

432 Radiology Team



(4): Nuclear Medicine in Thyroid & Parathyroid imaging.

* Many thanks to 430 & 431 teams for their helpful notes *



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COLOR GUIDE: • Females' Notes • Males' Notes • Important • Additional

Objectives

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

1. How is the thyroid scan performed?
2. When is thyroid scanning helpful?
3. What is significant about whether a nodule is "hot" or "cold?"
4. What is the role of nuclear medicine in the treatment of thyroid disorders?
5. Discuss the principles of dual-phase and dual-isotope parathyroid imaging
6. Identify the common imaging features of pathologic parathyroid glands.
7. Discuss causes of false negative scans.
8. Identify causes of false negative and false positive scans.

How is the thyroid scan performed?

Thyroid Scan: Procedure

We can do thyroid scan using one of two radiopharmaceuticals either Tc-99m Pertechnetate or I-123

	Tc-99m Pertechnetate	I-123
Dose (not imp)	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 <u>not organified</u>	Trapped and organified

Note(s):

☞ Radiotracer measuring unit is curie (Ci).

**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.

Radiopharmaceutical and dose: (doses are not imp)

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 Tc99 m: ANT, LAO and RAO images obtained.

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

Note(s):

☞ ANT: Anterior
LAO: left anterior
RAO: right anterior

THYROID UPTAKE MEASUREMENT

(I-123 Sodium Iodide)

- 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

Patient Preparation:

- Must be off thyroid hormones:
 1. Thyroxine (T-4) for at least 3-4 weeks.
 2. Triiodothyronine (T-3) for at least 10 days.
- 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 (IVP, CT with contrast, myelogram, angiogram) for at least 3 weeks.
- Other agents may interfere, but usually only to a small extent.
- NPO 2-4 hours before and for at least 1 hour after ingesting the radiopharmaceutica

Note(s):

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)

Equipment :

Uptake only: Uptake probe (single crystal probe with flat field collimator).

Imaging plus uptake studies: Gamma camera

Radiopharmaceutical : dose given orally

Imaging plus uptake studies: I-123: 500 μ Ci .

Uptake study only: I-123: 100 μ Ci

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

Patient position: Sitting. **Detector field of view:** Neck.



THYROID UPTAKE MEASUREMENT WITHOUT IMAGING (I-123 Sodium Iodide)

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%)**

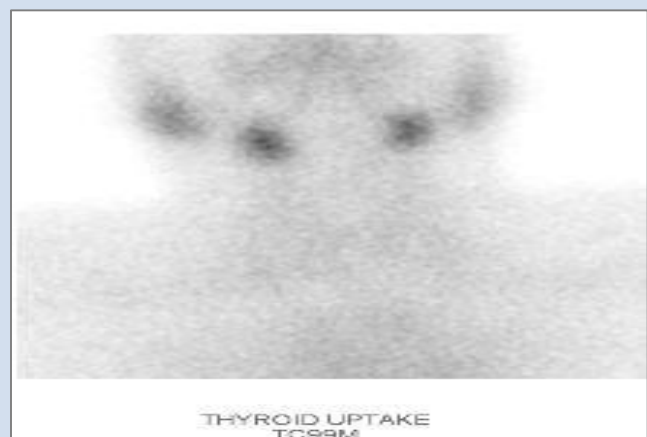
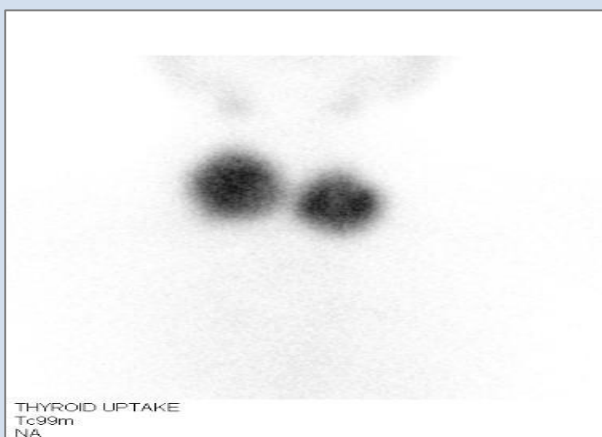
*If more than these values, that means the gland is hyperactive.

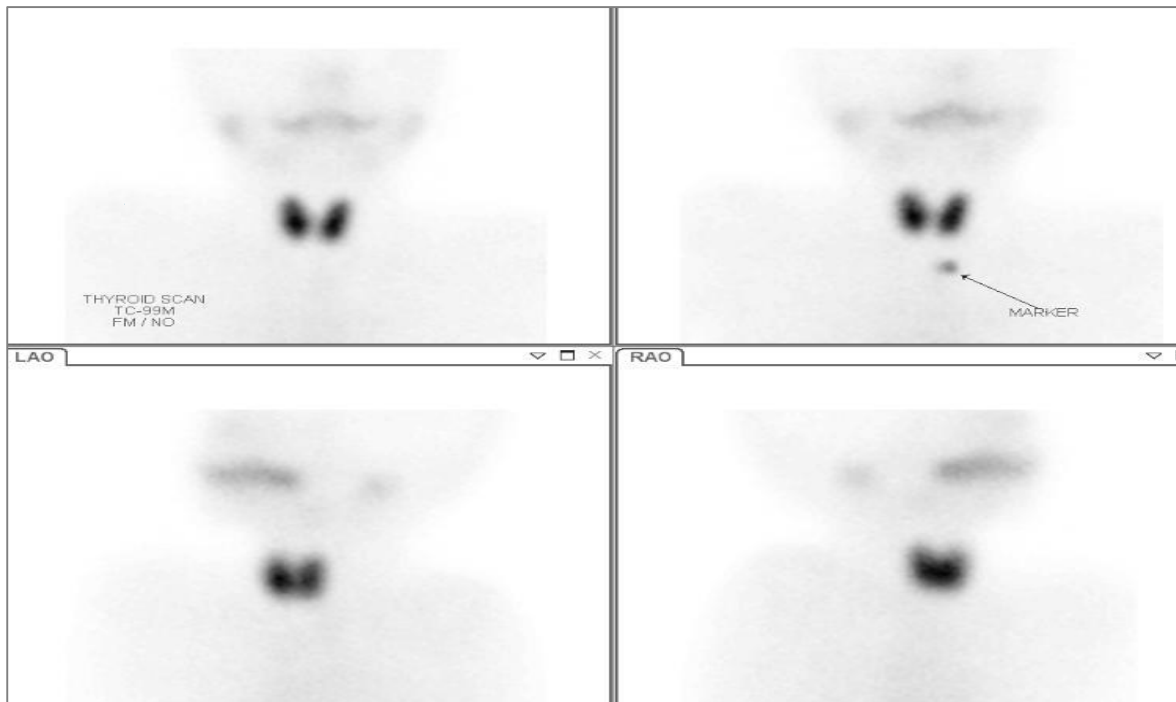
Causes of High Thyroid Uptake

- **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**
- **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





Normal Thyroid Scan

(Arrow) A marker on Suprasternal notch to see how far is the thyroid from the sternum in case of retrosternal enlarged thyroid.

ALYAMI EBTISAM HUSS 843223 Study Date Study Time

THYROID UPTAKE : 2.96 %

Area 29.8 (sqcm)

Mass 53.0 g

Normal

Patient Name : ALYAMI EBTISAM HUSS
Patient ID : 843223
Exam Date : 03Jun2007
THYROID UPTAKE

Adac Laboratories BV
Maarsse
The Netherlands

ANTERIOR

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

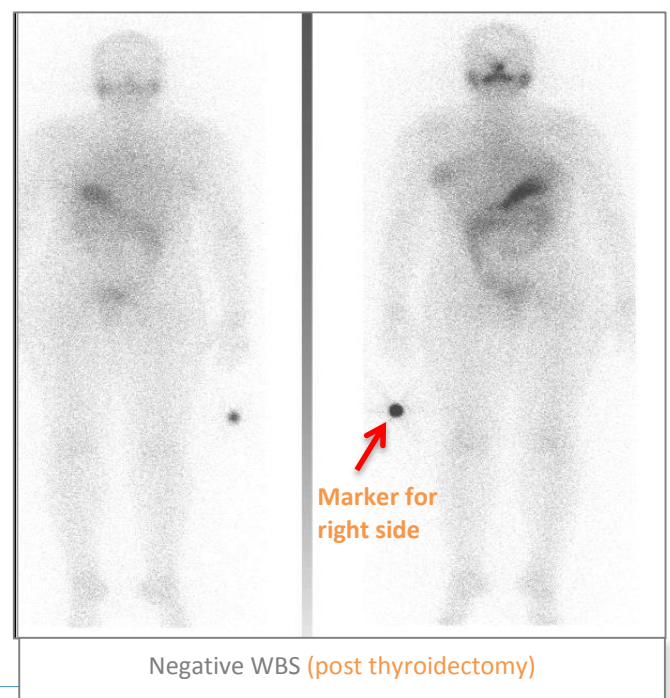
- Radiopharmaceutical: Oral administration

a. I-123 as sodium iodide: 2 mCi

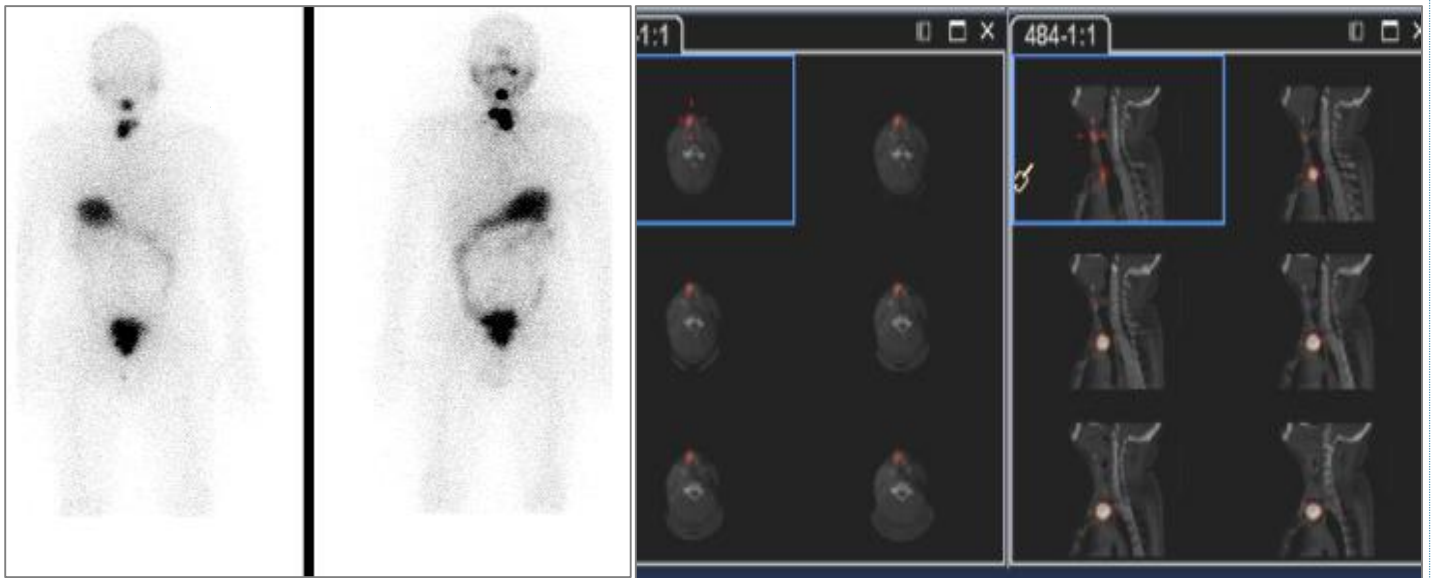
b. I-131 as sodium iodide: 2-10 mCi

Imaging using Gamma camera :

Whole body scan (WBS)

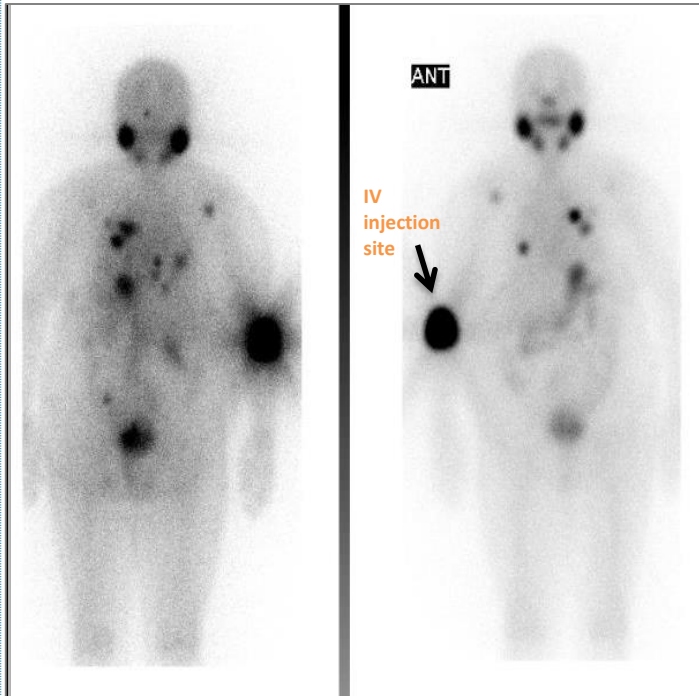


I-123 or I-131 Whole Body Scan (WBS)



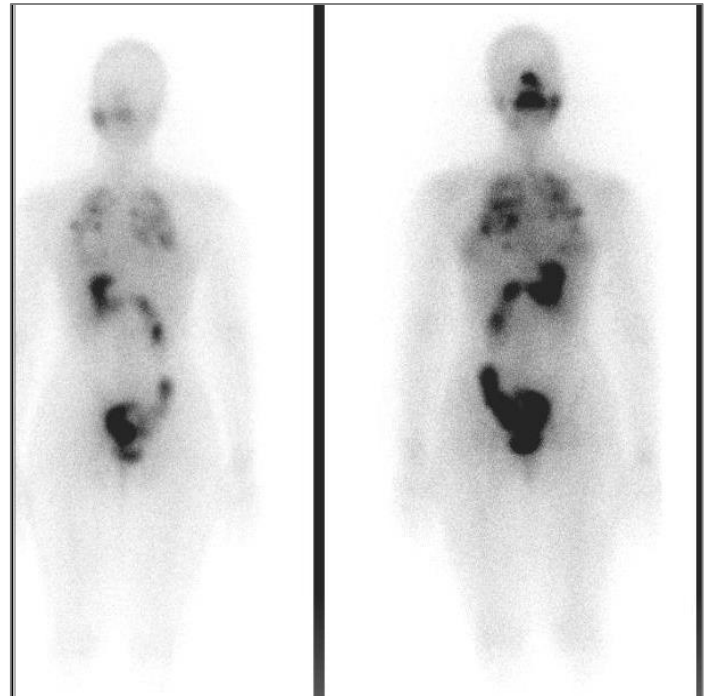
Planar Vs SPECT CT (Local Recurrence)

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



Bone Metastases

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



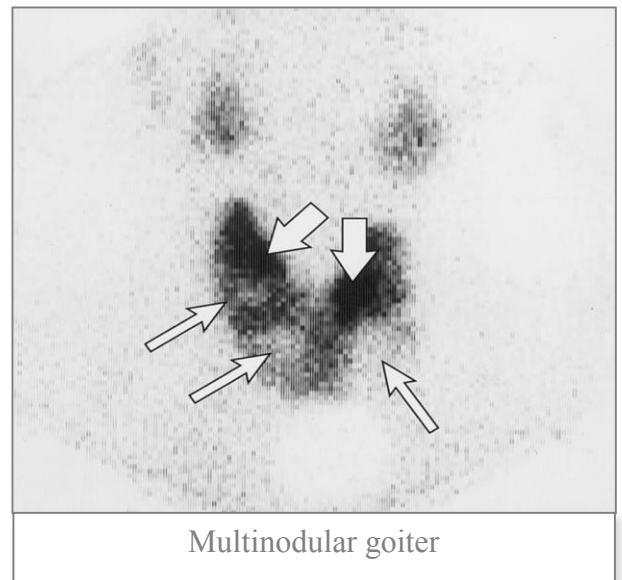
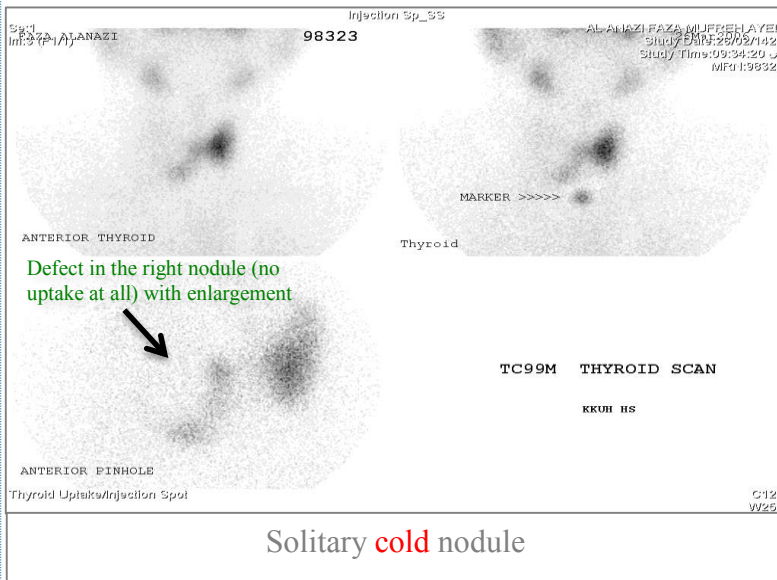
Lung Metastases

When is thyroid scanning helpful?

Indications for Thyroid Scan

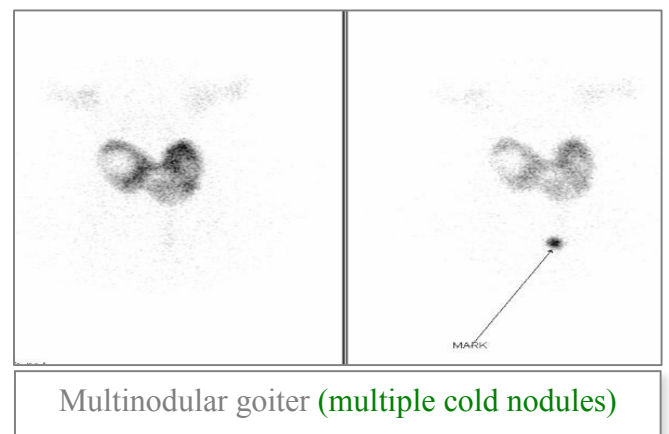
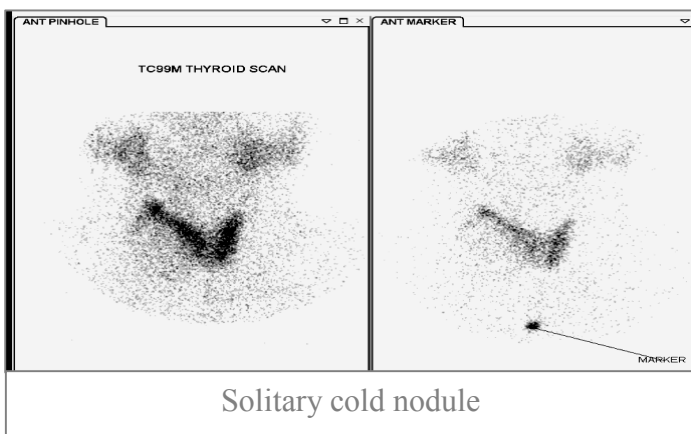


1. Evaluation of thyroid nodules: Single vs MNG

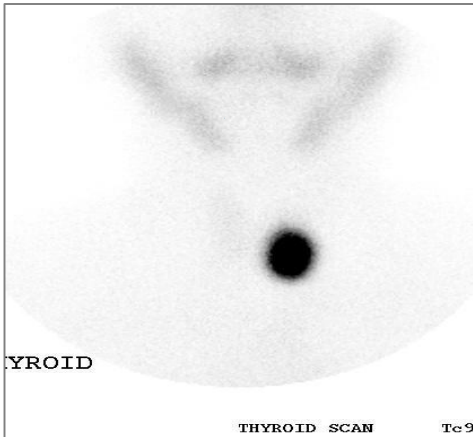


*The chance of malignancy is more in Solitary cold nodule than in MNG

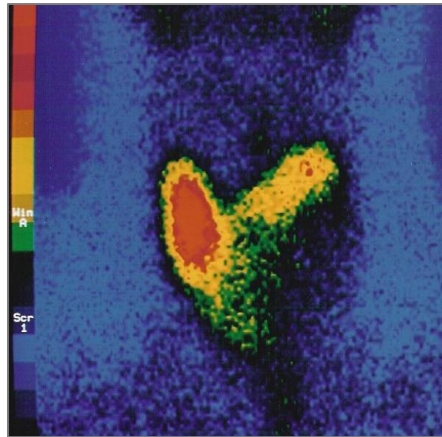
As the number of nodules increase, the chance of malignancy decrease



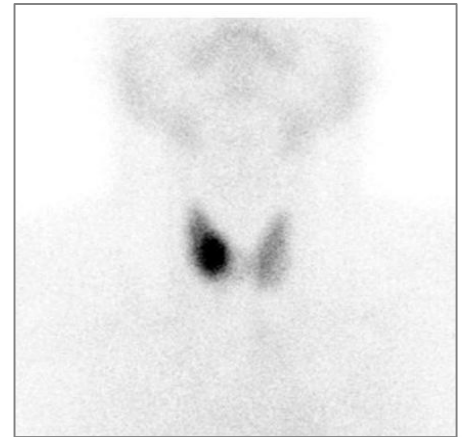
2. Evaluation of thyroid nodules Hot vs Cold vs warm



Hot
(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



Cold
(No uptake at all in the affected side)



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

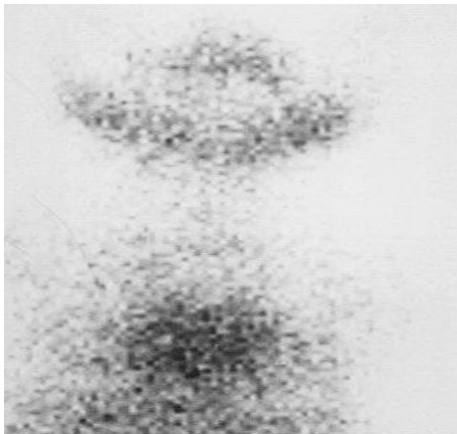
<5% Malignant

15-20% Malignant
 Female Male

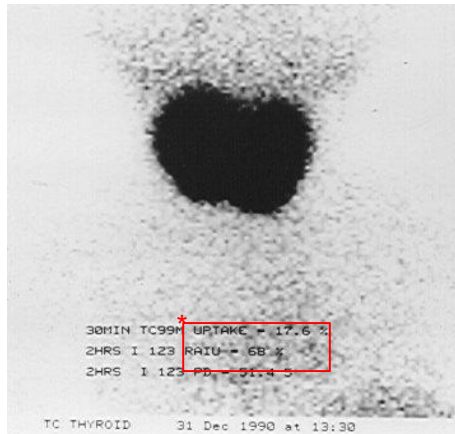
Suspicious

(Follow up is necessary)

3. Evaluation of congenital hypothyroidism (Agenesis vs Dyshormonogenesis)



Agenesis (absent of the thyroid)
Treatment is thyroxin whole life



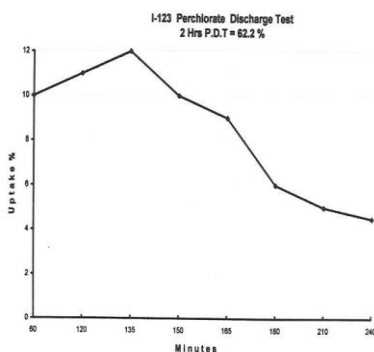
Dyshormonogenesis
 *Uptake is very high because of dyshormonogenesis (enzyme deficiency of the thyroid hormone synthesis which result in hypothyroidism) .
 There is high TSH and enlargement of the gland in attempt to produce hormones

Note(s):

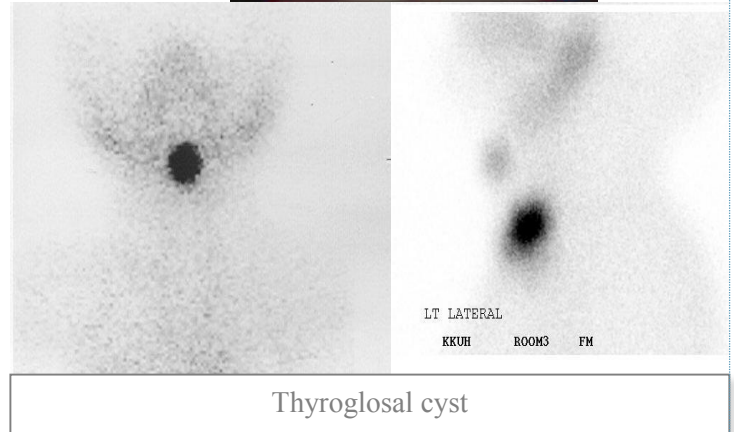
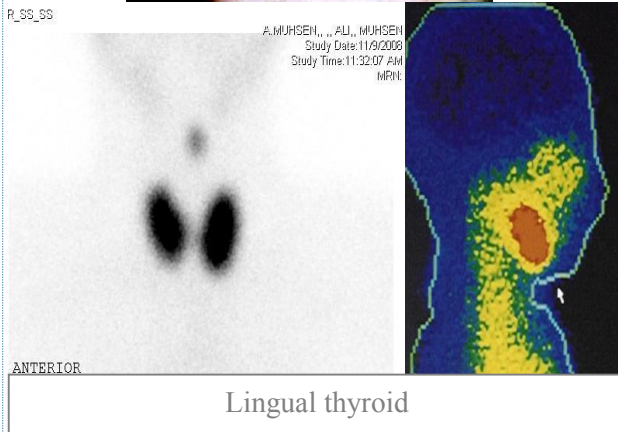
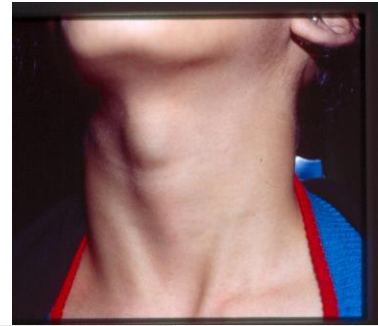
TSH tests are routinely ordered for newborns as part of the screening program to evaluate how well the thyroid gland is working.

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)

Perchlorate discharge test is used to confirm dyshormonogenesis



4. Evaluation of neck masses (ectopic thyroid vs thyroglossal cyst)



5. 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)

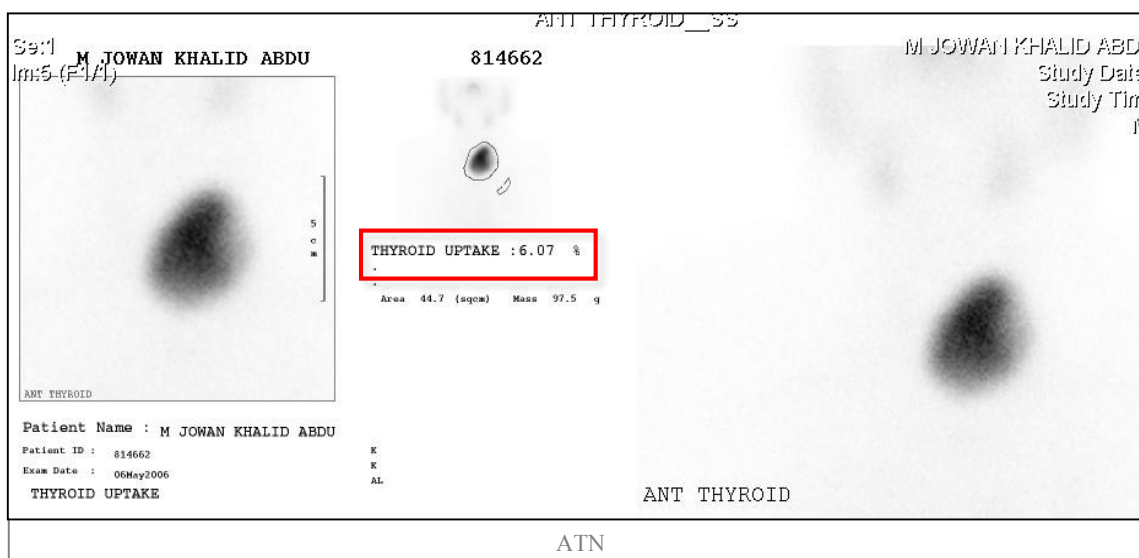
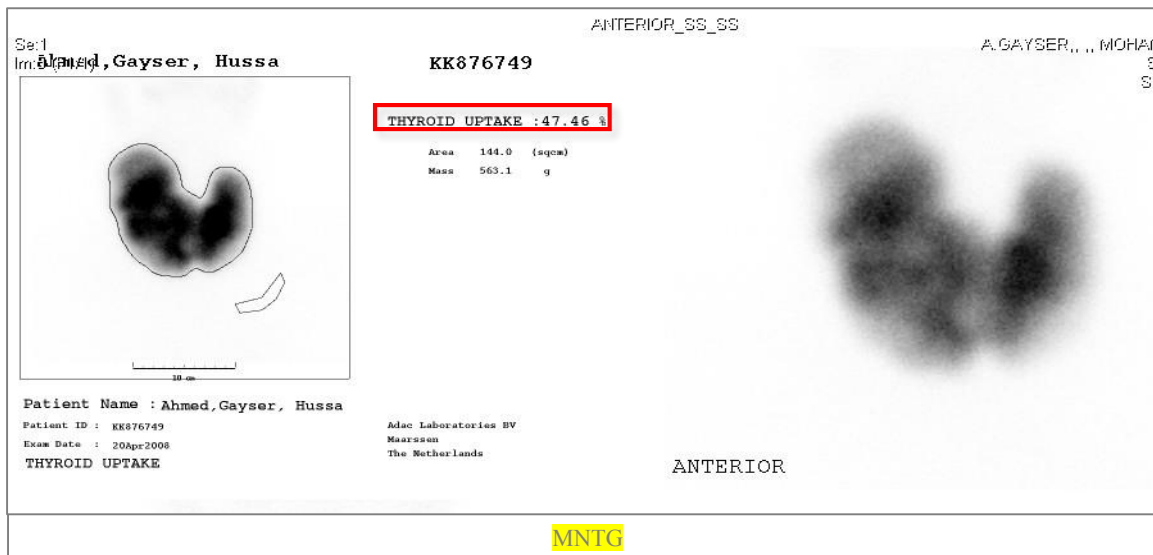
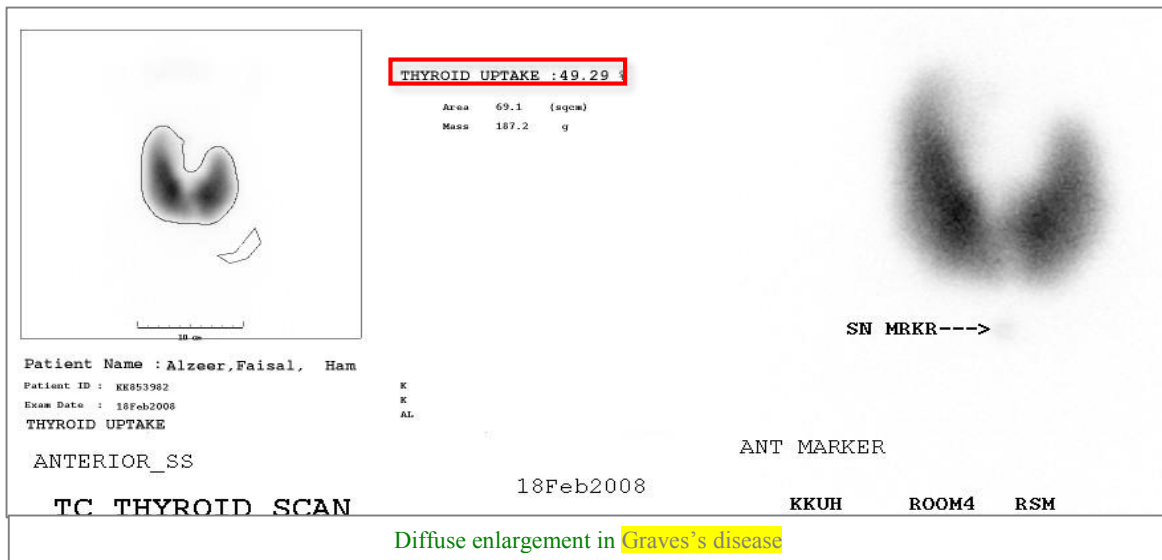
Thyrotoxicosis with hyperthyroidism (imp)

- Graves' Disease.
- Neonatal hyperthyroidism.
- Toxic nodular goiter:
 - MNTG (multinodular toxic goiter) or Plummer's disease
 - ATN (Autonomous Toxic Nodule) or toxic adenoma
- Iodine induced (Jod-Basedow disease)
- Rare causes:

Excessive HCG by trophoblastic tumor

Hypothalamic pituitary neoplasms (TSH induced)

Thyrotoxicosis with hyperthyroidism



Thyrotoxicosis without hyperthyroidism:

- Subacute thyroiditis (SAT).
- 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 (to delay the onsets of hypothyroidism)

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

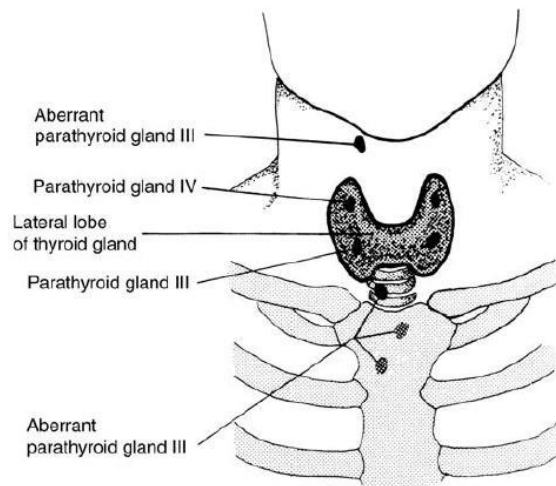
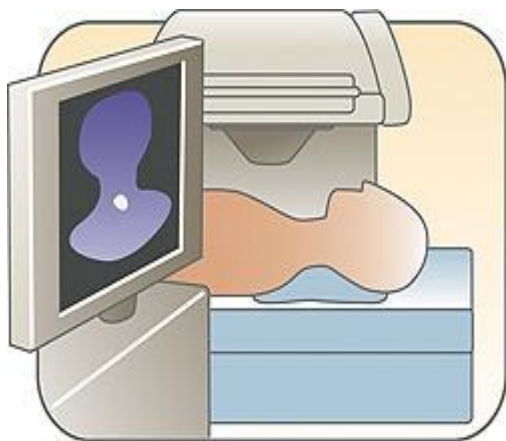


Figure 13.10. Normal and aberrant distribution of the parathyroid glands.

Techniques

- TL-201_Tc-99msubtraction
- 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.

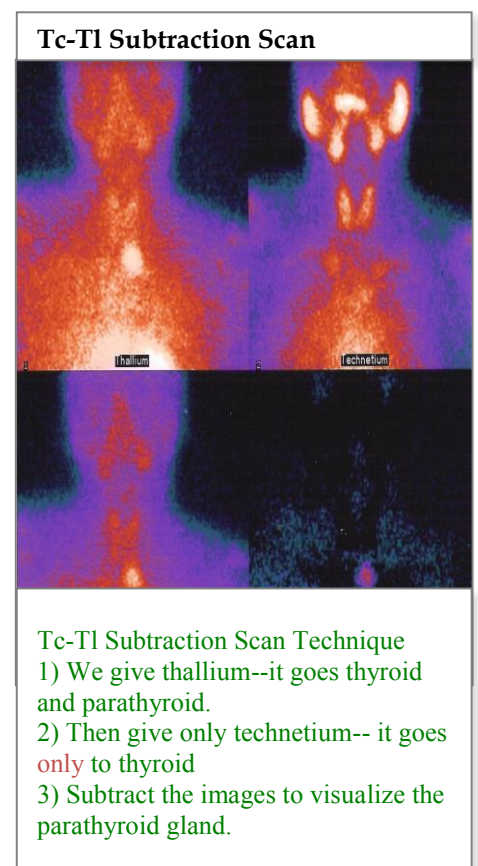
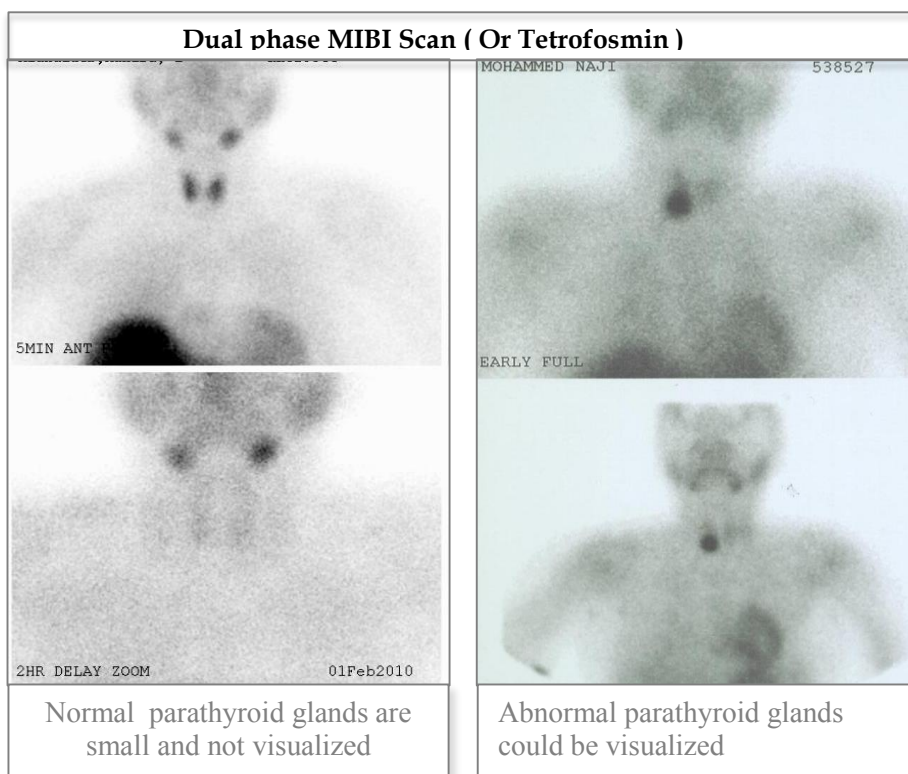
Radiopharmaceutical, Dose, & Technique of Administration

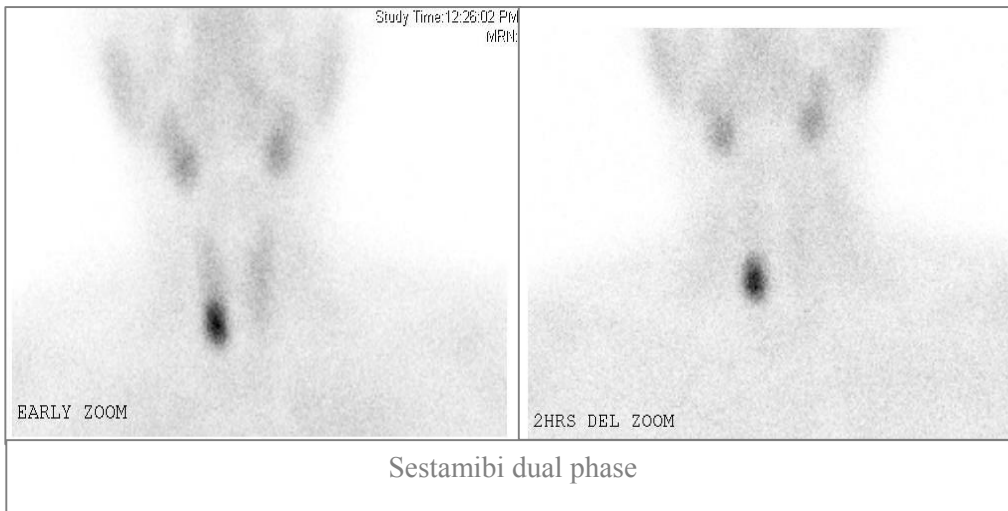
- Radiopharmaceutical: 25 mCi Tc-99m-sestamibi i.v.
- Patient position: Supine with head and neck extended and immobilized.
- Gamma camera imaging field:
 1. Neck.
 2. Upper two thirds of the mediastinum.

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

[OBJ]



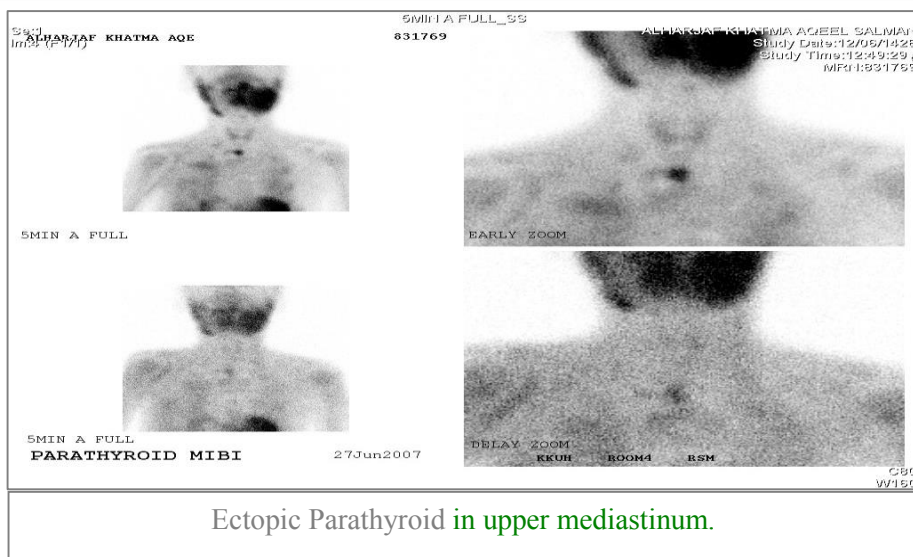
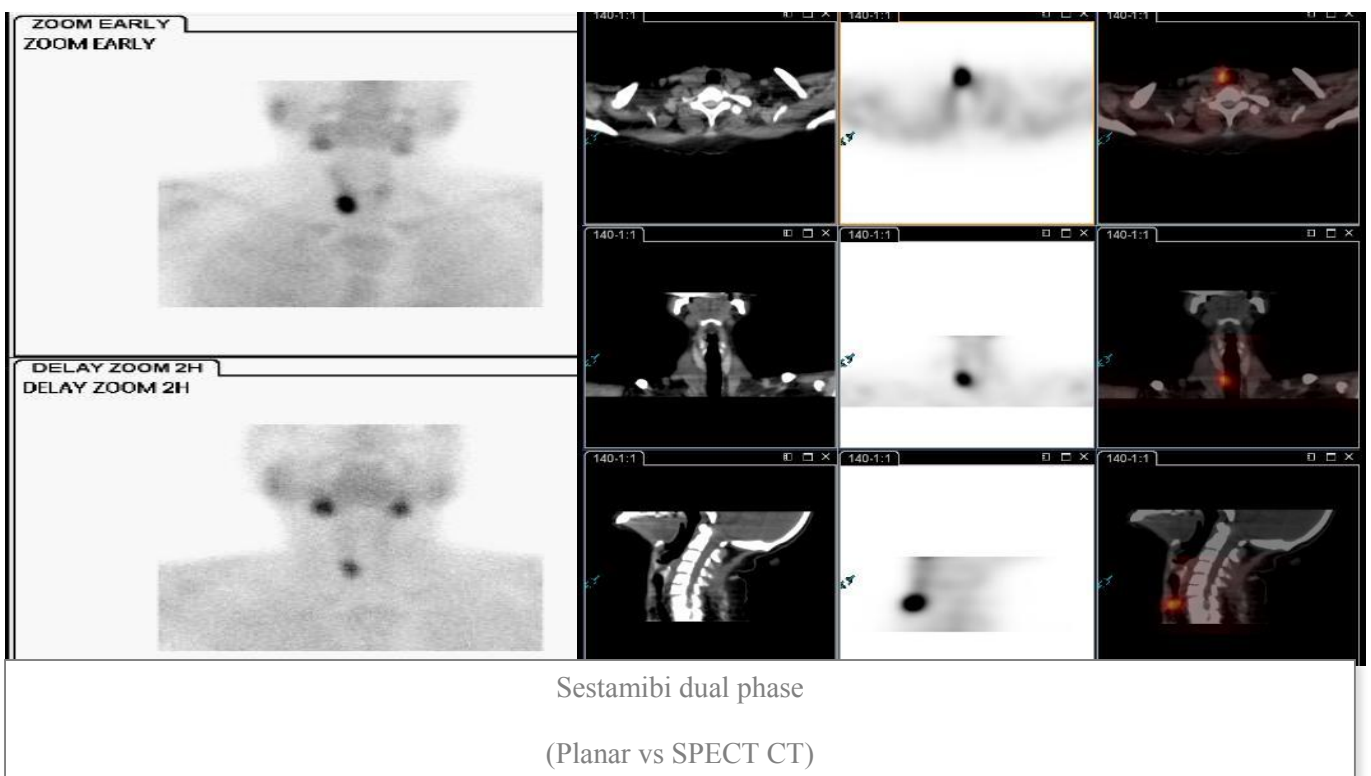


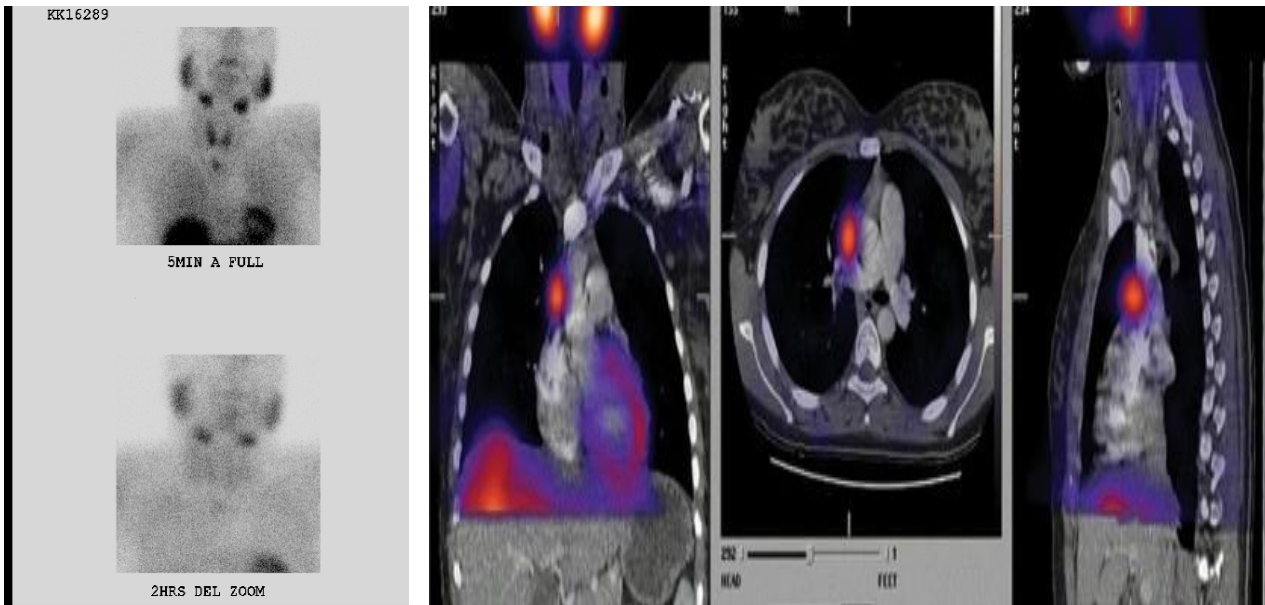
Note(s):

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)

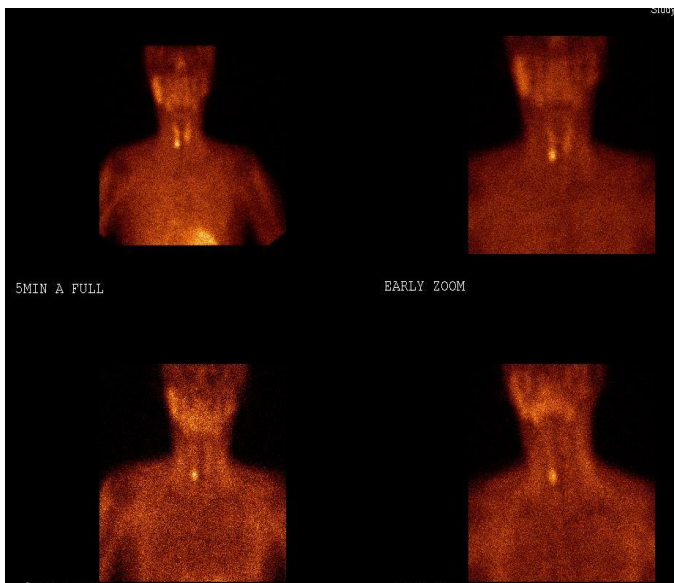




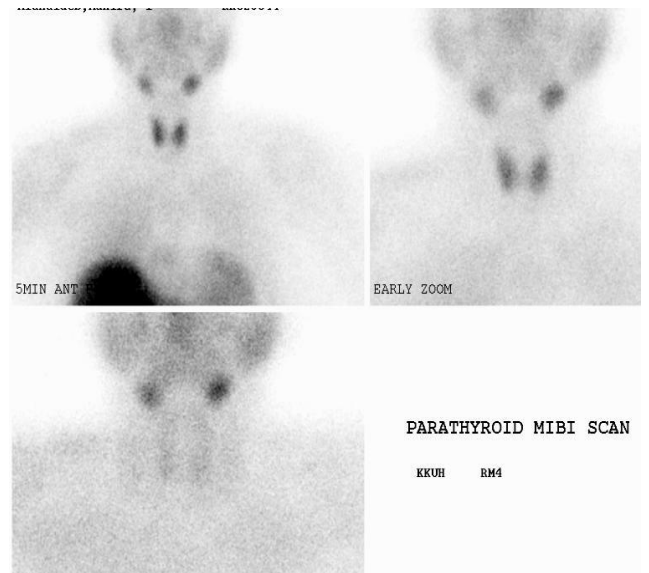
Ectopic Parathyroid Adenoma (PLANAR vs SPECT/CT)

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)

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

A: Mechanism of sestamibi uptake

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**.)]

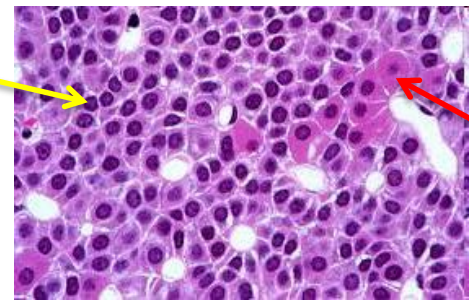
While the normal oxyphil cell does not synthesize and secrete PTH, the oxyphil cells of pathologic parathyroid glands do secrete the hormone.

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:

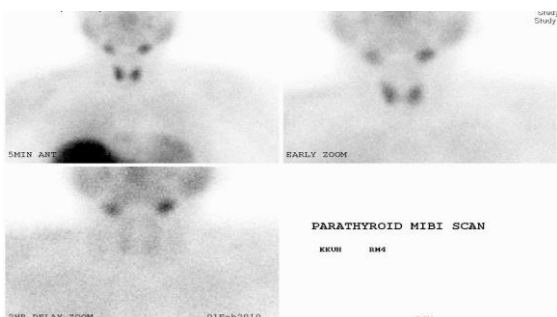
Lipophilicity : The lipophilic sestamibi molecule is concentrated by mitochondria. This explains why adenomas with an abundance of mitochondrial-rich oxyphil cells retain the sestamibi Cationic charge
 - b. Cell Type : A predominance of oxyphil cells within an adenoma is more likely to lead to a positive scan.
 - c. Local factors: blood flow, trans-capillary exchange, interstitial transport and negative intracellular charge of both mitochondria and membranes.

Chief cell

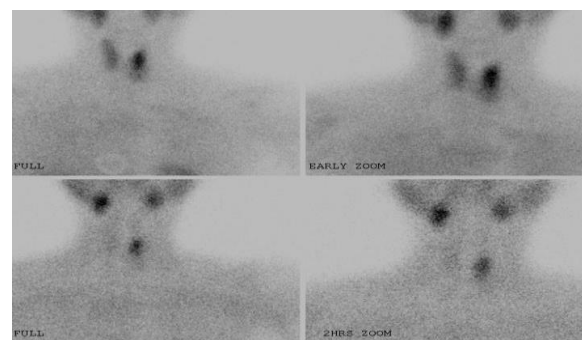


Oxyphil cells

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.
 - 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.

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.

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 I123.
- 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. Dysmorphogenesis.
 - c. Evaluation of neck masses: ectopic thyroid, thyroglobin cyst.
 - d. Evaluation of thyrotoxicosis.
- 16- Perchlorate discharge test is used to confirm dysmorphogenesis
- 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.

Questions

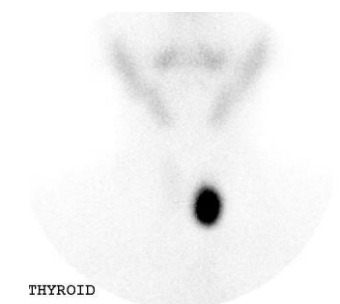
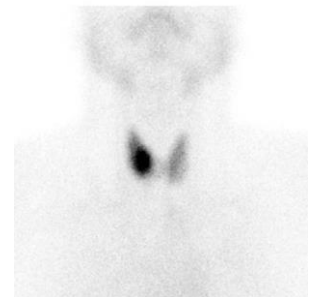
- 1) Half life of Technetium 99m is:
 - a. 4 Hours
 - b. 6 Hours
 - c. 10 Hours
 - d. 13 Hours

- 2) Which of the following nodules has the lowest chance to be malignant:
 - a. Cold nodule
 - b. Hot nodule
 - c. Suspicious nodules
 - d. Small nodule

- 3) Main side effect of Radioactive Iodine therapy is:
 - a. Hyperthyroidism
 - b. Hypothyroidism
 - c. Hypertension
 - d. Hypoglycemia

- 4) A 27 ys , F, with signs and symptoms of hyperthyroidism. Thyroid scan revealed right functioning thyroid nodule.. what do you see?
 - a. Cold nodule
 - b. Hot nodule
 - c. Warm nodules
 - d. Small nodule

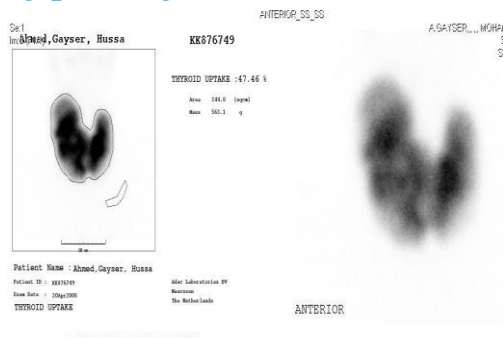
- 5) A 35 years old female patient with signs and symptoms of hyperthyroidism. Thyroid scan revealed left autonomous toxic nodule. What do you see?
 - a. Cold nodule
 - b. Hot nodule
 - c. Warm nodules
 - d. Small nodule



THYROID

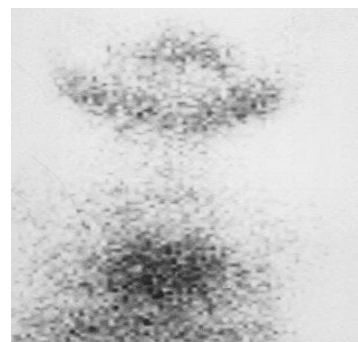
6) 45-year-old female with clinical hyperthyroidism..
What do you see in the picture?

- a. Cold nodules
- b. Warm nodules
- c. Multinodular toxic goiter (MNTG)
- d. Autonomous Toxic Nodule (ATN)



7) On routine investigation of TFTs in a newborn we found Elevated TSH and low T4 what do you think the cause based on the picture below?

- a. Agenesis.
- b. Dyshormonogenesis
- c. Autonomous Toxic Nodule (ATN)
- d. Multinodular toxic goiter (MNTG)



Further explanations

Q4 Warm nodule because 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.

Q5 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.

Q6 Graves on top of **multi nodular goiter (MNG)** → Marine- Lenhart syndrome.

Remember >> Graves→diffuse uniform uptake.

MNG→there're hot and cold nodules.

Answers:

- 1: b
- 2: b
- 3: b
- 4: c
- 5: b
- 6: c
- 7: a

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