Diagnostics and radiotherapy of thyroid and parathyroid diseases

Department of Nuclear Medicine

Basedow-disease

Serious Basedow-disease with cachexy and exophtalmopathy

Nuclear Medicine

The root of the matter:

using of the radioactive isotopes in the diagnostic and in the therapy.

Radioactivity

Is the spontaneous disintegration (decay) of the nucleus of a radioactive atom, while the element becomes to an other one. The behaviour of a radioactive atom is the same in the body as the inactive form (e.g. 127- and 131-Iodine).

Using of radioactive material as a tracer (Hevesy György 1923.)

Gamma radiation

- Really electromagnetic radiation
- Phisically similar to X-rays, but it comes from the nucleus of the atom
- Very penetrated and easily pass trough tissue
- SO: it can be detected externally well!
- E.g. 99meta-Technetium for the diagnosis

The equipments I.

Gamma-camera (Anger, 1951)

- it „sees” the whole entire area below the detector

Radiation exposure

- Principle of ALARA (as low as reasonable achieveble) both the patients and the staff
- *Correct indication of the examination!*
- Examinations of pregnant women is contraindicated
- Children should be examined carefully

In vivo radionuclide studies

- *are based on the function of an organ or an organ system!*
- **are easily performed**
- **need no premedication**
- **are not associated with any morbidity and complication, have only minimal risk**
- **are very sensitive, but aspecific methods**
- **are very good for screening studies**

Static studies: scintigraphies

An optimal time-period after the subject administration is delayed and pictures are made of the organ from different directions

- Negative scintigraphy:

pathological decreased activity or lack of the activity (focal defect) is found

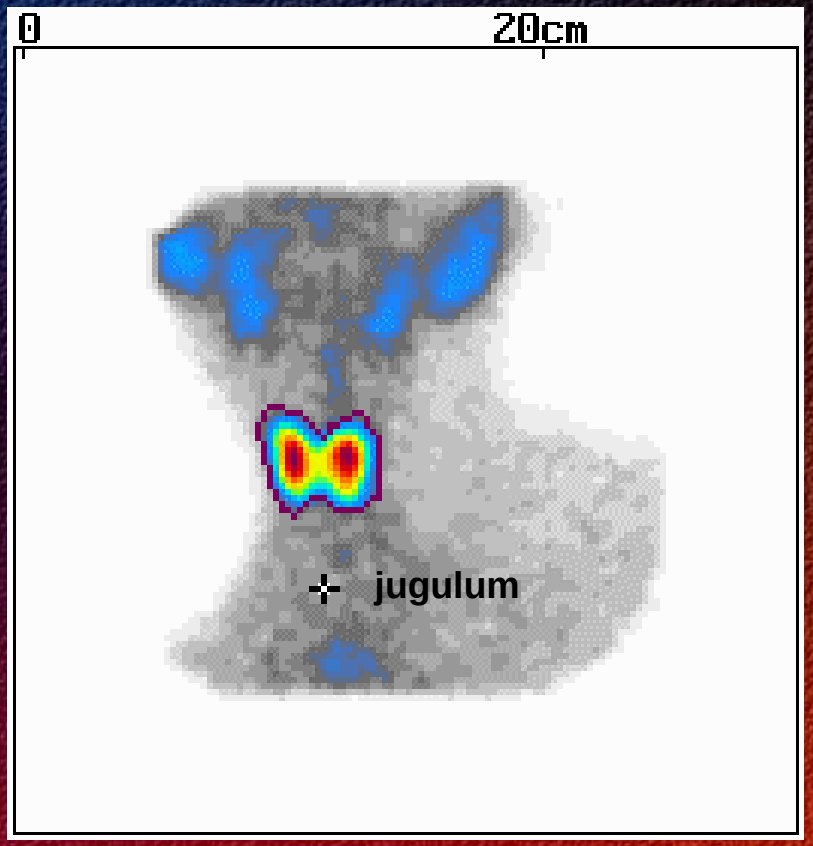
- Positive scintigraphy:

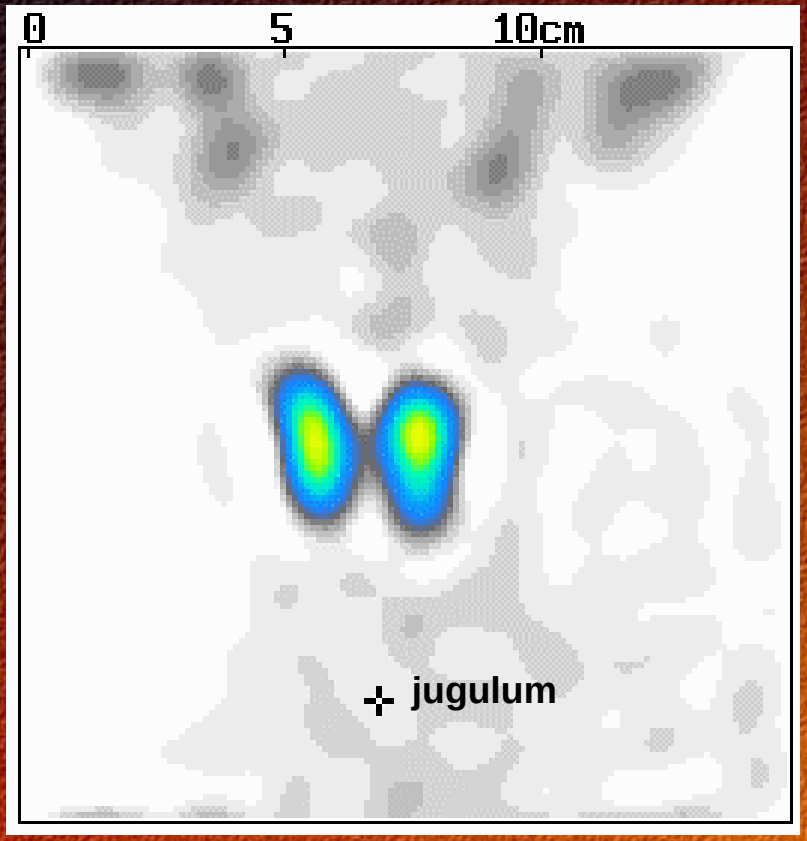
pathological increased activity (hot spot) is found

Thyroid scintigraphy

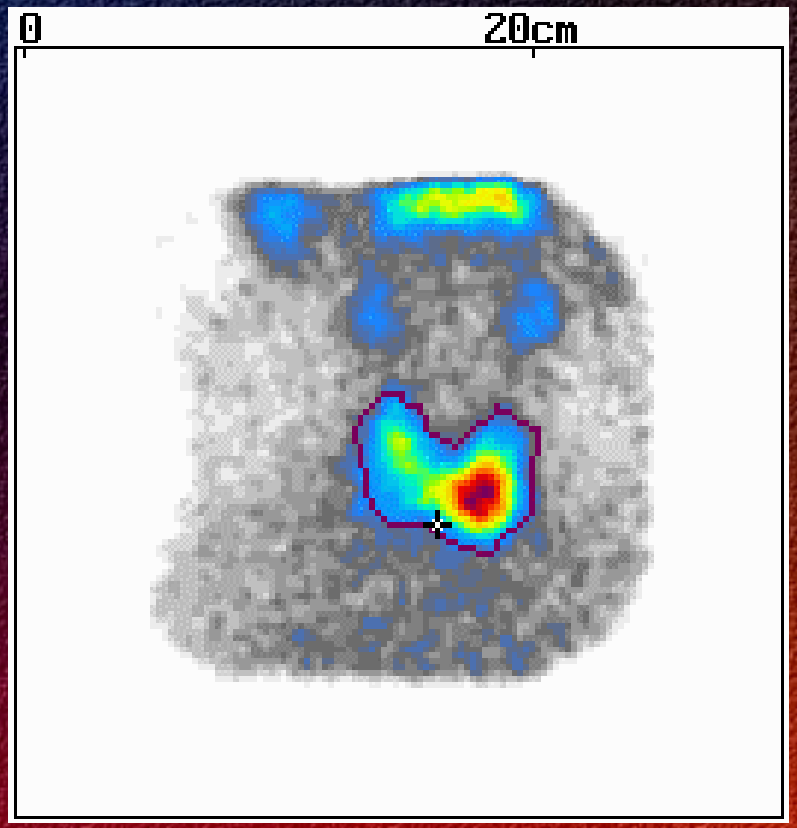
- The function and the morphology of the thyroid can be evaluated, mainly the nature of the palpable nodules
- 131-Iodine scintigraphy was the first nuclear medicine method
- Today 99mTc- pertechnetate is used, the radiation exposure is less!

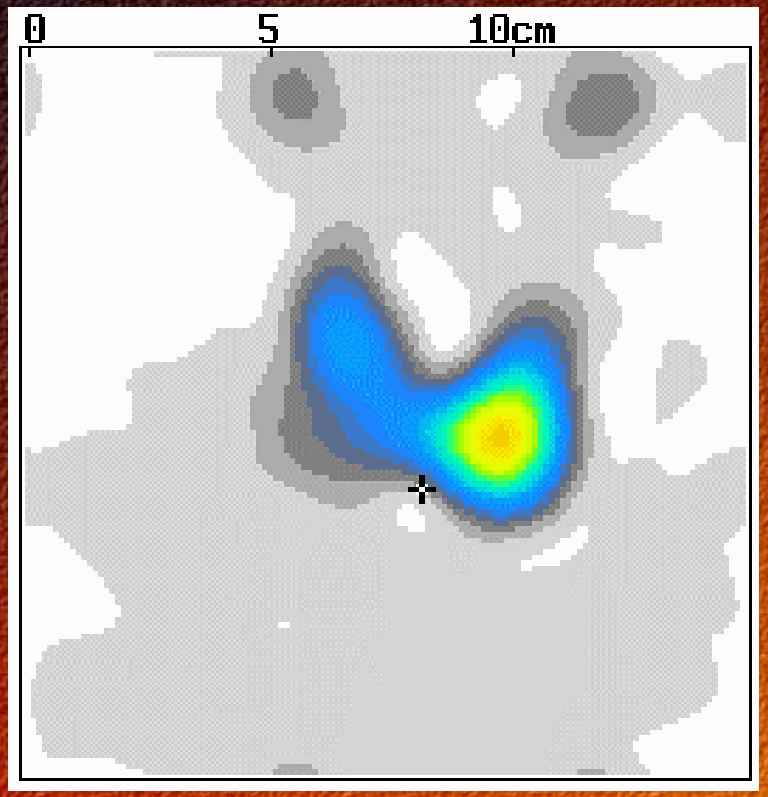
Normal thyroid scintigraphy



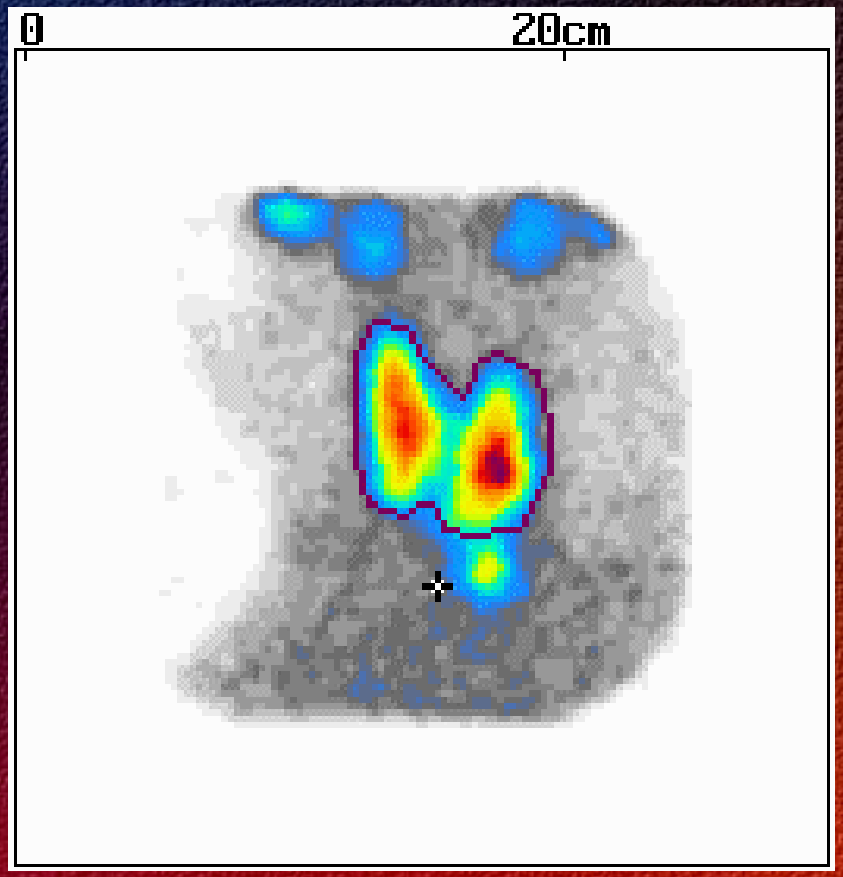


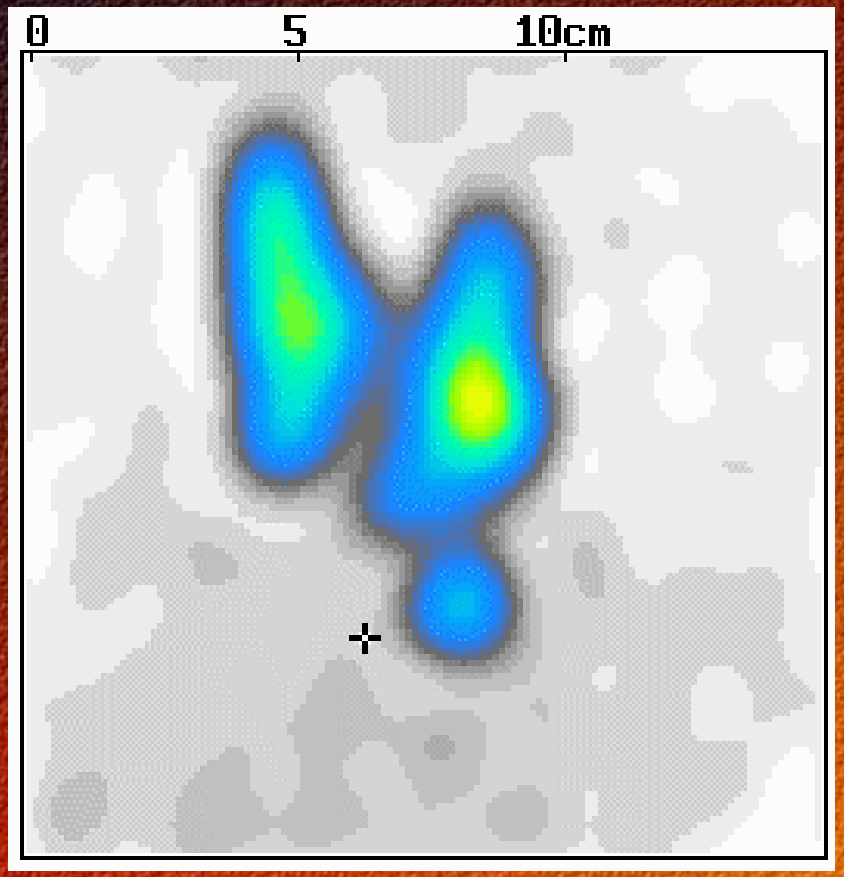
Substernal thyroid





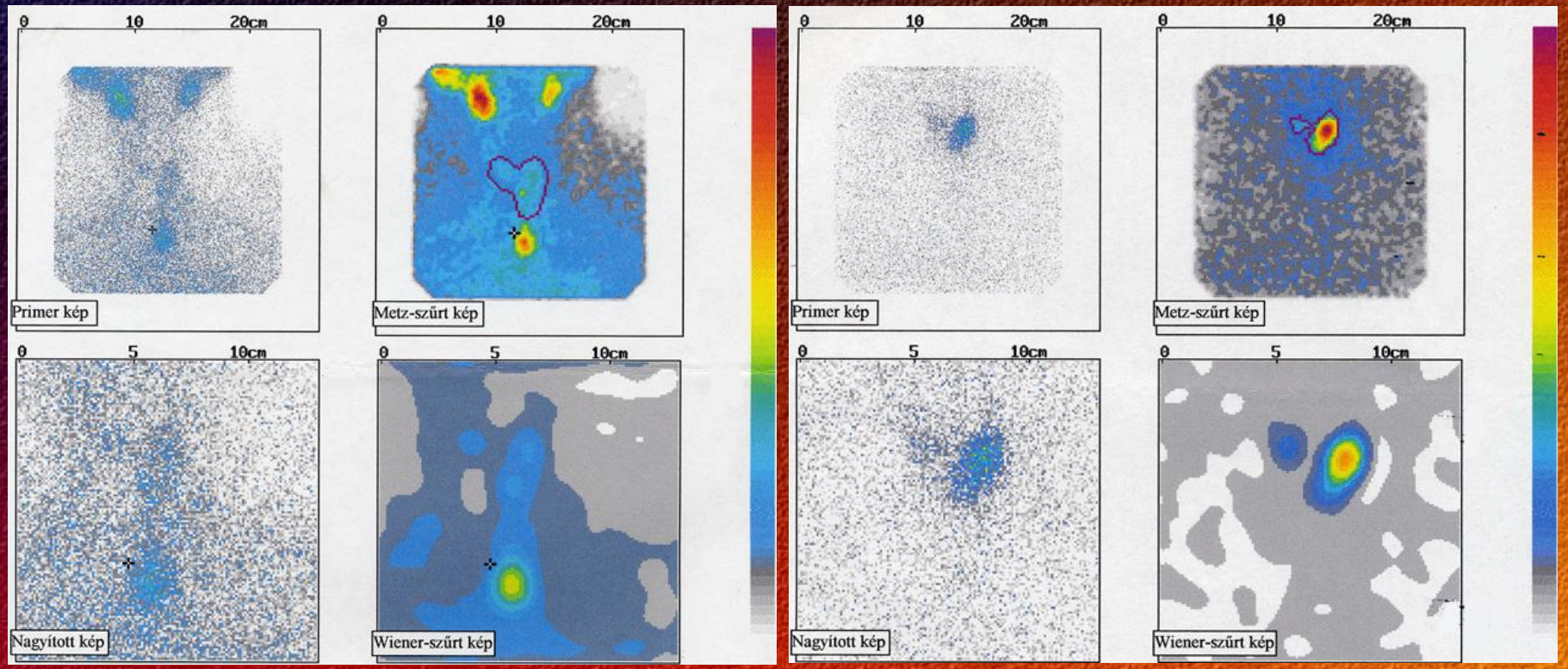
Ectopic thyroid tissue



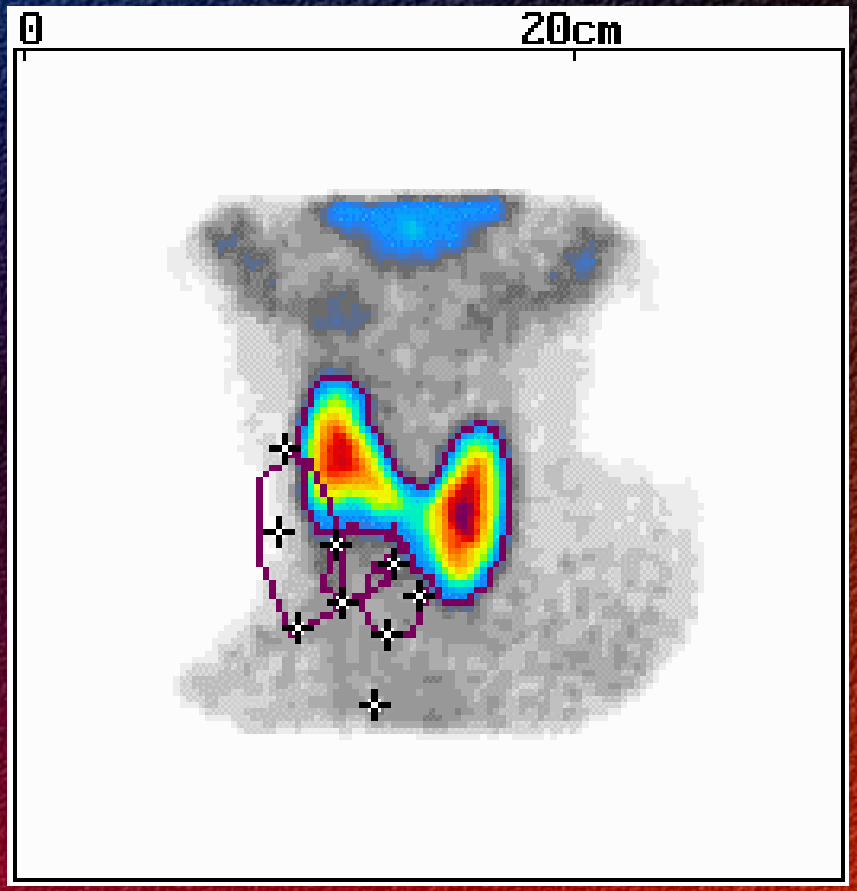


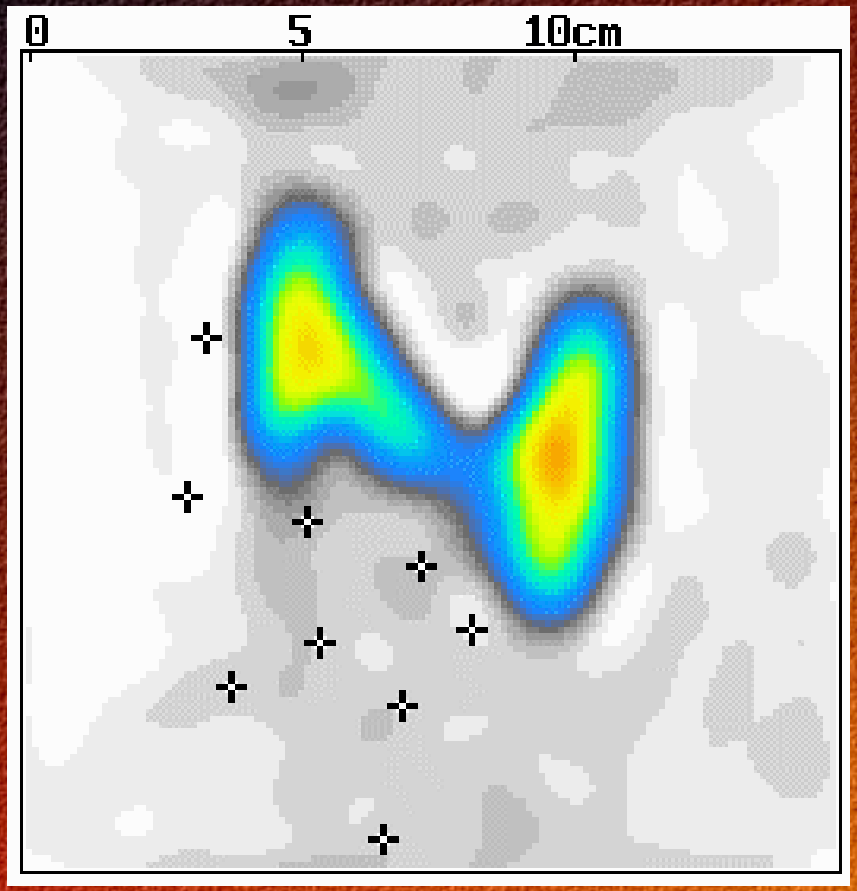
Thyroid scintigraphy by different isotopes

99m-Technetium **131-Iodine**

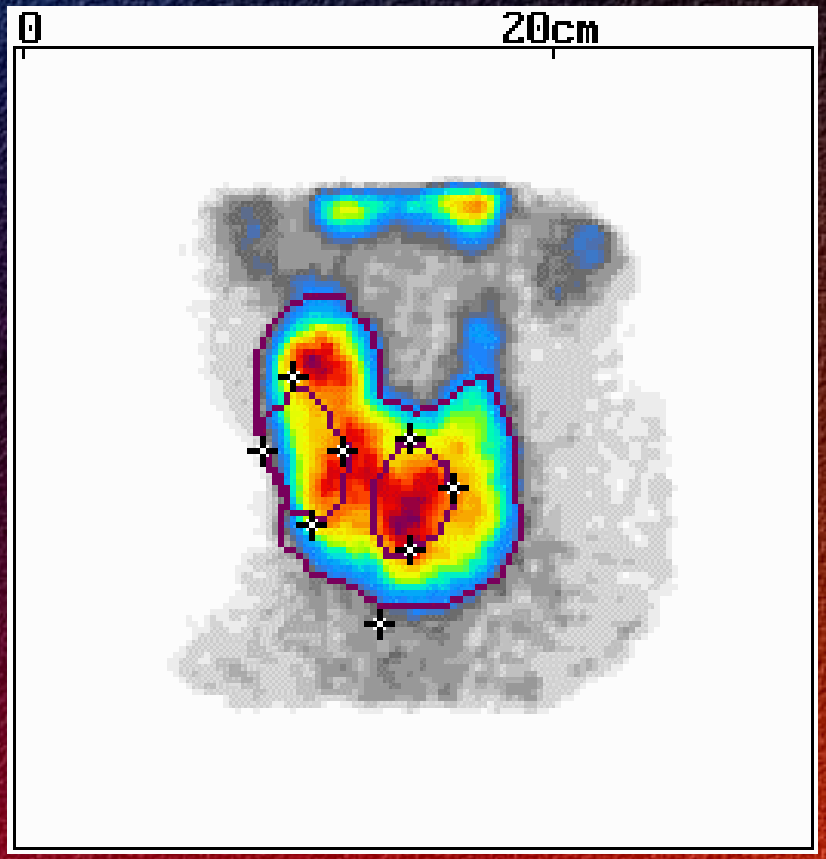


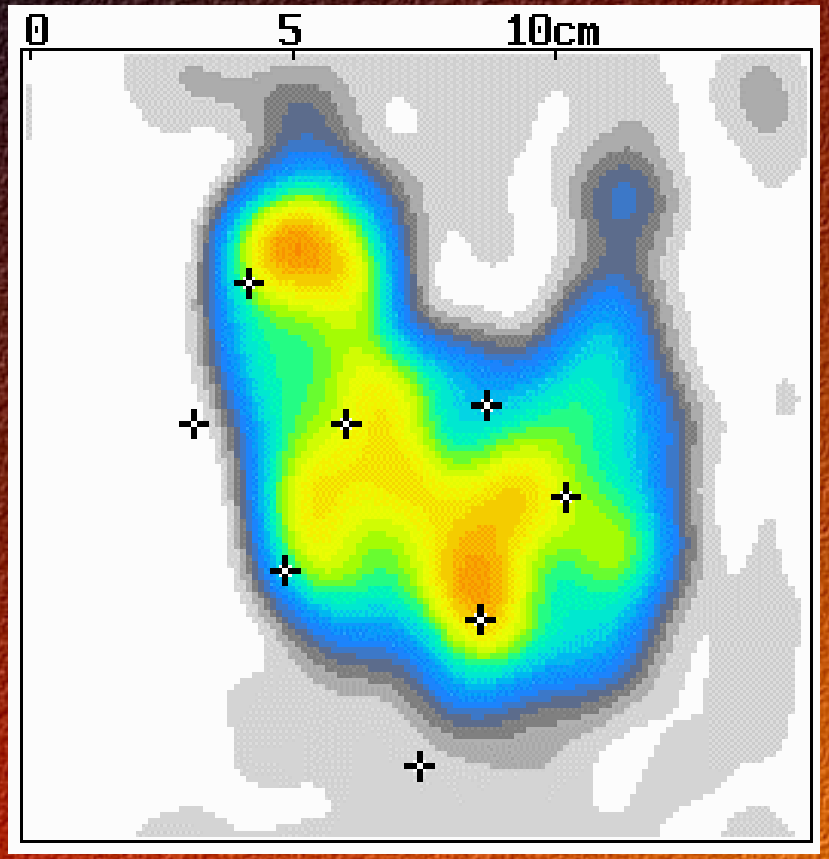
Cold nodules



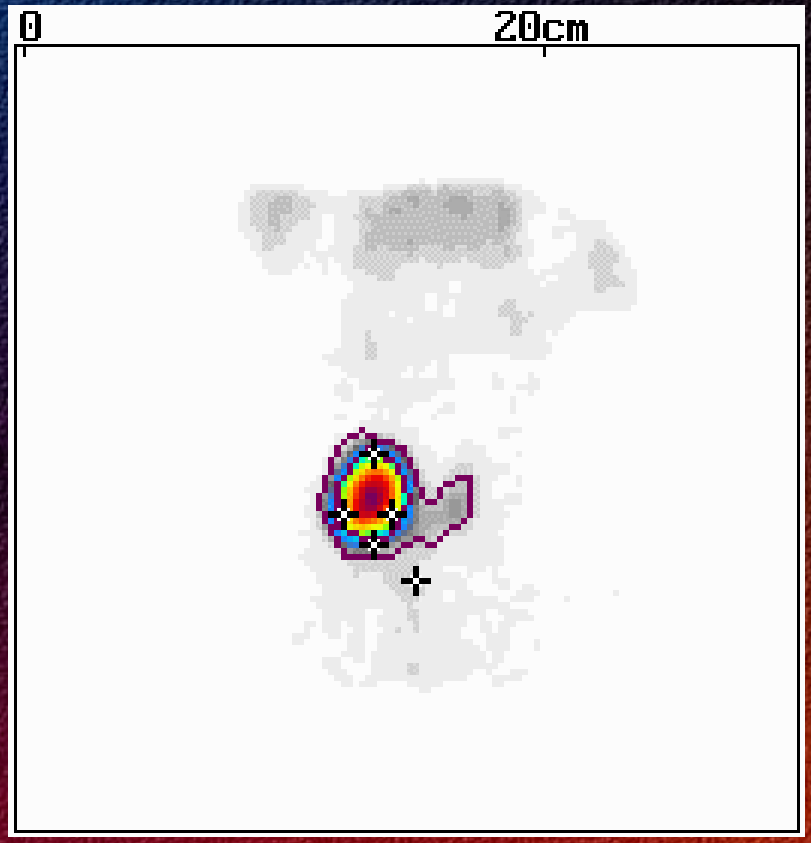


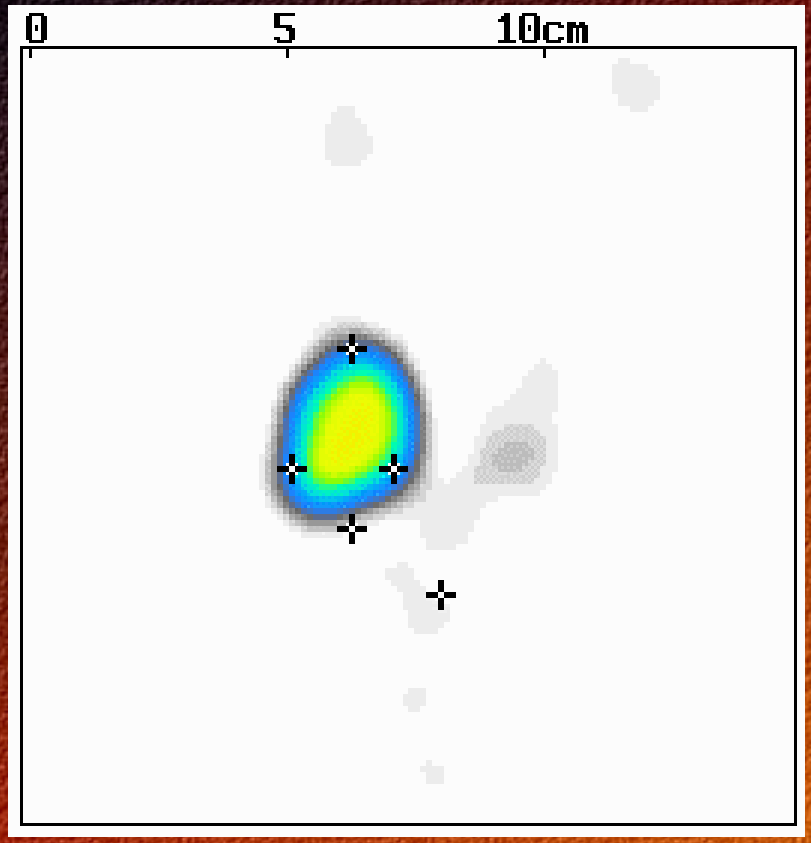
Substernal thyroid with cold nodules



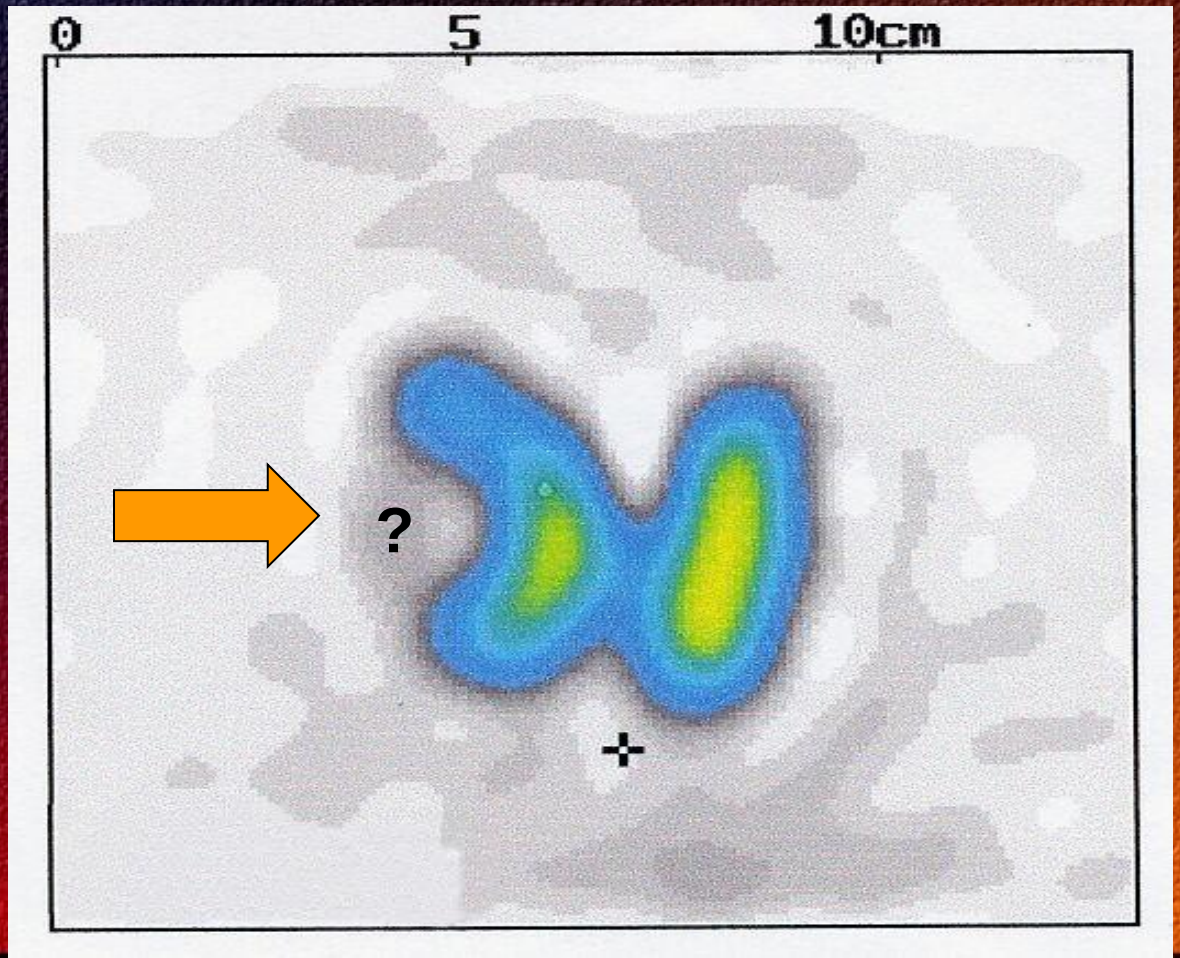


Hot nodule

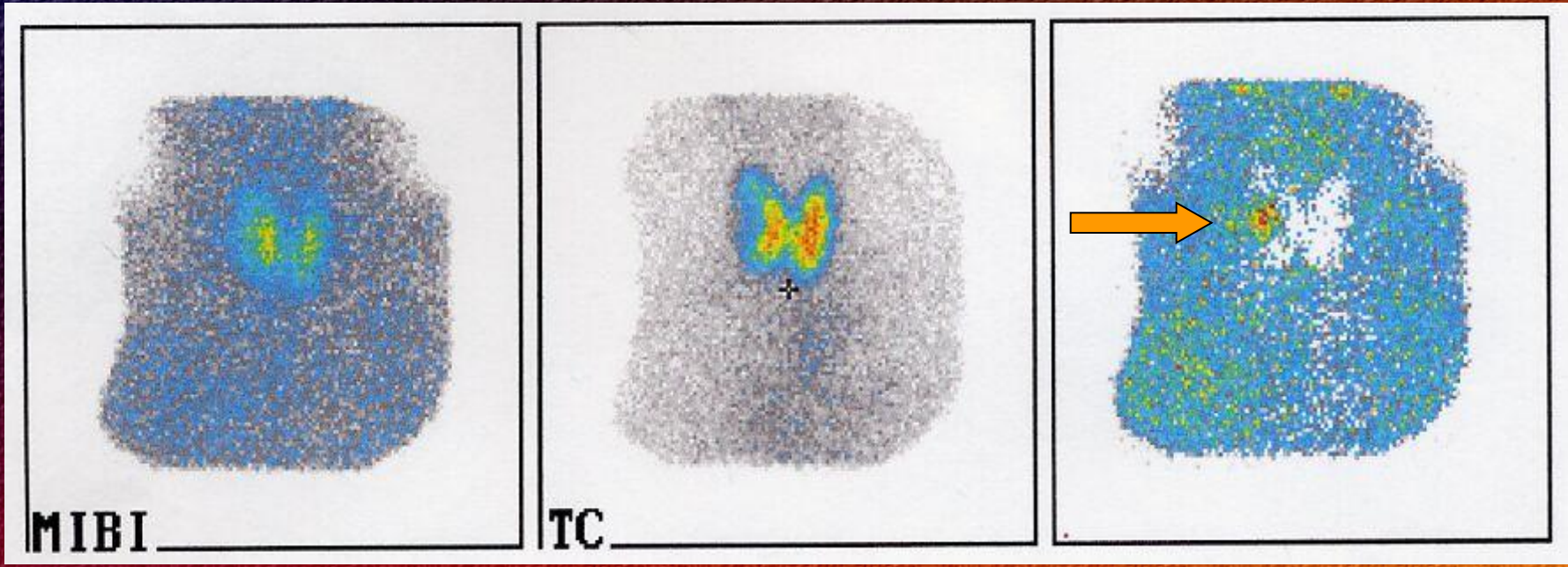




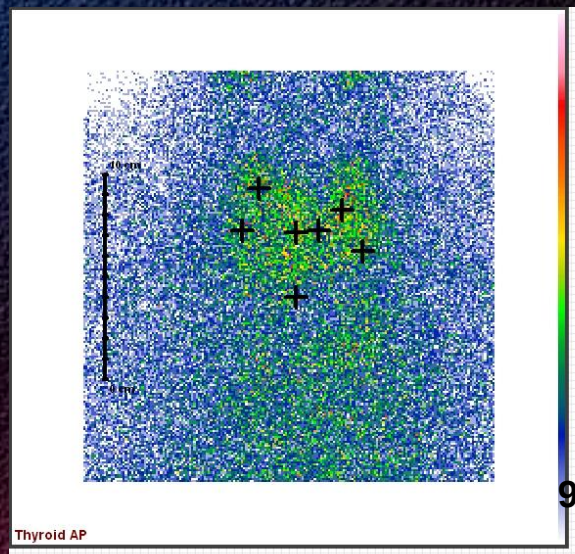
Thyroid scintigraphy cold nodule: cancer? cyst?

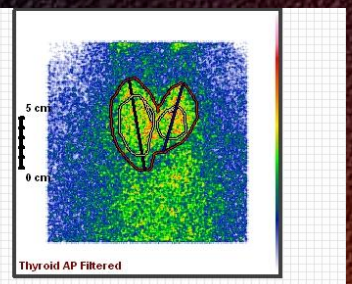


Differenciated thyroid cancer – enhancement of MIBI in the cold nodule



Double phase thyroid scintigraphy

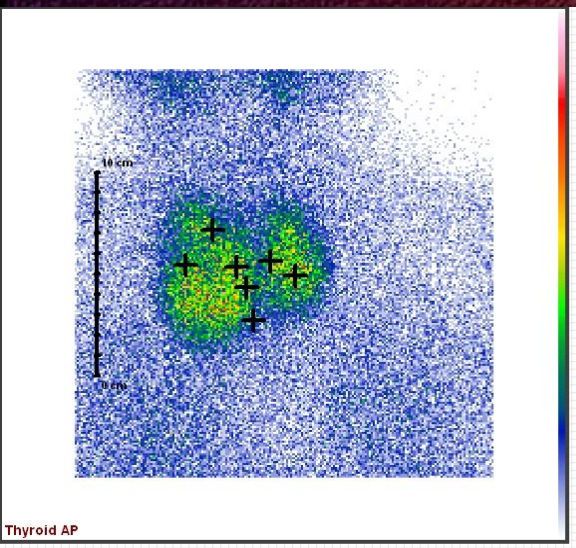


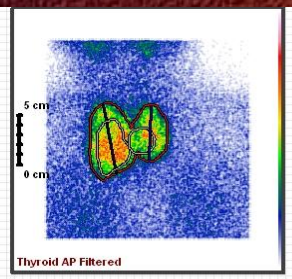


Size estimation summary

Thyroid weight	50.4 g
Area of Full Thyroid	54.9 cm2
Area of Nodule [1]	16.8 cm2
Area of Nodule [2]	7.8 cm2

99mTc-pertechnetate

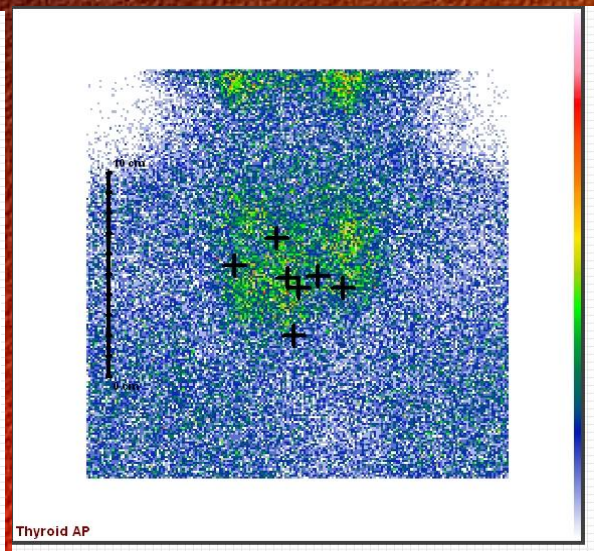


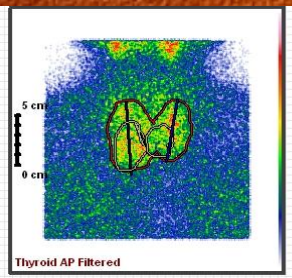


Size estimation summary

Thyroid weight	31.1 g
Area of Full Thyroid	44.1 cm2
Area of Nodule [1]	14.2 cm2
Area of Nodule [2]	5.8 cm2

99mTc-MIBI 15 min





Size estimation summary

Thyroid weight	35.4 g
Area of Full Thyroid	45.7 cm2
Area of Nodule [1]	12.6 cm2
Area of Nodule [2]	7.4 cm2

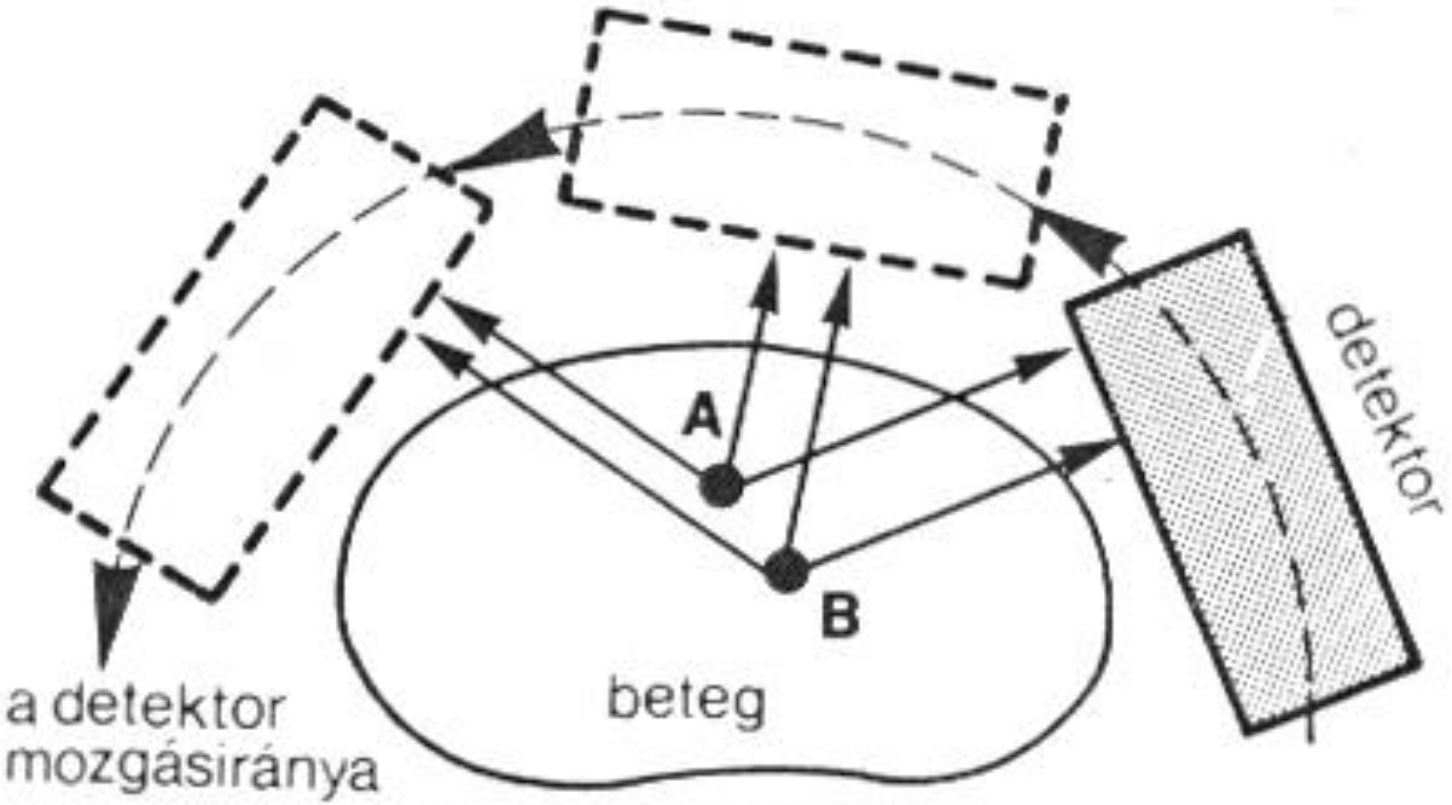
99mTc-MIBI 120 min

The equipments II.

SPECT
(Single Photon Emission Computer Tomograph)

SPECT/CT
(Multimodality equipment)

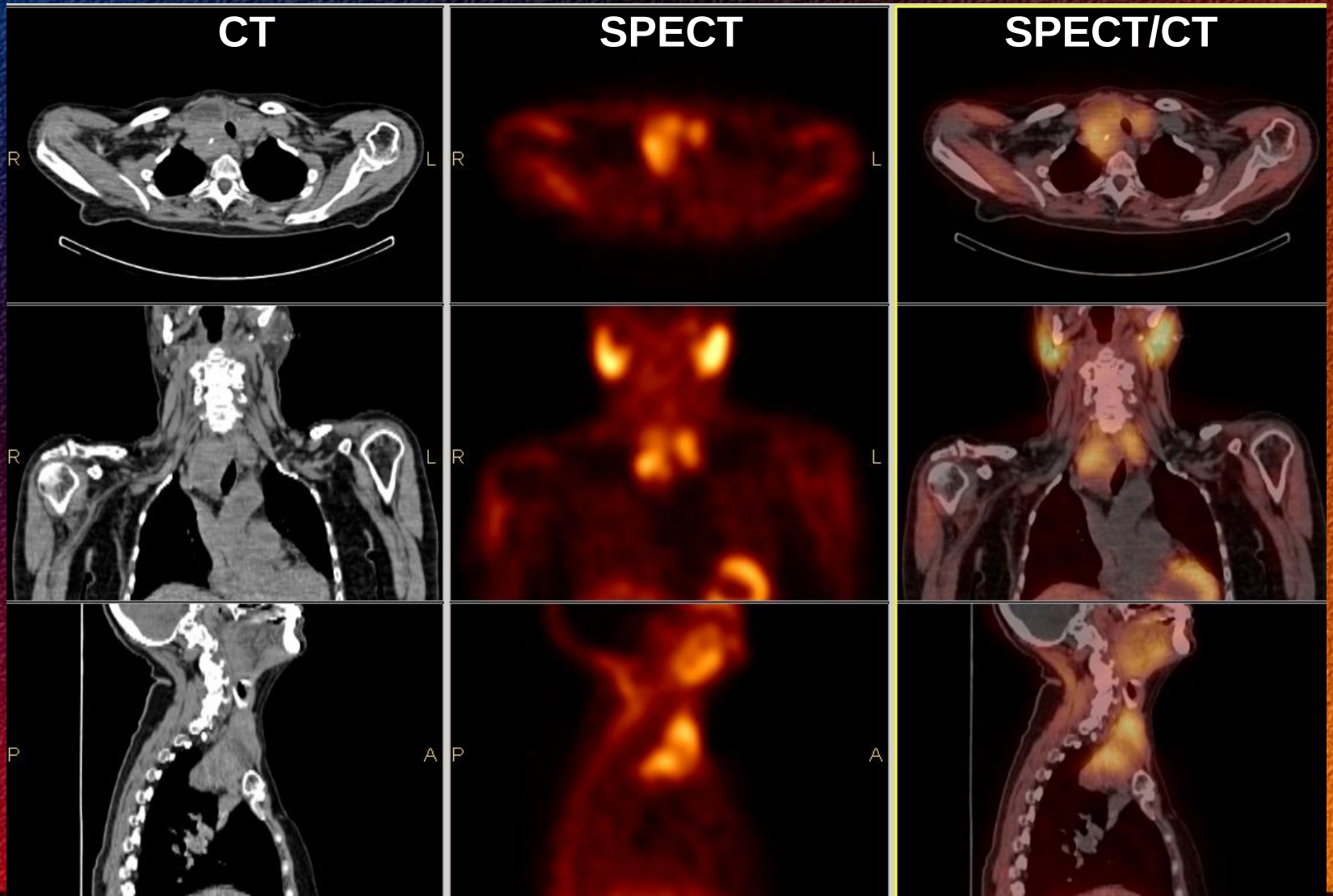
The principle of the SPECT



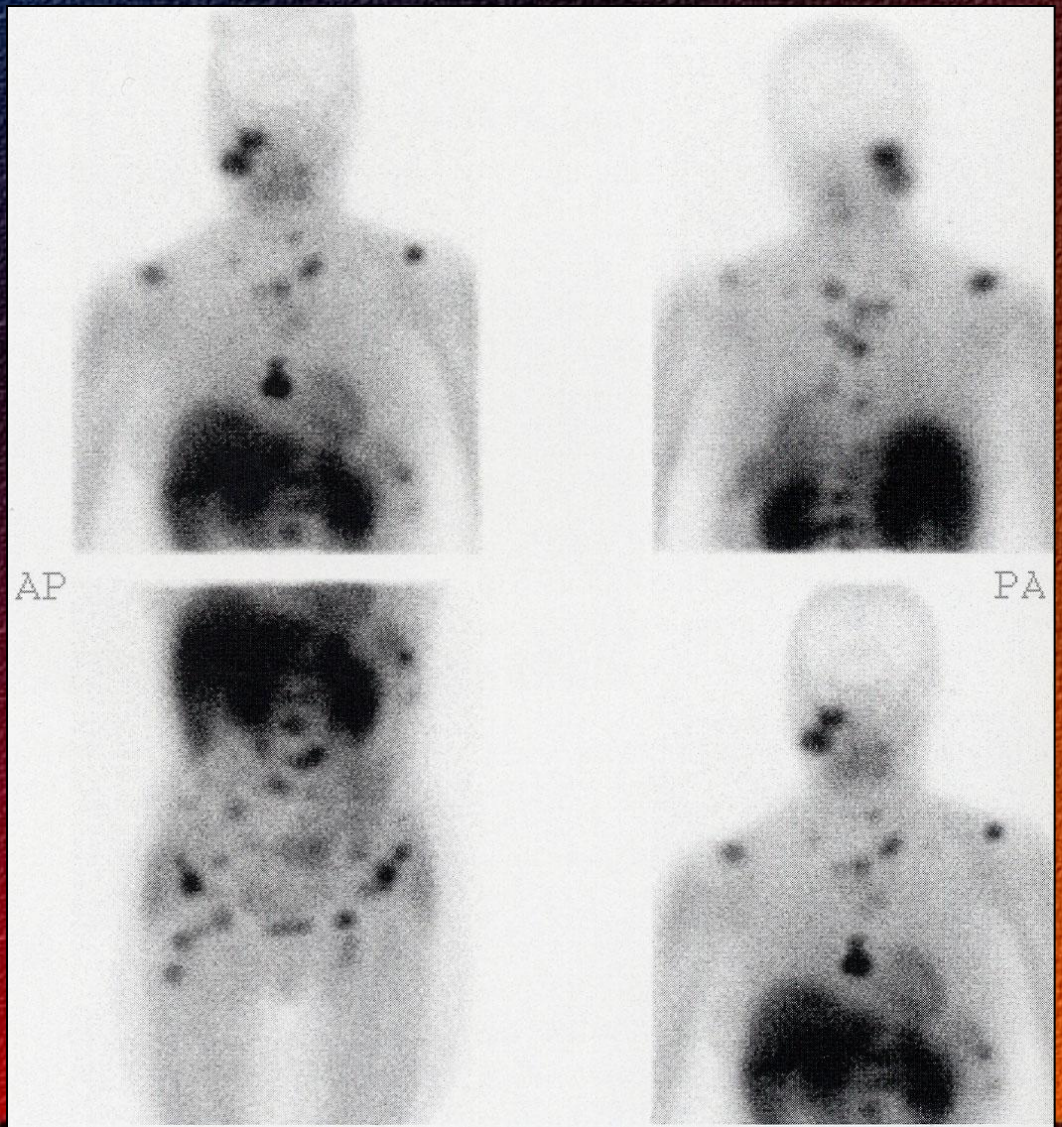
52. ábra. A SPECT elve

The detectors whirl around the patient and make pictures from different steps. The reconstruction and/or the reorientation are made by the computer program from this pictures after the imaging. Transversal, sagittal and coronal slices are reconstruated and evaluated.

SPECT/CT imaging of the neck by 99mTc-MIBI



Bone metastases in thyroid cancer by 99mTc-tetrofosmin



Beta radiation

- The emission of high-speed electrons
- The range in tissue is only a few millimeters
- External detection is impossible
- The biological damage to tissues is high
- SO: they are used for radiotherapy
- E.g. 131-Iodine for thyroid therapy

131-Iodine therapy

Oral administration of 131-Iodine has been a commonly accepted procedure for treatment of benign and malignant conditions of the thyroid since the 1940s. Physicians responsible for treating such patients should have an understanding of the clinical pathophysiology and natural history of the disease processes, should be familiar with alternate forms of therapy, and should be able to collaborate closely with other physicians involved in the management of the patient's condition.

Uncleared questions

- Therapy by fix or calculated dose?
- How much should be the fix administered activity?
- How to calculate the administered activity?
- Therapy is performed by who?
- Where? In hospital or at home?

Definitions

- 131-Iodine is a ß-emitting radionuclide with a physical half-life of 8.1 d, a principal gamma-ray of 364 KeV, and a principal ß-particle with a maximum energy of 0.61 MeV, and a range in tissue of 0.8 mm.
- Therapy means the oral administration of 131-Iodine as sodium iodide.
- *Benign conditions* include Graves' disease (toxic diffuse goiter), toxic or nontoxic nodular goiter, and autonomously functioning toxic or nontoxic nodules.
- *Malignant conditions* include thyroid cancer that is sufficiently differentiated to be able to synthesize thyroglobulin and, in most cases, accumulate radioiodine.

Radio-iodine uptake (RAIU)

The phases of thyroid hormon synthesis are studied in vivo.

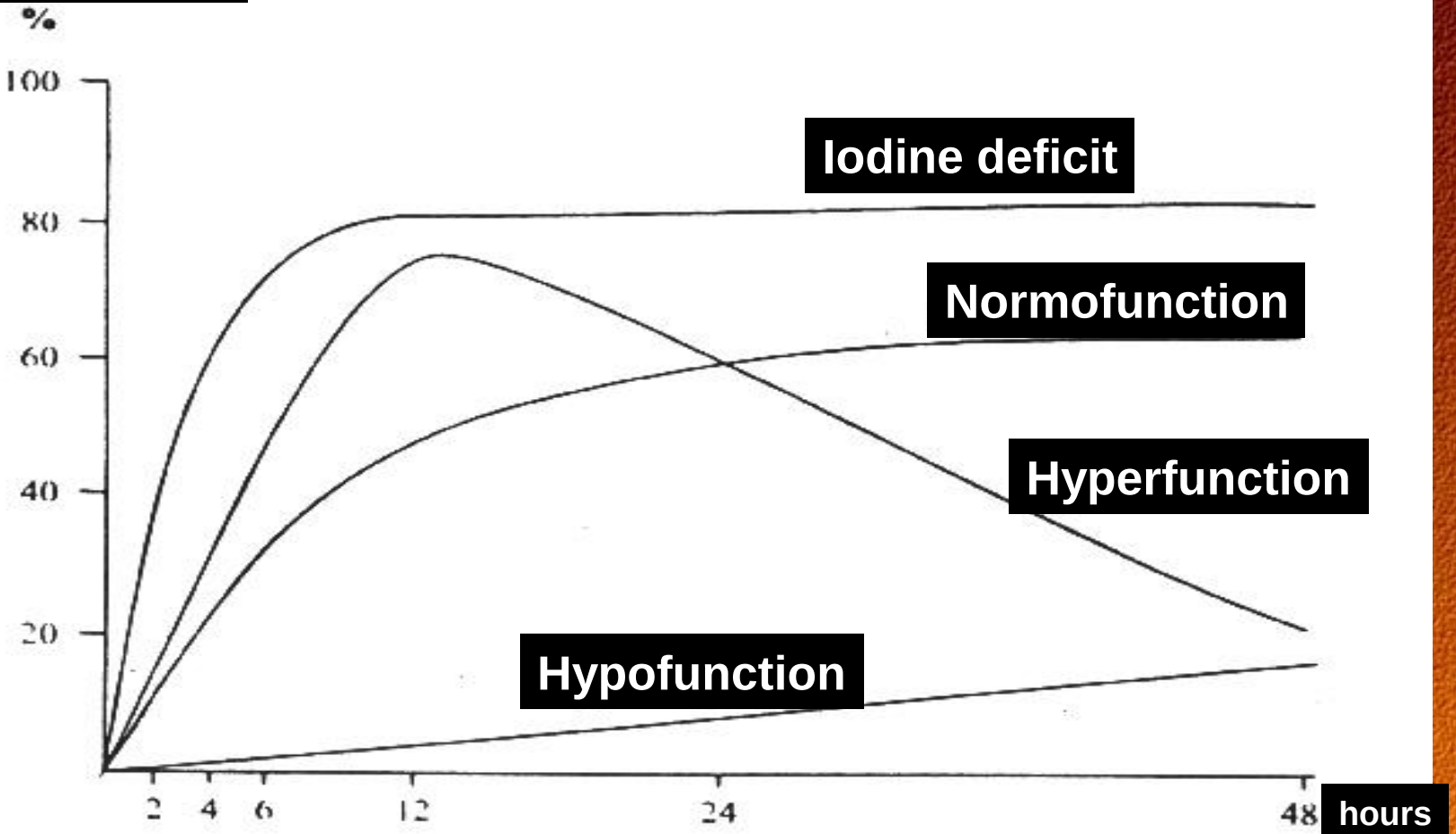
- **Radiopharmaceutical: 0.15 - 0.37 MBq**

131-I-NaI per os (empty stomach!)

- **Measurement: (classical method: 2,4,6,12,24,48 hours after the adiministration) or on the 7. day (our method), 25 - 30 cm from the neck and the thigh, background**

$$\text{- RAIU (\%)} = \frac{\text{neck (cpm) - thigh (cpm)}}{\text{admin. activity (cpm) - background (cpm)}} \times 100$$

Time-activity curves of RAIU



The most types of the curves

Dose selection for hyperthyroid patients

To estimate thyroid gland mass in gram by the scintigraphy and the results of a 7-day RAIU (radioiodine uptake) test.

Delivered activity of 2.96–7.4 MBq/gram of thyroid tissue is generally appropriate. The thyroid radiation dose depends on the RAIU as well as the biological and effective half-life of the radioiodine in the thyroid gland. This biological half-life can vary widely. Thyroid concentrations toward the upper end of the range (i.e., 7.4 MBq/gm) are especially suitable for patients with nodular goiters, very large toxic diffuse goiters, and repeat therapies.

In much of Europe, empiric rather than calculated dosage strategies are often used (250-800 MBq).

Hyperthyreosis

The ame:

- **to abolish the autonomy, to decrease the volume of the thyroid mass**
- **up to 550 MBq 131-Iodine to outpatients, repeated small doses**
- **medicaments eliminate for 2 days**
- **no pregnancy till 4 months**
- **long-term follow-up will be necessary**
- **it is contraindicated in pregnancy and lactation**

Calculation of the therapeutic dose

- Therapeutic dose = $\frac{3.5 \times \text{thyroid-mass} \times D}{\text{7-day RAIU (\%)}}$

The value of D (focal dose):

- **In Basedow-disease: *70-100 Gy* depend on the size and nodules of the thyroid**
- **Toxic multinodular goiters: *150 Gy***
- **Toxic adenoma: *350 Gy***
- **The fix dose of euthyreoid struma: *500 MBq*, it can be repeated, if necessary**

General guidelines given to patients who are going home may include the following items:

Up to 250 MBq:

- Arrange to have sole use of a bathroom for two days following treatment.
- Avoid public transportation for the first day following treatment.
- Limit personal automobile travel with others to only a few hours per day for the first two days following treatment. Keep as much distance as possible between you and other passengers.
- Sleep in a separate room for the first two nights following treatment.
- Arrange for any pregnant individuals or children less than two years old currently living at your residence to stay at a separate residence for seven days following treatment.
- Avoid close contact with others by maintaining a distance of 1 meter (approximately three feet) for up to three days following treatment.
- Avoid going shopping, to the movies, to restaurants, etc., for the first two days following treatment.

250-550 MBq:

- Every time period is about two times longer.

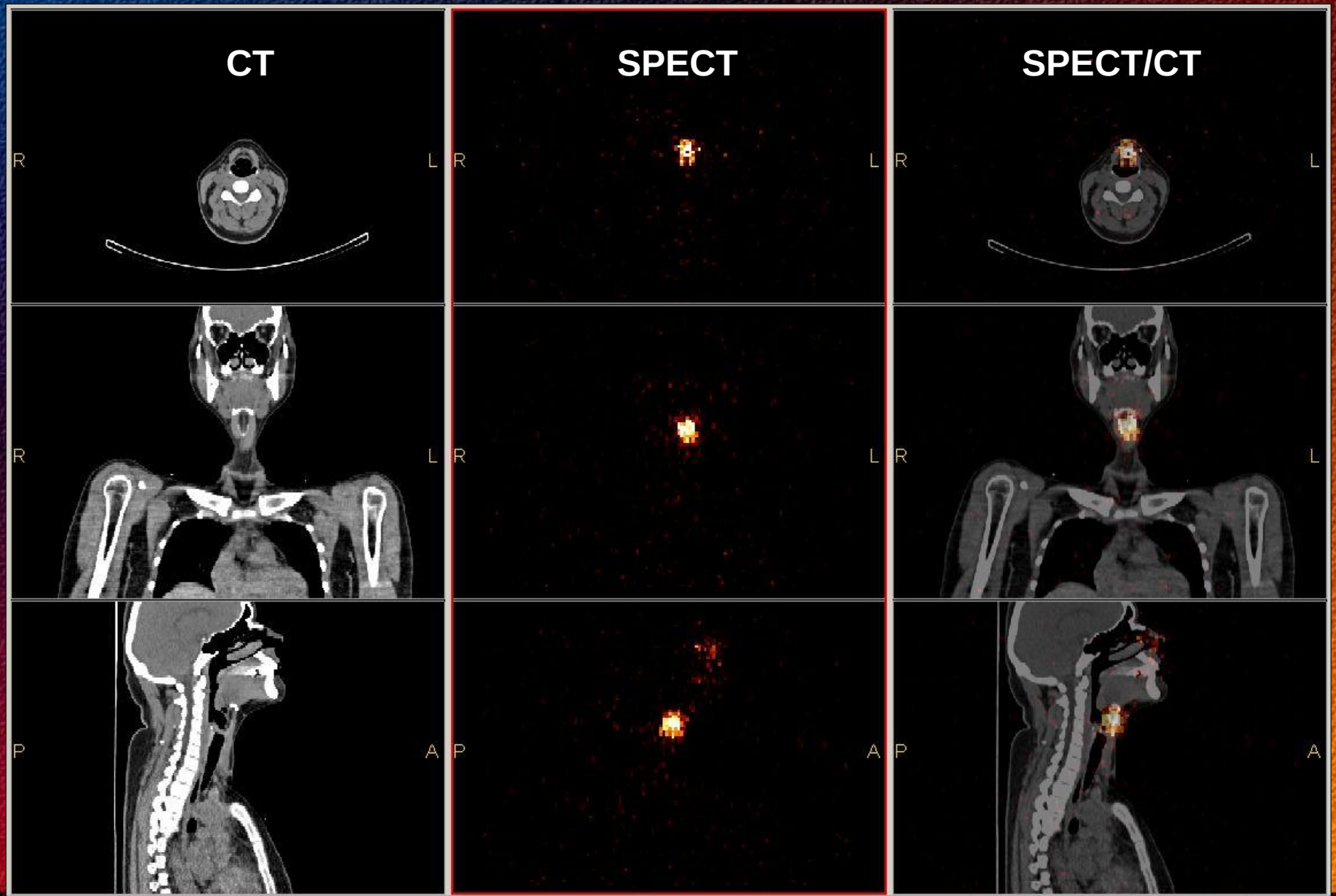
Treatment of thyroid cancers

- Near total or total thyreoidectomy
- Remnant ablation in differenciated cancers by radioiodine (1000 - 3700 MBq)
- TSH supression by L-thyroxin or *recombinant human TSH (alfa-tirotropin) – better life quality!*
- Radioiodine treatment of the lung and bone metastases
- Percutan irradiation in special cases
- Long-life follow up examinations (Tg, calcitonin) and hormone substitution
- Genetical screen in medullary cancer
- Only in hospital (Pécs!)
- Long-life hormonal substitution

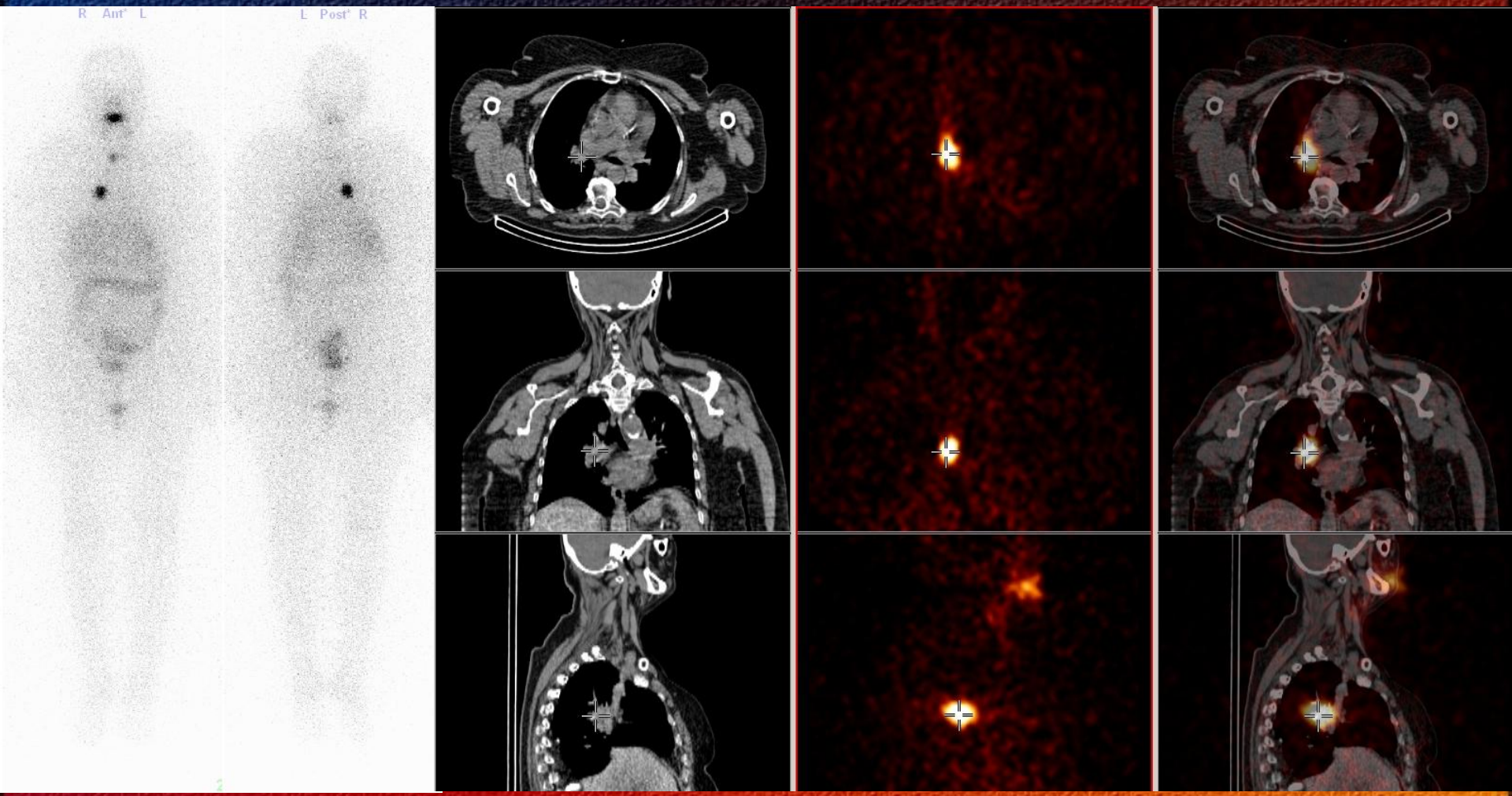
Papillary cancer

Medullary cancer

D. thyreoglossus residuum after high-dose radioiodine therapy

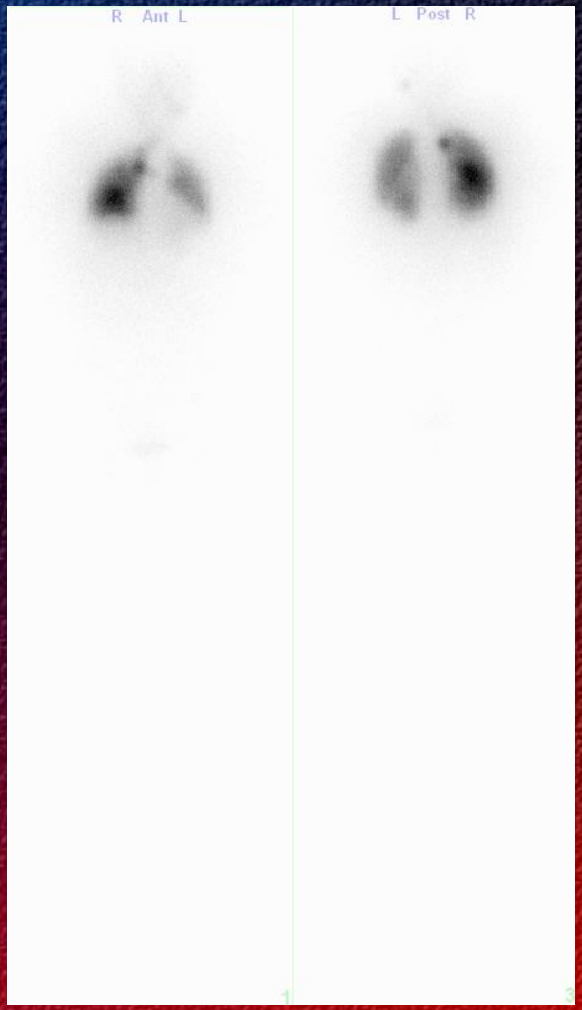


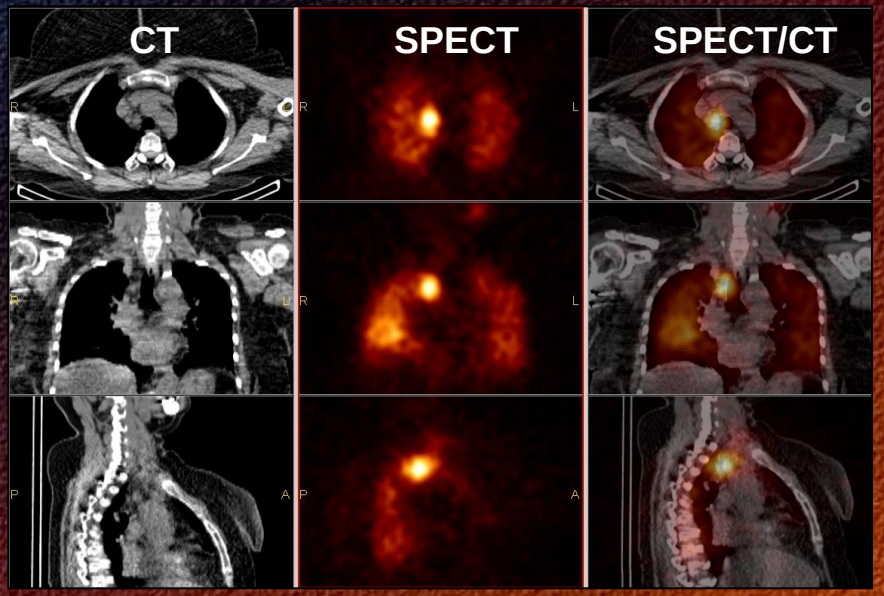
Thyroid remnant + lung metastasis after high-dose radiotherapy of follicular thyroid cancer

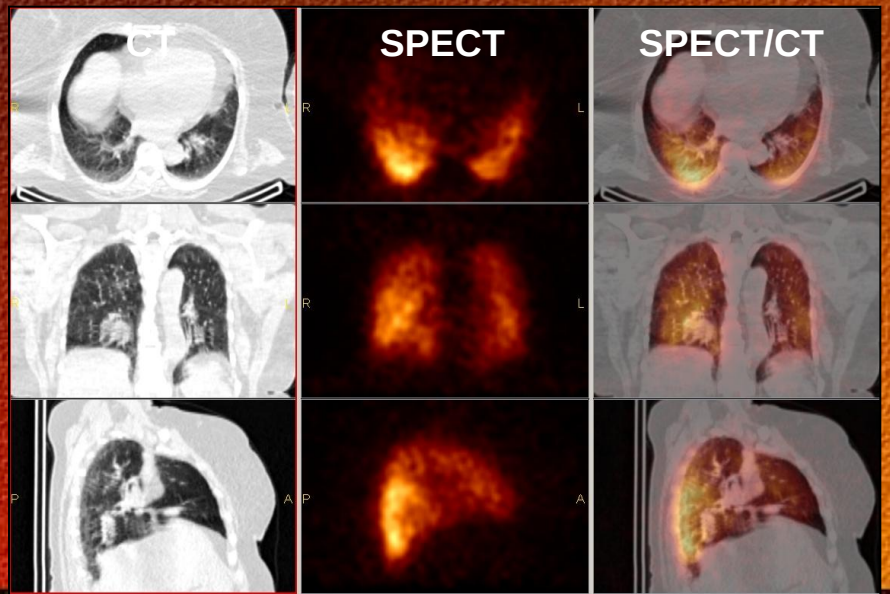


Lymphatic and diffuse lung metastases after high-dose radiotherapy of papillar cancer

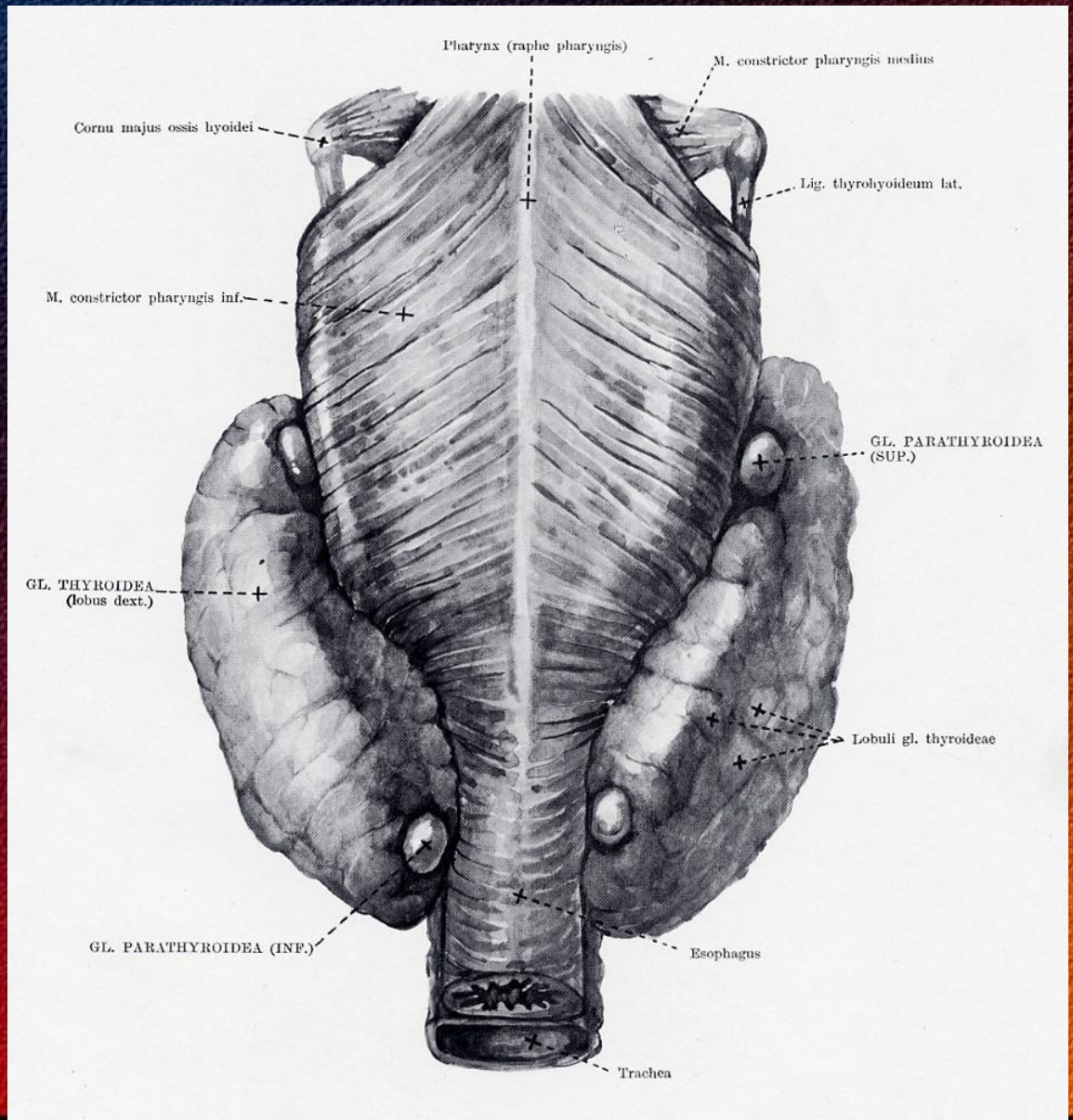
Whole body scan







Parathyroid glands



Parathyroid scintigraphy

- 99mTc-sestamibi allows detection of hyperplastic glands, although with less sensitivity than adenomas.
- Dual-phase or double-phase imaging refers to utilizing 99mTc-sestamibi and acquiring early and delayed images.
- Dual-isotope or subtraction studies refer to protocols using 2 different radio-pharmaceuticals (99m-Tc-pertechnetate) for imaging acquisition.

Pathophysiology

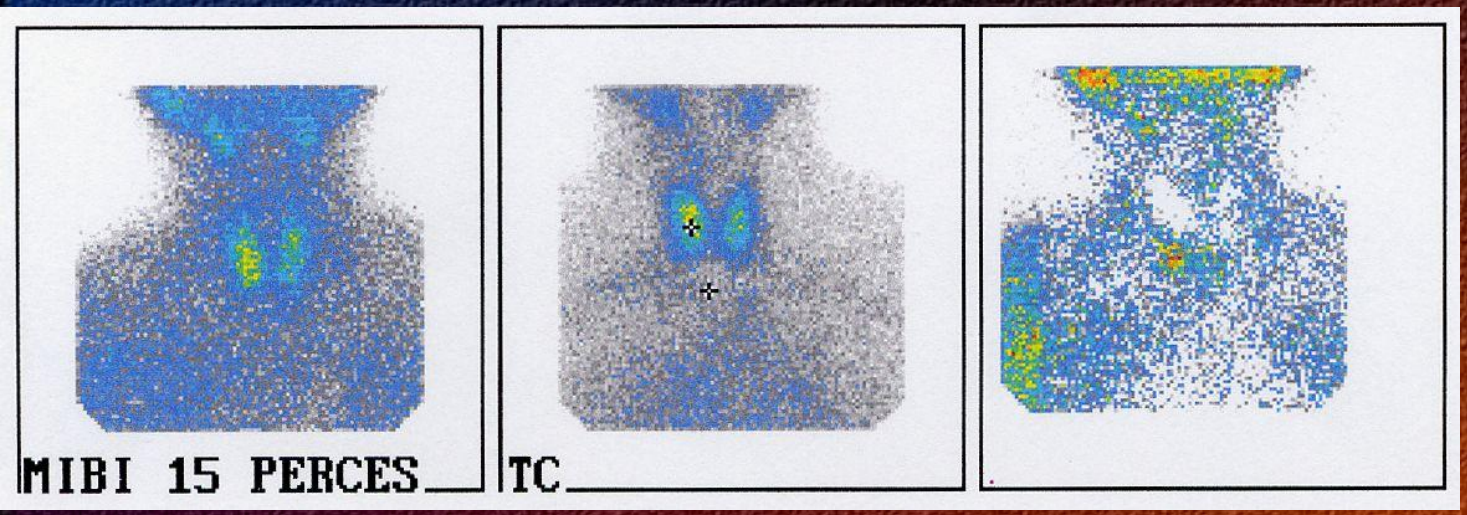
Increased parathormon secretion:

- hyercalcaemia
- increased bone metabolism
- nephrolithiasis
- ulcerativ diseases

Primary: adenoma – unilateral

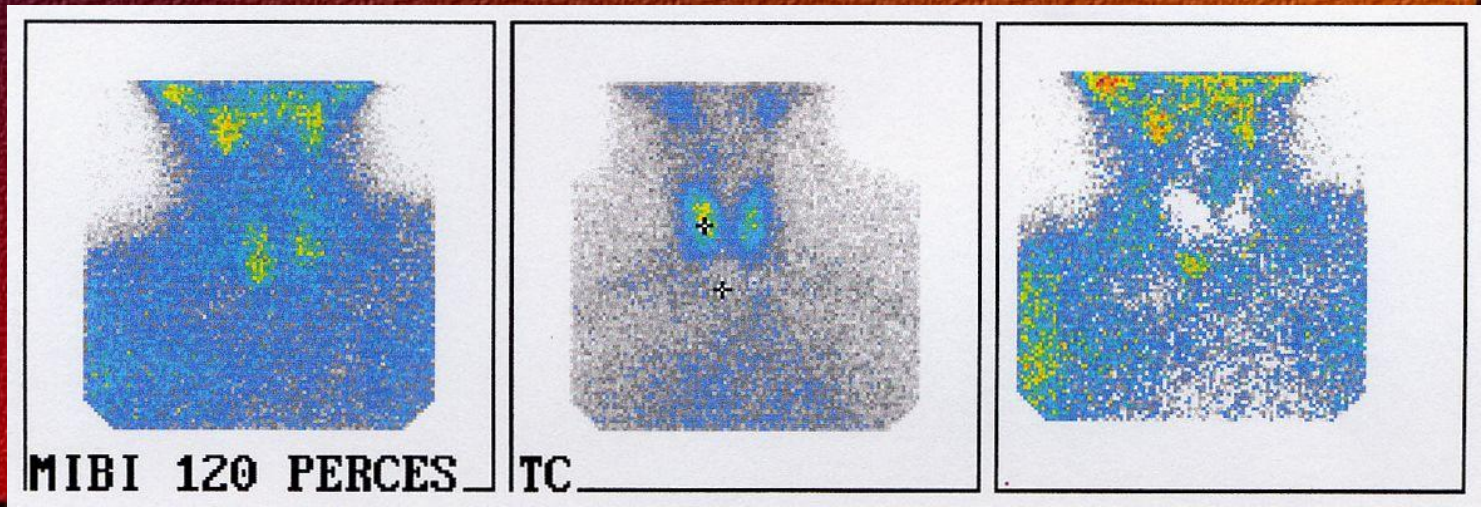
Secunder: hyperplasia – bilateral

Parathyroid adenoma by subtraction „wash-out” technique



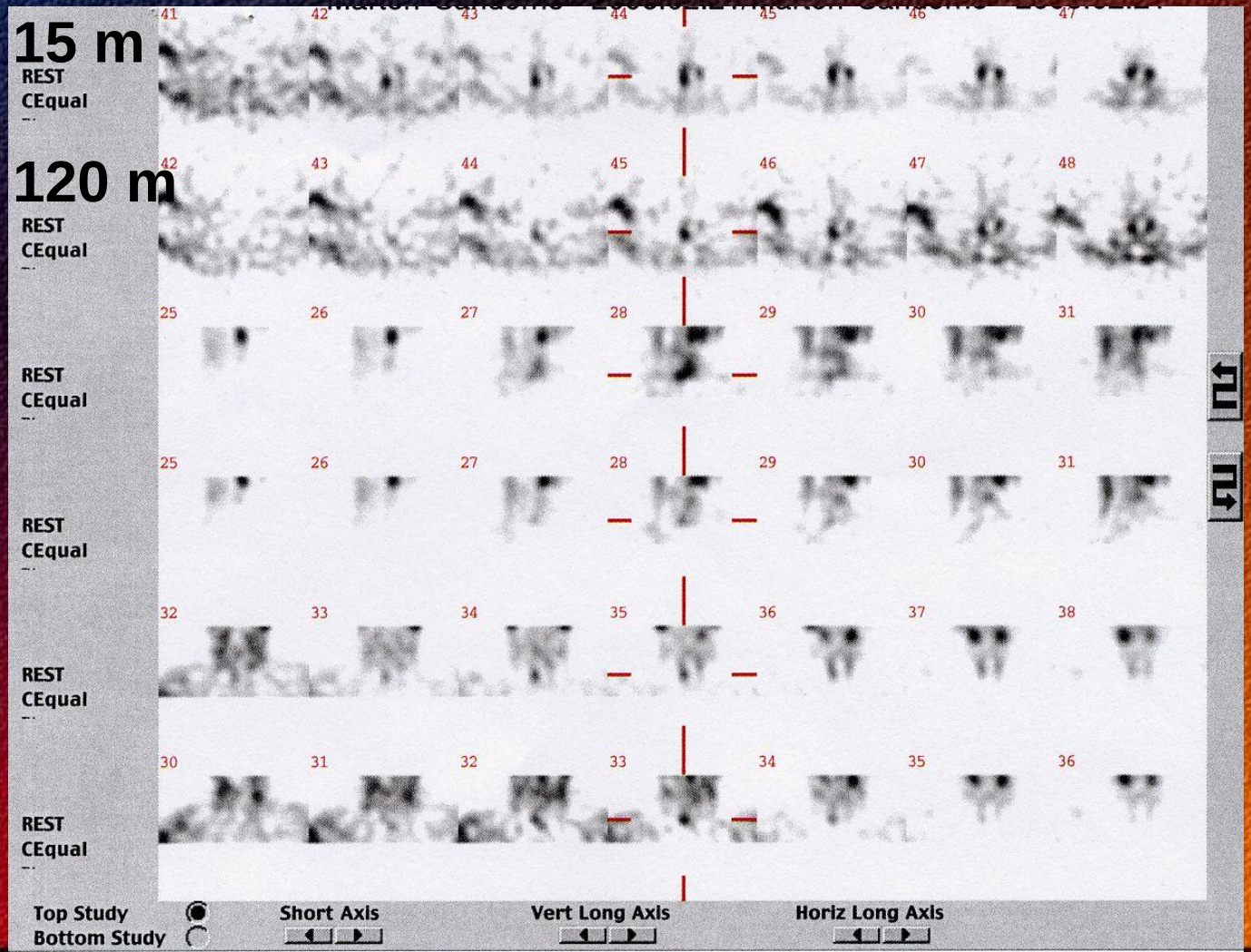
Early phase

Delayed phase

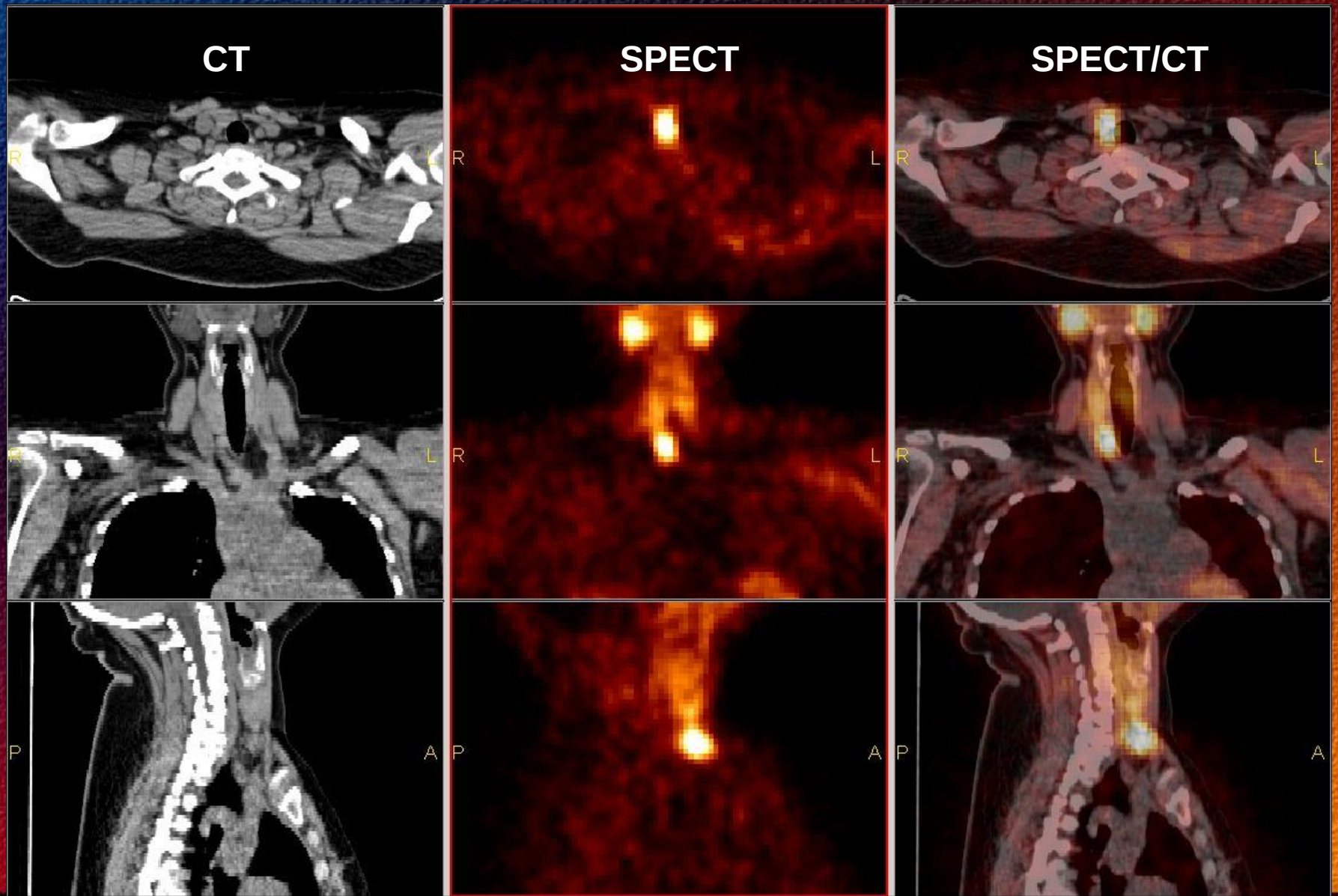


Parathyroid adenoma in the lower part of the right lobe

by early and delayed SPECT imaging

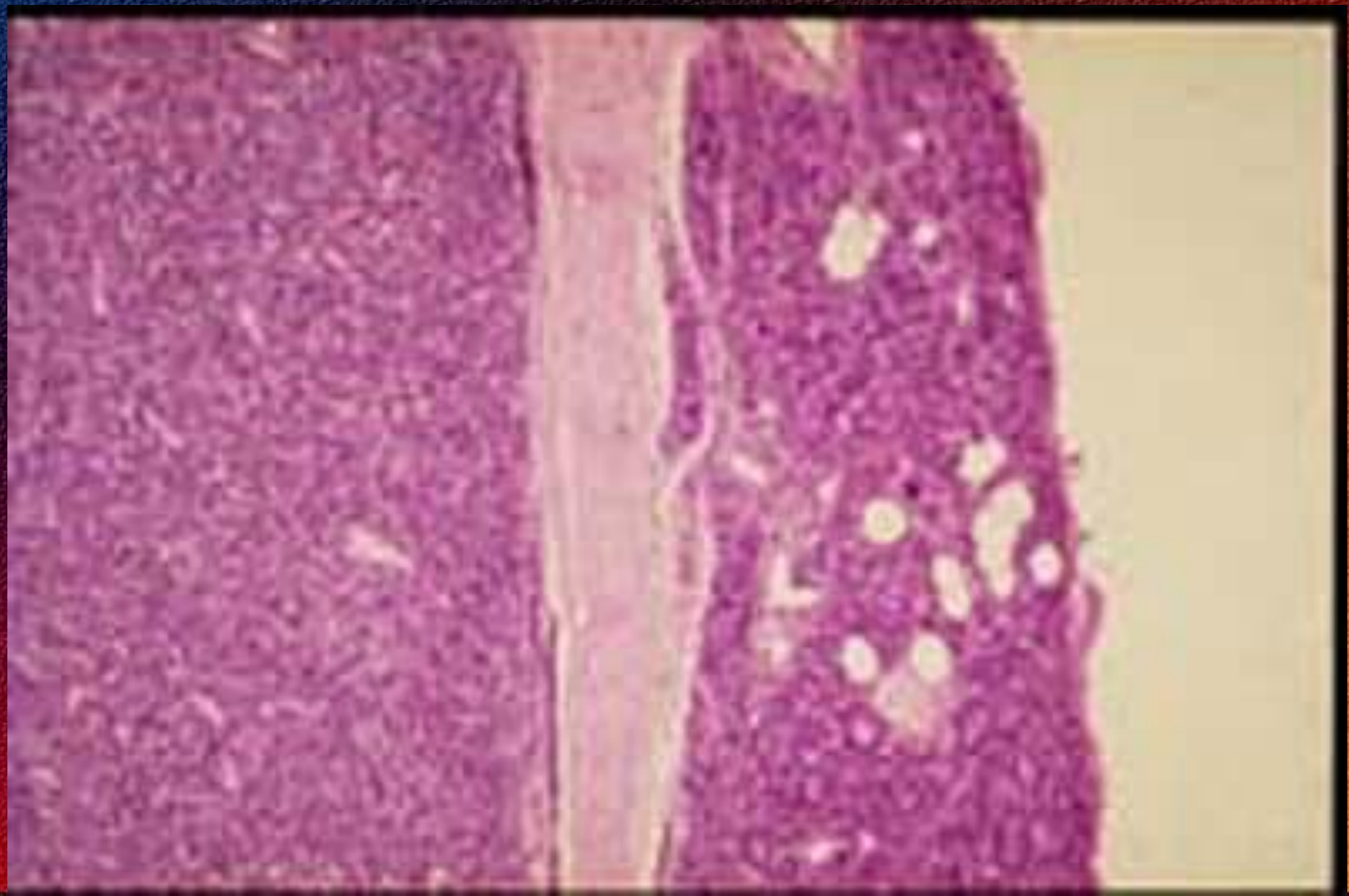


Parathyroid adenoma by SPECT/CT

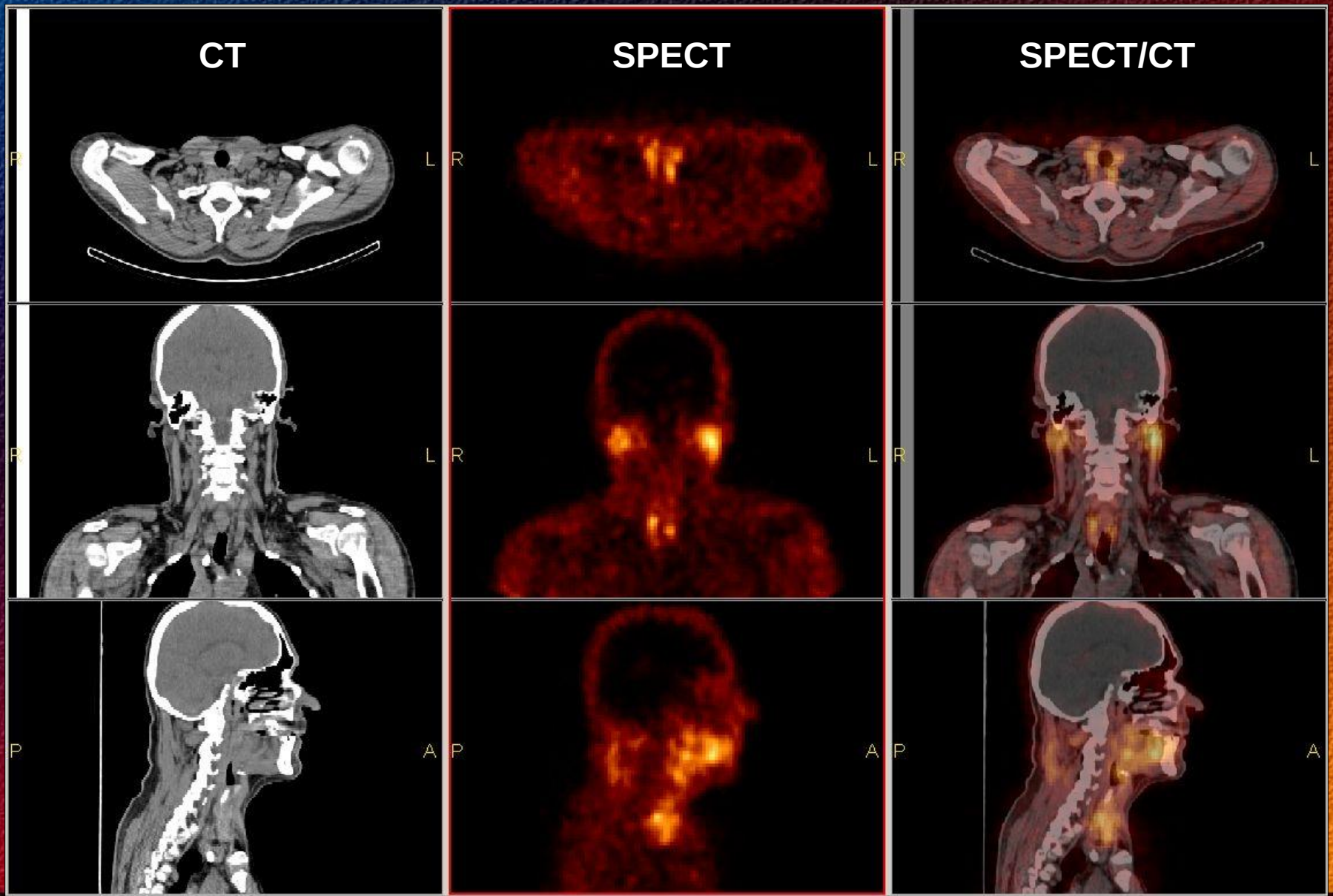


Operative removal of the adenoma

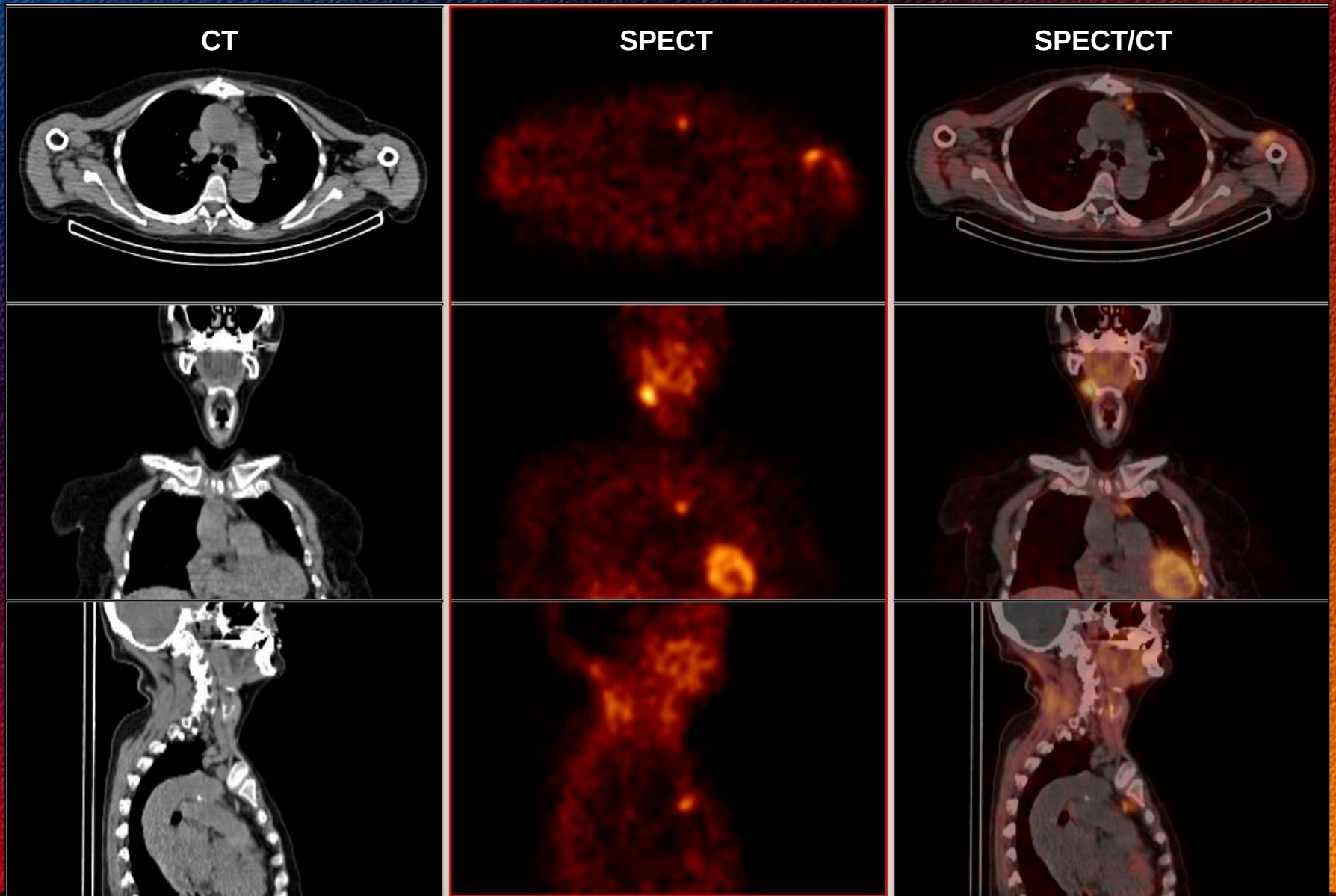
Histology of the adenoma



Multifocal parathyroid adenomas



Recidiv retrosternal parathyroid adenoma after previous surgery



Diffusely increased bone metabolism – no renal uptake


Thank you for your attention!