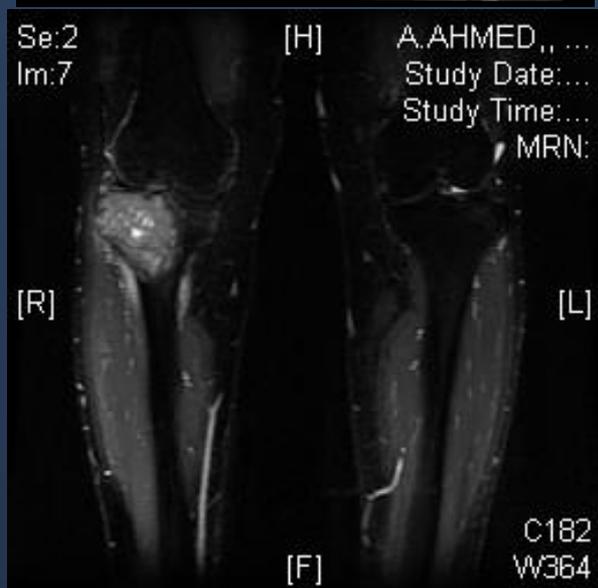
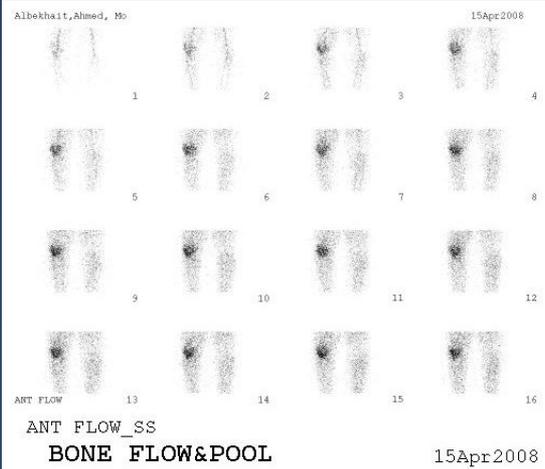
CA STOMACH

# Bone Scan In Bone Tumors

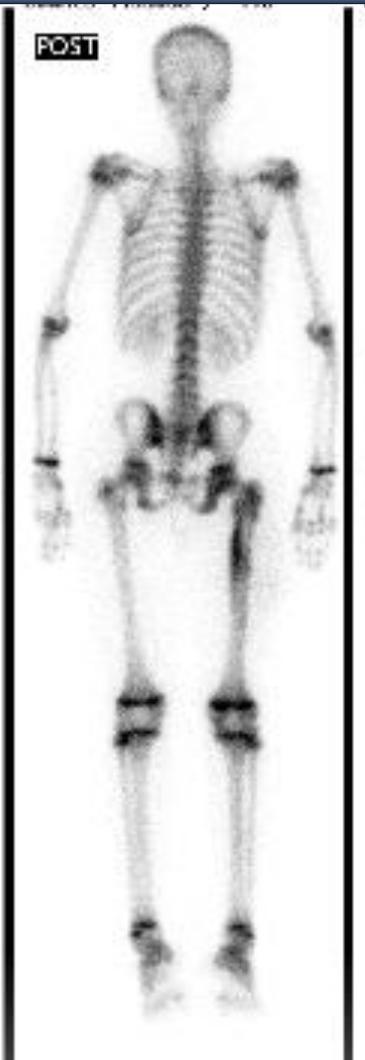
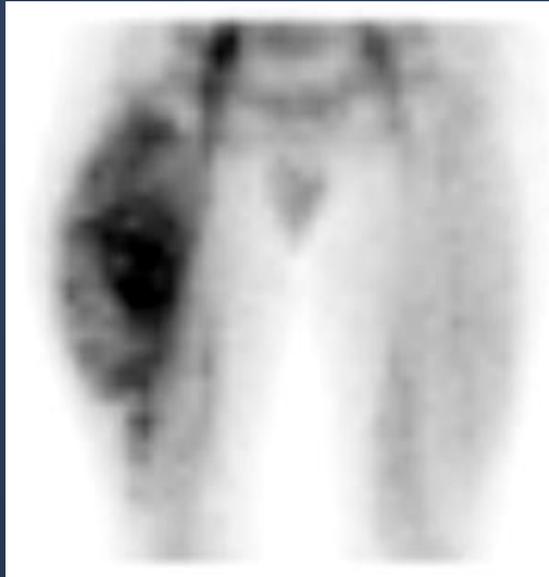
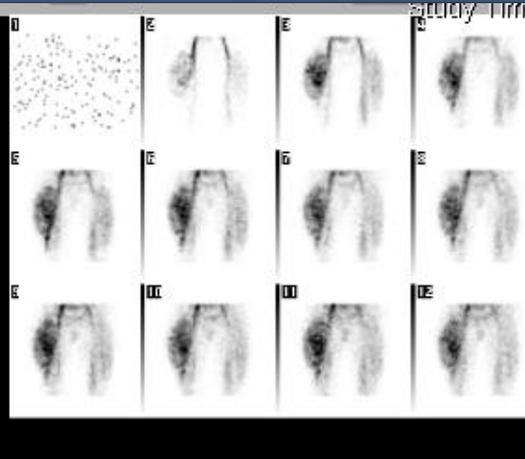
## Osteoid Osteoma



# Giant Cell Tumor



# Soft Tissue Sarcoma



# Gallium 67 Citrate (Ga-67)



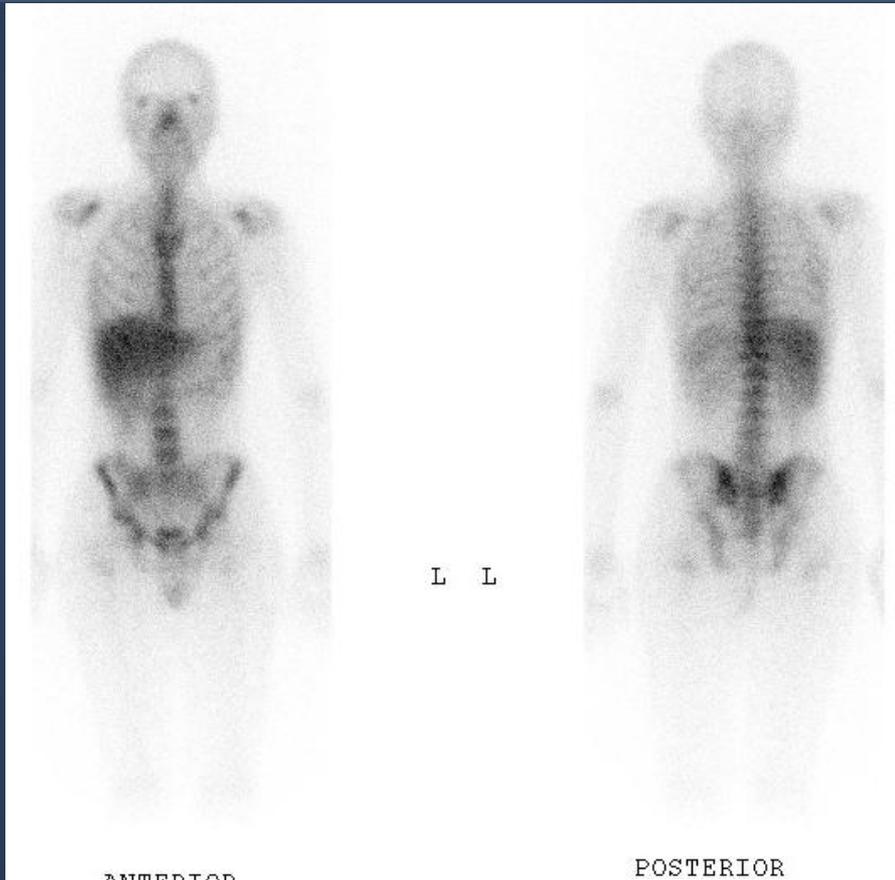
- Non specific for infection-inflamation and tumors
- Mechanism : Binds to transferrin
- Excretion: Kidneys and large bowel
- Dose :5-10 mCi
- Imaging : 24-72 hours postinjection
- Tumors : Lymphoma, bronchogenic carcinoma , malignant melanoma , hepatoma

# Gallium 67 Citrate (Ga-67) In Lymphoma



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

# Gallium Scan in Lymphomas



**Normal Gallium Scan**



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

# Ga-67 Scan In Lymphoma

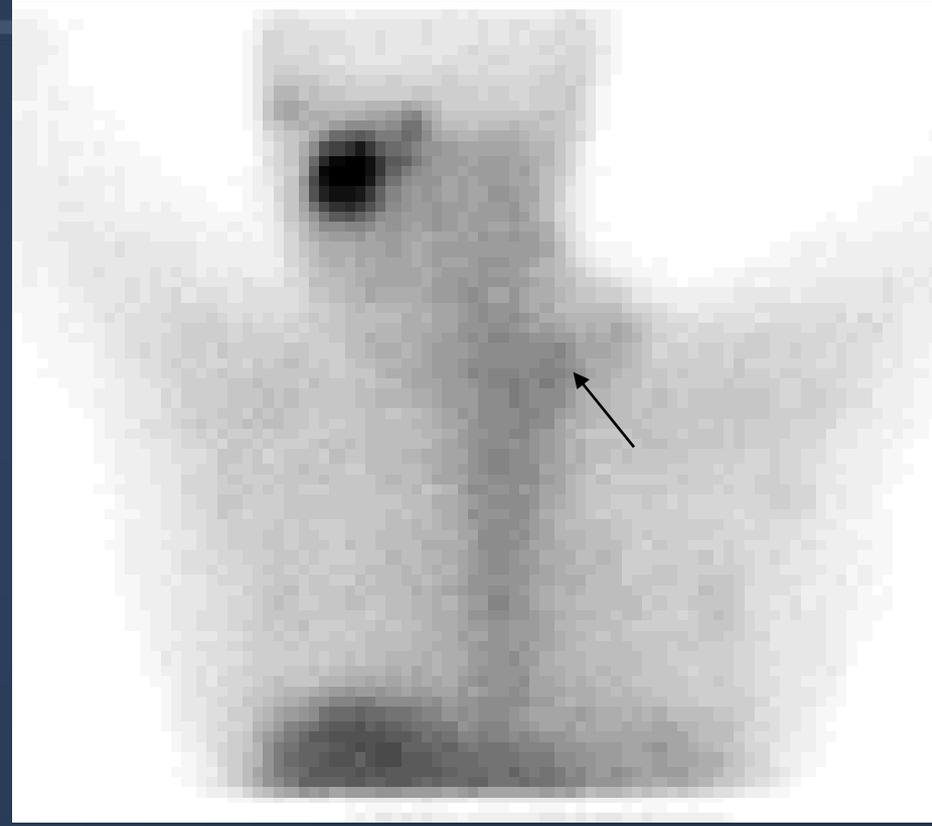
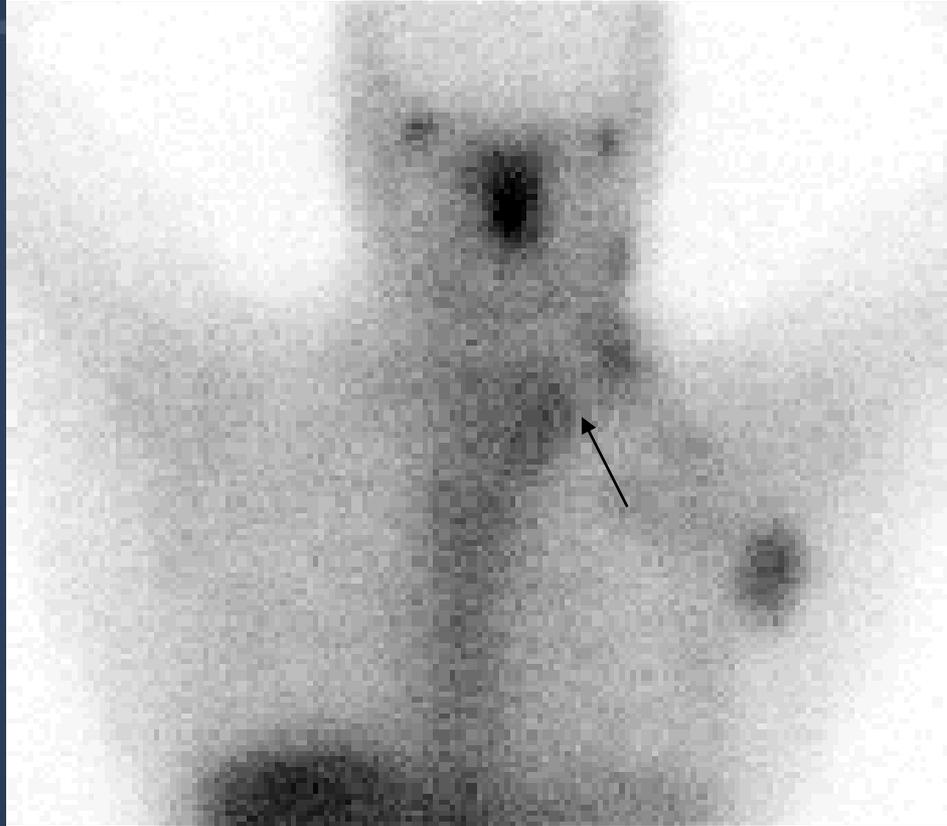
## Prediction of response to therapy



**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 .

# Ga-67 Scan In Lymphoma

## Prediction of outcome



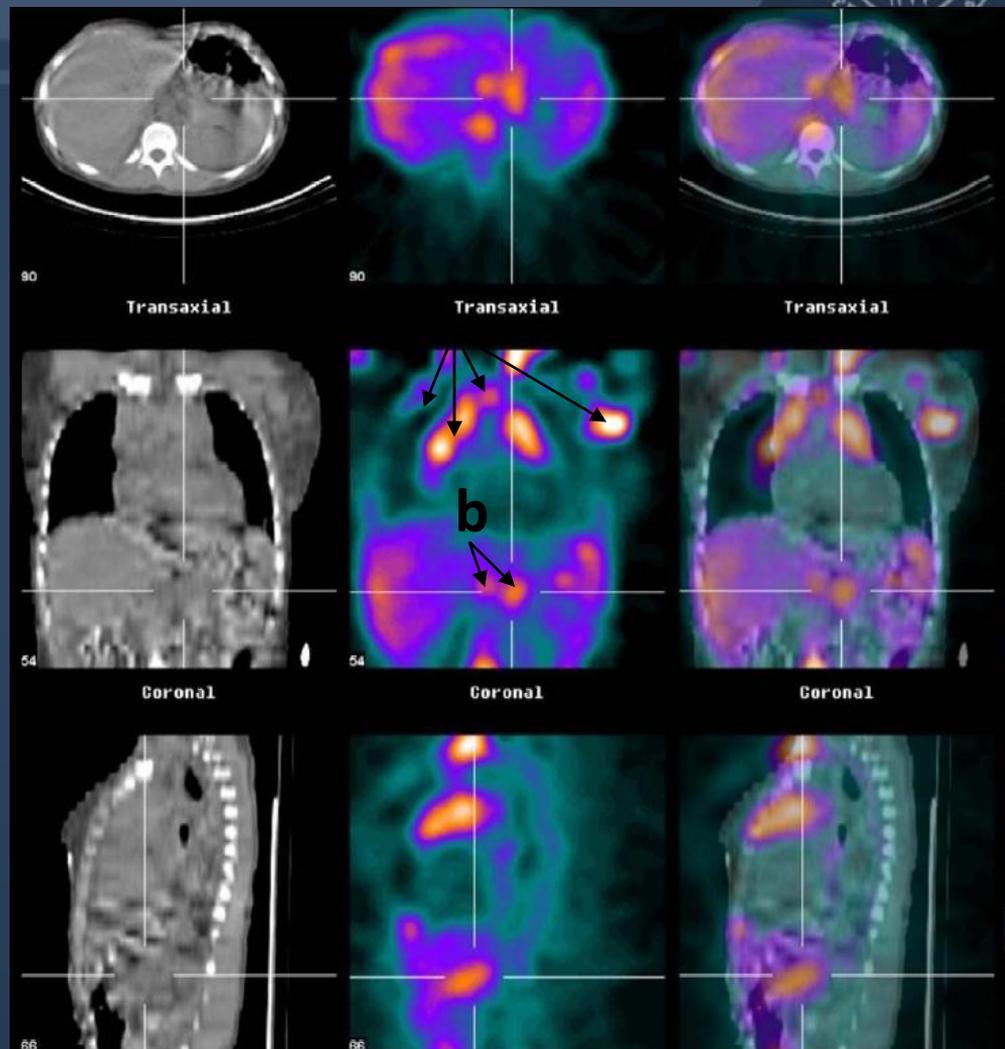
**Residual gallium uptake after treatment is a poor prognostic sign, indicates viable tumor and treatment should be modified.**

# 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.



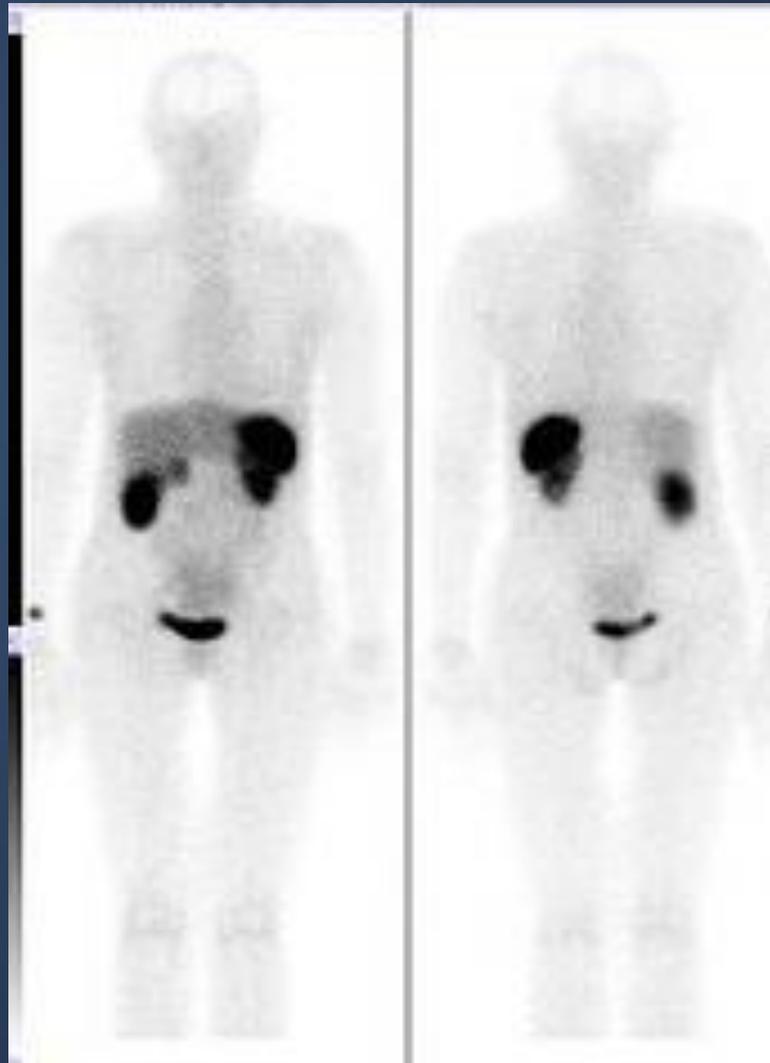
# Neuroendocrine Tumors



- In-111 octreoscan.
- I123 MIBG Scan.

# Somatostatin Receptor Imaging Indium-111 Octreoscan

**NORMAL STUDY**



# In - 111 octreoscan

## Insulinoma

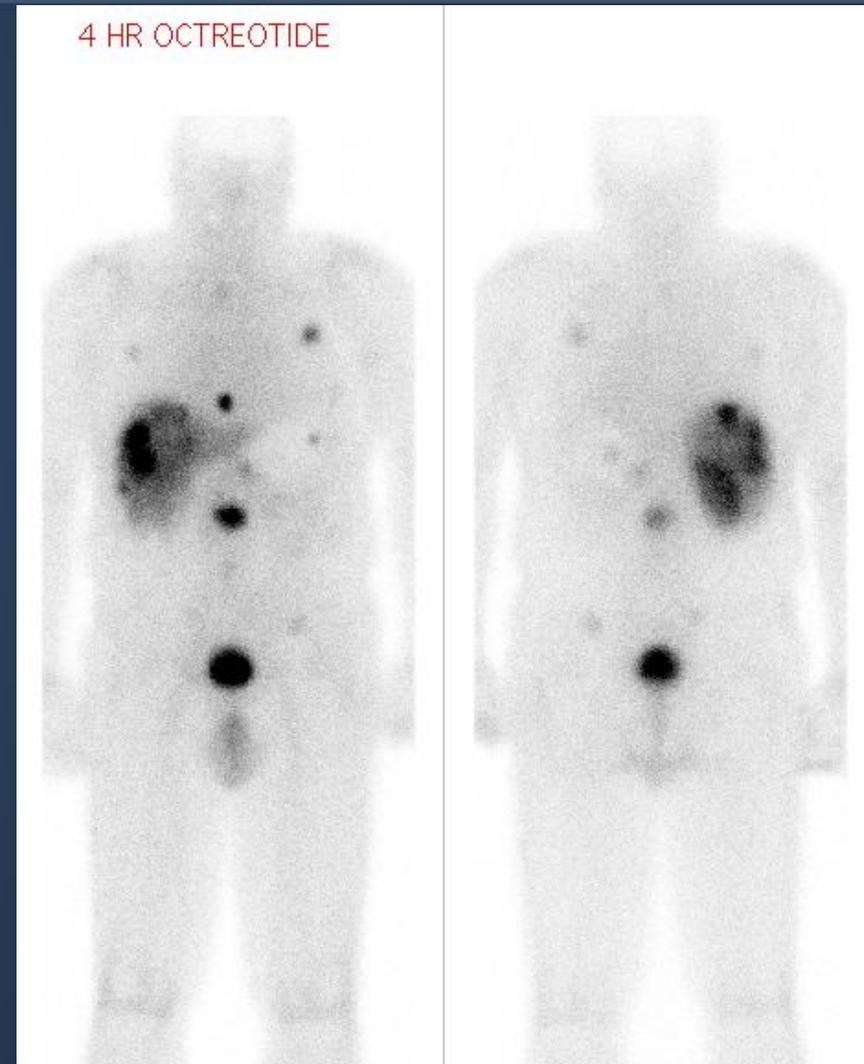


### Clinical History

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

### Findings :

Multiple lung, mediastinum , liver and abdominal metastases.





# I123 MIBG Scan

- MIBG : **M**eta **I**odo **B**enzyl **G**uanidine
- 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

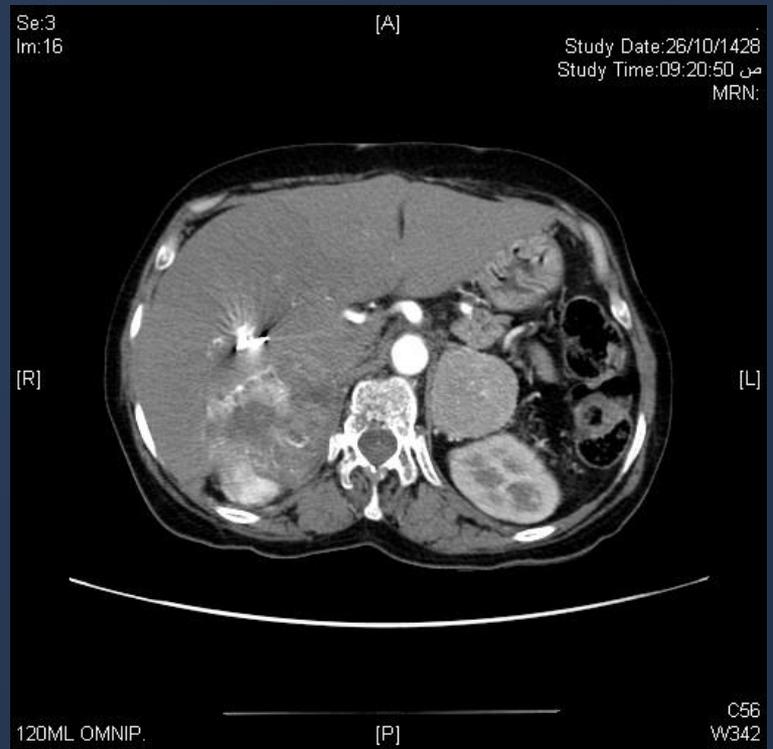
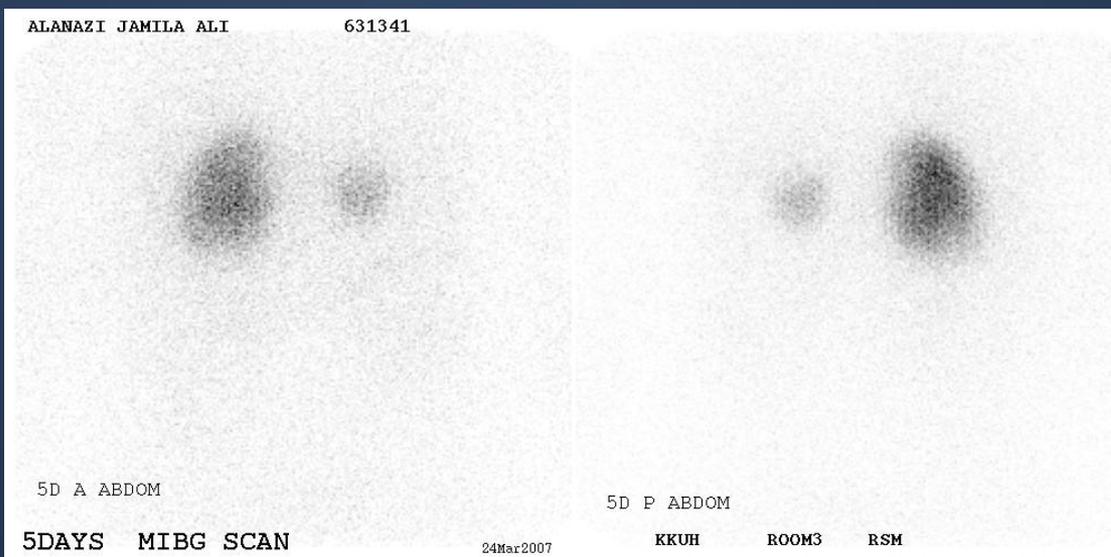
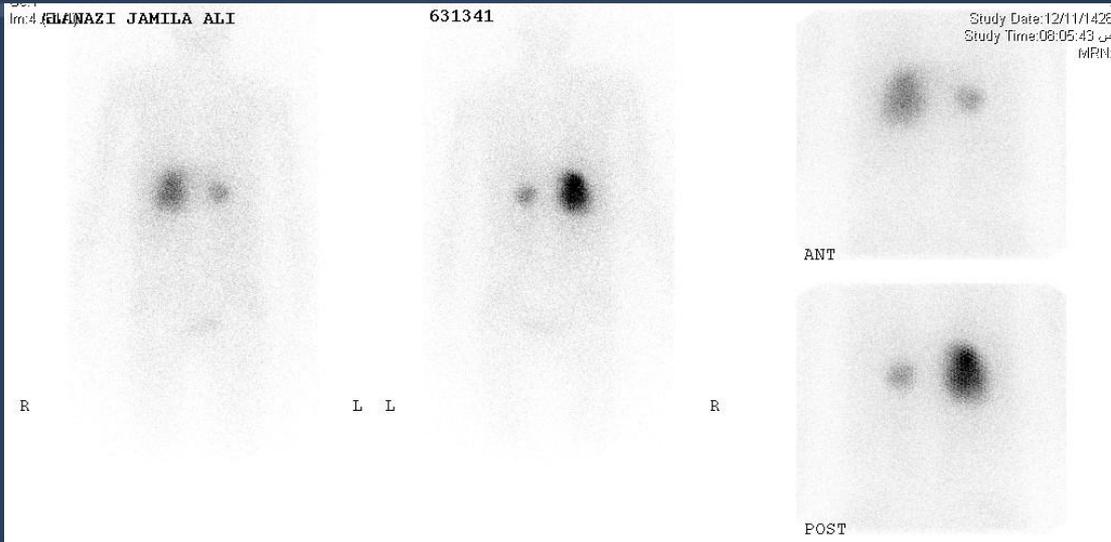
## Indications



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

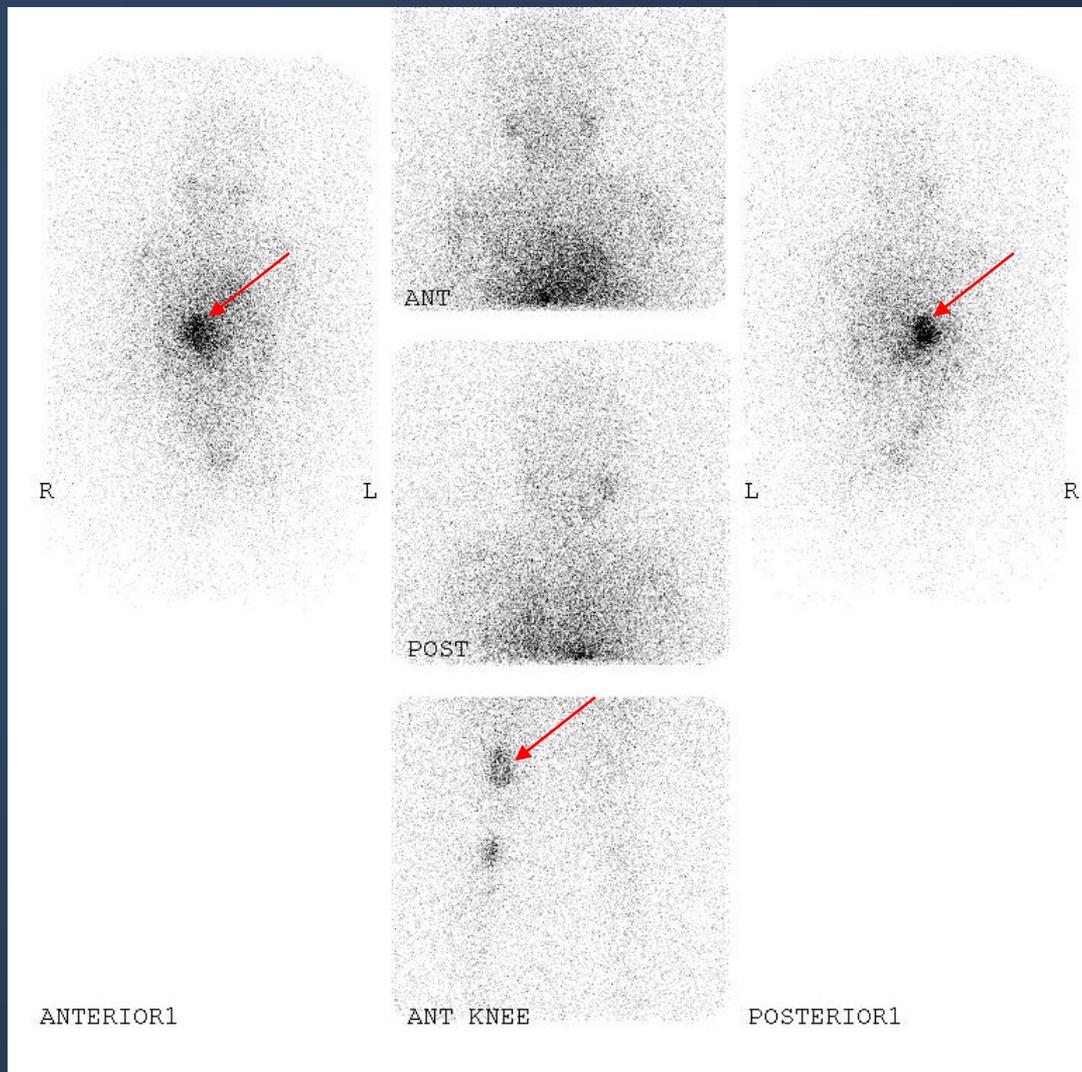
# MIBG In Pheochromocytoma

## Bilateral Disease



# I131 MIBG Total body scan

## 1ry neuroblastoma /bone mets



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



## Indications

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

## Patient Preparation

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

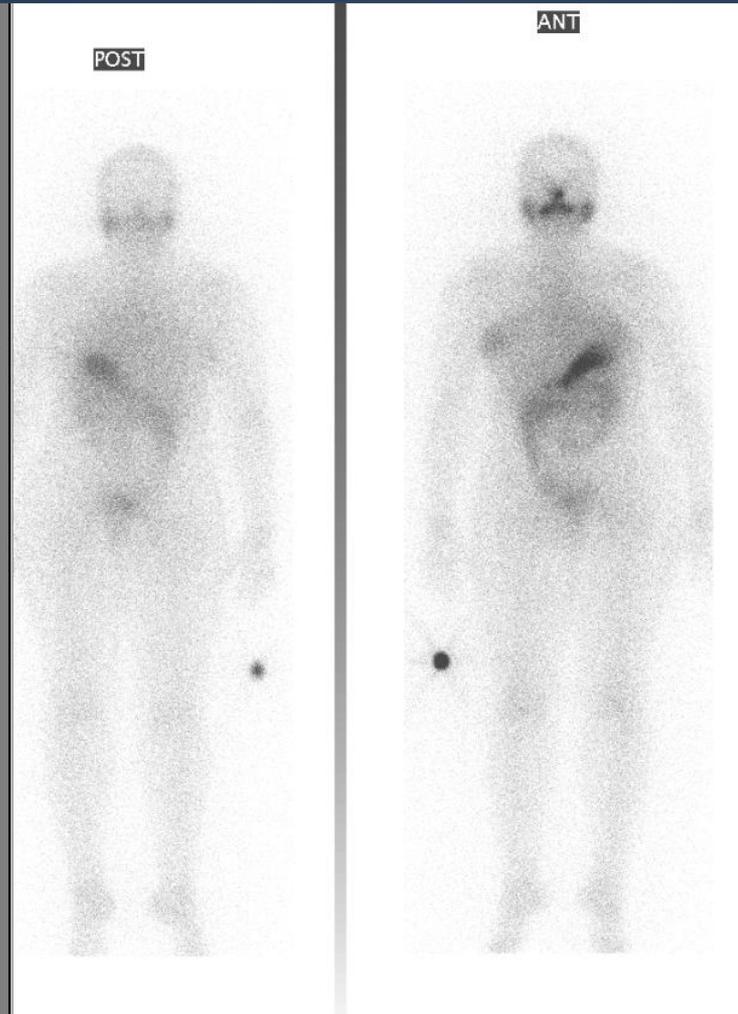
## Tracer , Dose, & Technique of Administration

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

**Imaging using Gamma camera :** Whole body scan

# Thyroid Cancer

## I-123 WB Scan



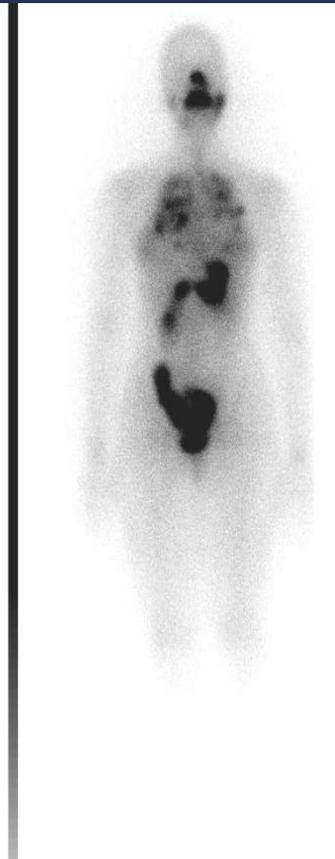
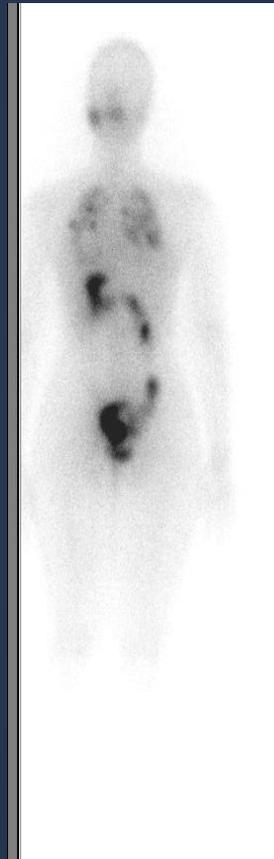
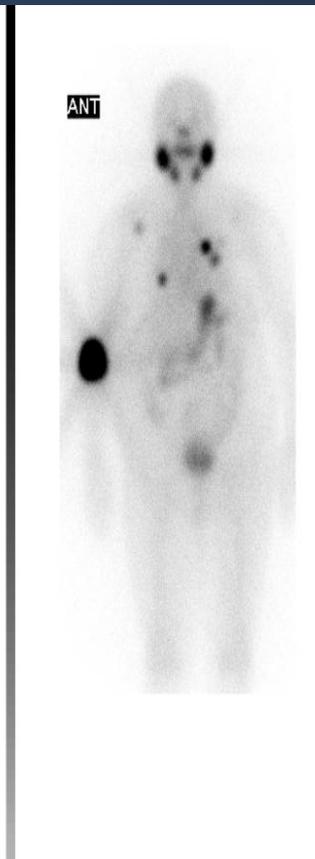
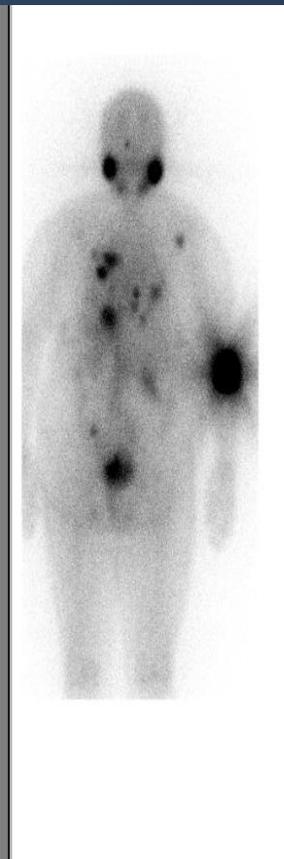
Negative I-123 WB Scan



I-123 WB Scan : Post operative Thyroid remnants

# THYROID METASTASES STUDY

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



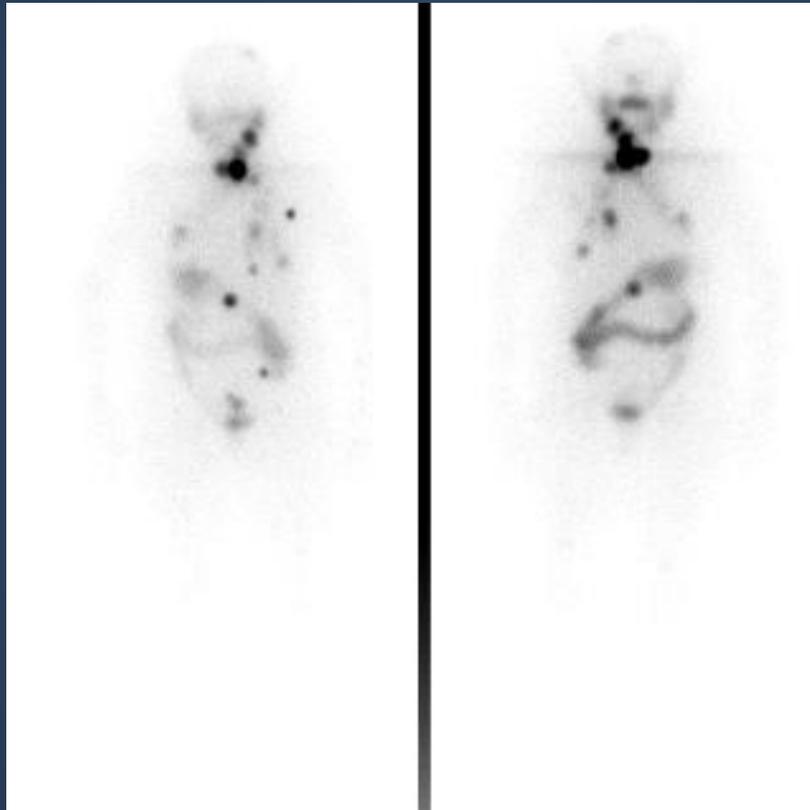
Local Recurrence

Bone Metastases

Lung Metastases

# Thyroid Cancer

## I-131 Pre & Post therapy



Dec04



March06

# 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 : 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.....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.

# PET CT

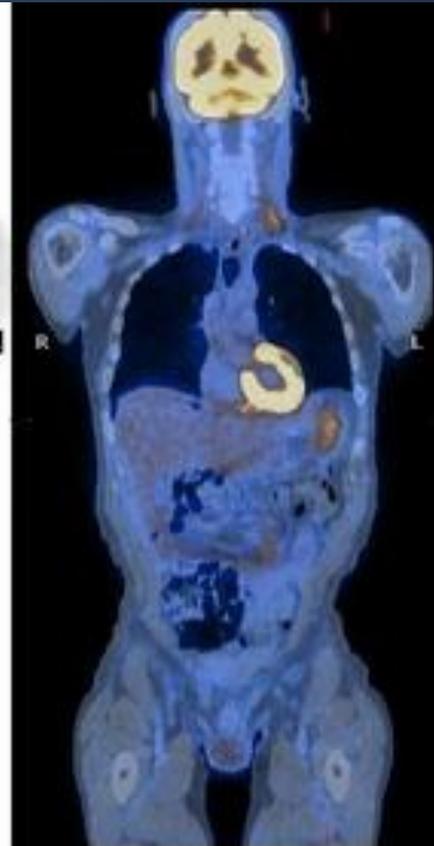
**PET CT = PET + CT = Function + Form**



**CT Transmission  
Scan**



**Attenuation  
Corrected  
PET Emission Scan**



**PET-CT  
Fusion Scan**



**Non-Attenuation  
Corrected (NAC)  
Emission Scan**

# Positron Emitting Isotopes



Cyclotron produced isotopes:

<u>Isotope</u>	<u>T/2</u>
Oxygen-15	2 min
Nitrogen-13	10 min
Carbon-11	20 min
<b>Fluorine-18</b>	<b>110 min</b>

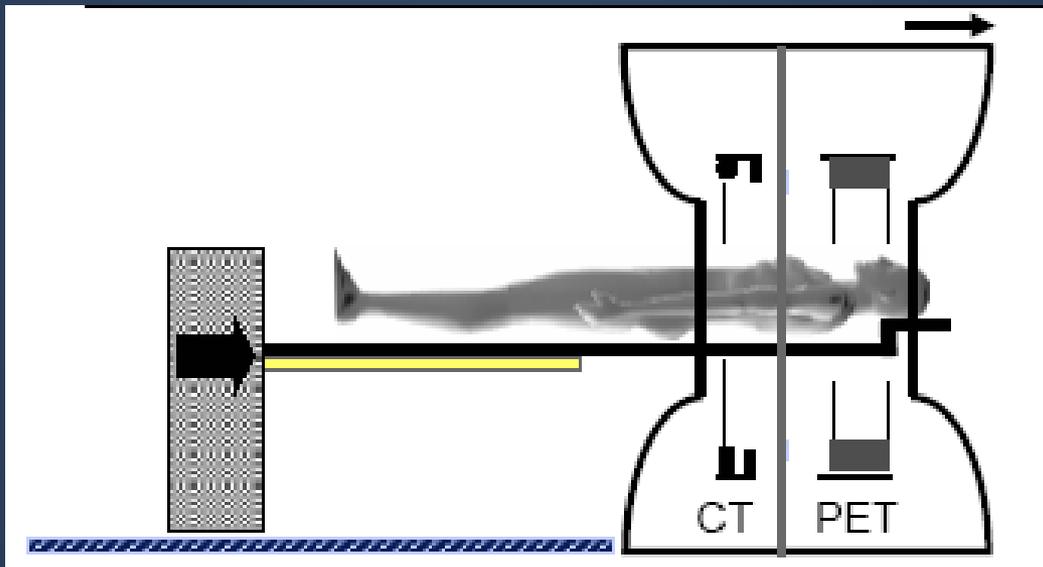
# FDG PET CT : Procedure



- 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



# 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

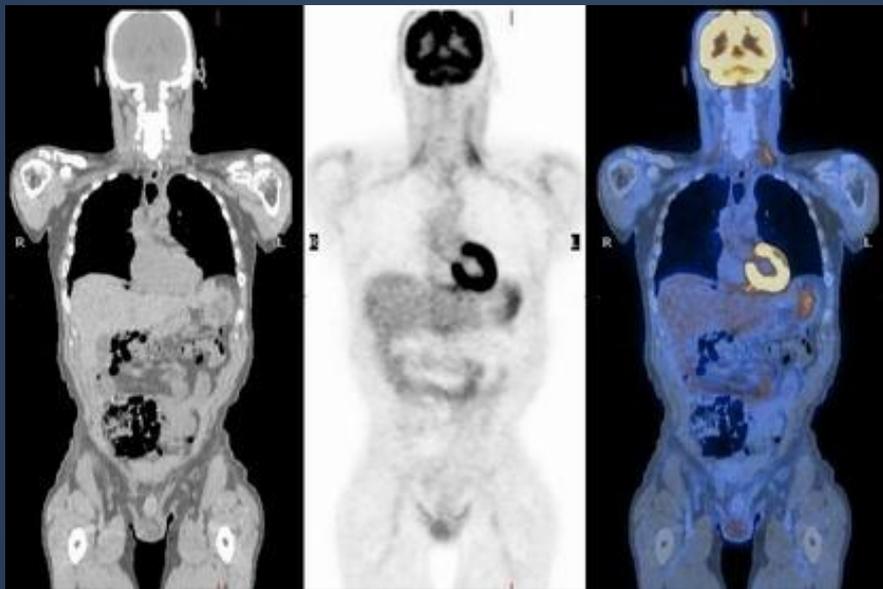


**FDG PET : Normal**



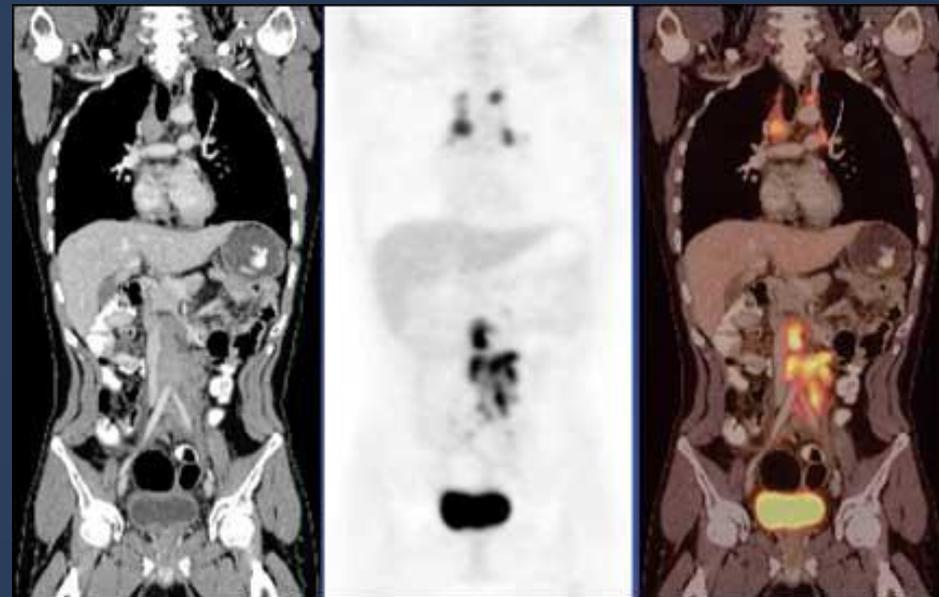
**FDG PET : Staging of NHL**

# FDG PET-CT



**FDG PET-CT**

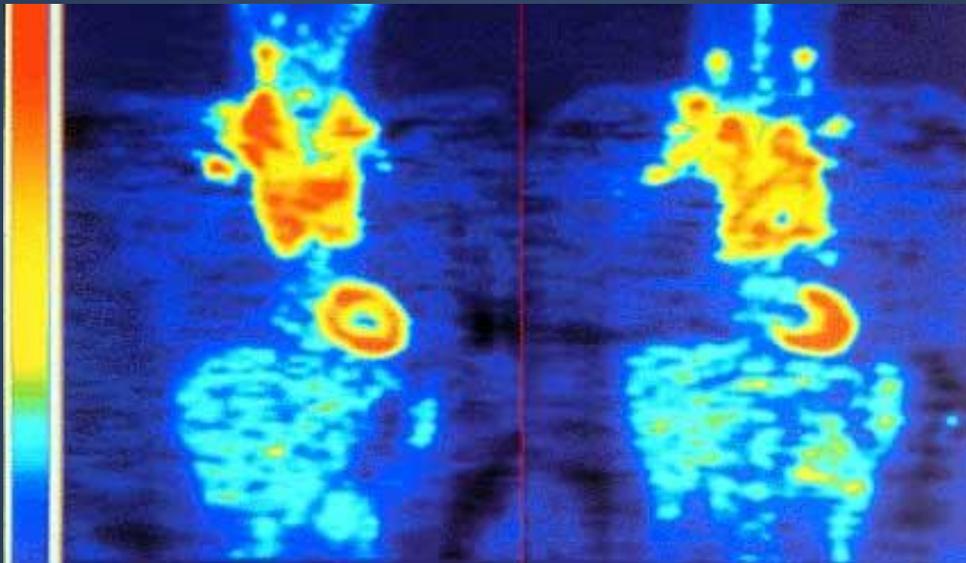
Normal



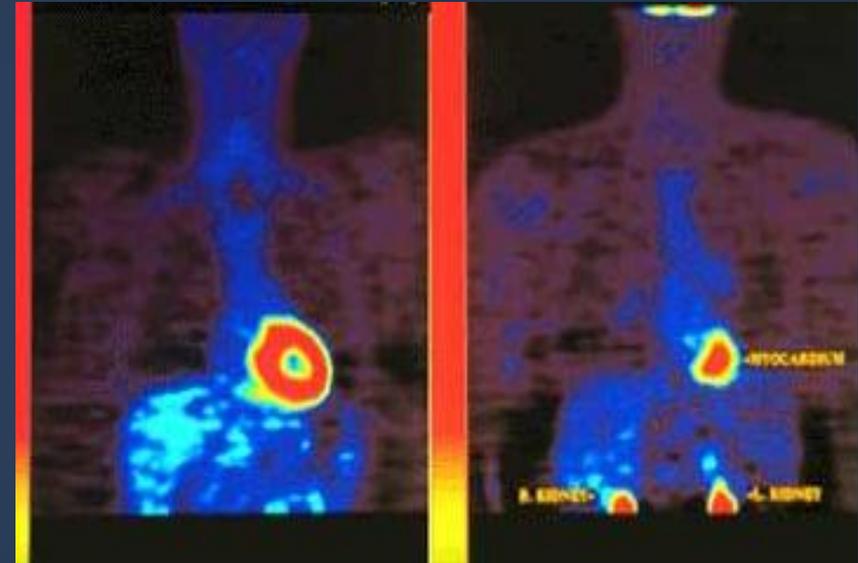
**FDG PET-CT**

Staging Of Lymphoma

# Assessment of therapy response FDG PET in HD



**Baseline**

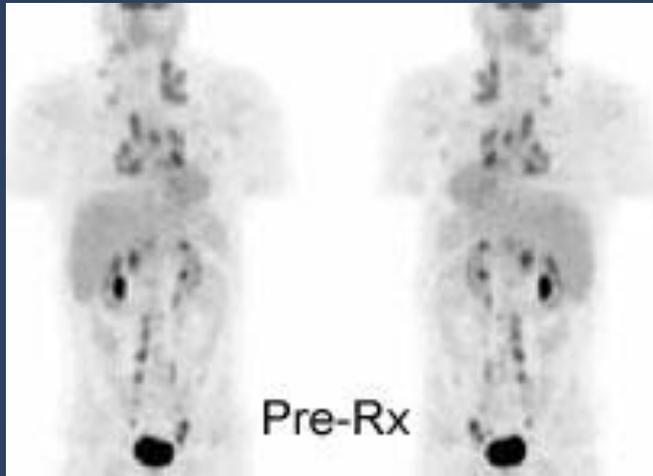


**Post therapy**

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.

# FDG in Non-Hodgkin's lymphoma

## Response to therapy

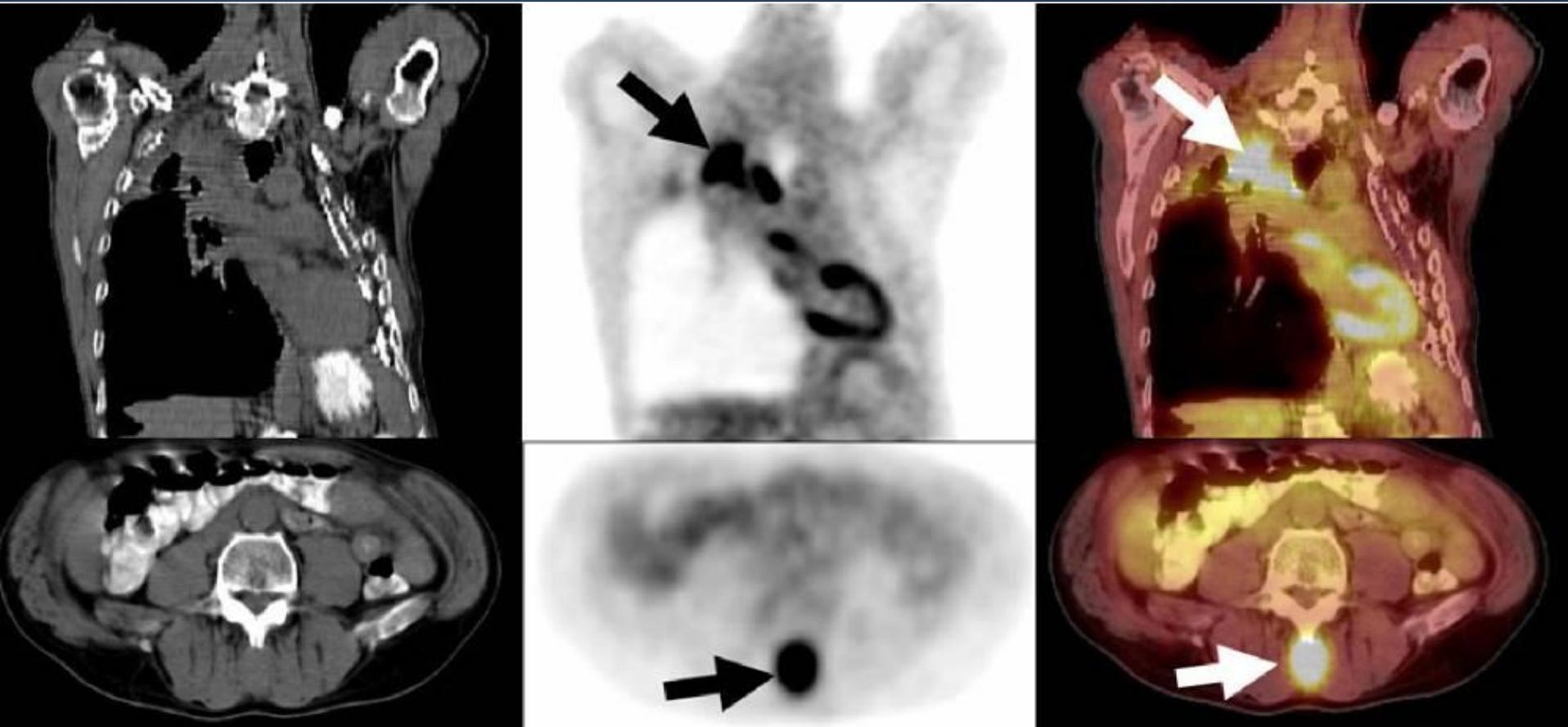


# PET CT In Lymphoma



	<b>Sensitivity</b>	<b>Specificity</b>
	<b>(%)</b>	<b>(%)</b>
<b>CT</b>	<b>61</b>	<b>89</b>
<b>FDG-PET</b>	<b>78</b>	<b>98</b>
<b>FDG-PET and CT</b>	<b>91</b>	<b>99</b>
<b>FDG-PET/CT</b>	<b>96</b>	<b>99</b>

# 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)



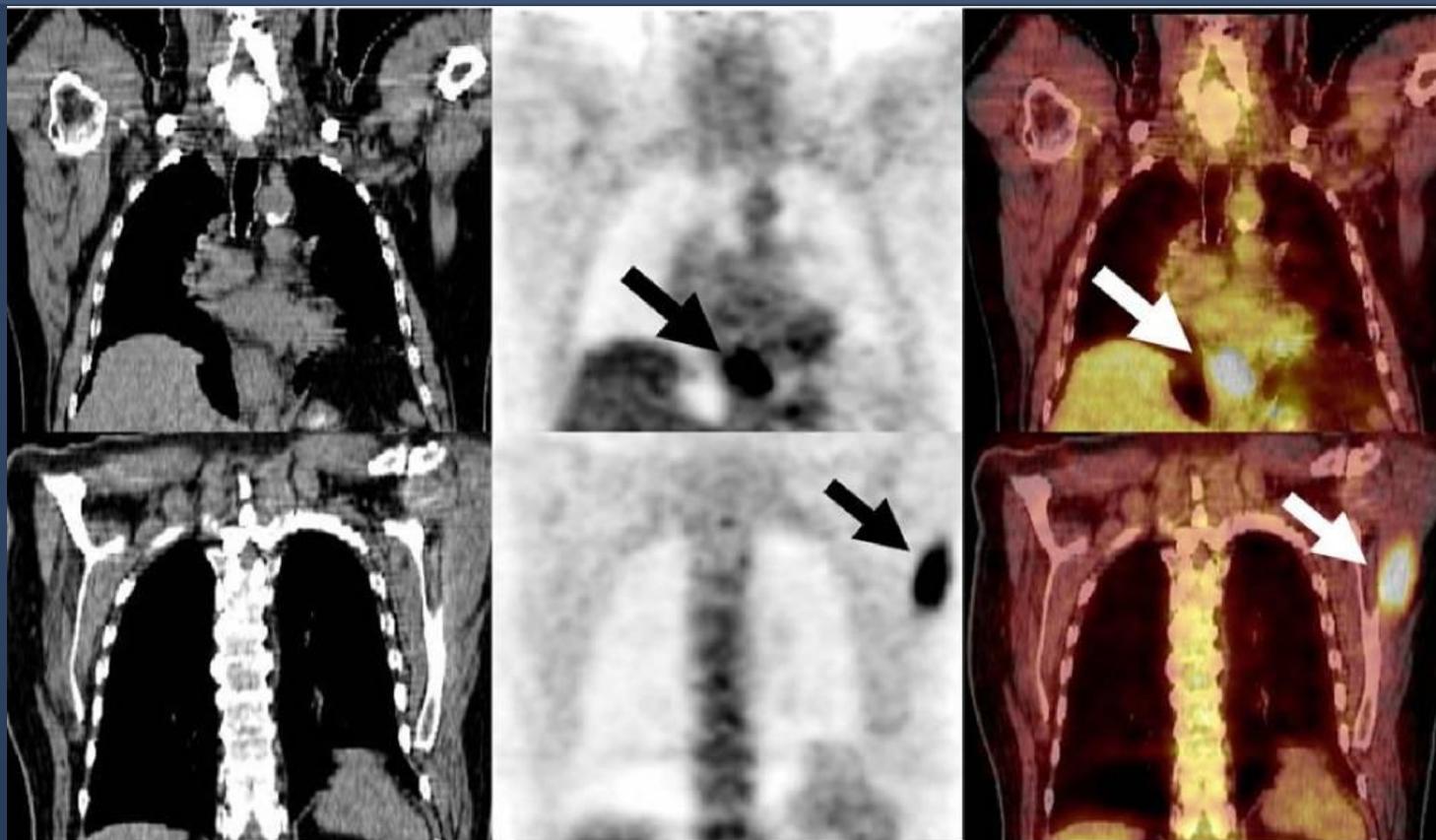
- Sensitivity : 82 – 100 %
- Specificity : 67 – 100 %

# CA Rectum



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



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



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

- |   |                   |   |
|---|-------------------|---|
| • <b>I131</b>                                     | • Thyroid cancer  | 100-200 mCi   |
| • <b>131 MIBG</b>                                 | • Neuroblastoma   | 100-300 mCi   |
| • <b>Strontium-89</b>                             | • Bone metastasis | 40-60uCi/kg<br>1.0 mCi per kg   |
| • <b>Sm-153-EDTMP</b>                             |                   |   |
| • <b>Phosphorus- 32</b>                           | • Polycythaemia   | 2.3mCi/m <sup>2</sup>   |
| • <b>Y-90-Ibritumomab<br/>Tiuxetan [Zevalin®]</b> | • B-Cell NHL      | Y-90-ibritumomab tiuxetan.<br>> Platelet count > 150,000 cells/mL: 0.4 mCi/kg<br>> Platelet count 100,000-150,000 cells/mL:<br>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.**

# Teaching Points

## NM tumor imaging



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

# Reference book and the relevant page numbers..

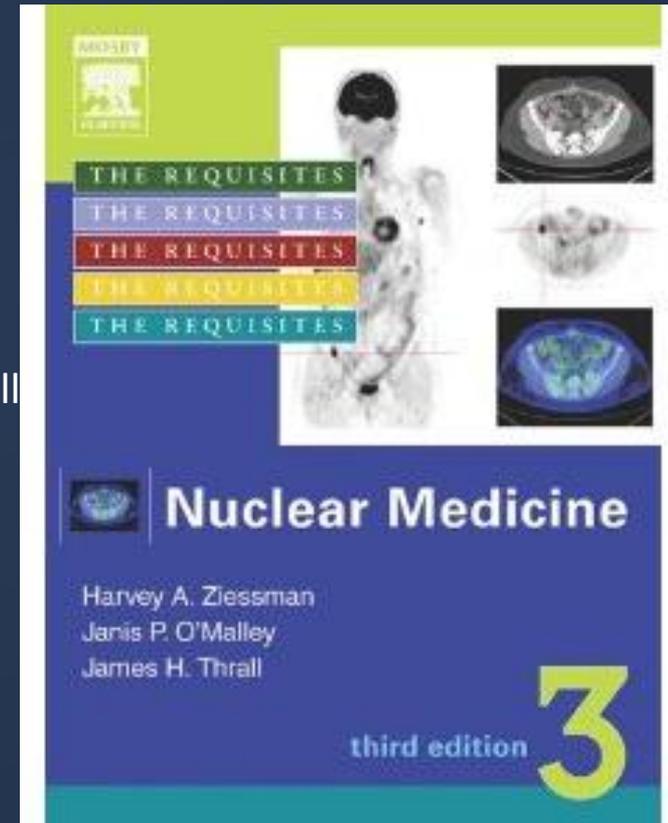


- **Aunt Minnie.com**
- **Nuclear Medicine: The Requisites, Third Edition (Requisites in Radiology) [Hardcover]**

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**



# Thank You 😊



Radiology (Nuclear Medicine)

Dr. Saleh Othman

11-13 February 2012