Thyroid and Parathyroid Imaging

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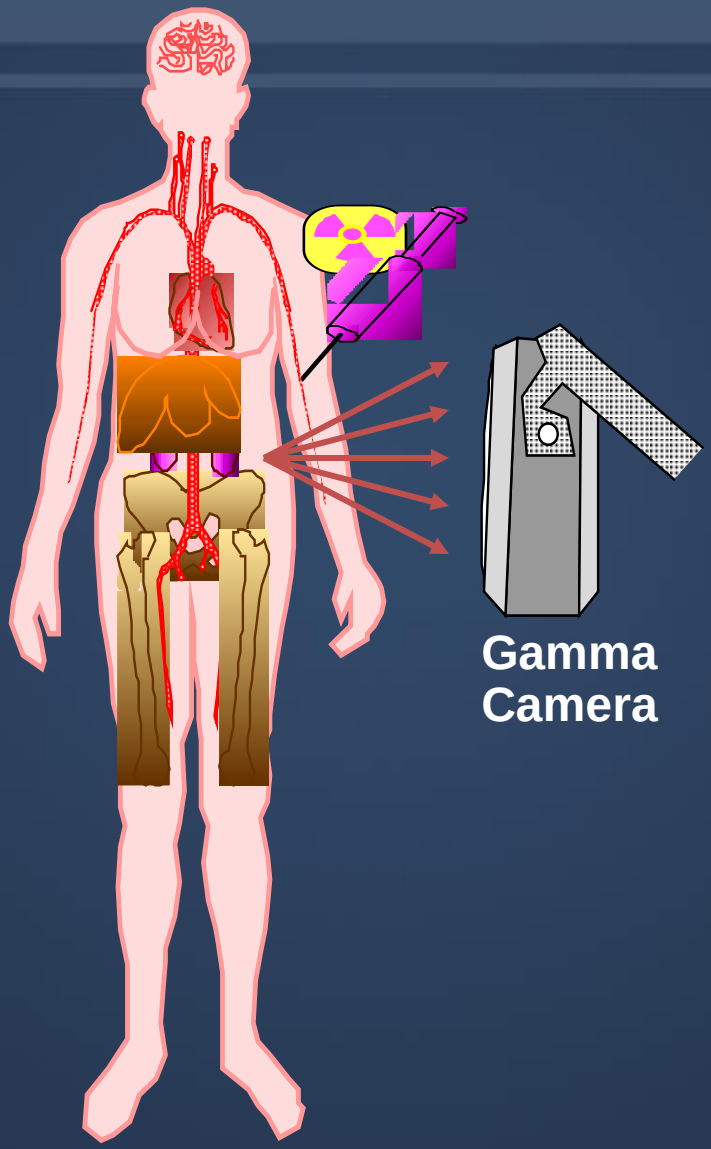
Nuclear Medicine Procedure



- *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

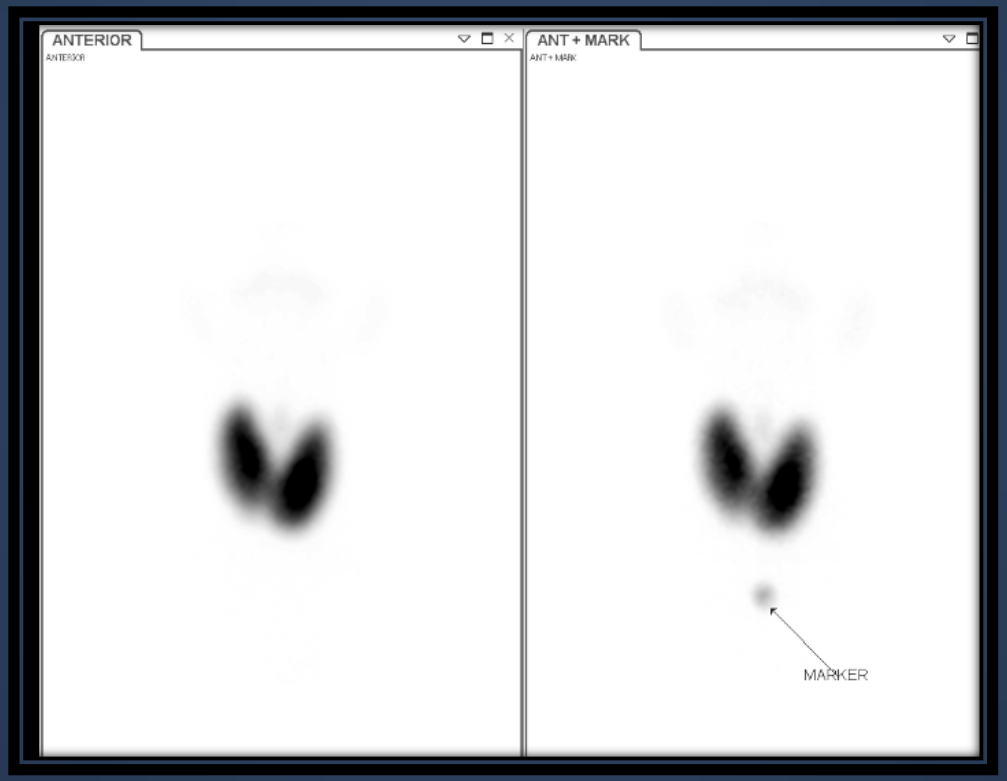
- **I131 OR I-123 RAIU (4 & 24 hours) :**

  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

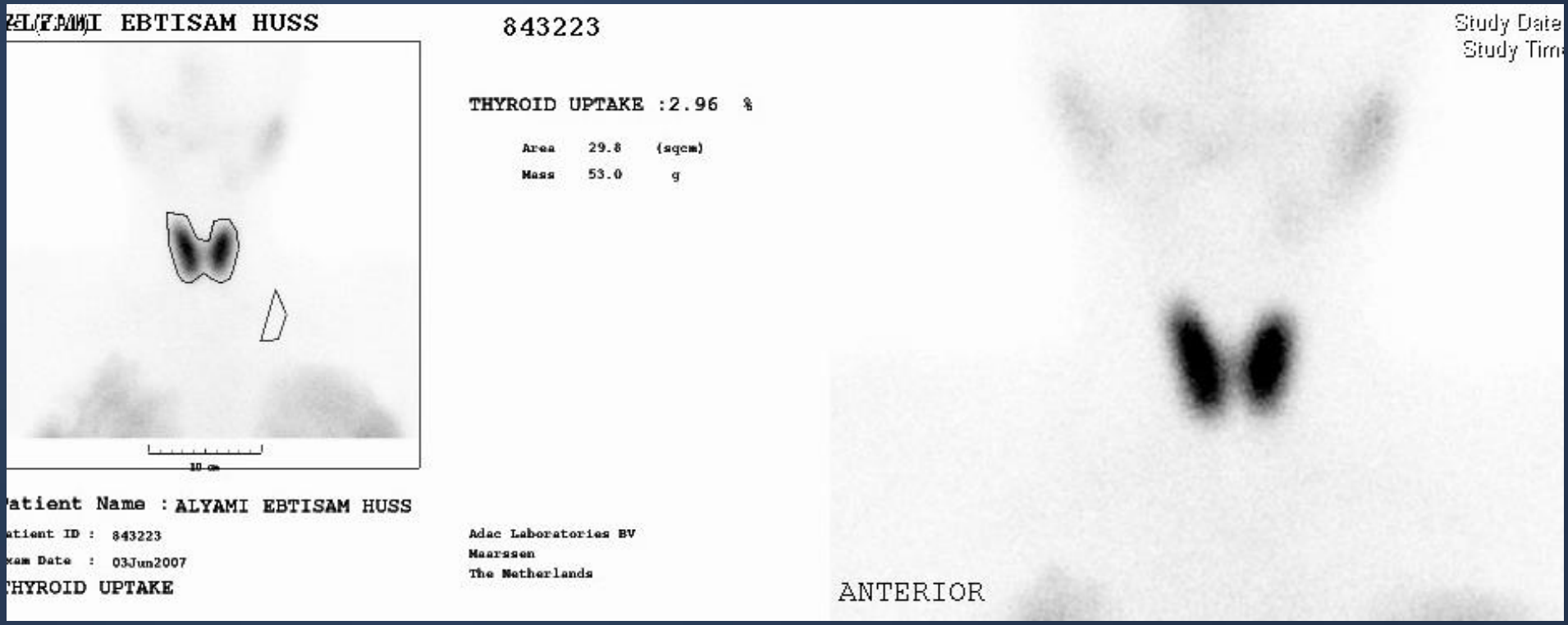


- **Hyperthyroidism :** Grave's Disease or TSH-secreting pituitary adenoma
- **Autonomous toxic nodule**
- **Multinodular toxic goiter** (Plumer's Disease)
- **Enzyme defects :** Dyshormonogenesis.
- **Iodine starvation** (Iodine deficiency)
- **Lithium Therapy**
- **Recovery phase of thyroiditis.**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

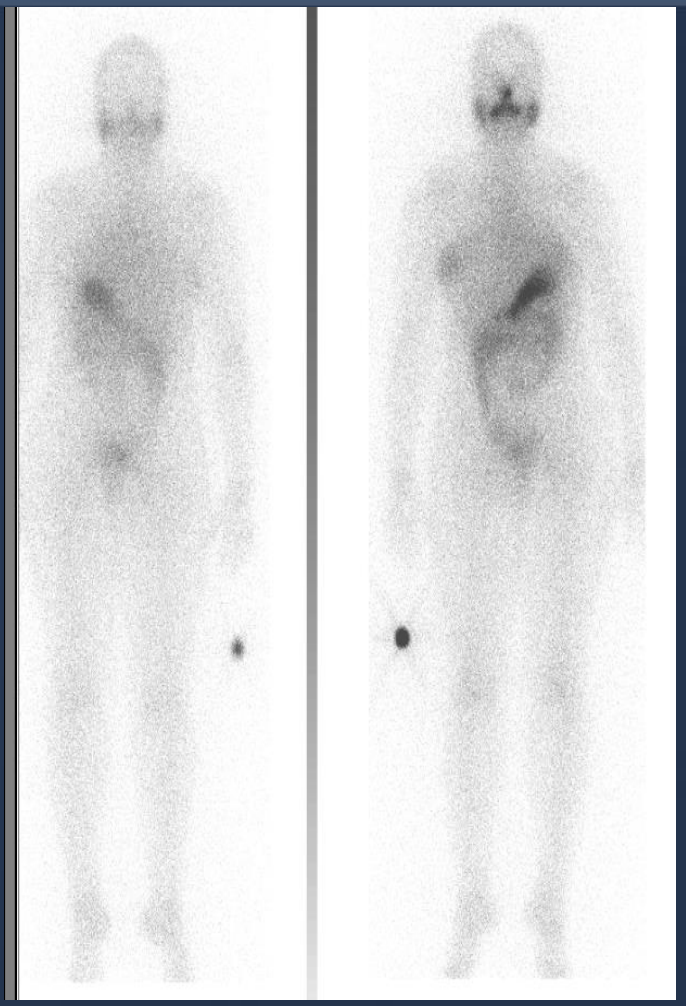
- The patient should be NPO for at least 4 hours prior to radiopharmaceutical administration and for at least 1 hour afterwards

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

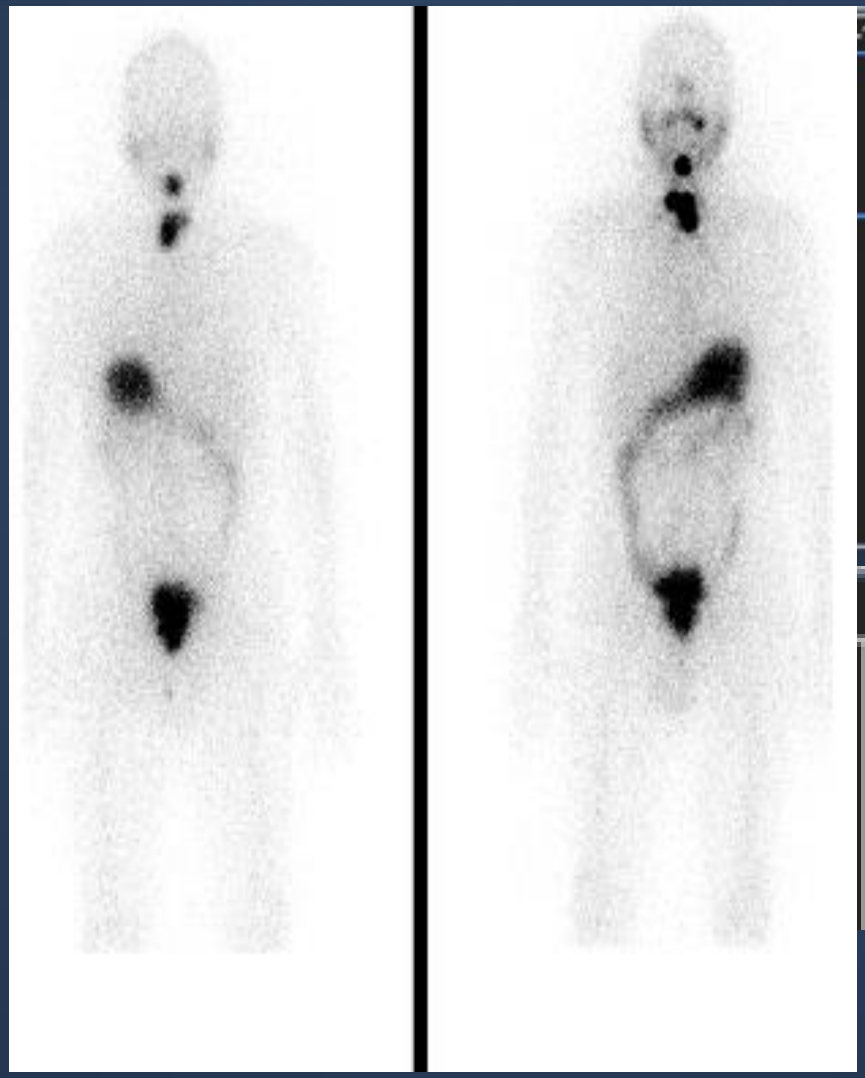
Imaging using Gamma camera : Whole body scan

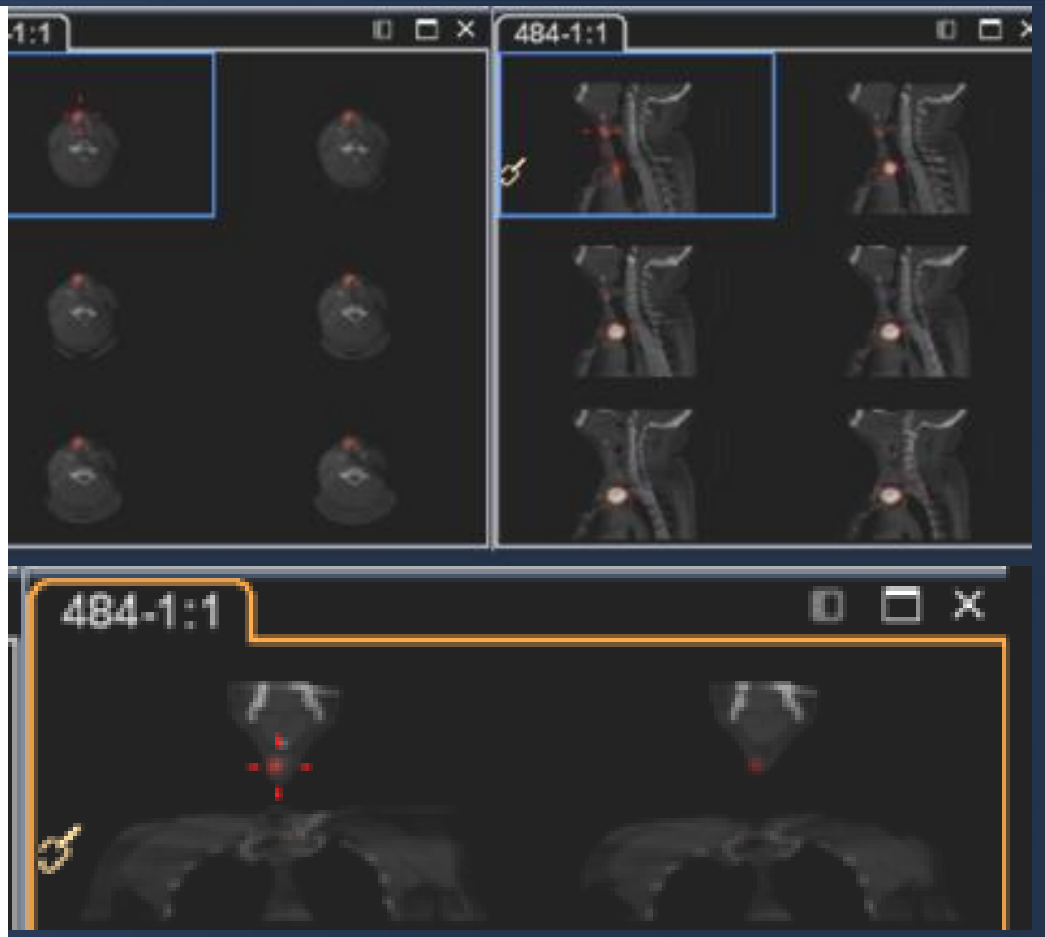


Negative WBS

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

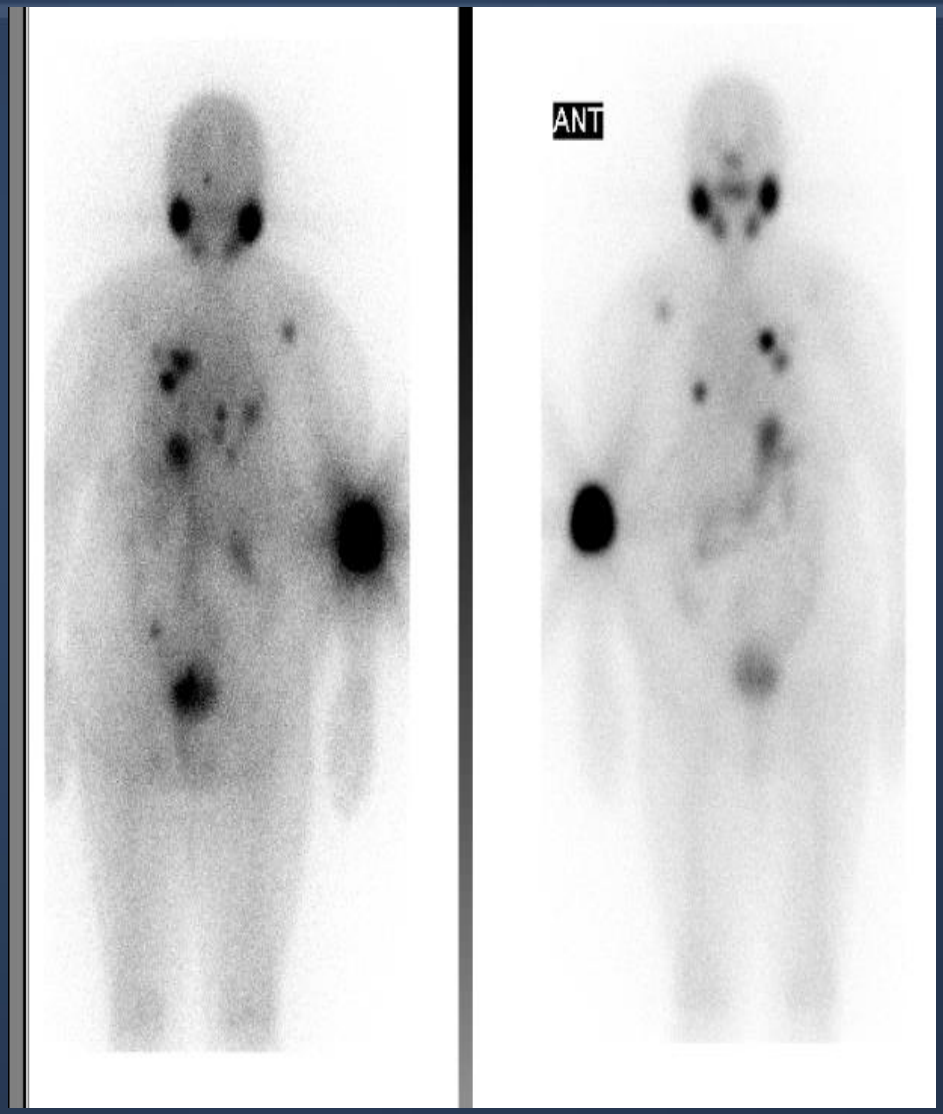
Planar Vs SPECT CT





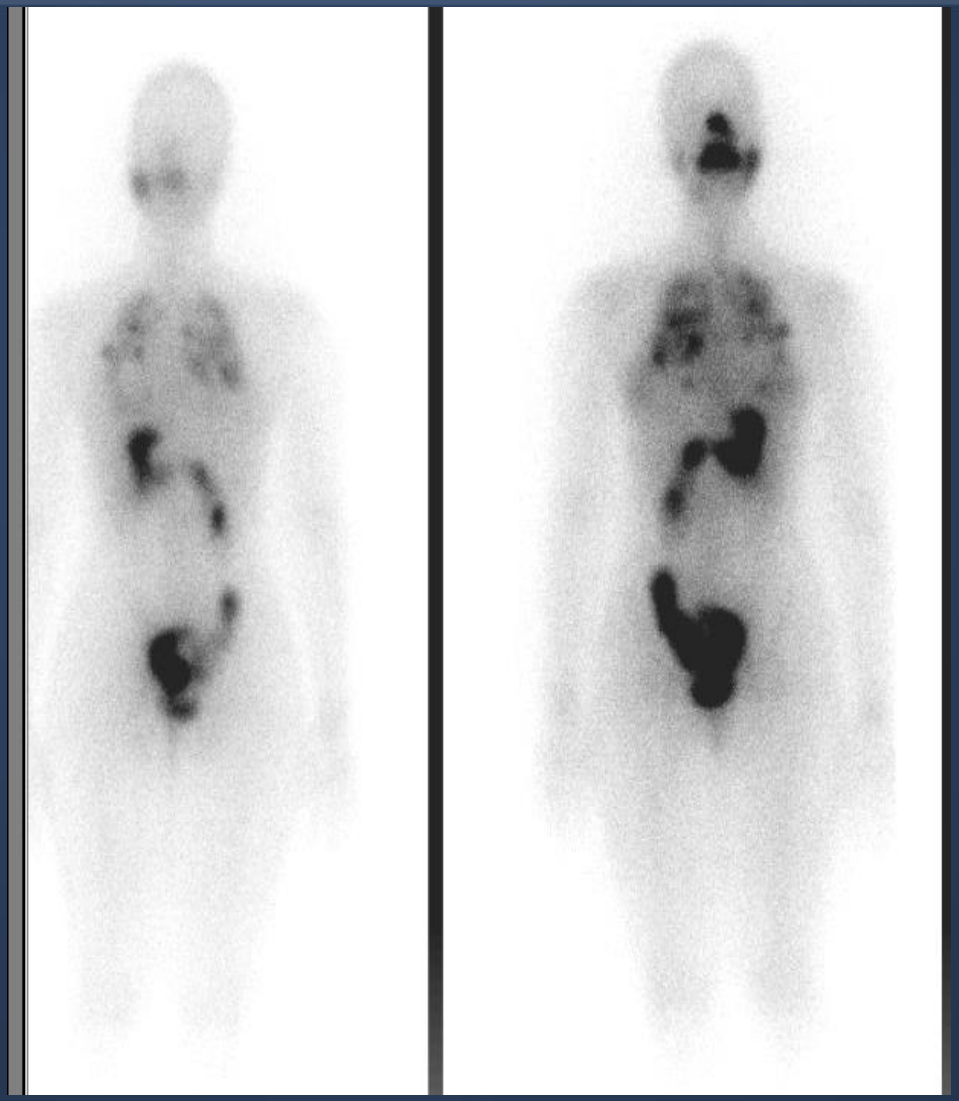
Local Recurrence

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



Bone Metastases

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



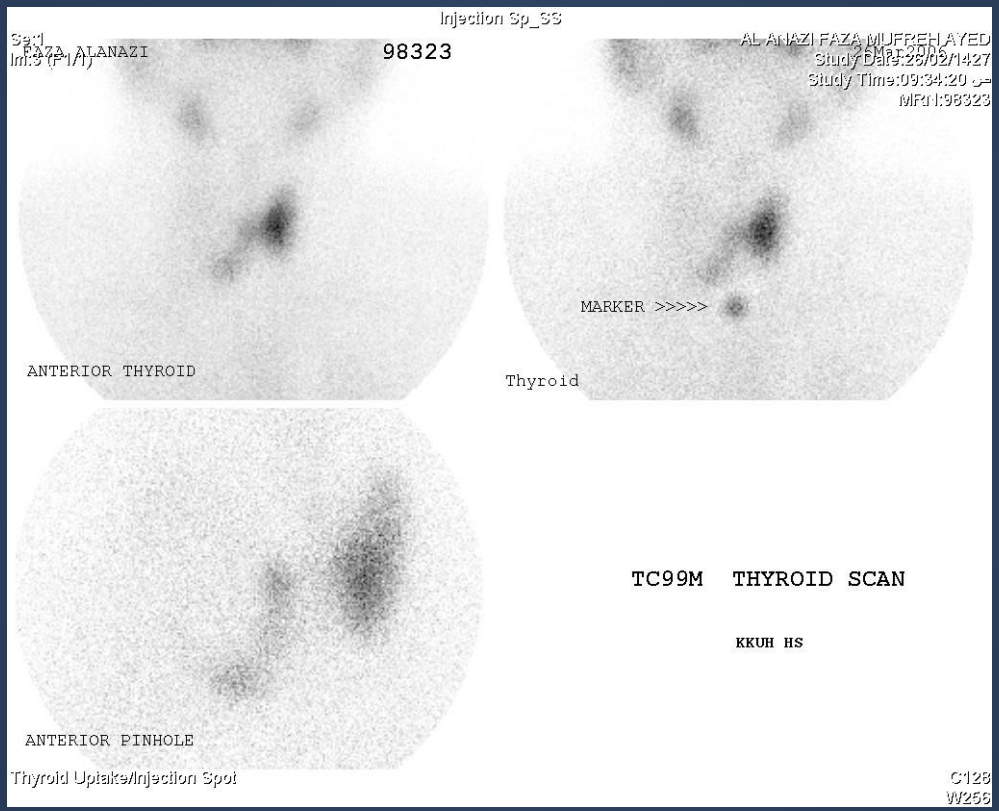
Lung Metastases

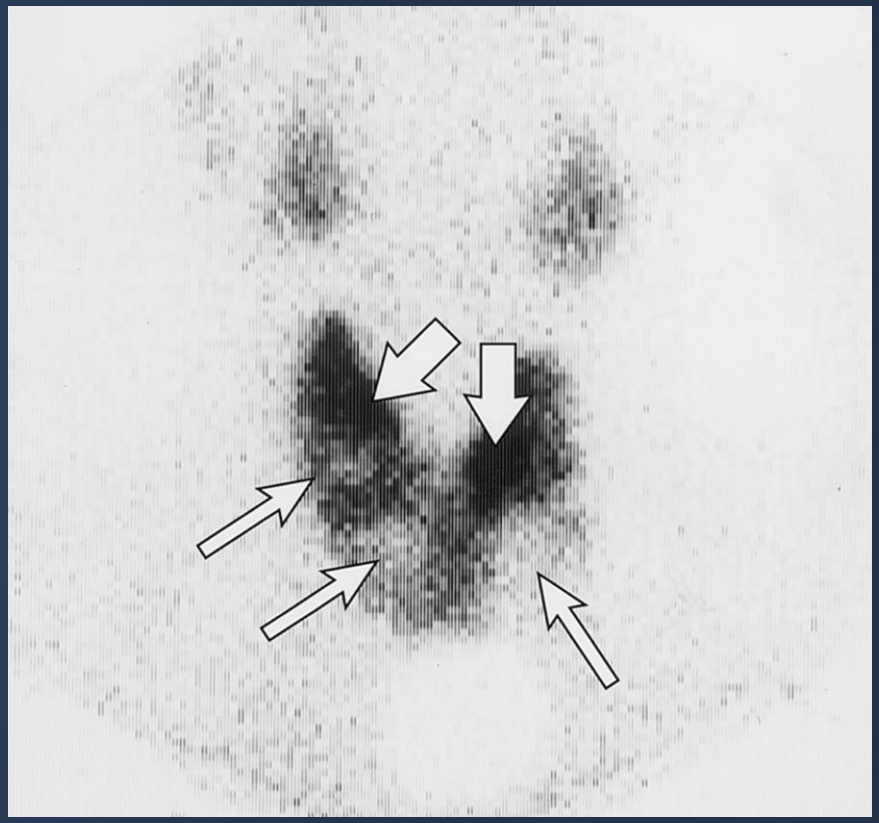
When is thyroid scanning helpful?
Indications for Thyroid Scan

- 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





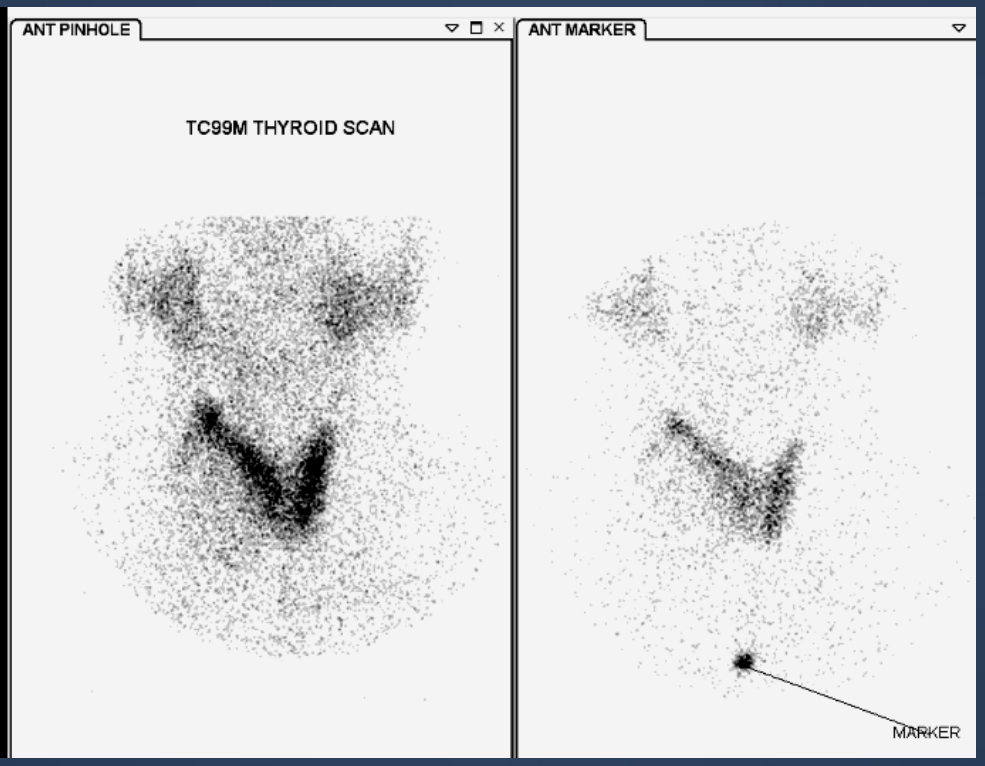
Solitary cold nodule

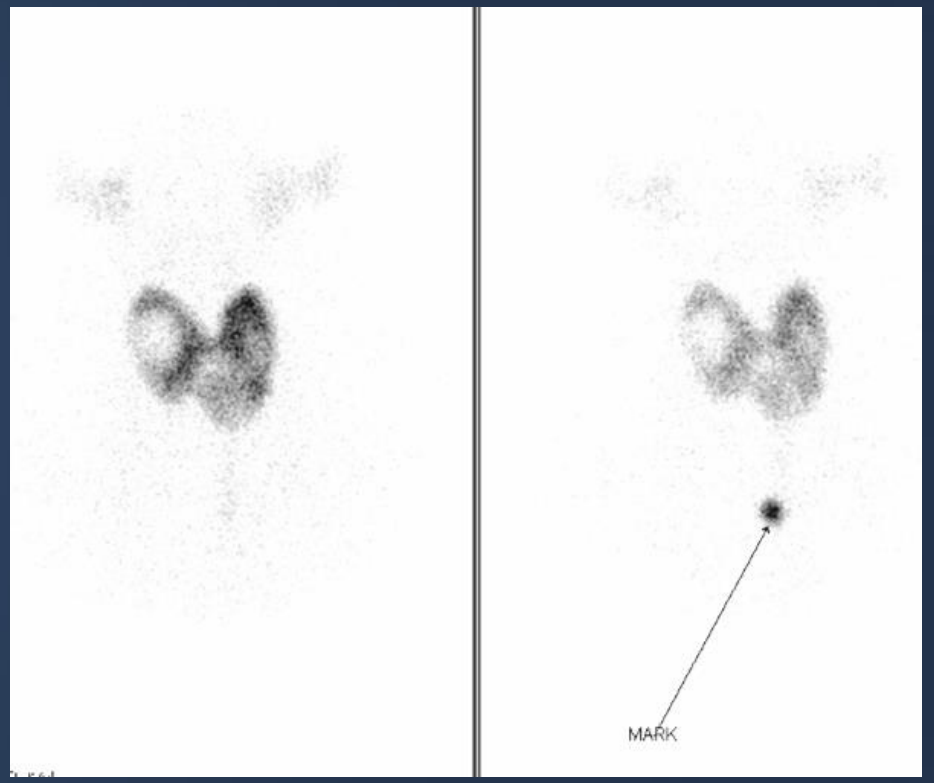
Multinodular goiter

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

Evaluation of thyroid nodules

Single vs MNG





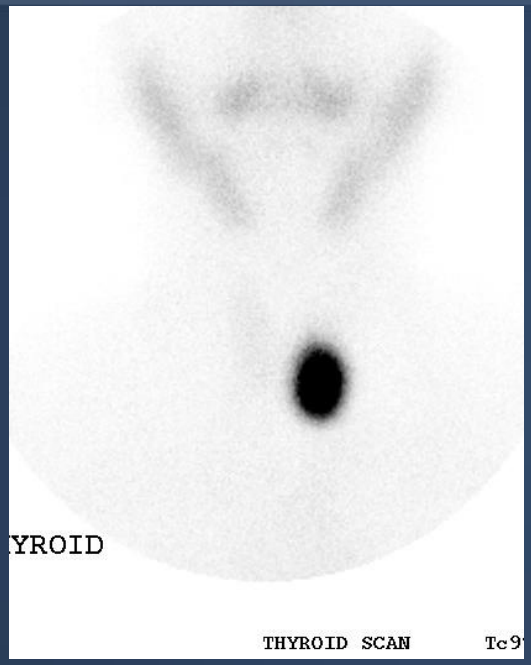
Solitary cold nodule

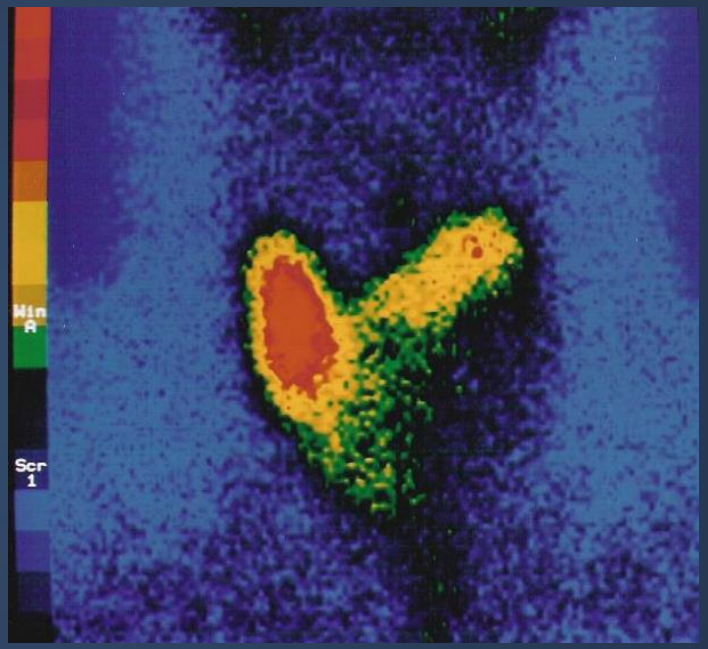
Multinodular goiter

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

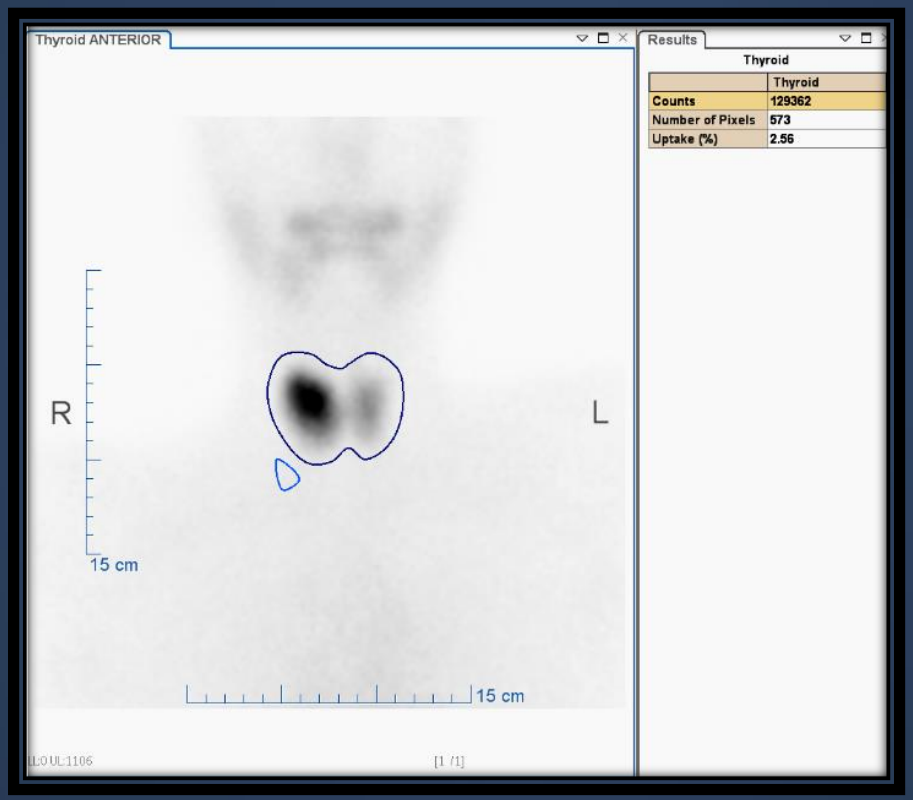
Cold

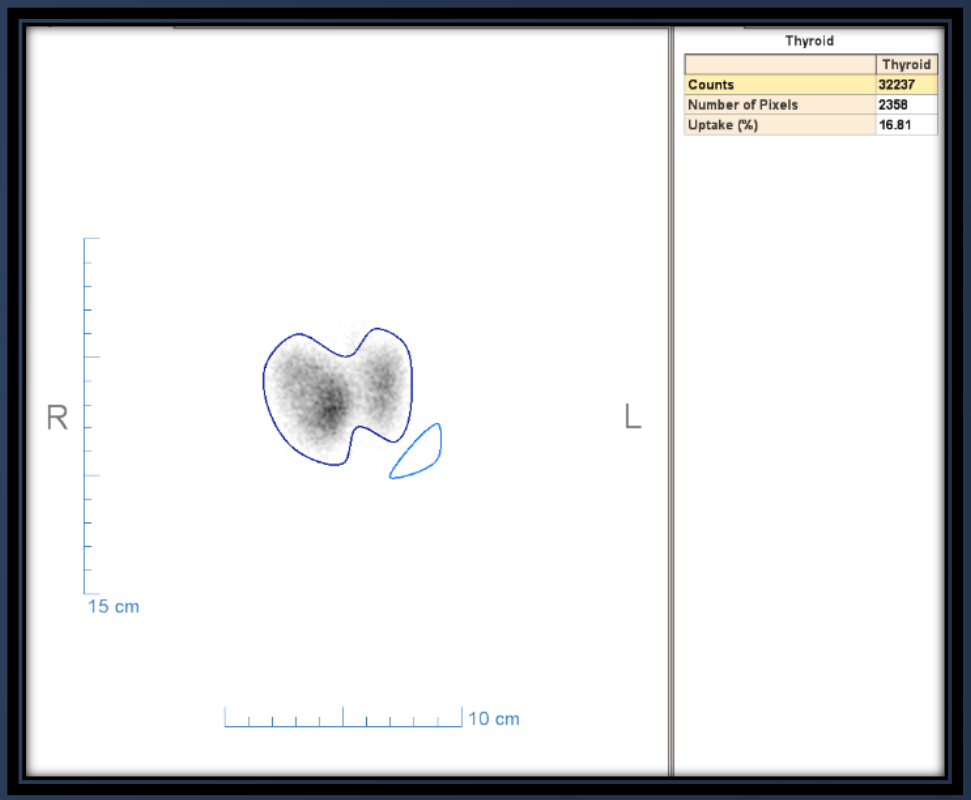
15-20% Malignant

warm

Suspicious

Discordance Tc –I123 Scan

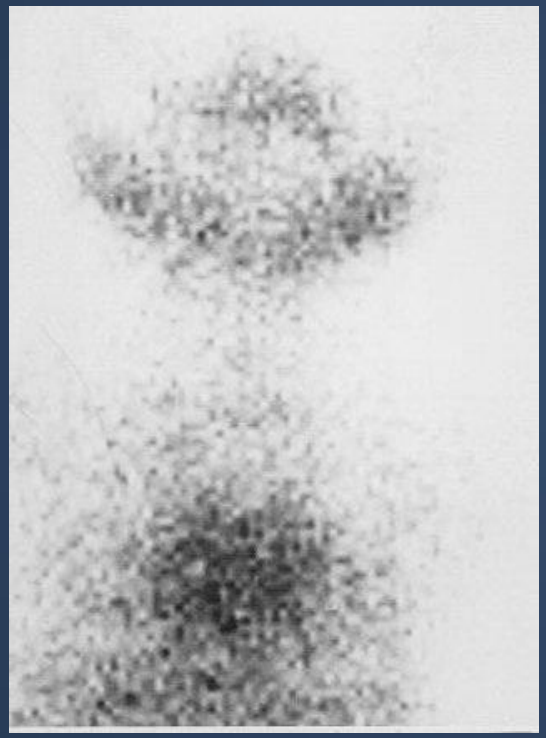




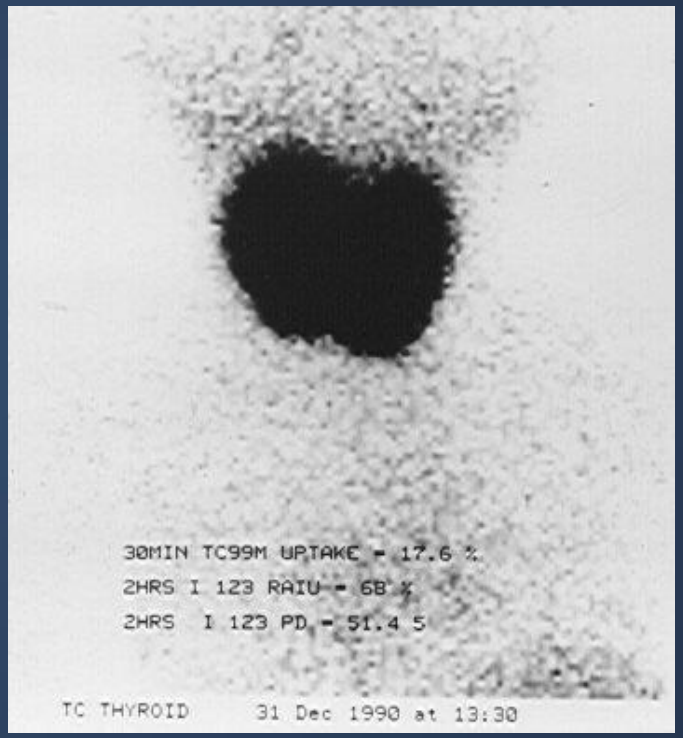
The chance of malignancy of a discordant nodule about 20%

Evaluation of congenital hypothyroidism

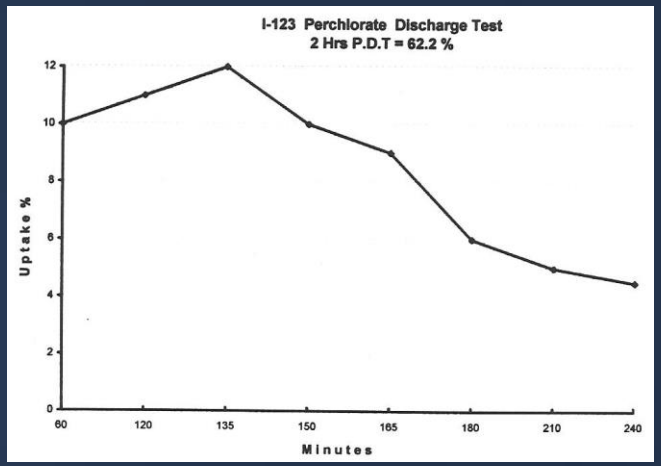
Agenesis vs Dyshormonogenesis



Agenesis



Dyshormonogenesis

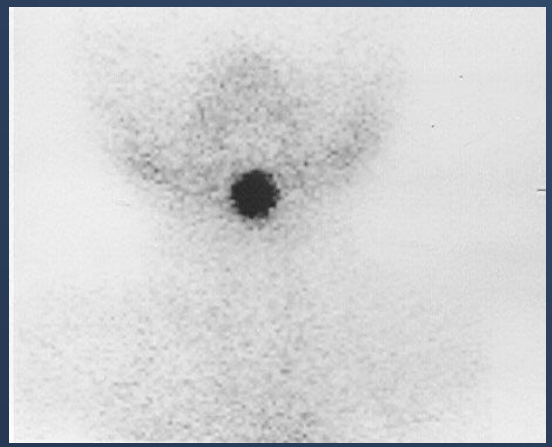


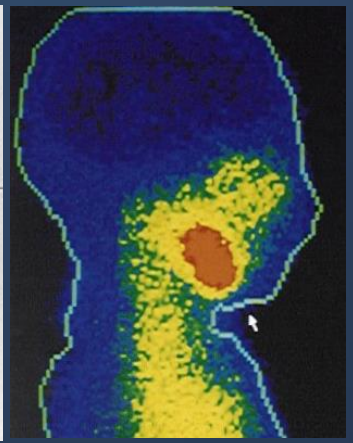
Perchlorate Discharge Test

- 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.

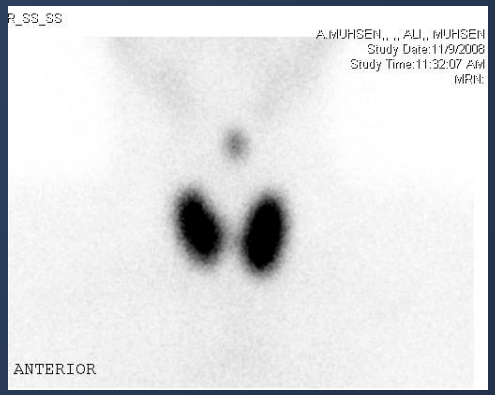
Evaluation of neck masses

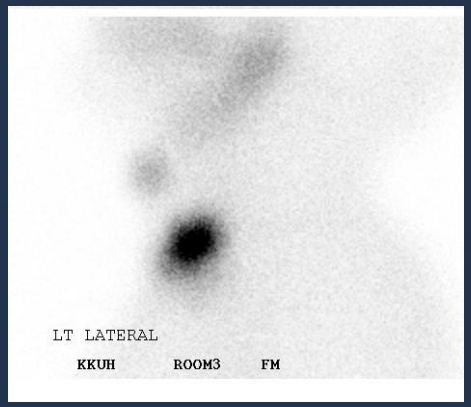
ectopic thyroid vs thyroglosal cyst





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 :

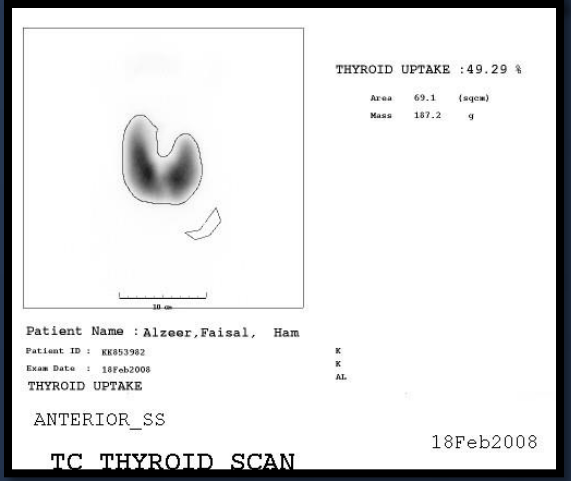
  MNTG or Plummers disease

  ATN or toxic adenoma
- Iodine induced

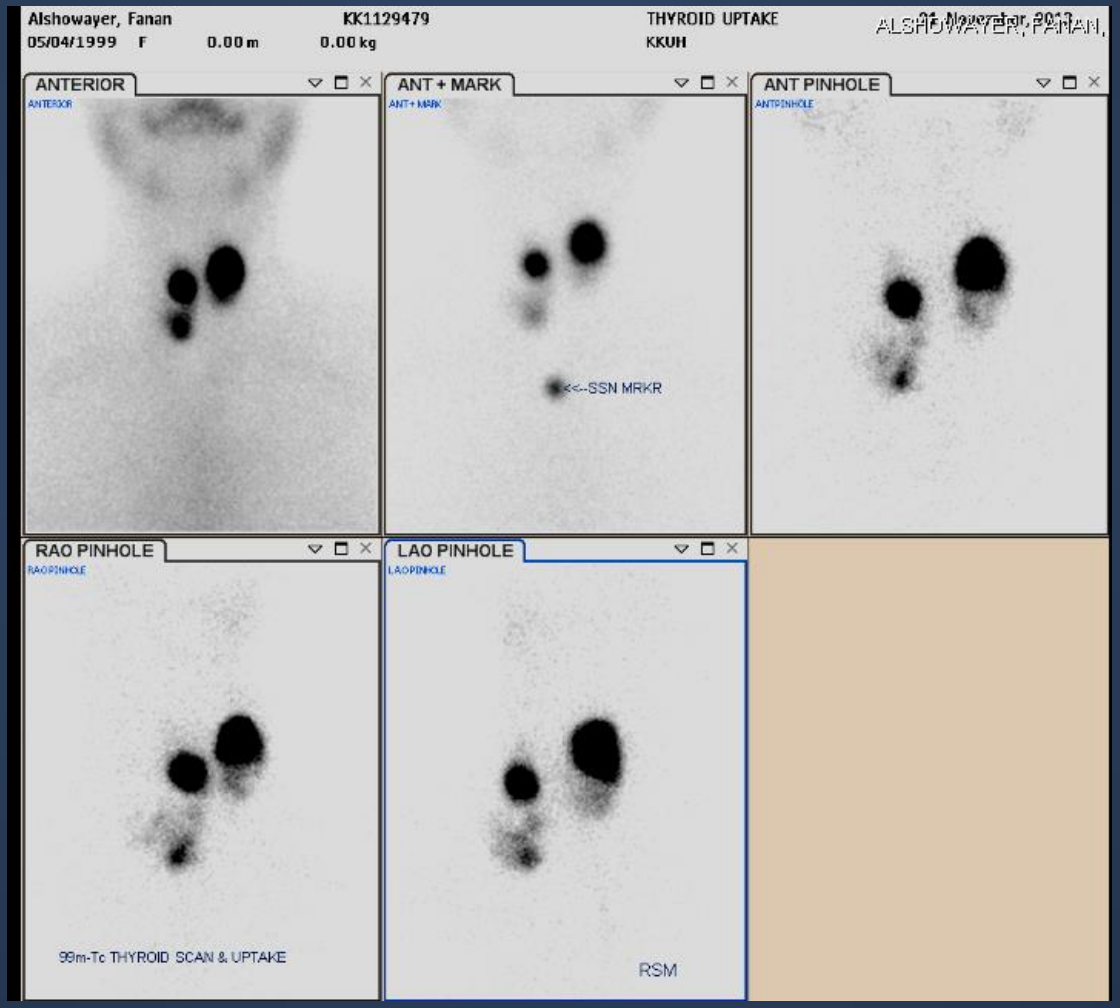
  (Jod-Basedow disease)
- Rare causes :

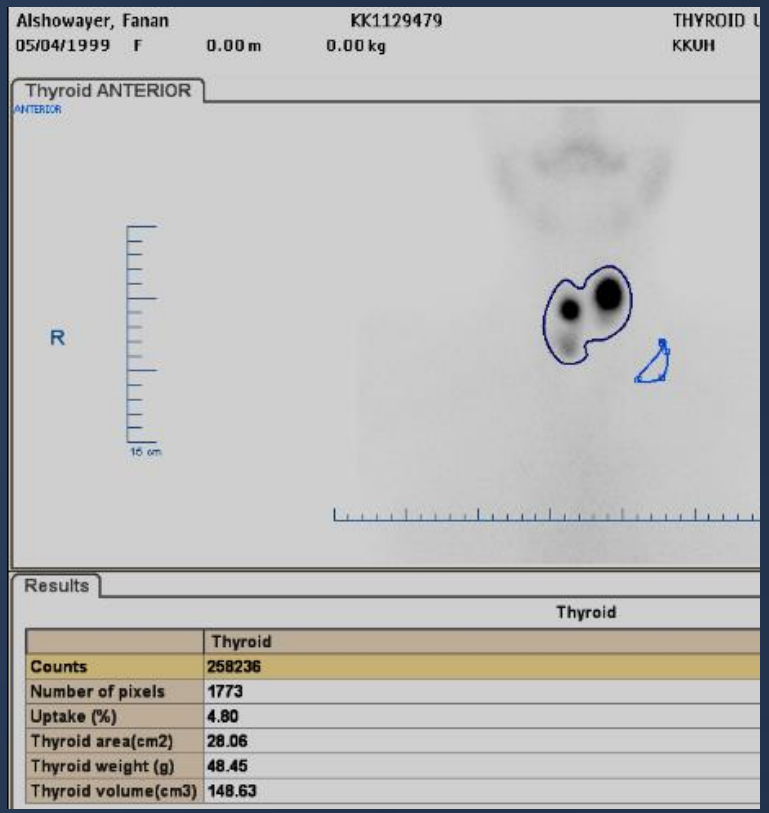
  Execssive HCG by trophoblastic tumor

  Hypothalamic pituitary neoplasms (TSH induced)



MNTG (Plummers Disease)



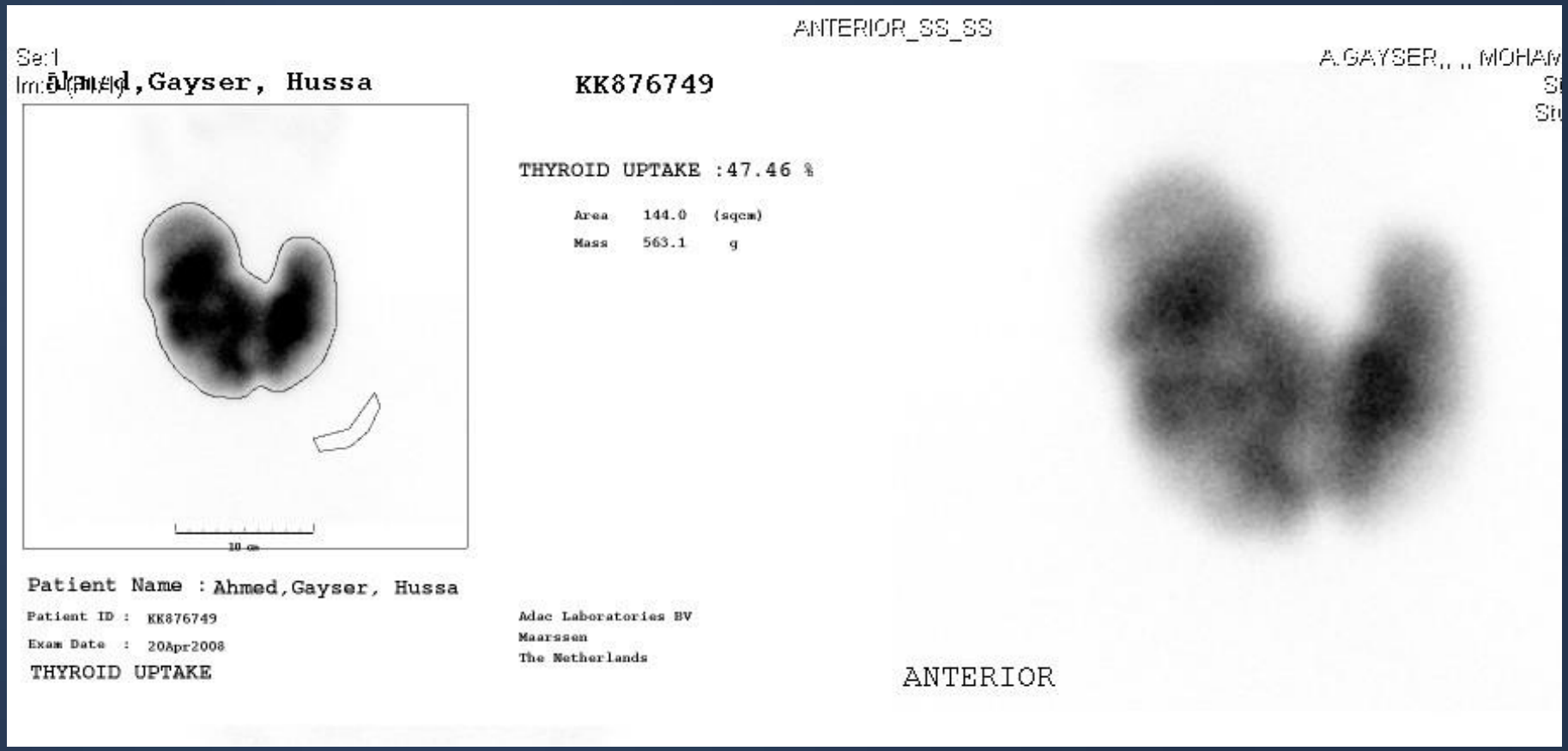


Results

	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

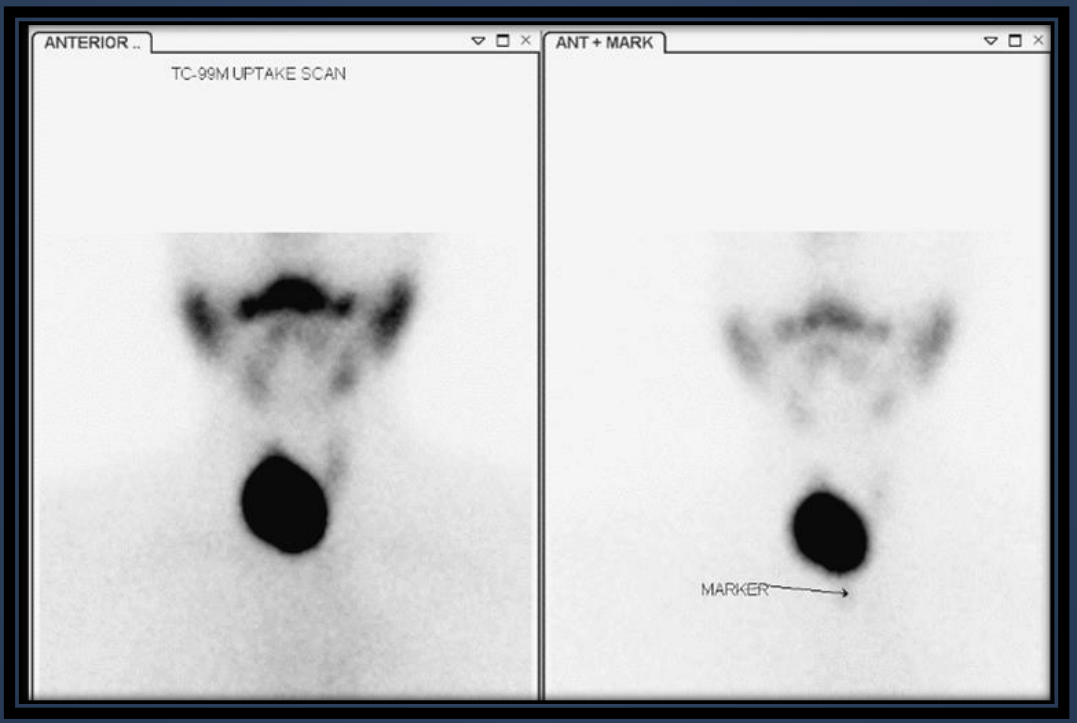


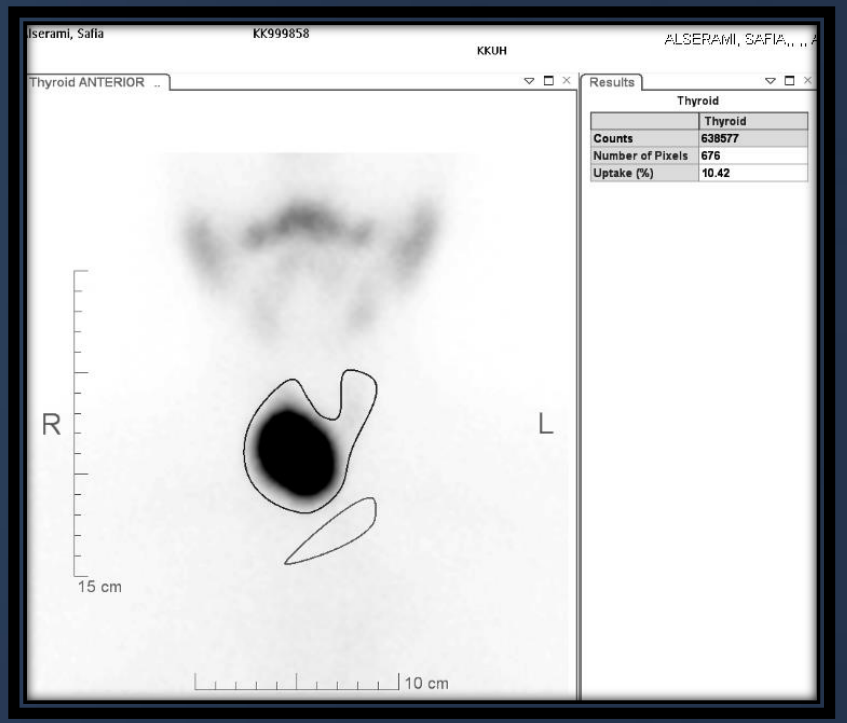
Graves' Disese on top of MNG

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

Evaluation of thyrotoxicosis

Thyrotoxicosis with hyperthyroidism





ATN

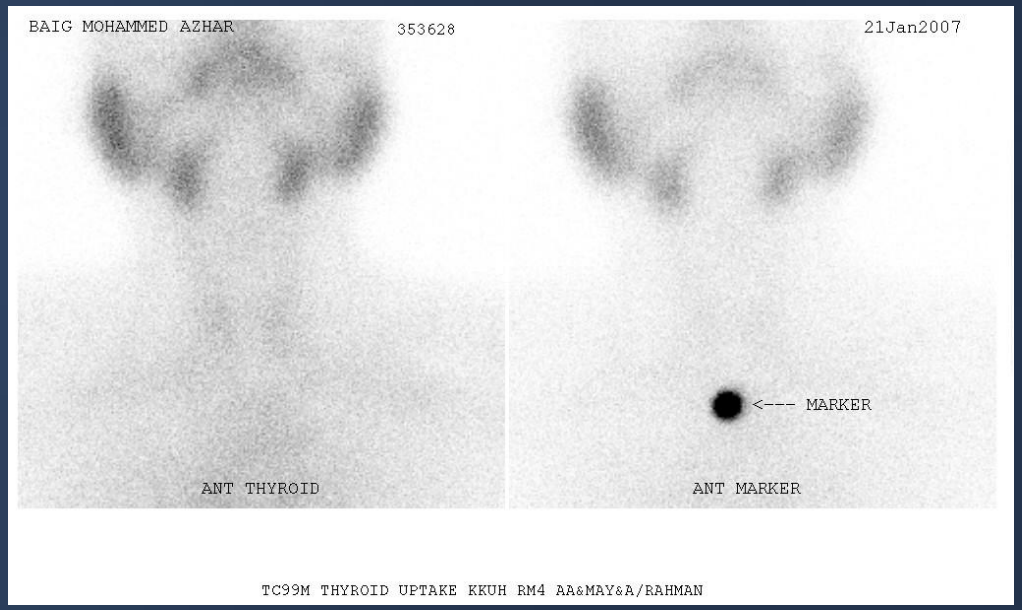
Evaluation of thyrotoxicosis

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

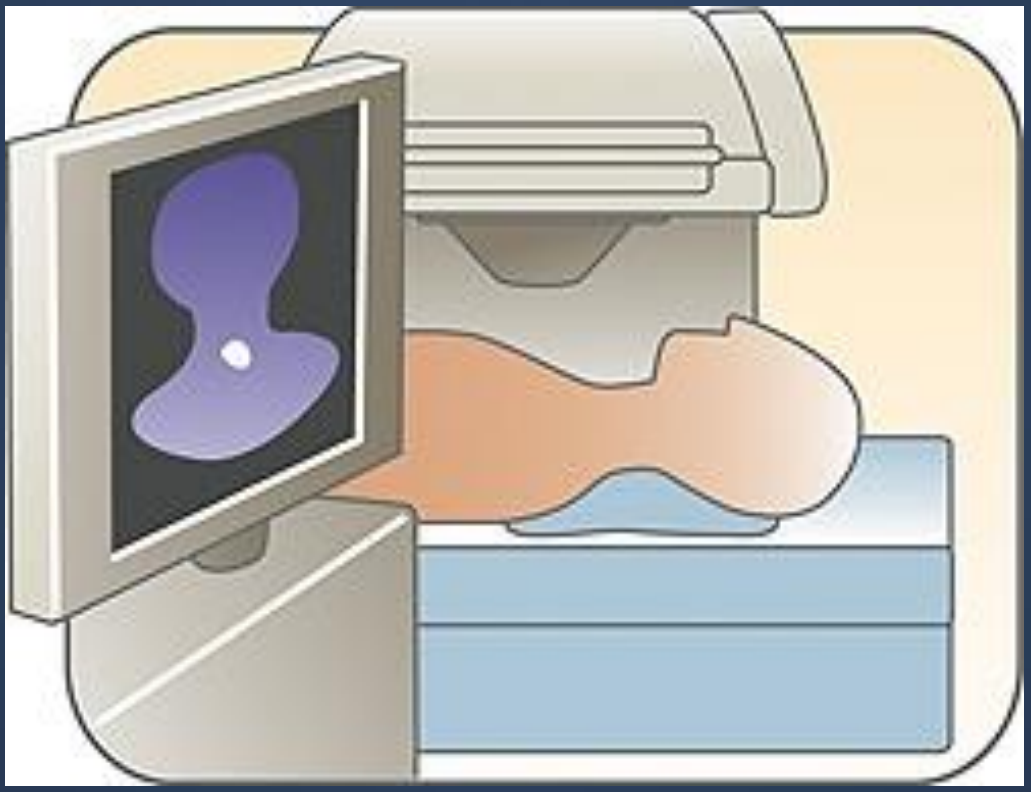
Radioactive Iodine Therapy for Thyroid Cancer

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



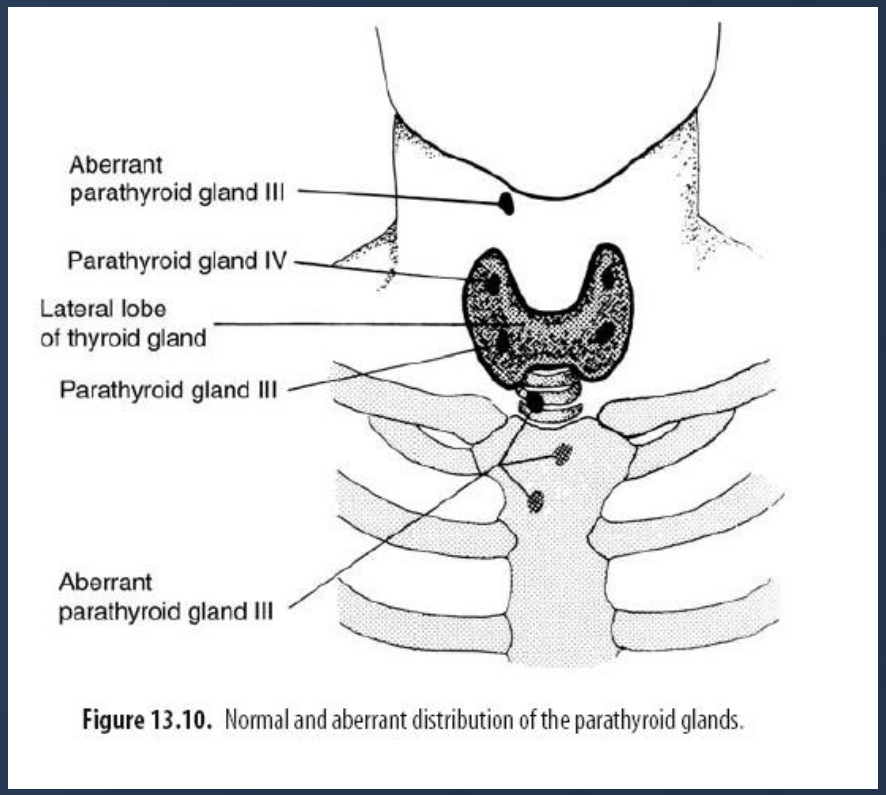


Figure 13.10. Normal and aberrant distribution of the parathyroid glands.

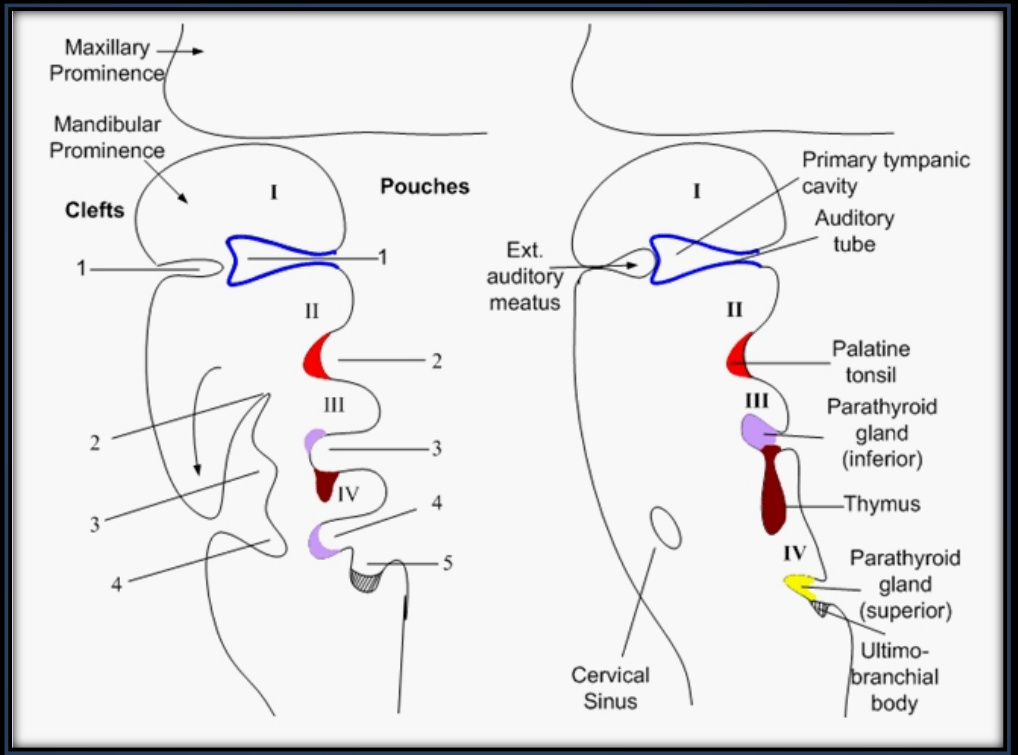
Parathyroid Scan

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



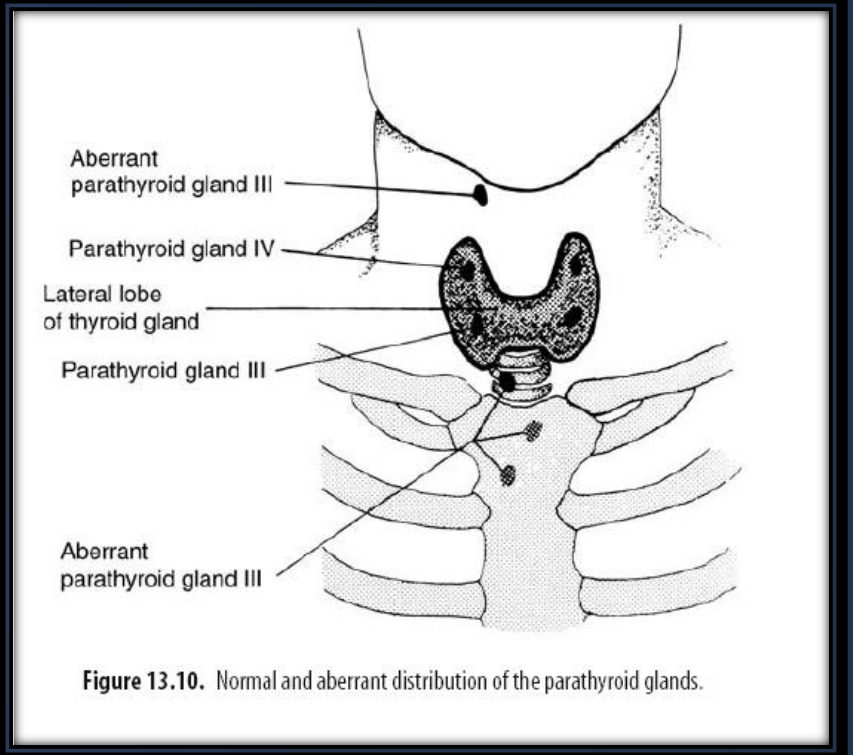


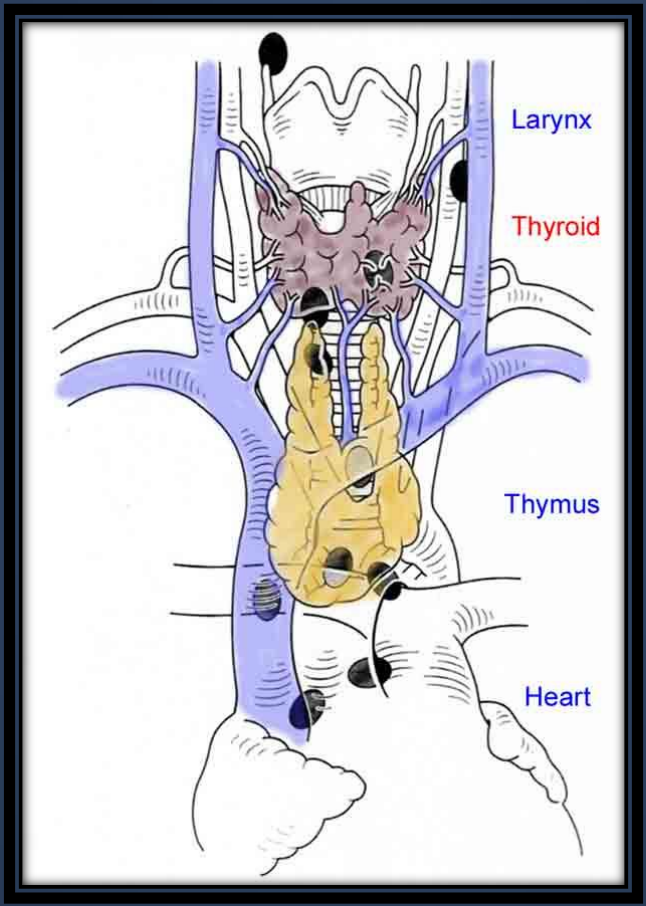
Figure 13.10. Normal and aberrant distribution of the parathyroid glands.

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; 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. Then acquire similar Tc images without moving patient. 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.

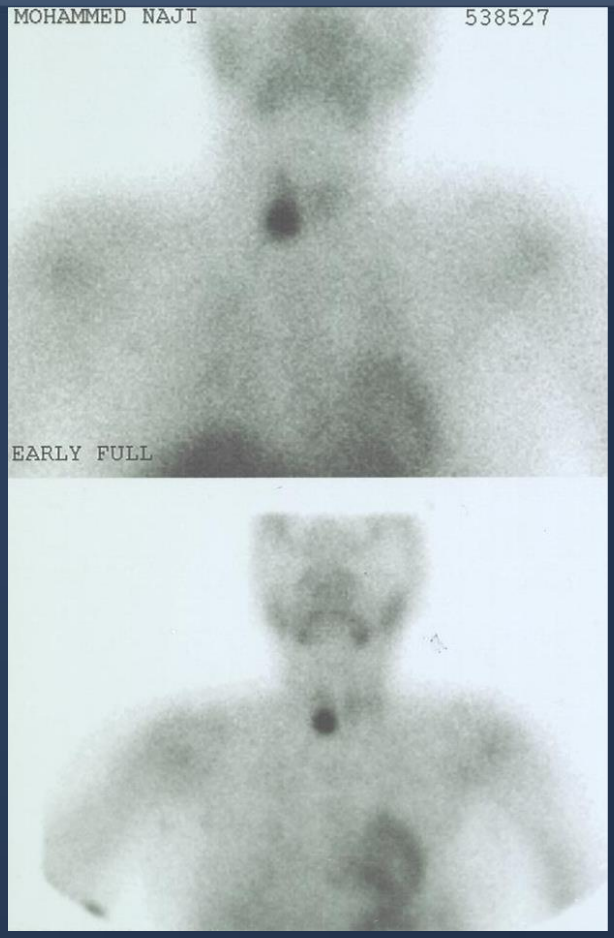
Acquire images at 15 minutes and 2-3 hours post injection.
SPECT/SPECT CT images improves localization.

- **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)

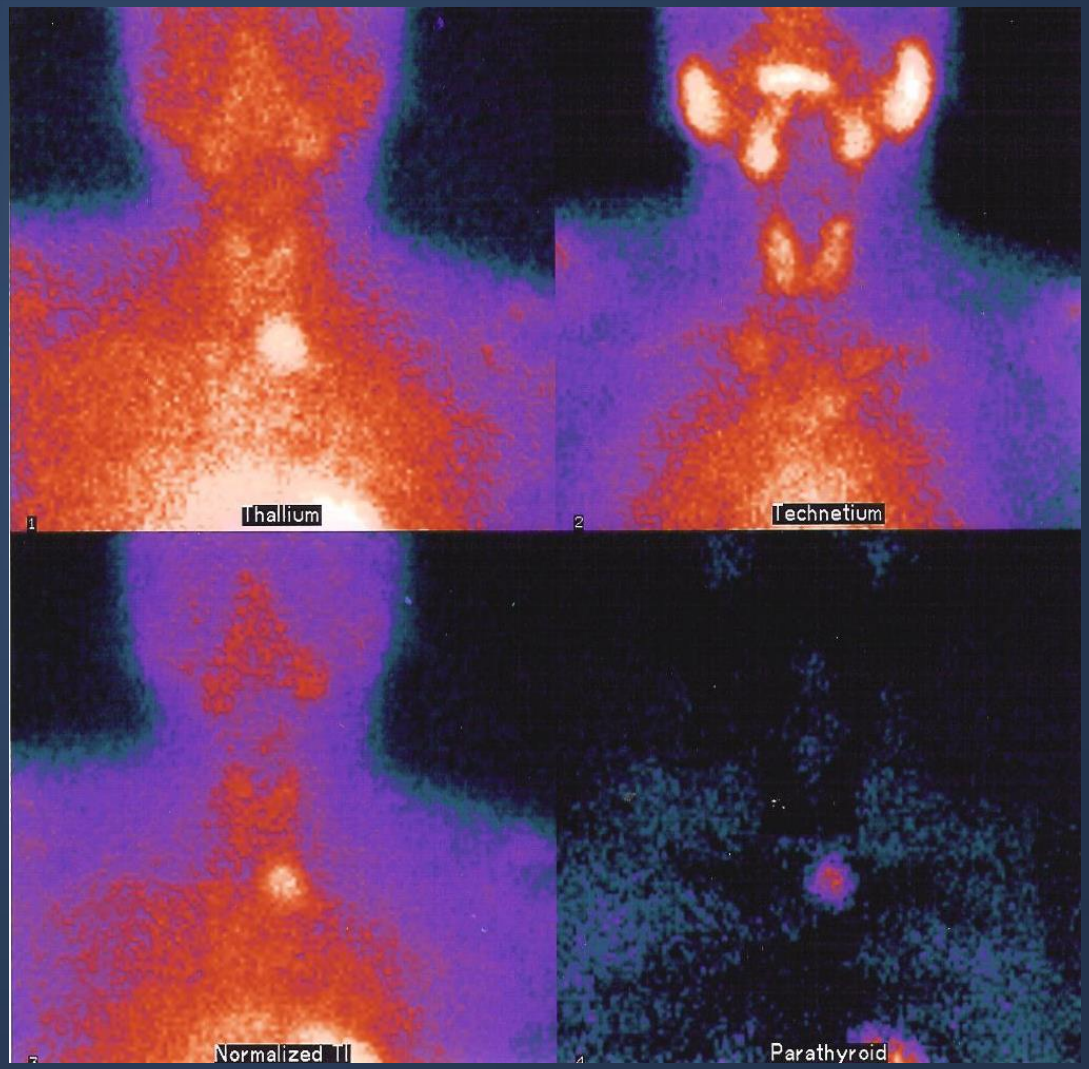
Normal parathyroid glands
are small and not visualized



Abnormal parathyroid glands
could be visualized

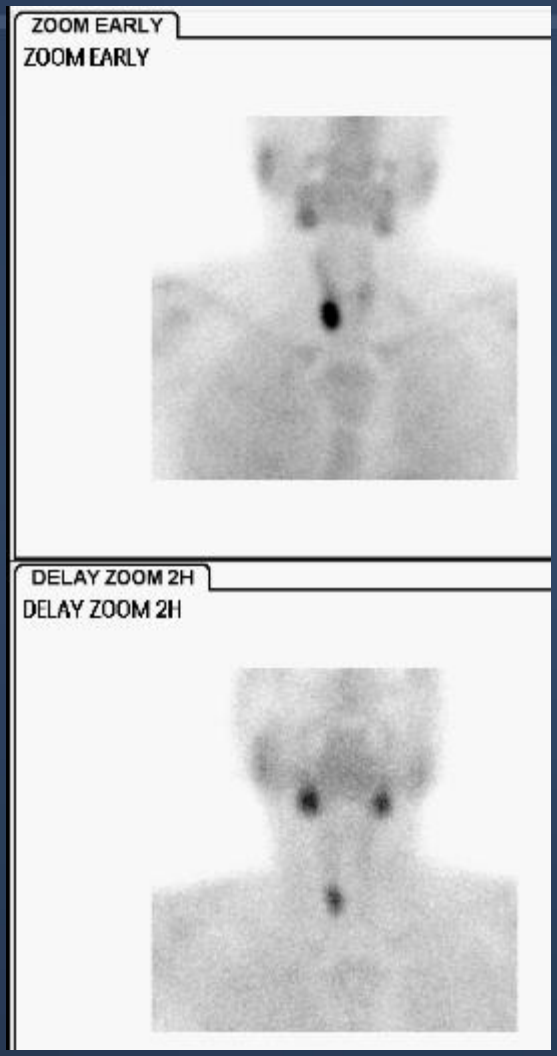
Parathyroid Scan

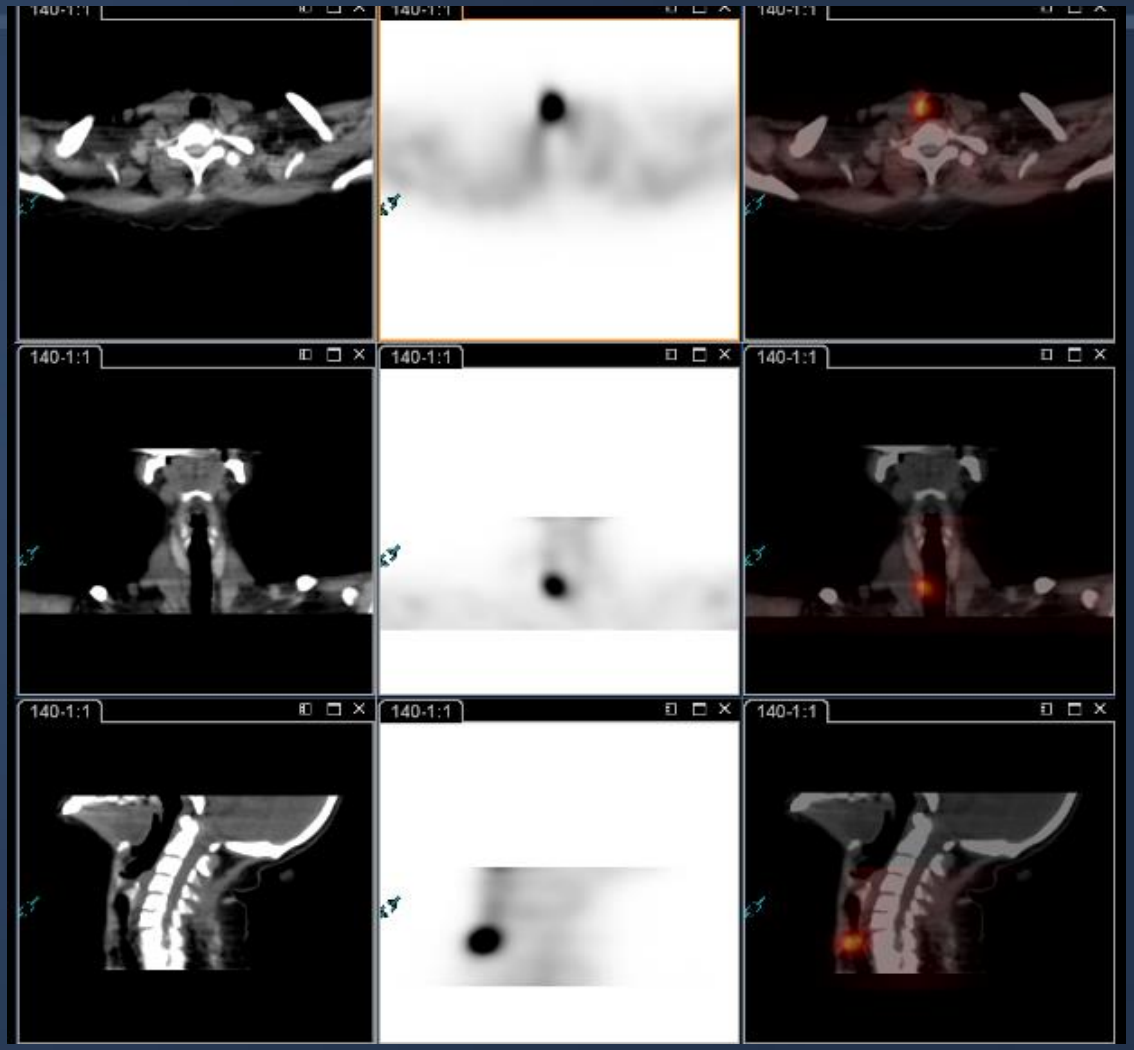
Tc-Tl Subtraction Scan



Parathyroid Scan
Sestamibi dual phase

Sestamibi Dual Phase
(Planar vs SPECT CT)



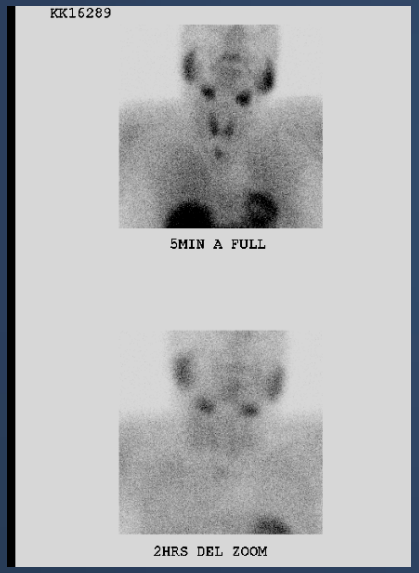


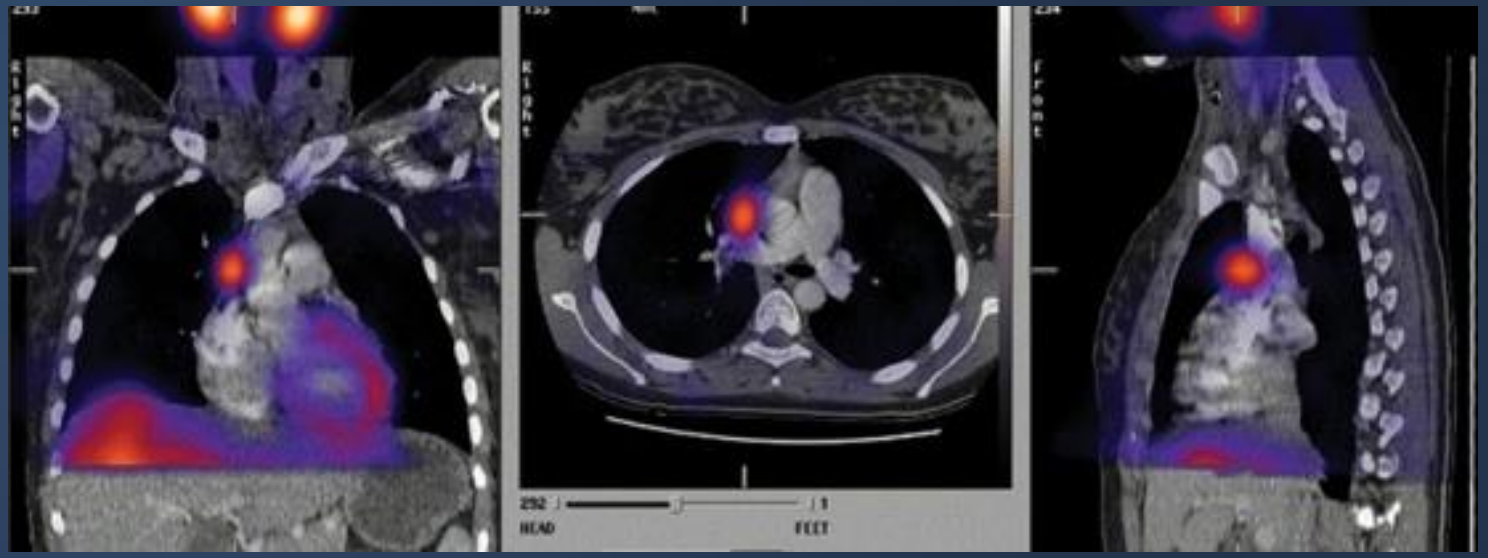
Parathyroid Scan

Ectopic Parathyroid : 16% of total adenomas

Ectopic Parathyroid Adenoma

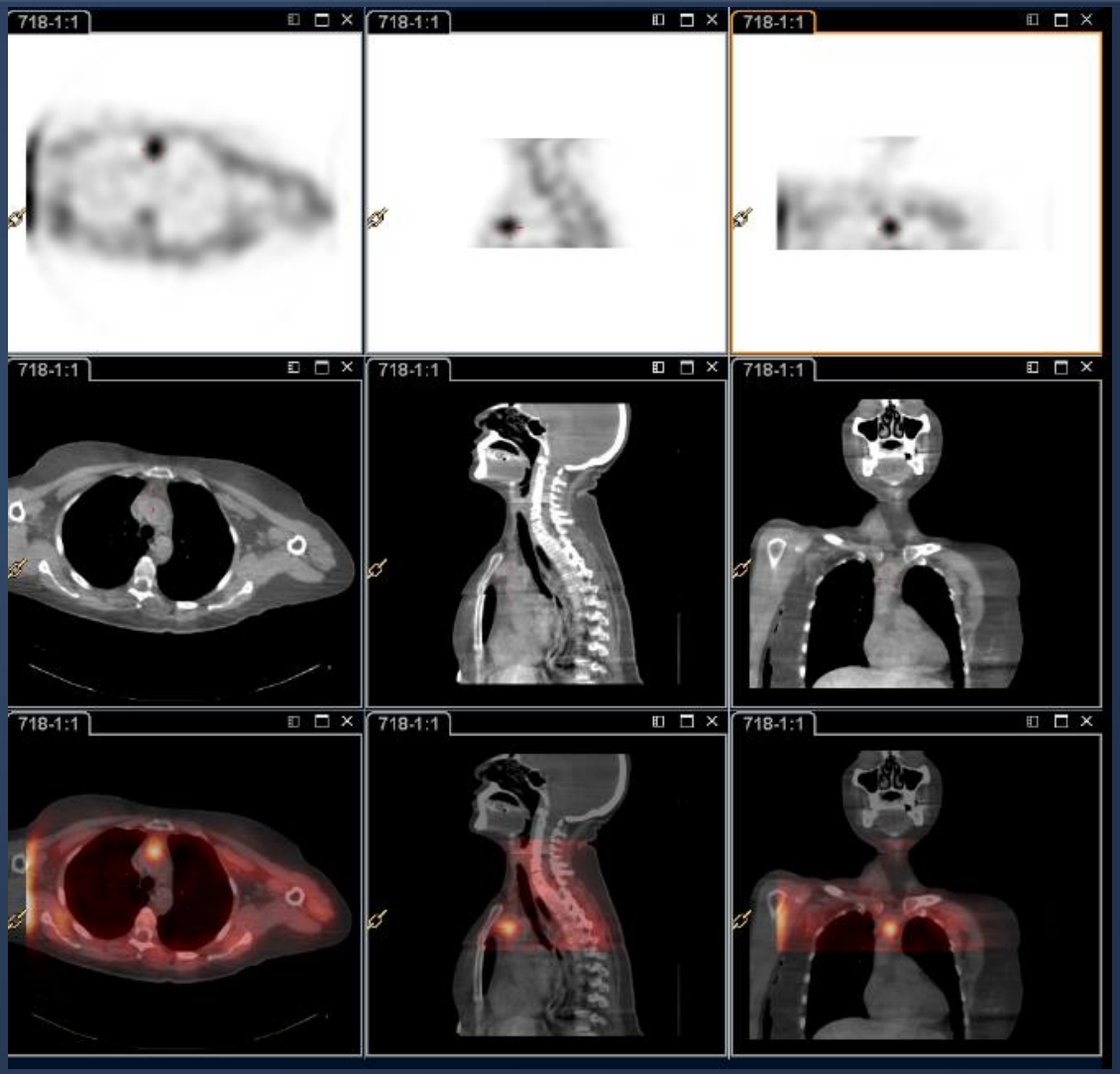
PLANAR vs SPECT/CT





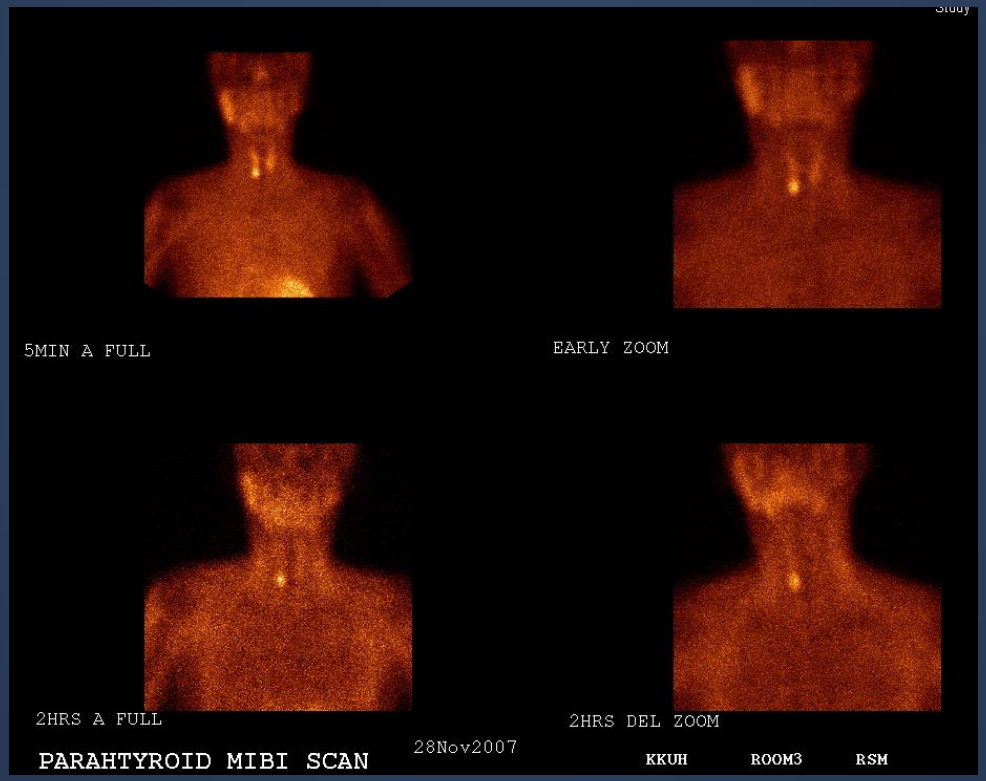
SPECT-CT images accurately localize the adenoma and guide the surgeon to the best surgical approach

Ectopic parathyroid adenoma
Antero-superior mediastinum



Sestamibi Parathyroid Scan Result

High PTH /High Ca



TP

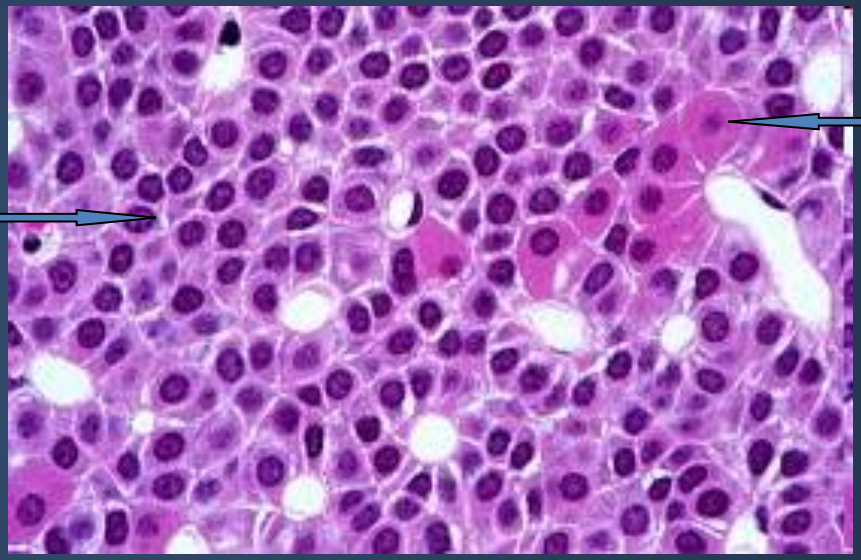
High PTH / High Ca

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

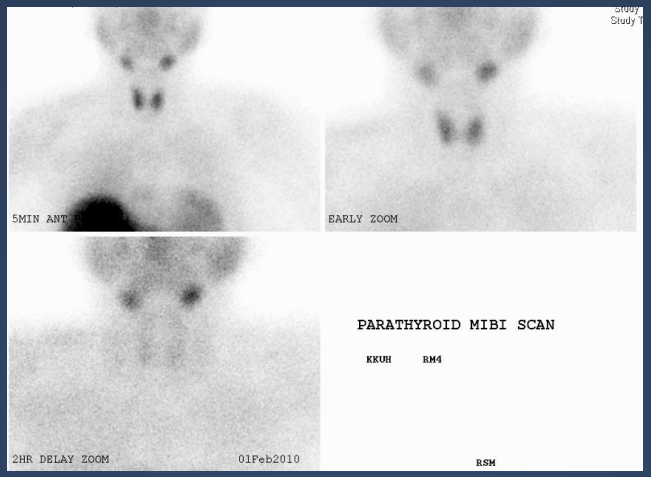
Cationic charge

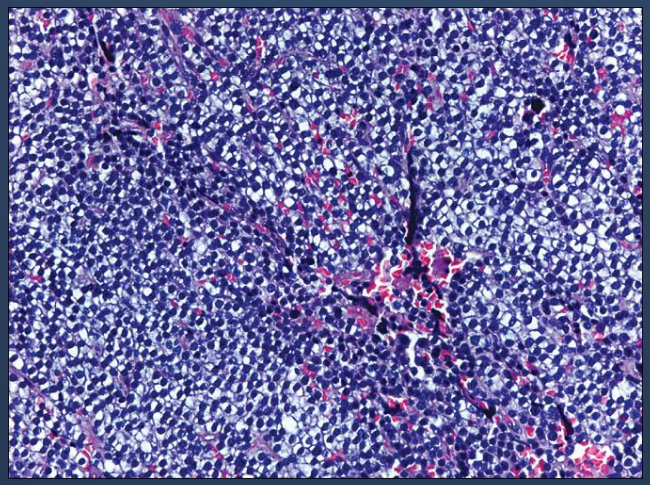
b. Cell Type : A predominance of oxyphil cells within an adenoma is more likely to lead to a positive scan.

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

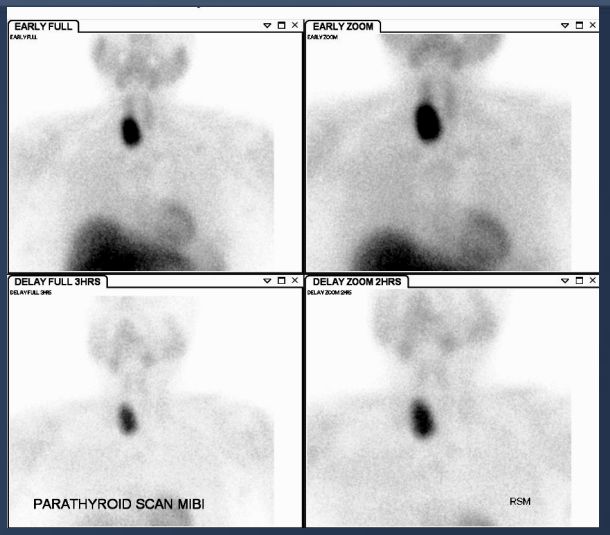
J Nucl Med. 1990; 31: 1166-1167.

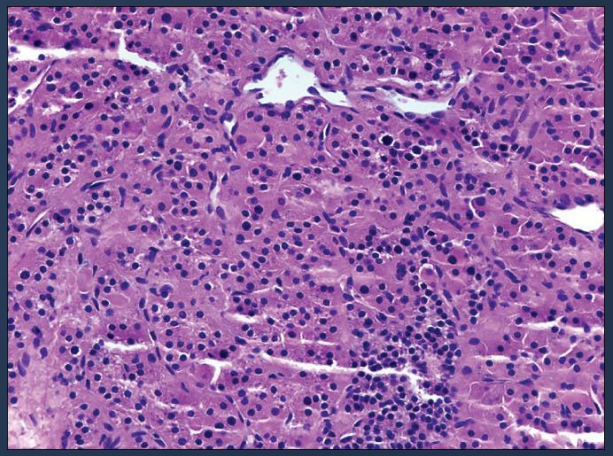
Cell Type and Scan Result





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

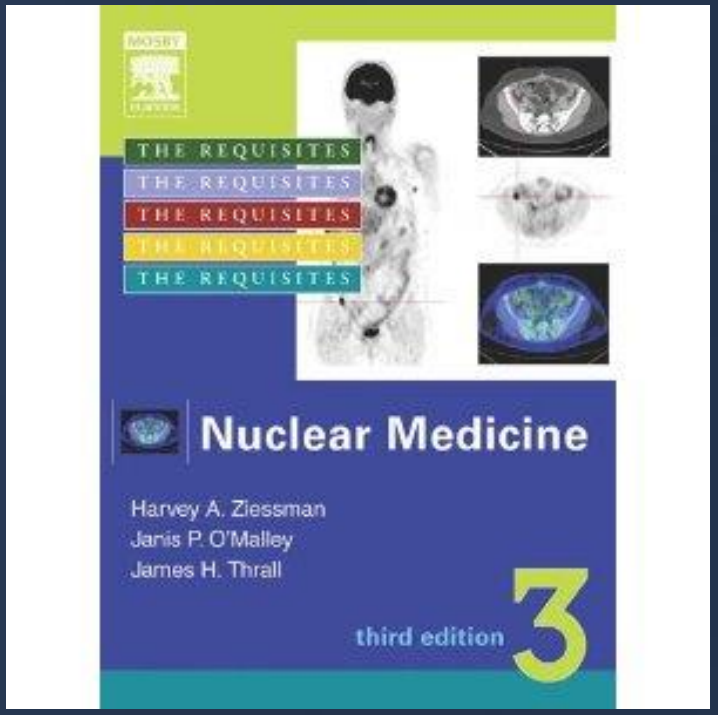
Even with refinements in sestamibi scanning, the fact that all parathyroid adenomas are not created equal on a cellular level may inevitably lead to FN scans in a certain number of cases.

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

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