



431

## Radiology Team

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# Lecture 8: Nuclear Medicine in Thyroid and Parathyroid



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

\*We thank 430 Team for their helpful notes\*

# Thyroid scan

## Learning objectives

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

How is the thyroid scan performed?

When is thyroid scanning helpful?

What is significant about whether a nodule is "hot" or "cold"?

What is the role of nuclear medicine in the treatment of thyroid disorders?

### Thyroid scan procedure

Radiotracer measuring unit is curie (Ci).  
Doses are not imp.

	Tc-99m Pertechnetate	I-123
Half life	6 Hours	13 Hours
Time of Imaging	20 min <b>post injection</b>	6 and 24 hours <b>post ingestion</b>
Remarks	Trapped not organified*	Trapped and organified*

\*When Iodine is trapped by the thyroid gland thyroid hormones are synthesized, then it would be organified to form Thyroxine. In Tc-99m it is not organified so when there is problem in organification, we can't use it. **To assess the organification we use I-123.**

### Patient Preparation:

The patient must be off thyroid hormones:

1. Thyroxine (T-4) for at least 3-4 weeks.
2. Triiodothyronine (T-3) for at least 10 days.

The patient must not be taking antithyroid medications:

1. Propylthiouracil (PTU) and tapazole for at least 3-5 days.

The patient must not i.v iodinated contrast agents

(IVP, CT with contrast, myelogram, angiogram) for at least 3 weeks.

Gamma camera: Small or large field of view.

Patient position: Supine with chin tilted up.

### Imaging:

20 min. post injection of Tc99 m : ANT, LAO and RAO images obtained.

6 and 24 hours post oral dose for I123 : ANT, LAO and RAO images .

Any agents that **inhibit** the thyroid gland should be stopped 3 weeks before the scan

ANT: Anterior  
LAO: left anterior  
RAO: right anterior

# THYROID UPTAKE MEASUREMENT

## (I-123 Sodium Iodide)

### Indications:

- Diagnosis of Grave's disease.
- Evaluation of subacute and chronic thyroiditis.
- Thyroid Cancer

### Patient Preparation:

Similar to thyroid scan

### Equipment :

Uptake only : Uptake probe

Imaging plus uptake studies: Gamma camera

*Thyroid uptake measurements may be determined using Tc-99m pertechnetate.*

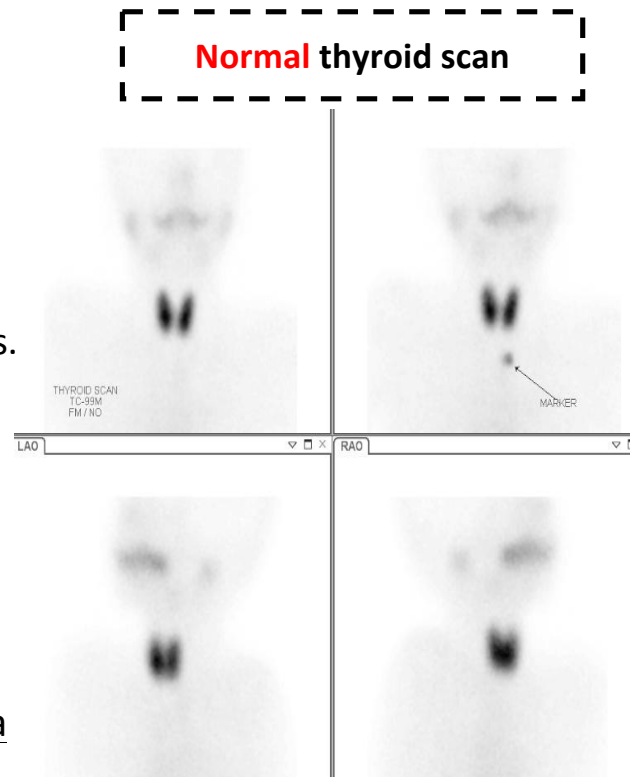
Patient position: Sitting.

Detector field of view: Neck.

### Acquisition Protocol:

- Place I123 capsule(s) in neck phantom.
- Acquire counts for 1 minute , record the counts, time of acquisition, and time of day on the thyroid Uptake Worksheet.
- Immediately administer the capsule(s) to the patient.
- At 6 hours position the probe in front of the patient's neck .
- Acquire counts for 1 minute for I-123 and record the counts, time of acquisition, and time of day on the Worksheet.
- Position the probe over the thigh for 6 hour "background" measurement.
- Acquire counts for 1 minute for I-123 and for 2 minutes for I-131; record the counts, time of acquisition, and time of day on the Worksheet.
- Using the Thyroid Uptake Worksheet, calculate the 6 hour thyroid uptakes. Remember to correct the standard counts for decay.

*Twenty four hour uptake measurement in the same way as the 6 hours.*



## 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%)**

\*If more than these values, that means the gland is hyperactive.

## Causes of **High** Thyroid Uptake (**IMP**)

- 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 (lithium causes iodine starvation)
- Recovery phase of thyroiditis.
- Rebound following abrupt withdrawal of antithyroid meds.



## Causes of **Low** Thyroid Uptake (**IMP**)

- 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**



843223

THYROID UPTAKE	: 2.96	%
Area	29.8	(sqcm)
Mass	53.0	g

Normal

Adac Laboratories BV  
 Maastricht  
 The Netherlands



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

## Indications

- Detection and localization of persistent or recurrent functioning thyroid cancer

## Patient Preparation:

Similar to thyroid scan

Imaging using Gamma camera :

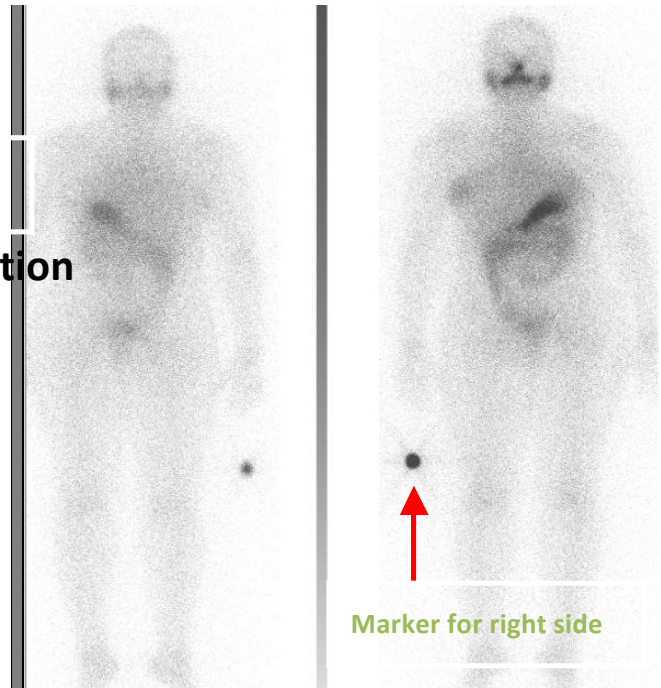
Whole body scan  Negative

- Radiopharmaceutical: Oral administration

a. I-123 as sodium iodide : 2 mCi

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

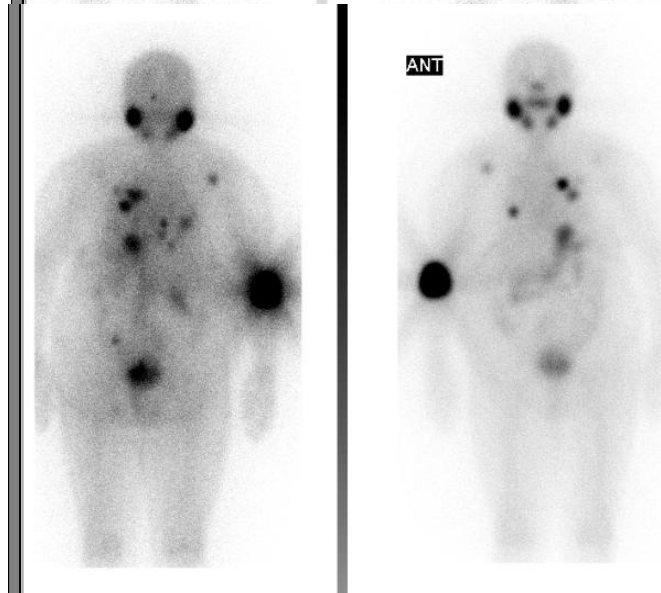
SPECT CT is very important to determine the exact location of the abnormality



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

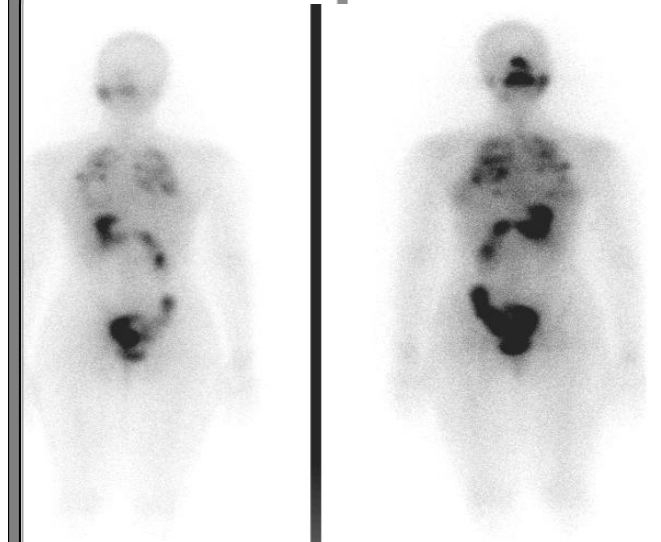
### Bone Metastases

Iodine uptake in salivary glands,  
Several ribs and left humerus.



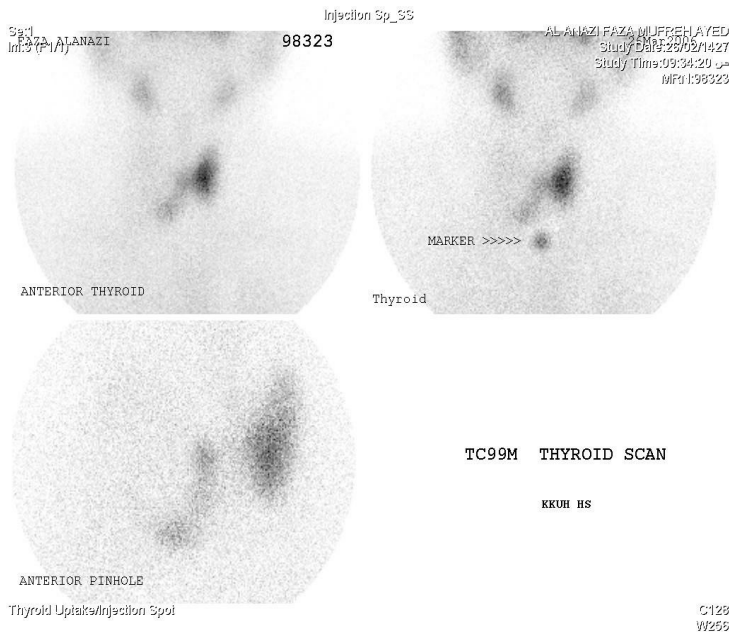
## I-123 or I-131 Whole Body Scan(WBS)

### Lung Metastases

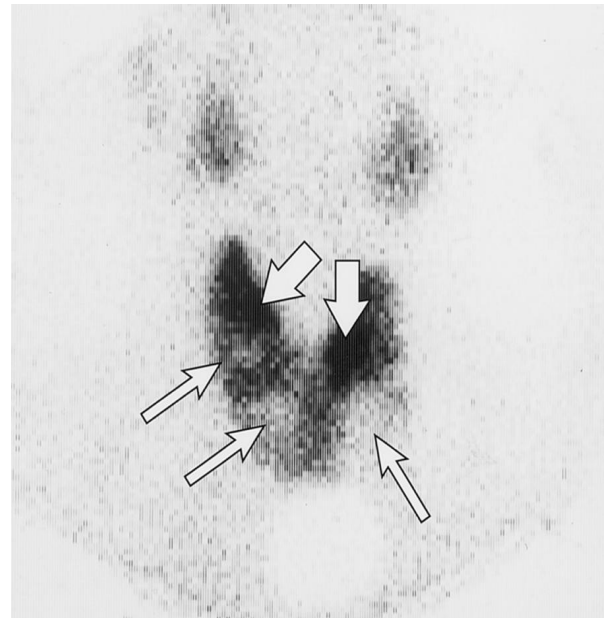


# Indications for Thyroid Scan

## 1. 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

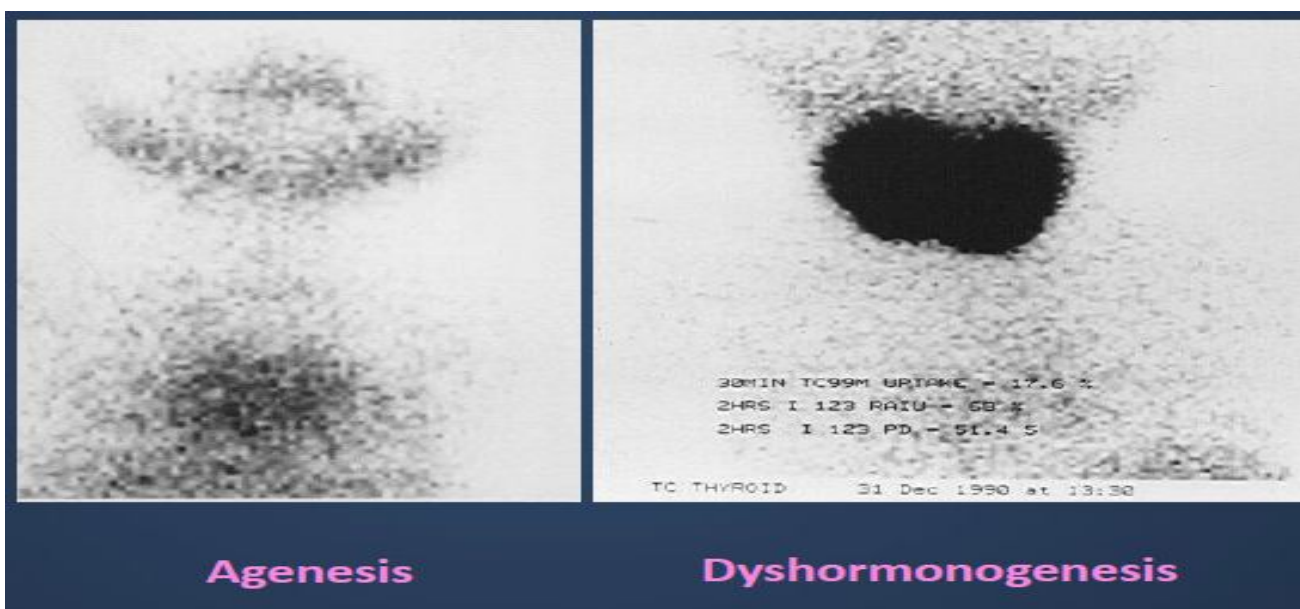
As the number of nodules increase, the chance of malignancy decrease

## 2. Evaluation of thyroid nodules Hot vs Cold vs warm

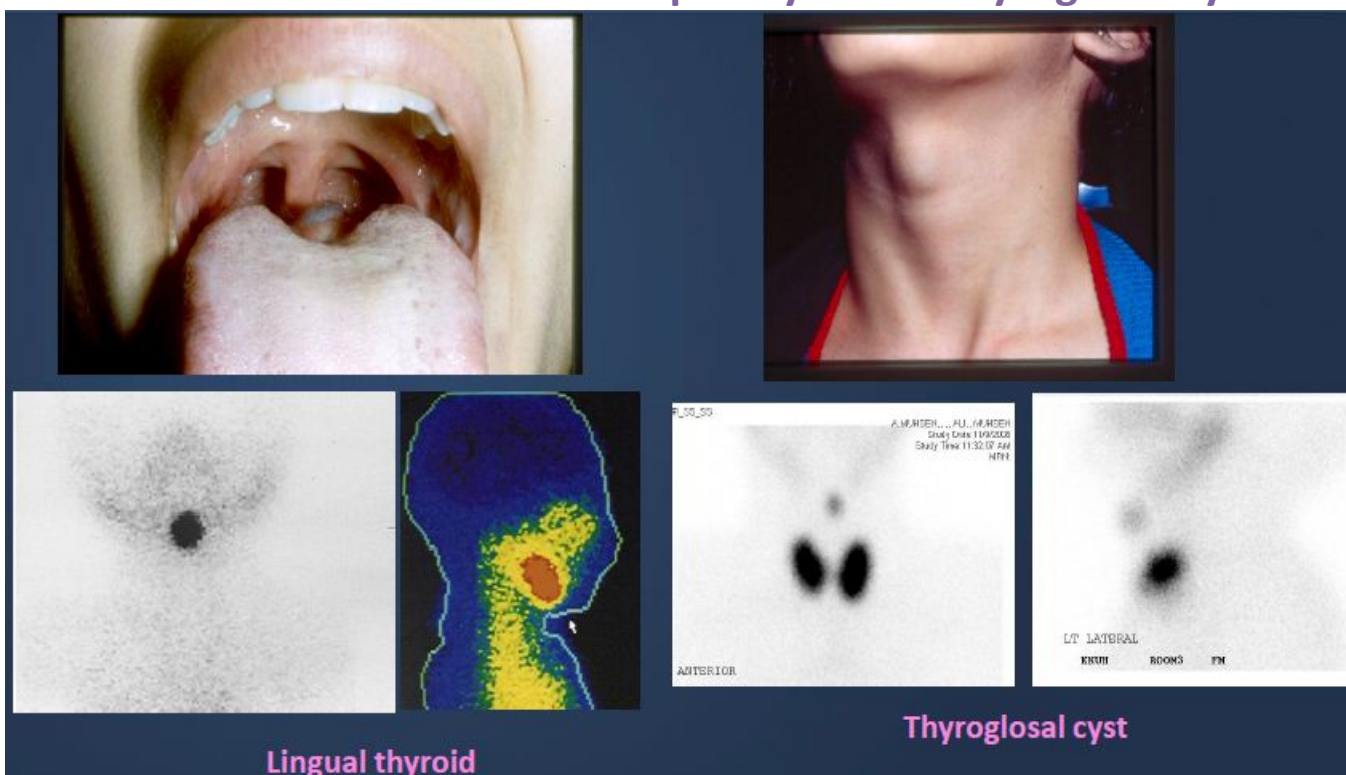


## 3. Evaluation of congenital hypothyroidism **Agnesis** vs **Dyshormonogenesis**

Perchlorate discharge test is used to **confirm** dyshormonogenesis



#### 4. Evaluation of neck masses ectopic thyroid vs thyroglossal 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)

# Thyrotoxicosis **with** hyperthyroidism **needs definitive treatment** Graves' Disease.

Neonatal hyperthyroidism.

Toxic nodular goiter:

MNTG or Plummer's disease

ATN or toxic adenoma

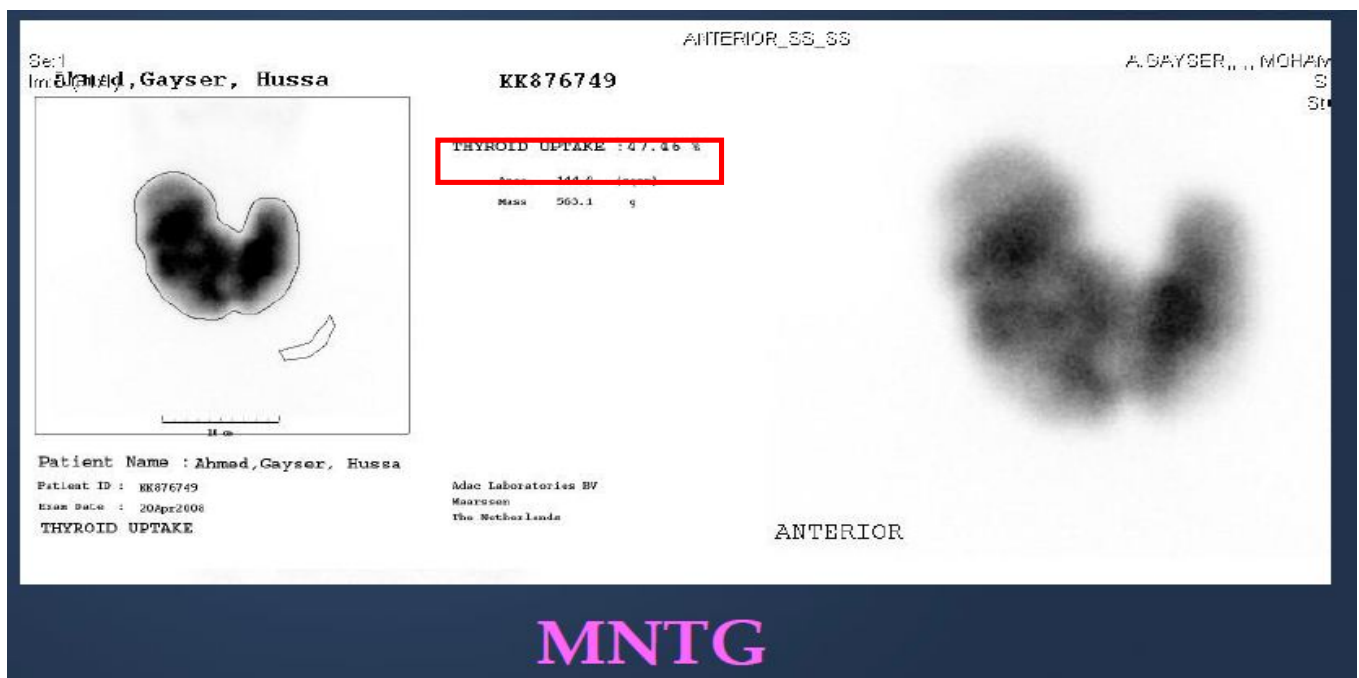
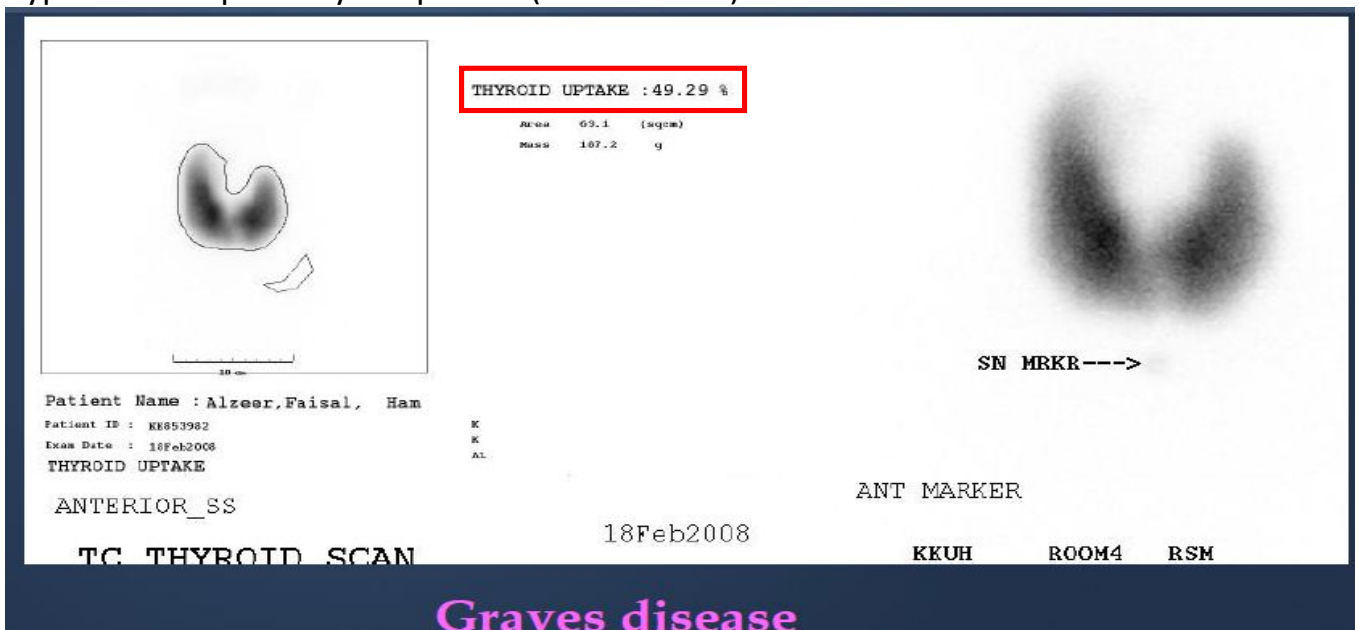
Iodine induced

( Jod-Basedow disease )

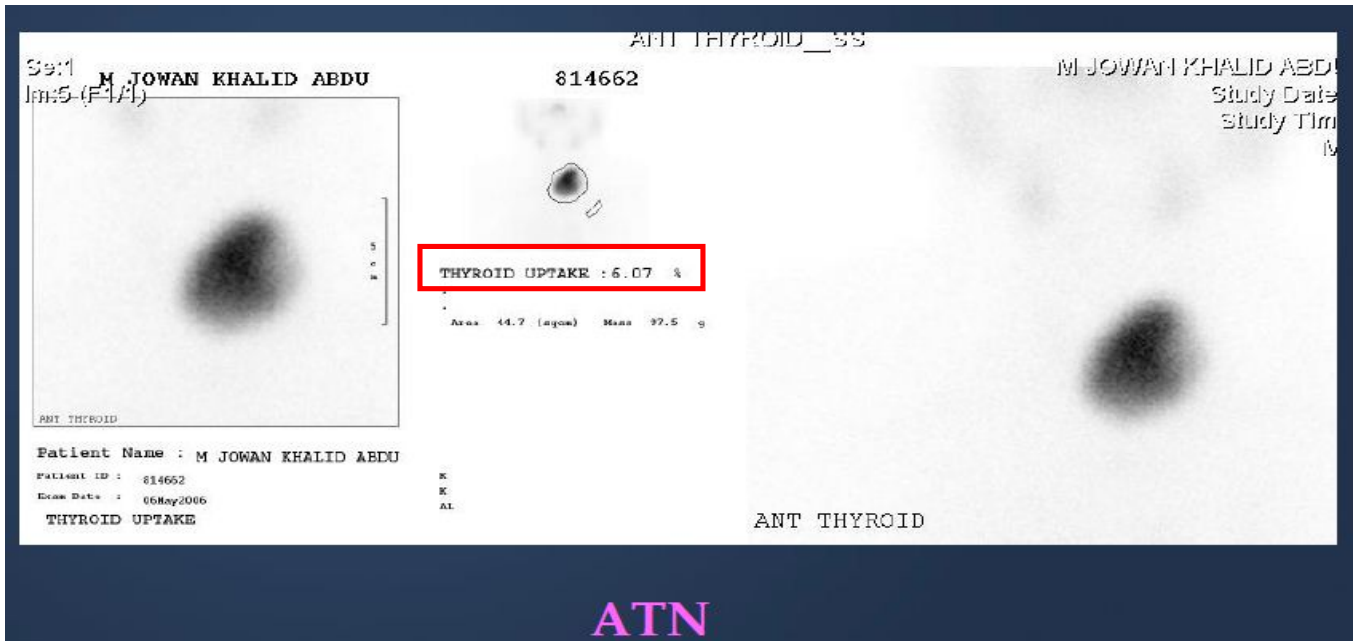
Rare causes:

Excessive HCG by trophoblastic tumor

Hypothalamic pituitary neoplasms (TSH induced)







**Thyrotoxicosis without hyperthyroidism** needs symptomatic treatment  
Subacute thyroiditis.

Chronic thyroiditis with transient thyrotoxicosis

Thyrotoxicosis factitia (exogenous hormone).

Thyroid extract (e.g. Hamburger thyrotoxicosis)

Ectopic thyroid :

Metastatic thyroid carcinoma

Struma ovari

## Radioactive Iodine Therapy for Hyperthyroidism

Isotope used : I131

Physical Properties: Solution or capsule

Main side effect : **Hypo**thyroidism

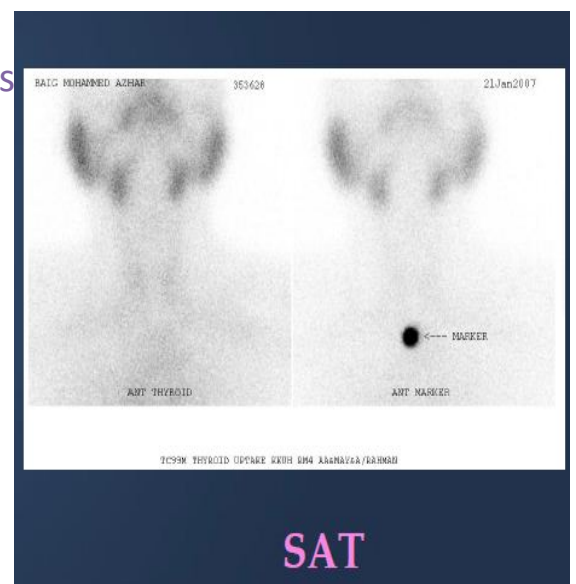
Dose :

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

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

Discuss the principles of dual-phase and dual-isotope parathyroid imaging.

Identify the common imaging features of pathologic parathyroid glands.

Discuss causes of false negative scans.

Identify causes of false negative and false positive scans.

### Techniques:

TL-201 \_ Tc-99m subtraction

Tc-99m Sestamibi ( Dual Phase ) **Golden standard currently**

Tc-99m Tetrofosmin ( Dual Phase )

<u>Radiopharmaceutical</u>	<u>99mTc / 201Tl Subtraction</u>	<u>99mTc sestamibi</u>
<b>Activity administered</b>	80 MBq (2 mCi) 201Tl; 370 MBq (10 mCi) 99mTc	925 MBq (25 mCi)
<b>Images acquired</b>	Inject Tl first 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

# Tc-99m-Sestamibi

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

**Patient Preparation** :None

- **Radiopharmaceutical**: 25 mCi Tc-99m-sestamibi i.v.
- **Patient position**: Supine with head and neck extended and immobilized.
- **Gamma camera Imaging field**:

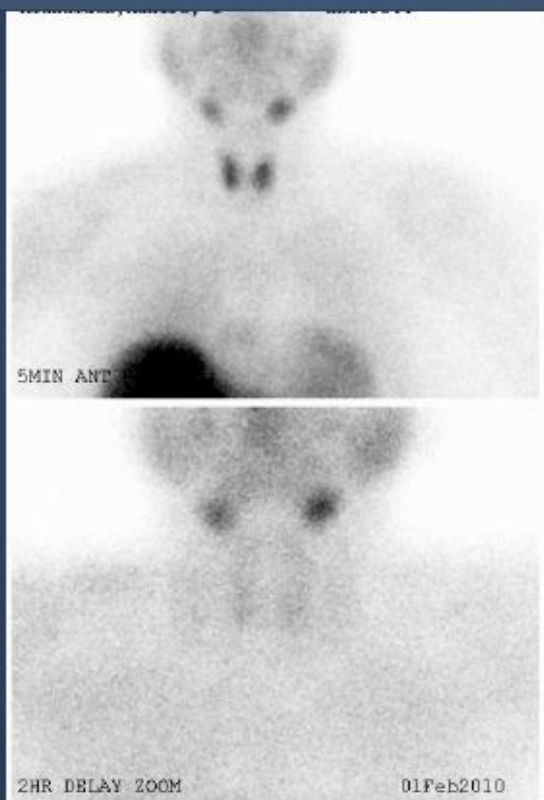
1. Neck. 2. Upper two thirds of the mediastinum.

Acquire images at 15 minutes and 2-3 hours post injection.

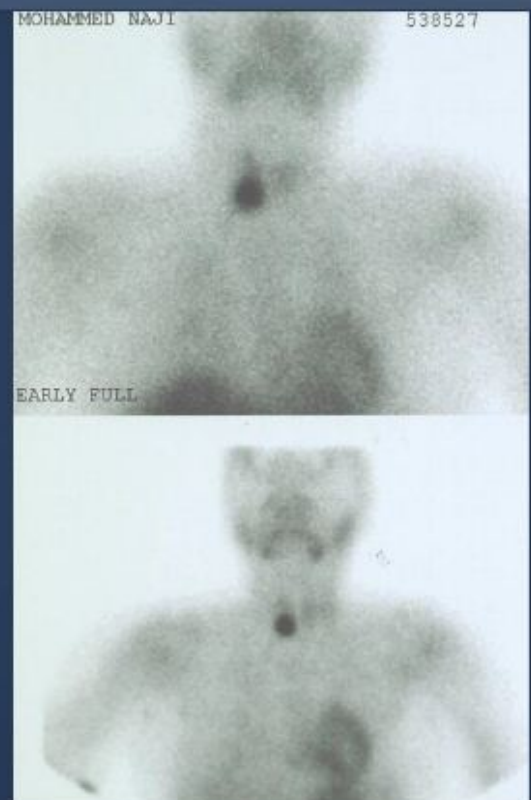
SPECT images improves localization.

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

## Dual phase MIBI Scan ( Or Tetrofosmin )

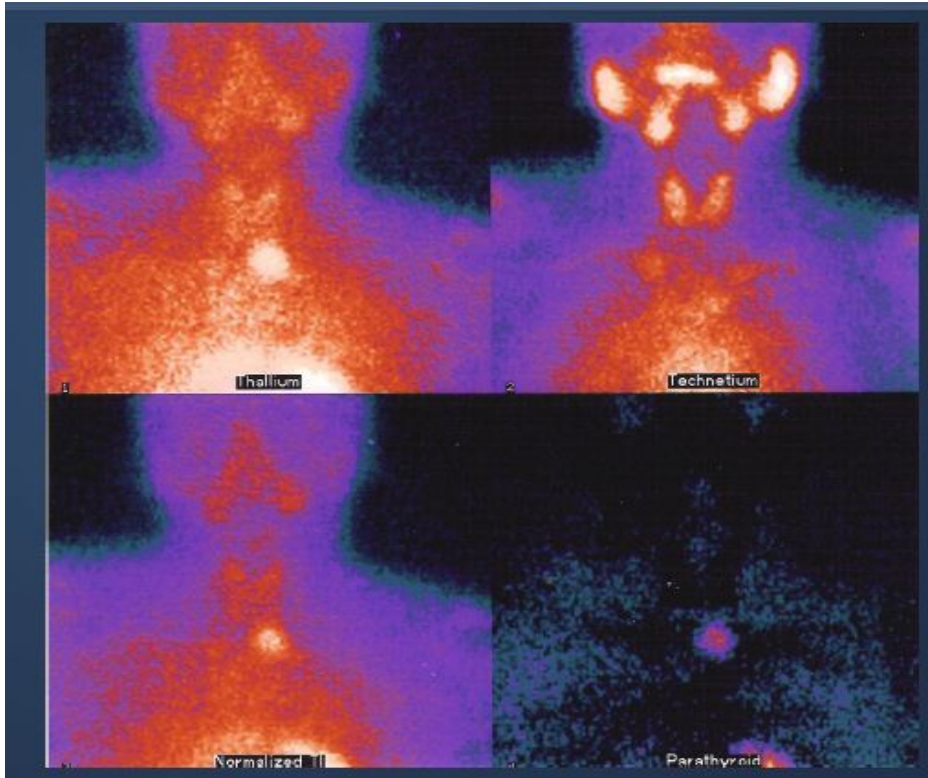


**Normal parathyroid glands  
are small and not visualized**



**Abnormal parathyroid glands  
could be visualized**

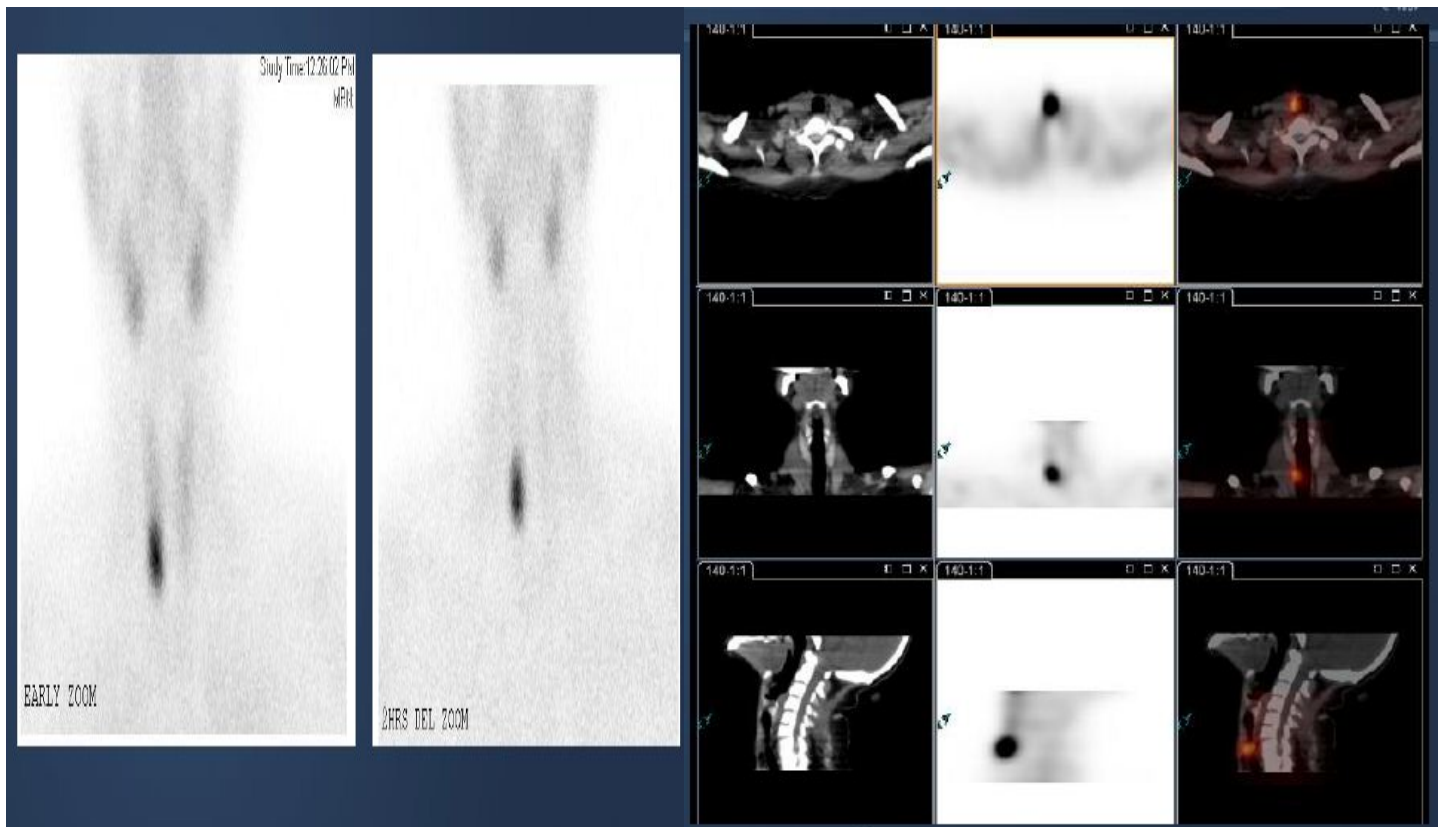
# Tc-Tl Subtraction Scan



Tc-Tl Subtraction Scan: 1) We give thallium → it goes thyroid and parathyroid. 2) Then give only technetium → it goes only to thyroid 3) Subtract the images to visualize the parathyroid gland.

# Sestamibi dual phase

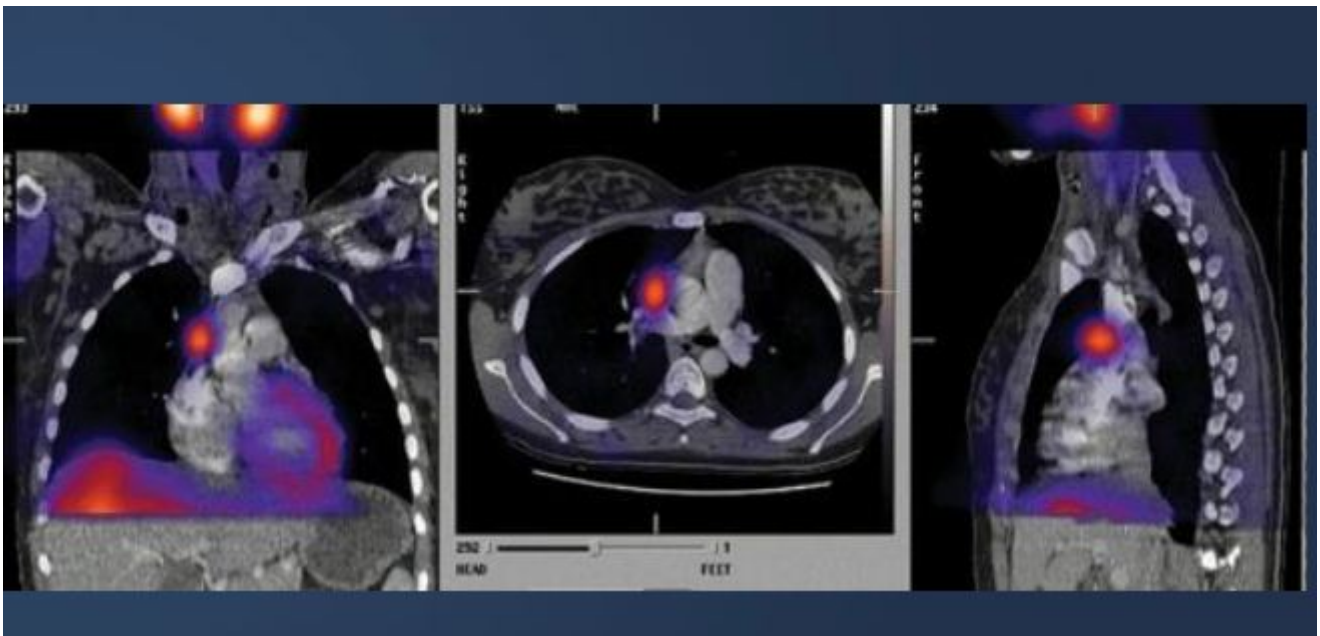
( Planar vs SPECT CT)



# Ectopic Parathyroid in upper mediastinum.

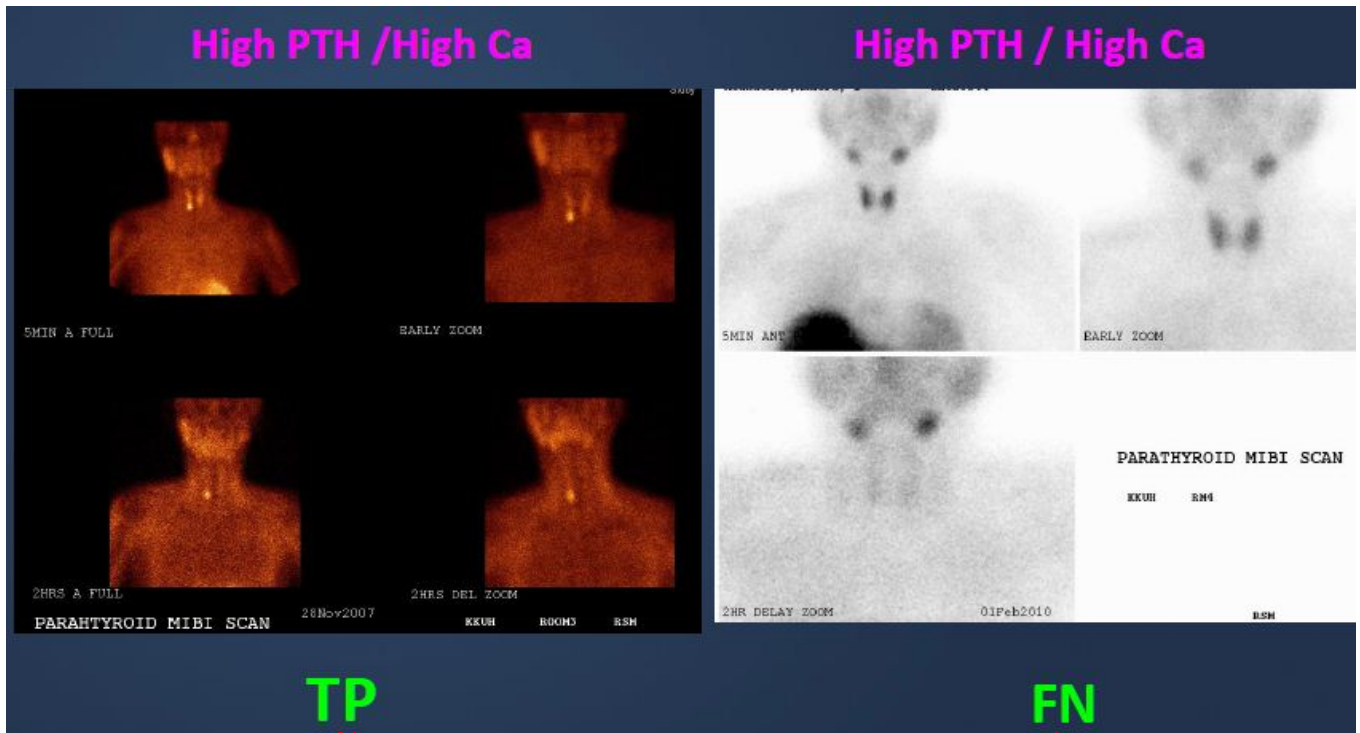


## Ectopic Parathyroid Adenoma



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

# Sestamibi Parathyroid Scan Result

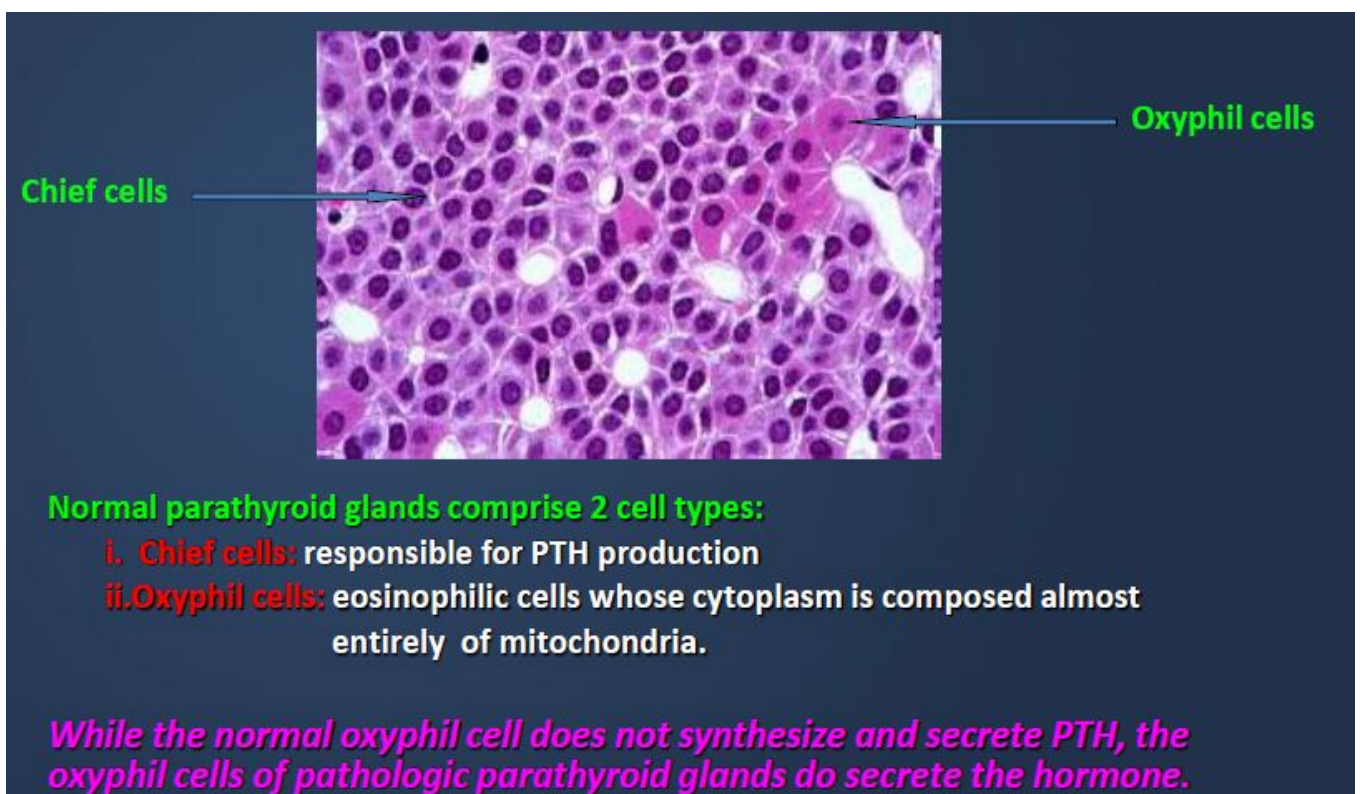


True positive

False negative

Q: What is the cause of the FN results? A: Mechanism of sestamibi uptake.

## Parathyroid Cells



## 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:

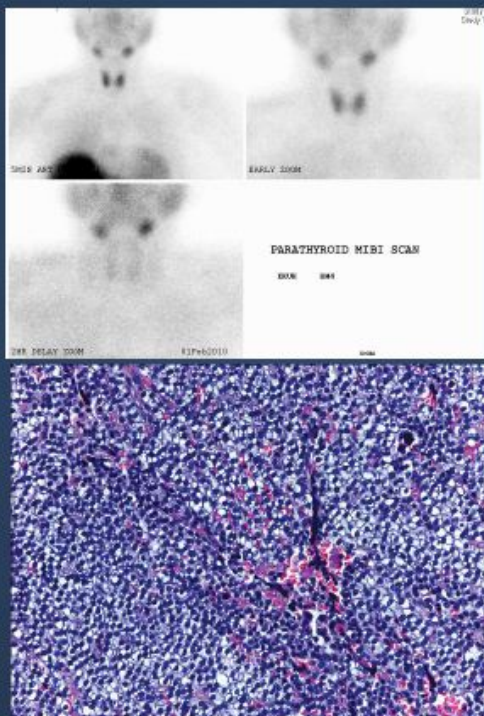
### a. Biochemical properties of the tracer :

**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**

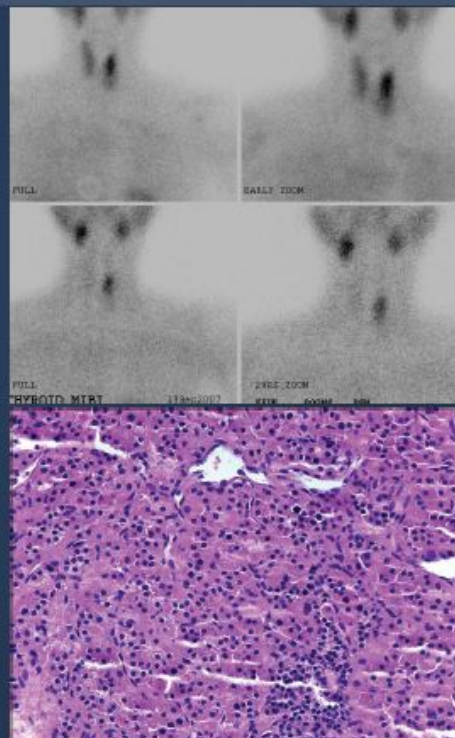
**b. Cell Type** : A predominance of oxyphil cells within an adenoma is more likely to lead to a positive scan.

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

# Cell Type and Scan Result



Parathyroid adenoma composed entirely of glycogen-rich chief cells.



Parathyroid adenoma composed mainly of mitochondrial-rich oxyphil cells.

# “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

## Points To Remember Before Proceeding For Parathyroid Imaging

**Imaging is not for diagnosis**: High Ca and PTH establish the diagnosis

**Imaging does not identify normal parathyroids**: These are too small to be seen (20-30mg)

**Imaging should detect abnormal parathyroid(s) and indicate the approximate size and the precise relationship to the thyroid gland**:  
lateral , SPECT and SPECT /CT

**Imaging should identify ectopic glands** : SPECT and SPECT/CT

**Optimal imaging should be able to differentiate patients with single adenoma from those with MGD**

**Imaging should identify thyroid nodules which may require concurrent surgical resection**



# Summary

- 1- Technetium half-life is 6 hours.
- 2- To assess the organification we use I123 not Tc-99.
- 3- The gold standard tracer in RAIU is 123.
- 4- If patient is on thyroxin s/he should stop it 3-4 weeks before thyroid scan.
- 5- If patient is on antithyroid s/he should stop it 3-5 days before thyroid scan.
- 6- The patient should not have any I.V contrast for at least 3- weeks before scan.
- 7- RAIU is to determine how much of the dose we give to the patient is taken by the thyroid gland.
- 8- I 123 is used for diagnosis while I131 for therapy (cancer or hyperthyroidism).
- 9- Causes of abnormal thyroid uptake. ( either high or low)
- 10- A common cause of thyroid cancer is irradiation.
- 11- In thyroid cancer the uptake is most likely normal.
- 12- Hot nodules have no chance of being malignant.
- 13- Cold nodules have 15% chance of malignancy in females and higher in males 20%.
- 14- The most common cause of hot nodule is ATN.
- 15- Indication of thyroid nuclear imaging include:
  - a. Evaluation of thyroid nodules
  - b. Evaluation of congenital hypothyroidism: Agenesis Vs. Dyshormonogenesis.
  - c. Evaluation of neck masses: ectopic thyroid, thyroglobulin cyst.
  - d. Evaluation of thyrotoxicosis.
- 16- Perchlorate discharge test is used to confirm dyshormonogenesis
- 17- RAIU is used also to evaluate:
  - a. Thyroiditis : subacute and chronic thyroiditis.
  - b. Thyroid Cancer : Remnants uptake in preparation for therapy. (after surgery how much remnants is left, to prepare for I131 therapy).
- 18- Lactating mothers should stop breast feeding according to the following
  - a. Completely after I 131 therapy
  - b. 3 weeks after diagnostic I 131
  - c. 12 h after 99mTc
- 19- The main side effect of radioactive iodine therapy for hyperthyroidism is hypothyroidism.
- 20- Parathyroid imaging needs combination of several modalities. Sestamibi and MRI are the best combination.
- 21- Parathyroid scan results depends on the histological type of adenoma.

## MCQs

**Half life of Technetium 99m is:**

1. 4 Hours
2. 6 Hours
3. 10 Hours
4. 13 Hours

**Which of the following nodules has the lowest chance to be malignant:**

1. Cold nodule
2. Hot nodule
3. Suspicious nodules
4. Small nodule

**Main side effect of Radioactive Iodine therapy is:**

1. Hyperthyroidism
2. Hypothyroidism
3. Hypertension
4. Hypoglycemia

**Answers: 2 - 2 - 2**

