# Thyroid and Parathyroid Imaging

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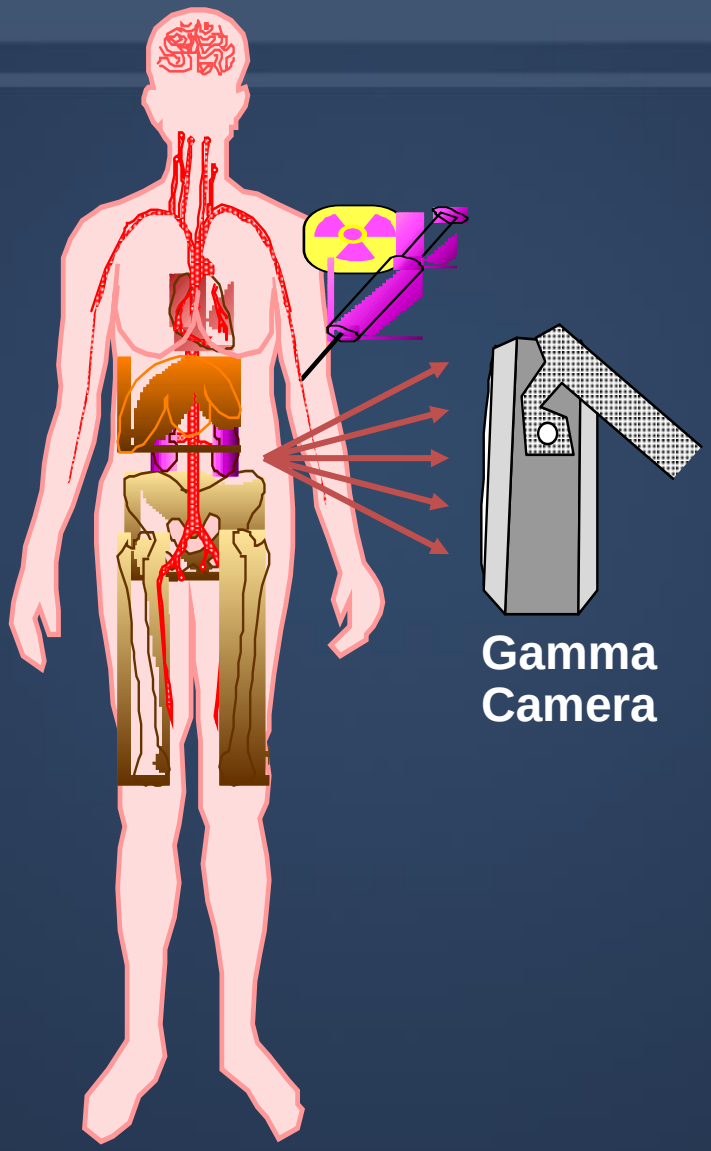
# Nuclear Medicine Procedure




- *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.*

# What are the nuclear medicine imaging methods?

**Conventional tumor imaging :**

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

PLANAR / SPECT

SPECT CT

**Onco PET :**

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

PET CT

# Physical Properties
# SPECT Radionuclides

| 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 |

# Physical Properties of positron emitting ( PET ) Radionuclides

| Radionuclide | T/2 phy-sical (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) |

# Thyroid Scan : Procedure

| | Tc-99m Pertechnetate | I-123 |
|---|---|---|
| Dose | 0.5-4.0 mCi given IV | 0.5 mCi orally |
| Half Life | 6 Hours | 13 Hours |
| Cost | Not Expensive (Generator) | Expensive (Cyclotrone) |
| Time of imaging | 20 min post injection | 6 and 24 hours post ingestion |
| Remarks | Trapped not organified | Trapped and organified |

# Normal Values Of Thyroid Uptake

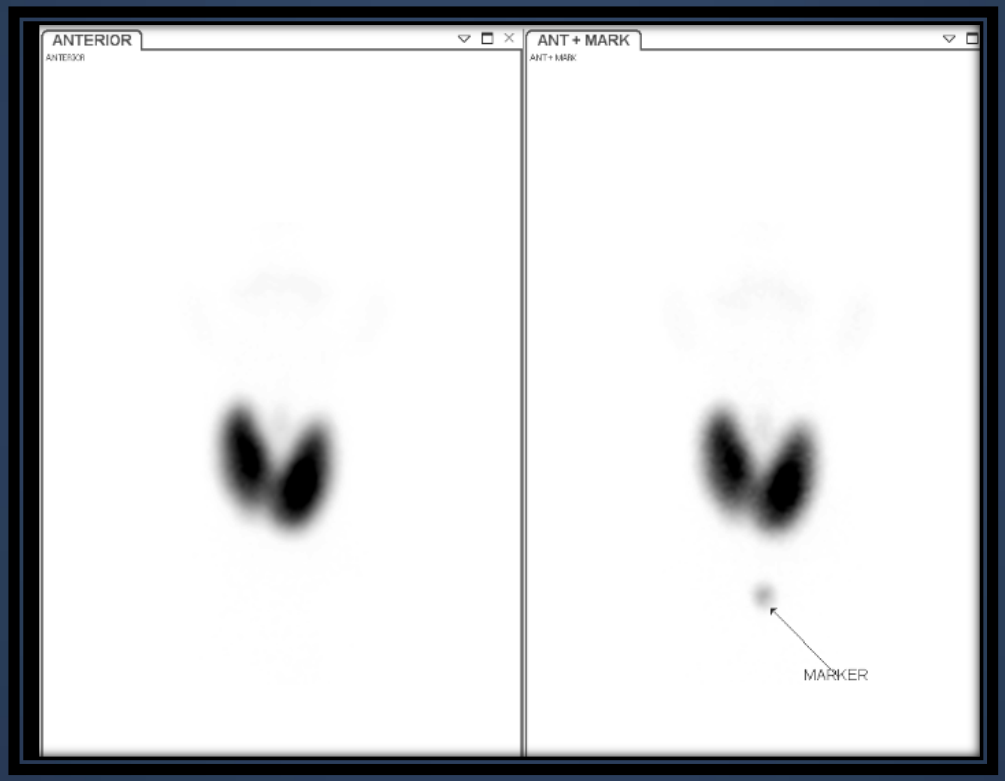
- **I131 OR I-123 RAIU (4 & 24 hours) :**

  **Normal 4 hour RAIU : 5 - 15%**

  **Normal 24 hour RAIU : 8 - 35%**

- **Tc- 99m Uptake (20 min Uptake) : N (0.5 -4 .0%)**

# Causes of High Thyroid Uptake

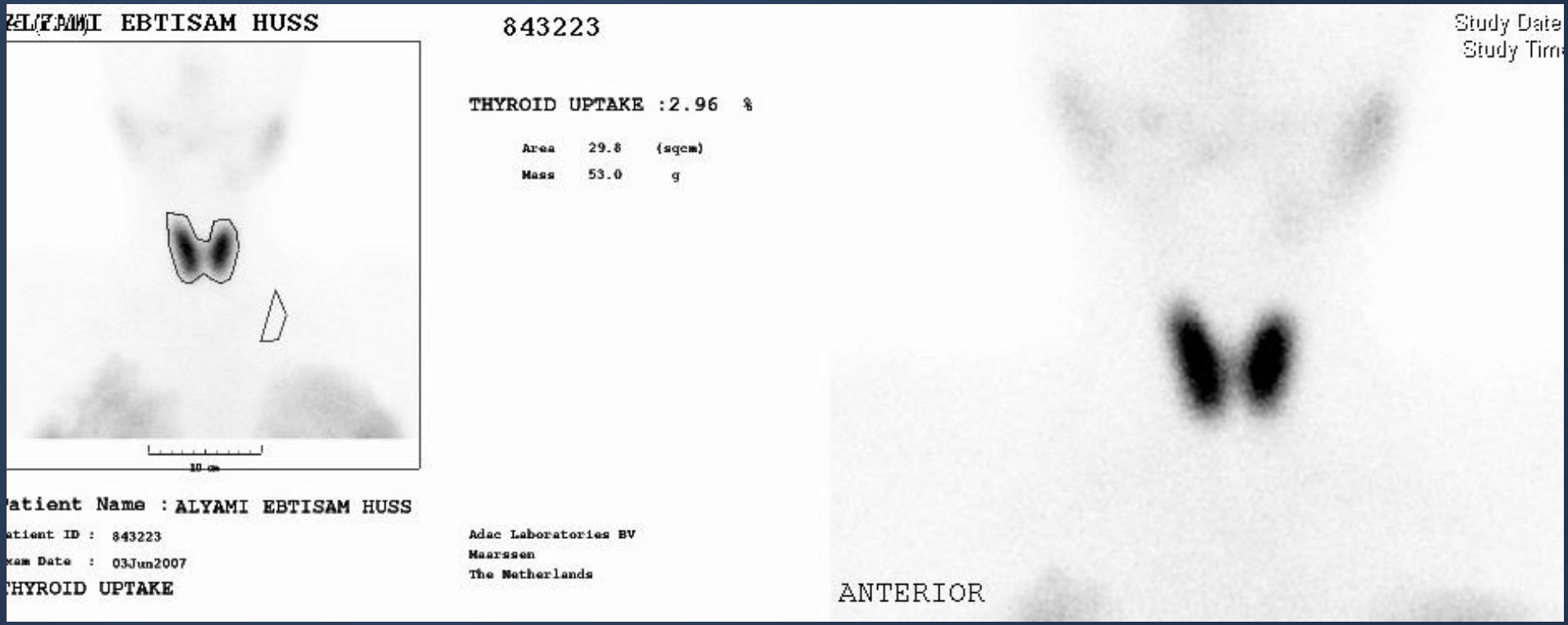



- **Hyperthyroidism :** Grave's Disease or TSH-secreting pituitary adenoma
- **Autonomous toxic nodule**
- **Multinodular toxic goiter** (Plumer's Disease)
- **Enzyme defects :** Dyshormonogenesis.
- **Iodine starvation** (Iodine deficiency)
- **Lithium Therapy**
- **Recovery phase of thyroiditis.**
- **Rebound** following abrupt withdrawal of antithyroid meds

# Causes of Low Thyroid Uptake


- **Parenchymal Destruction:**
  - Acute, Subacute and Chronic Lymphocytic Thyroiditis
- **Hypothyroidism:**
  - Primary or Secondary (insufficient pituitary TSH secretion)
  - Surgical/Radioiodine Ablation of Thyroid
- **Blocked Trapping:**
  - Iodine load (most common): Iodinated contrast material, Food rich in iodide: fish , cabbage ,…etc
  - Exogenous thyroid hormone replacement depressing TSH levels (thyrotoxicosis factitia)
  - Ectopic thyroid: Struma Ovarii
- **Blocked Organification:**
  - Antithyroid medication (PTU): Note- Tc-99m uptake should not be affected

# Tc-99m Thyroid scan and uptake
## Imaging plus uptake studies



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

## Indications

- Detection and localization of persistent or recurrent functioning thyroid cancer

## Patient Preparation

- Stimulation of potentially functioning thyroid tissue:

A. Inject recombinant human thyrotropin on 2 consecutive days and administer the radiopharmaceutical 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 .

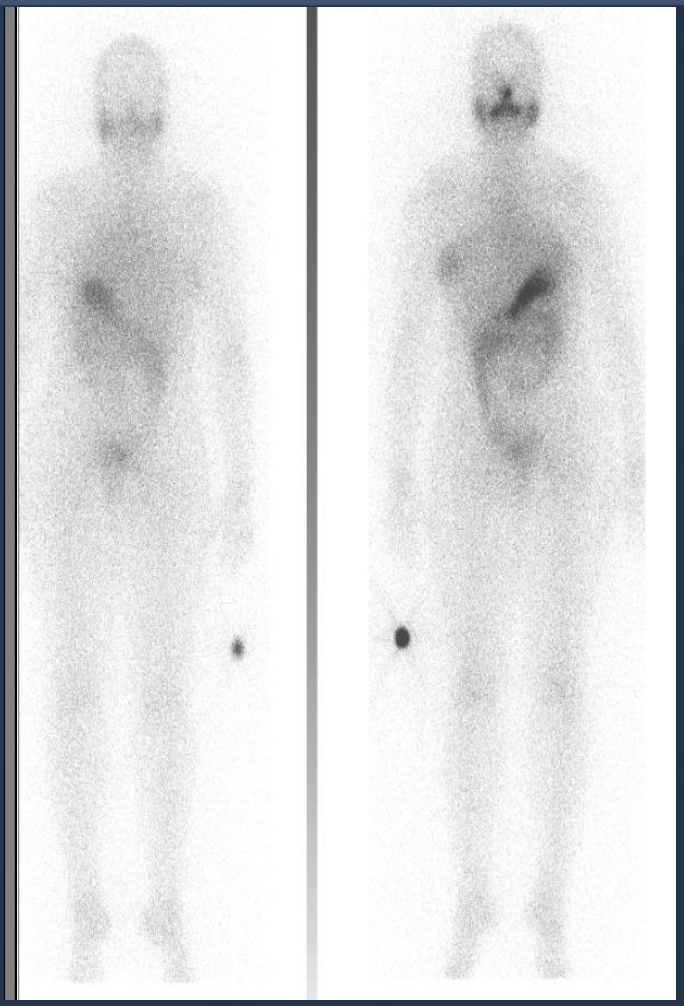
- The patient should be NPO for at least 4 hours prior to radiopharmaceutical administration and for at least 1 hour afterwards

## Radiopharmaceutical, Dose, & Technique of Administration

- Radiopharmaceutical: Oral administration

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

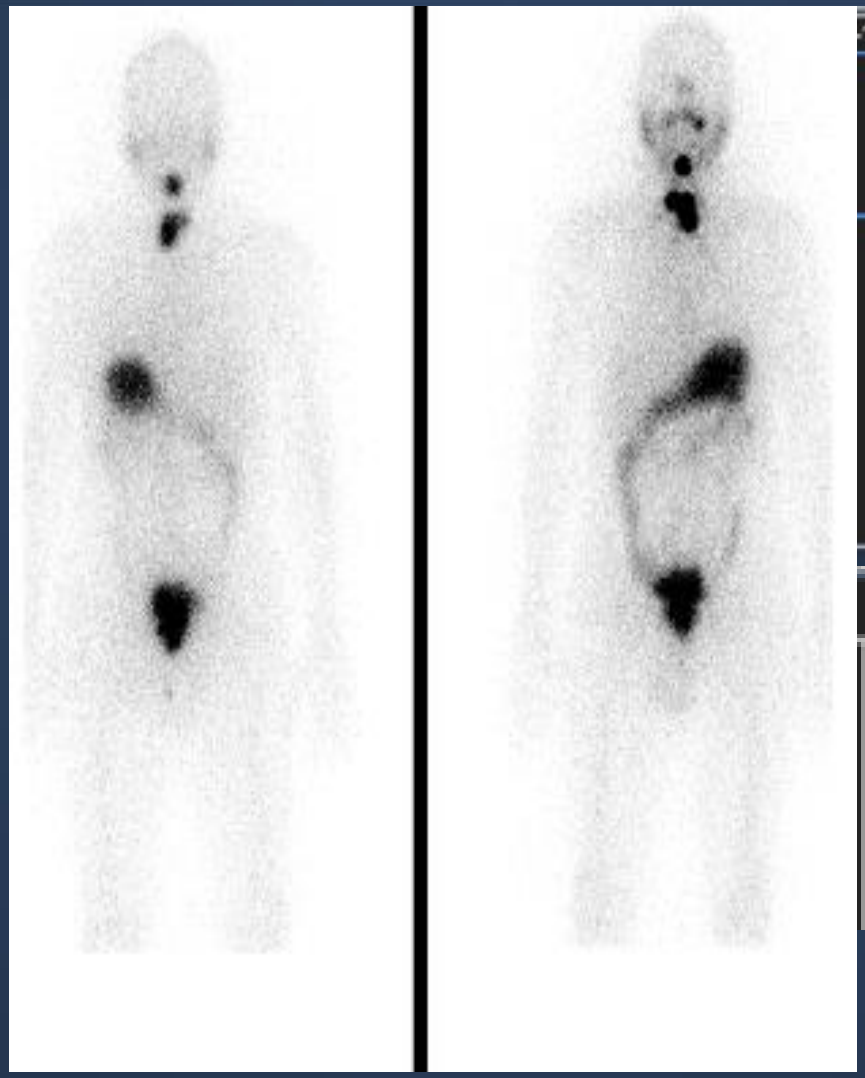
Imaging using Gamma camera : Whole body scan

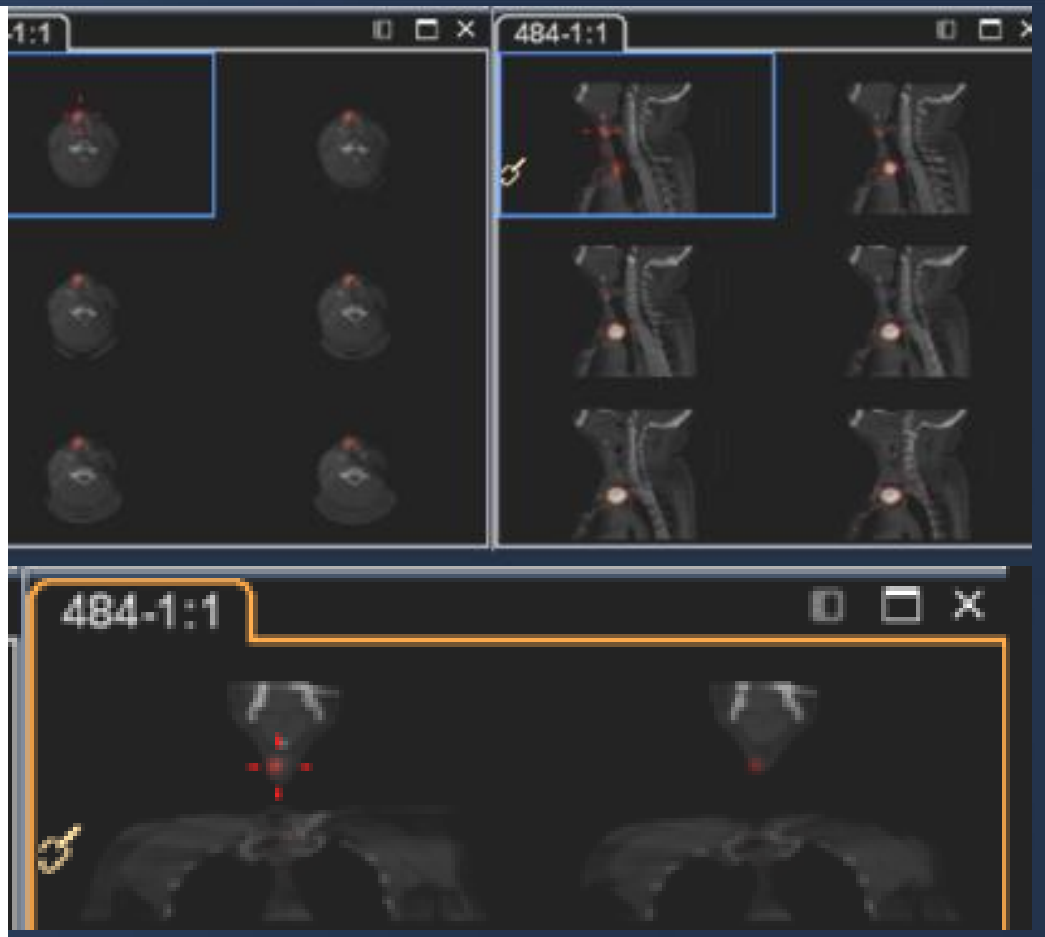


Negative WBS

# I-123 or I-131 Whole Body Scan(WBS)

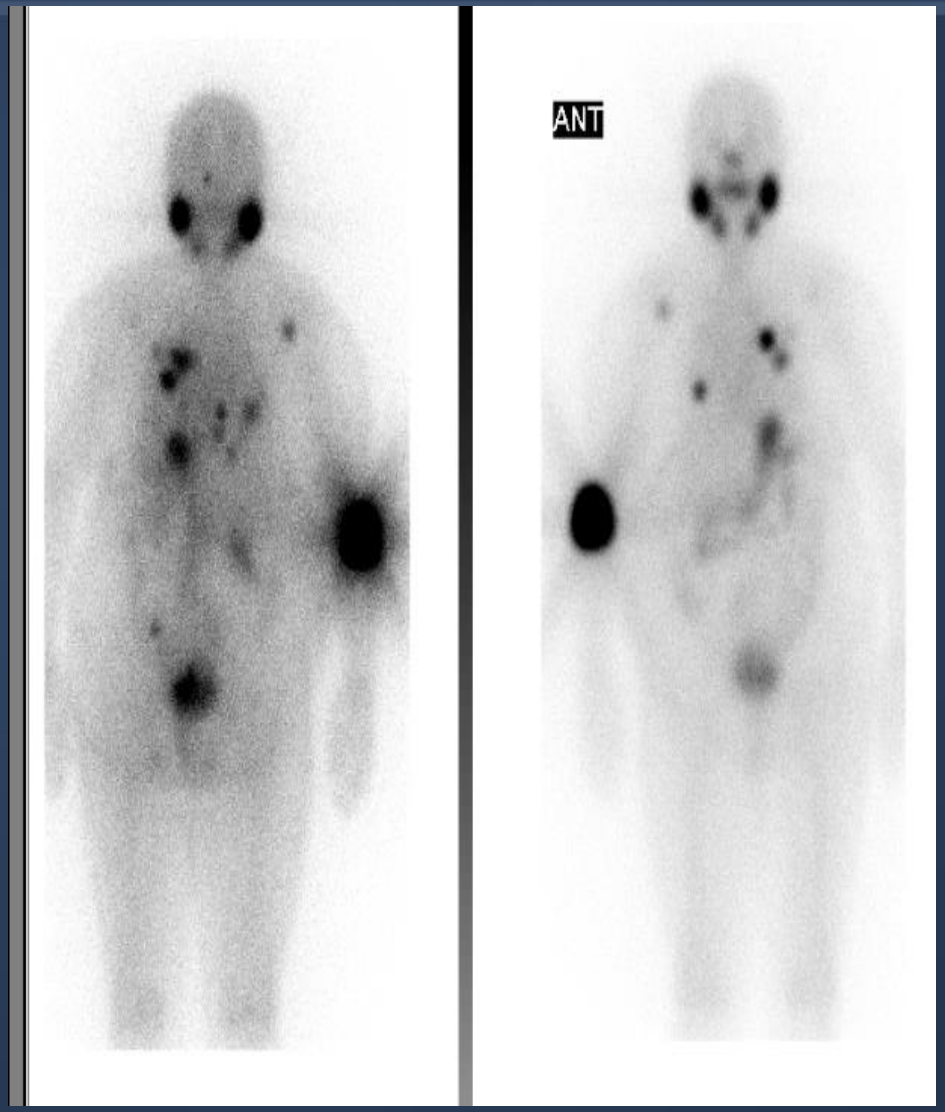
## Planar Vs SPECT CT





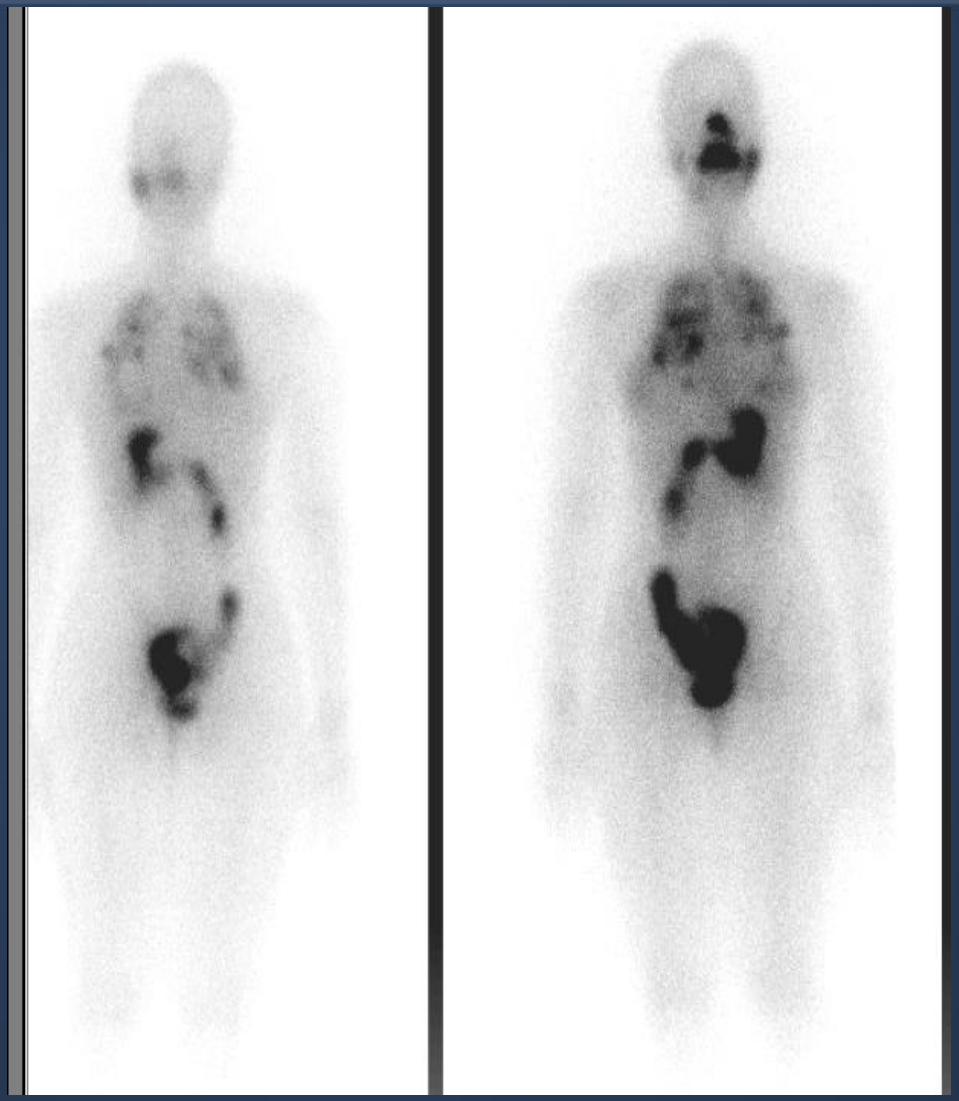

Local Recurrence

# I-123 or I-131 Whole Body Scan(WBS)




Bone Metastases

# I-123 or I-131 Whole Body Scan(WBS)



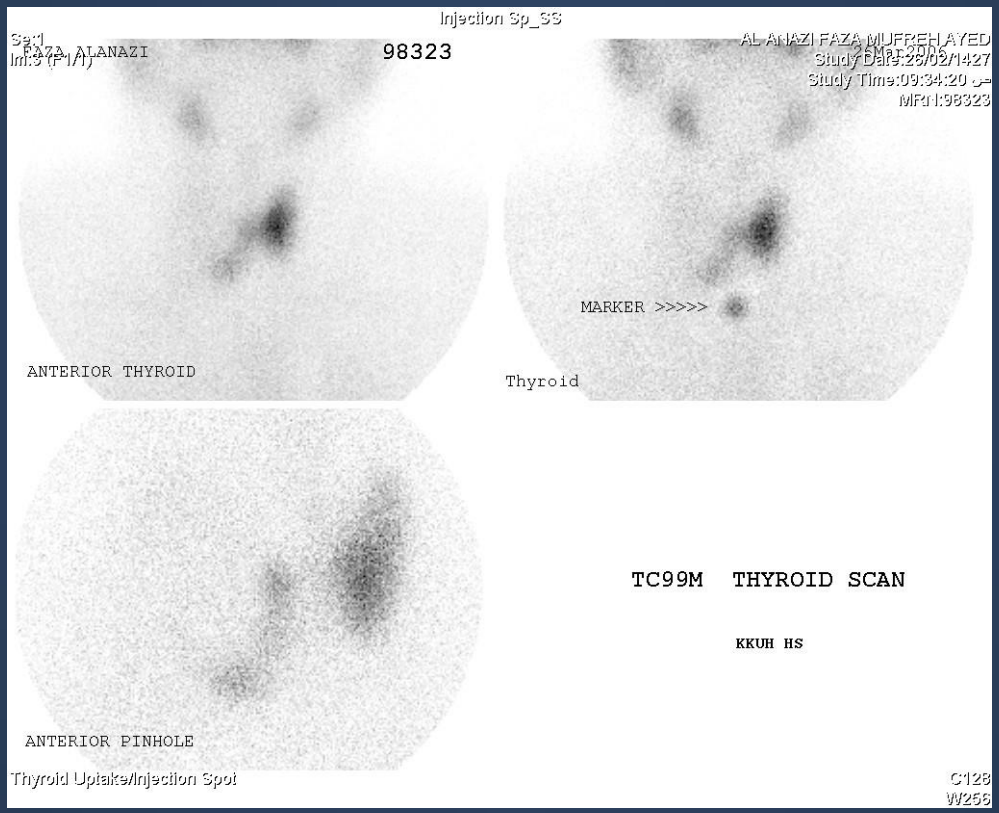
Lung Metastases

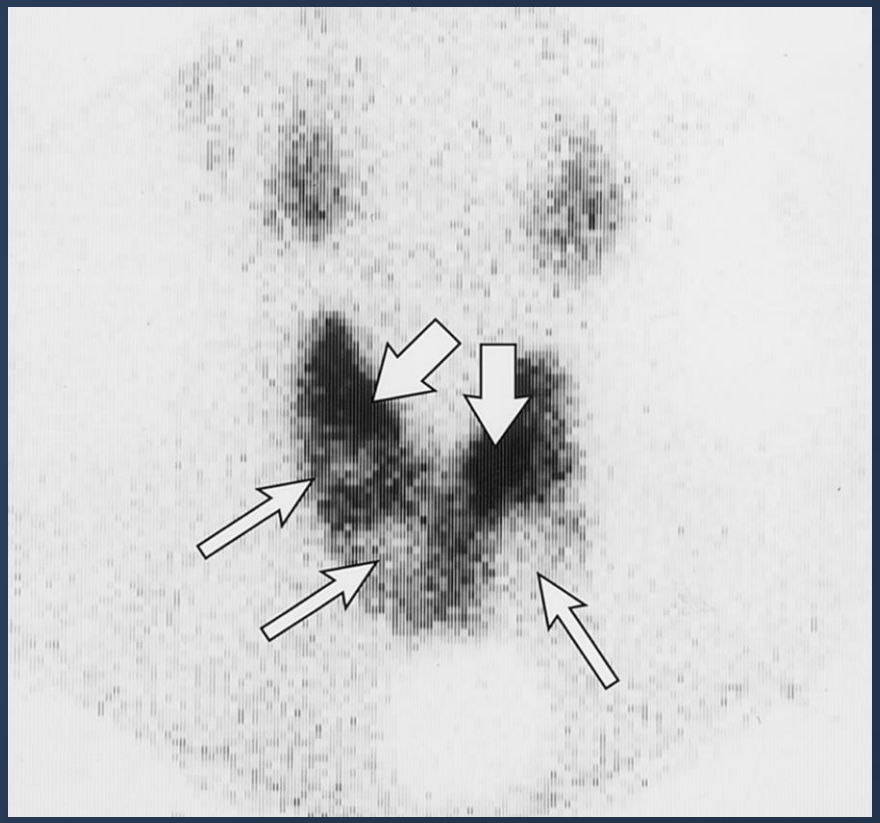
# When is thyroid scanning helpful?
## Indications for Thyroid Scan

- Evaluation of thyroid nodules : No. & type
- Evaluation of congenital hypothyroidism : Agenesis Vs. Dyshormonogenesis.
- Evaluation of neck masses : ectopic thyroid, thyroglobal cyst.
- Evaluation of thyrotoxicosis.

# Evaluation of thyroid nodules

## Single vs MNG



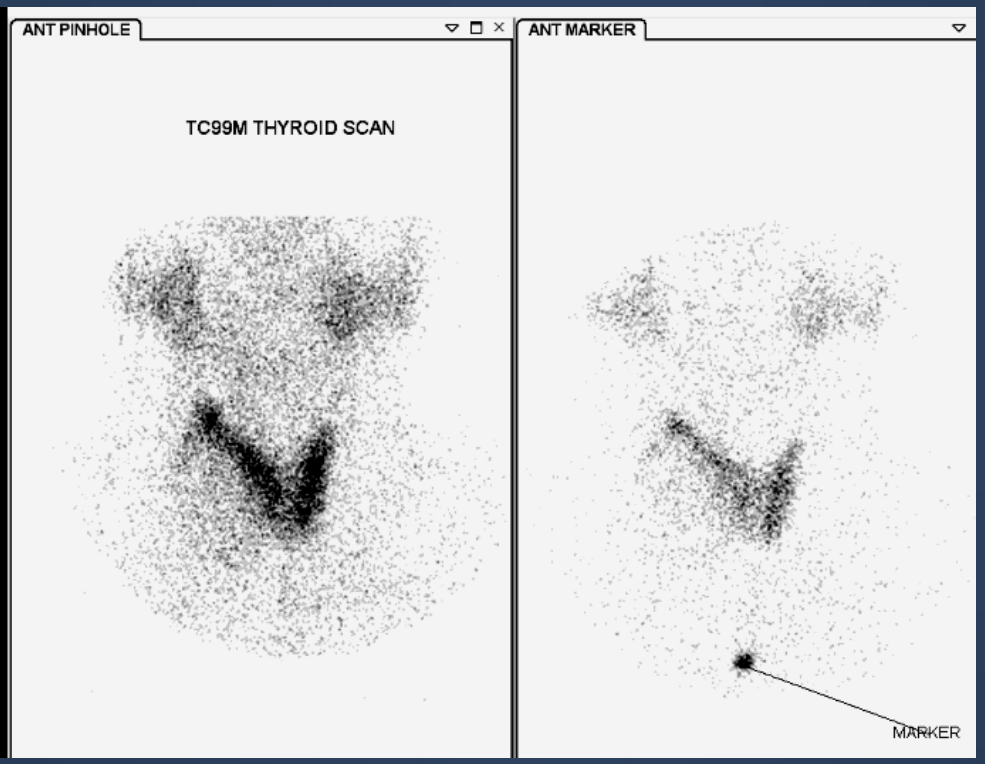
Solitary cold nodule

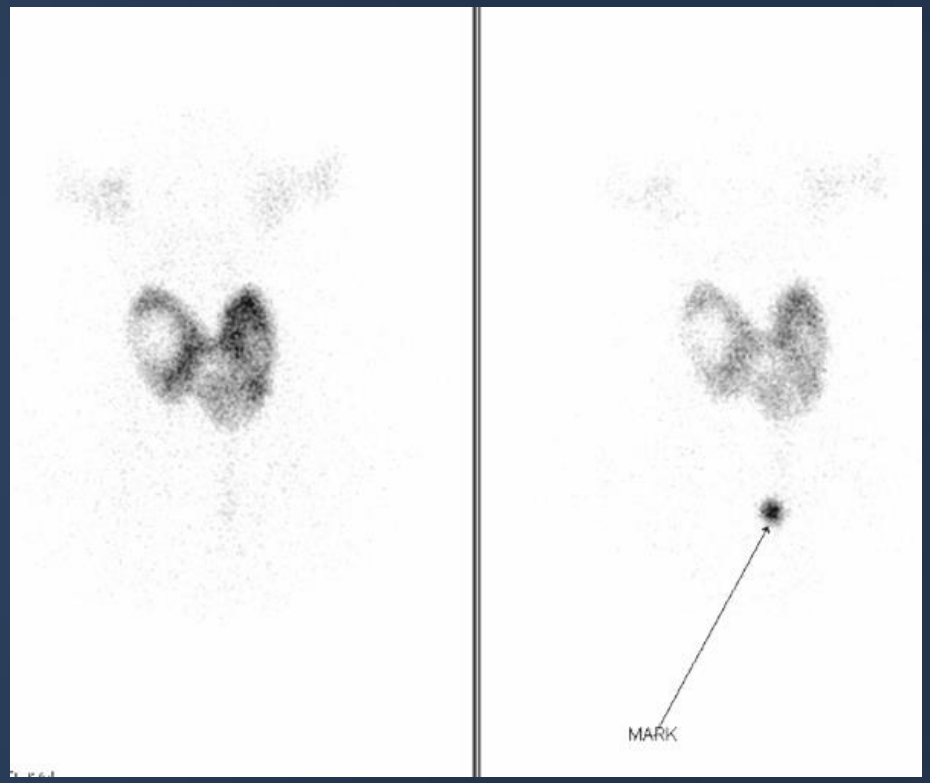
Multinodular goiter

**The chance of malignancy is more in Solitary cold nodule than in MNG**

# Evaluation of thyroid nodules

## Single vs MNG



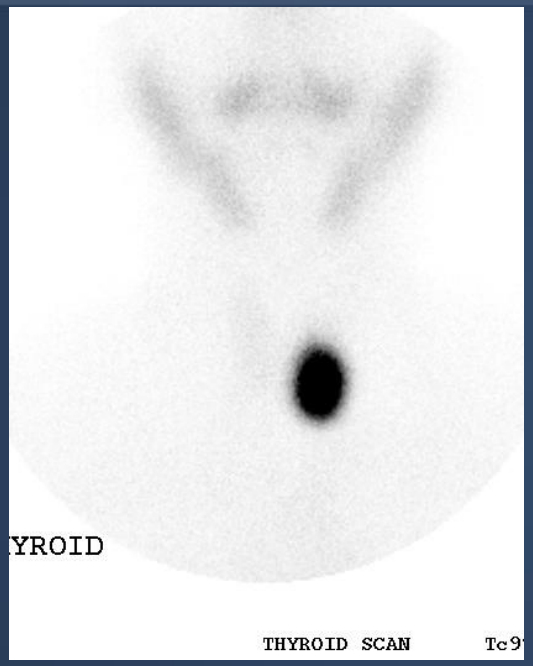

Solitary cold nodule

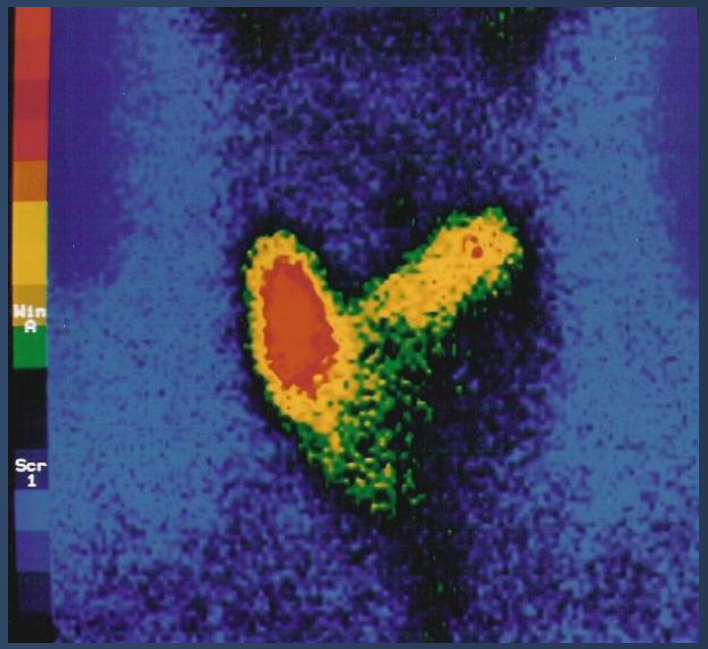
Multinodular goiter

**The chance of malignancy is more in Solitary cold nodule than in MNG**

# Evaluation of thyroid nodules

## Hot vs Cold vs warm




**Hot**

**< 5% Malignant**

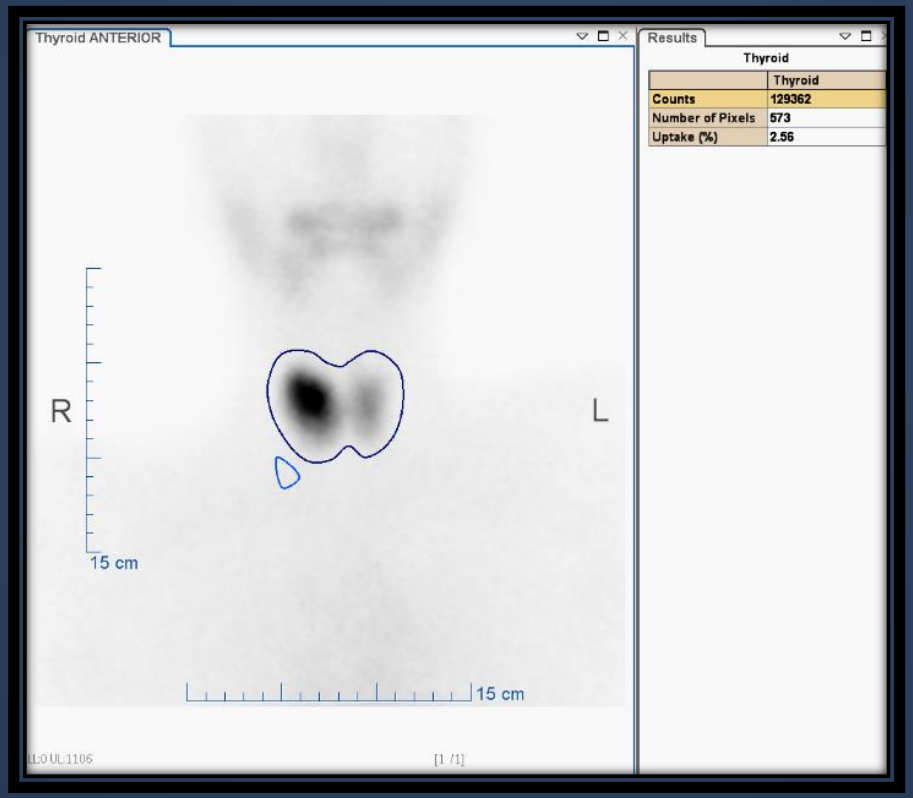
**Cold**

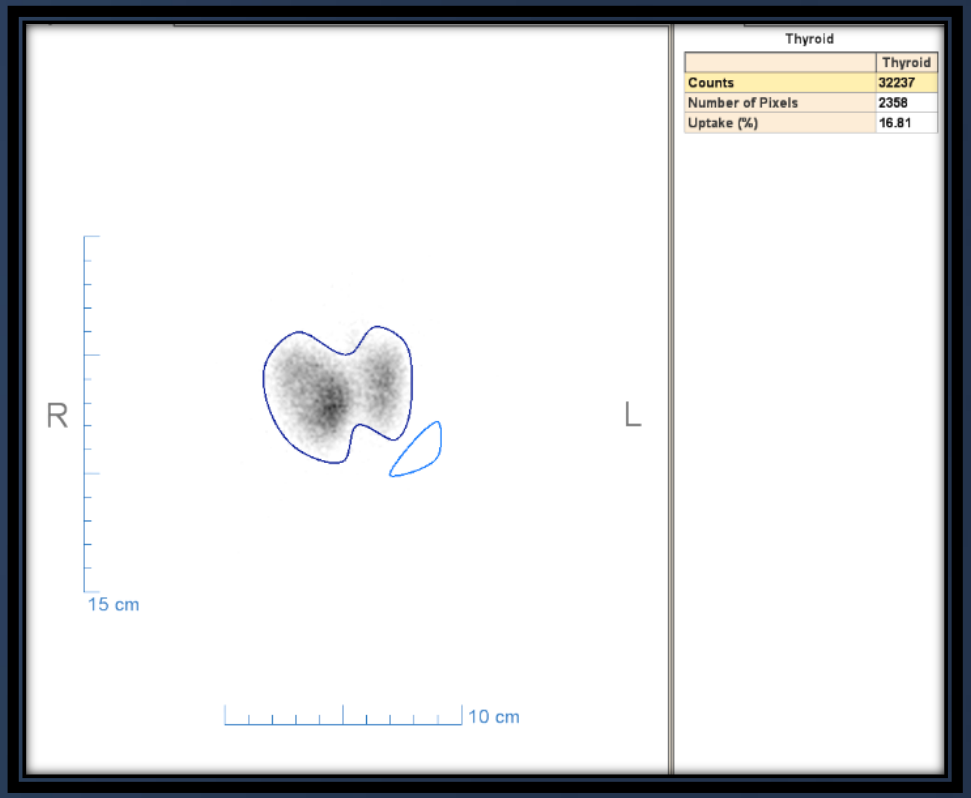
**15-20% Malignant**

**warm**

**Suspicious**

# Discordance Tc –I123 Scan

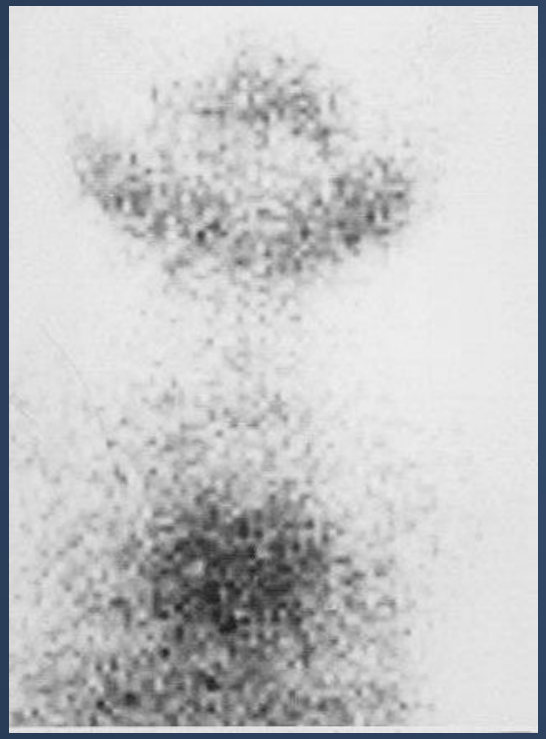


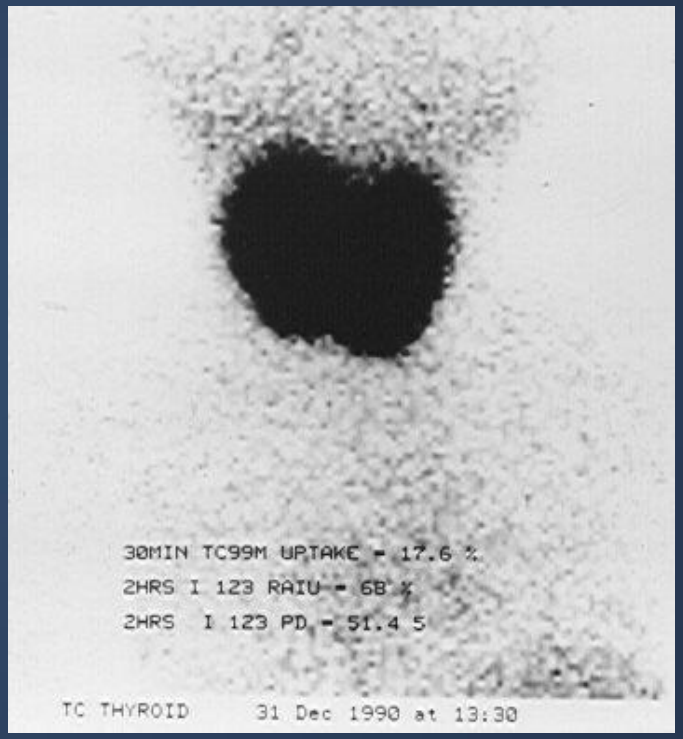

**The chance of malignancy of a discordant nodule about 20%**

# Evaluation of congenital hypothyroidism

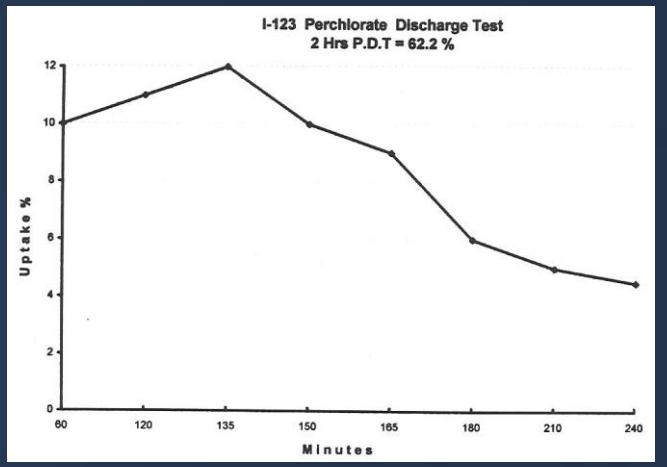
## Agenesis vs Dyshormonogenesis



Agenesis




Dyshormonogenesis

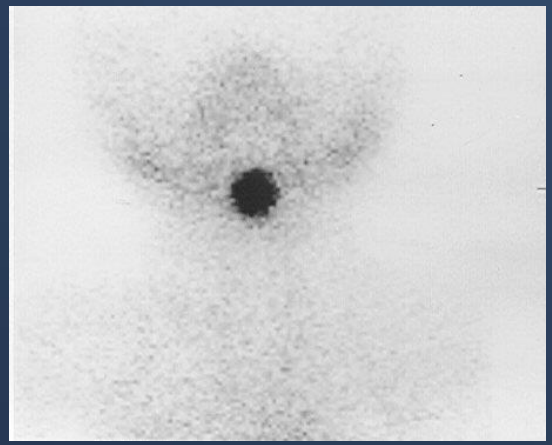


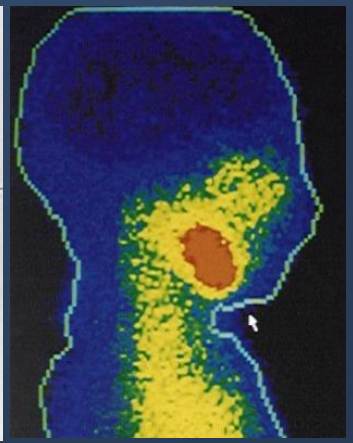

### Perchlorate Discharge Test

- 50 - 80 uCi $I^{123}$ orally.
- 2 hrs RAIU
- 400 mg Kclo4
- RAIU/ 15 min for 2 hrs.
- Positive test : >= 15 fall of RAIU below 2 hrs. uptake.

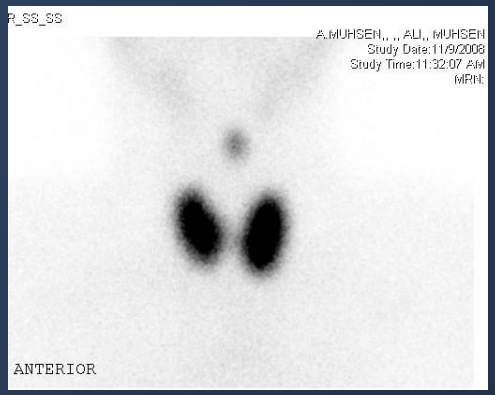
# Evaluation of neck masses

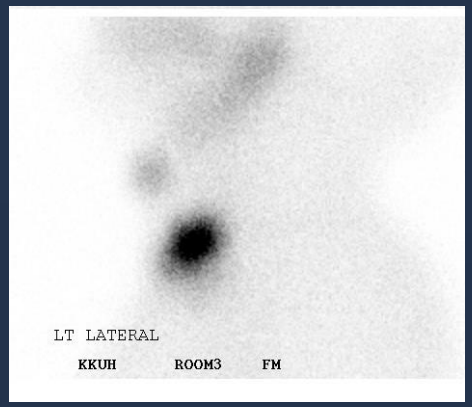
## ectopic thyroid vs thyroglosal cyst





Lingual thyroid




Thyroglosal cyst

# Evaluation of Thyrotoxicosis

- Thyrotoxicosis **IS NOT** synonymous to Hyperthyroidism

- **Thyrotoxicosis:** Is a complex of signs and symptoms due to elevated thyroid hormones in the blood

- **Hyperthyroidism :** Overproduction of thyroid hormones by the thyroid gland (hyperactive gland)

# Evaluation of thyrotoxicosis

## Thyrotoxicosis with hyperthyroidism

- Graves' Disease .
- Neonatal hyperthyroidism.
- Toxic nodular goiter :

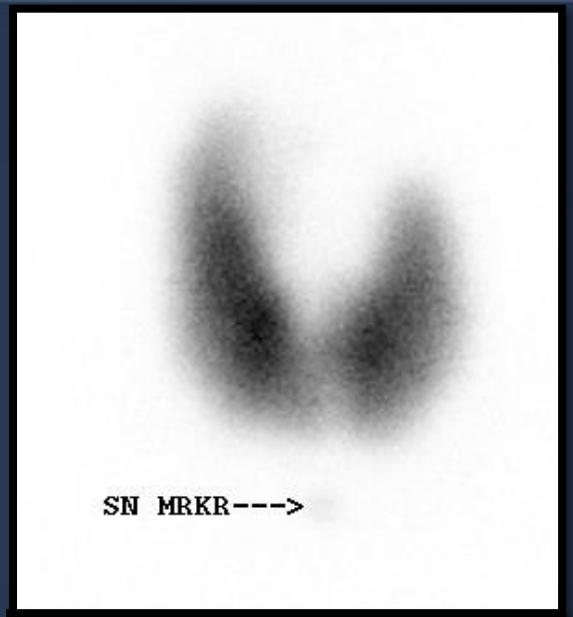
  MNTG or Plummers disease

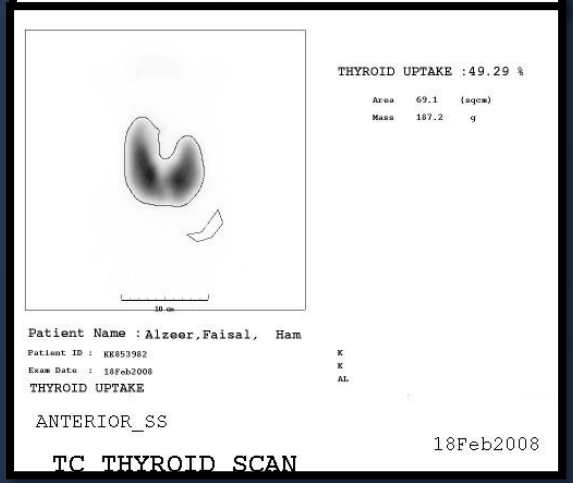
  ATN or toxic adenoma
- Iodine induced

  ( Jod-Basedow disease )
- Rare causes :

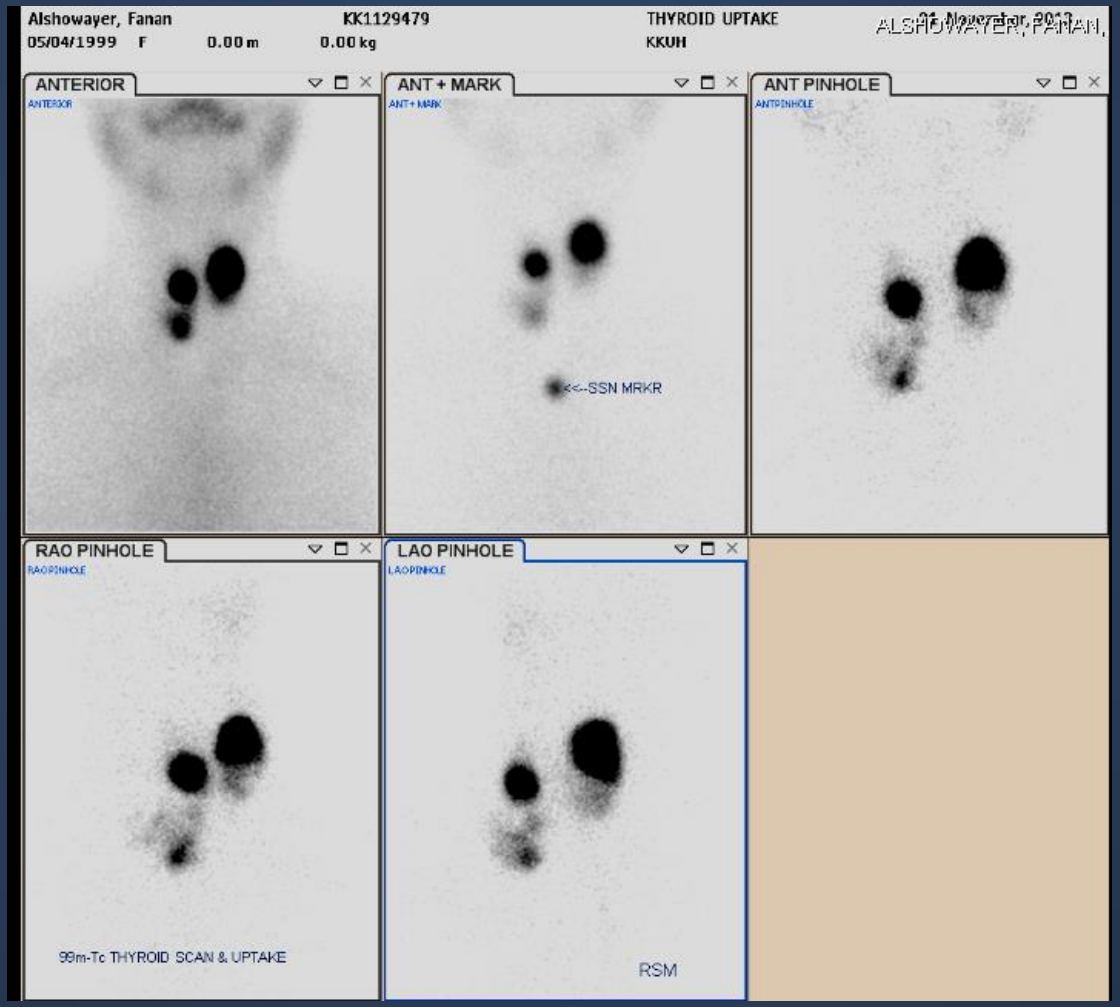
  Execssive HCG by trophoblastic tumor

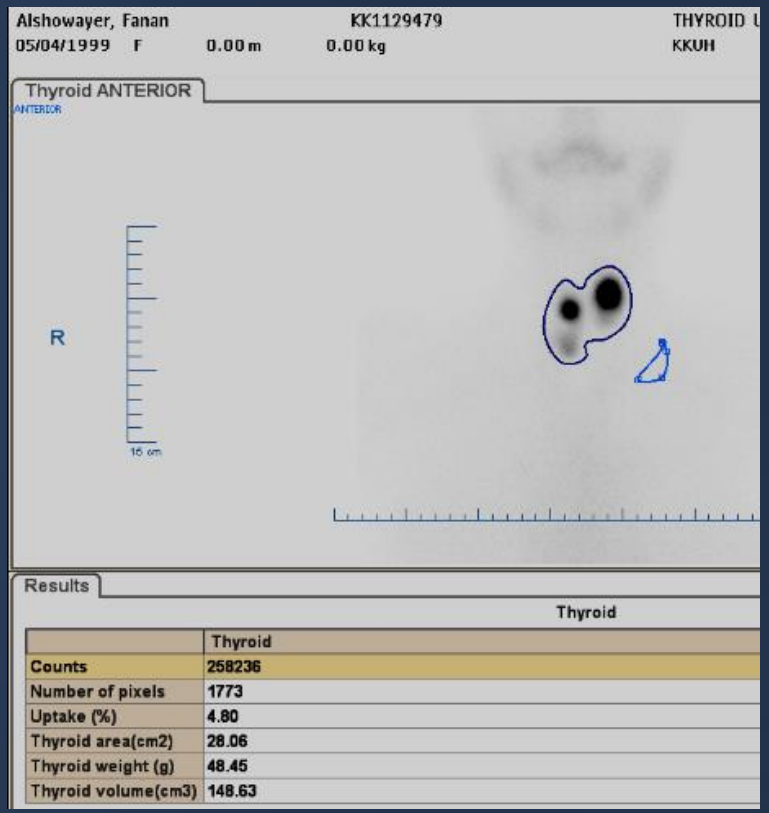
  Hypothalamic pituitary neoplasms (TSH induced)



# MNTG (Plummers Disease)

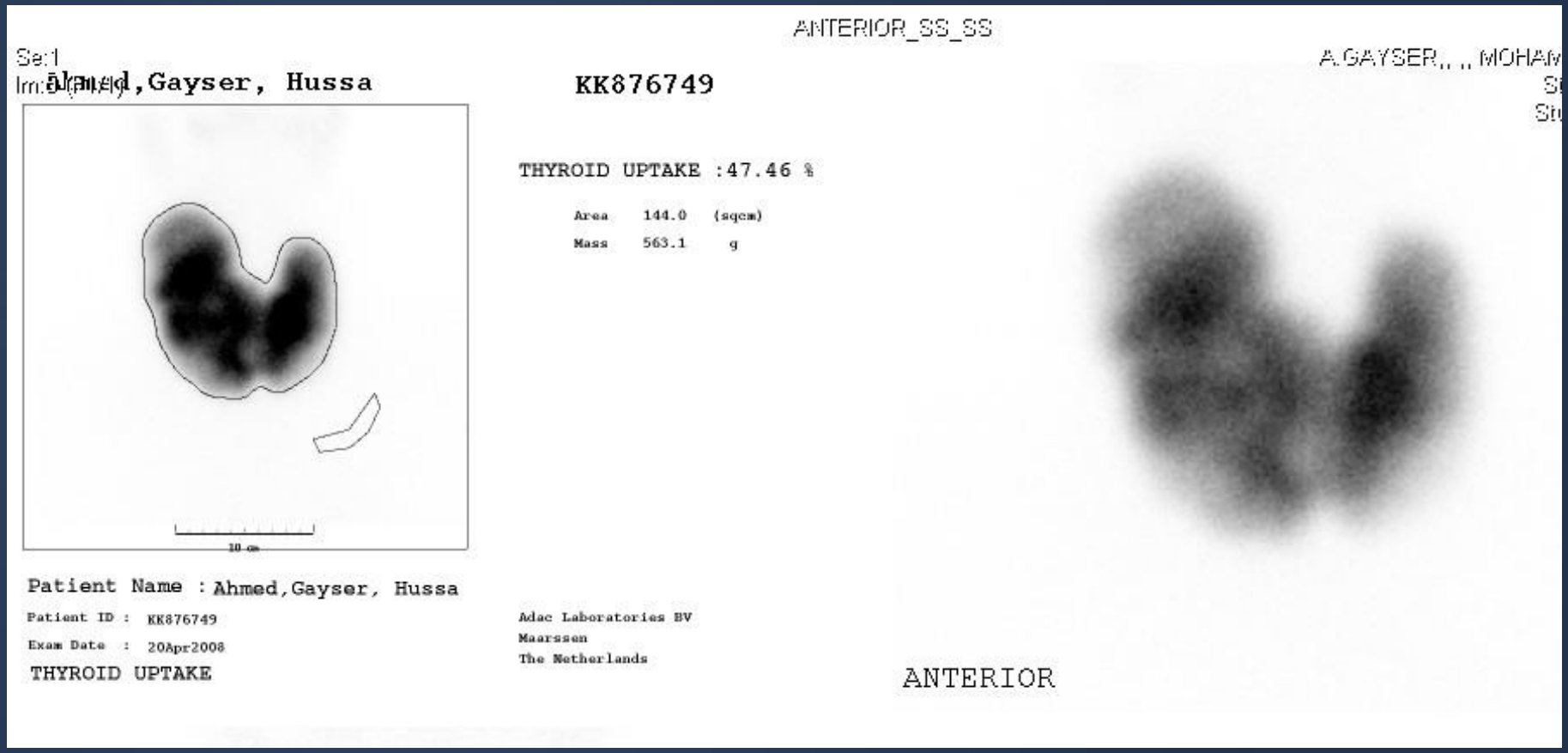



| | Thyroid |
|---|---|
| Counts | 258236 |
| Number of pixels | 1773 |
| Uptake (%) | 4.80 |
| Thyroid area(cm2) | 28.06 |
| Thyroid weight (g) | 48.45 |
| Thyroid volume(cm3) | 148.63 |

# Evaluation of thyrotoxicosis

## Thyrotoxicosis with hyperthyroidism

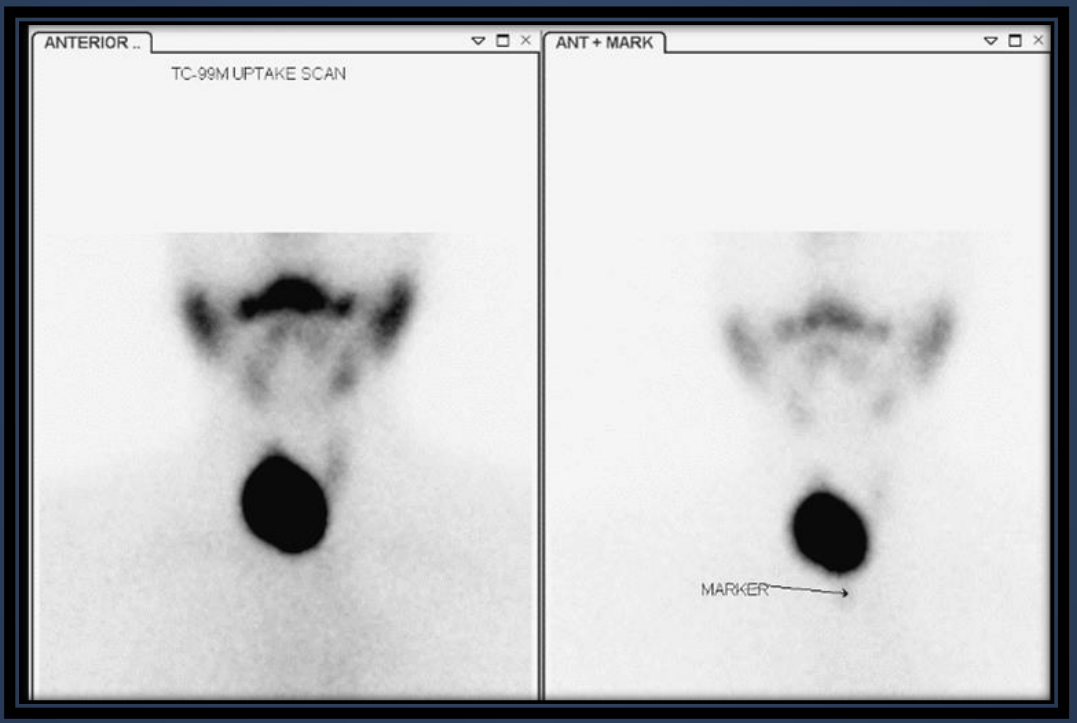


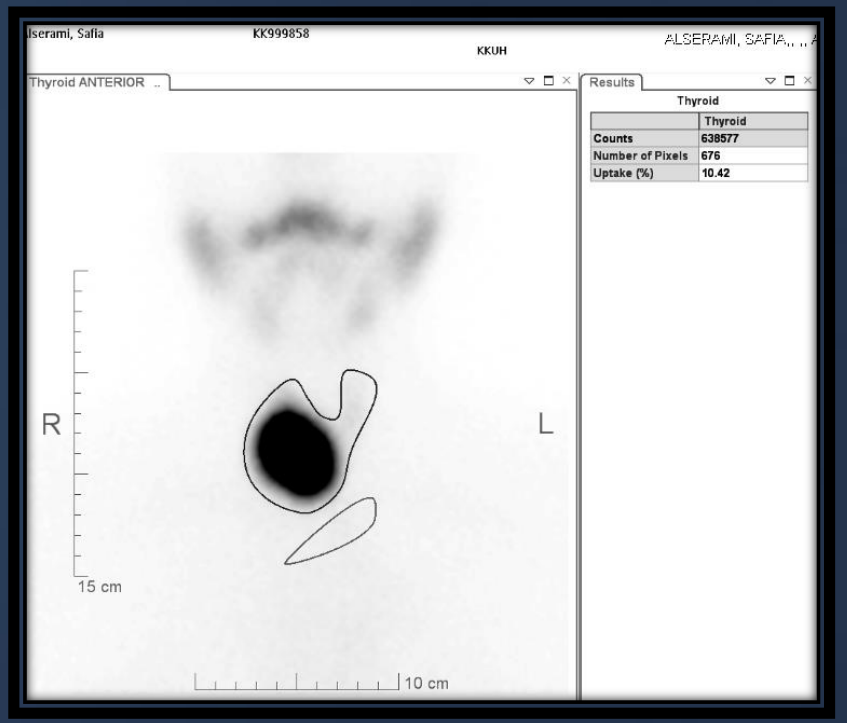

**Graves' Disese on top of MNG**

**Nodular Graves Disease (**Marine-Lenhart syndrome **)**

# Evaluation of thyrotoxicosis

## Thyrotoxicosis with hyperthyroidism




ATN

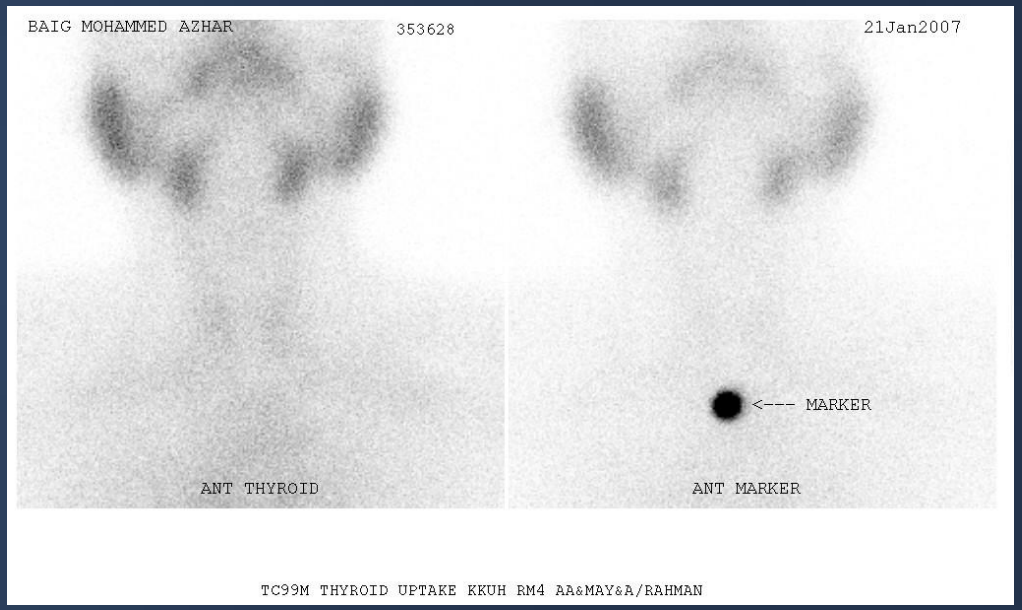
# Evaluation of thyrotoxicosis

## Thyrotoxicosis without hyperthyroidism

- **Subacute thyroiditis.**
- **Chronic thyroiditis with transient thyrotoxicosis**
- **Thyrotoxicosis factitia** (exogenous hormone).
- **Thyroid extract** (e.g.Hamburger thyrotoxicosis)
- **Ectopic thyroid :**

  Metastatic thyroid carcinoma

  Struma ovari




SAT

# Radioactive Iodine Therapy for Hyperthyroidism

- **Isotope used :** I131
- **Physical Properties:** Solution or capsule
- **Main side effect :** Hypothyroidism
- **Dose :**

a. Calculated : Considering weight and uptake of the gland

b. Empirical :

Graves: 5-15 mCi

ATN : 15-20 mCi

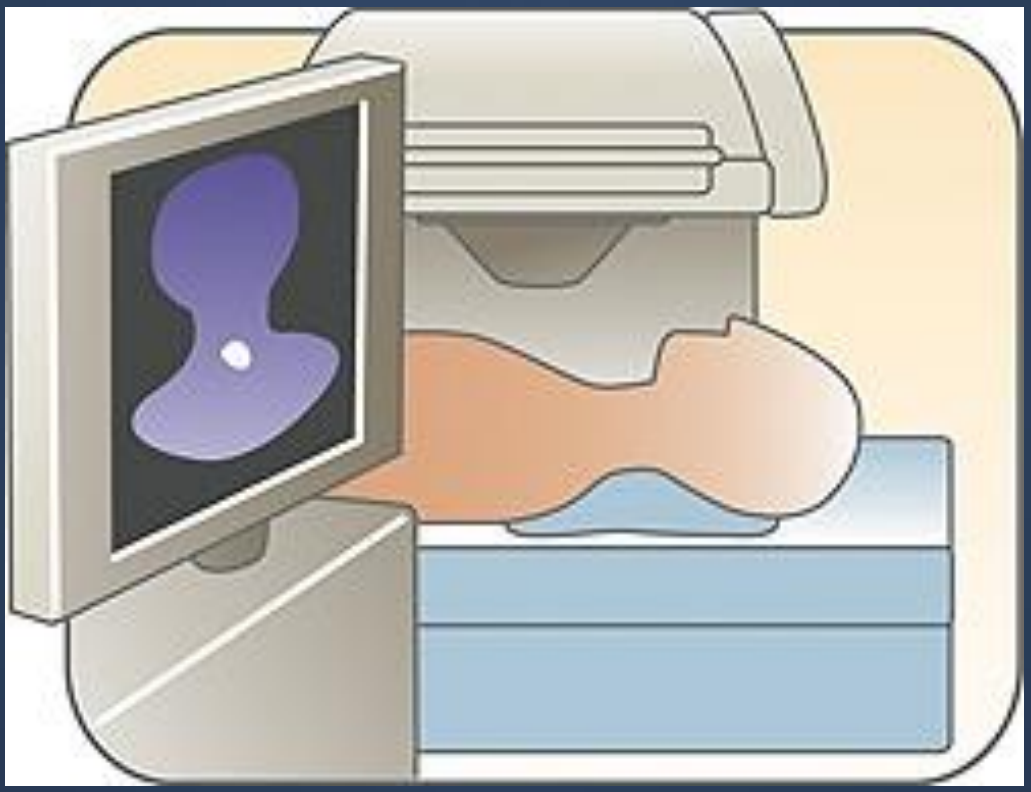
# Radioactive Iodine Therapy for Thyroid Cancer

**Isotope used : I131**

**Physical Properties: Solution or capsule**

- **Thyroid remnant : 80-100 mCi**
- **Lymph Node Mets : 100 mCi**
- **Local Recurrence : 100 mCi**
- **Lung Mets : 150 mCi**
- **Bone Mets : 200 mCi**

# Parathyroid Scan



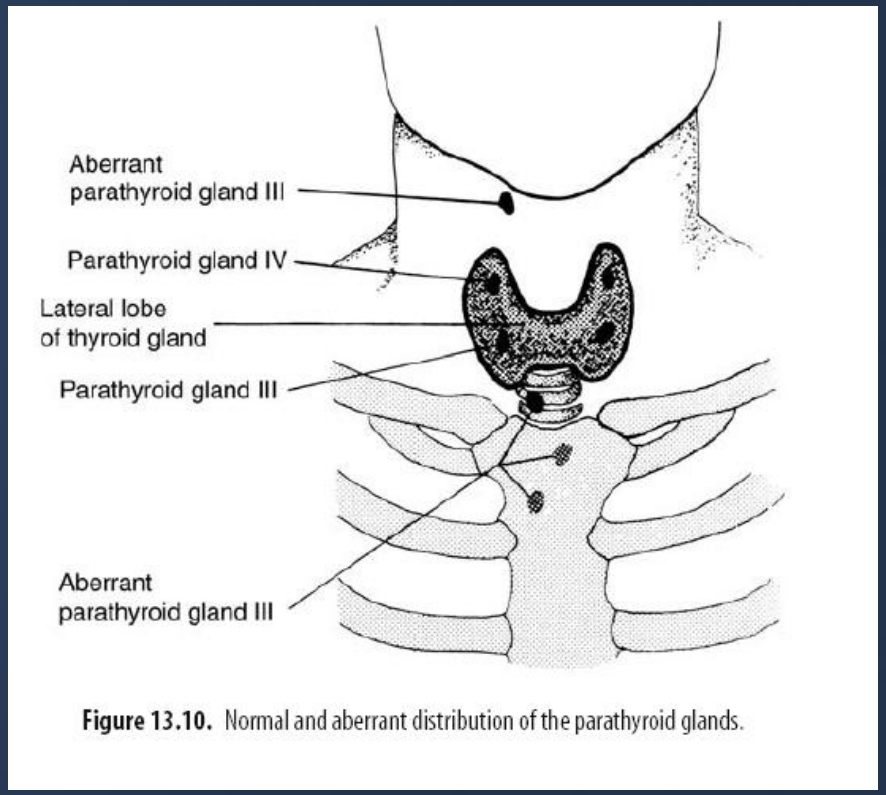



**Figure 13.10.** Normal and aberrant distribution of the parathyroid glands.

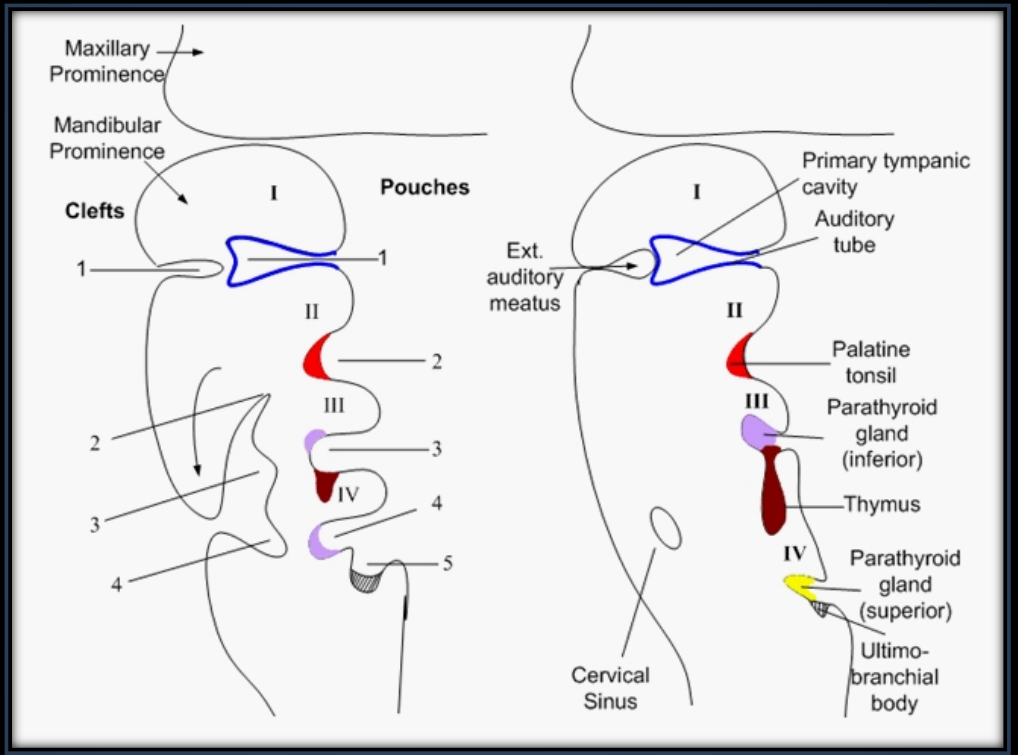
# Parathyroid Scan

## LEARNING OBJECTIVES…

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

- Describe the physiologic principles of underlying Tc-99m parathyroid scintigraphy .
- Describe the various methods used for parathyroid scintigraphy with emphasis on SPECT and SPECT /CT .
- Identify the common imaging features of pathologic parathyroid glands.
- Discuss causes of false negative and false positive scans.

# Normal and Ectopic Parathyroid Glands



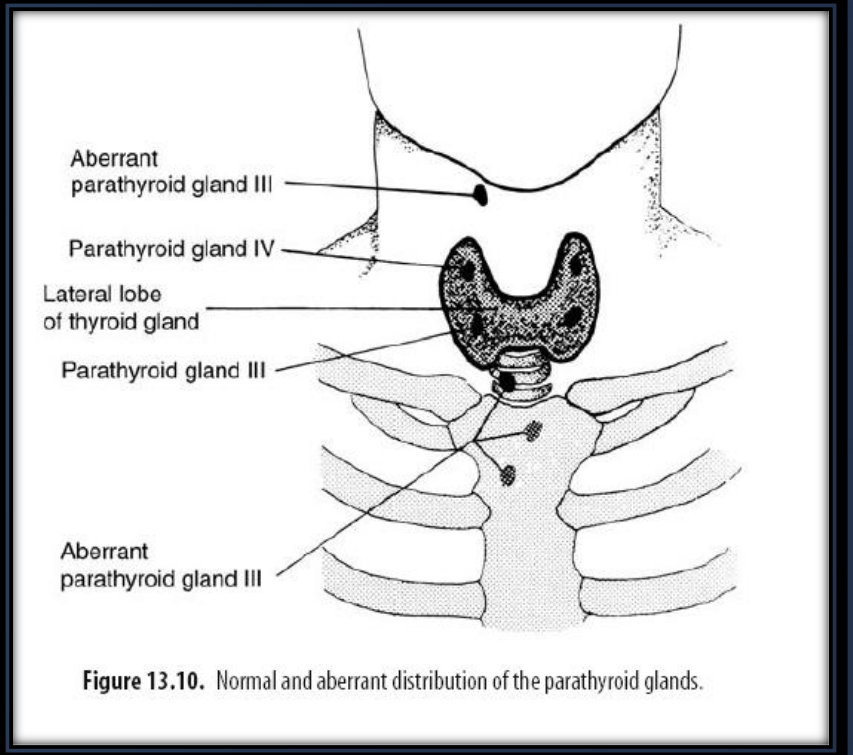



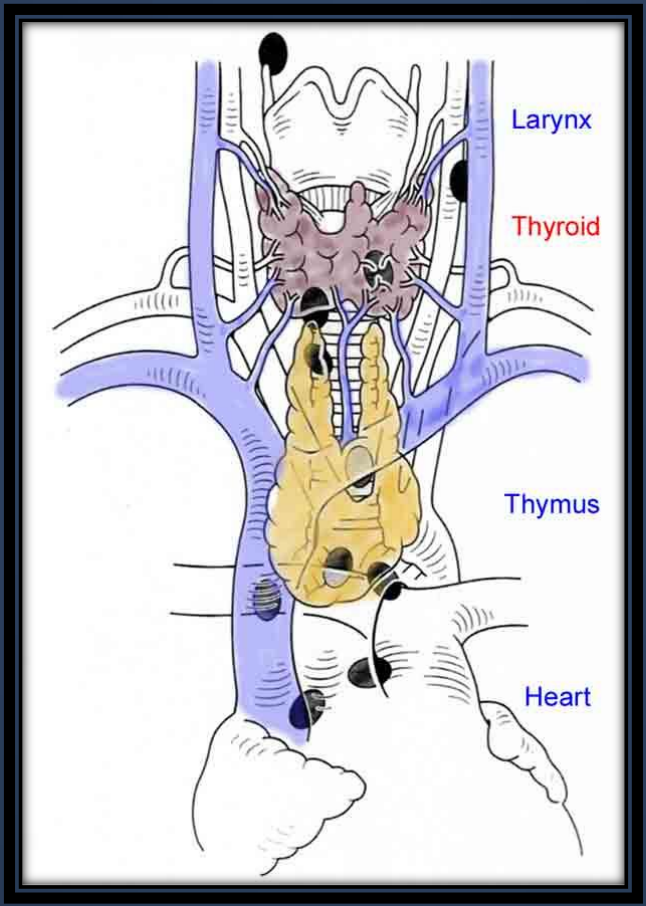

**Figure 13.10.** Normal and aberrant distribution of the parathyroid glands.

**The third pair of pouches:** proliferates into the **inferior parathyroid glands** and the **thymus**

**The fourth pair of pouches:** proliferates into the **superior parathyroid glands** and the **lateral analge of the thyroid gland.**

Because the inferior parathyroid glands undergo more extensive migration during embryogenesis, they are more likely to be found in ectopic locations.

# Ectopic Parathyroid Glands




**Location of an ectopic parathyroid glands**

- Submandibular
- Retropharyngeal
- Retroesophageal
- Posterosuperior mediastinal
- Intrathyroidal
- Within the tracheoesophageal groove Carotid sheath
- Thyrothymic ligament
- Intrathymic

  Antero-superior mediastinal.

# Parathyroid Scan
# Techniques

- TL-201 _ Tc-99m subtraction
- Tc-99m Sestamibi ( Dual Phase )
- Tc-99m Tetrofosmin ( Dual Phase )

# Parathyroid imaging

| Radiopharmaceutical | 99mTc / 201Tl Subtraction | 99mTc sestamibi |
|---|---|---|
| Activity administered | 80 MBq (2 mCi) 201Tl;<br>370 MBq (10 mCi) 99mTc | 925 MBq (25 mCi) |
| Images acquired | Inject Tl .rst and acquire 15-min 100 000 count view of neck and mediastinum.<br>Then acquire similar Tc images without moving patient.<br>Subtract Tc data from Tl after normalization to equal count densities | Anterior (and oblique) views at 15 min and at 2–3 h; SPECT as needed |

# PARATHYROID IMAGING

## Tc-99m-Sestamibi

- The Parathyroid Study depicts hypertrophied parathyroid tissue, probably because of uptake of Tc-99m-sestamibi in the mitochondria of hyperactive cells.

**Indications :** Detect and localize parathyroid adenomas .

**Patient Preparation :** None.

**Radiopharmaceutical, Dose, & Technique of Administration**

- **Radiopharmaceutical:** 25 mCi Tc-99m-sestamibi i.v.
- **Patient position:** Supine with head and neck extended and immobilized.
- **Gamma camera Imaging field:**
  1. Neck.
  2. Upper two thirds of the mediastinum.

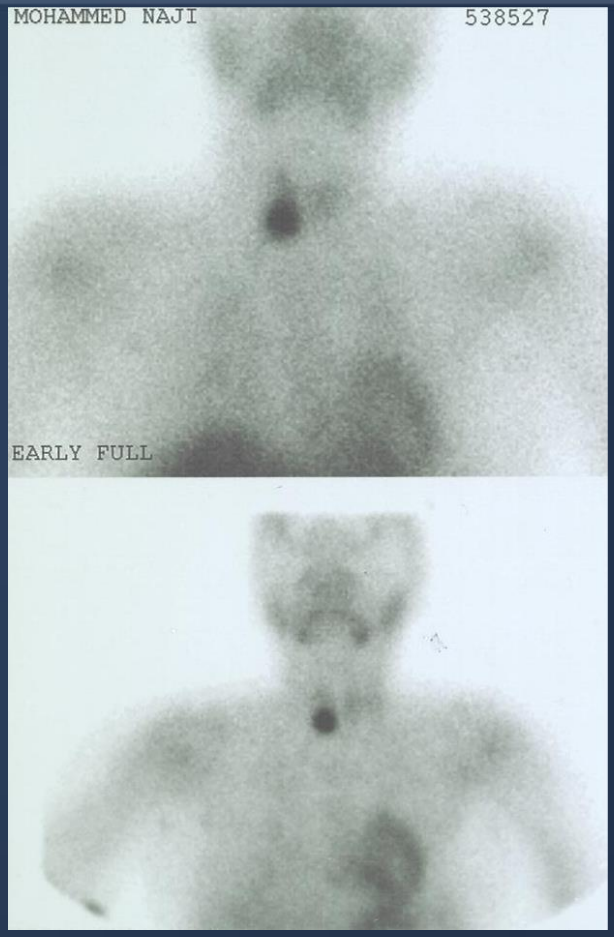
Acquire images at 15 minutes and 2-3 hours post injection.
SPECT/SPECT CT images improves localization.

- **TI – Tc99m subtraction :** Several protocols have been developed for routine subtraction of thyroid tissue from parathyroid tissue

# Parathyroid Scan

## Dual phase MIBI Scan ( Or Tetrofosmin )

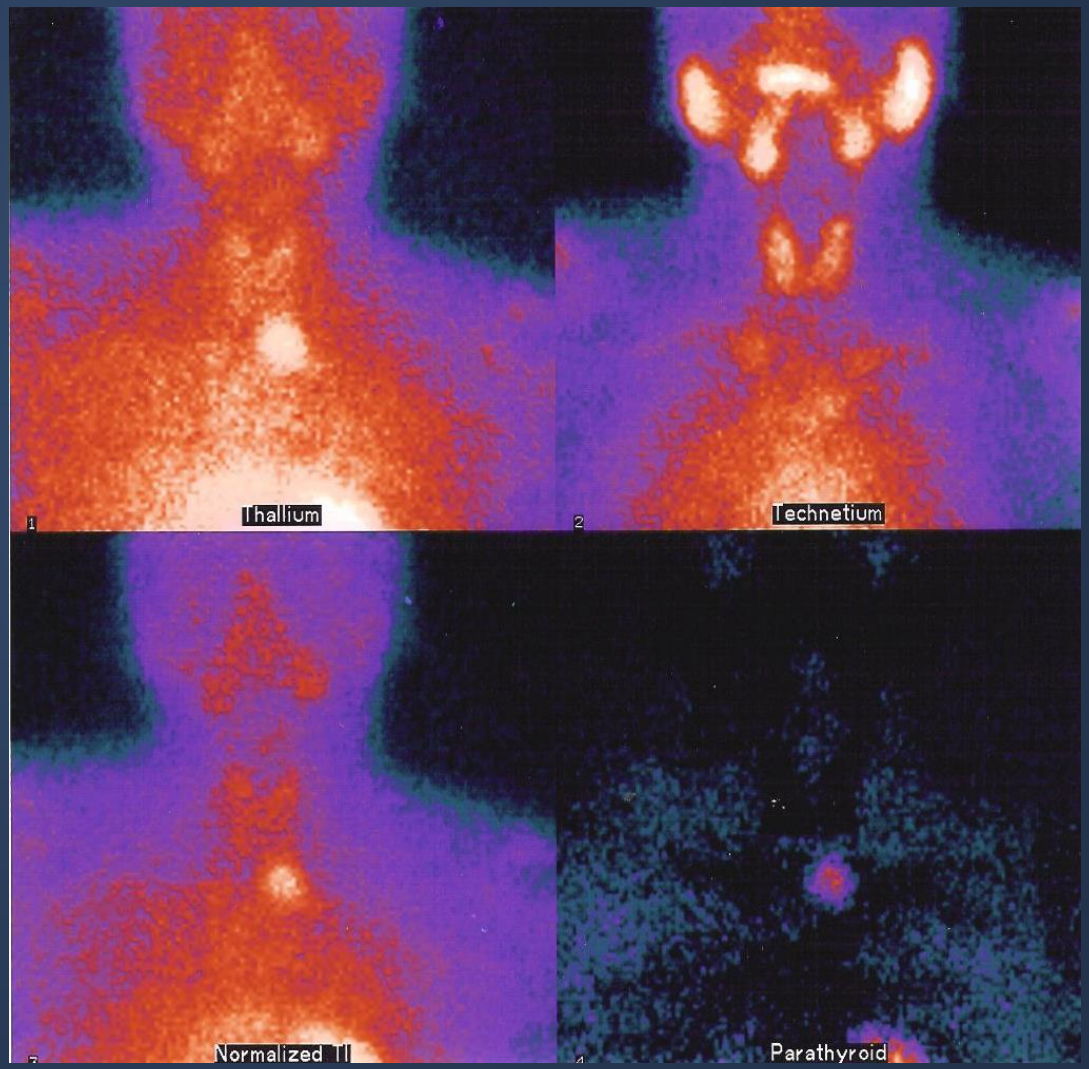

Normal parathyroid glands
are small and not visualized




Abnormal parathyroid glands
could be visualized

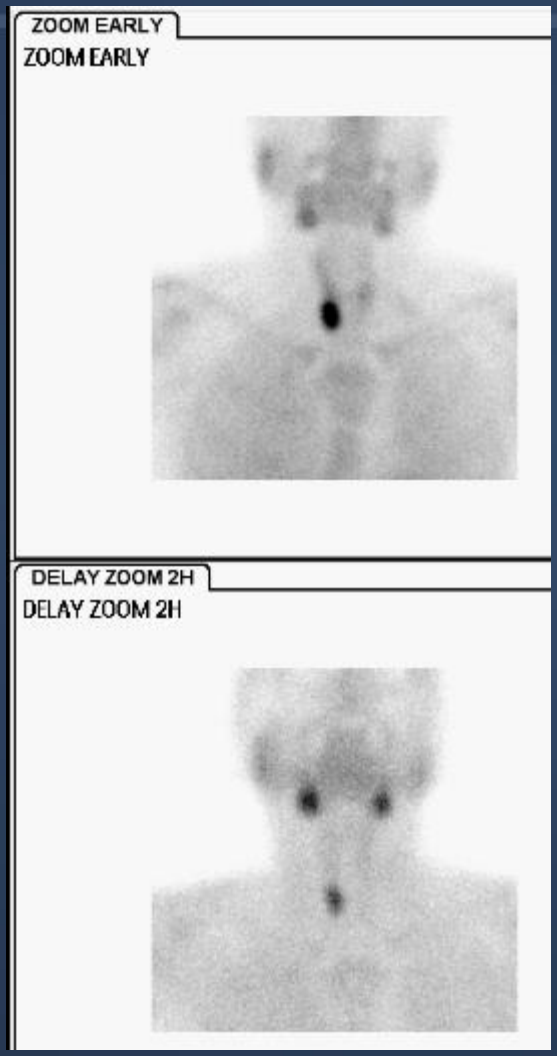
# Parathyroid Scan

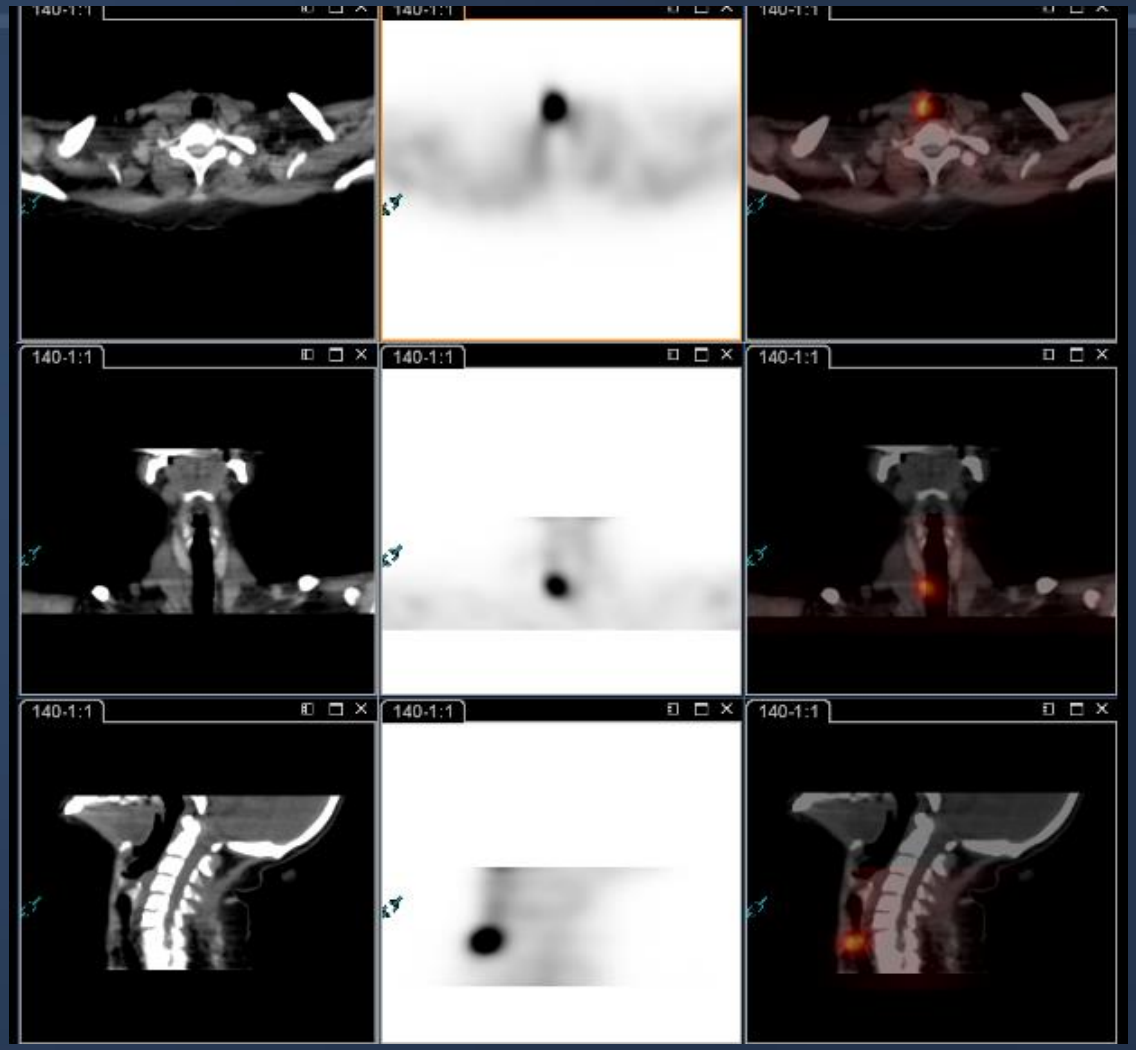
## Tc-Tl Subtraction Scan



# Parathyroid Scan
# Sestamibi dual phase


# Sestamibi Dual Phase
# ( Planar vs SPECT CT)



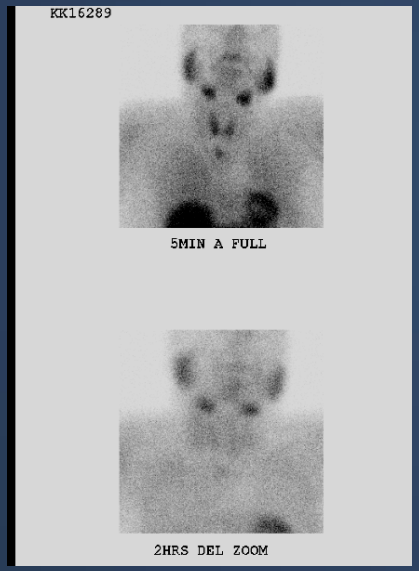



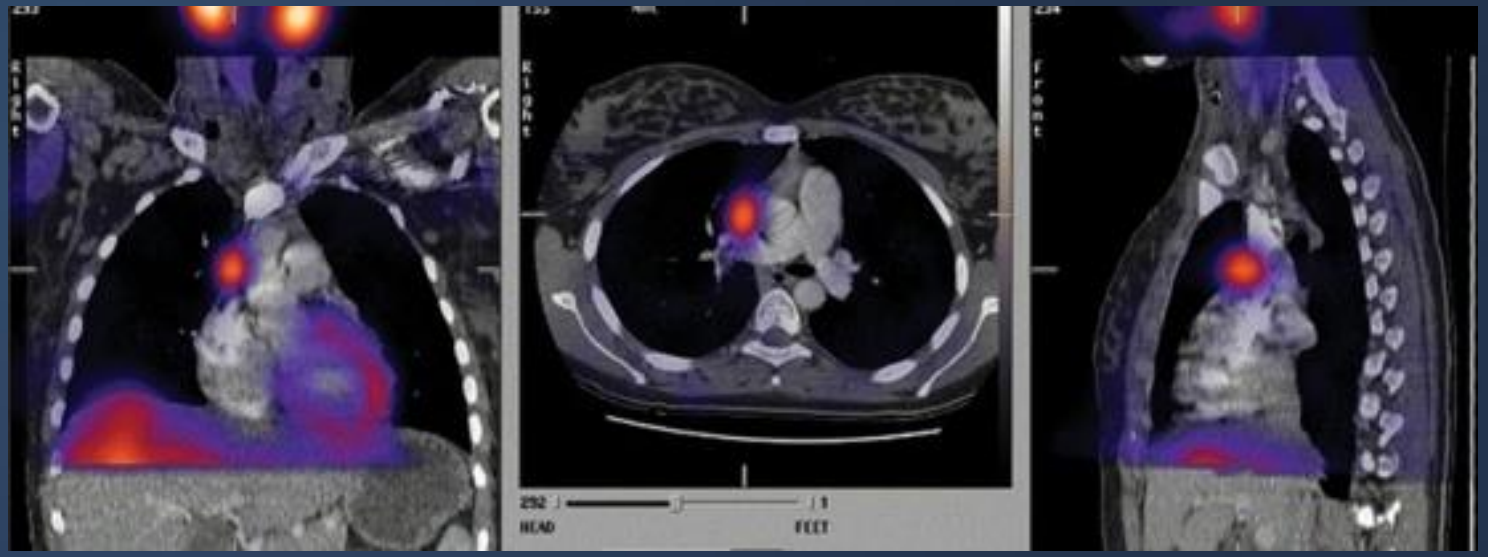
# Parathyroid Scan

## Ectopic Parathyroid : 16% of total adenomas

# Ectopic Parathyroid Adenoma

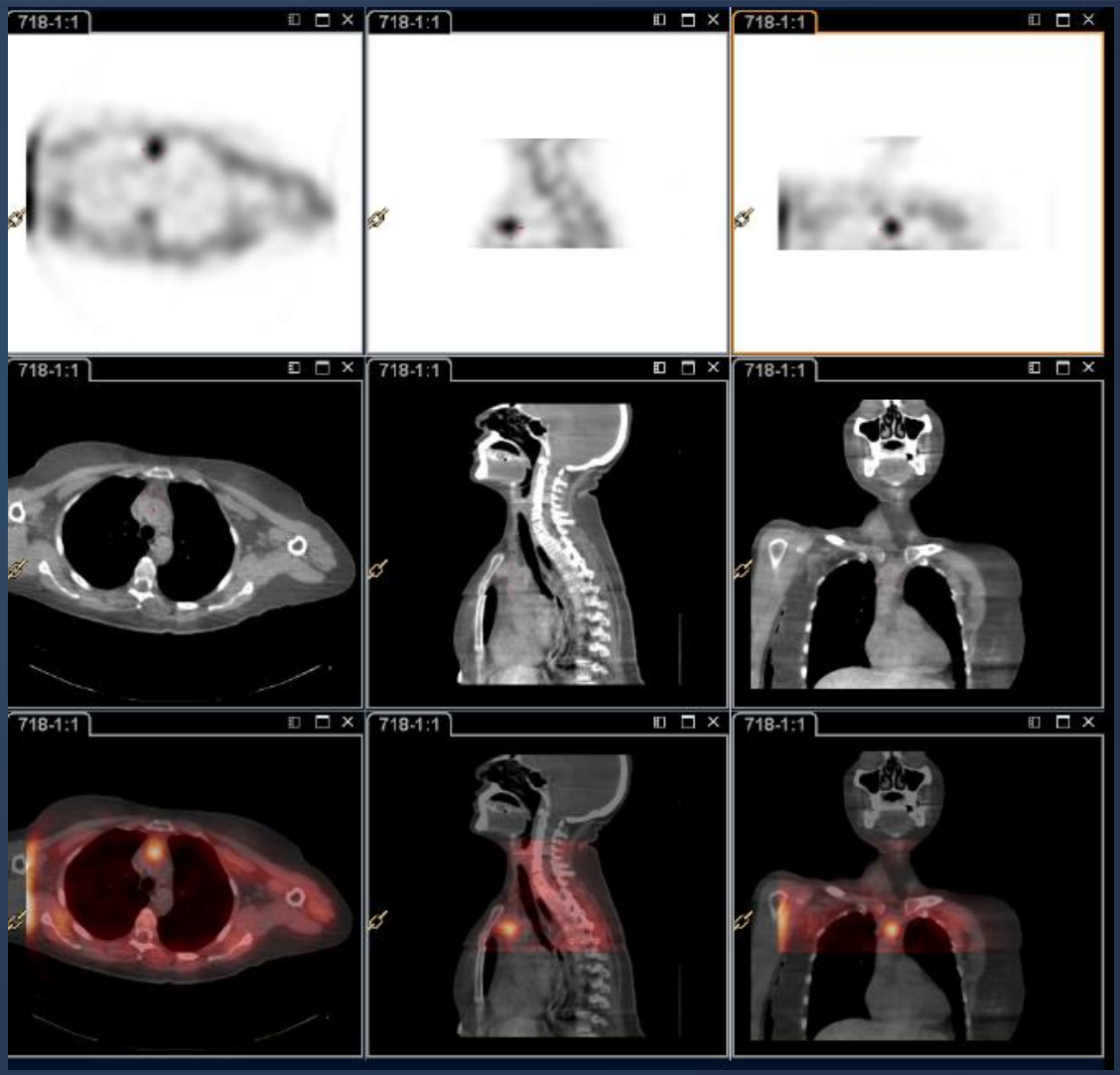
## PLANAR vs SPECT/CT



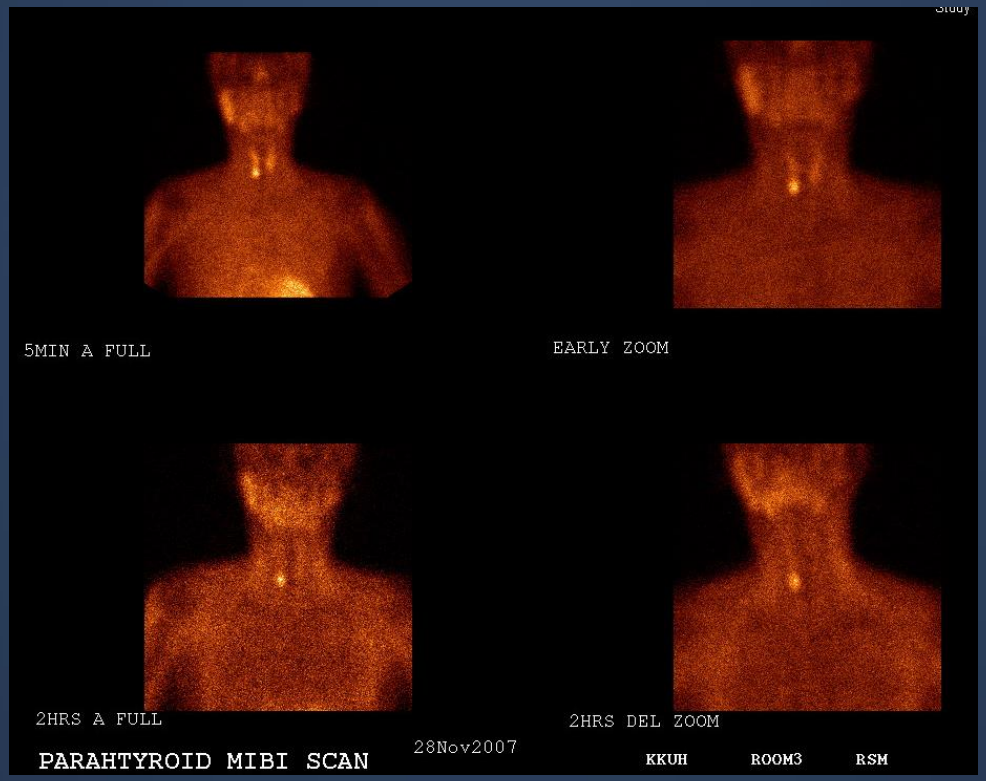

*SPECT-CT images accurately localize the adenoma and guide the surgeon to the best surgical approach*

# Ectopic parathyroid adenoma
# Antero-superior mediastinum



# Sestamibi Parathyroid Scan Result

## High PTH /High Ca




TP

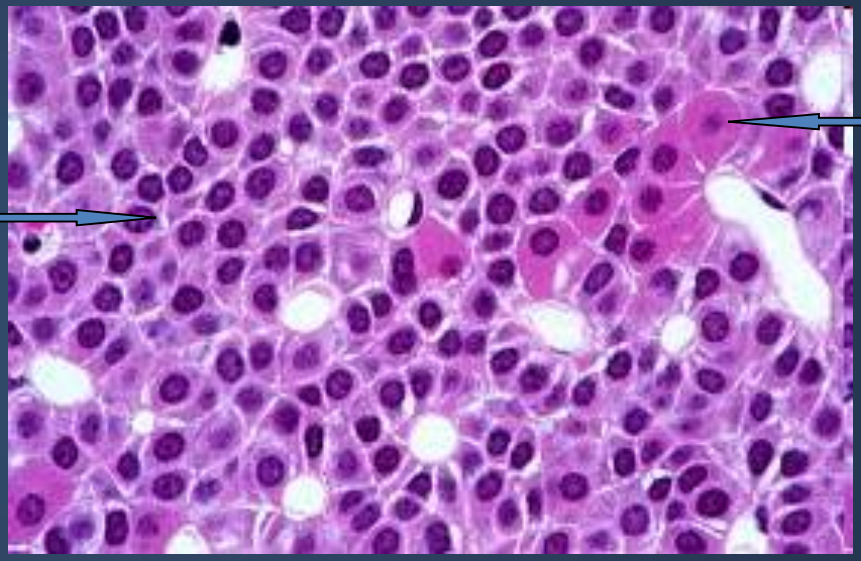
## High PTH / High Ca


FN

# Q:What is the cause of the FN result…?

A: Mechanism of sestamibi uptake

# Parathyroid Cells




**Normal parathyroid glands comprise 2 cell types:**

i. **Chief cells:** responsible for PTH production

ii. **Oxyphil cells:** eosinophilic cells whose cytoplasm is composed almost entirely of mitochondria.

***While the normal oxyphil cell does not synthesize and secrete PTH, the oxyphil cells of pathologic parathyroid glands do secrete the hormone.***

# Mechanism of Sestamibi uptake

**SESTAMIBI :** METHOXYISOBUTYLISONITRILE

- Its parathyroid uptake was first reported by Coakley et al. in 1989
- Mechanism of MIBI uptake and retention is still unclear. Multifactors have been proposed:

**a. Biochemical properties of the tracer :**

**Lipophilicity :** The lipophilic sestamibi molecule is concentrated by mitochondria. This explains why adenomas with an abundance of mitochondrial-rich oxyphil cells retain the sestamibi

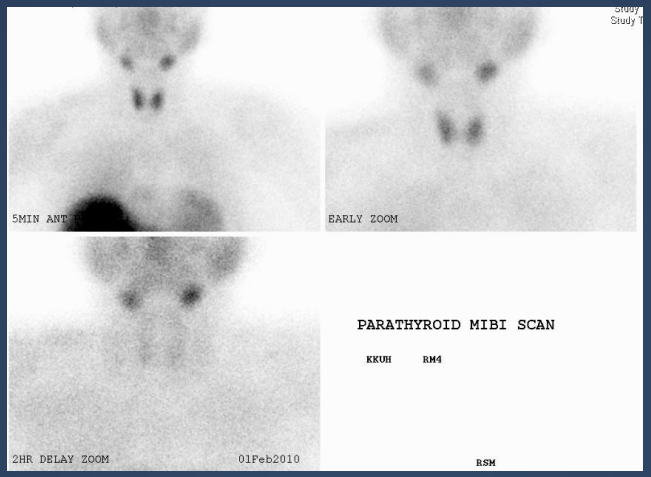
Cationic charge

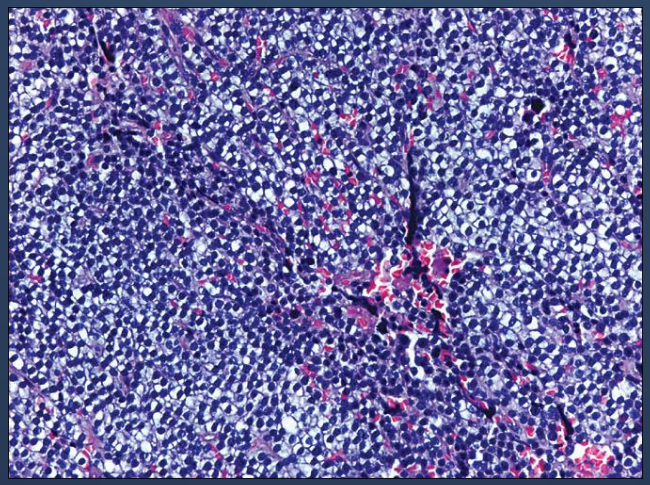
**b. Cell Type :** A predominance of oxyphil cells within an adenoma is more likely to lead to a positive scan.

**c. Local factors:** blood flow, trans-capillary exchange, interstitial transport and negative intracellular charge of both mitochondria and membranes.

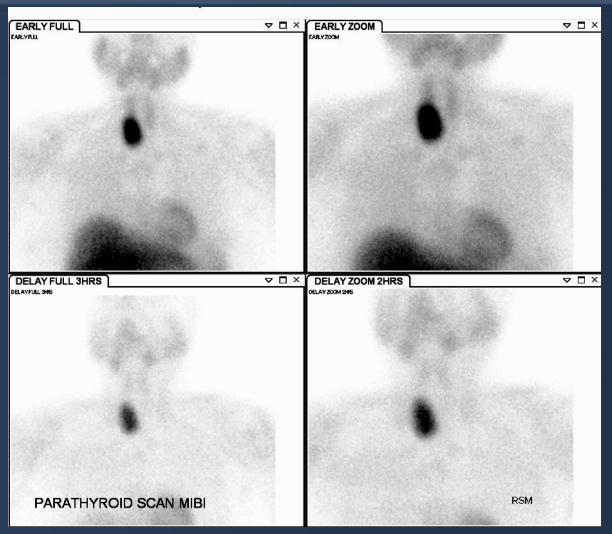
*J Nucl Med. 1990; 31: 1166-1167.*

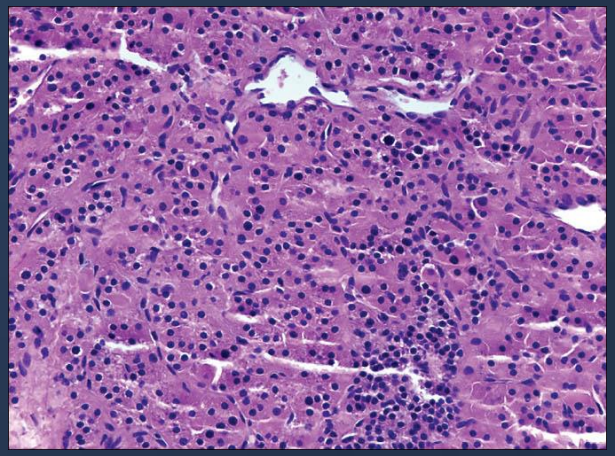
# Cell Type and Scan Result



Parathyroid adenoma composed entirely of glycogen-rich chief cells.



Parathyroid adenoma composed mainly of mitochondrial-rich oxyphil cells.

# Q

**What is the cause of the**

**FN result…?**

# "FN" Sestamibi Scan…?

- **Histologic type :** False-negative scans can occur with parathyroid glands containing predominantly clear cells.
- **Size and Location:** Smaller-volume parathyroid adenomas and those in the upper position are less likely to be localized with sestamibi scans.
- **Number of adenomas:** FN rate is increased with MGD compared with patients with a single adenoma .
- **Decreased tracer concentration :** Possible association.
  a. P-glycoprotein expression
  b. Multidrug resistance–related protein expression
- **Variability of radiotracer uptake in parathyroid adenomas:** Related to differences in perfusion and metabolic activity

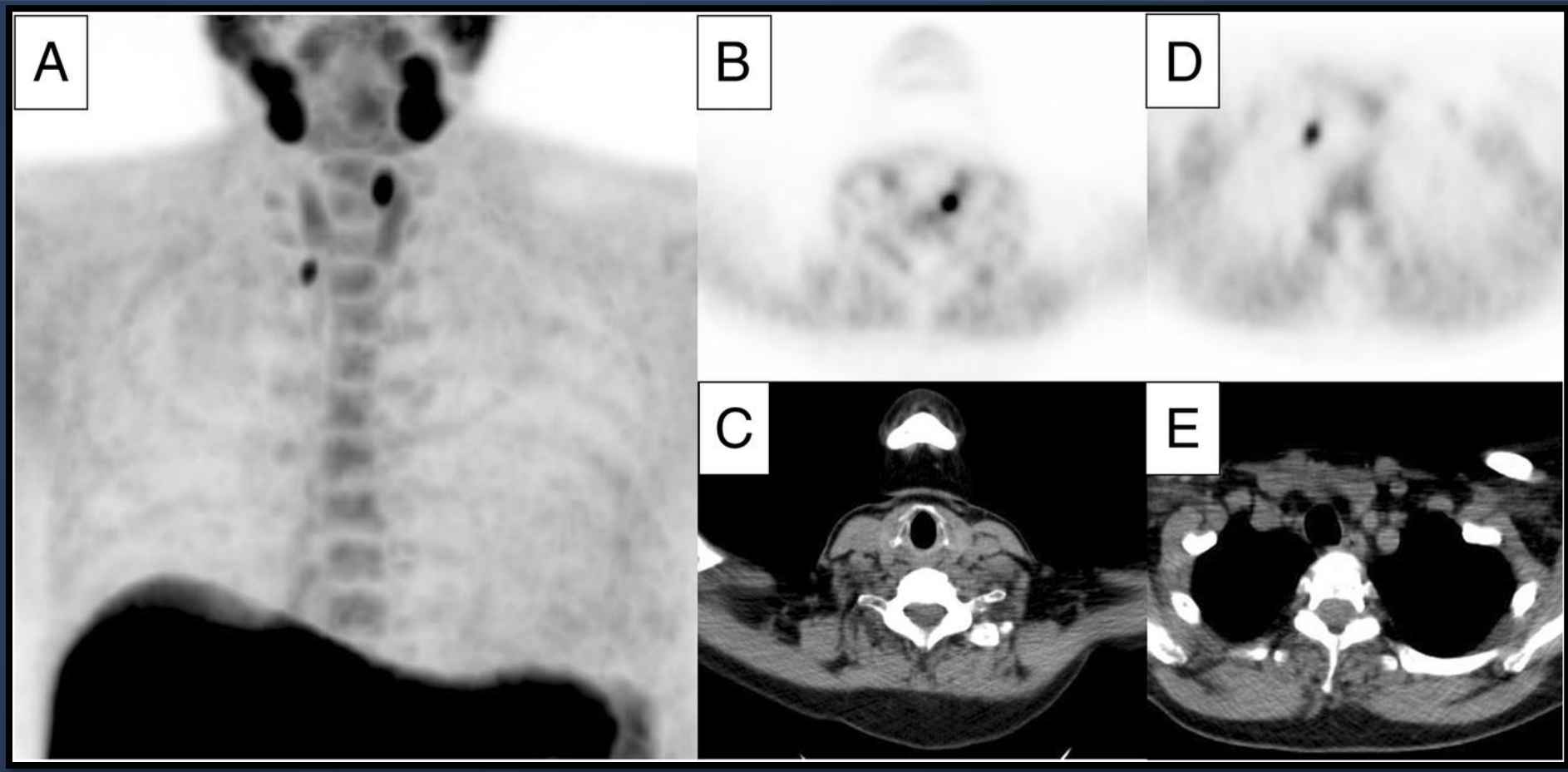
***Even with refinements in sestamibi scanning, the fact that all parathyroid adenomas are not created equal on a cellular level may inevitably lead to FN scans in a certain number of cases.***

*Arch Surg.* 2007;142(4):381-386.

# New Tracer For Parathyroid Imaging

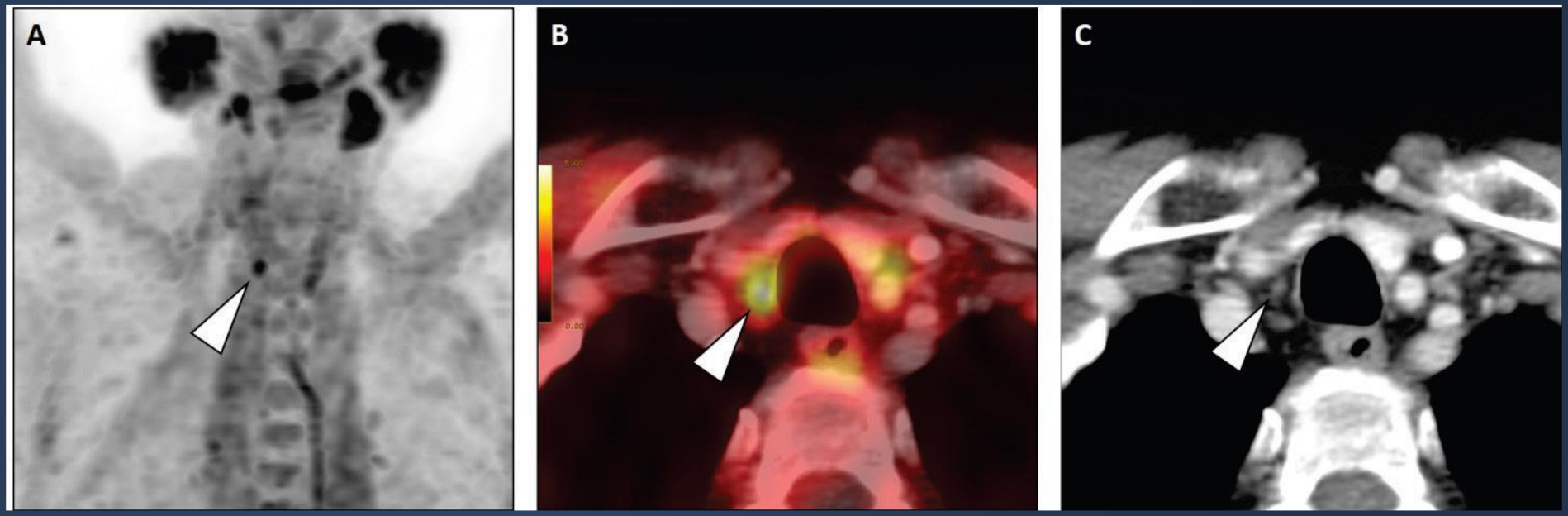
**$^{18}$F-fluorocholine PET/CT**

# $^{18}$F-fluorocholine PET/CT Parathyroid scan




**Double parathyroid adenoma (SESTAMIBI scan was negative)**

# $^{18}$F-fluorocholine PET/CT Parathyroid scan



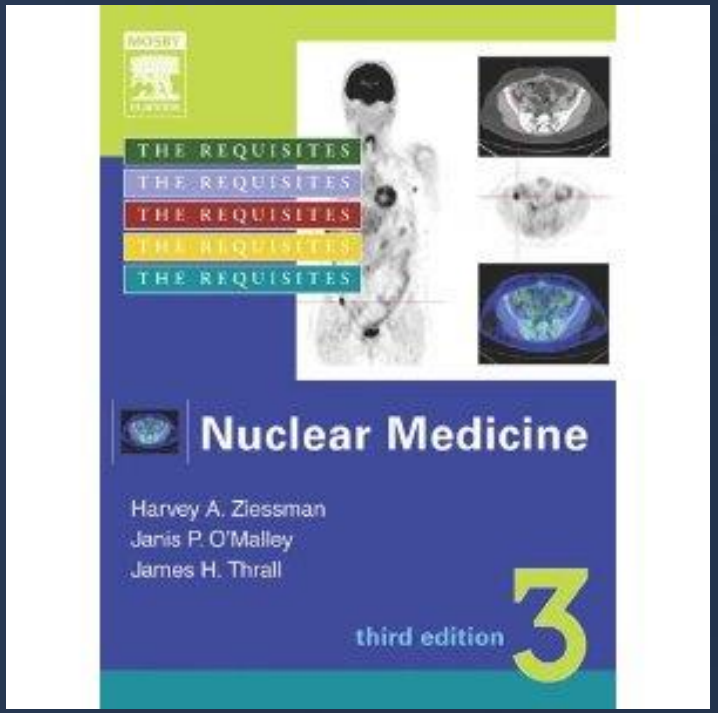

**Focal hyperactivity posterior to the right caudal pole of right thyroid lobe and, histologically confirmed as parathyroid adenoma.**

**Previous imaging by neck US and MIBI was inconclusive**

# 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 :***

**I- Thyroid and Parathyroid : 71-105**

**II- Oncology : 264-274 , 279 -283 ,302 -345 ,119-133**

**109 -112 ,296 -299**