Endocrine Nuclear Medicine

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Organs:

Thyroid

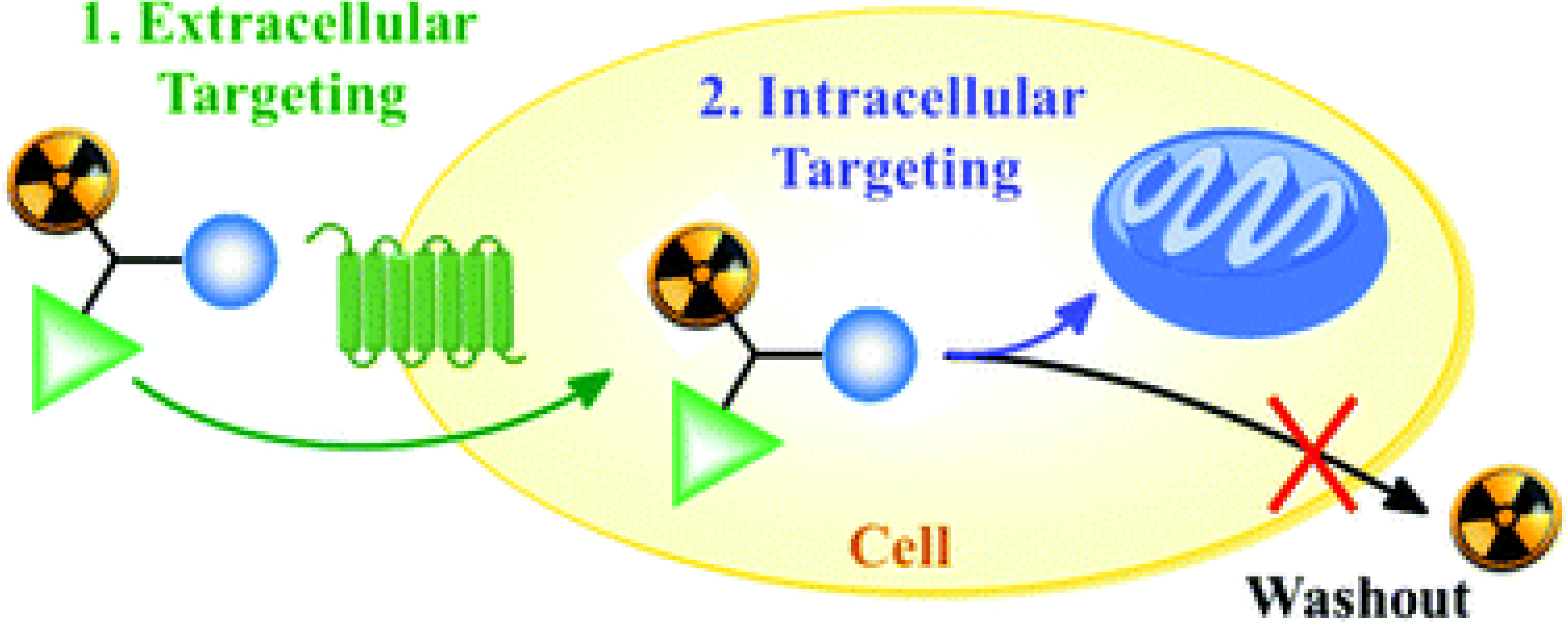
Parathyroid

Adrenal Gland

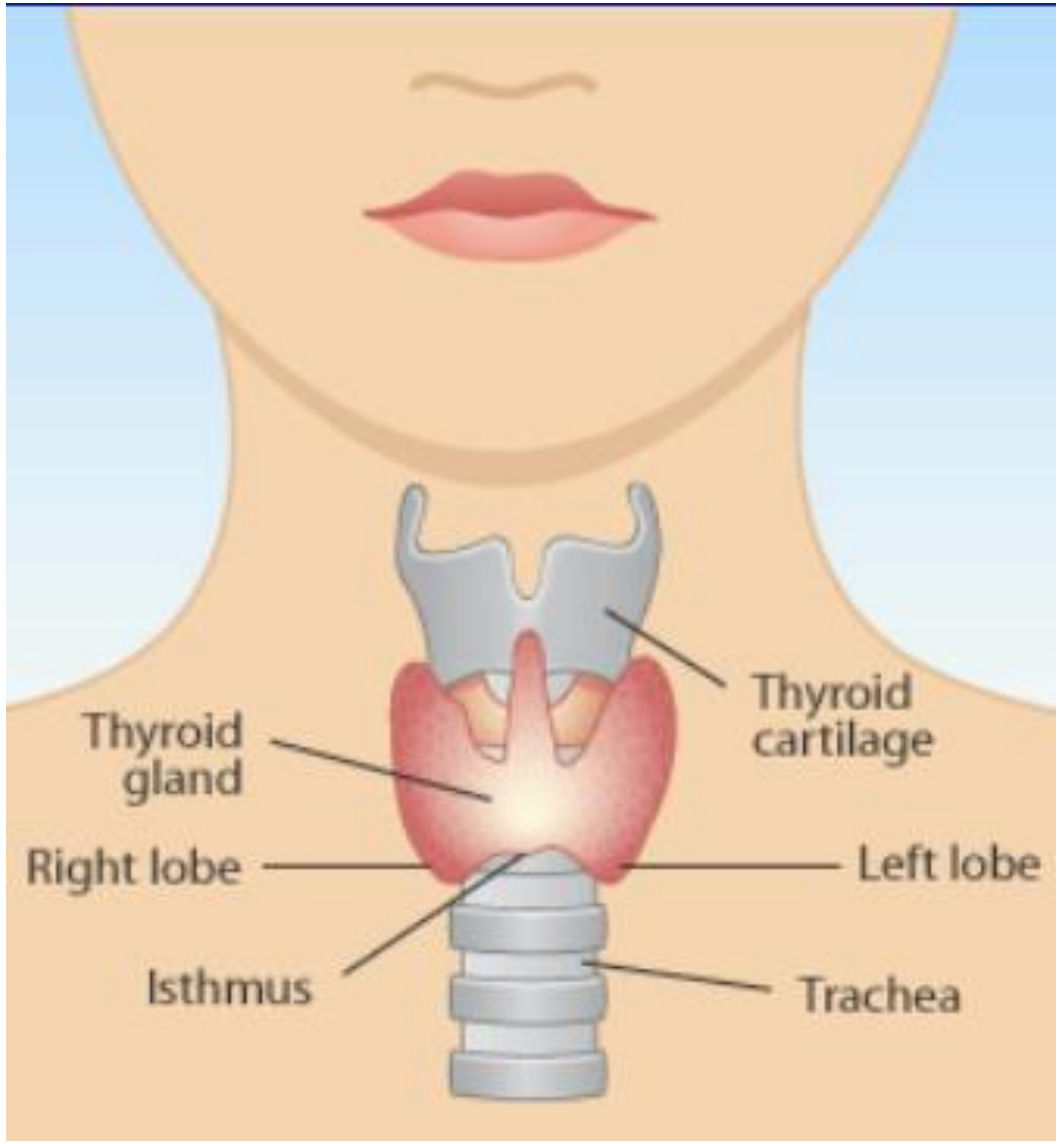
Functional imaging

The aim of nuclear medicine is to identify and track physiological actions using a “tracer” labelled with a radioisotope.

Anatomical information may be inferred from the physiological image but this is secondary.


1. Extracellular Targeting
2. Intracellular Targeting
Cell
Washout

The Thyroid Gland



Thyroid imaging

When should it be performed?

How does it help diagnosis?

What alternatives are there for imaging the thyroid?

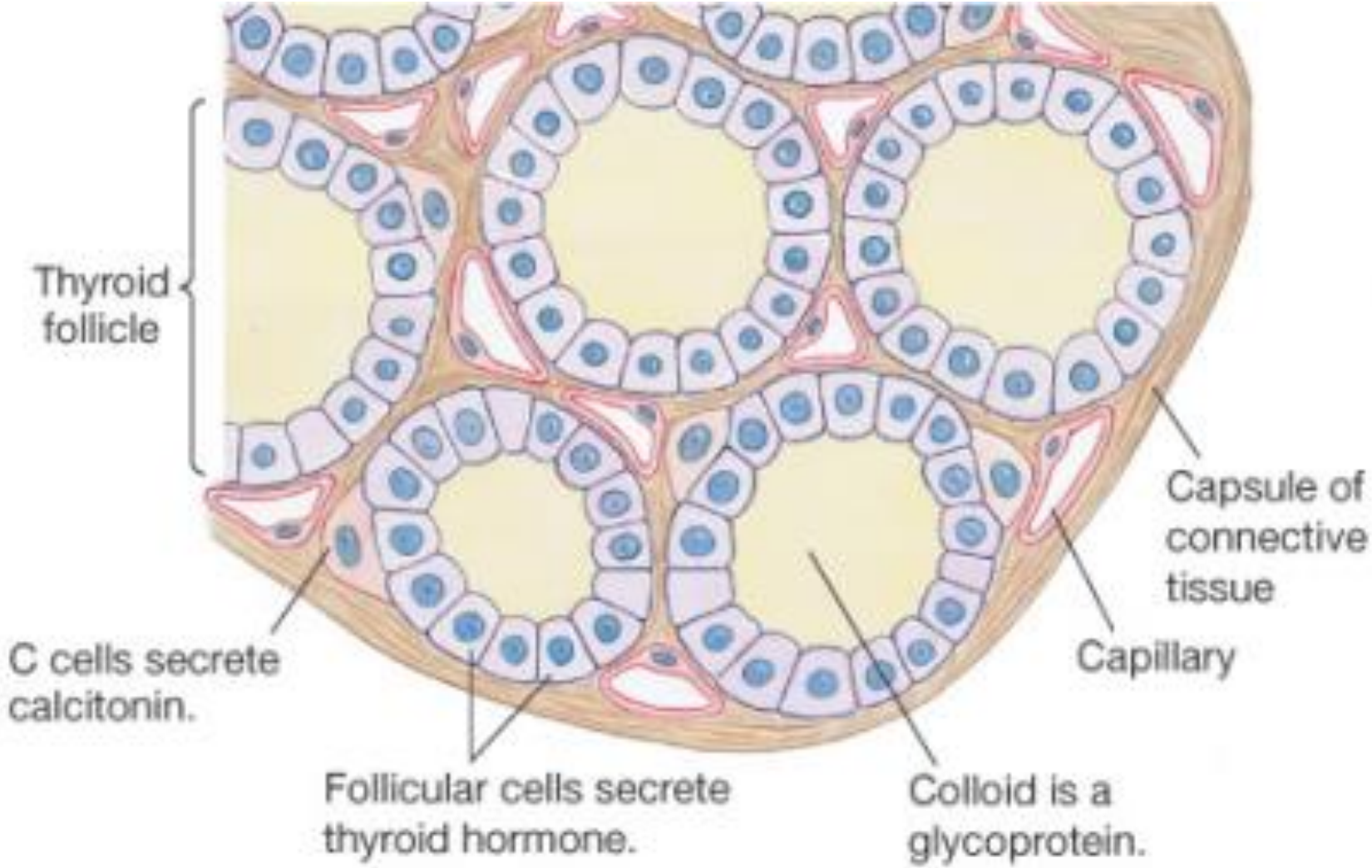
How do the results of the nuclear medicine scan affect treatment?

Functional Imaging of Thyroid

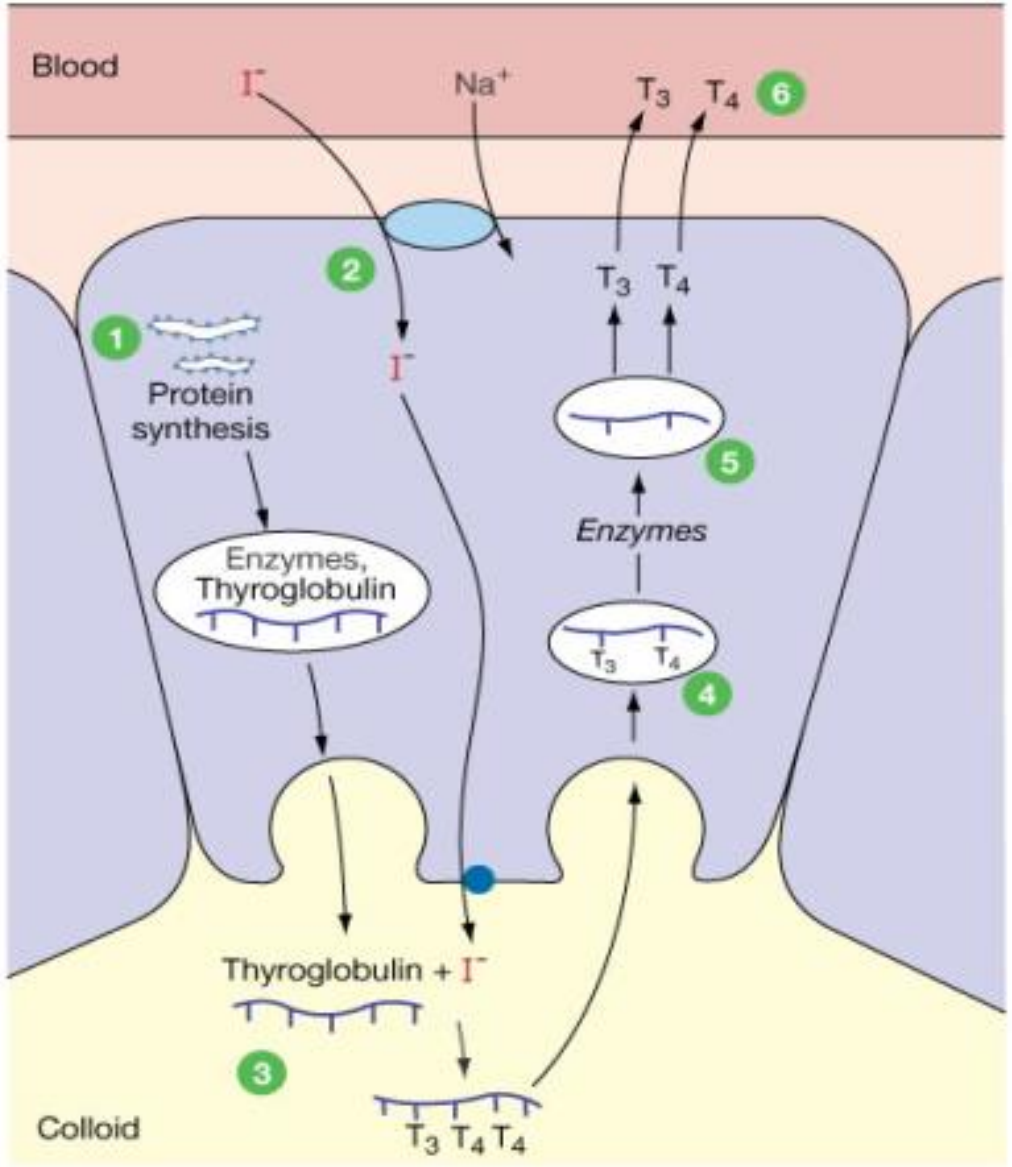
Overactive

Underactive

Malignancy


Thyroid follicle
C cells secrete calcitonin.
Follicular cells secrete thyroid hormone.
Colloid is a glycoprotein.
Capillary
Capsule of connective tissue

Production of Thyroid Hormones



1. Follicular cell synthesizes enzymes and thyroglobulin for colloid.
2. I^- is co-transported into the cell with Na^+ and transported into colloid.
3. Enzymes add iodine to thyroglobulin to make T_3 and T_4.
4. Thyroglobulin is taken back into the cell.
5. Intracellular enzymes separate T_3 and T_4 from the protein.
6. Free T_3 and T_4 enter the circulation.

NIS mediated uptake of iodide into follicular cells of the **thyroid** gland is the **first step** in the synthesis of **thyroid** hormone.

Thyroid Scanning

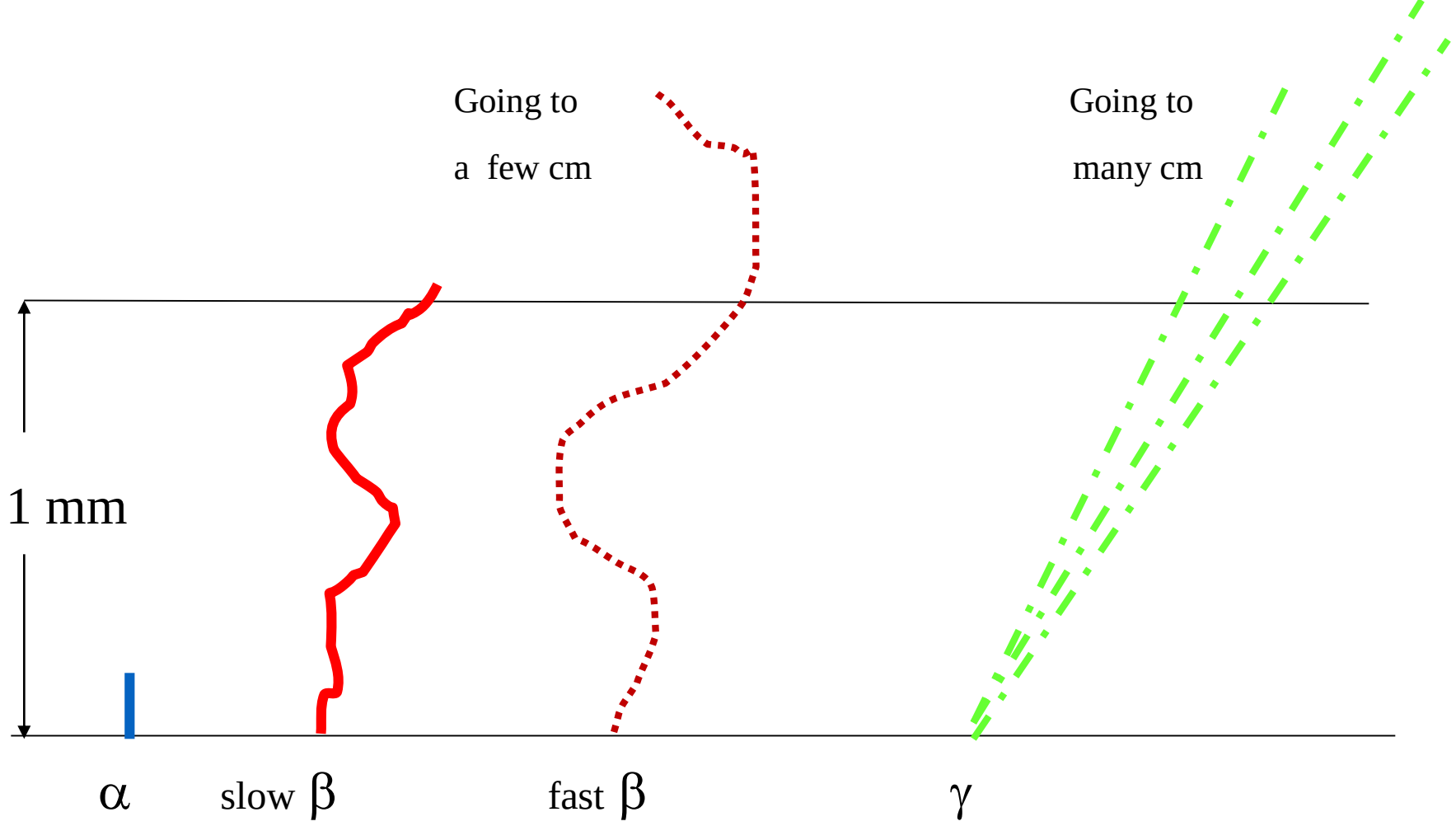
Radio Active iodine Uptake (RAIU)

The **^{131}I isotope** has a half-life of **8 days** and emits γ radiation and β particles.

Iodine-123 decays by electron capture with half-life of **13 hours**.

Iodine-125 It is the second longest-lived radioisotope of iodine **(60 days)**, after iodine-129

Technetium-99m (molybdenum) is a short-lived form of Tc-99 that is used as a medical diagnostic tool. It has a short half-life (**6 hours**) and does not remain in the body or the environment for long.


Going to
a few cm
Going to
many cm
1 mm
α
slow β
fast β
γ

Gamma camera

Scintigraphy

Application of isotope and its uptake in functional parenchyma of endocrine gland. Extracorporal detection of γ-emission.

^{131}I	**β+γ emitter**
^{99m}Tc-MIBI	**γ-emitter**
^{131}I-MIBG	**β+γ emitter**
^{99m}Tc-octreotide	**γ-emitter**

Notice: Despite textbooks, no other isotope is used in diagnosis of endocrine disorders, now.

Iodide uptake is a critical first step in thyroid hormone synthesis. The thyroid gland extracts iodine from the circulation in a highly efficient manner. For example, **10–25% of radioactive tracer** is taken up by the normal thyroid gland over 24 h; this value can rise to 70–90% in Graves' disease.

The thyroid gland selectively transports radioisotopes of iodine (^{123}I, ^{125}I, ^{131}I) and ^{99m}Tc, allowing thyroid imaging and quantitation of radioactive tracer fractional uptake.

The selective expression of NIS in the thyroid allows isotopic scanning, **treatment** of hyperthyroidism, and ablation of thyroid cancer with radioisotopes of iodine, without significant effects on other organs.

Technetium-99m

Most common radioactive isotope tracer used for SPECT (single-photon emission computerized tomography) imaging of the brain, bones, lungs, kidneys, thyroid, heart, gall bladder, liver, spleen, bone marrow, salivary and lachrymal glands, blood pool, and sentinel nodes.

Technetium-99m Sodium Pertechnetate

Technetium-99m Methylene Diphosphonate

Technetium-99m Octreotide

Technetium-99m Dimercaptosuccinic acid (DMSA)

Technetium-99m Metaiodobenzylguanidine (MIBG)

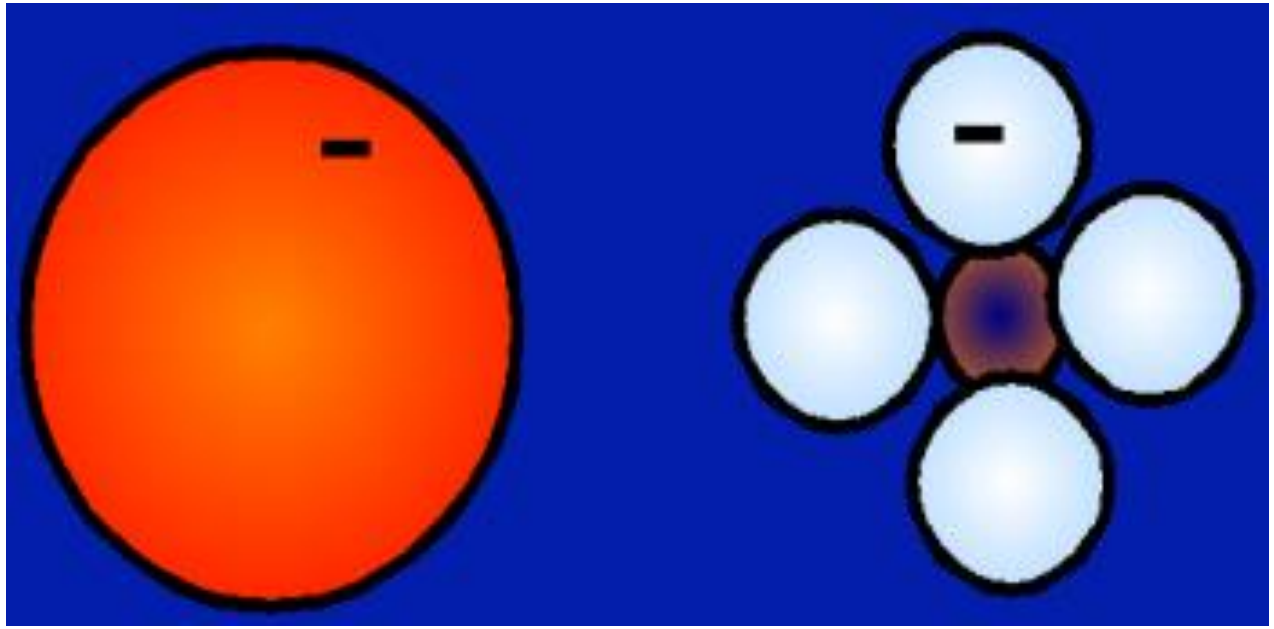
Technetium-99m Sestamibi (Methoxyisobutylisonitrile)

Technetium-99m Sulfur Colloid

Technetium-99m Pyrophosphate

Iodine and Pertechnetate

Both Iodine and pertechnetate have similar size and charge



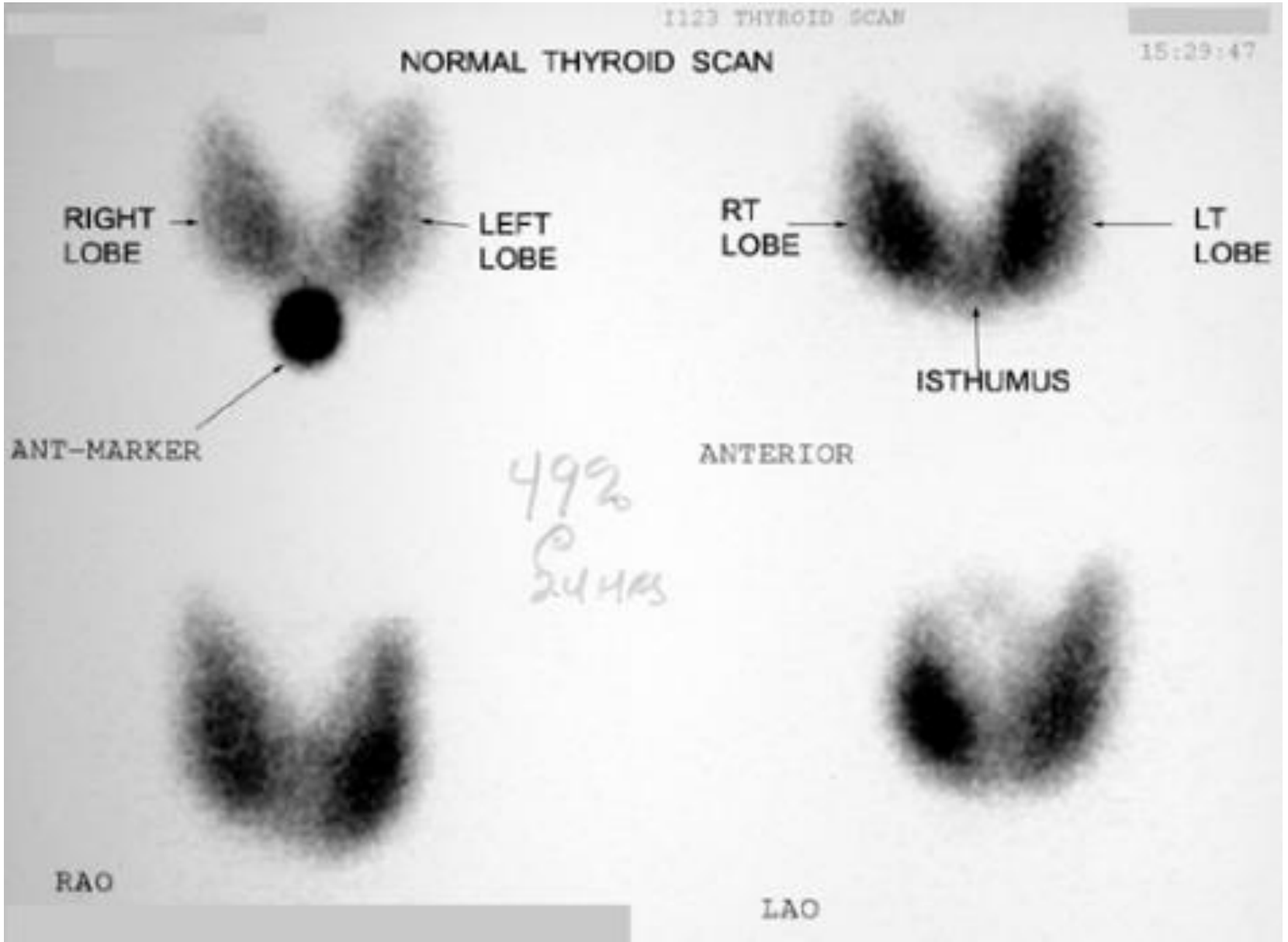
Graves' disease is characterized by an enlarged gland and increased tracer uptake that is distributed homogeneously.

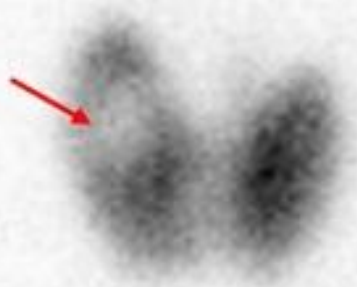
Toxic adenomas appear as focal areas of increased uptake, with suppressed tracer uptake in the remainder of the gland.

Subacute thyroiditis is associated with very low uptake because of follicular cell damage and TSH suppression.

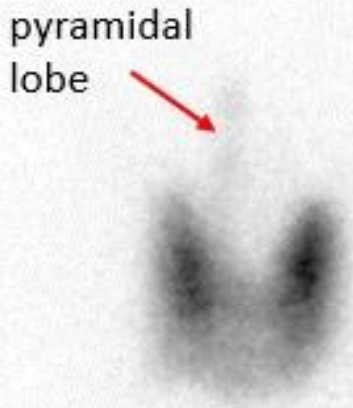
Thyrotoxicosis factitia is also associated with low uptake.

Normal Thyroid Gland

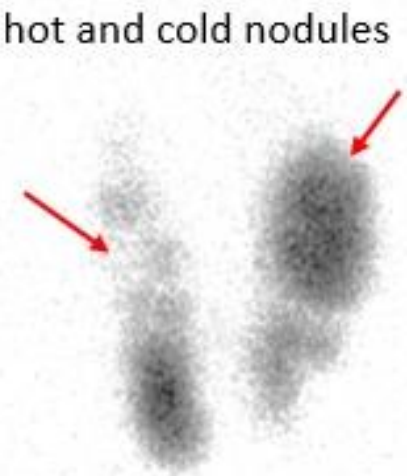




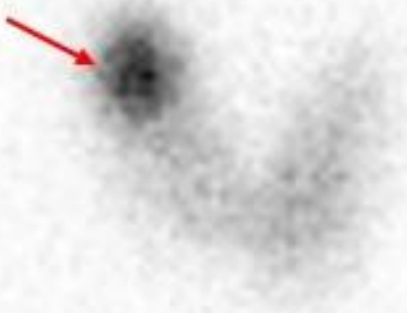
COLD NODULE



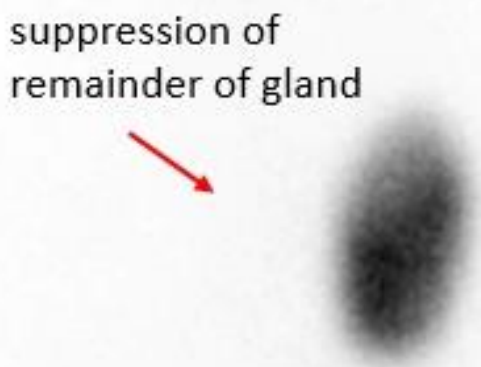
GRAVE DISEASE



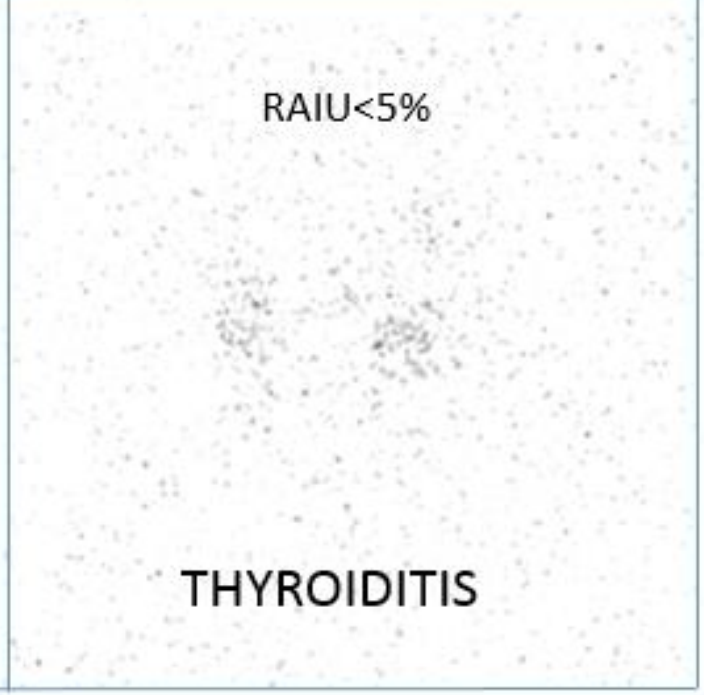
TOXIC MULTINODULAR



HOT NODULE



AUTONOMOUS NODULE



THYROIDITIS

The Scan

Stop relevant medication:

Mthimazole: 48 hr. for radioiodine

Propylthiouracil: 48 hr. for radioiodine

Levothyroxine: 4-6 weeks

Liothyronine: 1-2 weeks

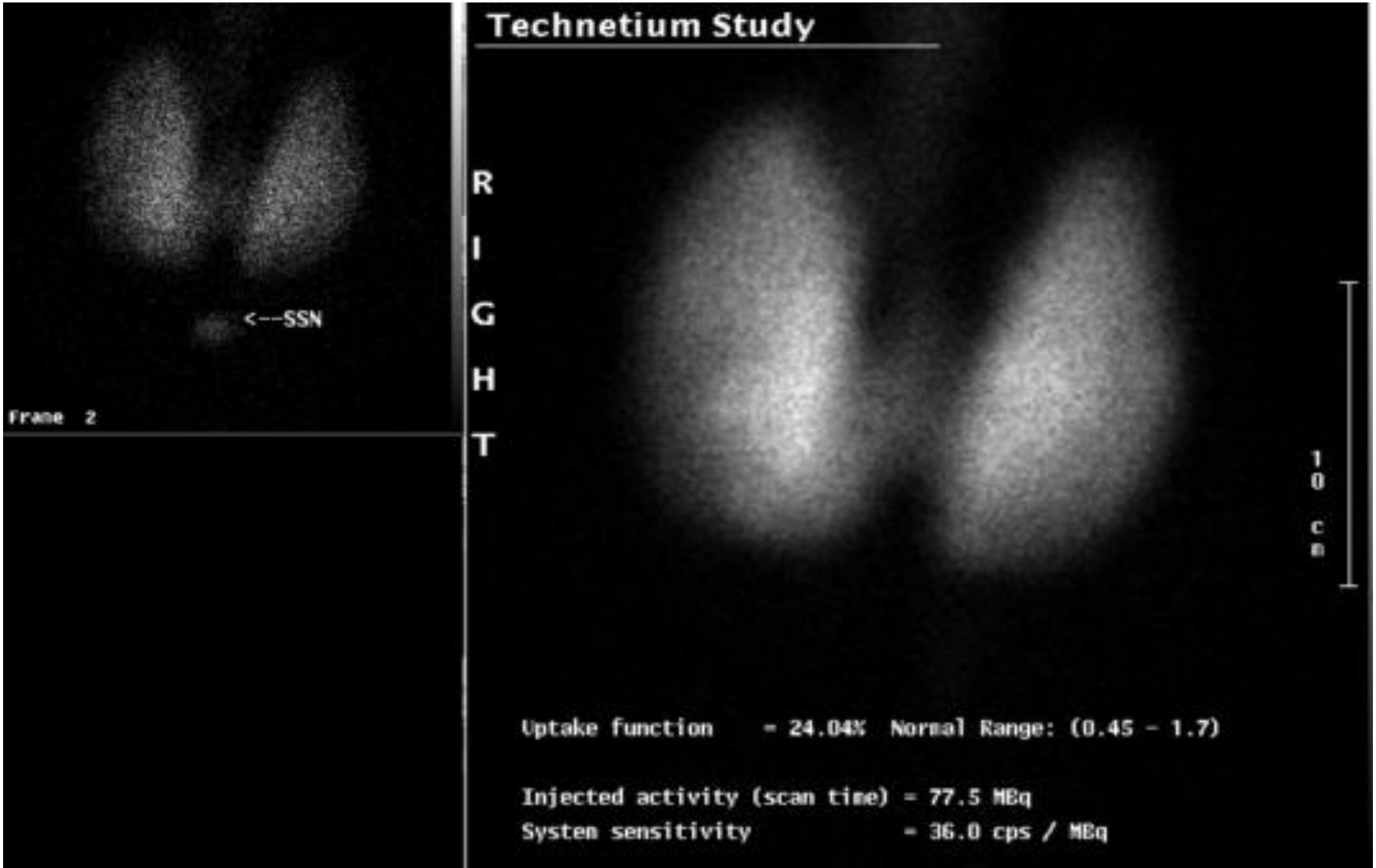
Other factors in patient history may affect scan:

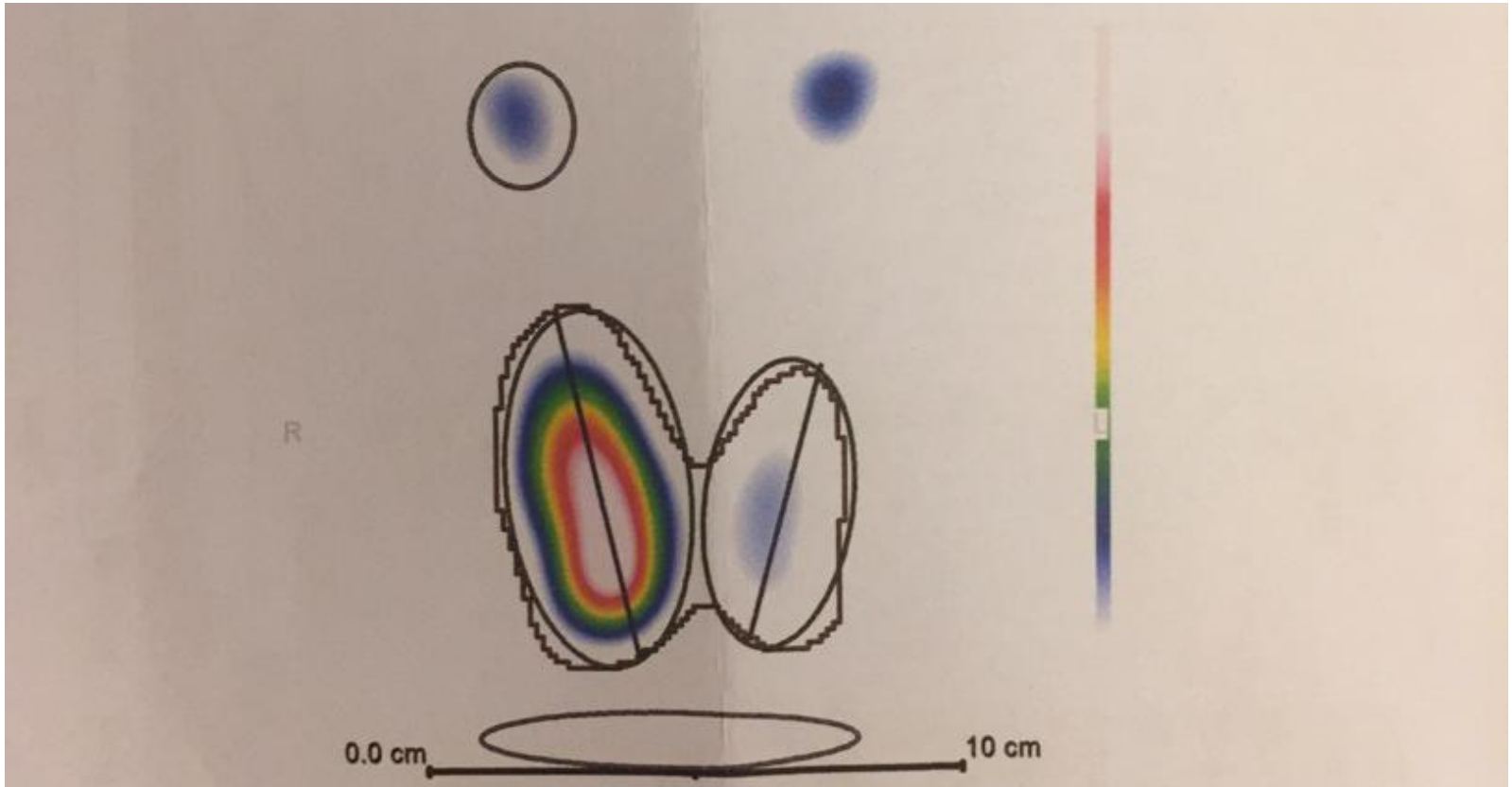
*Iodine containing radiological contrast agents (wait 6-8 weeks)

*High level of intake of Kelp product

*Amiodarone

Graves disease





Uptake calculation summary

Roi	Uptake	Upt. to Full Thyr.
Full Thyroid	0.99 %	100.00 %
Left Lobe	0.16 %	16.39 %
Right Lobe	0.81 %	82.42 %
Other [1]	0.07 %	6.98 %

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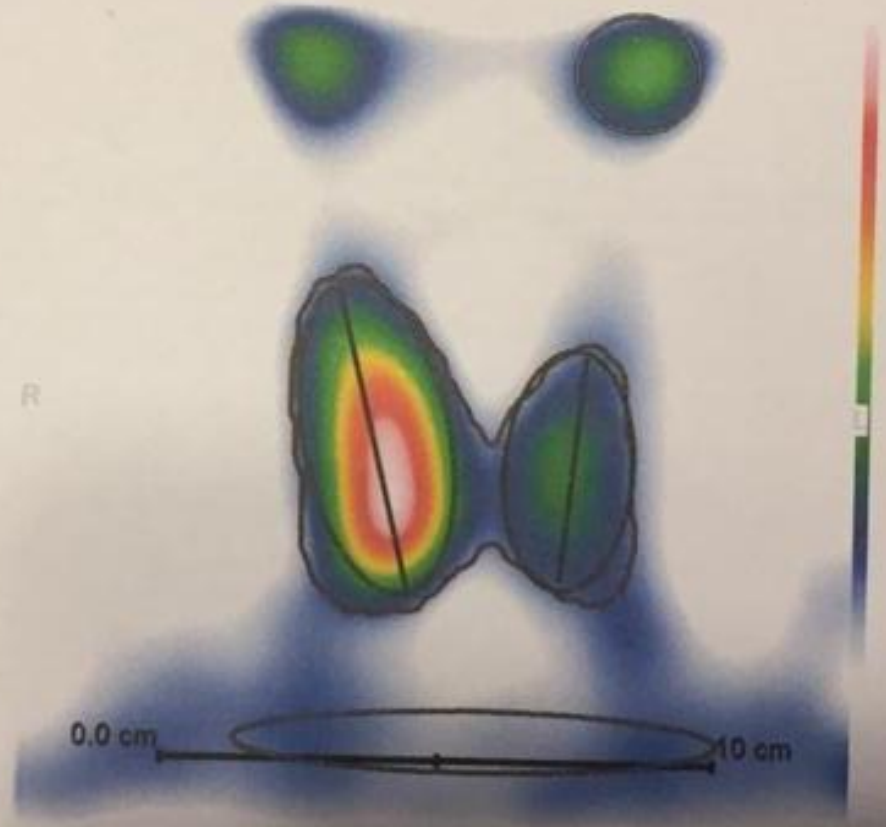
Acquisition date: 09/08/2020 19:19:42



Uptake calculation summary

Roi	Uptake	Upt. to Full Thyr.
Full Thyroid	0.37 %	100.00 %
Left Lobe	0.06 %	17.44 %
Right Lobe	0.28 %	75.11 %
Other [1]	0.04 %	10.53 %

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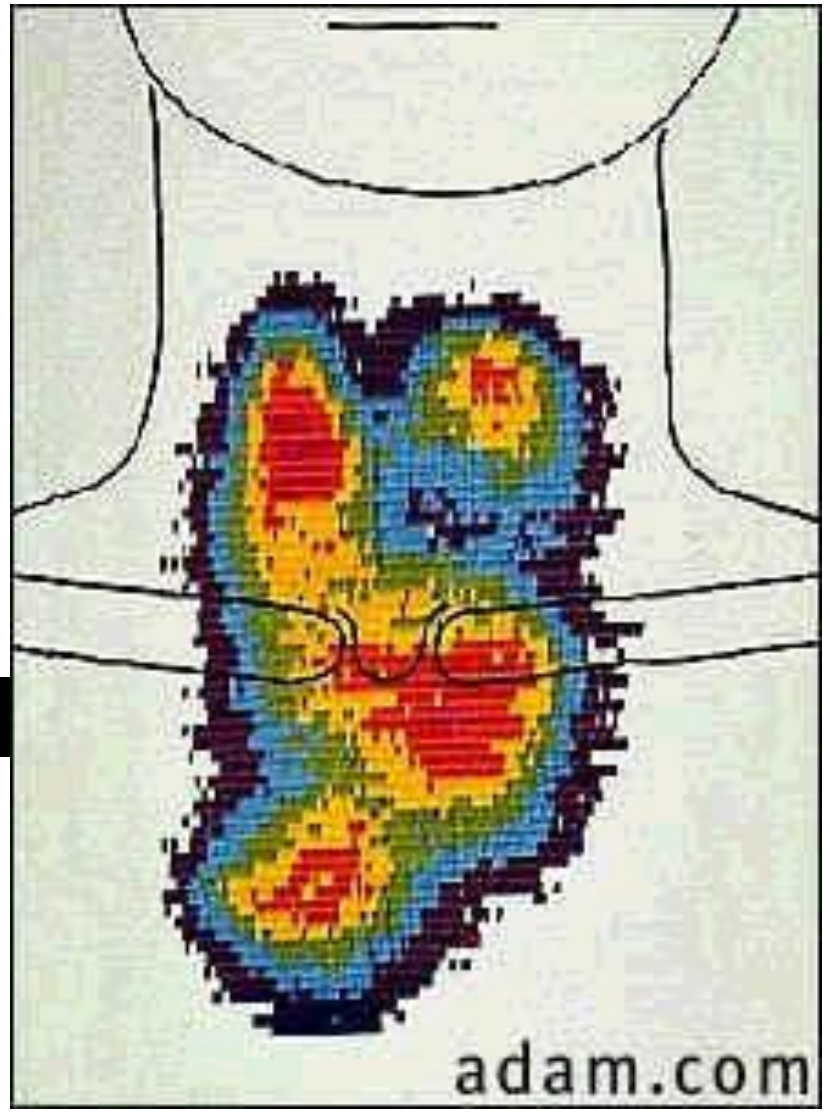
^{131}I

Retrosternal goiter



Hypothyroidism

Not so useful as uptake low

Especially difficult to see nature of nodes

Hashimoto’s Thyroidtis is most common cause of hypothyroidism -

autoimmune condition (can be toxic in very early stage)

scan appearances vary with stage

chronic : inhomogeneous tracer uptake

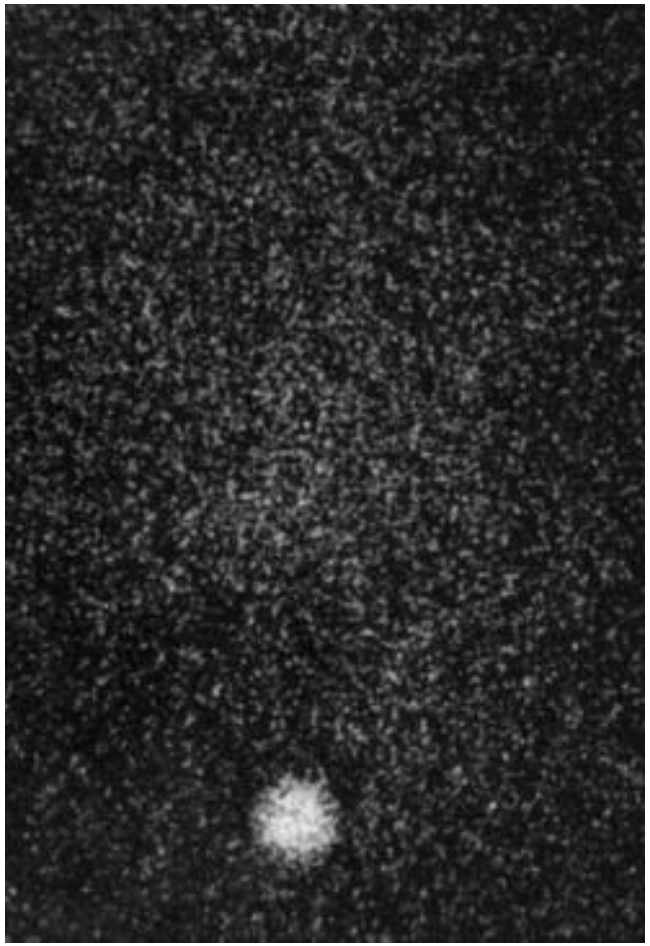
Thyroiditis

Subacute thyroidits (also known as de Quervains)

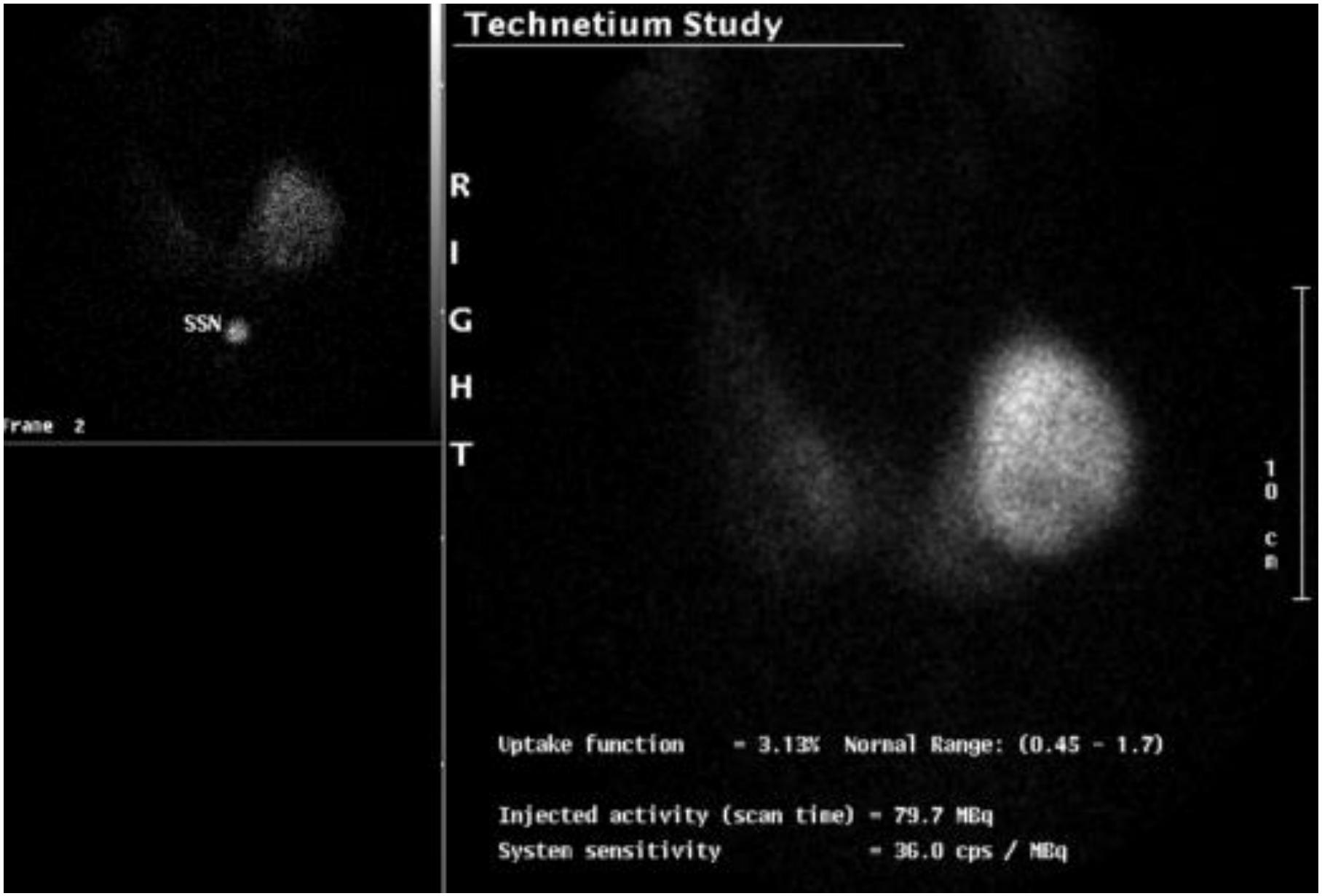
Very good test as Iodine and pertechnetate are not taken up in acute phase (first 4 weeks after onset of symptoms)

- Patient initially toxic
- Reduced uptake persists 4-8 weeks
- Tends to be normal by 12 weeks
- Scan these within 10 days of request

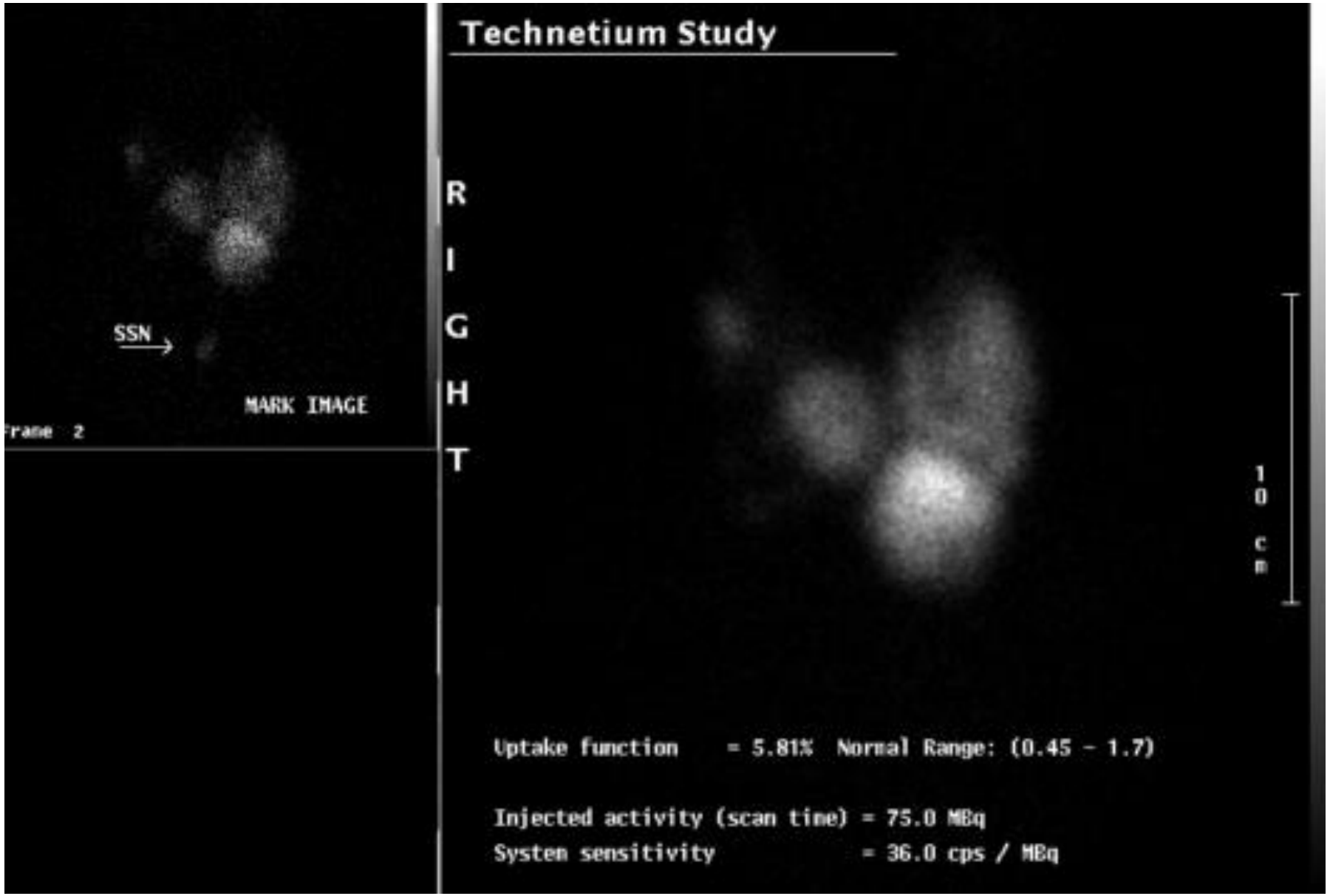
SAT



Thyroid Nodules (Hot nodule)



MNG


Technetium Study
SSN
MARK IMAGE
Frame 2
R
I
G
H
T
10 cm
Uptake function = 5.81% Normal Range: (0.45 - 1.7)
Injected activity (scan time) = 75.0 MBq
System sensitivity = 36.0 cps / MBq

Treatment of Benign Thyroid Disease

Conditions

- Graves
- Toxic Nodules – high activity required (600MBq) **1 mCi = 37 MBq**
- MNG – high activity required (600MBq)

Treatment : 131I

- Discuss with patient: treatment options e.g. surgery
- Informed consent – risk of hypothyroidism
- Radiation protection issues: exposing family members and public (time and distance!!)

Restrictions last up to ≈ 3 weeks e.g. separate bed from partners, avoid pregnancy for 6 months

Lifelong follow up (regular thyroid blood tests)

Thyroid cancer

Ablation Therapy: 6 weeks post thyroidectomy (papillary and follicular ca.) **30-200 mCi** 131I ablation therapy.

Have to stop T4 for 4weeks and T3 for 10 days.

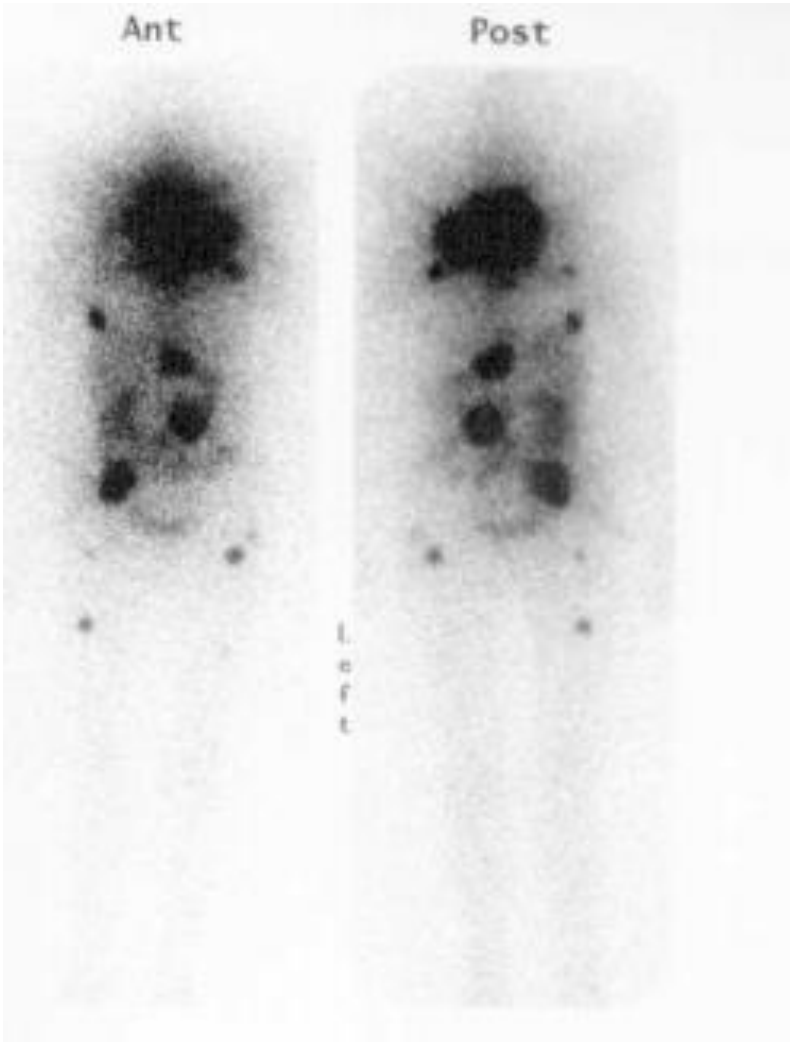
Can be given with TRH, rTSH.

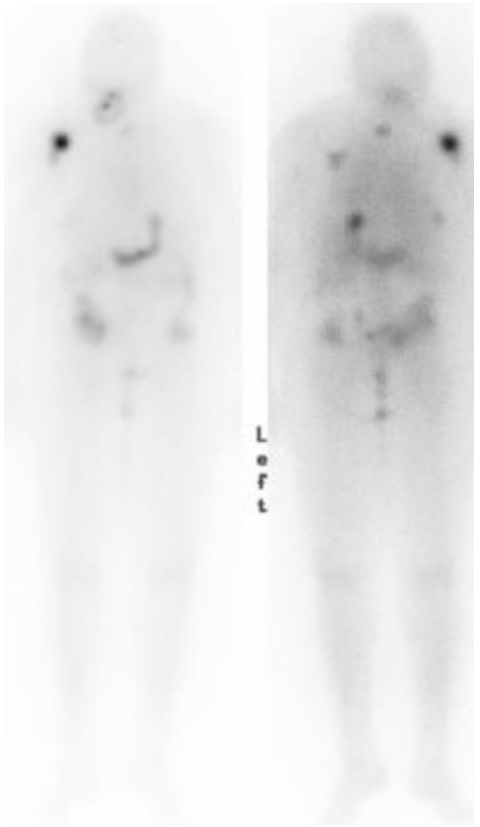
Scan at 3 – 5 days.

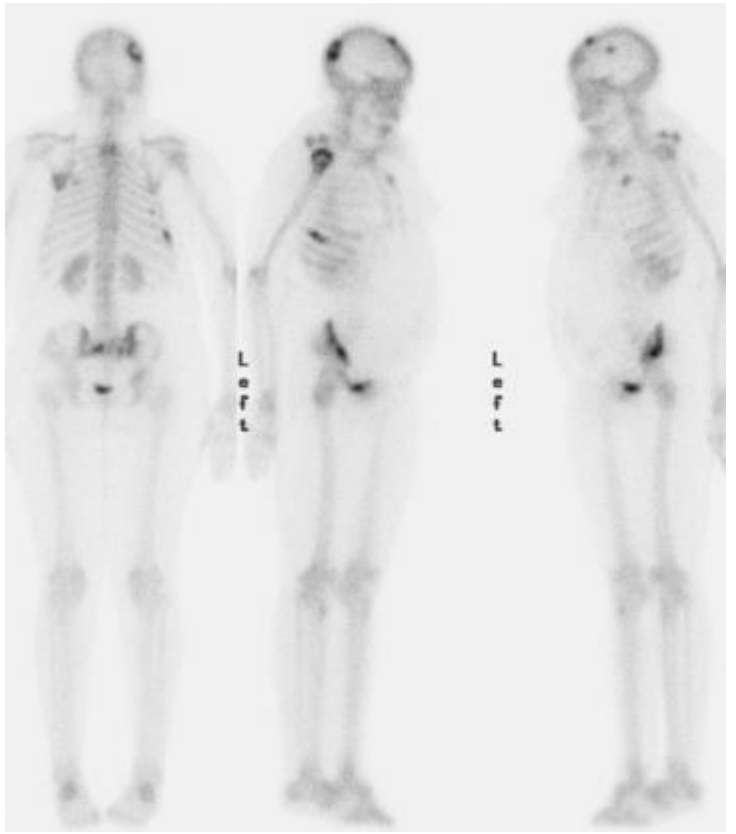
Repeat therapies till thyroid bed and any mets disappear 3-6 monthly intervals

Has NO role in anaplastic ca or lymphoma

Multiple Metastases on 1st Dose I131







Imaging Medullary Carcinoma of the Thyroid (MTC)

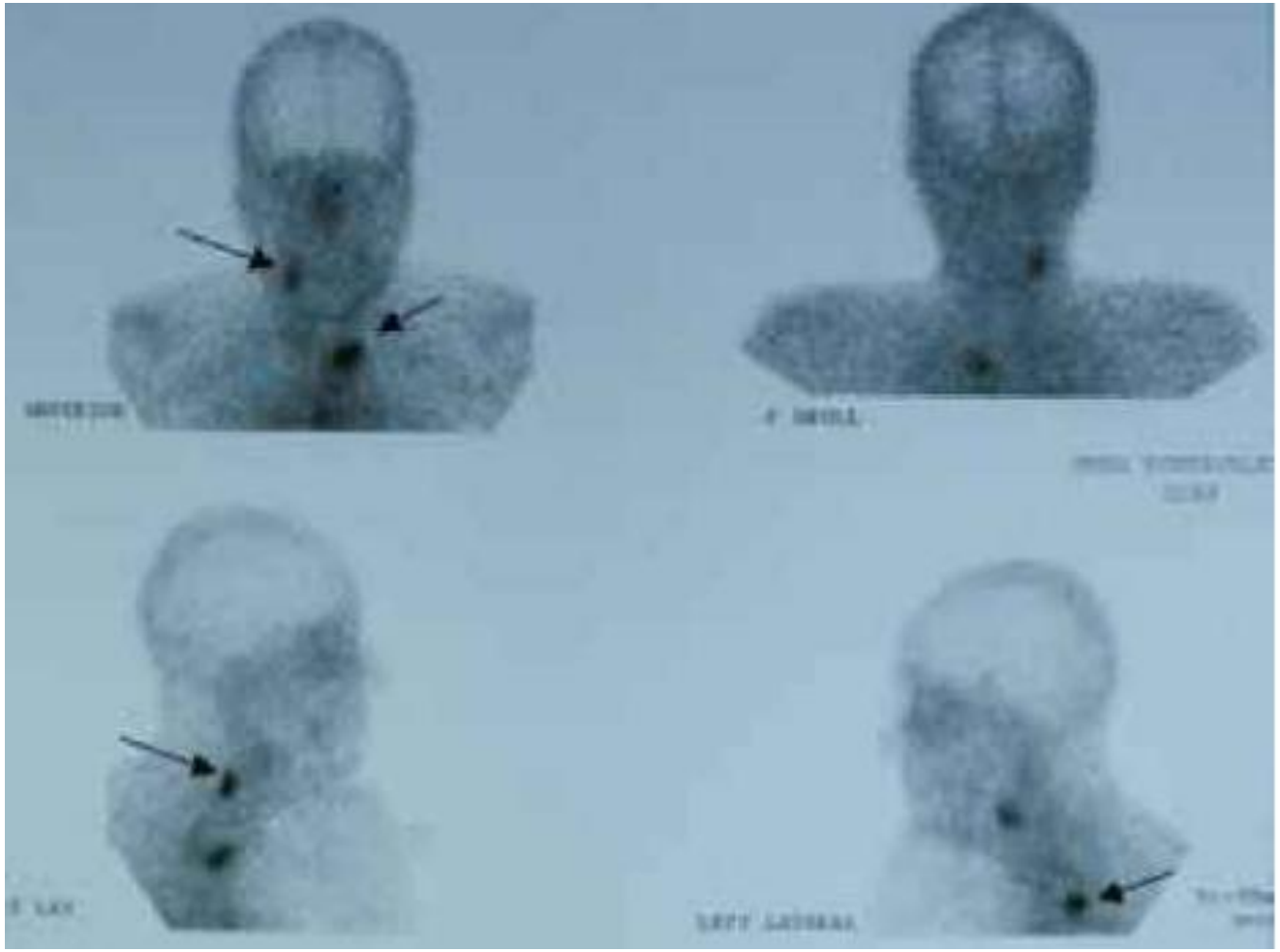
Tc-99m DMSA

123I MIBG - Therapy version available with 131I MIBG

111In Octreotide - Therapy version available with Octreotide

18F- FDG PET/CT

Tc -99m DMSA scan shows neck and superior mediastinal metastases in a patient with elevated postoperative serum calcitonin.



Parathyroid Glands

Role of Nuclear Medicine

Diagnosis

Localization, Missed adenoma, Ectopic adenoma

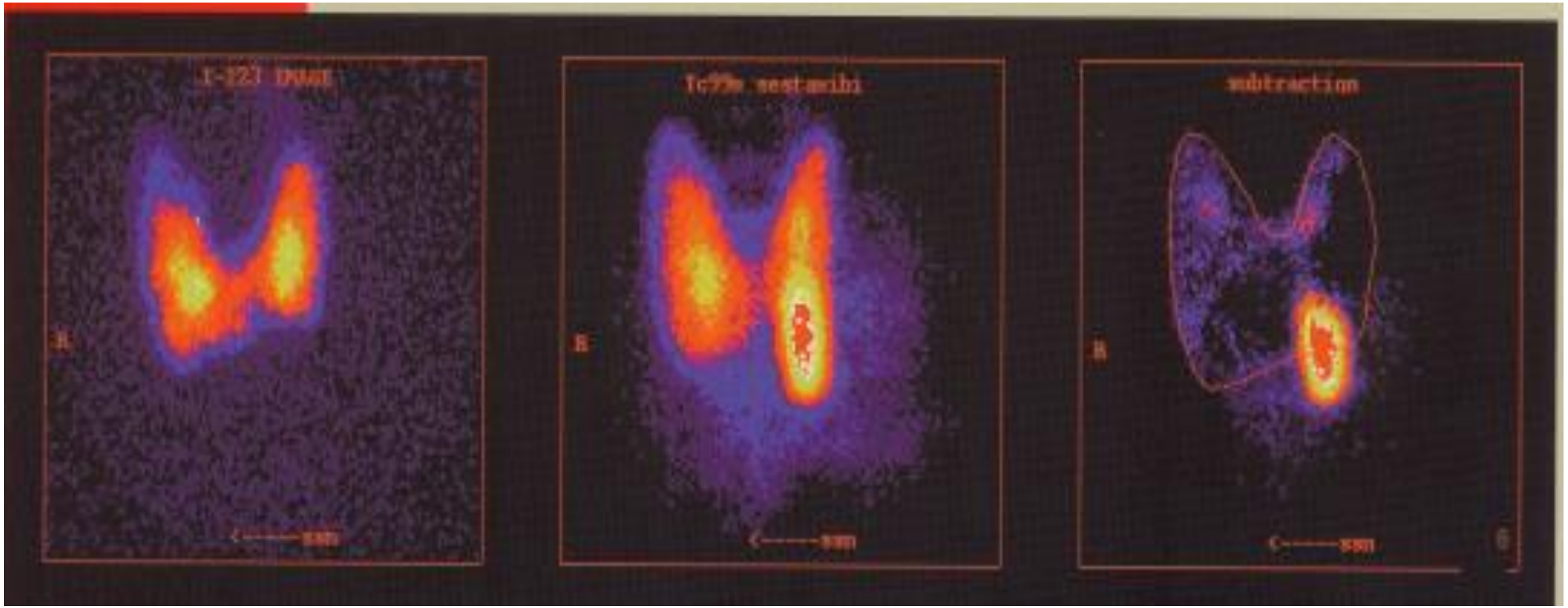
Assist surgeon in reducing surgical operating times

May help reduce morbidity

Aids use of minimally invasive techniques

Exploits functional aspects of tumor

- Ideally need an agent taken up **only by parathyroid** but no such agent currently available
- Some agents only have uptake in **both thyroid and parathyroid** Technetium-99m Sestamibi
- Others have initial uptake in both organs but **“washout”** of normal thyroid **Subtraction technique**


I-123 DOSE
Tc99m sestamibi
subtraction

Washout technique

Inject agent which washes out of thyroid but not parathyroid (99m Tc MIBI)

Wait 15 minutes

Perform planar and/or SPECT images

Wait a further 2 hours

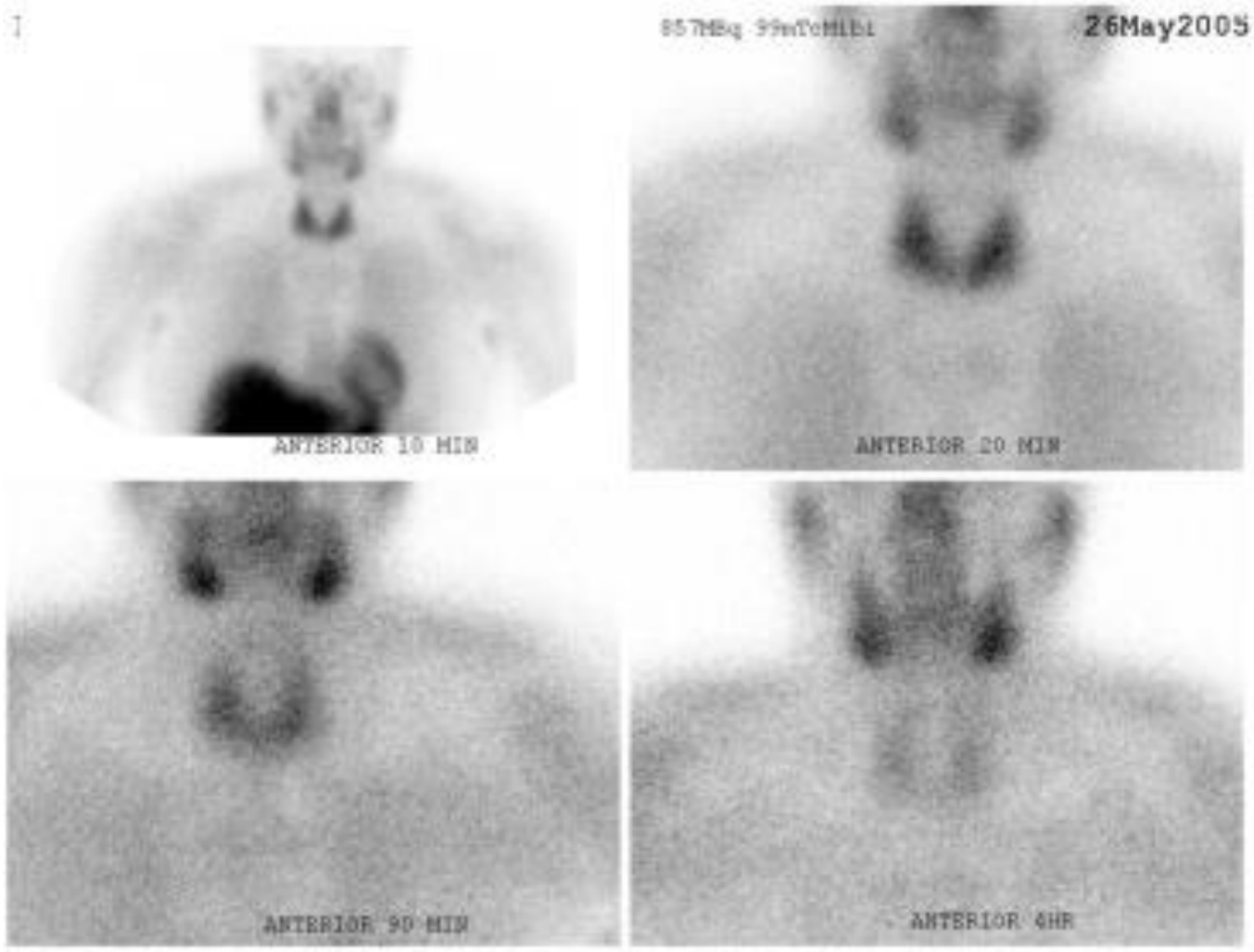
Repeat planar and/or SPECT images

Review images.

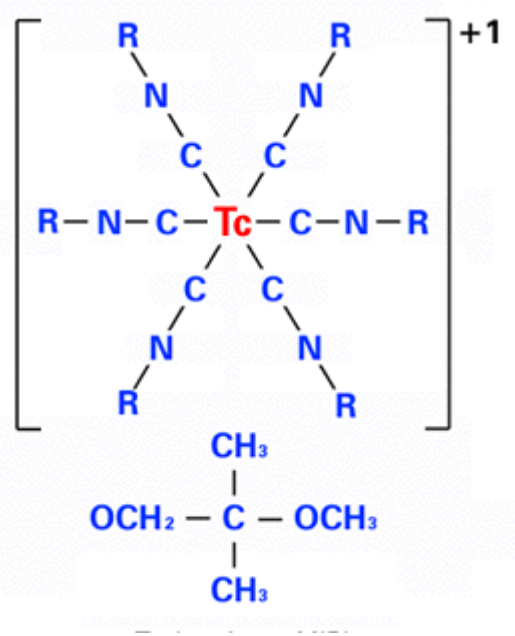
Normal (Negative) Washout Scan

Early

Late



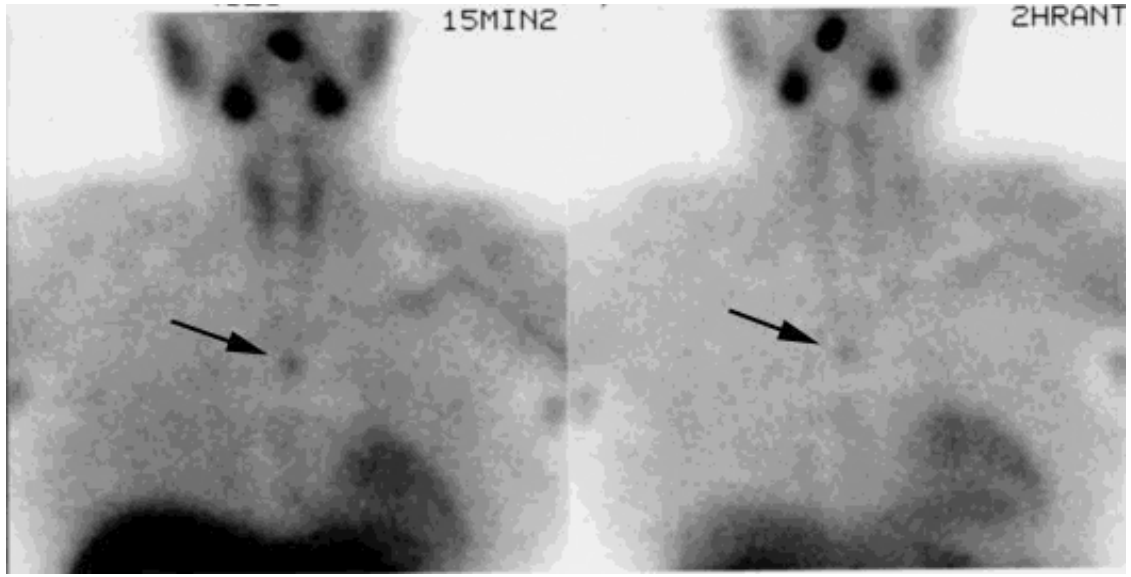
Scintigraphy



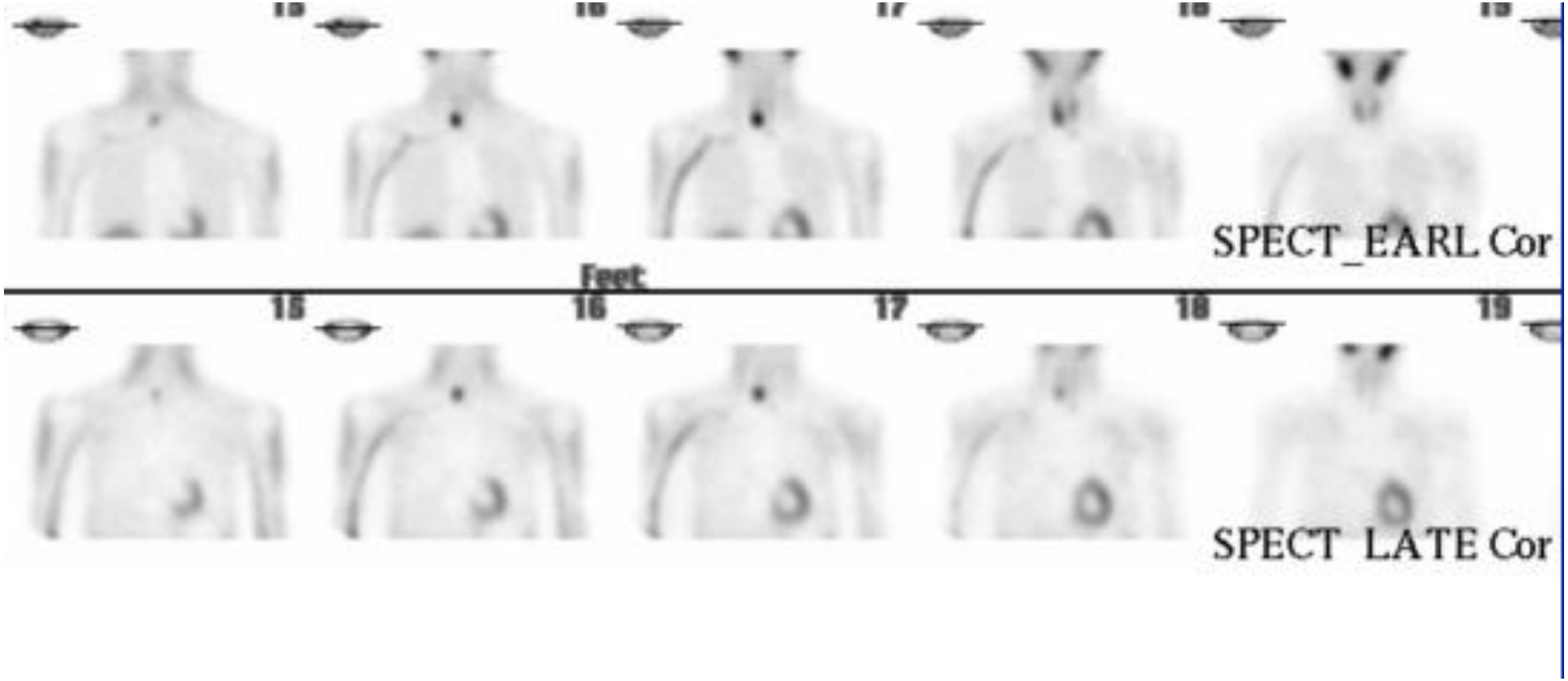
^{99m}Tc-MIBI = methoxy isobuthyl isonitril

The molecule passes cells membranes passively, once intracellular it further accumulates in the mitrochondrias. Detection of ^{99m}Tc gamma emission

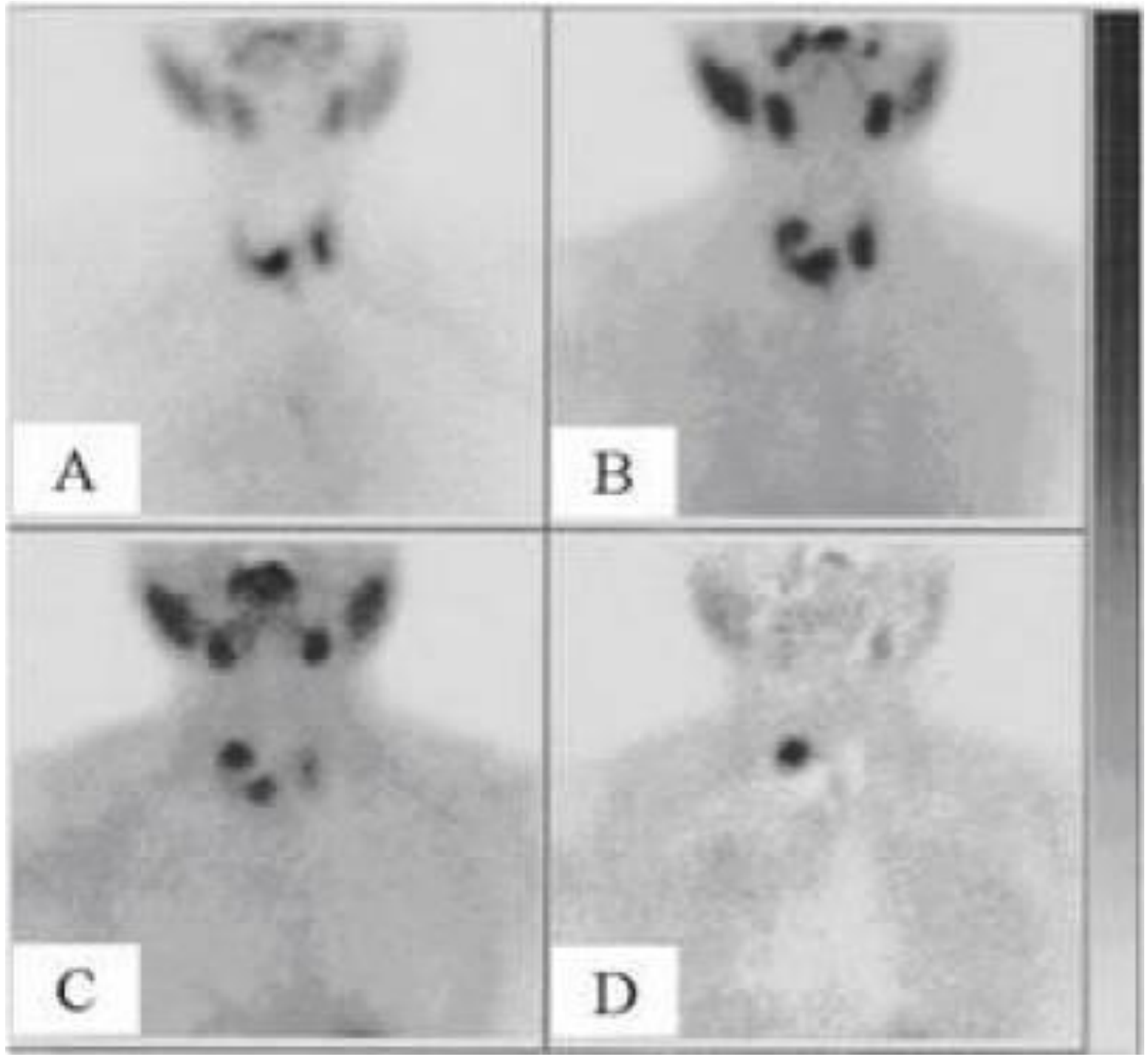
Atypical retrosternal PTH adenoma

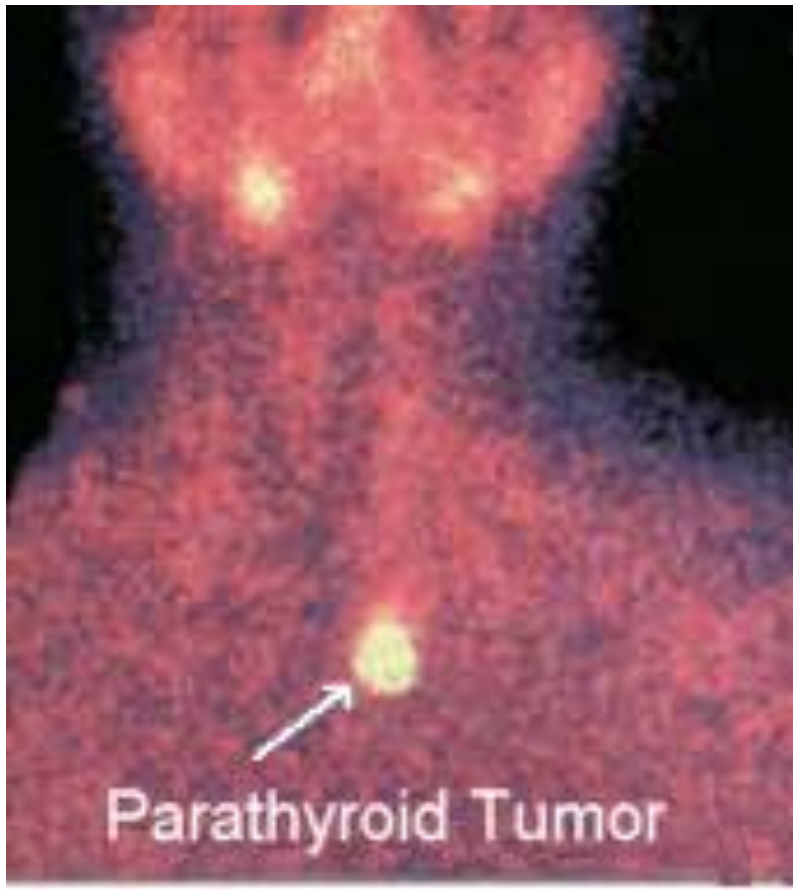


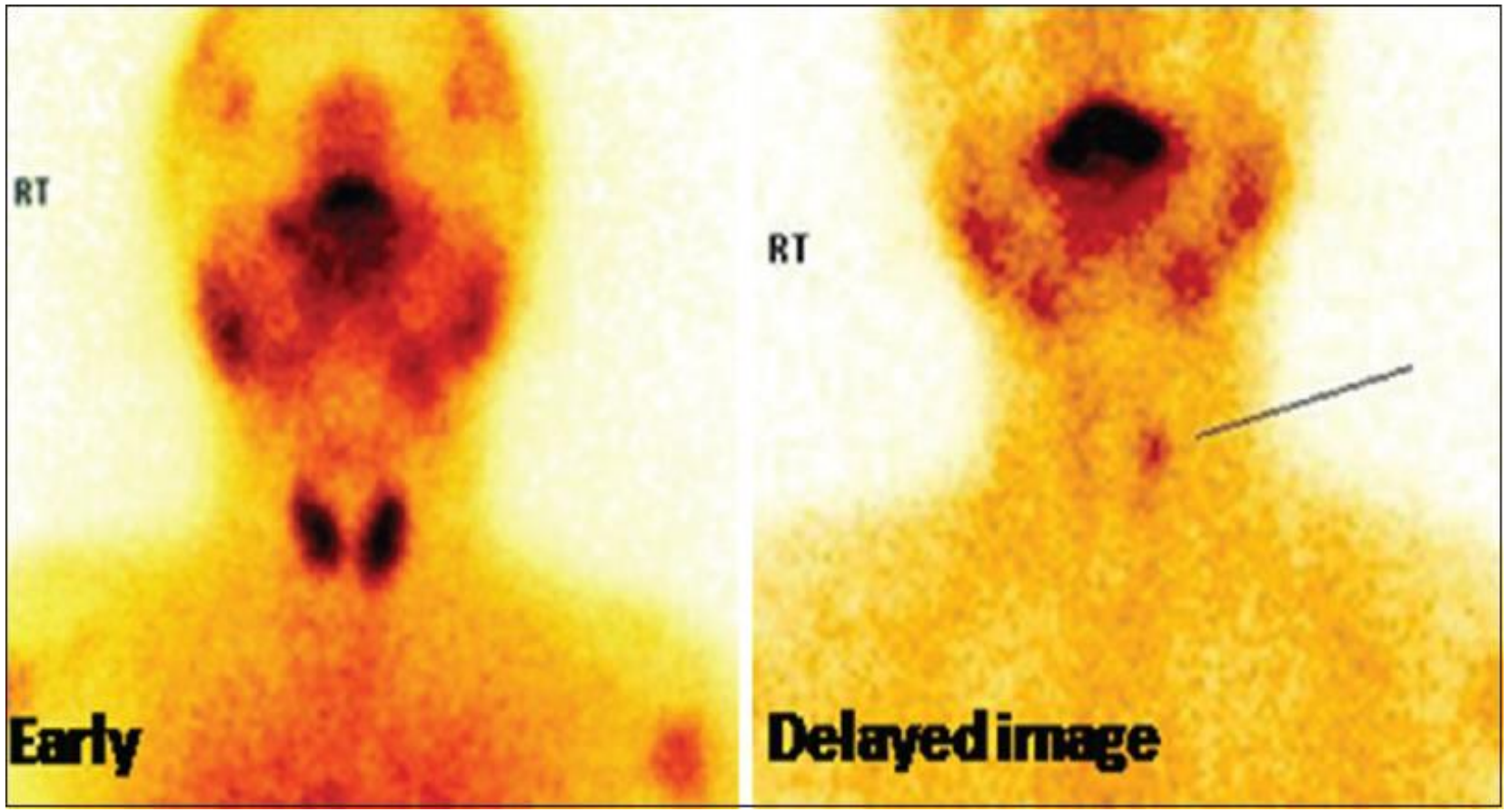
Parathyroid Adenoma



Tc-99m sestamibi


A
B
C
D


Parathyroid Tumor


RT
Early
RT
Delayed image

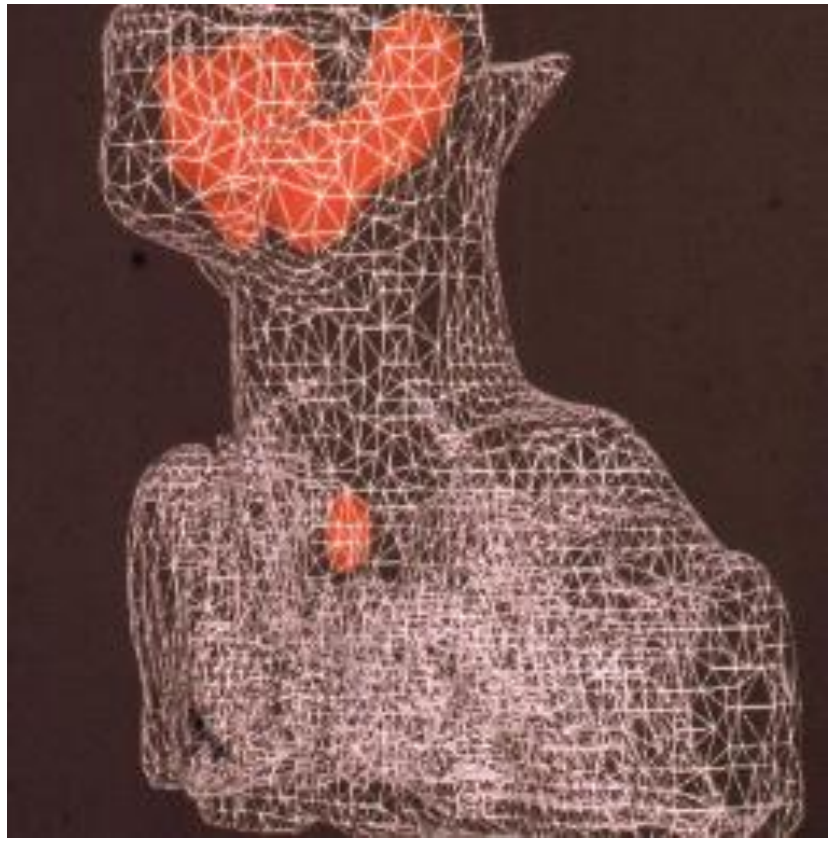
Advantages of SPECT in parathyroid imaging

Allows increased contrast (fewer overlapping structures)

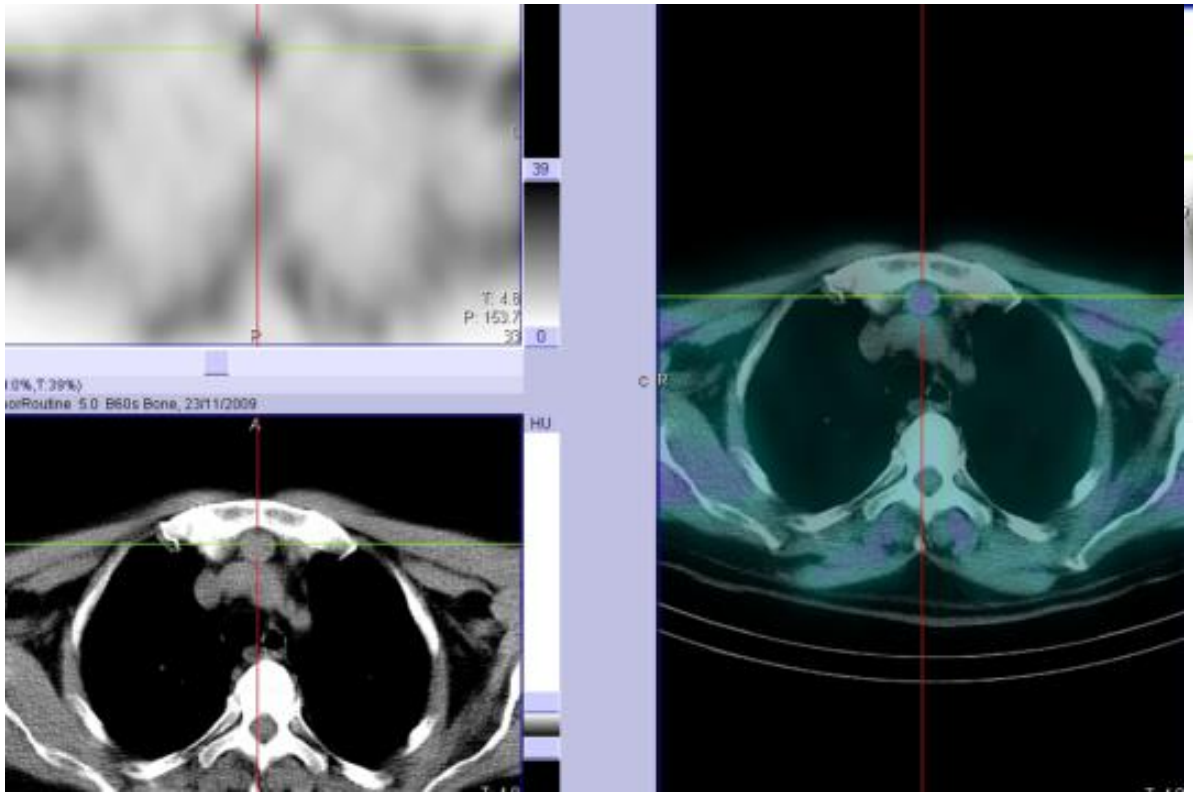
Better localization

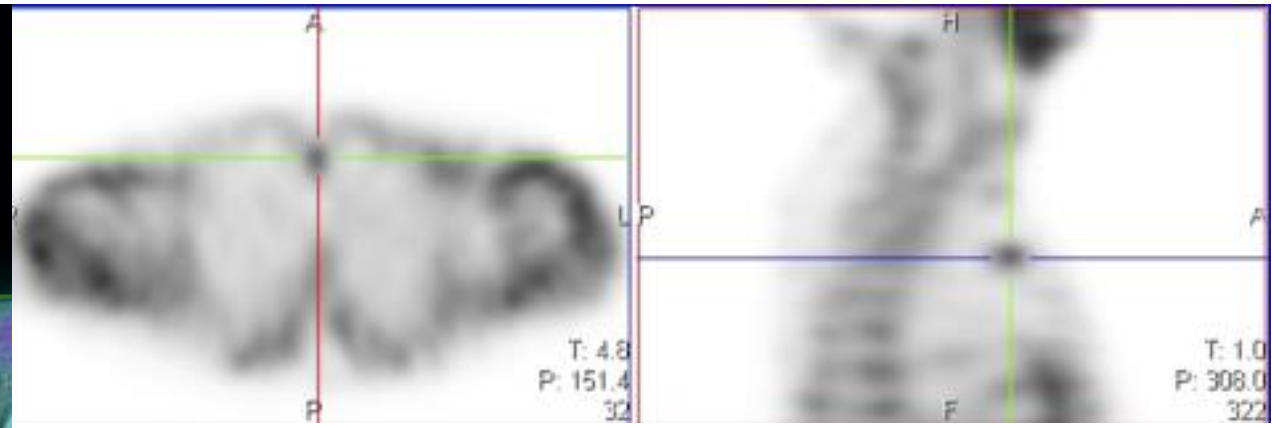
Should find lesions 7mm and above

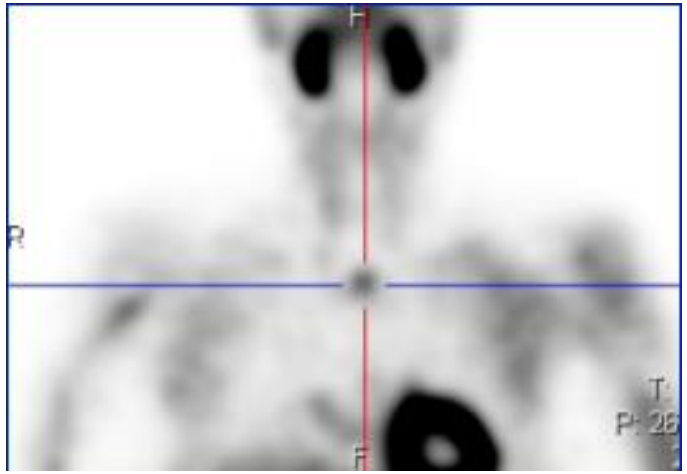
Interactive display possible



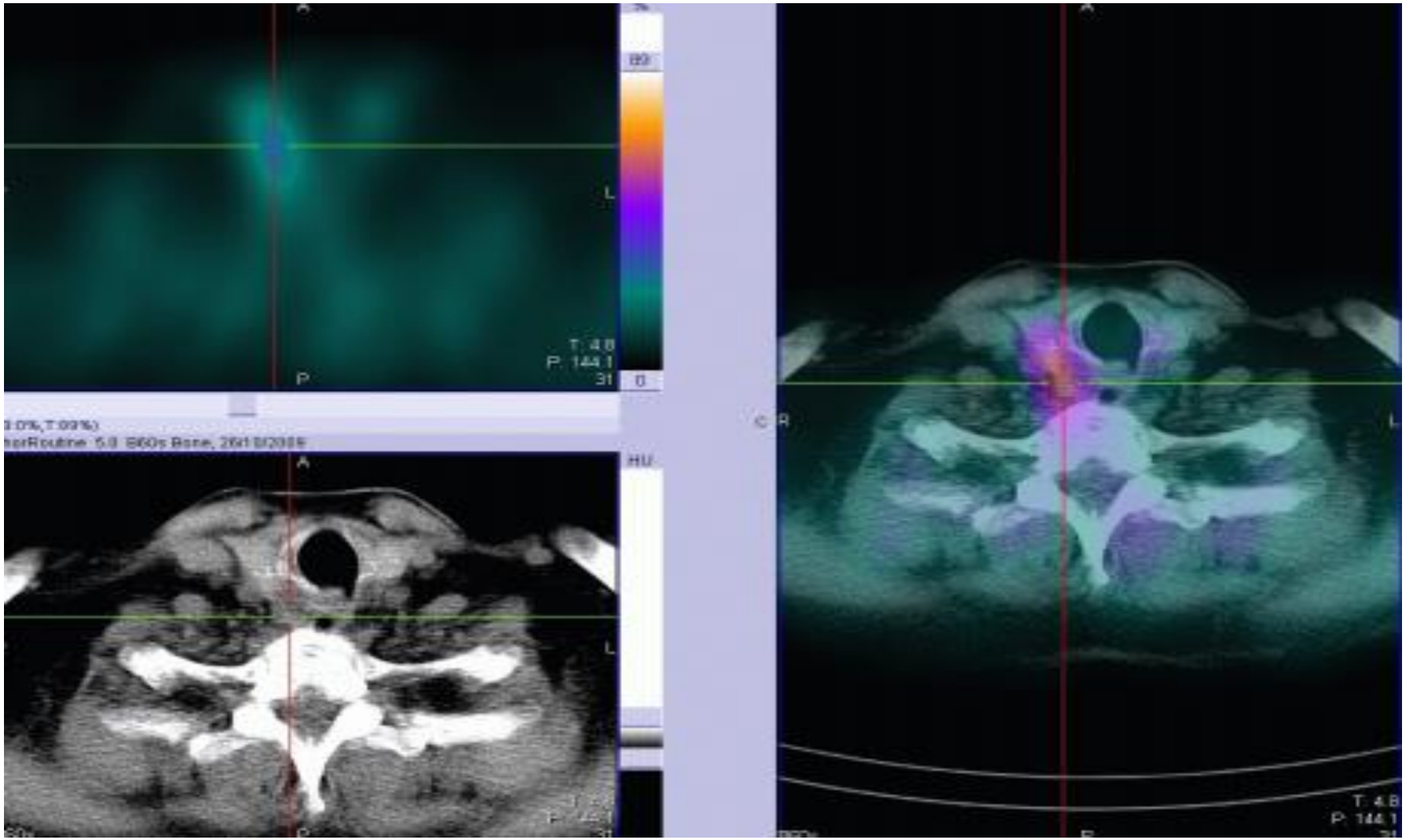
SPECT alone







MIBI with SPECT



Adrenal Imaging

- Adrenal gland lies in retroperitoneal space

  - Right – above right kidney

  - Left – superomedial to left kidney

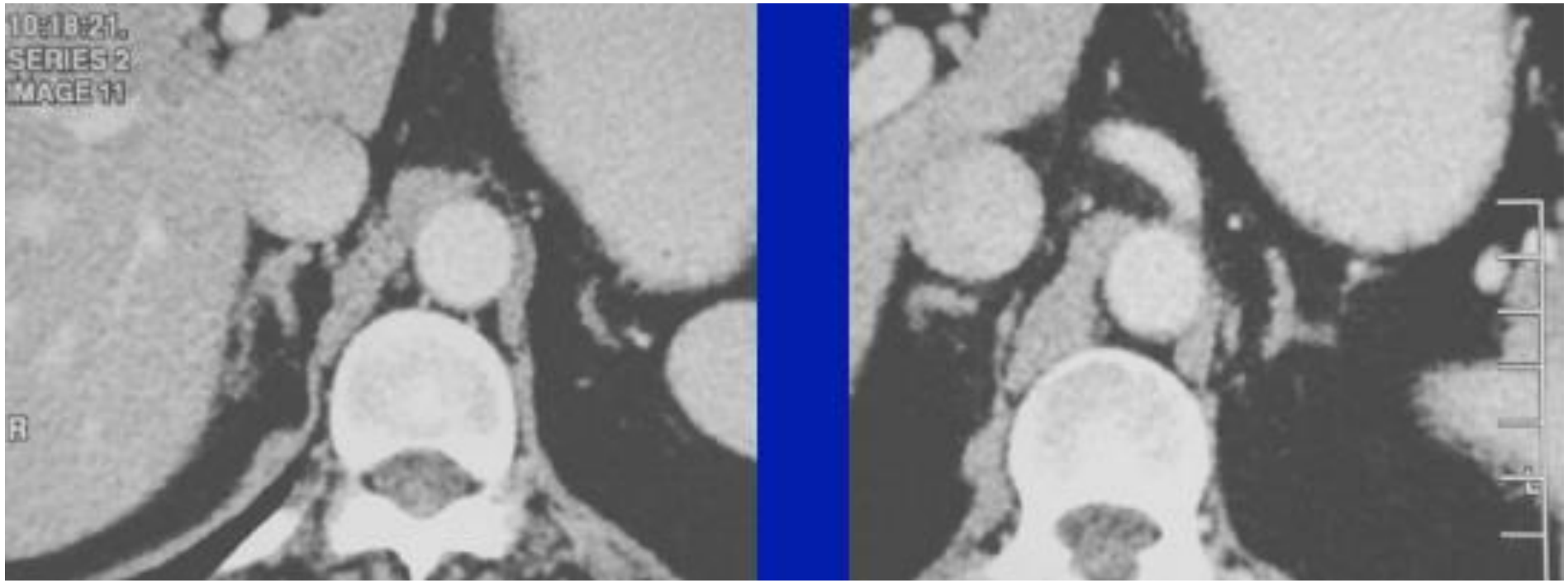
- Gland is divided into two anatomical and functional regions:

  Cortex – produces hormones derived from cholesterol (aldosterone, steroids and androgens)

  Medulla – produces catecholamines (adrenaline and noradrenaline).

Adrenal Glands on CT

RIGHT LEFT



Imaging of the Adrenal Gland
Adrenal Medulla

Indication: localization of phaeochromocytoma

Tracer: 131I MIBG (Metaiodobenzylguanidine)

Method of uptake: amine uptake transporter mechanism present in neuroectodermal tissue

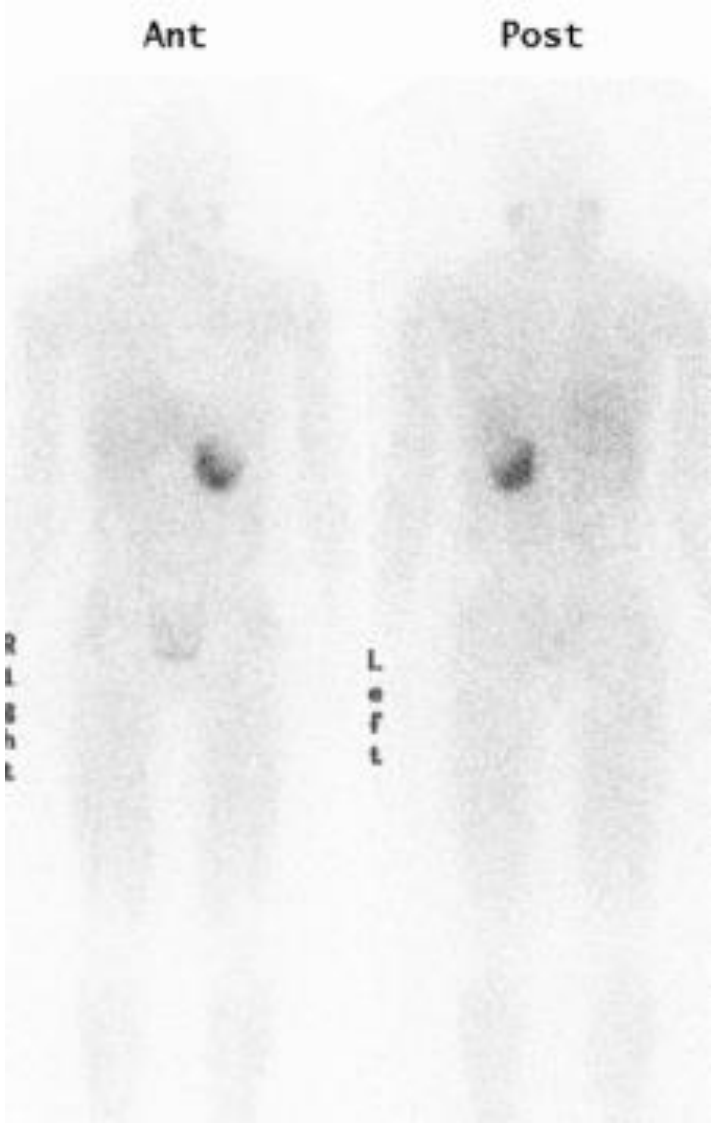
Give thyroid blockade: e.g. potassium iodide 60mg bd for 3 days

Phaeochromocytoma

- Neoplasm arising from adrenal medulla

‘10%’

- 10% malignant
- 10% bilateral
- 10% ectopic
- 10% found in children
- 10% associated with syndrome
- 10% neg MIBG scan

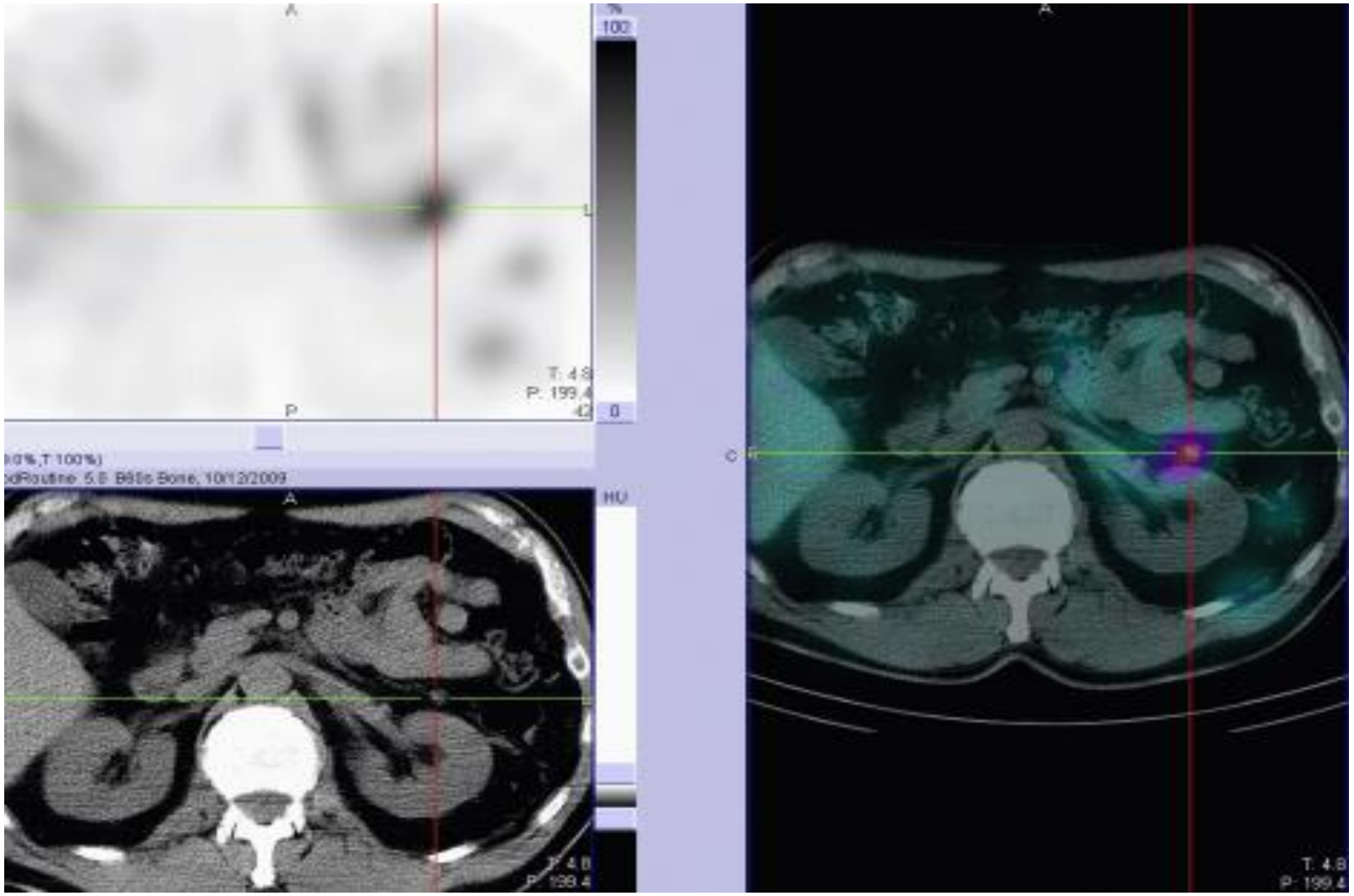


Phaeochromocytoma

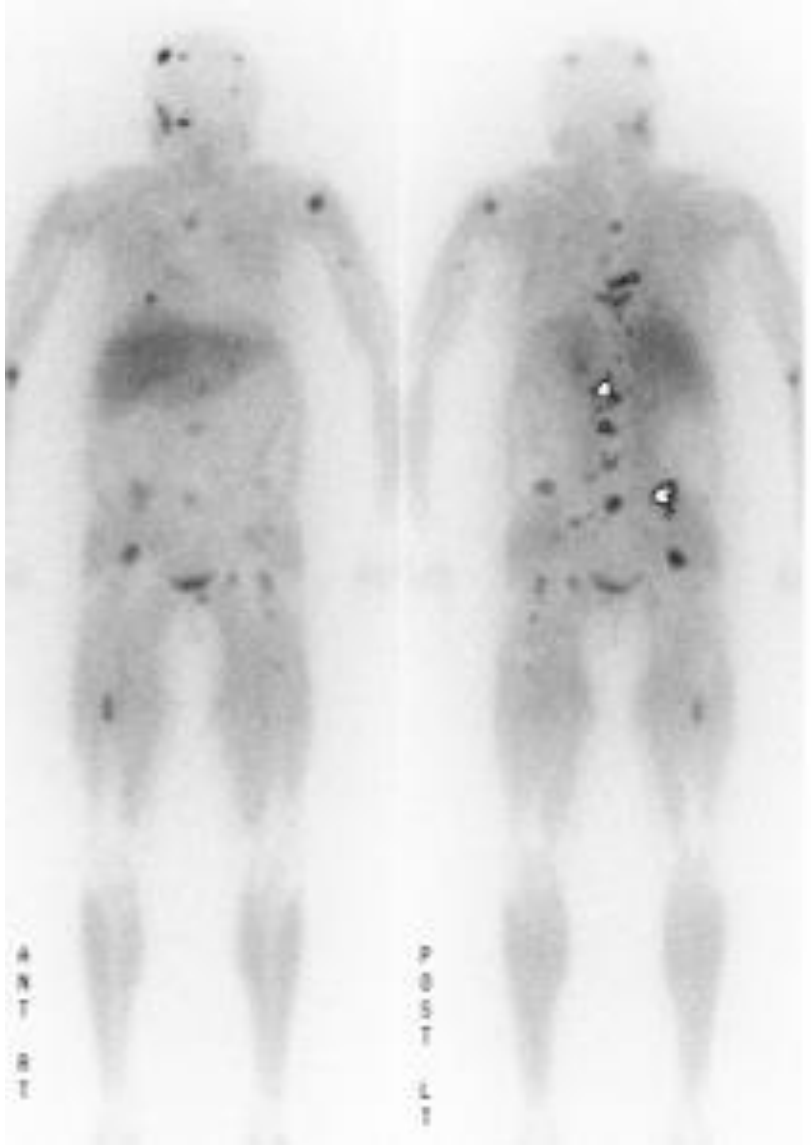
Pre Surgery

Post Surgery

I 123 MIBG (Metaiodobenzylguanidine) with SPECT

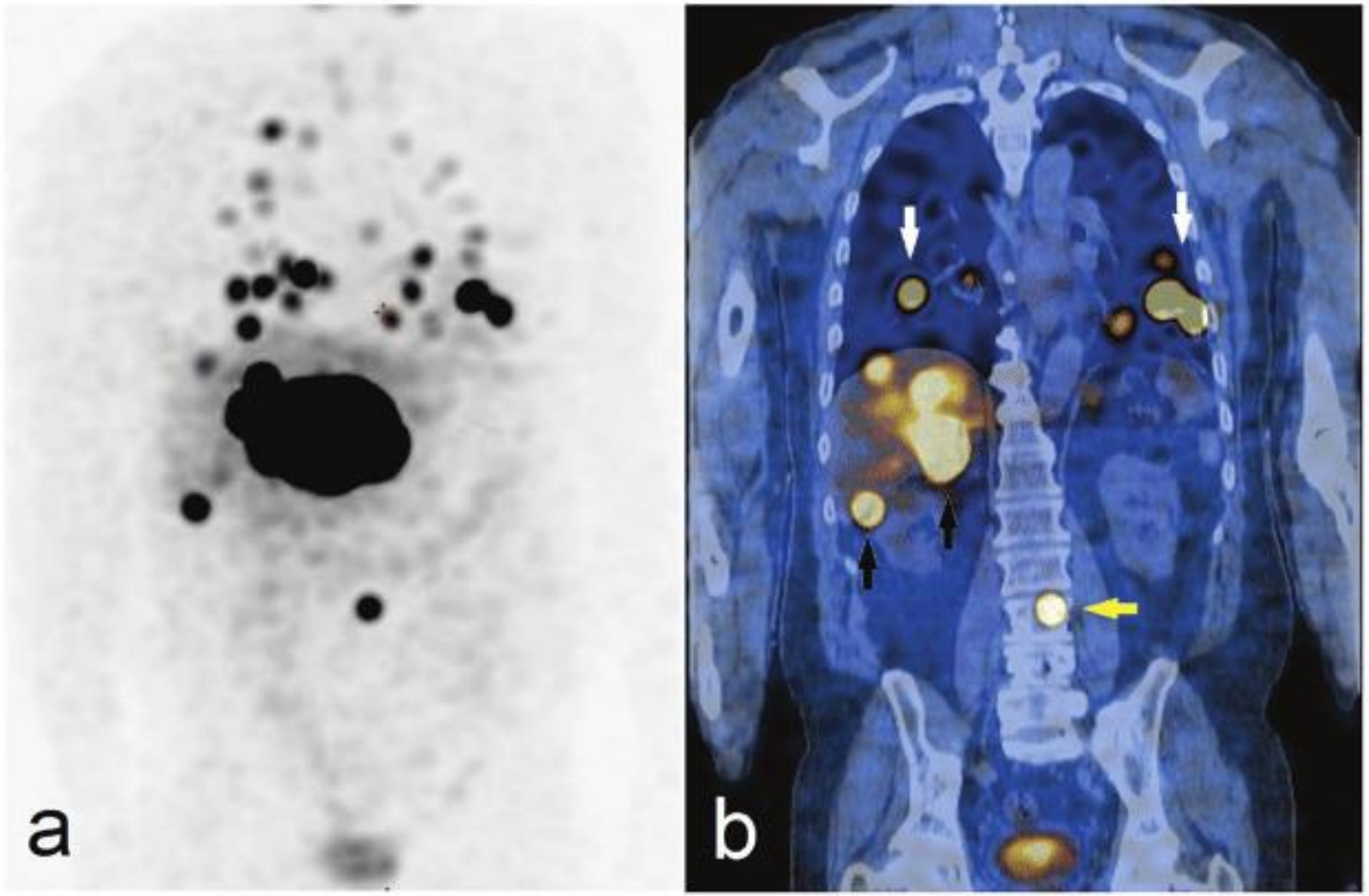


Malignant Metastatic Phaeochromocytoma



123 I-MIBG SPECT/CT study

(a) maximum-intensity projection, (b) coronal slice. Re-staging examination reveals the metastatic spread of malignant pheochromocytoma into the lungs (white arrows), liver (black arrows), and vertebra L3 (yellow arrow).



48-year-old male with pheochromocytoma

Fused coronal I-123 MIBG SPECT/CT showed avid uptake of radiotracer within the left adrenal pheochromocytoma.

Imaging of Adrenal Gland
Adrenal Cortex

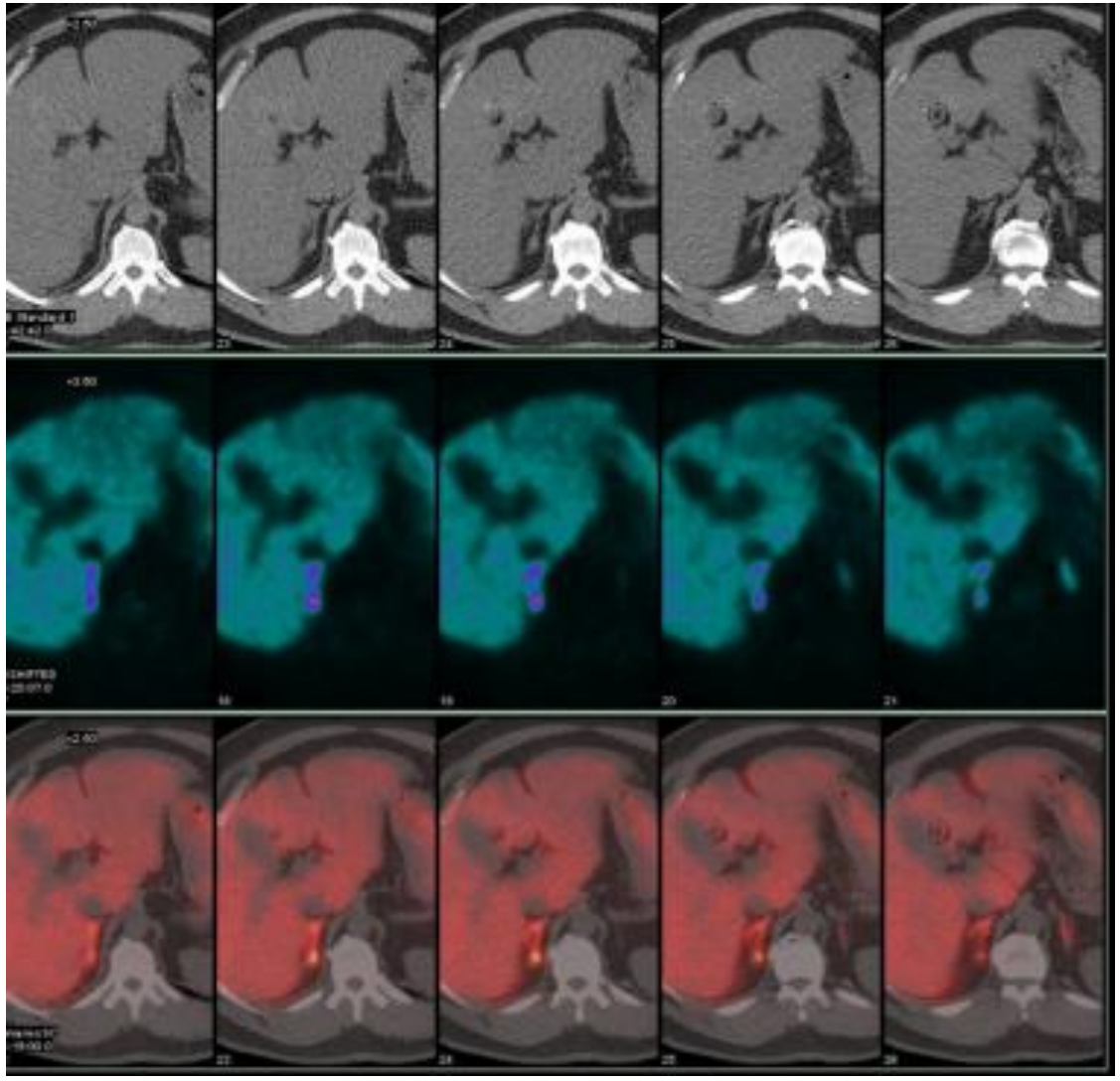
Nuclear medicine very rarely used in imaging of the adrenal cortex.

Biochemical tests e.g. serum cortisol levels, together with anatomical imaging (CT or MRI) usually used.

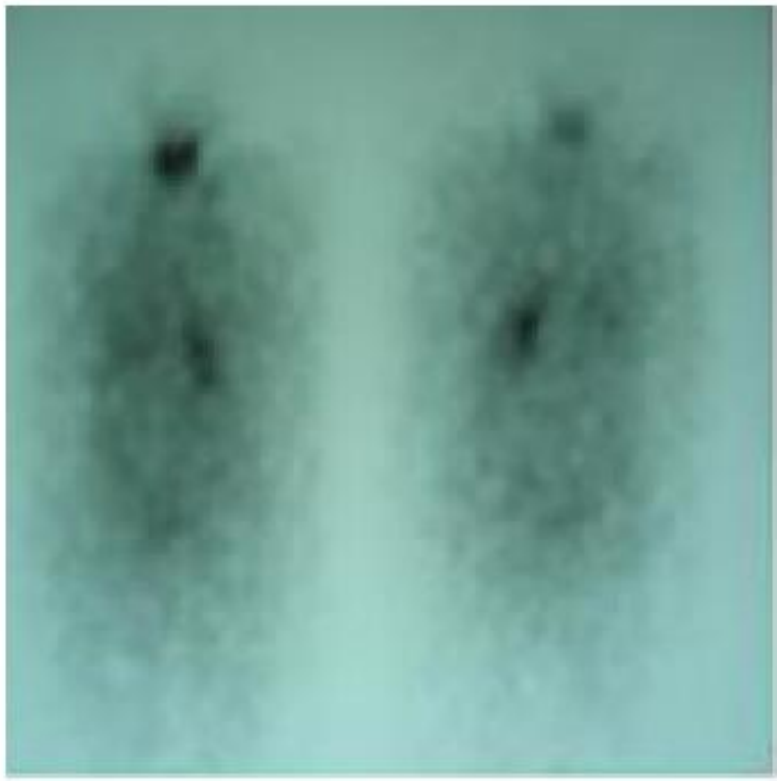
Tracers – limited availability **131 I-19 Iodocholesterol**

Iodocholesterol scan

Adrenal cortical adenoma



Cushing (Adrenocortical Adenoma)



Ectopic ACTH dependent Cushing

syndrome diagnosed with

Octreotide scan