



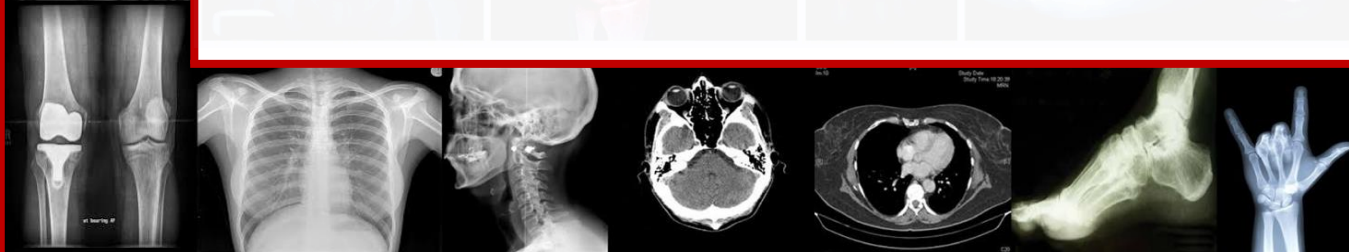
Radiology Team

Lecture 5 Nuclear Medicine in Thyroid and Parathyroid

Make sure you check the [Correction File](#)
before going through the lecture!

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Color Index:

- **Important**
- **Females' notes**
- Explanations
- **433 & 432 Teamwork**

Thyroid Scan

○ Learning Objectives:

- ✓ 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

As mentioned in the previous lecture we have to inject the patient with a radioactive material, we have 2 option:

	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) Always available	Expensive (it needs Cyclotrone which is not available in all hospitals)
Time of imaging	20 min post injection It only take half an hour, the patient comes to department then we inject the material after 20 min an image will be taken; THAT'S IT.	6 and 24 hours post ingestion While here the patient come to the department take the capsule/injection then has to come after 6 hours then again after 24 hours.
Remarks	Trapped not organified It <i>only</i> gives unformation about the trappin which the step before organofication	Trapped and organified Gives information about trapping and about organofication which is the synthesis of thyroxine (T4,T3) Its benefits comes when you're looking for enzymes, hormones deficiencies.
Notes	<p>*Radiotracer measuring unit is curie (Ci).</p> <p>*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.</p>	

❑ Thyroid Scan Procedure cont.

○ 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 have i.v iodinated contrast agents
 1. (IVP, CT with contrast, myelogram, angiogram) for at least 3 weeks.
- Also patient must avoid idoine-containg food such as fishe.

○ Radiopharmaceutical and dose:

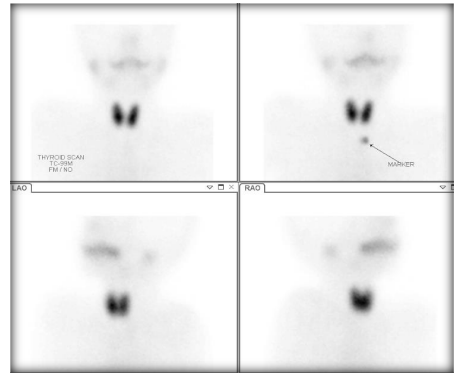
- ✓ Tc-99m as sodium pertechnetate 0.5 -4.0 mCi given Intravenously. **OR**
- ✓ I-123 Sodium Iodide 0.5 mCi orally.

○ Gamma camera: Small or large field of view.

○ Patient position: Supine with chin tilted up.

○ Imaging:

- ✓ **20 min. post injection of Tc99m:** ANT (Anterior), LAO (Left anterior) and RAO (Right anterior) images obtained.
- ✓ **6 and 24 hours post oral dose for I123:** ANT, LAO and RAO images.



Normal Thyroid Scan

A marker should be putted on the suprasternal notch it's very important in the case of retrosternal-goiter; different views will be obtained in order to appreciate any defects



❑ Thyroid Uptake Measurement (I-123 Sodium Iodide)

Simply it is a test with or without imaging, we would like to know if I am giving an idoine how much of what I gave will go to the thyroid.

- The Thyroid Uptake Measurement measures the metabolic activity of the thyroid gland as reflected by its extraction of iodine from the blood.
- **Indications**
 - ✓ Diagnosis of Grave's disease.
 - ✓ Evaluation of subacute and chronic thyroiditis .
 - ✓ Thyroid cancer.

□ Thyroid Uptake Measurement (I-123 Sodium Iodide) cont.

○ Patient Preparation: (will not be asked)

- ✓ 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.
- ✓ Must not have had intravenous or intrathecal iodinated contrast material
 1. (IVP, CT with contrast, myelogram, angiogram) for at least 3 weeks.
- ✓ NPO 2-4 hours before and for at least 1 hour after ingesting the radiopharmaceutical

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

□ Thyroid Uptake Measurement *With / Without* Imaging (I-123 Sodium Iodide)

	Uptake only	Imaging plus uptake studies
Equipment	Uptake probe (single crystal probe with flat field collimator)	Gamma camera
Radiopharmaceutical (dose given orally)	I-123: 100 μ Ci	I-123: 500 μ Ci
What's the difference?	Gives information about the <i>activity</i>	Gives information about the <i>shape</i>
Thyroid uptake measurements may be determined using Tc-99m-pertechnetate.		
Patient position	Sitting	
Detector field of view	Neck	



هناك كابسولتان "تحتويان على نفس النسبة"، واحدة موجودة في المختبر والأخرى تُعطى للمريضة، بعد يوم من بلع المريض/ة للكبسولة المعطاه يتم حساب نسبة الأيودين في كبسولتها ومقارنته بكبسولة المختبر.

❑ Thyroid Uptake Measurement Without Imaging (I-123 Sodium Iodide) “doctor skipped this part”

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%

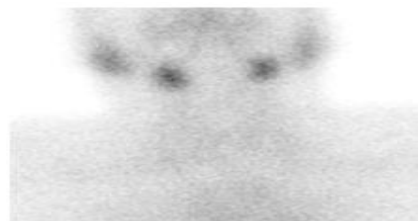
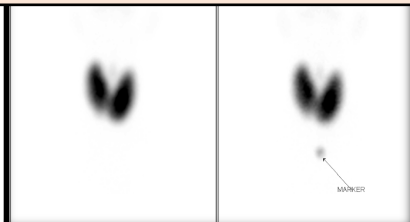
Normal 24 hour RAIU : 8 - 35%

Tc- 99m Uptake (20 min Uptake):

Normal: 0.5 -4 .0%

If less then the gland will be hypo-active if more it will be hyper-active.
No wander :)

Causes of HIGH Uptake imp.	Causes of LOW Uptake imp.
<p>*Hyperthyroidism: Grave’s Disease or TSH-secreting pituitary adenoma</p> <p>*Autonomous toxic nodule</p> <p>*Multinodular toxic goiter: Plumer’s Disease</p> <p>*Enzyme defects: Dyshormonogenesis.</p> <p>*Iodine starvation: Iodine deficiency like those who lives in allps.</p> <p>*Lithium Therapy</p> <p>*Recovery phase of thyroiditis.</p> <p>*Rebound following abrupt withdrawal of antithyroid meds</p>	<p>*Parenchymal Destruction: Acute, Subacute and Chronic Lymphocytic Thyroiditis</p> <p>*Hypothyroidism: Primary or Secondary (insufficient pituitary TSH secretion) OR Surgical/Radioiodine Ablation of Thyroid</p> <p>*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</p> <p>*Blocked Organification: Antithyroid medication (PTU): Note- Tc-99m uptake should not be affected</p>



❑ 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

*When I-123 is not available for example in rural areas I-131 can be used but in small doses.

○ 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

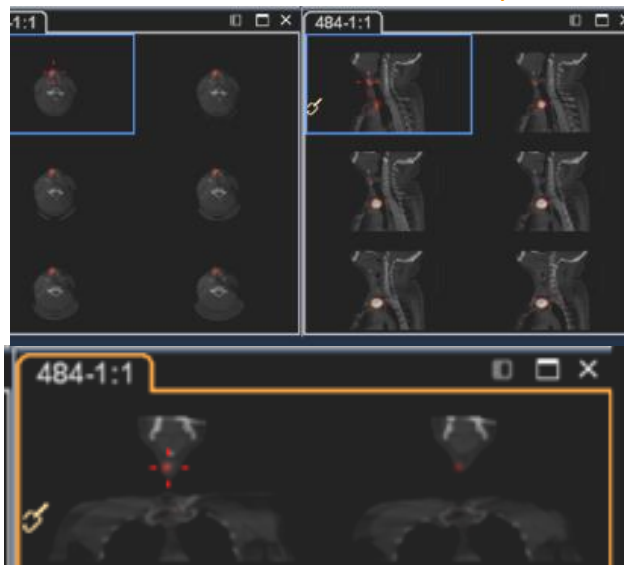
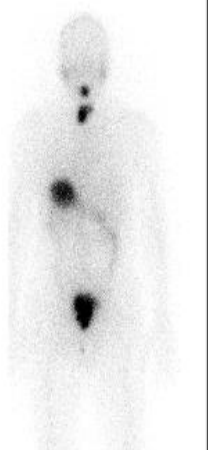
Thyroid tissue uptake is TSH dependent, so prior to whole body scan 2 exogenous TSH injections must be given to the patient to find out any metastases after thyroid cancer treatment.

❑ Thyroid Metastases Study (I-123 or I-131 as Sodium Iodide) cont.

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

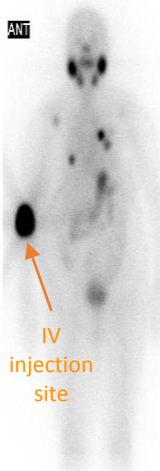
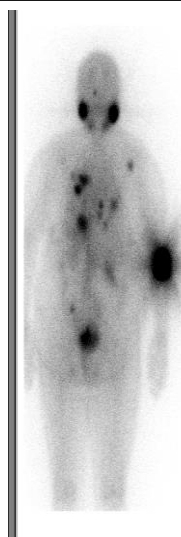
Planar Vs SPECT CT

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



There's multiple thyroid remnant in the neck, to know where exactly you have to do sect CT

Local Recurrence



IV injection site



Bone Metastases (Iodine uptake in salivary glands, several ribs and left humerus.)

Lung Metastases Specially follicular type because it has homatogenous spread

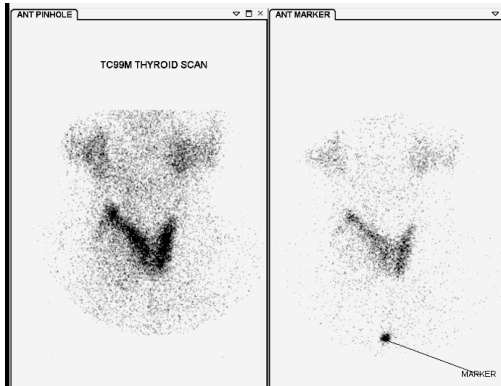
❑ Indications for Thyroid Scan

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

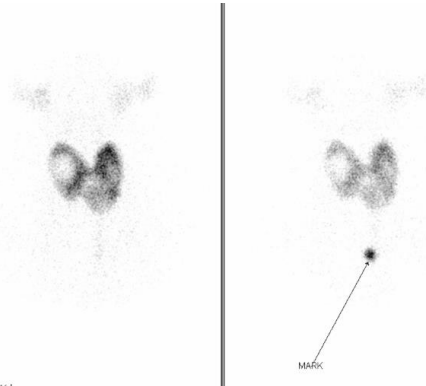
TSH tests are routinely ordered for newborns as part of the screening program to evaluate how well the thyroid gland is working. If TSH is high we want to know if there is thyroid or not so we do thyroid scan (we don't use US because we can't see the base of the tongue in case of ectopic thyroid in the base as well it can not evaluate the function)

❑ Evaluation of Thyroid Nodules

Single vs MNG



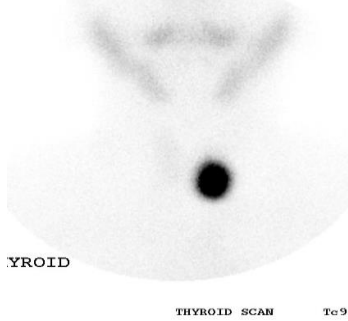
Solitary cold nodule



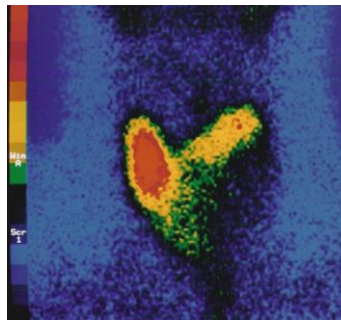
Multinodular goiter

- The chance of malignancy is more in Solitary cold nodule than in MNG
- As the number of nodules increase, the chance of malignancy decrease

Hot vs Cold vs Warm



Hot



Cold



Warm

(Autonomous toxic nodule) is a hot nodule that takes up all the tracer, suppressing the rest of the gland and independent on pituitary thyroid axis

(No uptake at all in the affected side)

Female
Male

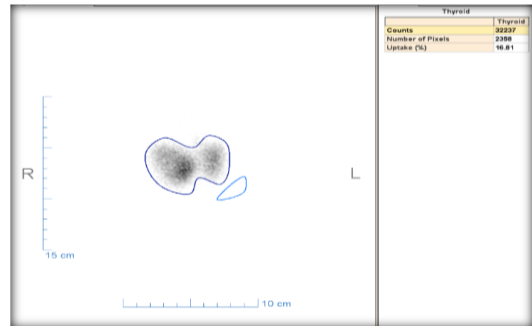
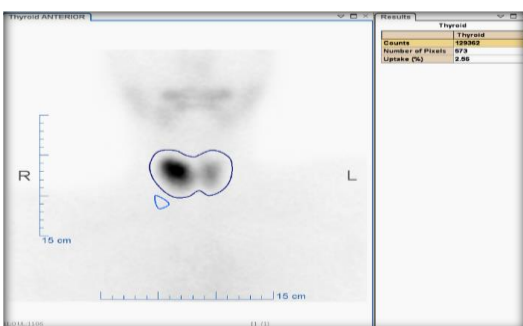
There is uptake more than the rest of the gland without suppressing the gland.

< 5% Chance becoming Malignant

15-20% Chance becoming Malignant

Suspicious

Discordance Tc -I123 Scan

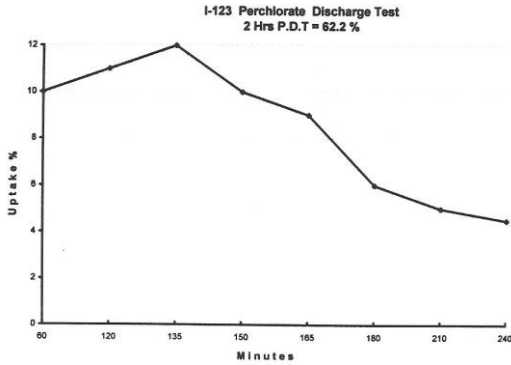


The chance of malignancy of a discordant nodule about 20%

- A warm nodule in Tc is worrying it can be cold when done by I123

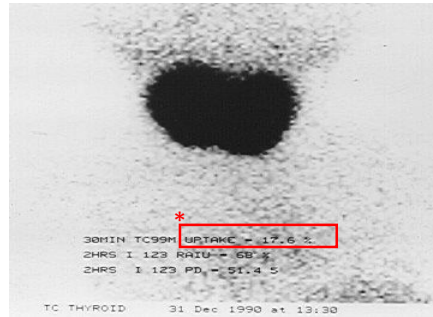
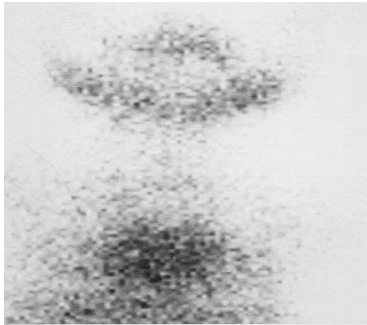
❑ Evaluation of Congenital Hypothyroidism

Agnesis vs Dyshormonogenesis



Perchlorate Discharge Test

- 50 - 80 uCi I123 orally.
- 2 hrs RAIU
- 400 mg Kclo4
- RAIU/ 15 min for 2 hrs.
- Positive test : ≥ 15 fall of RAIU below 2 hrs. uptake.



Agnesis

(absent of the thyroid)

Treatment is thyroxin whole life

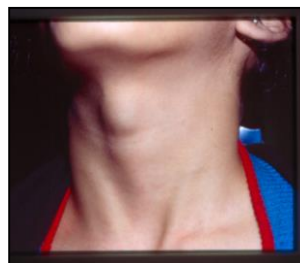
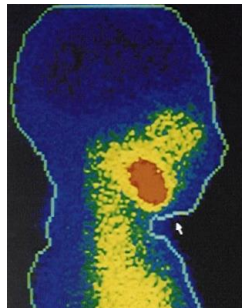
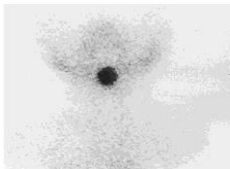
Dyshormonogenesis

*Uptake is very high because of dyshormonogenesis (enzyme deficiency of the thyroid hormone synthesis which result in hypothyroidism) . There is high TSH and enlargement of the gland in attempt to produce hormones

Perchlorate discharge test is used to confirm dyshormonogenesis

❑ Evaluation of Neck Masses

Ectopic thyroid vs Thyroglossal cyst



Lingual thyroid

Lateral view is taking to confirm the diagnosis.

Thyroglossal cyst

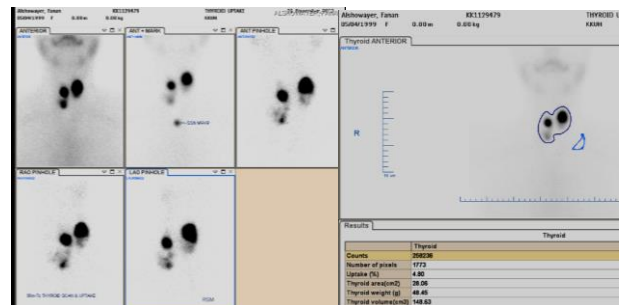
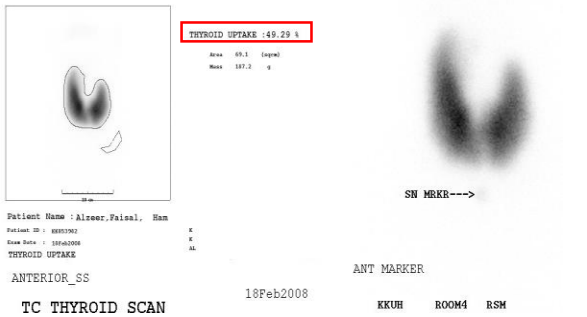
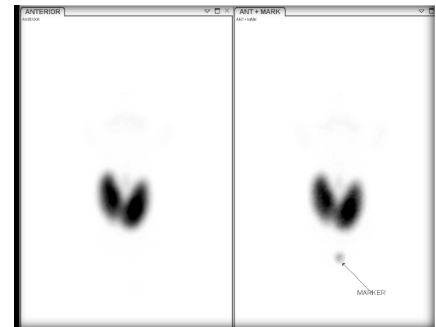
As the thyroid descend through the thyroglossal duct sometimes this duct remains producing a cyst.

❑ 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 **whatever the origin**.
- Hyperthyroidism : Overproduction of thyroid hormones by the thyroid gland (hyperactive gland)

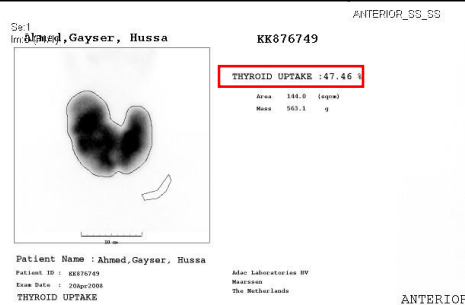
Thyrotoxicosis WITH hyperthyroidism

- **Graves' Disease.**
- **Neonatal hyperthyroidism**
- **Toxic nodular goiter:**
 - ✓ MNTG¹ 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)

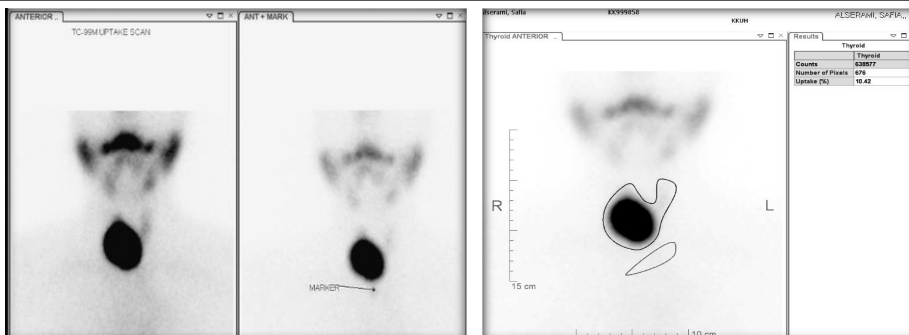


Diffuse enlargement in Graves disease

MNTG (Plummers Disease)



Graves' Disease on top of MNG the normal tissue between the nodules have graves Nodular Graves Disease (Marine-Lenhart syndrome)

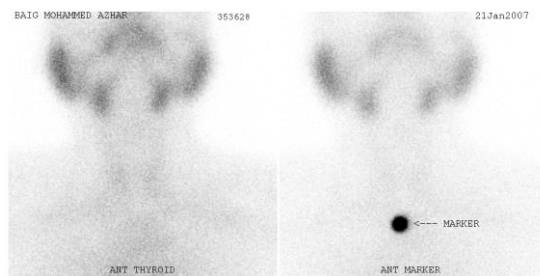


ATN (Autonomous Toxic Nodule)

❑ Evaluation of Thyrotoxicosis cont.

Thyrotoxicosis WITHOUT hyperthyroidism

- **Subacute thyroiditis.** Usually the history tells you that the patient had recent infection, 95% normally recover 5% will have complete hypothyroidism.
- **Chronic thyroiditis with transient thyrotoxicosis**
- **Thyrotoxicosis factitia**
 - ✓ (exogenous hormone).
- **Thyroid extract**
 - ✓ (e.g. Hamburger thyrotoxicosis)
- **Ectopic thyroid :**
 - ✓ Metastatic thyroid carcinoma
 - ✓ Struma ovarii



You don't see the thyroid gland

SAT

Here the treatment is mainly symptomatic while the other group we give definitive treatment which is: anti-thyroid drugs then the patient have a choice either to do surgery or the radioactive iodine.....

❑ Radioactive Iodine Therapy for Hyperthyroidism

- **Isotope used :** I131
- **Physical Properties:** Solution (be careful with elderly or kids risk of spilling) or capsule
- **Main side effect :** Hypothyroidism
- **Dose:**
 - Calculated : Considering weight and uptake of the gland (to delay the onsets of hypothyroidism)
 - Empirical:
 - ✓ Graves: 5-15 mCi
 - ✓ ATN : 15-20 mCi

❑ Radioactive Iodine Therapy for 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

You on't need to memorize these numbers EXCEPT the graves LOOK UP!

Parathyroid Scan:

Techniques:

- TL-201_Tc-99m subtraction
- Tc-99m Sestamibi (Dual Phase) used currently for parathyroid imaging (Gold standard)
- Tc-99m Tetrofosmin (Dual Phase)

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 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

- 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.

Cont.

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.

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

Parathyroid Scan

Dual phase MIBI Scan (Or Tetrofosmin)

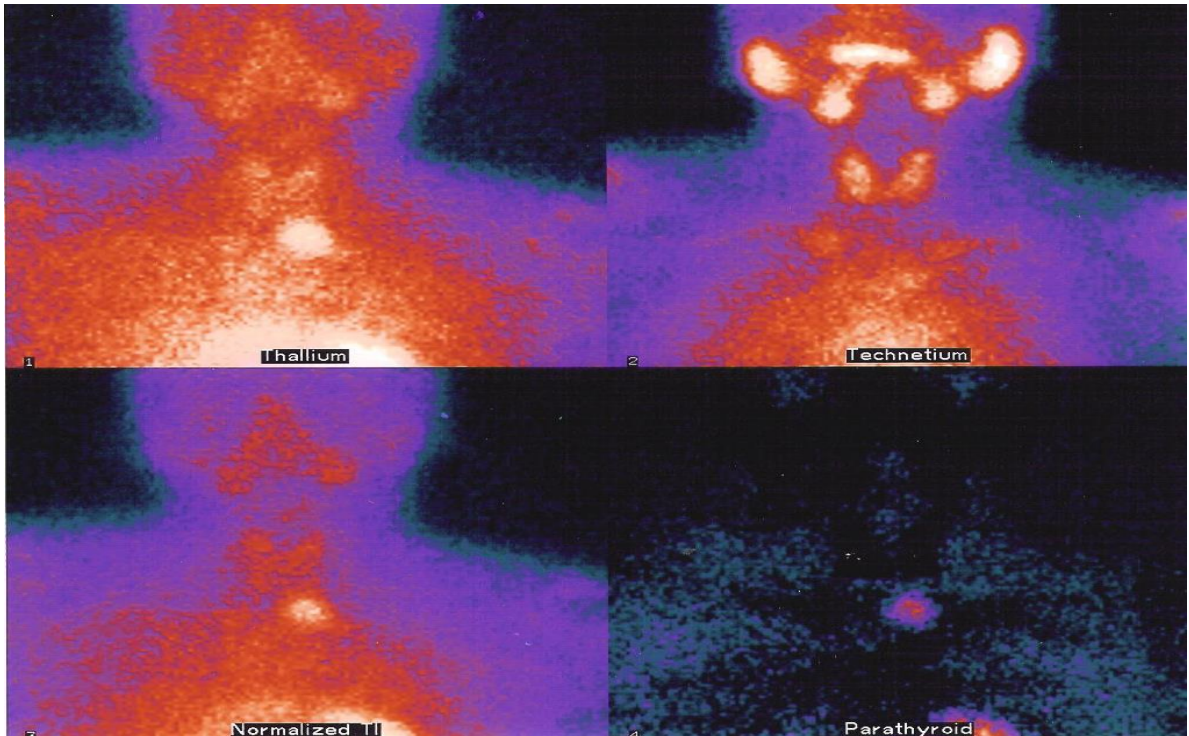


Normal parathyroid glands are small and not visualized



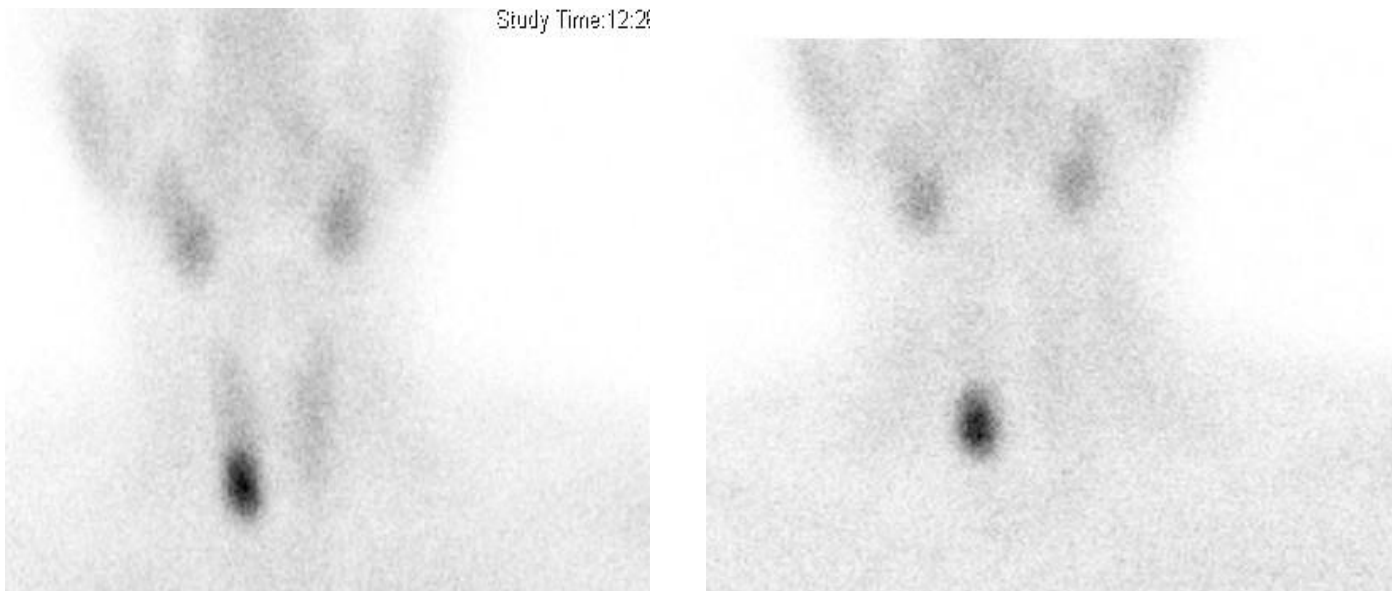
Abnormal parathyroid glands could be visualized

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.

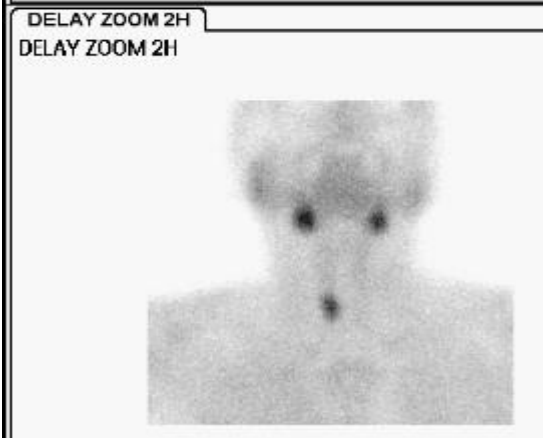
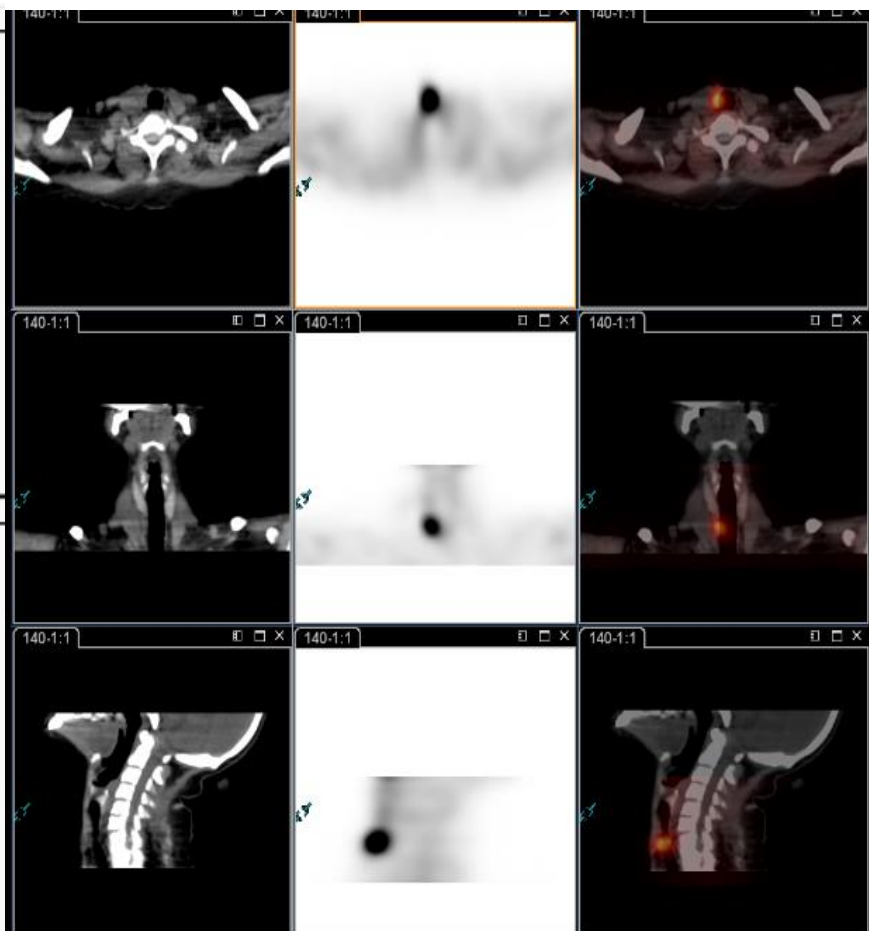
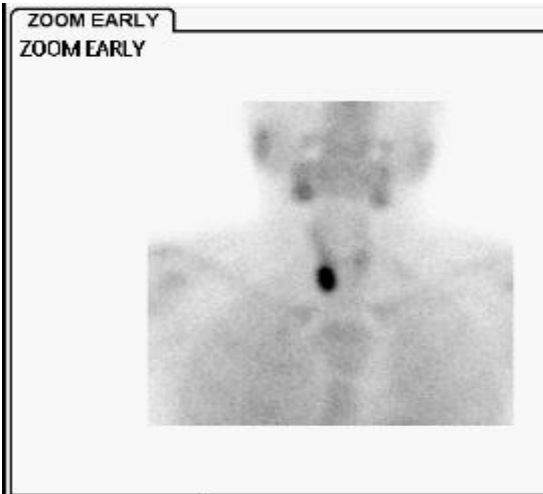
Sestamibi dual phase



Dual phase Technique:

- 1) We inject the sestamibi -- it will go to the thyroid and **abnormal** parathyroid. **(Early phase)**
- 2) After 2 hours we take another image. The remnants will represent the abnormal parathyroid. **(Late phase)**

Sestamibi Dual Phase (Planar vs SPECT CT)



Ectopic Parathyroid in upper mediastinum

img: (F17)



5MIN A FULL



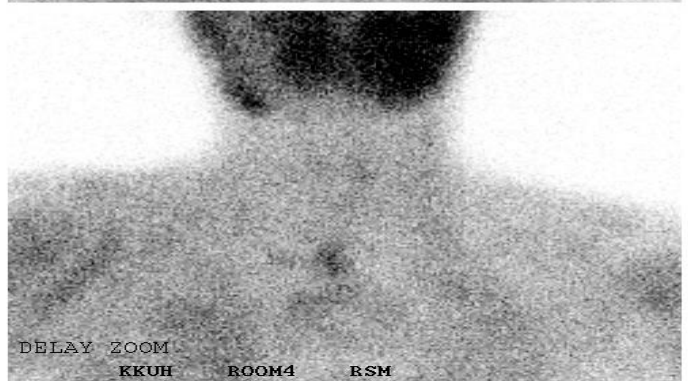
5MIN A FULL
PARATHYROID MIBI

27Jun2007

Study Date: 12/06/14 26
Study Time: 12:49:29 p
MFI: 1831759

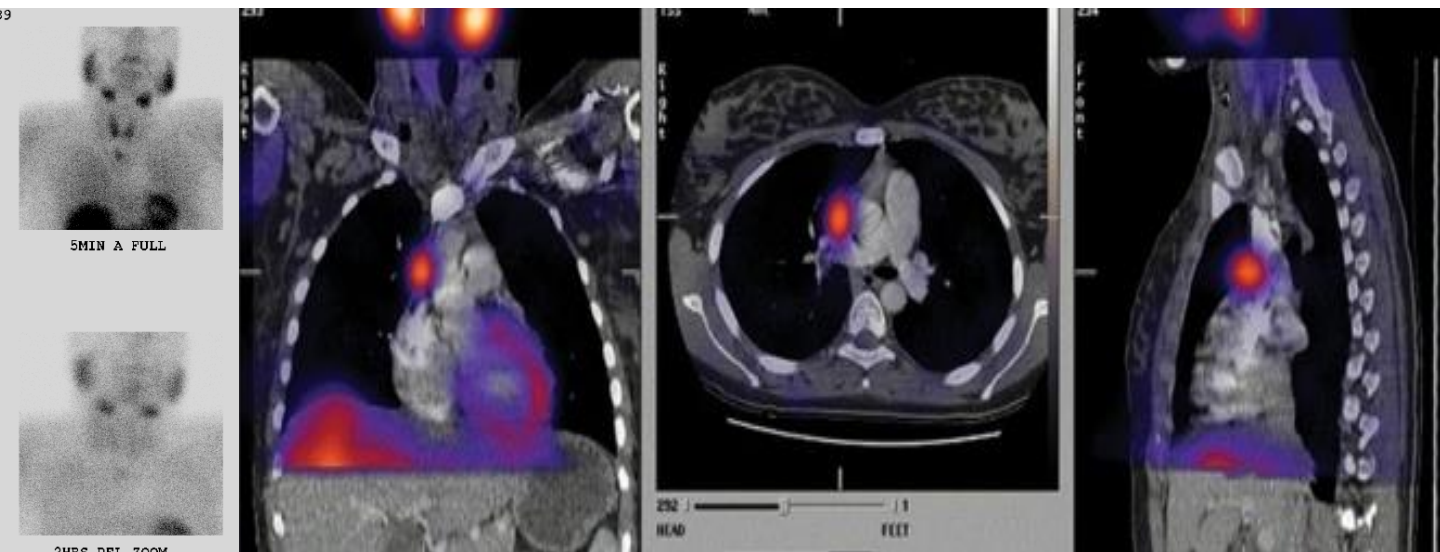


EARLY ZOOM



DELAY ZOOM
KKUH ROOM4 RSM

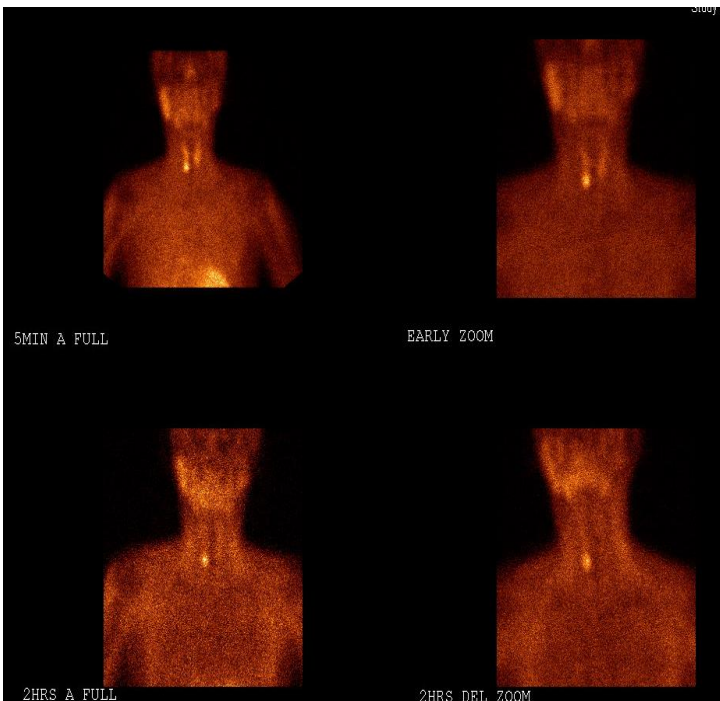
Ectopic Parathyroid Adenoma PLANAR vs SPECT/CT



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

Sestamibi Parathyroid Scan Result

High PTH / High Ca



TP (True positive)

High PTH / High Ca



FN (False negative)

•What is the cause of the FN result...?

Mechanism of sestamibi uptake.

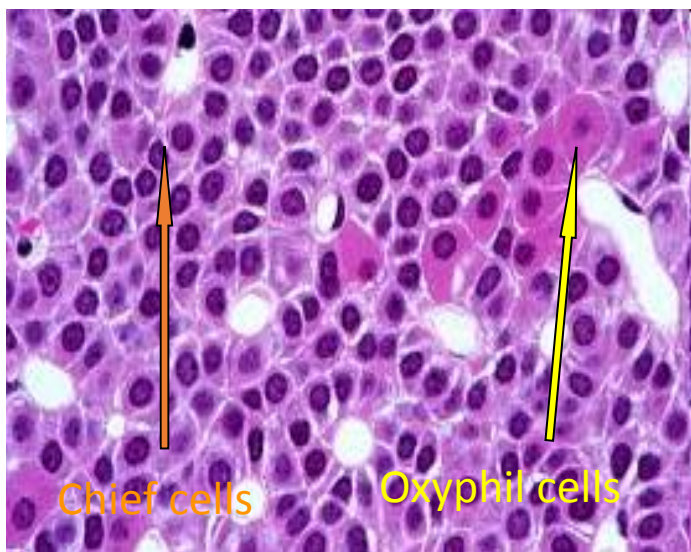
Parathyroid Cells

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.

(sestamibi concentrates in the mitochondria. if the adenoma derived from oxyphilic cell it will show on sestamibi (the scan will be **positive**) and if the tumor derived from Chief cell it will not show on sestamibi (it will not uptake the sestamibi and the scan will be **negative**.)]



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:

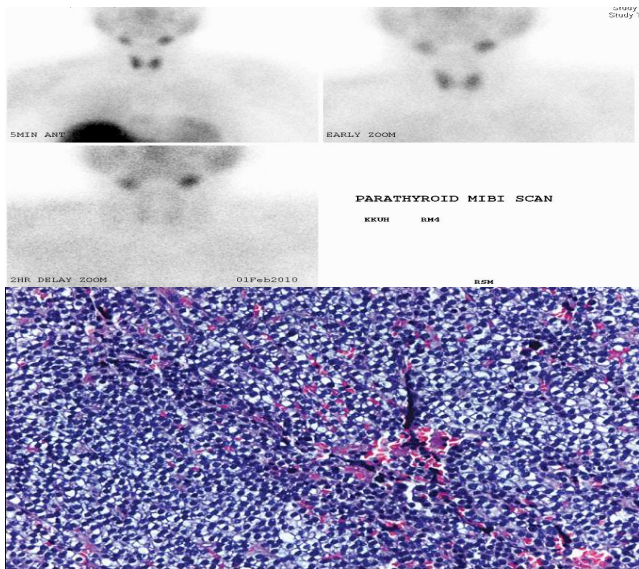
a. Biochemical properties of the tracer :

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

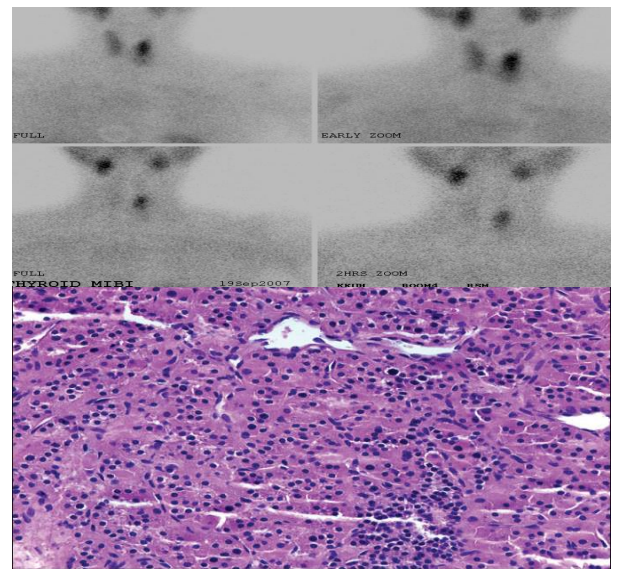
b. Cell Type : A predominance of oxyphil cells within an adenoma is more likely to lead to a positive scan.

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

Cell Type and Scan Result



Parathyroid adenoma composed entirely of glycogen-rich chief cells.



Parathyroid adenoma composed mainly of mitochondrial-rich oxyphil cells.

What is the cause of the FN result...?

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.

- P-glycoprotein expression
- 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.

False-Positive Scintigraphic Findings (Not imp)

- Solitary thyroid adenoma or a multinodular goiter
- Benign or malignant tumors : breast, lung, and head and neck carcinomas and their lymph node and osseous metastases, as well as bronchial carcinoids.
- Primary thyroid lymphomas.
- Cervical L.N. metastasis from PTC carcinoma
- Reactive lymph nodes
- Remnant thymus
- PTH-secreting paraganglioma
- Enlarged submandibular salivary gland .

* In the clinical setting of hyperparathyroidism, false-positive findings are uncommon.

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.

Don't Forget !

- 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.
- 22- normal parathyroid scan doesn't exclude parathyroid adenoma.