

Lecture (4)

Nuclear medicine in thyroid and parathyroid

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Resources:

- Lecture by Dr. Saleh Othman

Thyroid imaging

Thyroid Gland Tests :

- Thyroid scan
- Radioactive iodine Uptake (RAIU)
- Perchlorate discharge Test (PDT)
- Radioactive iodine therapy for hyperthyroidism

Radiotracer measuring unit is curie(Ci).
Dose is not imp.

Radiotracers

	Tc-99m Pertechnetate	I123
Dose	.5 – 4 mCi	50-100 uCi
Time of imaging	20 min post injection	6,24 hours after oral ingestion
Remarks	Trapped non organified	Trapped and organified

Tc 99m Pertechnetate

- Disadvantages
 - High salivary excretion
 - Only trapping
- Advantages
 - Scanning 20 min post injection
 - Short half life (6 hrs)**
 - Very low radiation exposure
 - Optimal availability
 - Low cost

Organified means that the thyroid gland use the tracer in synthesizing thyroid hormone. If we take blood sample from the patient after I123 the thyroxin will be radioactive.
to assess the organification we use I123.

Radioactive iodine Uptake (RAIU)

The Thyroid Uptake Measurement measures the metabolic activity of the thyroid gland as reflected by its extraction of iodine from the blood.

- **Quantitative measurements of thyroid uptake**
 - I131 OR I-123 gold standard 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%)
- **Patient Preparation**
 - Must be off thyroid hormones :
 - **Thyroxine (T-4)** for at least **3-4 weeks**.
 - Triiodothyronine (T-3) for at least 10 days.
 - Must not be taking **antithyroid** medications :
 - Propylthiouracil (PTU) and tapazole for at least **3-5 days**.
 - Must not have had **intravenous or intrathecal iodinated contrast** material (IVP, CT - with contrast, myelogram, angiogram) for at **least 3-4 weeks**.
 - NPO after midnight the night before and for at least 1 hour after ingesting the radiopharmaceutical and avoid iodine rich food such as fish and cabbage.

Radioactive Iodine Uptake Test (RAIU) Technique

$$\% \text{ Uptake} = \frac{[(\text{net neck counts} - \text{net thigh counts}) \times 100]}{(\text{net standard counts})}$$

Causes of High Thyroid Uptake (IMP)

- Hyperthyroidism : Grave's Disease or TSH-secreting pituitary adenoma
- Autonomous toxic nodule
- Multinodular toxic goiter (Plummer'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

Indication for thyroid imaging

- 1) Evaluation of thyroid nodules : No. & type (hot, warm or cold)

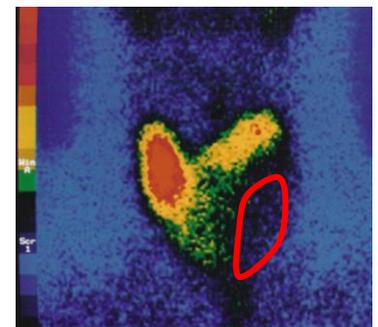
A 44 years old male patient with **history of neck irradiation** at age 13 and presented with lump in the neck.

Chance of malignancy: **Male :20%** , Female : 15%

RAIU is to determine how much of the dose we give to the patient is taken by the thyroid gland.

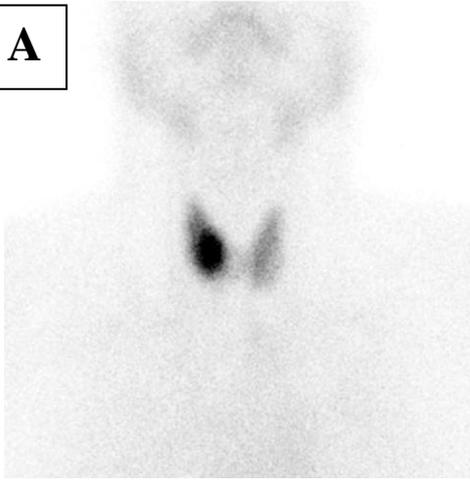
The technique:

- 1) We have two capsules with similar activity we give one to the patient and the other one is kept in the lab.
- 2) The next day we measure -by a specific probe- how much count did the thyroid take from the tracer then we compare to the one in the lab and calculate the percentage. e.g. the patient's uptake is 100 counts and the capsule in the lab has 1000 counts. The uptake is 10%.

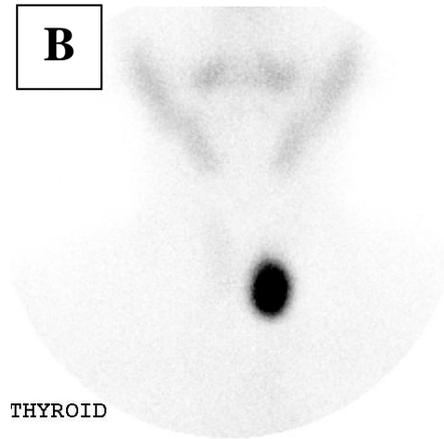


Cold nodule (no uptake)
-red borders-

A



B



THYROID

THYROID SCAN Tc99m

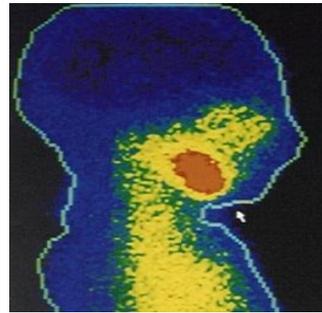
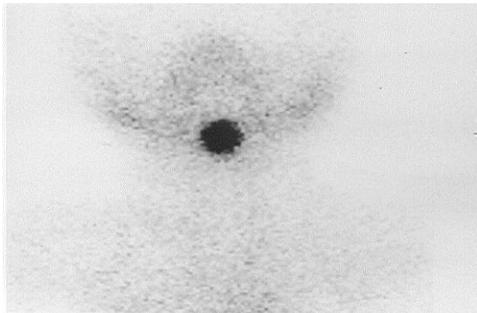
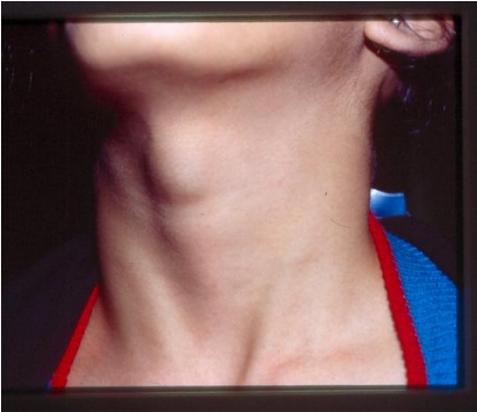
A 27 ys , F, with signs and symptoms of hyperthyroidism. Thyroid scan revealed right functioning thyroid nodule.

A 35 years old female patient with signs and symptoms of hyperthyroidism. Thyroid scan revealed left autonomous toxic nodule.

- A- Warm nodule: the rest of the thyroid is functioning but this nodule is hyper functioning so we can see the rest of the gland as opposite to the hot nodule where the rest of the gland is not visualized apart from the hot nodule.
- B- Hot nodule because its working **independent** to the hypothalamus pituitary thyroid axis. The rest of the gland is suppressed because of high thyroid hormone levels.

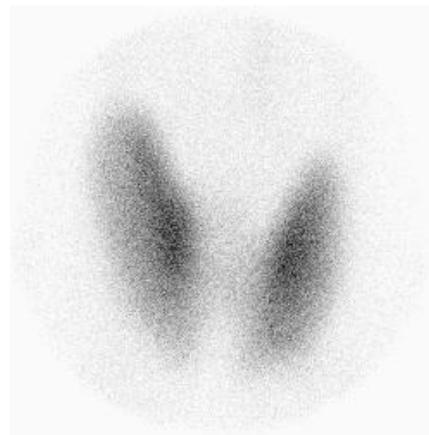
2) Evaluation of neck masses

- Ligual thyroid Mass in upper neck may represent the whole thyroid gland and thyroid scan is mandatory in this group of patients.



Thyroid bed is empty
thyroid gland is at the base of the tongue.

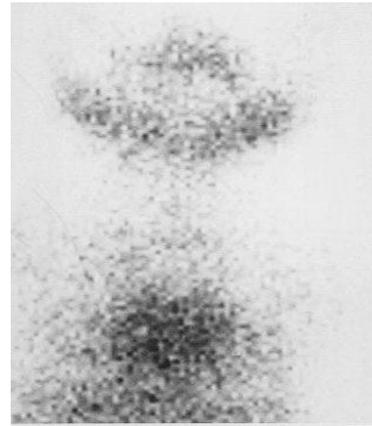
- **Diffuse Simple Goiter (Physiologic)**



3) Evaluation of congenital hypothyroidism

- **Thyroid Aplasia (no thyroid)**

No thyroid in thyroid bed or in mouth.



- **Dyshormonogenesis**

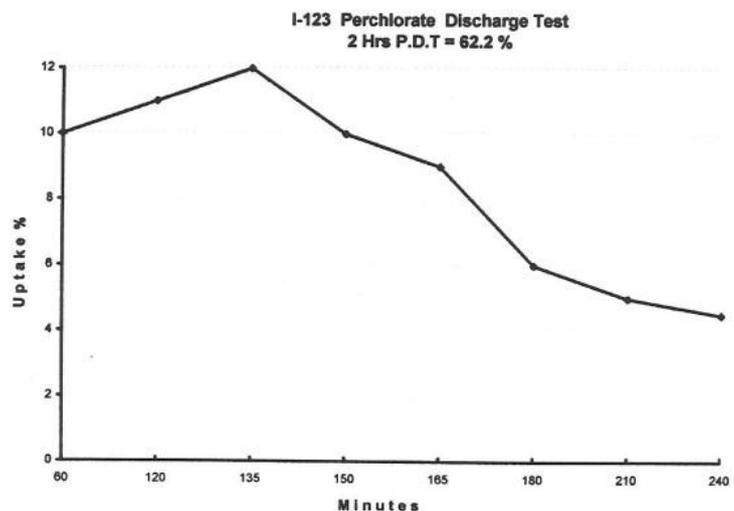
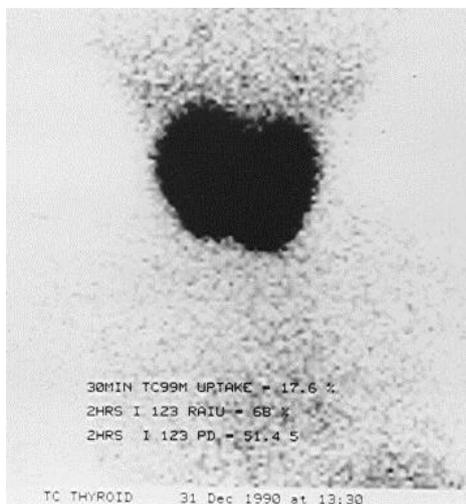
- New born baby with high TSH and high thyroid uptake.
- There is an enzyme deficiency in thyroid hormone synthesis. So the TSH is secreted to trap more iodine.

To confirm it we use **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.

PDT test technique:

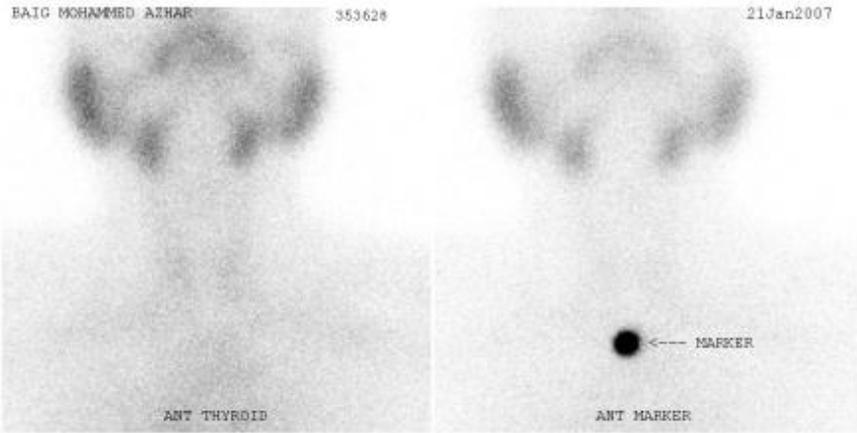
- 1) We do RAIU I¹²³.
- 2) After 2 hours we give the patient potassium perchlorate orally. It will go to thyroid and kick out all the trapped non organified iodine.
- 3) Then measure the uptake again after 2 hours of giving potassium perchlorate and if the drop is more than 15 % that means there was a lot of iodine trapped and non organified → positive test (the patient has organification defect -enzyme deficiency-)



Drop more than 15% → positive PDT.

4) Evaluation of Thyrotoxicosis (IMP)

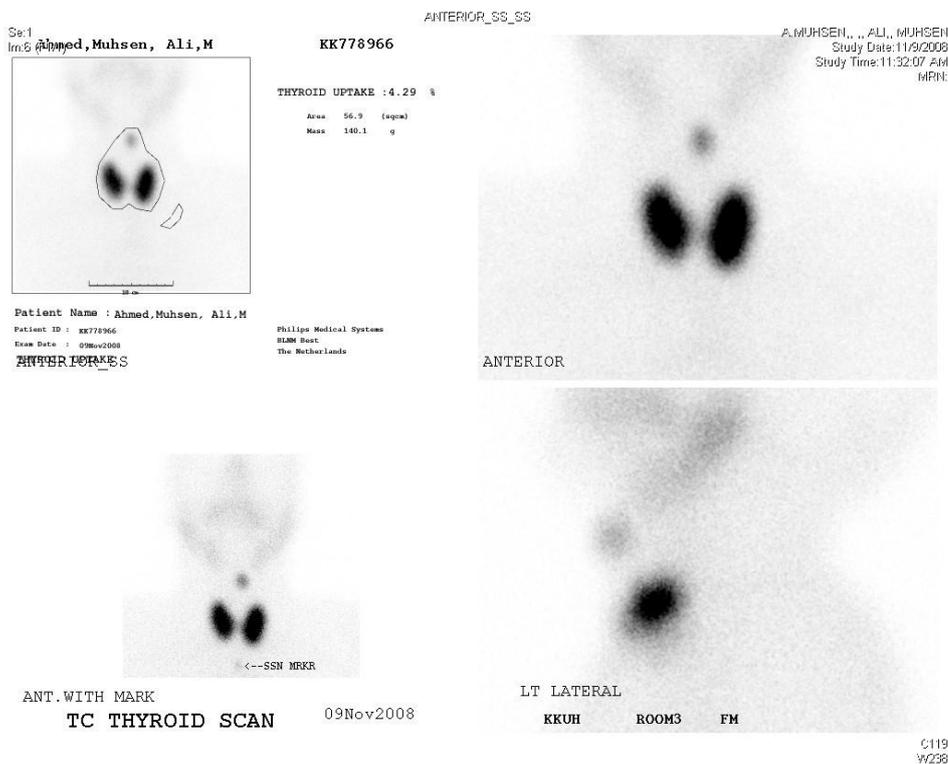
To differentiate cases with hyperthyroidism and those without hyperthyroidism because the management is different.



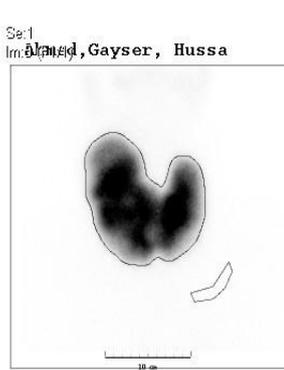
A 25 years old female patient with signs & symptoms of thyrotoxicosis. Tc-thyroid scan didn't visualize thyroid gland. (because the gland is inflamed and destructed)
Thyroiditis: inflammation of gland, all thyroid follicles were destructed and thyroid hormone stores went to blood.
 Tx is medically with conservative tx.



A 29 years old male patient with symptoms of thyrotoxicosis. Tc- thyroid scan showed goiter with increased uptake (15%).
 Tx: surgery or radiotherapy or antithyroid drugs.



-Graves & Thyroglossal active remnant (submental mass superior to thyroid gland).
 -Active means it produce thyroid hormone, contributing to thyrotoxicosis.



ANTERIOR_SS_SS
A.GAYSER,, MOHAM
SH
SH

KK876749

THYROID UPTAKE : 47.46 %

Area 144.0 (sqcm)
Mass 563.1 g



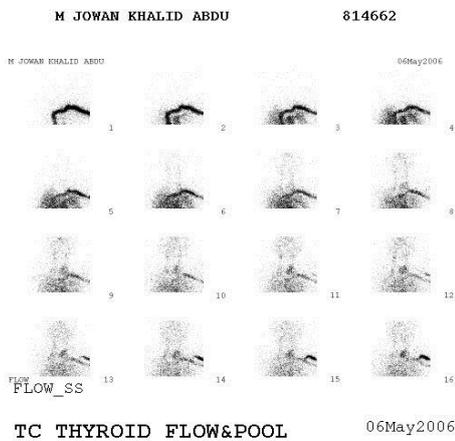
Patient Name : Ahmed, Gayser, Hussa
Patient ID : KK876749
Exam Date : 20Apr2008
THYROID UPTAKE

Adco Laboratories BV
Maarsseem
The Netherlands

- 45-year-old female with clinical hyperthyroidism.

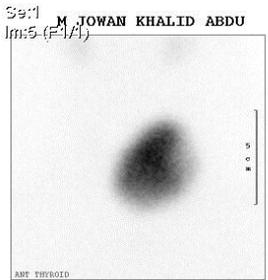
- Graves on top of **multi nodular goiter (MNG)** → Marine-Lenhart syndrome.

Graves → diffuse uniform uptake.
MNG → ther're hot and cold nodules.



A 35 years old female patient with signs and symptoms of thyrotoxicosis.

Thyroid scan revealed left **autonomous toxic nodule**. The rest of the gland is not visualized.

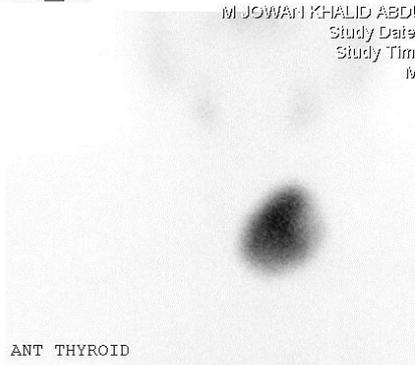


ANTH THYROID_SS
M JOWAN KHALID ABDU
Study Date
Study Time

814662

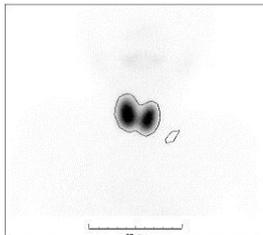
THYROID UPTAKE : 6.07 %

Area 44.7 (sqcm) Mass 97.5 g



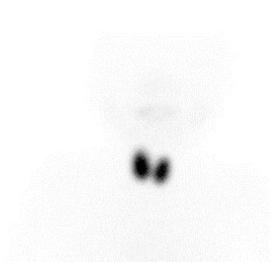
Patient Name : M JOWAN KHALID ABDU
Patient ID : 814662
Exam Date : 06May2006
THYROID UPTAKE

ALGHAMDI DANA KHAL 839271



THYROID UPTAKE : 19.14 %

Area 18.0 (sqcm)
Mass 26.5 g



Patient Name : ALGHAMDI DANA KHAL
Patient ID : 839271
Exam Date : 03Mar2007
THYROID UPTAKE

K
K
AL

ANTERIOR

Graves in children.

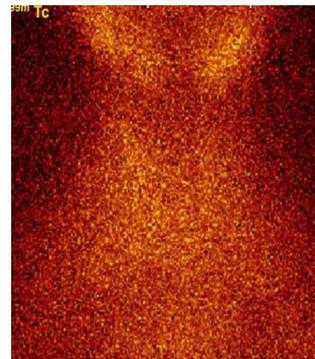
Thyrotoxicosis with hyperthyroidism (IMP)

- **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 (IMP)

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



Thyroid Scan In Lactating Mother

- A number of radionuclides are excreted in breast milk. It is recommended that breast feeding is suspended as follows:
 - **Completely after 131I therapy.**
 - **3 weeks after diagnostic iodine.**
 - **12 h after 99mTc.**

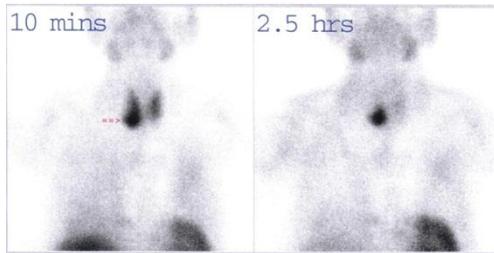
Radioactive Iodine **Therapy** for Hyperthyroidism

- **Isotope used : I131**
- Physical Properties: Solution or capsule
- **Main side effect : Hypothyroidism**
- Dose :
 - Calculated : Considering weight and uptake of the gland
 - Empirical : (used in KKUH)
 - Graves: 5-15 mCi
 - ATN : 15-20 mCi

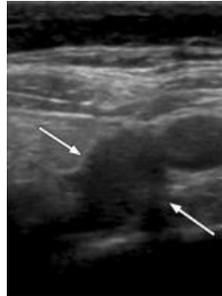
Parathyroid imaging

- 37 Years , Female , presented with fatigue and generalized bodyache.
- Lab Result: High Calcium and High PTH.

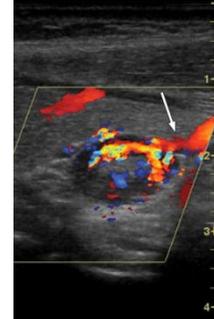
Imaging



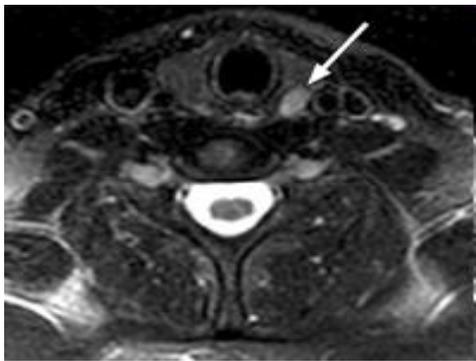
Parathyroid scan



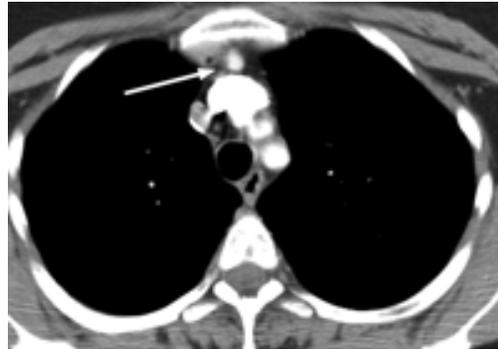
US



Doppler



MRI

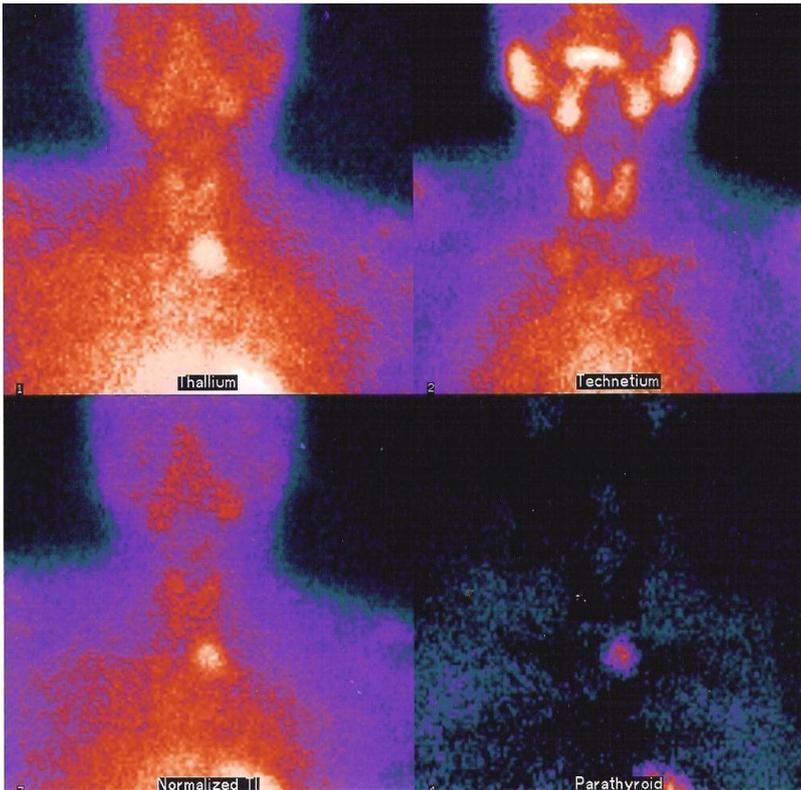


CT

To diagnose parathyroid adenoma we need to use at least two imaging modalities. Sestamibi and MRI are the best combination.

Techniques

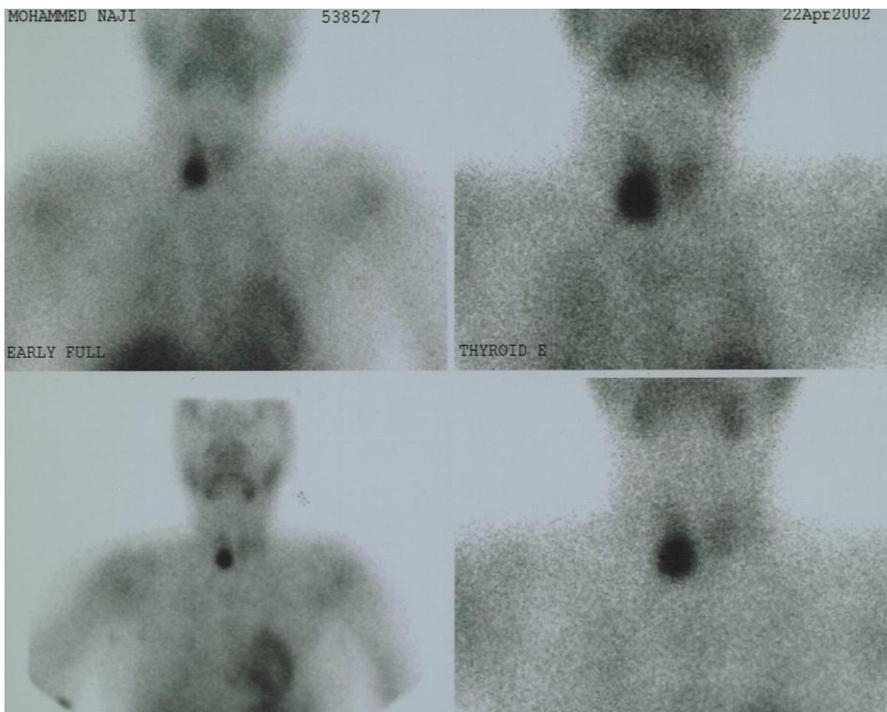
- TL-201 _ Tc-99m subtraction (used in the past)



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.

- Tc-99m Sestamibi (Dual Phase) or Tc-99m Tetrofosmin (Dual Phase) (now commonly used)

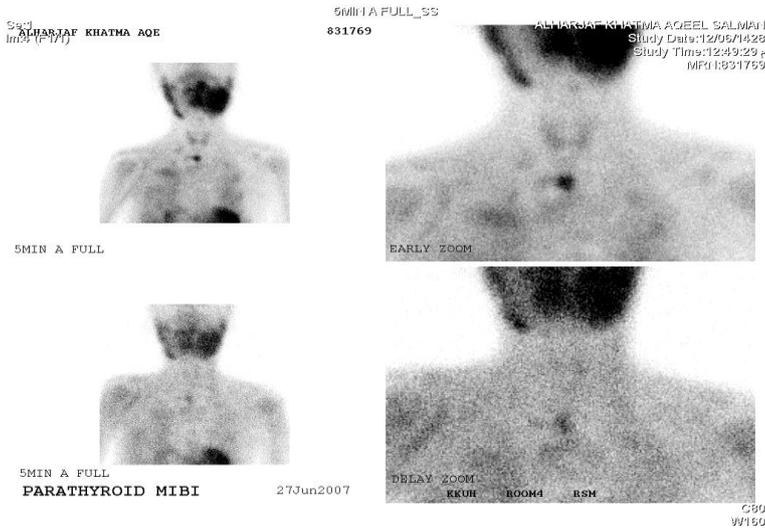


Dual phase MIBI Scan.

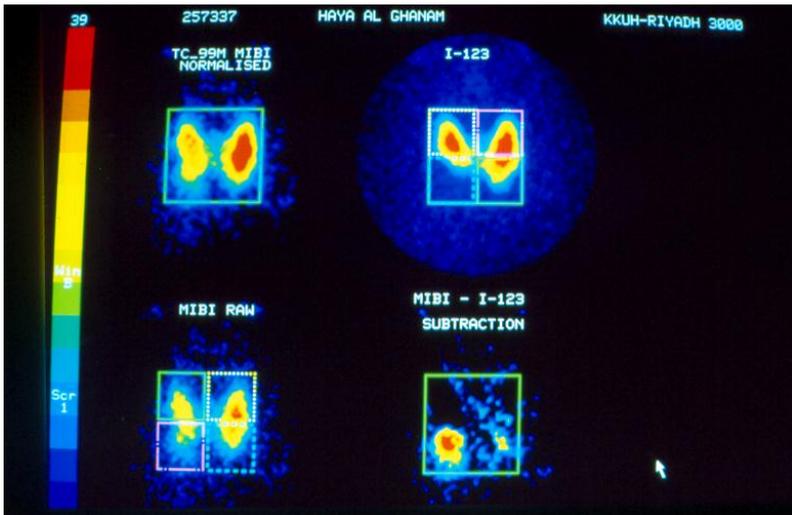
- 1) We inject the sestamibi → it will go to the thyroid and **abnormal** parathyroid.
- 2) After 2 hours we take another image. The remnants will represent the abnormal parathyroid.



Sestamibi dual phase

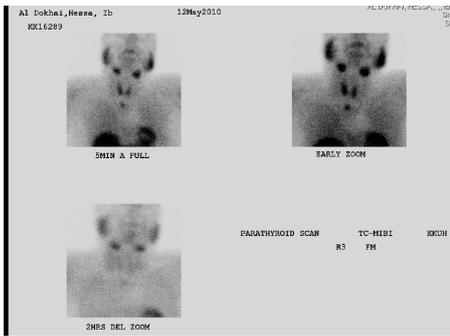


Mibi scan showing ectopic Parathyroid in upper mediastinum.

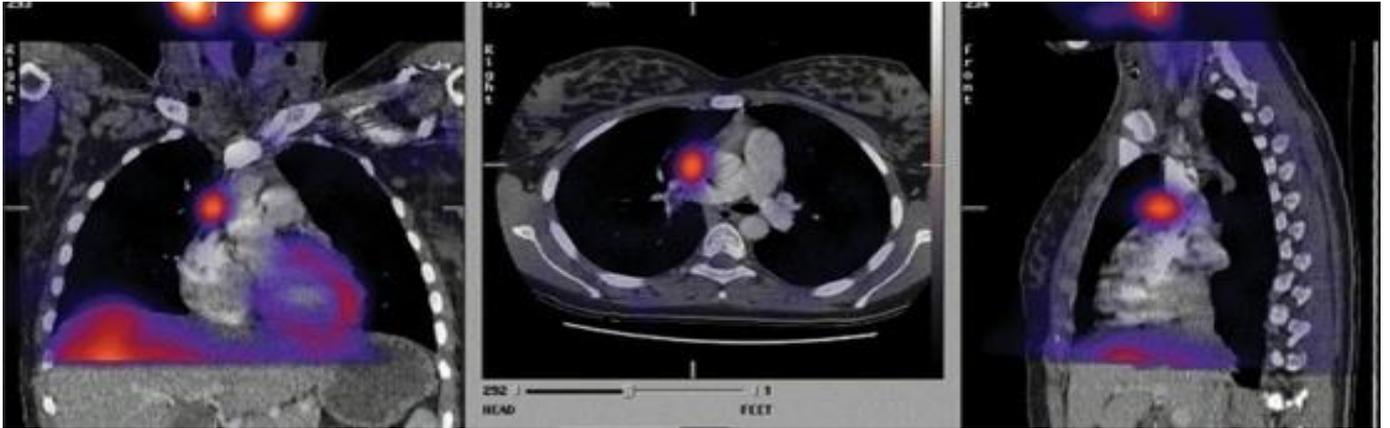


TL-201 _ Tc-99m subtraction showing right lower parathyroid adenoma.

PLANAR VS SPECT/CT



PLANAR

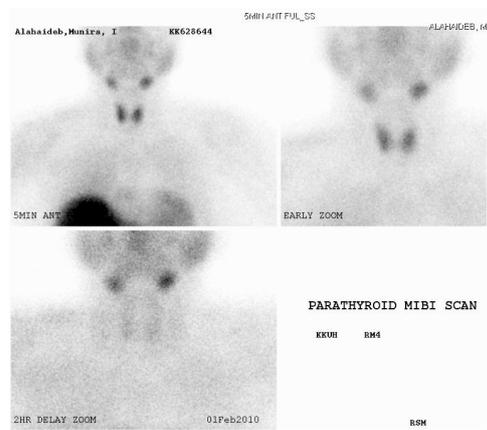


SPECT/CT shows right paratracheal ectopic parathyroid adenoma.

Sestamibi Parathyroid Scan Result

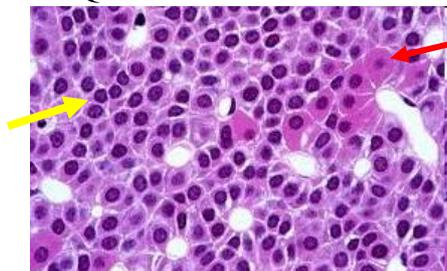


High PTH and calcium.
True positive



High PTH and calcium.
False negative

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



Normal parathyroid glands comprise 2 cell types:
 i. Chief cells (yellow arrow): responsible for PTH production
 ii. Oxyphil cells (red arrow): eosinophilic cells whose cytoplasm is composed almost entirely of mitochondria.

It depends on the histological type of adenoma. If the adenoma is composed of oxyphilic cells then it will uptake the sestamibi and the scan will be positive. But if the adenoma is composed of chief cells it will not uptake the sestamibi and the scan will be negative.

note: normally chief cells produce the PTH while oxyphilic cells don't. the sestamibi will go the abnormal cells which are oxyphil cells.

The message → normal parathyroid scan doesn't exclude parathyroid adenoma.

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, thyroglobular 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 131I therapy**
 - b. **3 weeks after diagnostic 131I**
 - 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.