Nuclear medicine

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Department of Nuclear Medicine

Imaging tehniques

Anatomy — Physiology — Metabolism — Molecular

X-ray / CT

Nuclear medicine / SPECT / PET

MRI

MR spectroscopy

fMRI

Ultrasound

Hybrid imaging: SPECT/CT, PET/CT, PET/MRI

The short history of nuclear medicine

- Discovery of radioactivity (Bequerel 1896)
- Using of radioactive material as a tracer (György Hevesy 1923)
- Development of arteficial radioactivity (Irene Curie és Frederic Joliot Curie 1934)
- Gamma-camera (Anger 1951)

Radioactivity

is the spontaneous desintegration (decay) of the nucleus of a radioactive atom, while the element becomes to an other one.

The hydrogen atom

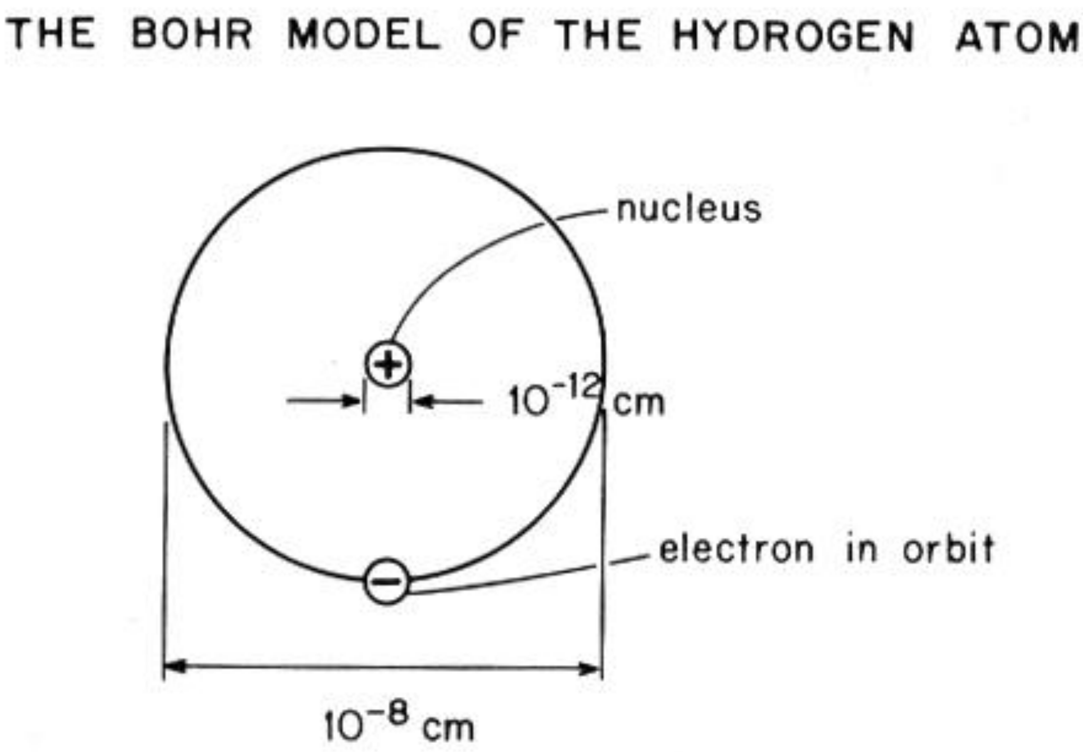


Fig. 1.1. The Bohr model of the hydrogen atom. The central nucleus contains essentially all the atom's mass, and is positively charged. The positive charge is balanced by the negative charge carried by the electron, which in this model circles the nucleus in a fixed orbit.

Sub-atomic particles

Table 1.1. PHYSICAL PROPERTIES OF SUB-ATOMIC PARTICLES

Particle	Electric Charge	Weight		Location
		Grams	a.m.u.	
Proton	+1	1.66×10^{-24}	1.0	Nucleus
Neutron	neutral	1.66×10^{-24}	1.0*	Nucleus
Electron	−1	9.1×10^{-28}	0.00054	Around nucleus

*The neutron is actually 0.08% heavier than the proton.

Number of protons

= elemental identity number

Number of protons and neutrons

= mass number

- ***Atoms with the same number of protons but differing number of neutrons are called isotopes of that element.***
- **The behaviour of the different radioactive isotopes of an element is the same as the stable form in every conditions.**

Radioactive isotopes

Only certain combinations of protons and neutrons are stable, the other ones are radioactive, which become stable form with the emitting different radioactive radiations.

Activity

of a radioactive atom is usually given in desintegrations per second or minute, this is the *dps* or *dpm*.

The unit of the activity

- 1 Bq = 1 disintegration/second
- 1 kBq = 10^3 disintegration/second
- 1 MBq = 10^6 disintegration/second (used in practice)

Measurement

- counts/second (cps) or counts/minute (cpm)

Half-life

is defined as the time required for one-half of the atoms in a group of radioactive atoms to decay.

- Physical half-life is characteristic for an element, independent on the external conditions.
- Biological half-life is depend on the physiological conditions (e.g. increased fluid input).
- Effective half-life: $1/T_{eff} = 1/T_{phys} + 1/T_{biol}$

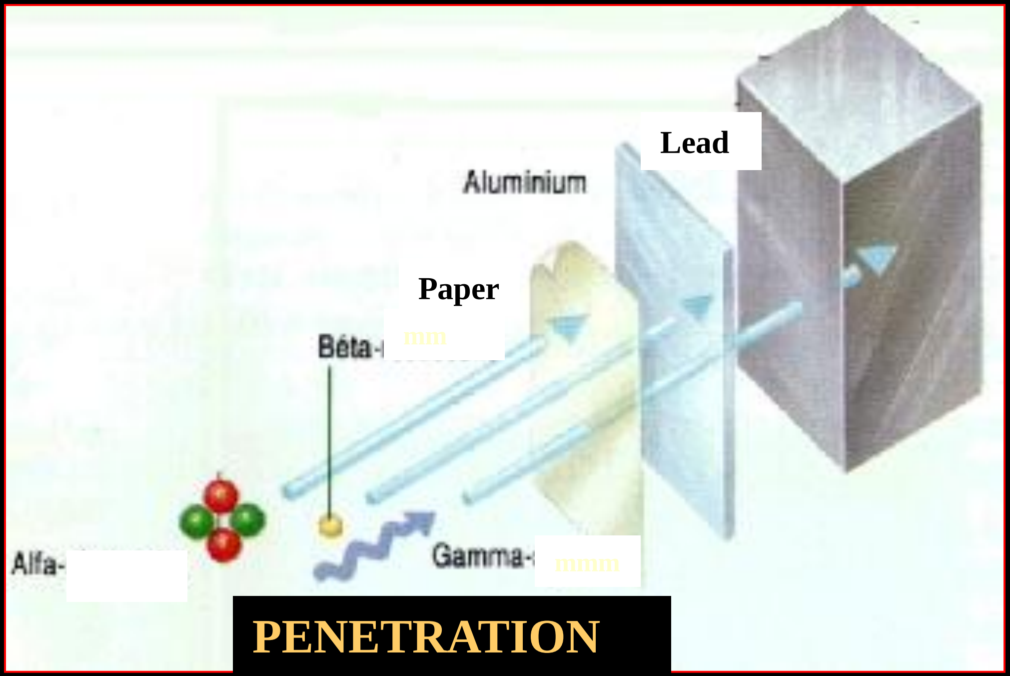
Energy

is emitted during the decay.

Units: eV, keV or MeV (1 eV is extremly small!)

Three kind of the radioactive radiation

1. Corpuscular : alpha
   -beta, +beta (positron)
2. Electromagnetic: gamma



Alpha radiation

- the emission of a helium nucleus (2 protons + 2 neutrons)
- the ionizating property and biological effectivity is great
- range in tissue is a few micrometers
- can not be detected outside!
- e.g. ^{226}Radium for therapy (it is a new trend!)

Beta radiation

- the emission of high-speed electrons
- the biological effectivity is smaller than
  the alpha radiation
- the range in tissue is a few millimeters
- external detection is impossible, too
- the biological damage to tissues is high
- very suitable for radiotherapy
- e.g. ^{131}Iodine for thyroid ablation

Gamma radiation

- really an electromagnetic radiation
- phisically similar to X-rays, but it comes from the nucleus of the atom
- very penetrated and easily pass trough tissue
- it can be detected externally well!
- e.g. 99mTechnetium for the diagnosis

The most commonly used isotopes

Isotope	Radiation	Half-time	Energy
99m-Technetium	γ	6 hours	140 kev
131-iodine	γ	8 days	364 keV
	(β		180 keV)
123-iodine	γ	13.2 hours	159 keV
111-indium	γ	2.8 days	172 keV
201-thallium	γ	3.1 days	76 keV

Equipments I.

Gamma-camera

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

The layout of gamma-camera

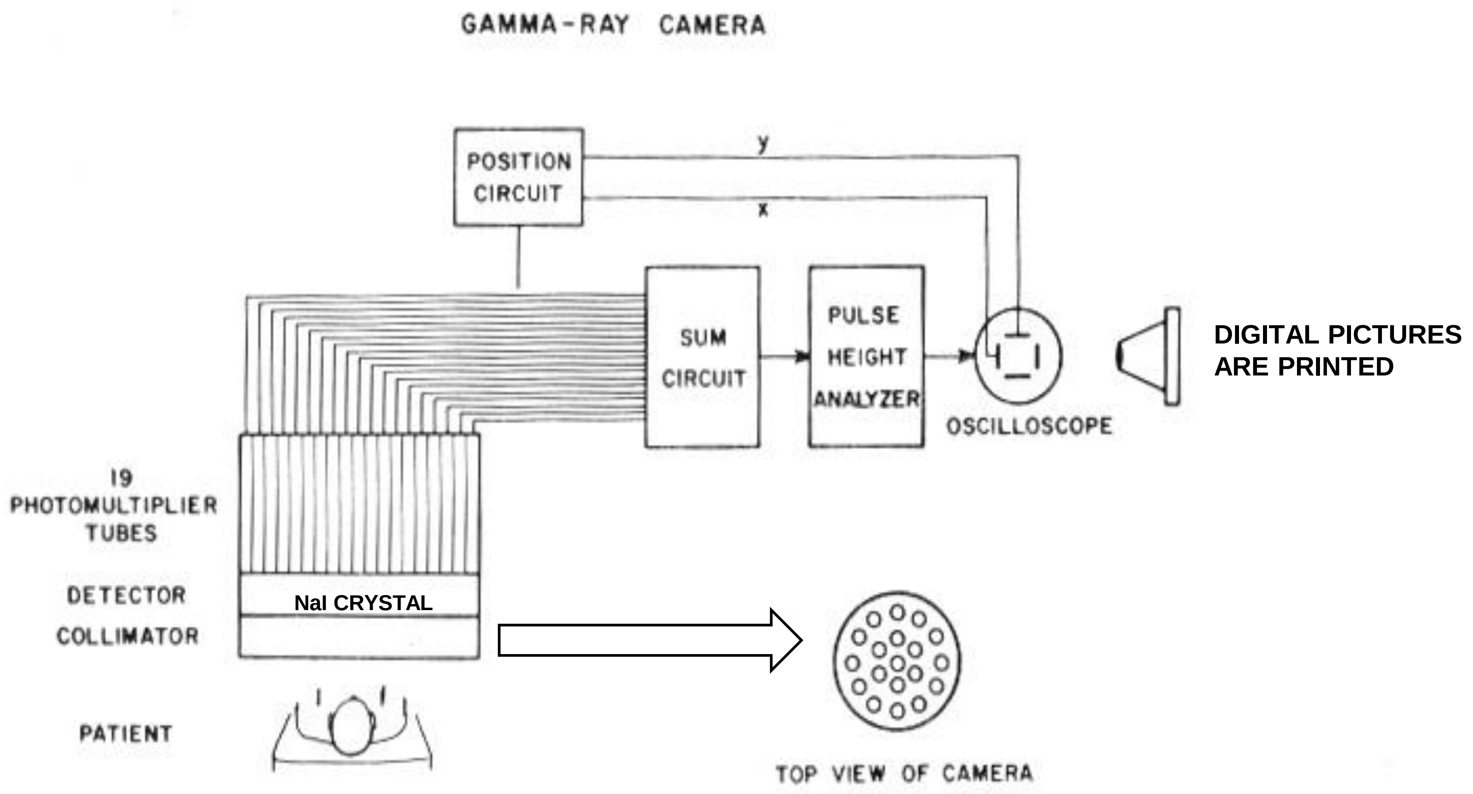


Fig. 1.11. The basic components of an Anger γ-ray camera. There is a one-to-one correspondence between the location of γ-ray interactions in the scintillation crystal and the location of the dot flashed on the oscilloscope screen.

Equipments II.

SPECT

Single Photon Emission

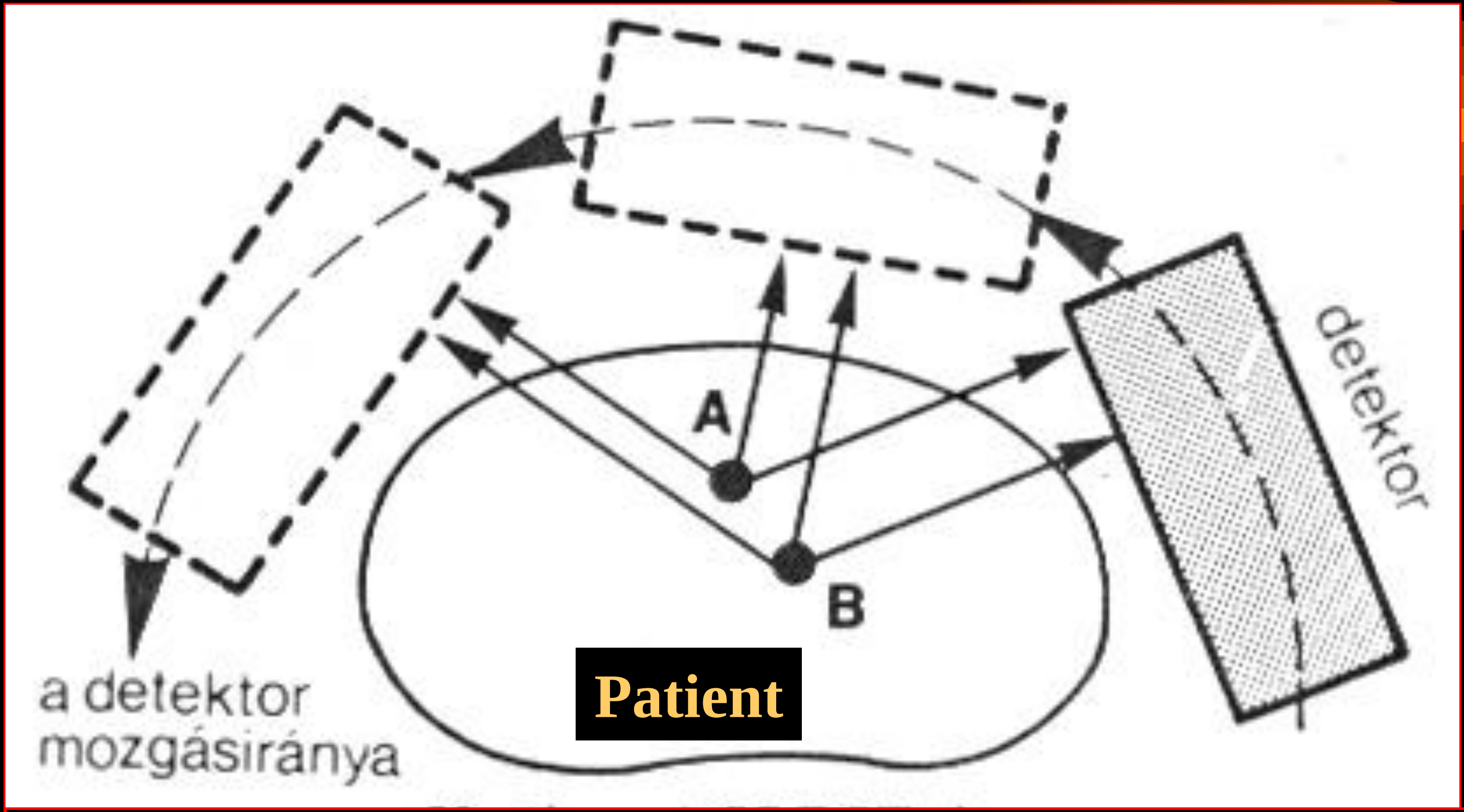
Computer Tomograph

SPECT/CT

Multimodality!

- the computer program reconstruates the transversal, sagittal and coronal slices of the organ + fusion imaging

The principle of the SPECT



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.

+Beta (positron) radiation

– too many protons are in the nucleus

– its life is very short, when it slows down, it combines with a normal electron in a process known annihilation, which destroyes both electron and positron and produces two energetic gamma photons each with 511 keV

– isotopes with ultrashort half-life (11C, 15O, 13N, 18F) are used for PET examinations

– the metabolic changes of the tumors, the brain and the heart can be examined

– e.g. 18Fluor-FDG shows the increased glucose metabolism of the tumors

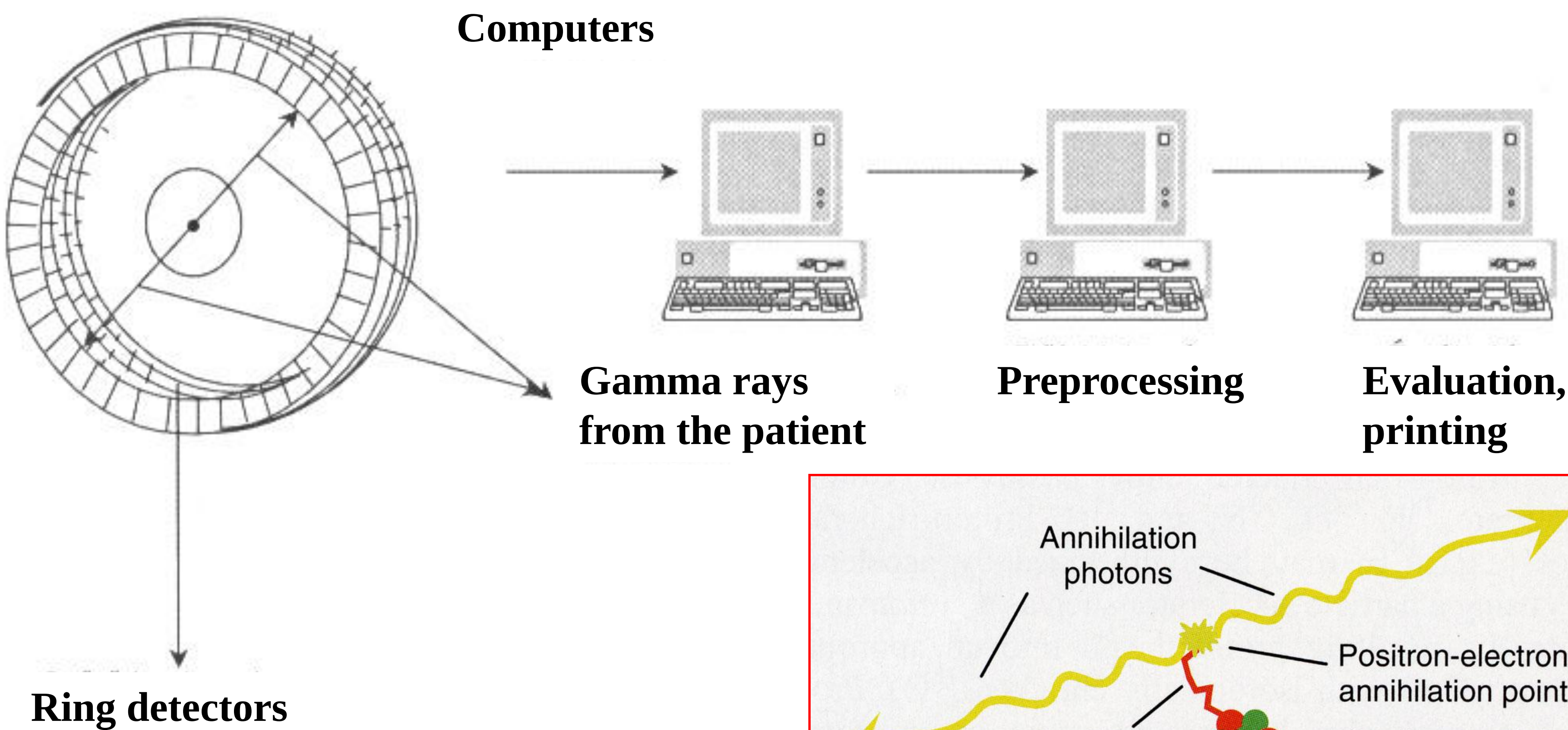
Equipments III.

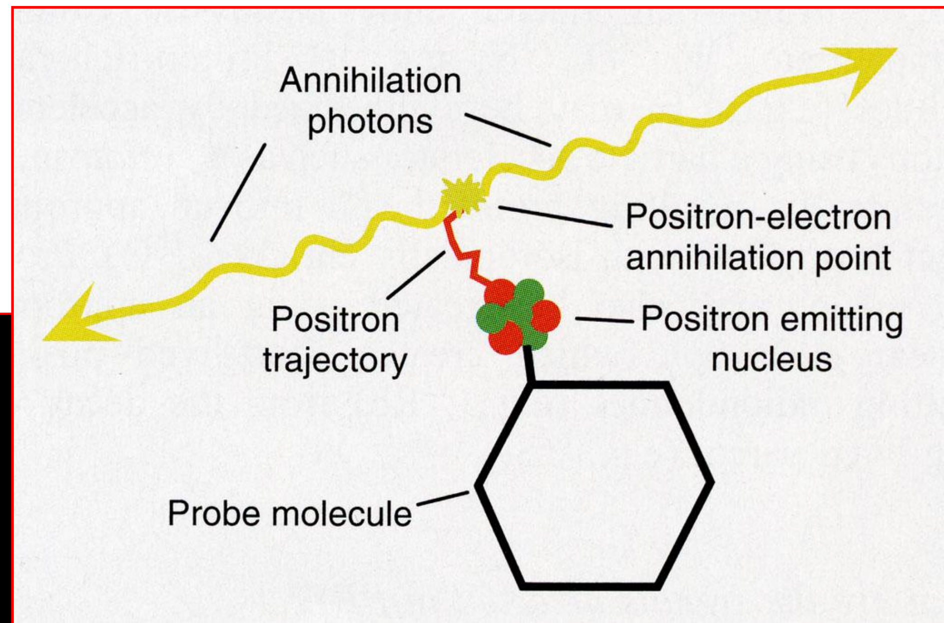
PET: Positron Emission Tomograph

PET/CT: multimodality!

Multiplex bone metastases by FDG

The principle of the PET





Radiation exposure

- principle of ALARA (as low as reasonable achieveble) both the patients and the staff
- correct indication of the examination!
- examination of pregnant women is contraindicated
- children should be examined carefully

Scintigraphies need

- gamma radiating isotope is detected by outside
- carrier molecule is participating in the examined function of the organs
- together is radiofarmaceutical
- administered in sterile intravenous NaCl injection
- delayed times are different before the examinations
- imaging by scintillation detector

In vivo radionuclide studies

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

The types of the examinations

Static examinations (scintigraphy):

- an optimal time-period after the subject administration is delayed and several photos are made of the organ from different directions

Dynamic studies:

- a frame-serie is stored in the computer from the time of the isotope injection during an optimal time-period of the examined organ function

Static examinations

- **Thyroid** with 99mTc-pertechnetate
- **Lung** with MAA (big particulums of HSA)
- **Bone** with MDP (methyl-diphosphonate)
- **Bone marrow** with Nanoalbumon (small particulated colloid)
- **Liver and spleen** with Fyton (big particulated colloid)
- **Kidney** with DMSA (dimercapto-succinate)
- **Brain** with DTPA (diethylen-triamine-pentaacetate)

Dynamic studies

- **Hepatobiliary scintigraphy**

  Measurment of the hepatobiliary function from the blood through the liver to the bowels

- **Camera-renography**

  Measurment of the renal function from the blood through the kidneys to the bladder

- **Perfusion studies**

  Measurment of the perfusion of the several organs with fast excreted radio-pharmaceuticals through the kidneys

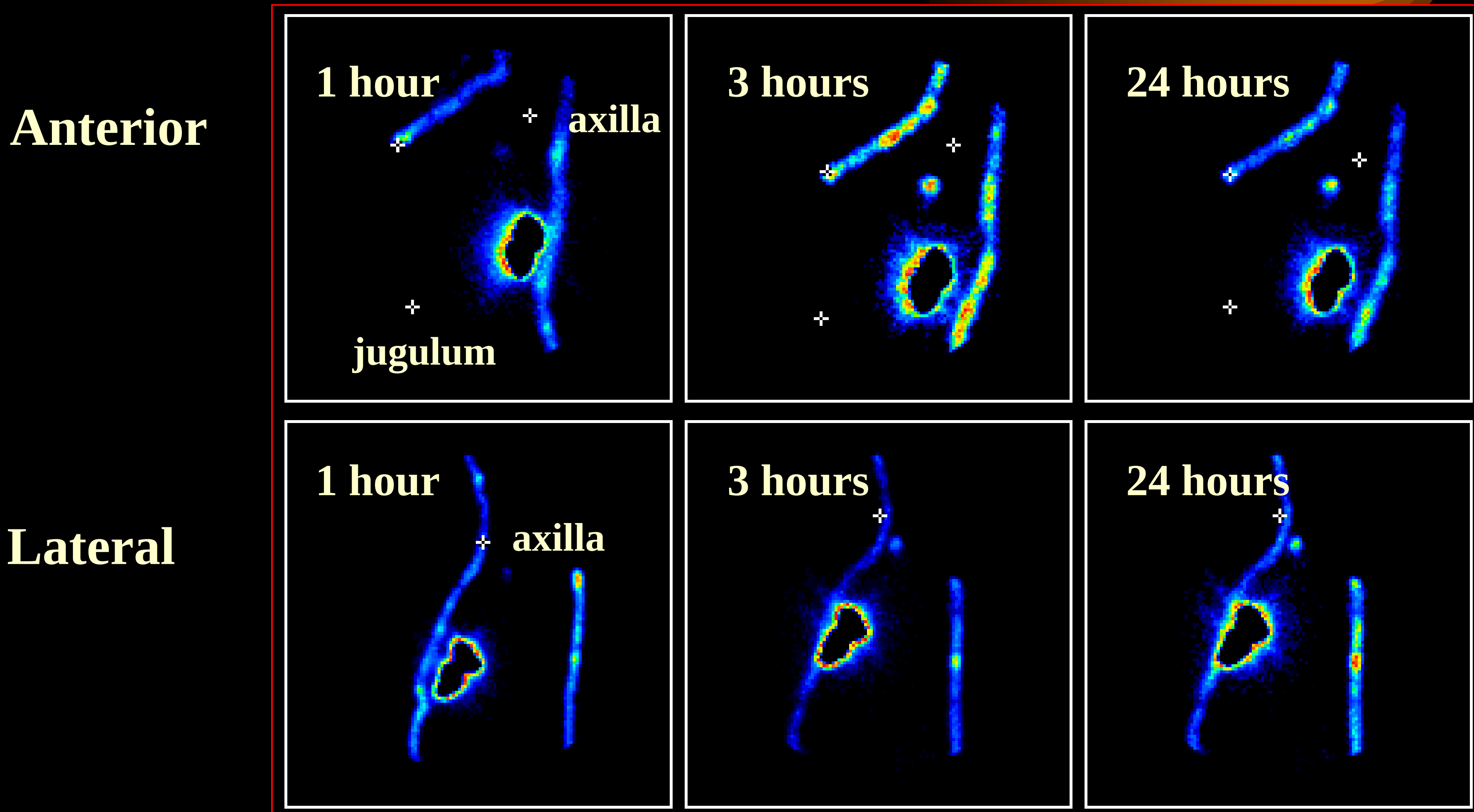
Nuclear oncology

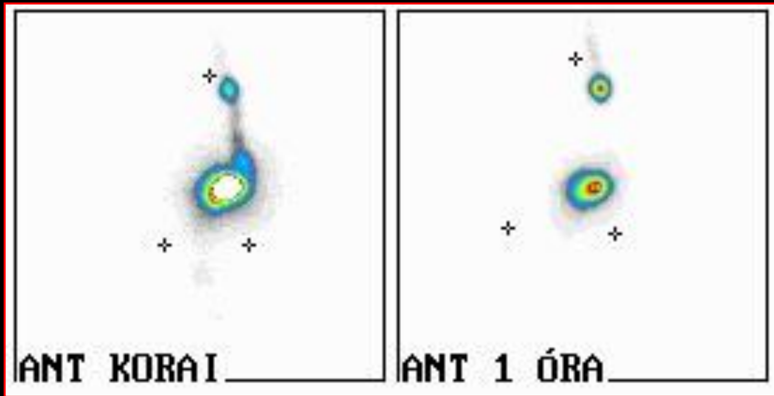
- Sentinel lymph node examination by human serum albumin (99mTc-Sentiscint)
- Neuroendocrine receptor study by 123I- or 131I-MIBG (pheochromocytoma, neuroblastoma)
- Somatostatin receptor study by 111In-octreotide or 99mTc-depreotide (carcinoid tumors, small cell lung cancer, medullary thyroid cancer)

Sentinel lymph node examination

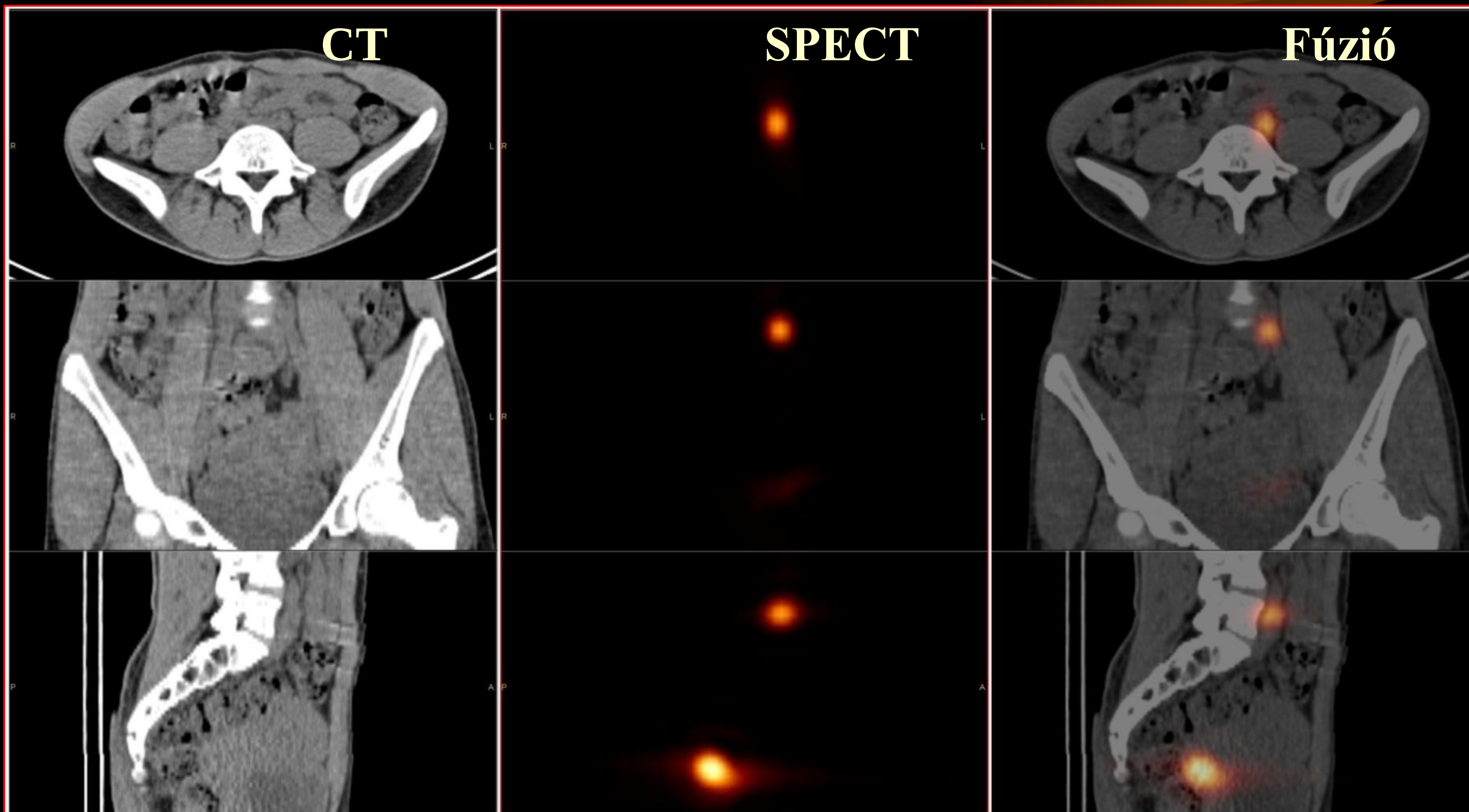
- **Indications:** - mamma cancer
  - melanoma malignum
  - vulvar and penis malignancies
- **Method:** - peritumoral injections by 4x15 MBq (4x0.2 ml) HSA colloid (99mTc-Sentiscint)
  - static images from the lymph nodes 1, 3 és 24 hours after the injection
  - the sentinel lymph nodes are marked on the skin, the operation is on the following day with help of *intraoperative gamma-probe*

Sentinel lymph node scintigraphy in breast cancer in the left side





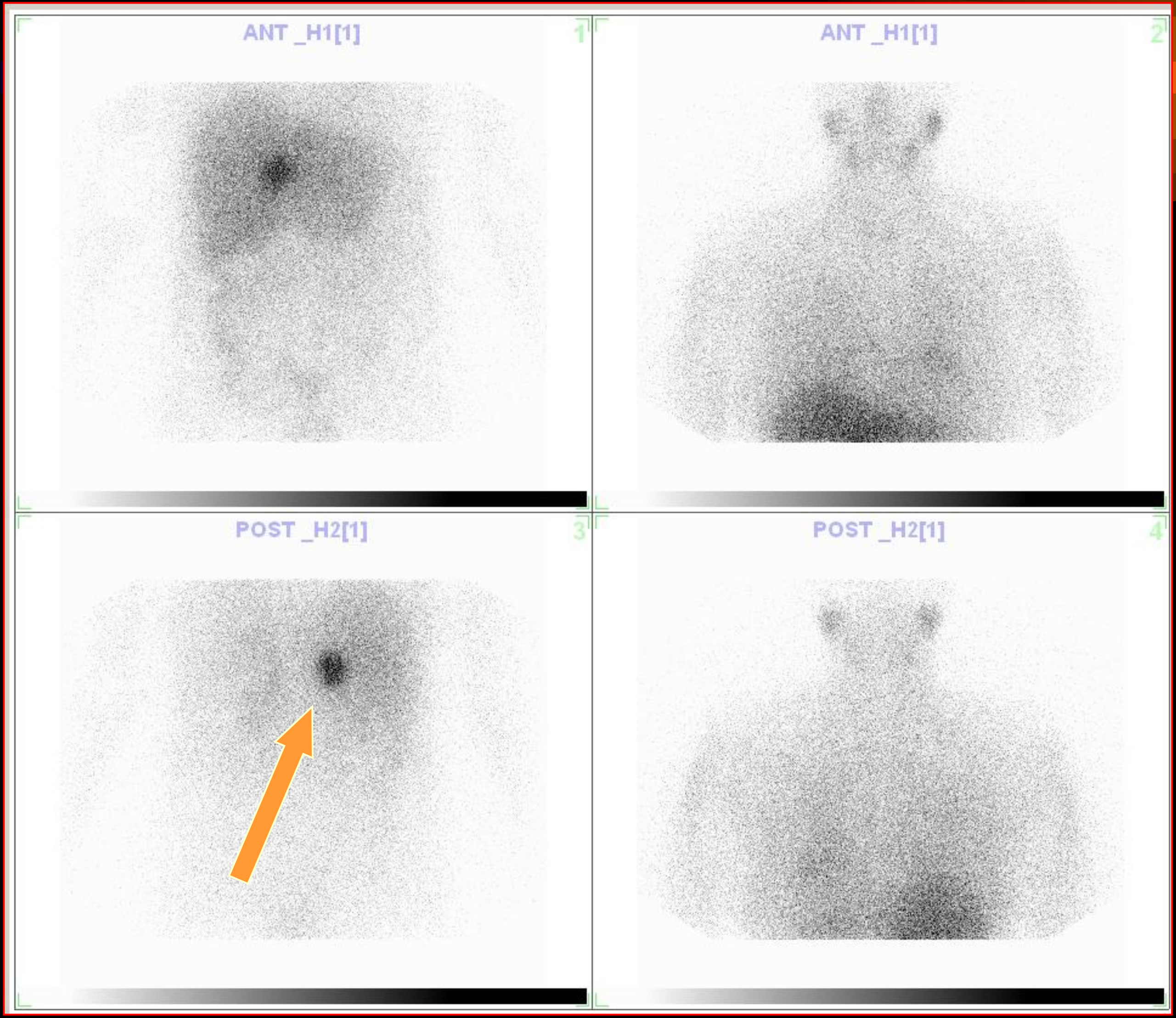
Sentinel lymph node scintigraphy in adenocc cervicis uteri in the left parailiacalis region



Adrenerg receptor scintigraphy

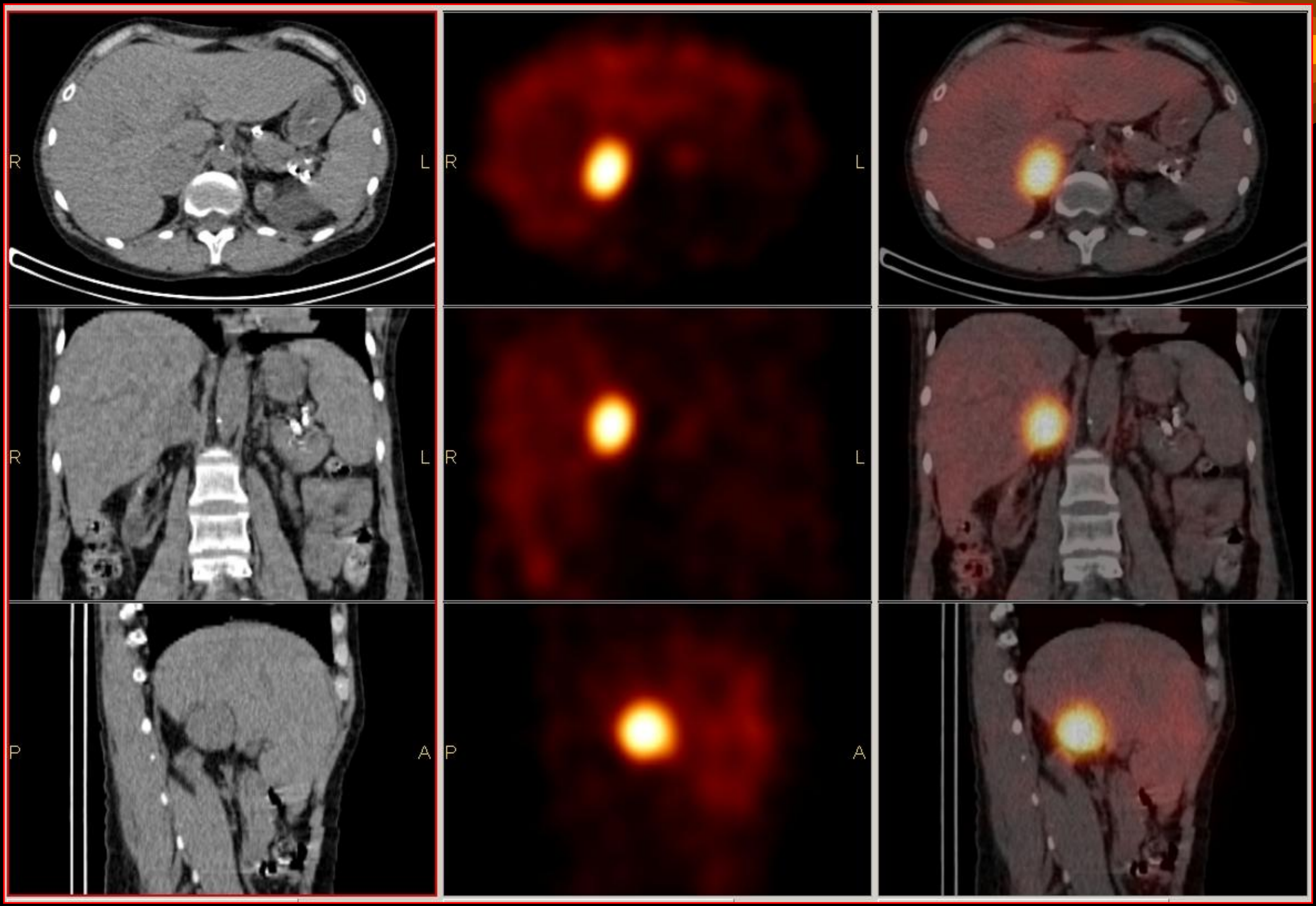
- **Injected subject:** 185 MBq 123-iodine-MIBG (metaiodobenzyl-guanidine) is binding to adrenerg receptors of the tumor-cells
- **Imaging time:** 6 és 24 hours after the intravenous injection (SPECT/CT imaging!)
- **Indications:** - neuroendocrine tumors
  - pheochromocytoma
  - neuroblastoma

Phaeochromocytoma in the right adrenal gland

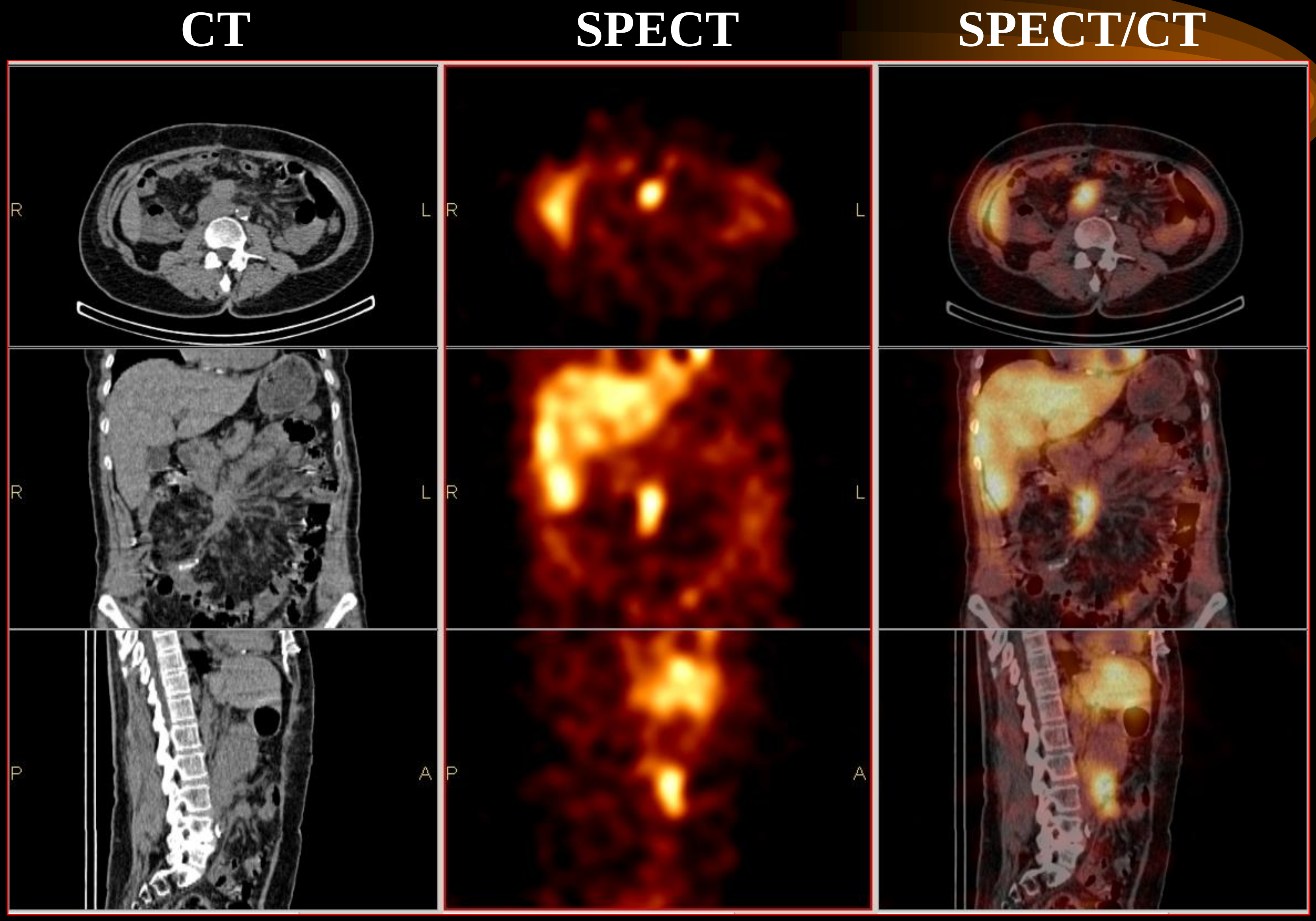


Phaeochromocytoma in the right adrenal gland by SPECT/CT

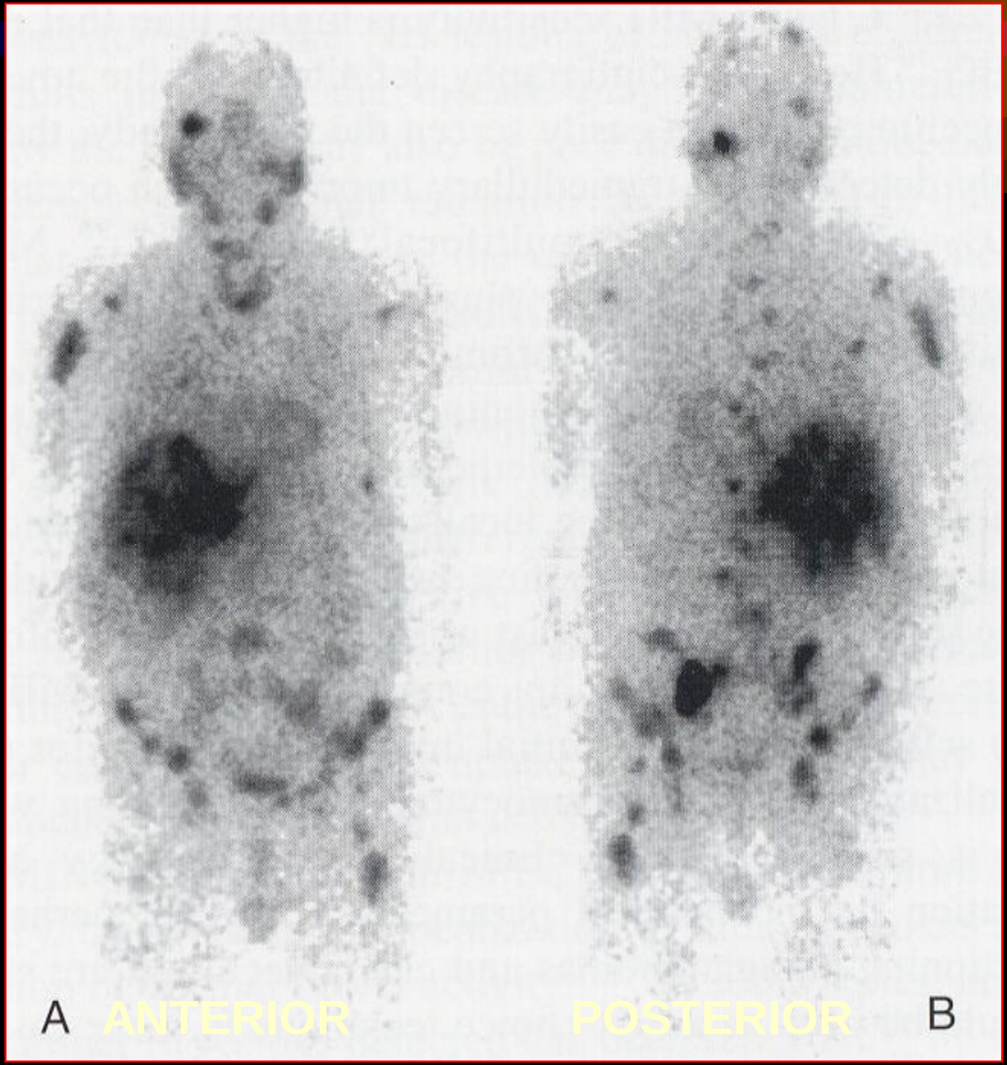
CT **SPECT** **SPECT/CT**



Metastases in retroperitoneal lymph nodes after operation of small intestine NET



Multiplex 123-iodine-MIBG cumulation in malignant pheochromocytoma

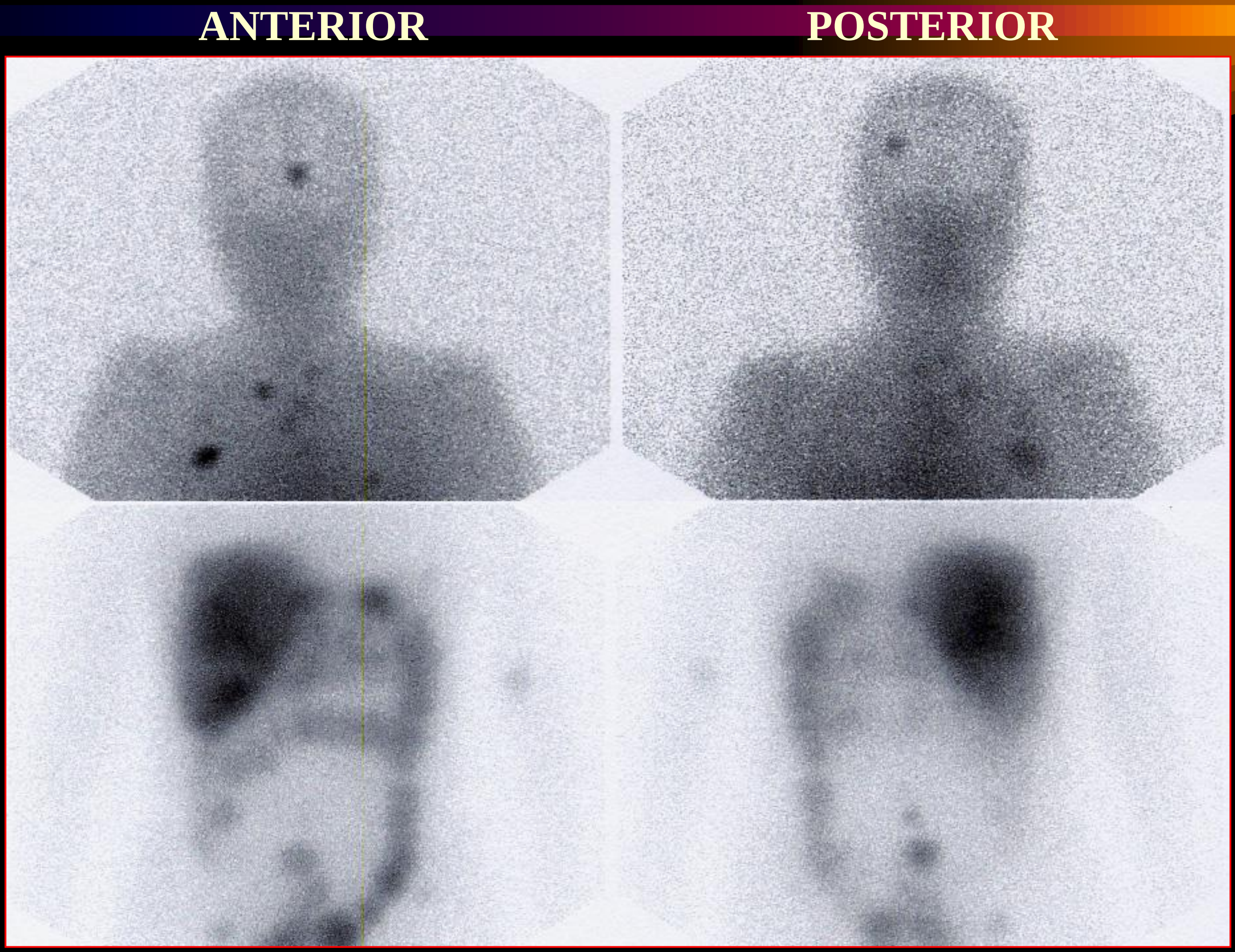


Somatostatin receptor scintigraphy

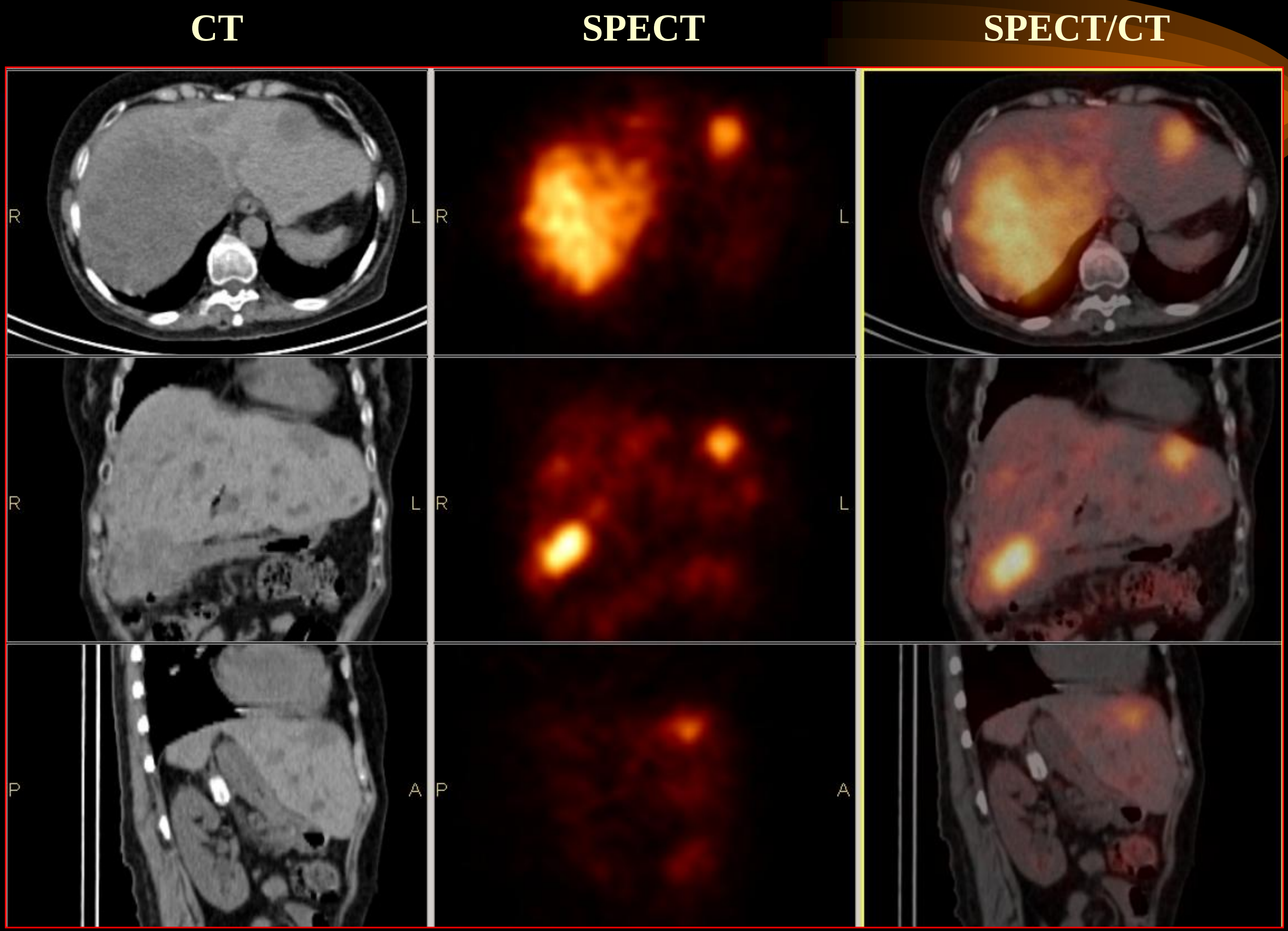
- **Injected subject:** 122 MBq 111-Indium-pentetreotide
  or 740 MBq 99m-Tc-depreotide
  (somatostatin analog peptids are binding to the receptors overexpressed on the surface of tumor cells)
- **Imaging time:** - 99m-Tc on the same day 2 hours later
  - 111-In 24 and 48 hours
  after the intravenous injection (SPECT/CT imaging!)
- **Indications:** - carcinoid és GEP tumors
  - small cell lung cancer
  - medullary thyroid cancer

St. p. pancreas head carcinoid operation, metastases?

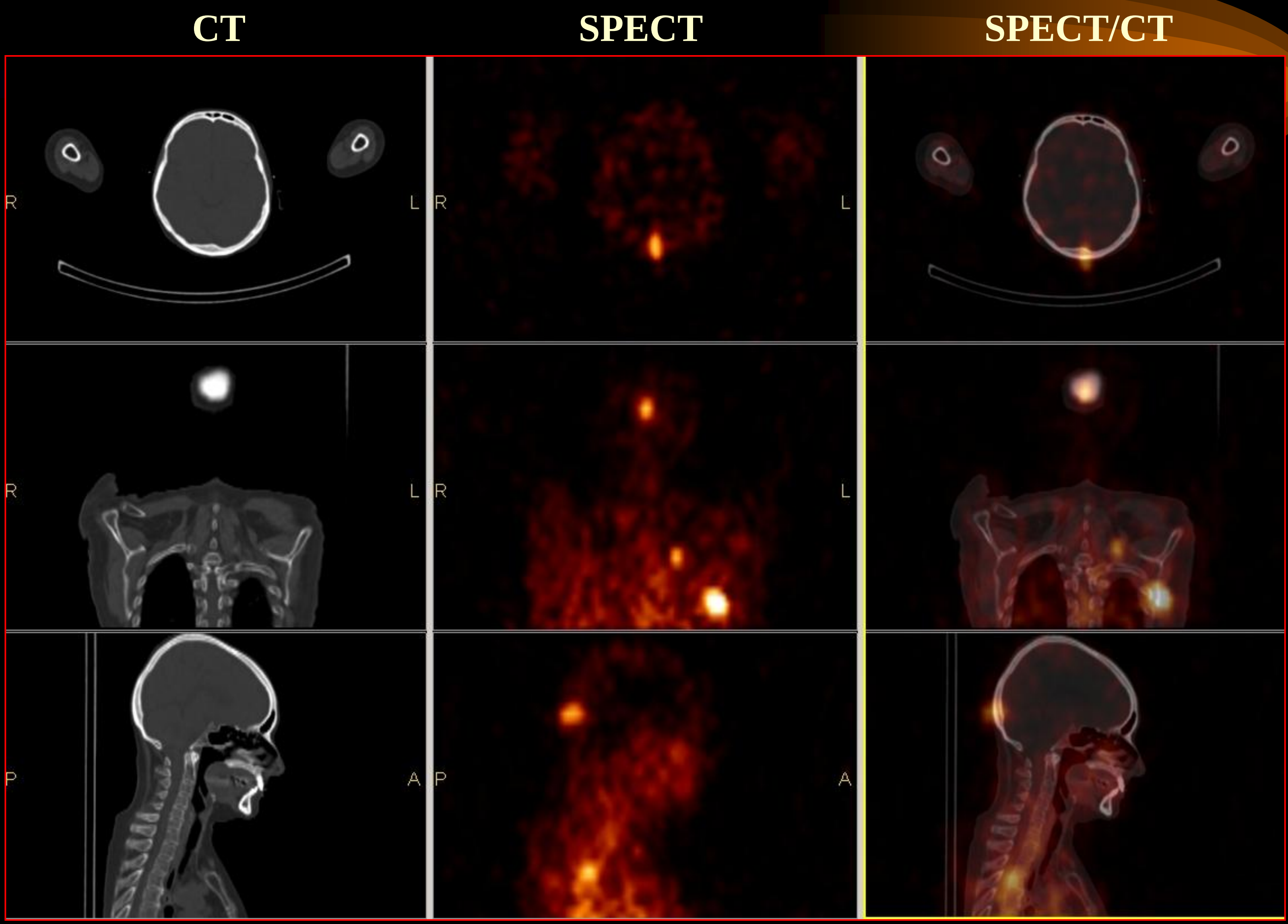
111In-Octreoscan-study



Multiplex liver metastases of carcinoid



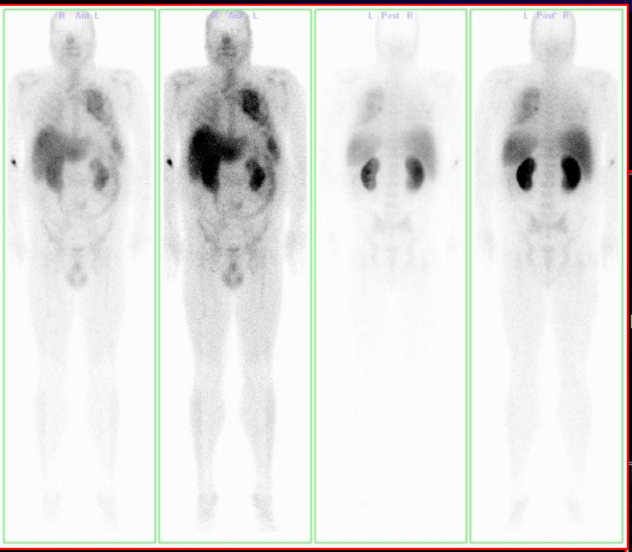
Multiplex bone metastases of carcinoid



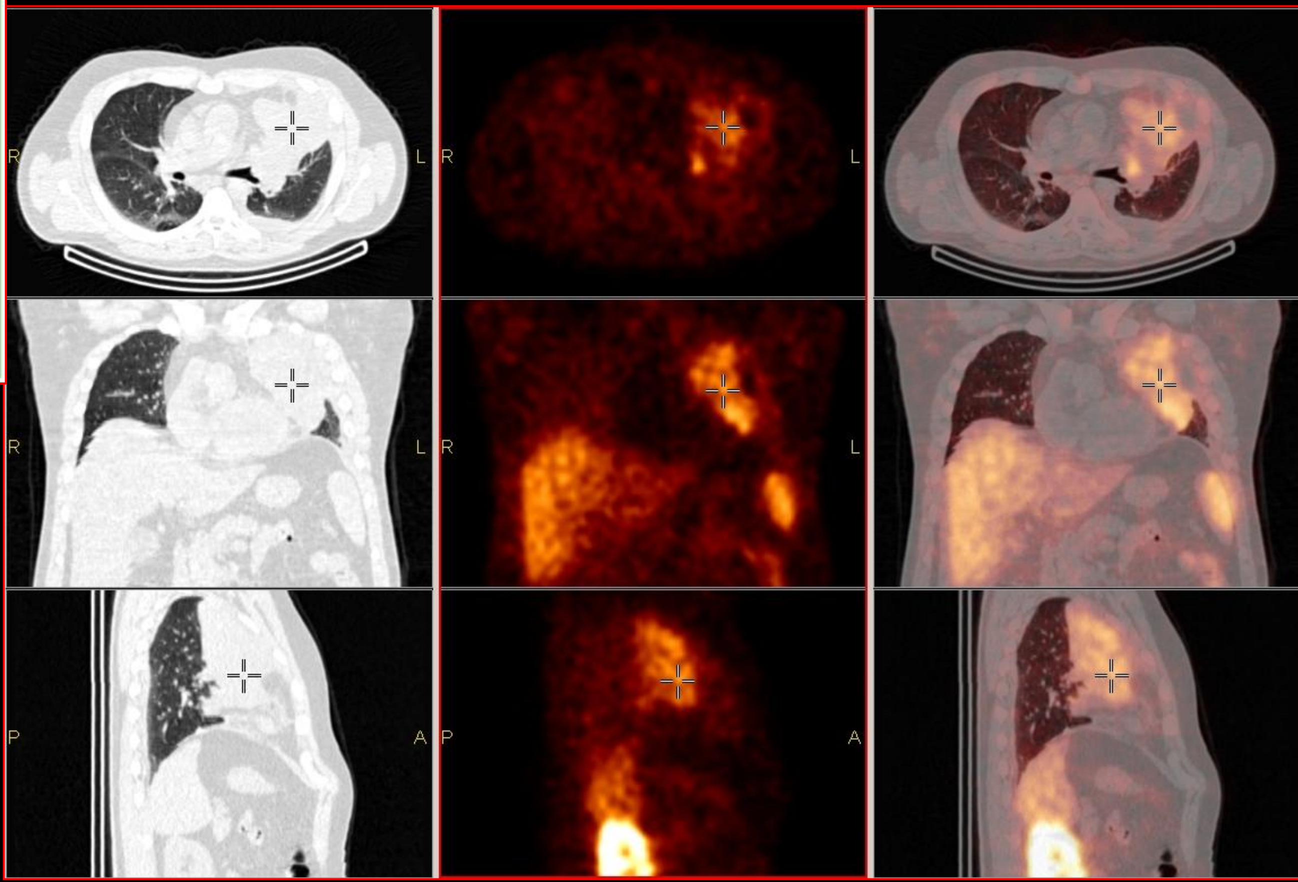
Carcinoid in the left lung?

99mTc-Neospect examination

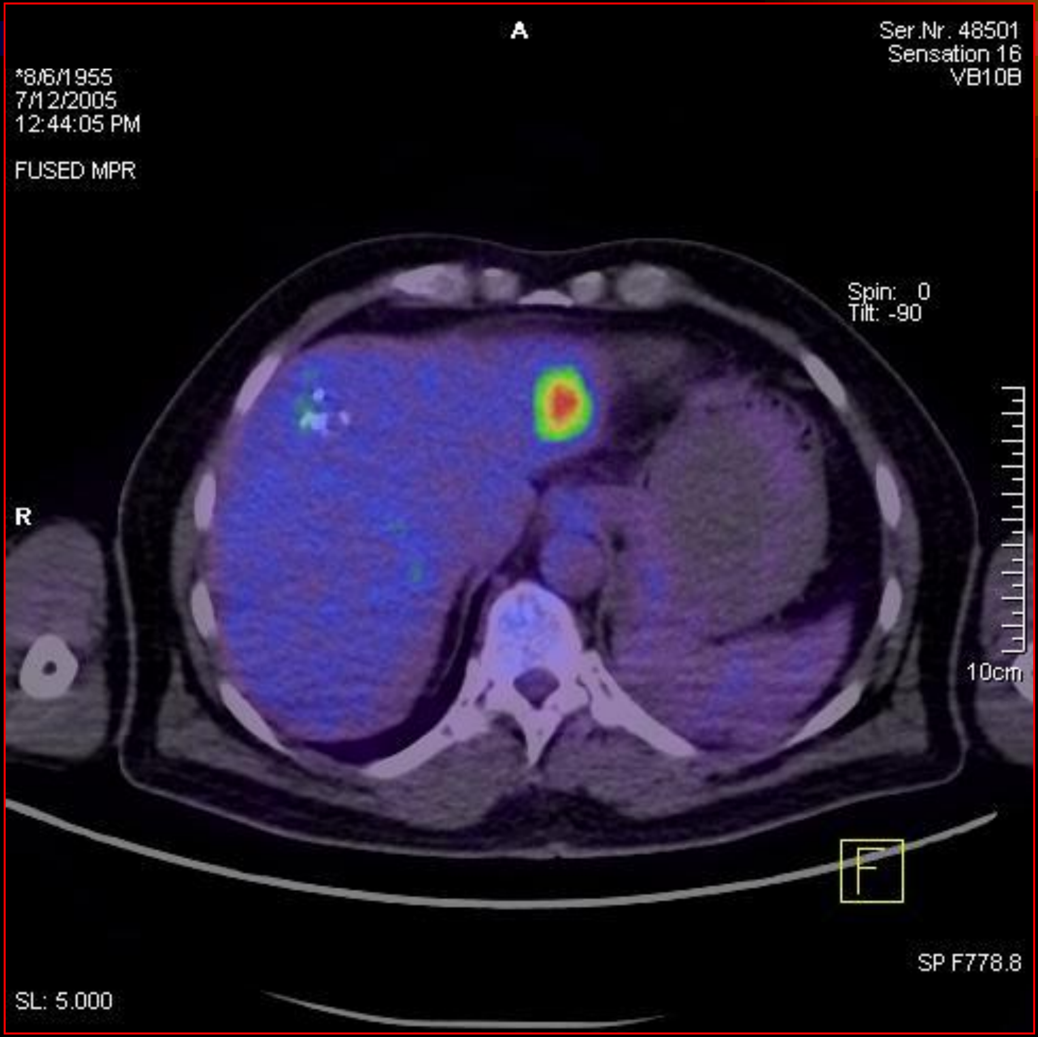
Whole body scan



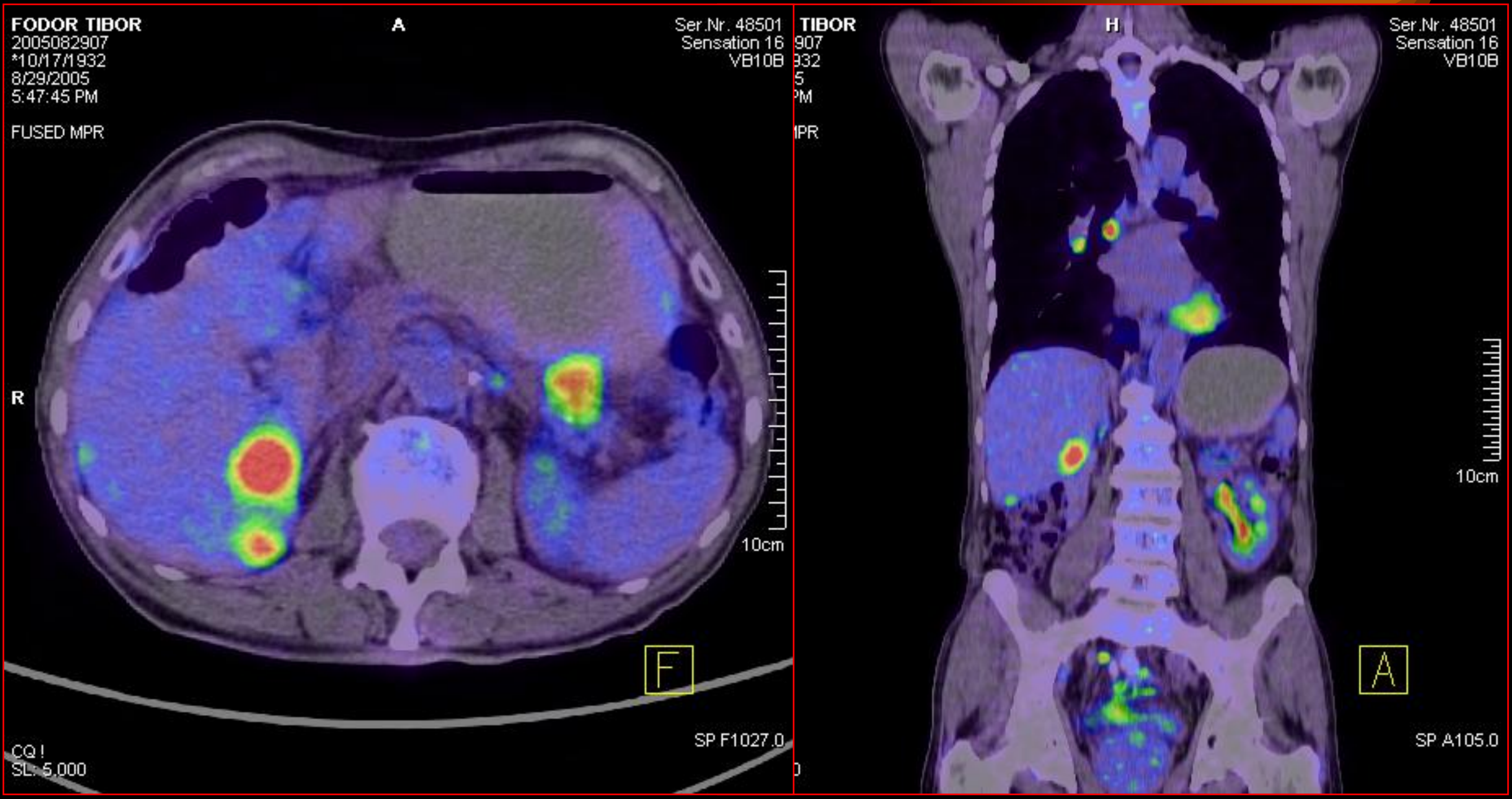
CT **SPECT** **SPECT/CT**



Liver metastasis of rectal cancer by 18F-FDG

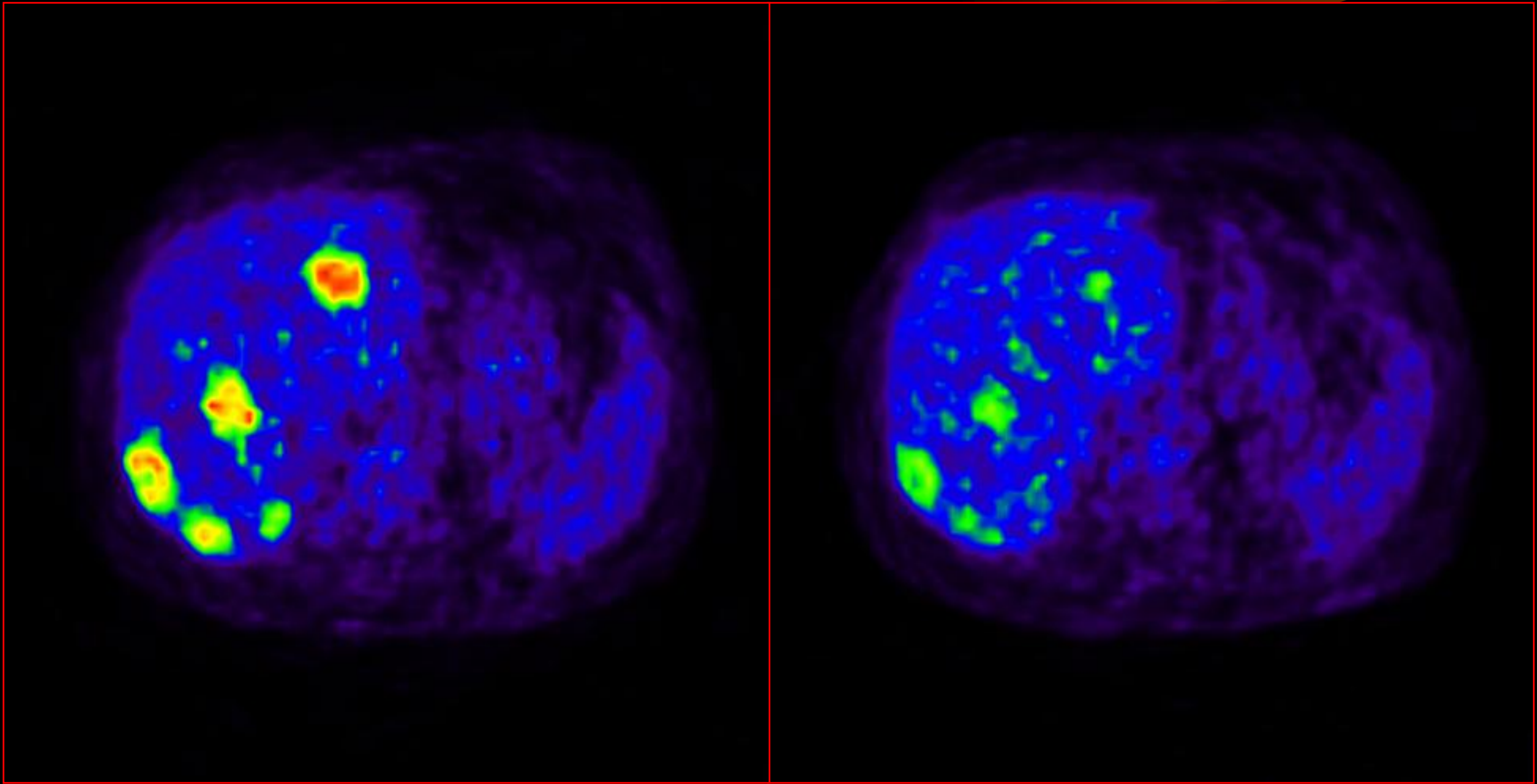


Multiplex metastases of pancreas tail cancer by 18F-FDG



Multiplex liver metastases of sigmatumor by 18F-FDG

Before therapy | **After therapy**



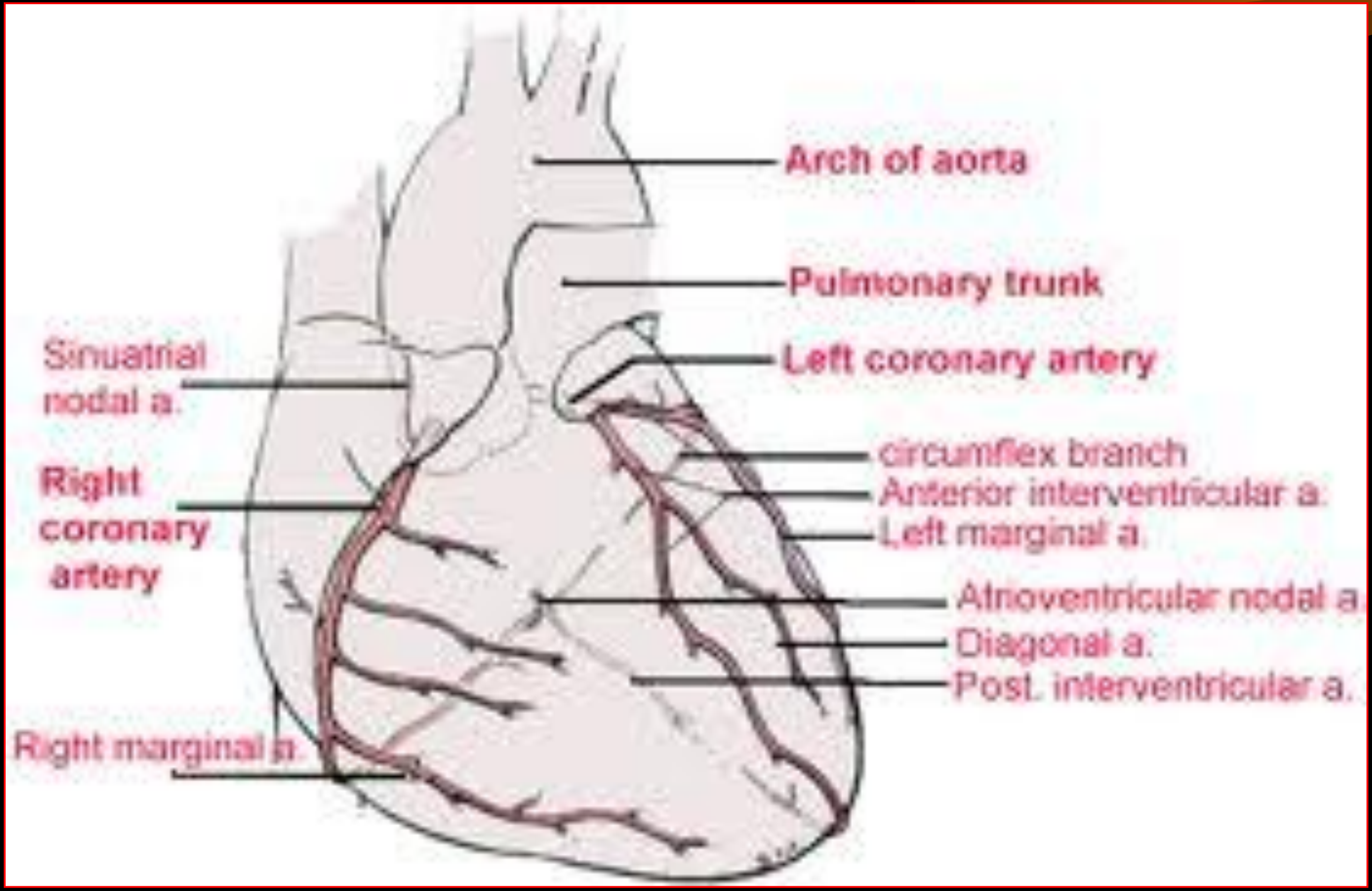
Nuclear cardiology

- Rest myocardial perfusion study
- Stress/rest myocardial perfusion study
- Radionuclide ventriculography (RNV), multigated analysis (MUGA)

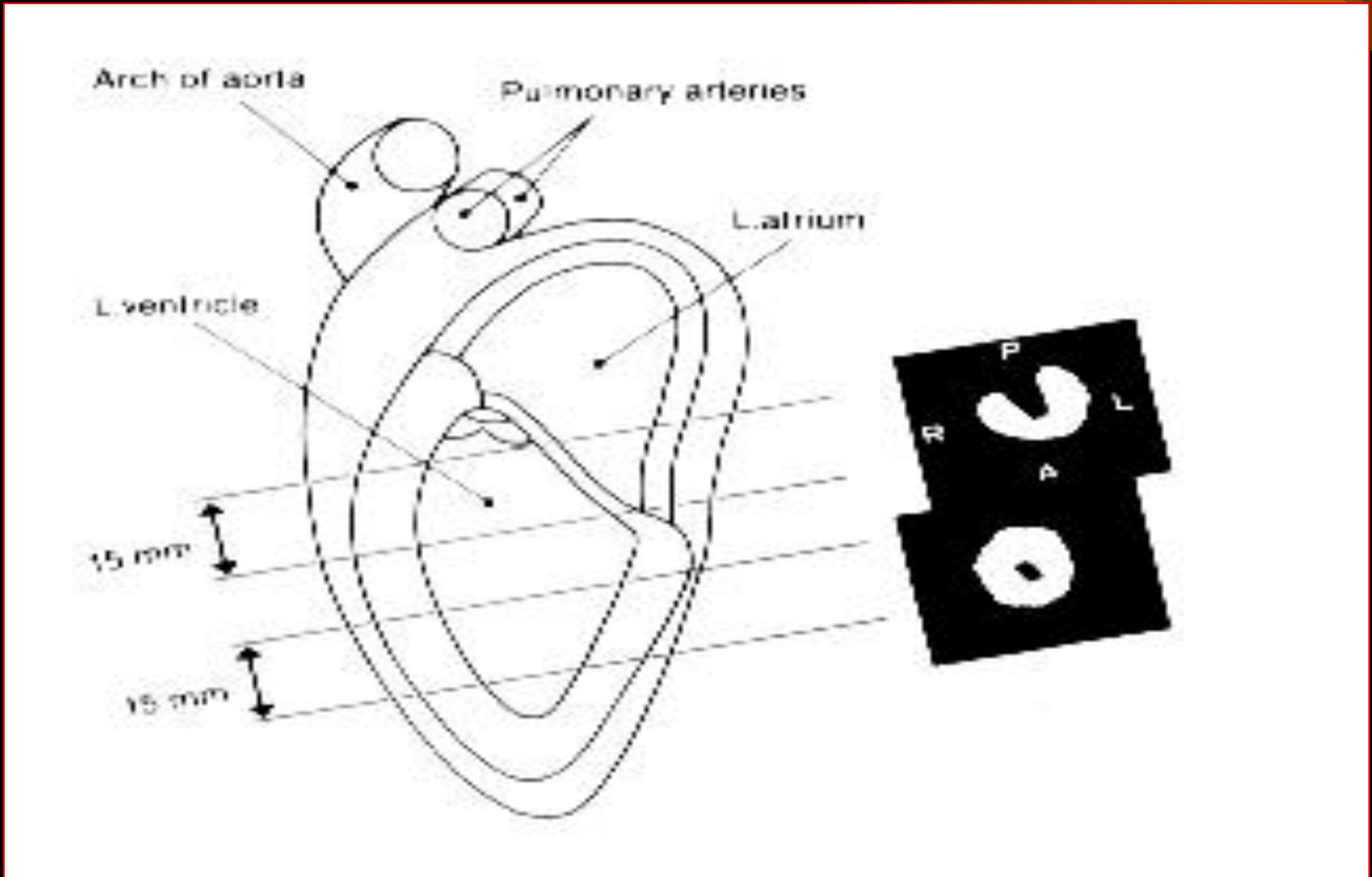
Myocardial perfusion imaging in rest conditions

- The **myocardium** is shown by radioactive tracers (99mTc-MIBI, 99mTc-tetrofosmin, 201-Tl-clorid)
- Reconstruated and reorientated slices are investigated from the left ventricle by **SPECT**
- The impairment of the **myocardial perfusion** is indicated by decreased activity or lack of the activity

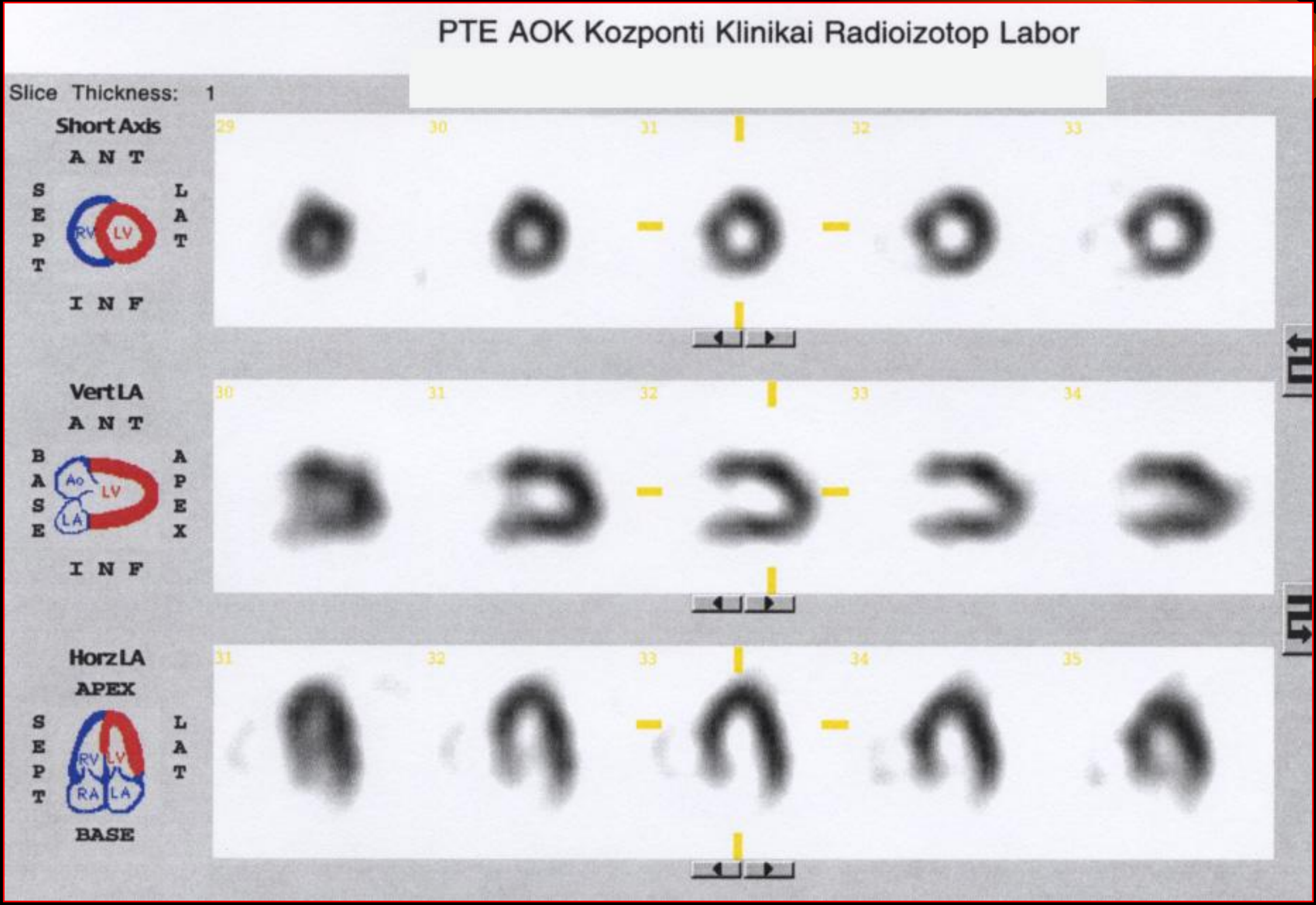
Coronary anatomy



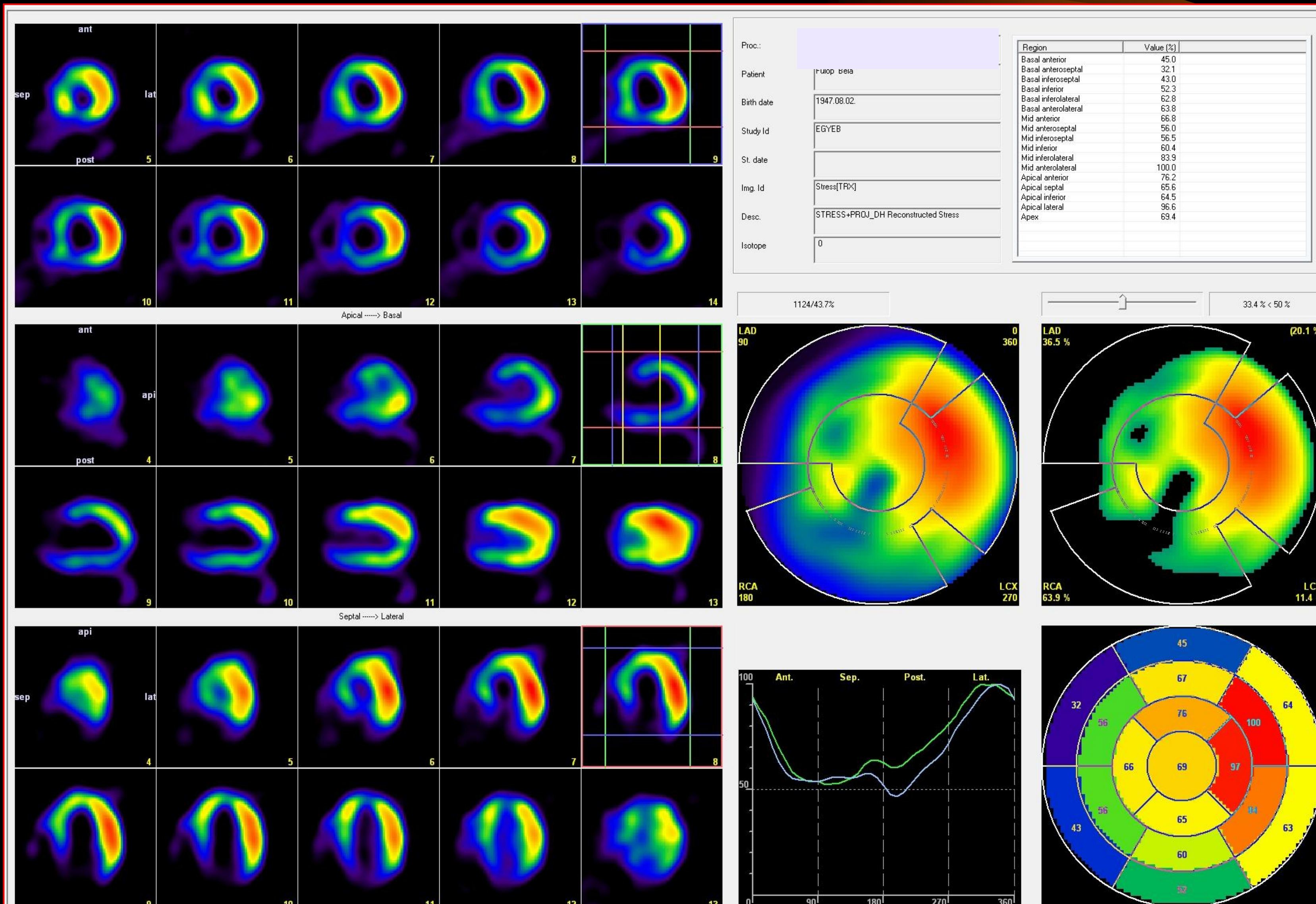
Long axis and short axis slices of the myocardium by SPECT



The transversal, sagittal and coronal slices of the myocardium



Infero-septal + antero-septal hypoperfusion

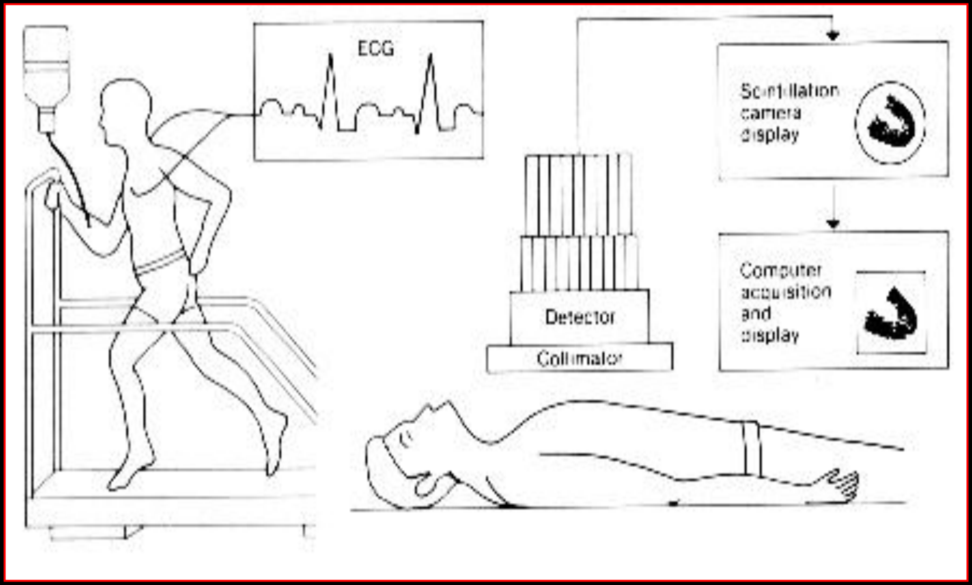


Stress/rest myocardial perfusion study

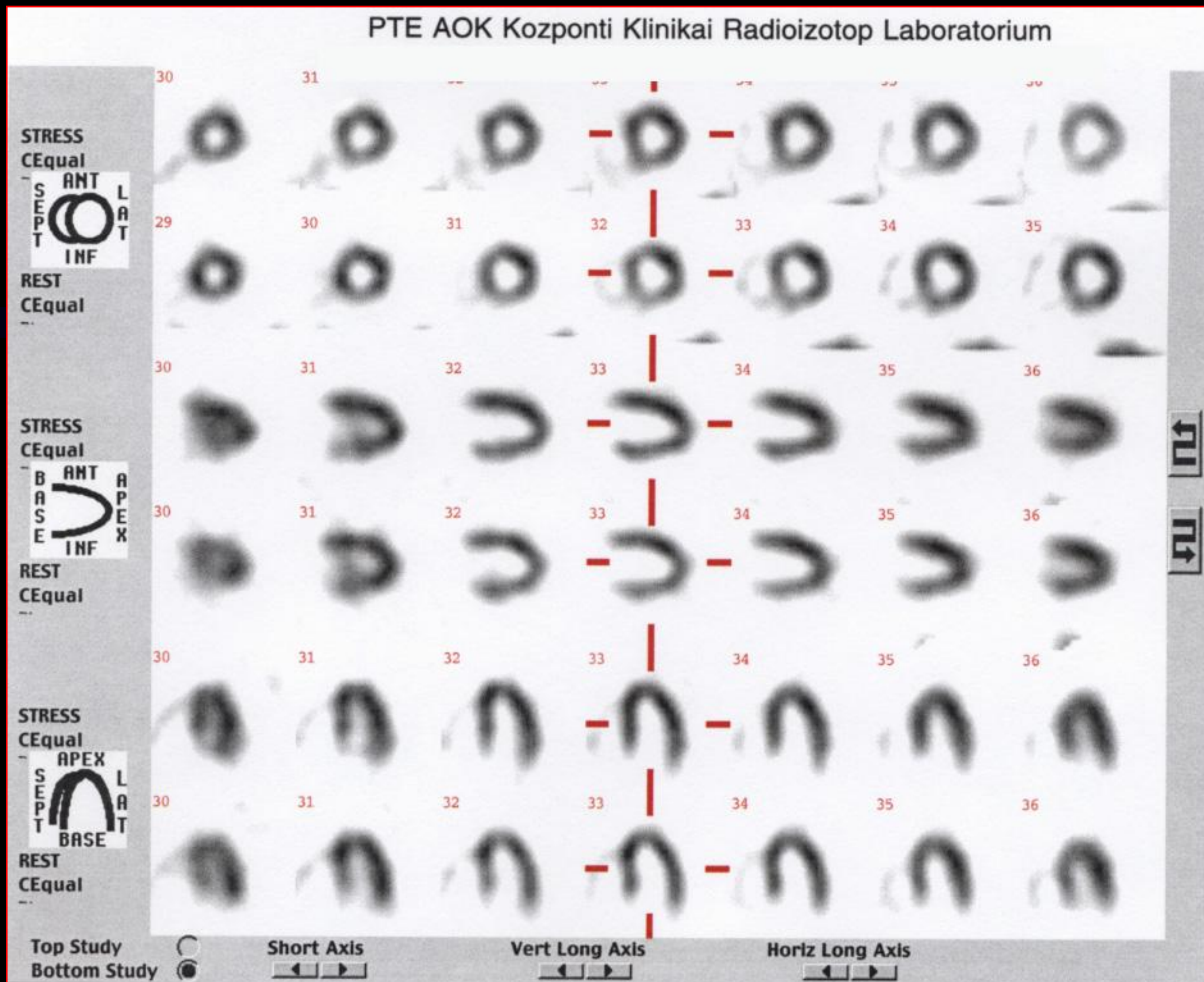
- Physical or pharmacological stress (Dipyridamol, Dobutrex) is applied
- The isotope is administered on the top of the stress » *SPECT-imaging*
- Rest *SPECT-imaging* is on the same day (Tl), or a day later (Tc-MIBI)
- Evaluation by two independent nuclear medicine experts + cardiologist

The method of the imaging by fixed 90 degree double-haed SPECT

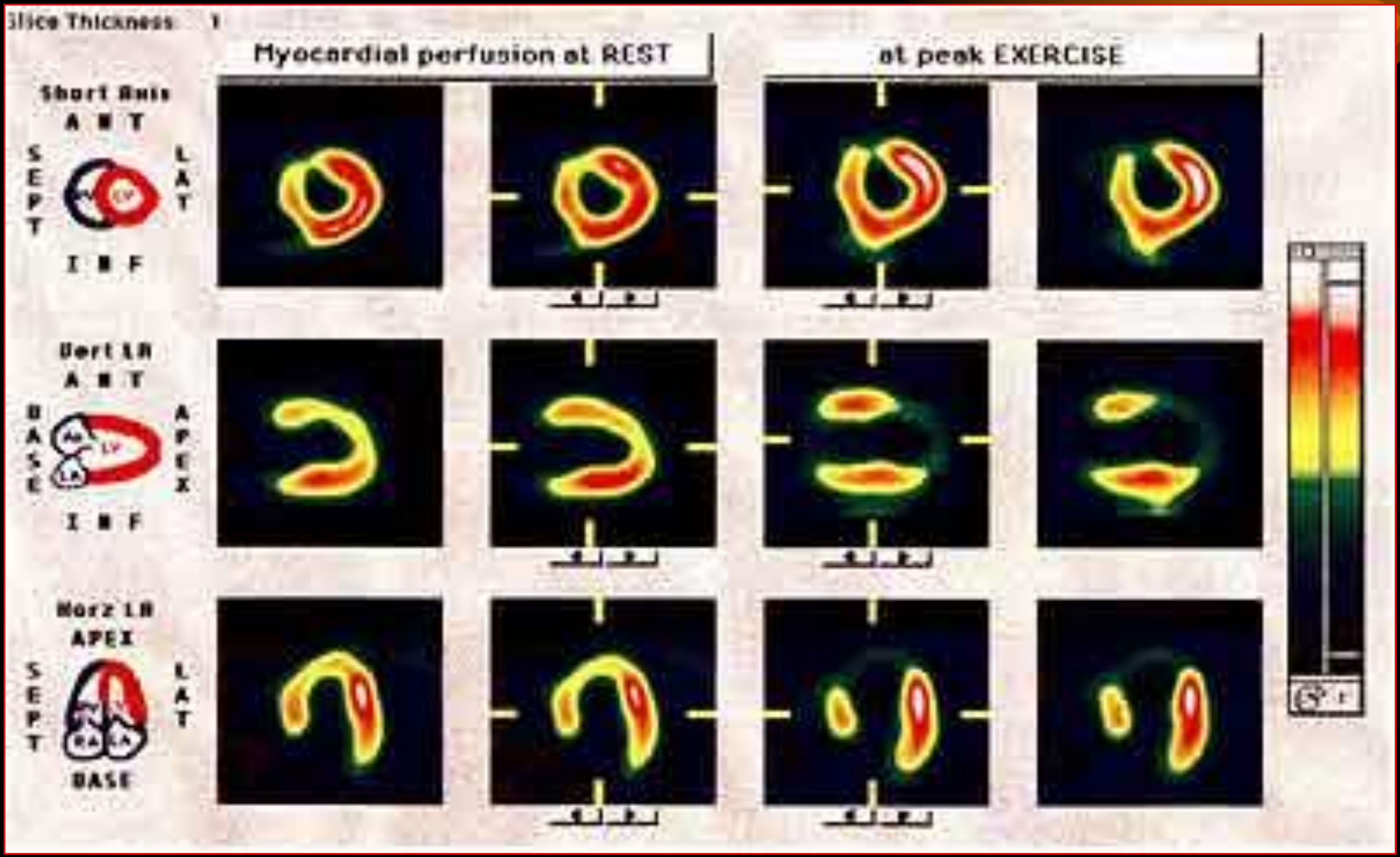
(Physical or Dipyridamol stress is used commonly)



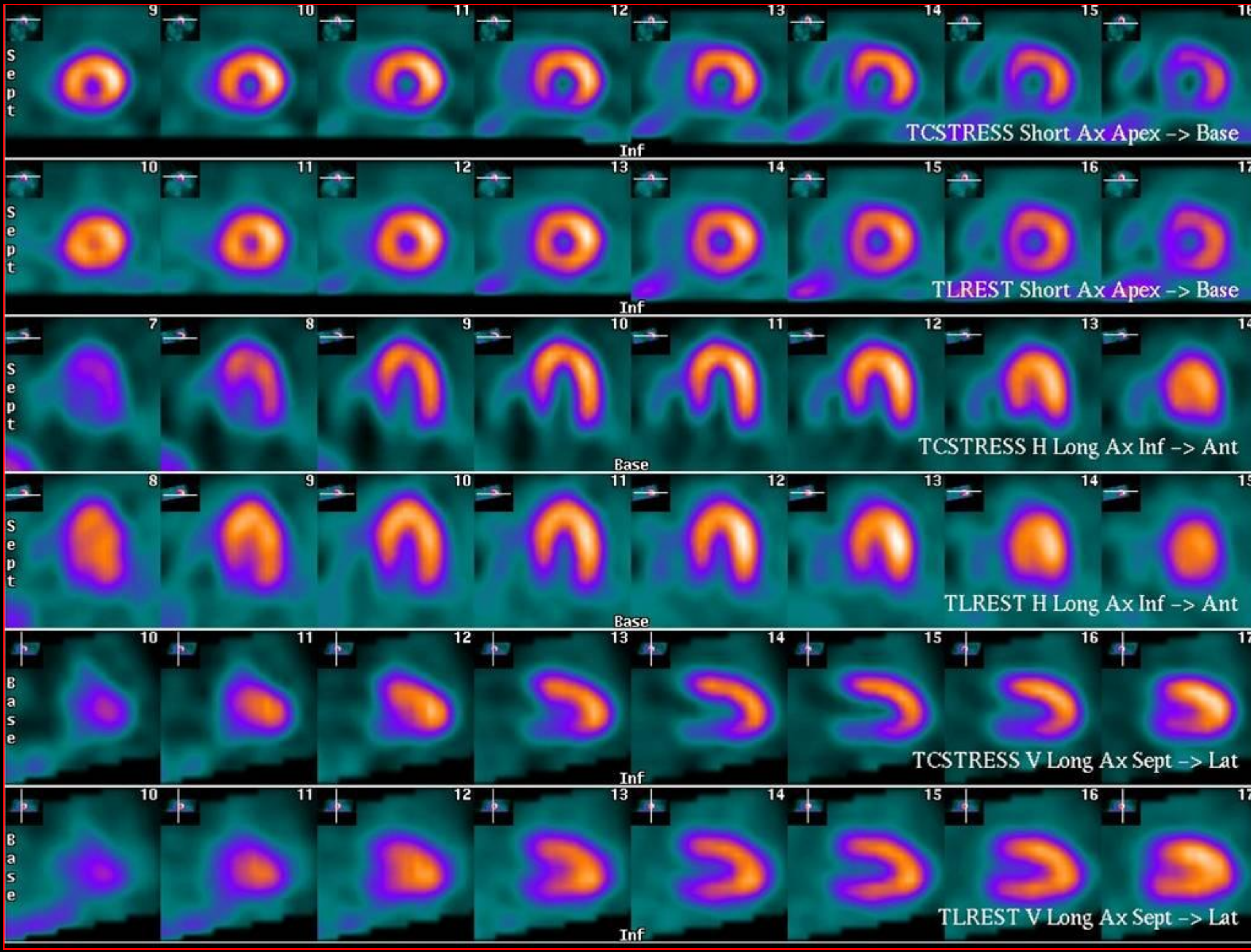
Normal stress/rest myocardial perfusion study



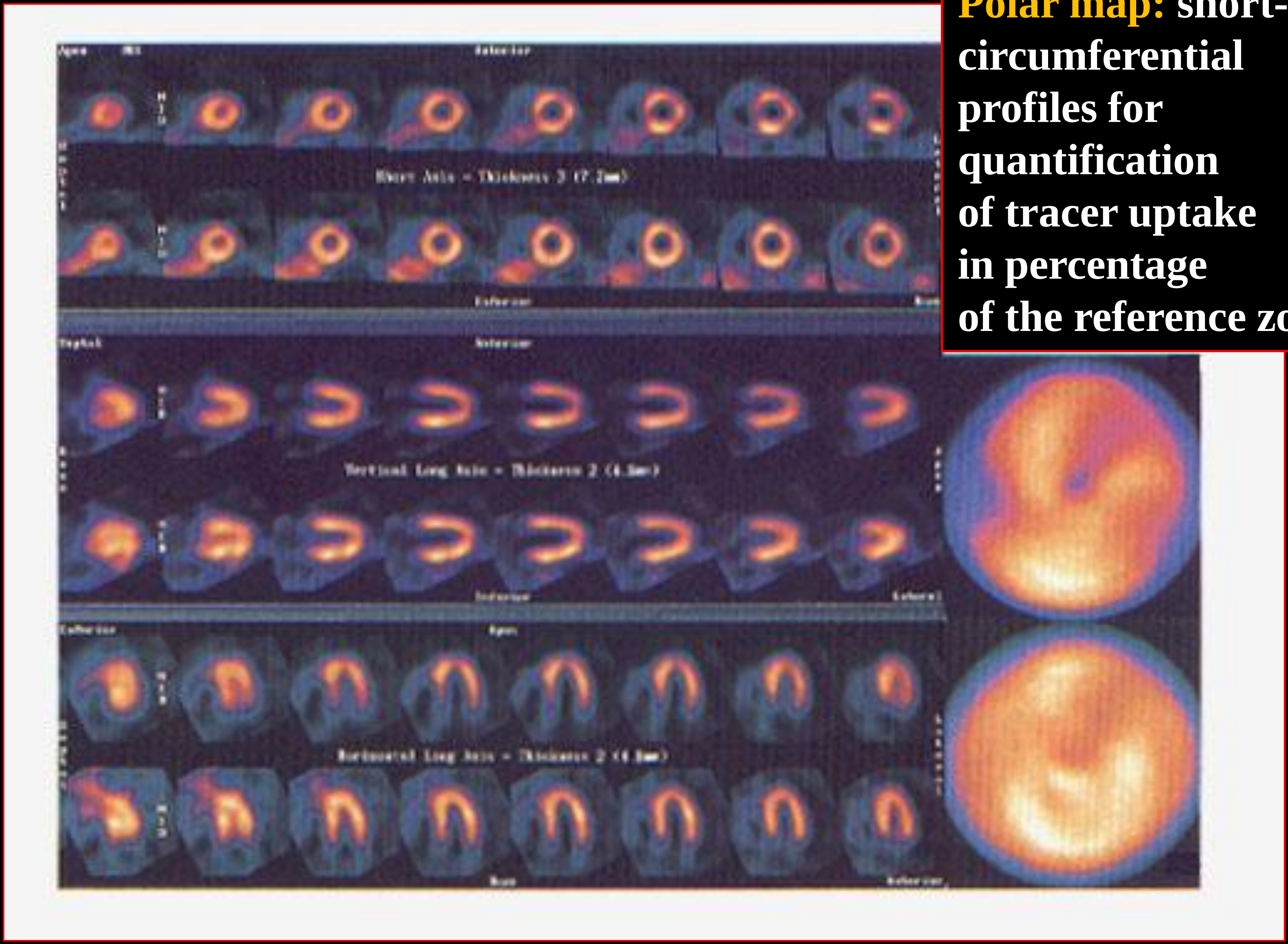
Transient ischaemy in the apex and in the apical part of the antero-septal wall



CAD in the infero-septal wall

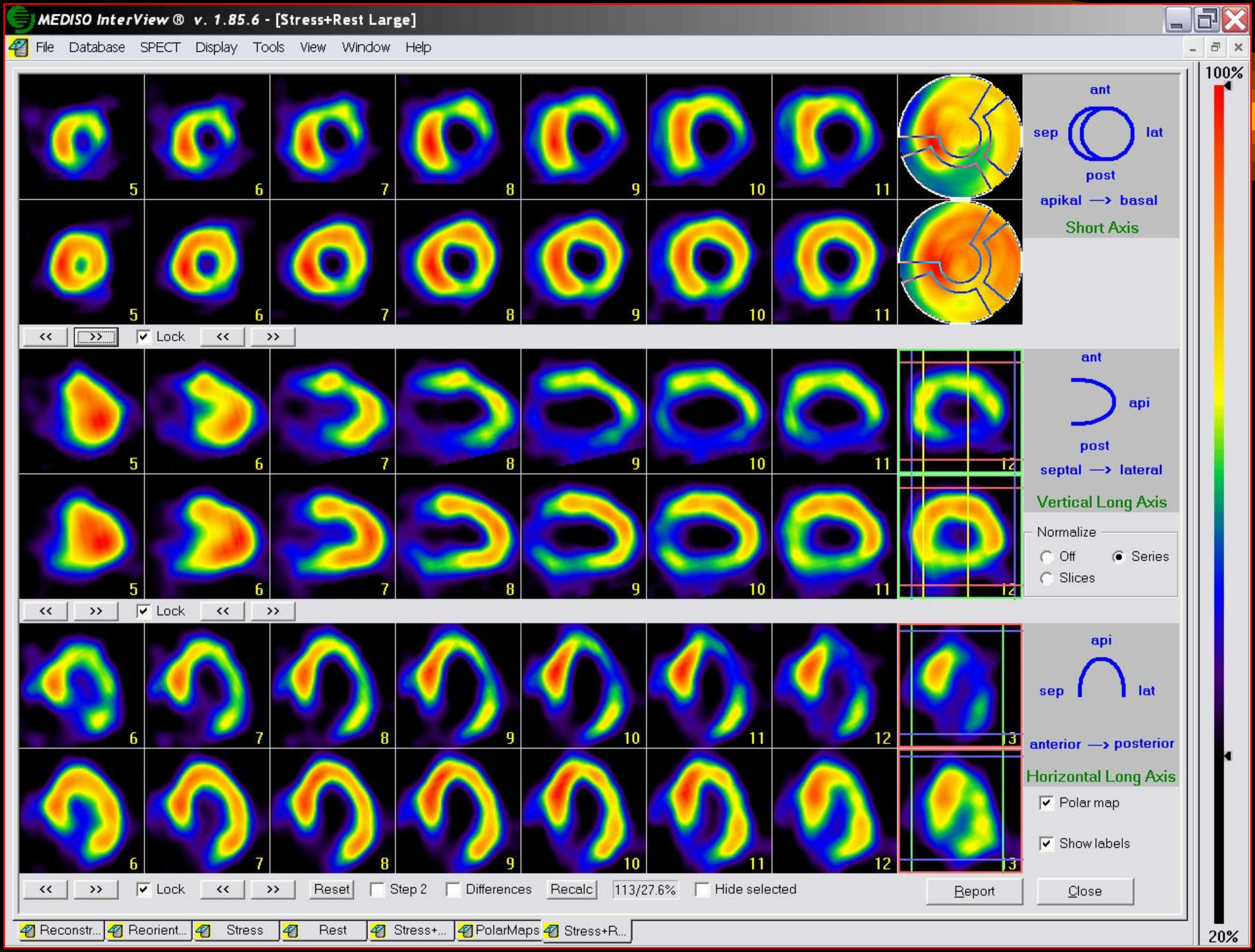


CAD in the basal part of the septum

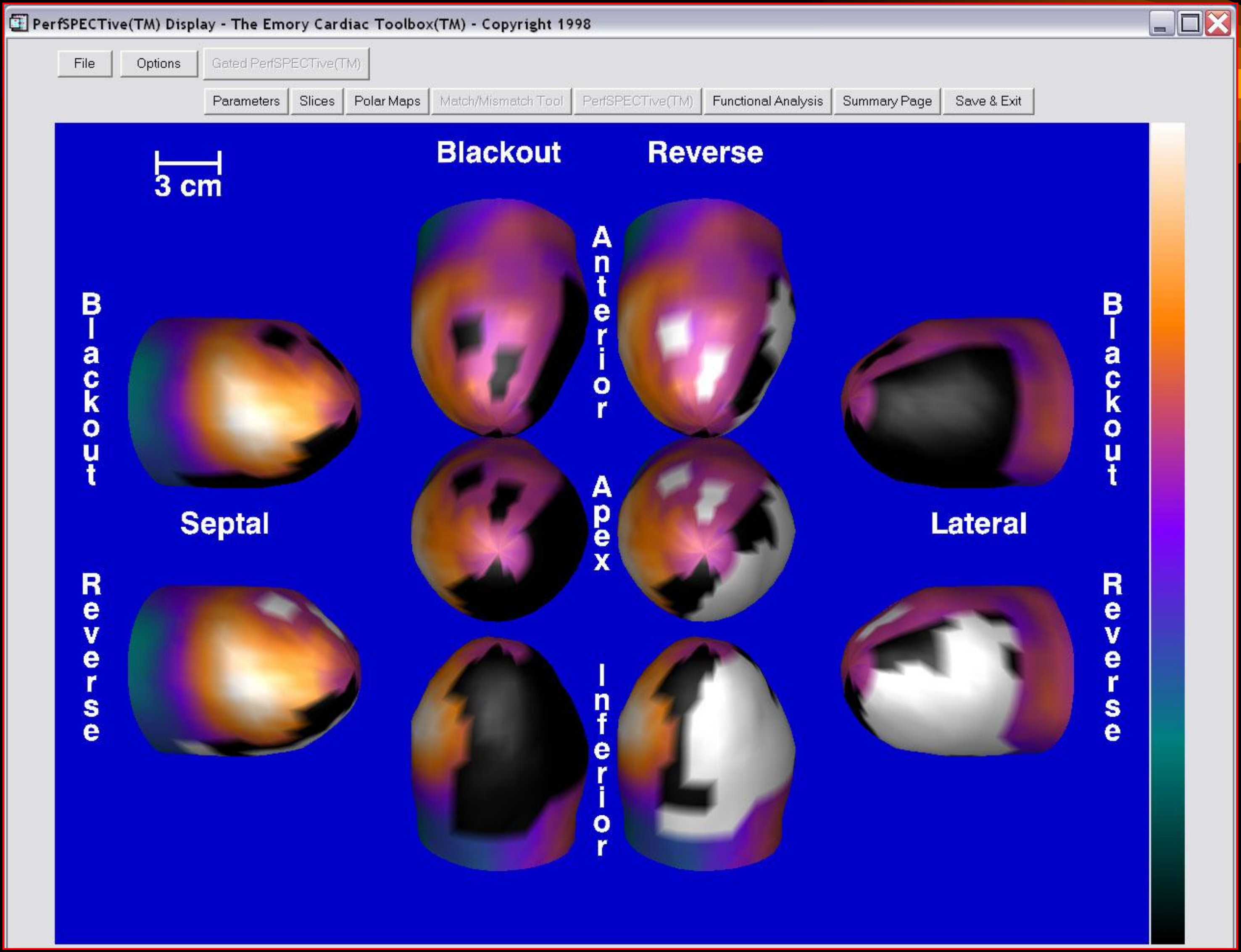


Polar map: short-axis
circumferential
profiles for
quantification
of tracer uptake
in percentage
of the reference zone

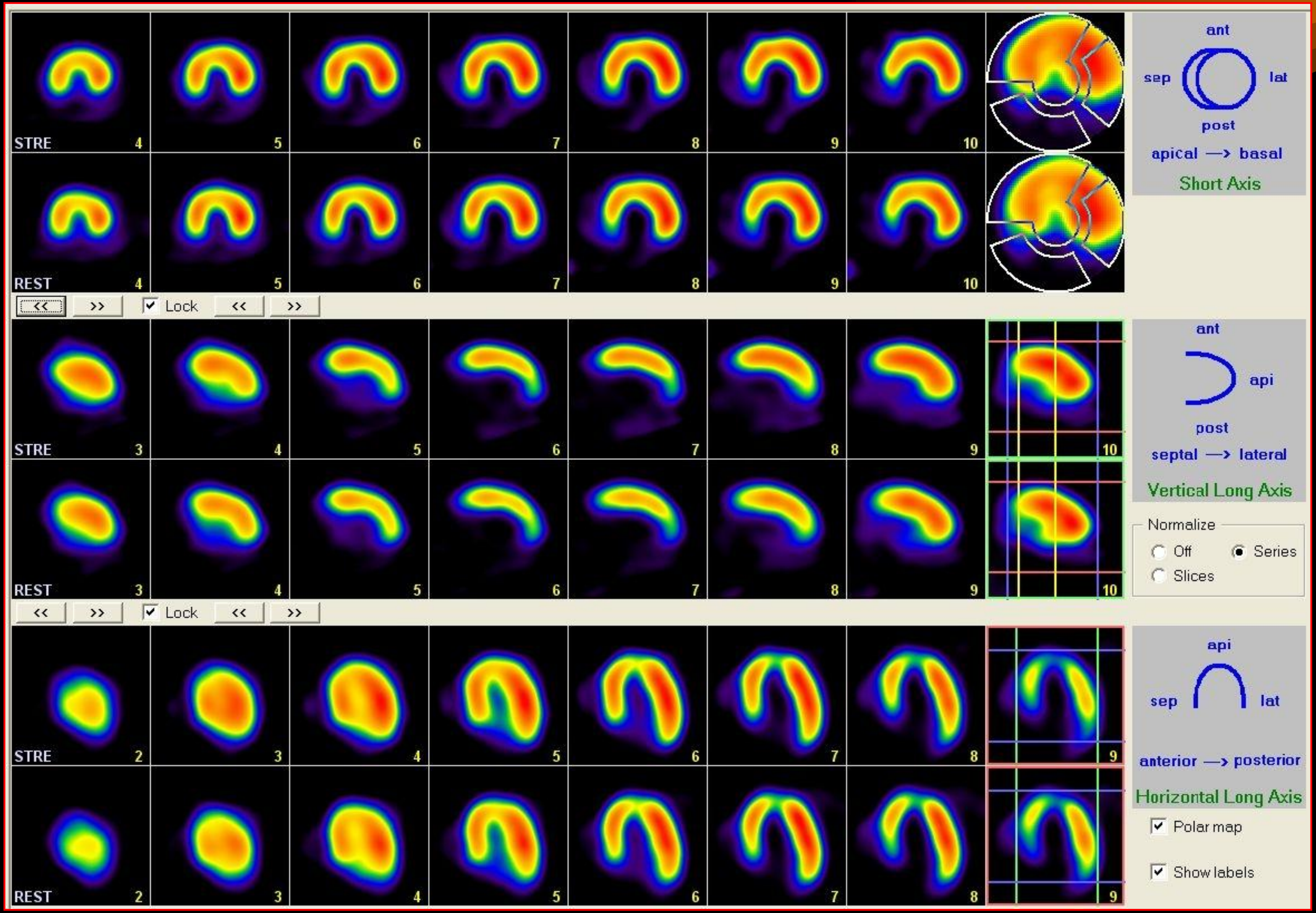
Severe infero-lateral transient ischaemy



Severe infero-lateral transient ischaemy – 3D processing



Scar in the inferior, infero-septal and infero-lateral wall

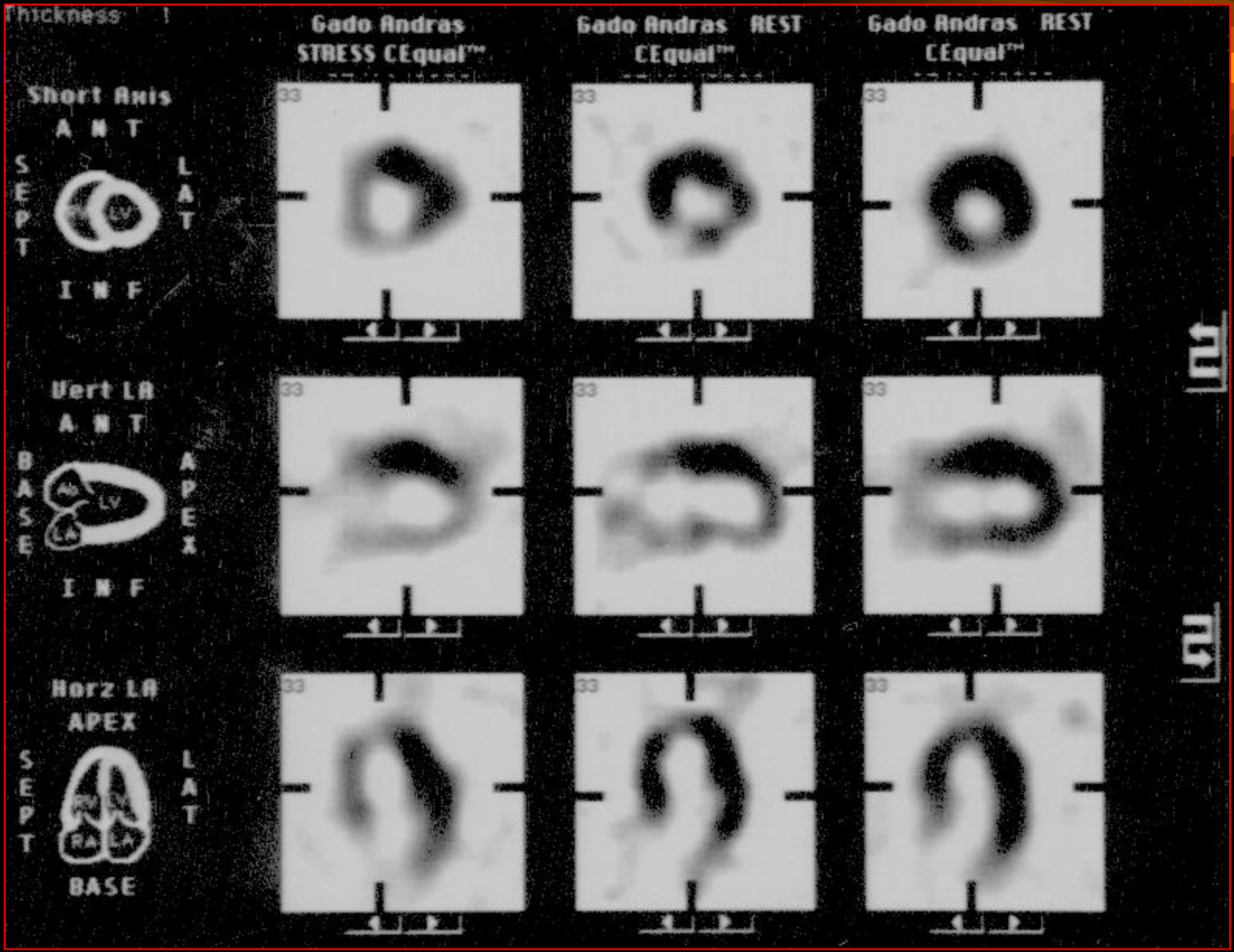


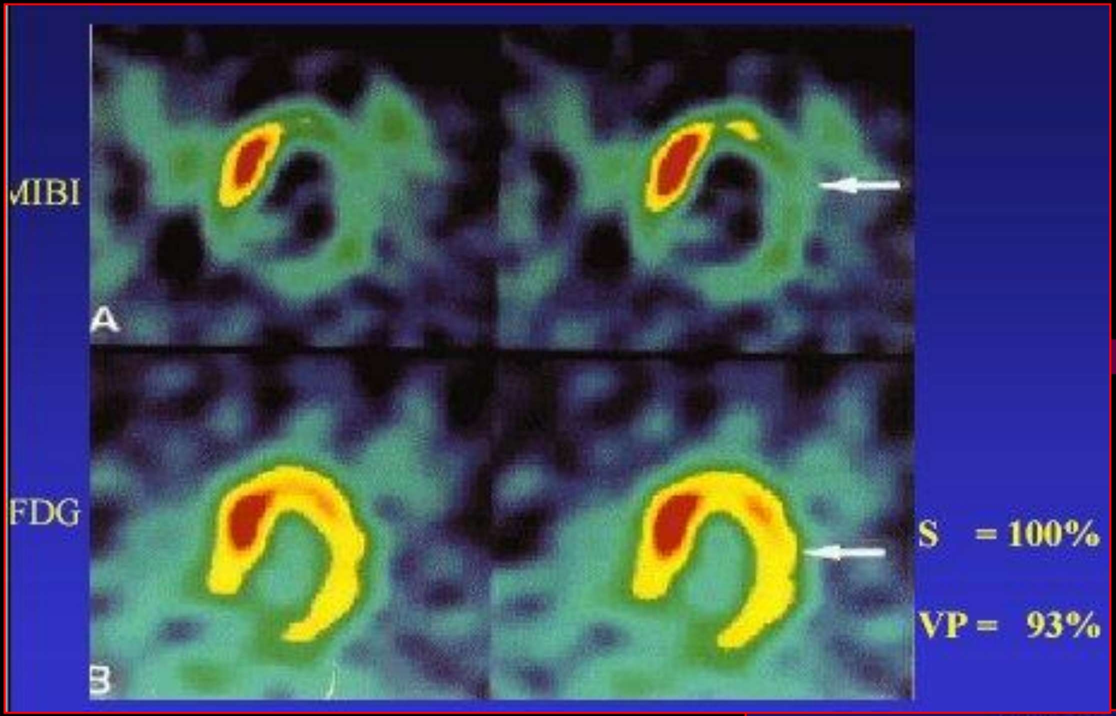
Viability of the myocardium

- When fix defect is found in both stress and rest situation (scar or hibernated myocardium) to assess the possibility for succesful revascularization
- 201Tl-chlorid has a specific redistribution pattern after 3-4 hours in rest, which depends on the wash-out from the myocytes
- After the reinjection the activity of the myocardium depends on primarily the perfusion by the coronary arteries

Viability examination by 201Tl-clorid

stress redistr. reinjection



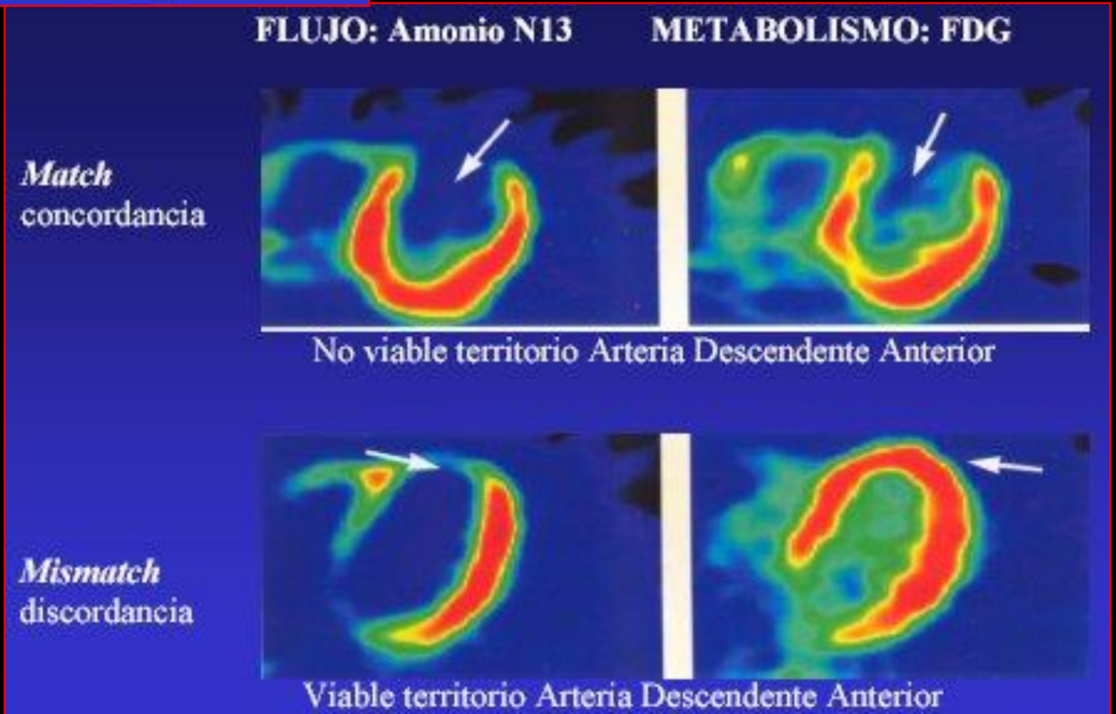


PET study
Perfusion-metabolic
„match"

scar

MIBI-FDG
„mismatch"

myocardium is viable



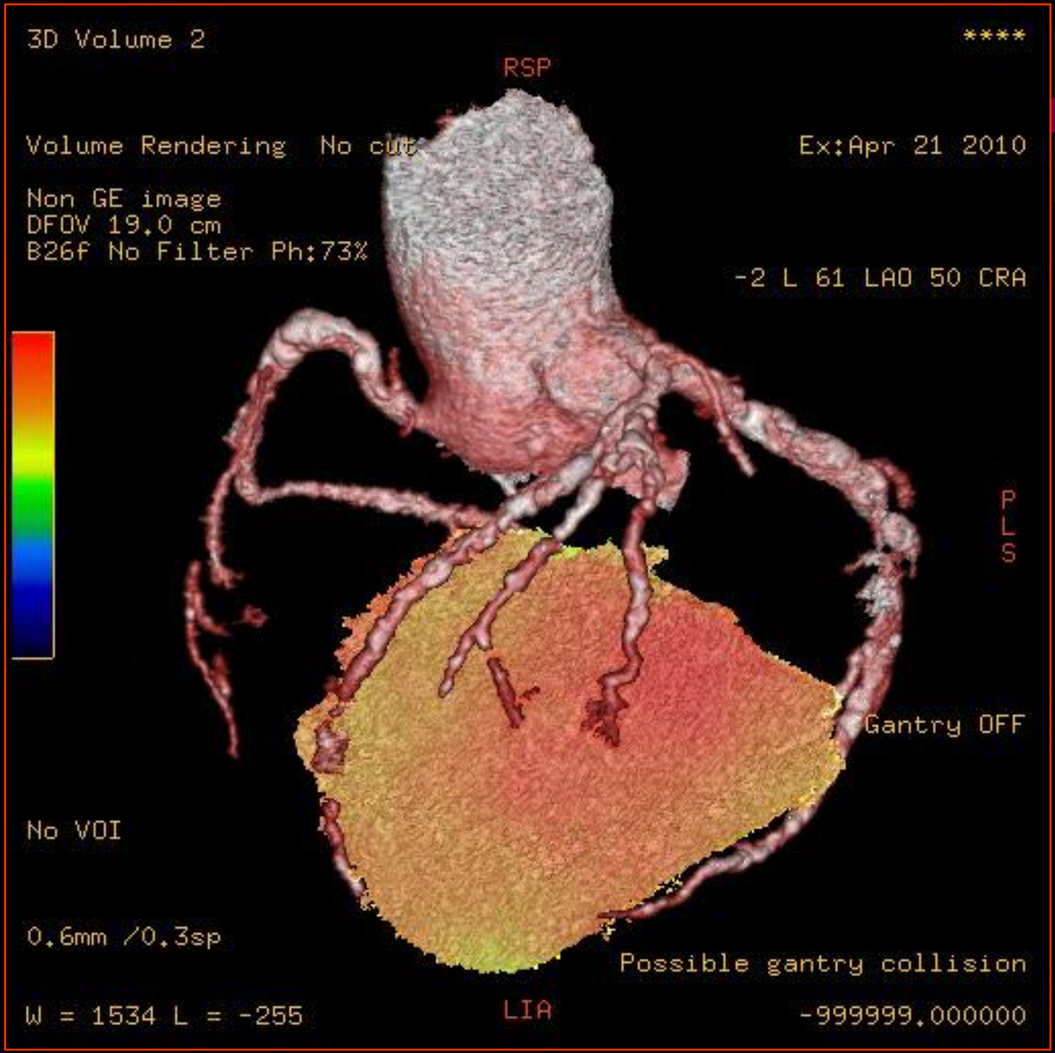
3D SPECT/CT imaging:

stenosis of right coronary artery

↓

apical hypoperfusion

Stress MPS + MSCT



Balogh I. – Kerecsen G.

Radionuclide ventriculography (RNV), multigated analysis (MUGA)

- The **blood-pool** of the heart is labelled (99mTc-pyrophosphate-RBC)
- **Gamma-camera-computer-R wave monitor system**
- EF=ED - ES/ED-BG (%)
- **Wall-motion** is analysed by parametric pictures

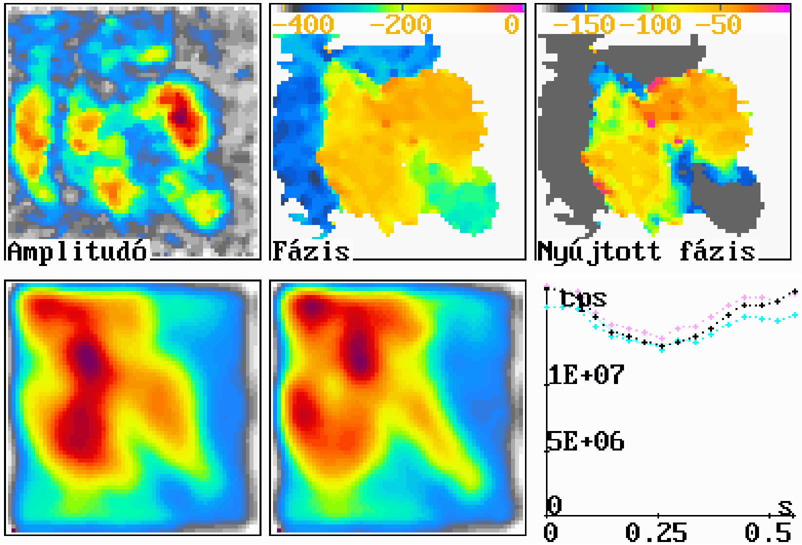
VENTRICULO SZINTIGRÁFIA EREDMÉNYLAP

PÉCSI TUDOMÁNYEGYETEM ÁLTALÁNOS ORVOSTUDOMÁNYI KAR
Központi Klinikai Radioizotóp Laboratórium
7624 Pécs, Ifjúság útja 13.   Tel.: (72) 326-222/1229
Intézetvezető: dr. Zámbó Katalin

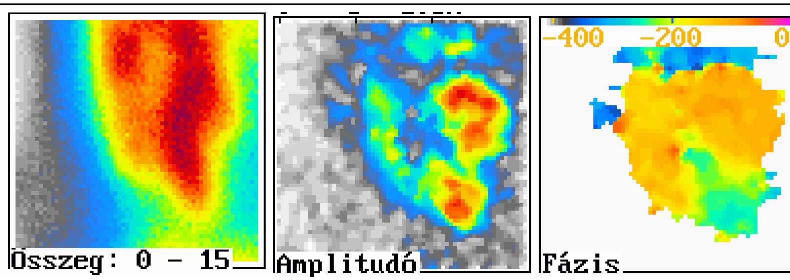
LARGE PARADOX WALL-MOTION IN THE APICAL PART OF THE HEART

Kódszám: KE0100
Szül.: 240308
Beküldô int.: Komló Bel.
Diagnosis: ISZB
Értékelte: Dr.Schmidt
Dátum: 2000.03.16
:

SZIVKAMRA-GÖRBE ELEMZÉSE
EF: 25.2 %
ES ideje: 270 ms
PER
ideje: 137 ms
seb.: -1.60 EDV/s
PFR
ideje: 392 ms
seb.: 1.26 EDV/s
PFR/PER: 0.79
Ciklusidö: 592 ms
Frekvencia: 101/min

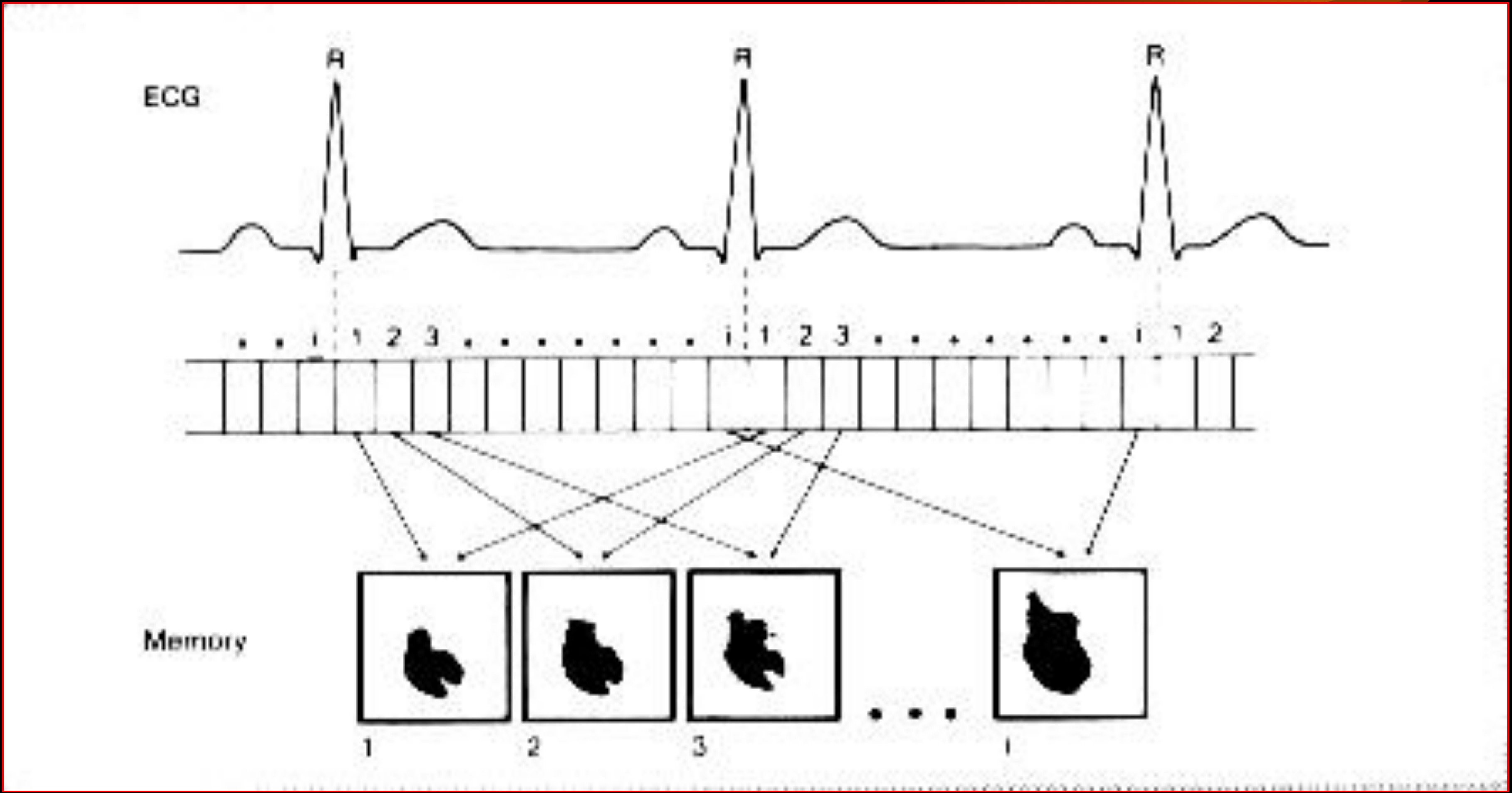


Lao30

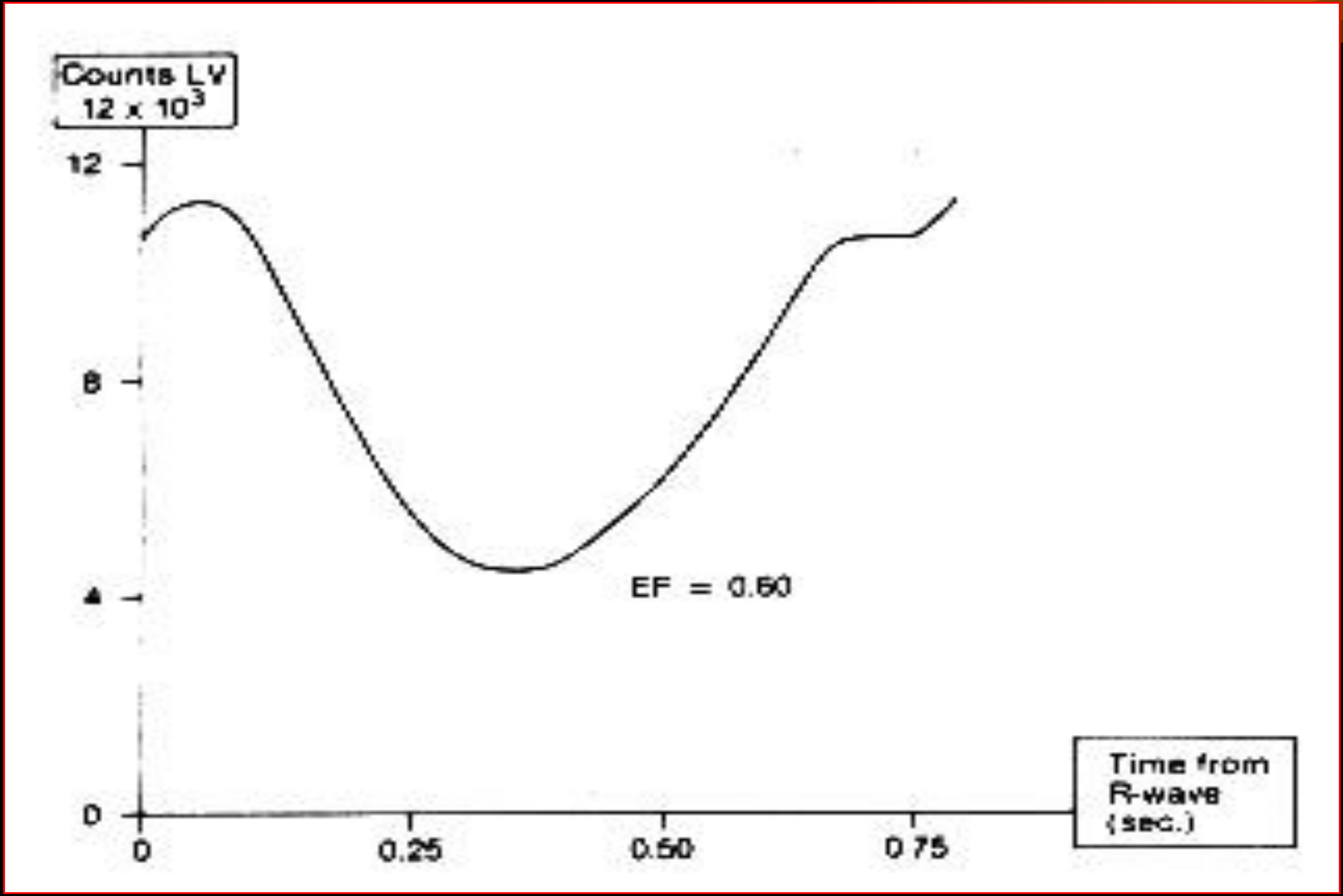


Lao70

An average cycle is generated from more hundred heart cycles



The ejection fraction curve



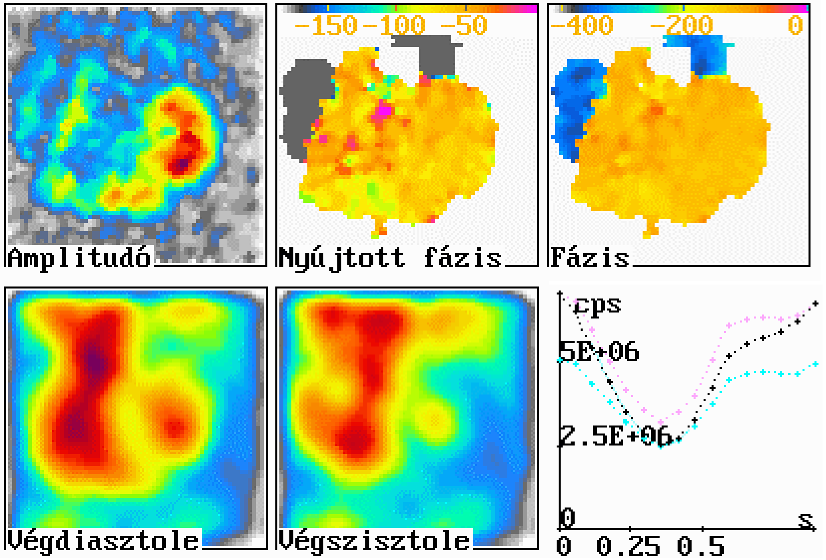
VENTRICULO SZCINTIGRÁFIA EREDMÉNYLAP

PÉCSI TUDOMÁNYEGYETEM ÁLTALÁNOS ORVOSTUDOMÁNYI KAR
Központi Klinikai Radioizotóp Laboratórium
7624 Pécs, Ifjúság útja 13. Tel.: (72) 326-222/1229
Intézetvezető: dr. Zámbó Katalin

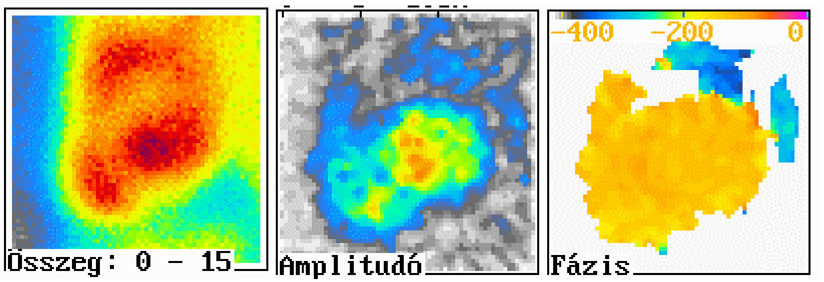
NORMAL FUNCTION OF THE LEFT VENTRICLE

Kódszám: KE0351
Szül.: 450515
Beküldô int.: Szigetvár Bel.
Diagnosis: St.p.inf.myoc.
Értékelte: Dr.Schmidt
Dátum: 2000.10.02
:

SZIVKAMRA-GÖRBE ELEMZÉSE
EF: 64.1 %
ES ideje: 398 ms
PER
ideje: 180 ms
seb.: -2.50 EDV/s
PFR
ideje: 550 ms
seb.: 2.18 EDV/s
PFR/PER: 0.87
Ciklusidö: 944 ms
Frekvencia: 64/min
Infl. pont: 768 ms



Lao30



Lao70

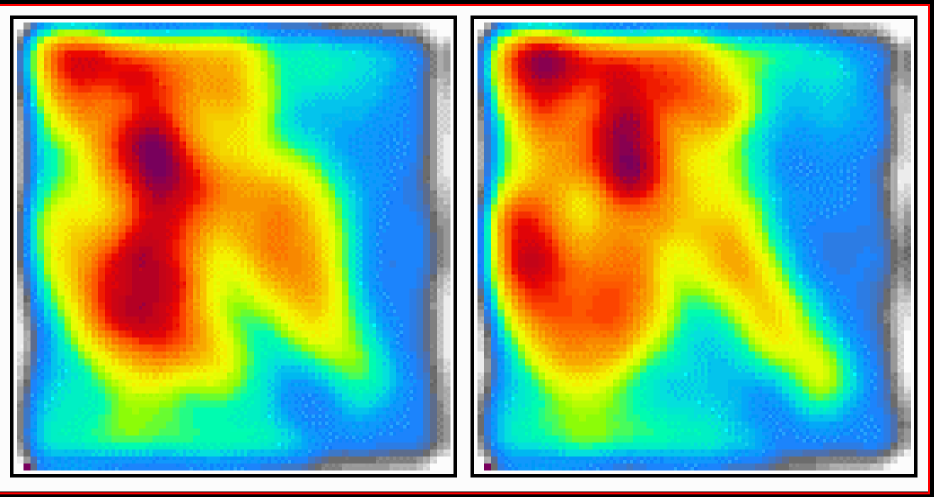
Parametric pictures

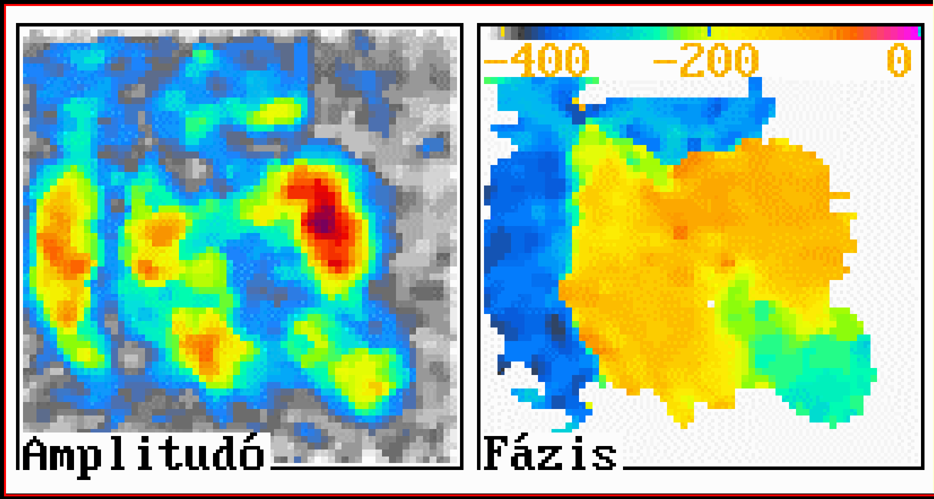
Amplitude picture

The colours represent the amplitude of the change of the activity of the pixels.

Phase picture

The colours represent the phase of the change of the activity of the pixels.





VENTRICULO SZCINTIGRÁFIA EREDMÉNYLAP

PÉCSI TUDOMÁNYEGYETEM ÁLTALÁNOS ORVOSTUDOMÁNYI KAR
Központi Klinikai Radioizotóp Laboratórium
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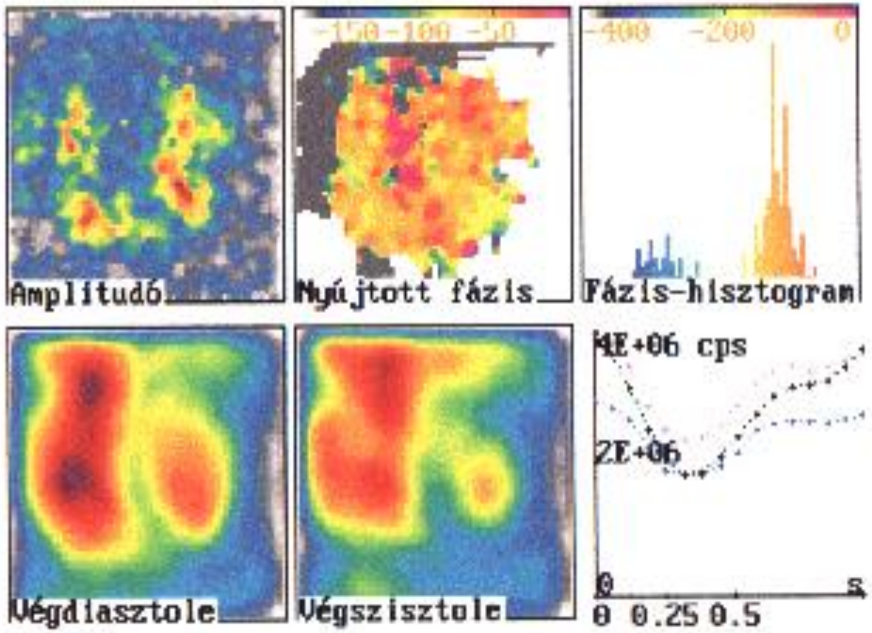
Intézetvezető: dr. Zámbó Katalin

POSTERO-INFERO-LATERALIS HYPOKINESIS

Kódszám: KE0082
Szül.: 50.12.08.
Beküldő int.: Szigetvár Kard.Szakr.
Diagnosis: St.p.AMI
Értékelte: dr.Udvaros
Dátum: 2000.03.01
:

SZIVKAMRA-GÖRBE ELEMZÉSE
EF: 52.6 %
ES ideje: 378 ms
PER
ideje: 190 ms
seb.: -2.53 EDV/s
PFR
ideje: 544 ms
seb.: 1.34 EDV/s
PFR/PER: 0.53
Ciklusidő: 1024 ms
Frekvencia: 59/min
Infl. pont: 803 ms



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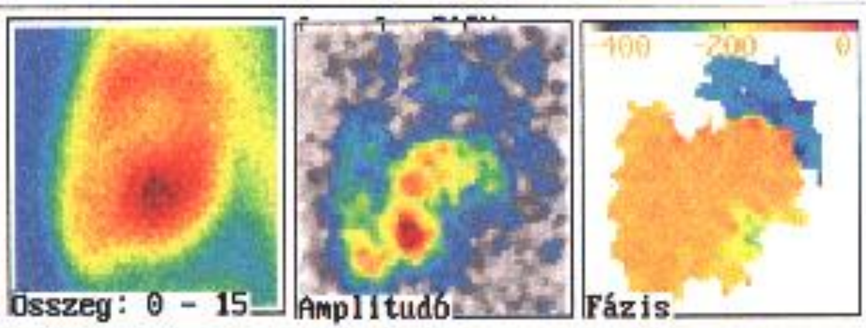

VENTRICULO SZCINTIGRÁFIA EREDMÉNYLAP

PÉCSI TUDOMÁNYEGYETEM ÁLTALÁNOS ORVOSTUDOMÁNYI KAR
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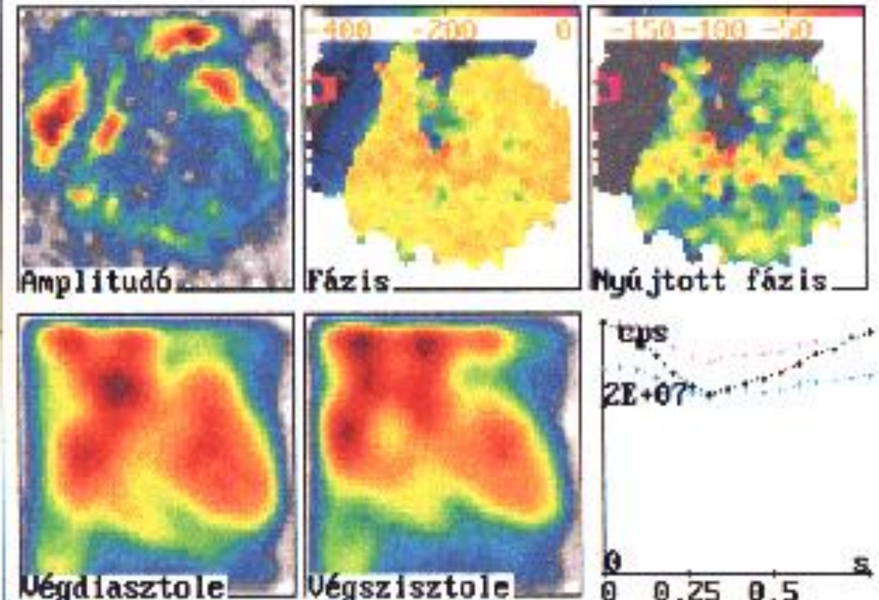
Intézetvezető: dr. Zámbó Katalin

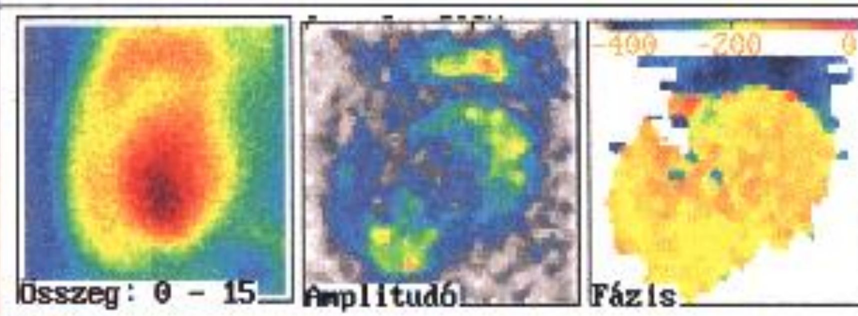
LARGE HYPOKINESIS IN DCM

Kódszám: KE0156
Szül.: 330801
Beküldő int.: PTE II.Bel.kl.
Diagnosis: DCM
Értékelte: dr.Schmidt
Dátum: 2000.04.19
:

SZIVKAMRA-GÖRBE ELEMZÉSE
EF: 28.5 %
ES ideje: 346 ms
PER
ideje: 194 ms
seb.: -1.30 EDV/s
PFR
ideje: 433 ms
seb.: 0.35 EDV/s
PFR/PER: 0.27
Ciklusidő: 832 ms
Frekvencia: 72/min
Infl. pont: 659 ms



Lao30

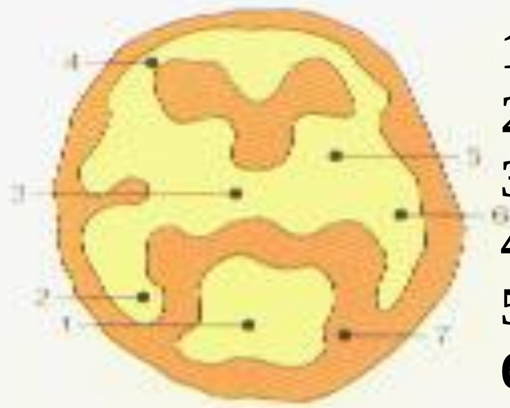


Lao70

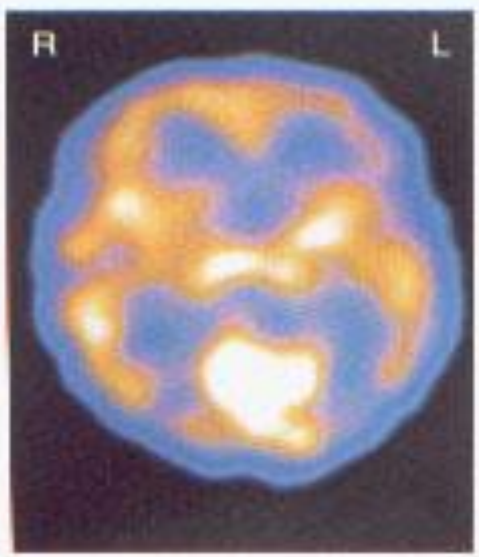
Brain perfusion study

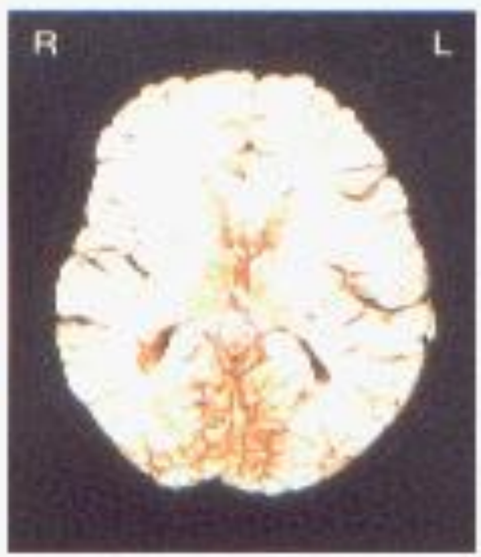
- The cortex and the basal ganglia are shown by a lypophil radioactive subject (99mTc-HM-PAO – hexamethyl-propilenamine-oxyme)
- Reconstruated and reorientated transversal, sagittal and coronal slices from the brain
- The impairment of the brain perfusion is indicated by decreased activity or lack of the activity

The parts of the brain

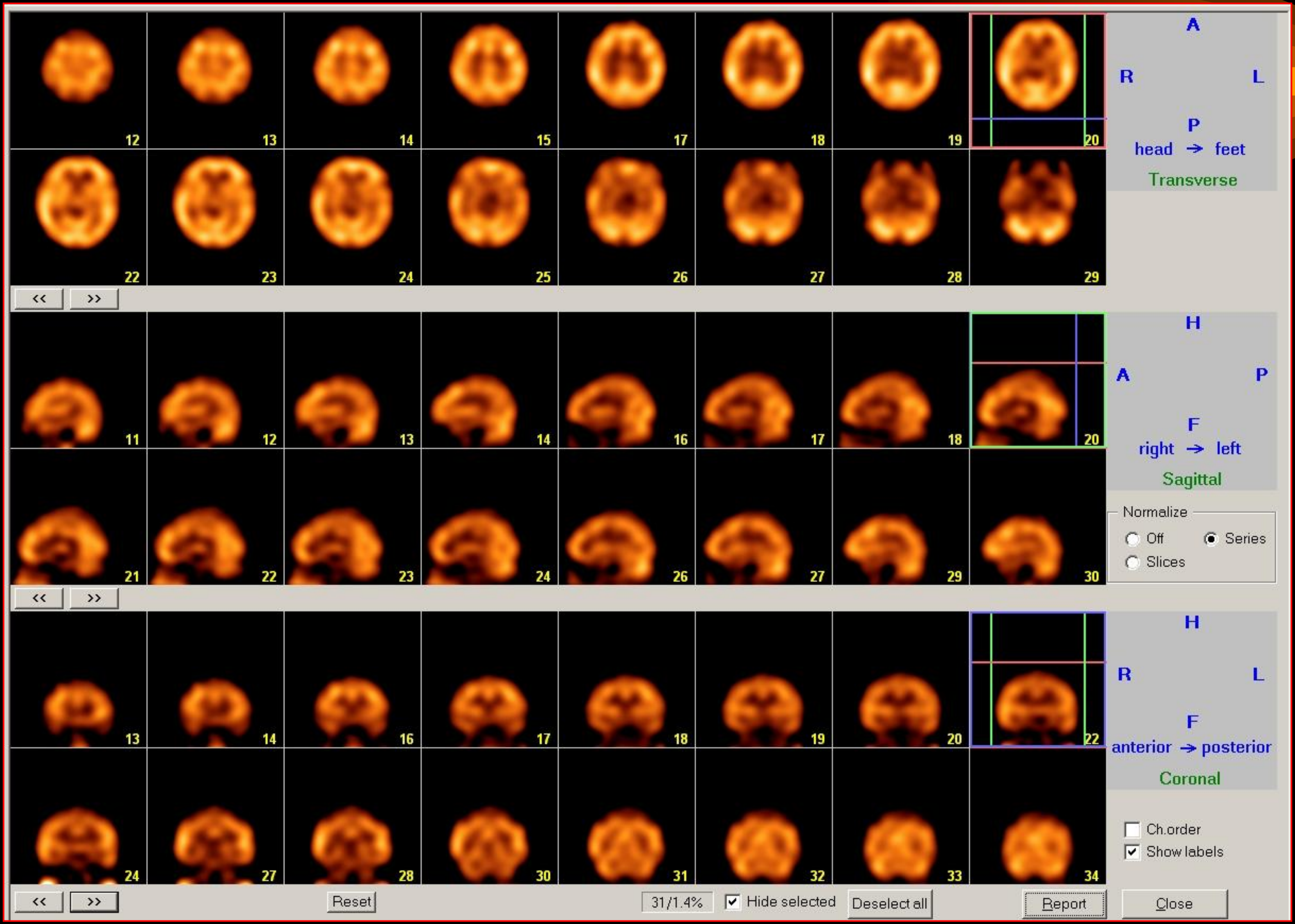


1. Seeing cortex
2. Occipital lobe
3. Thalamus
4. Frontal lobe
5. N. caudatus
6. Temporal lobe
7. Chambers

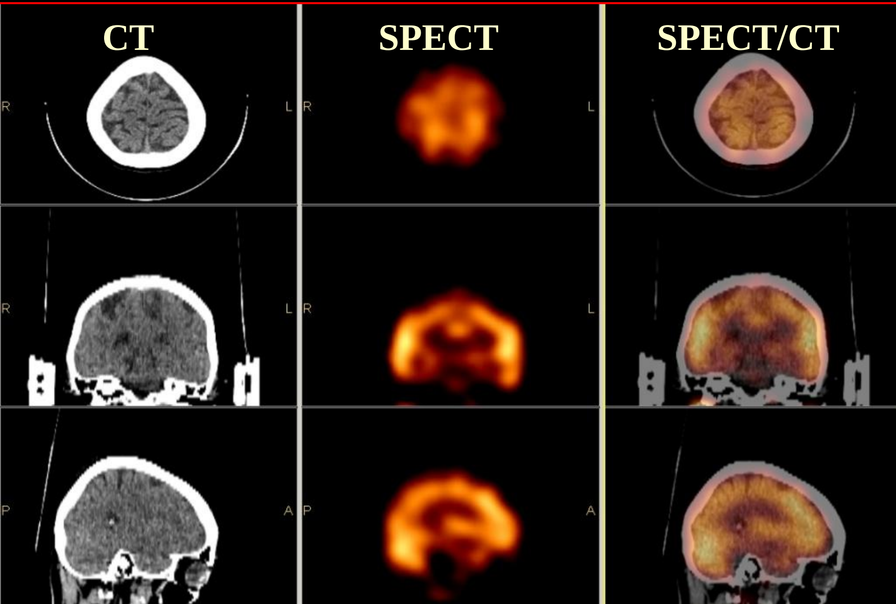


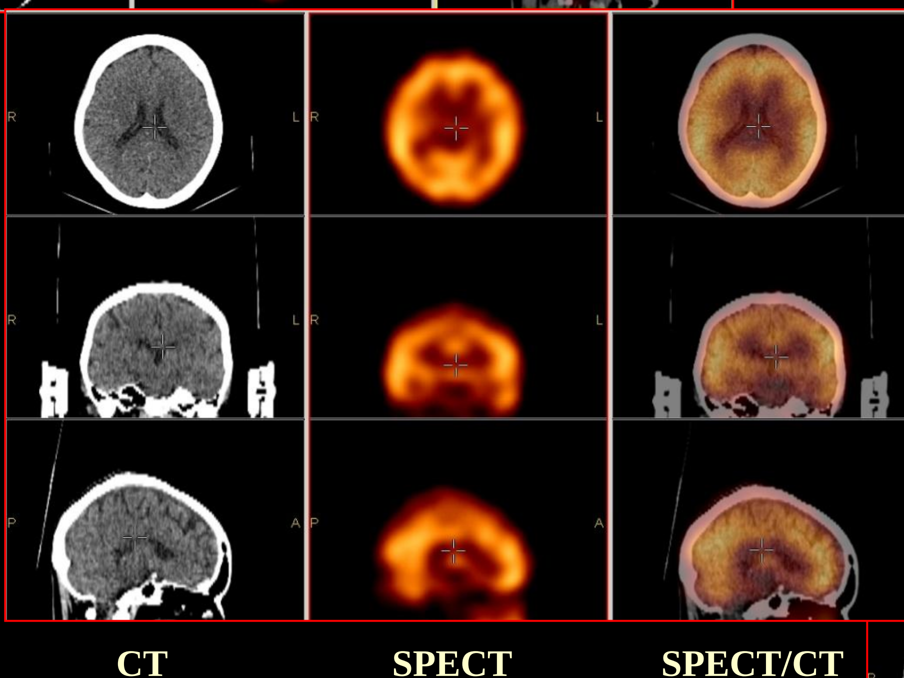


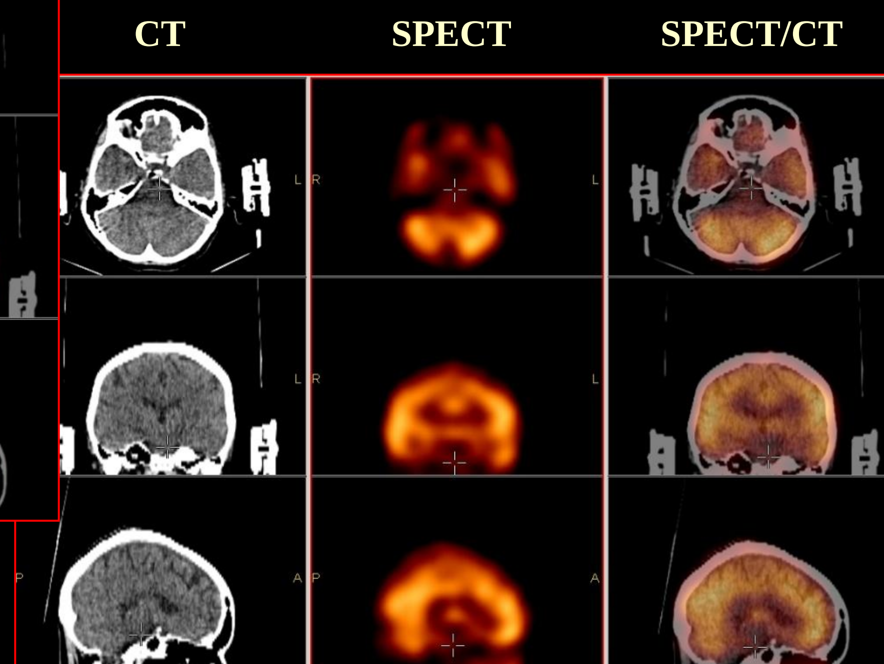
Normal brain perfusion



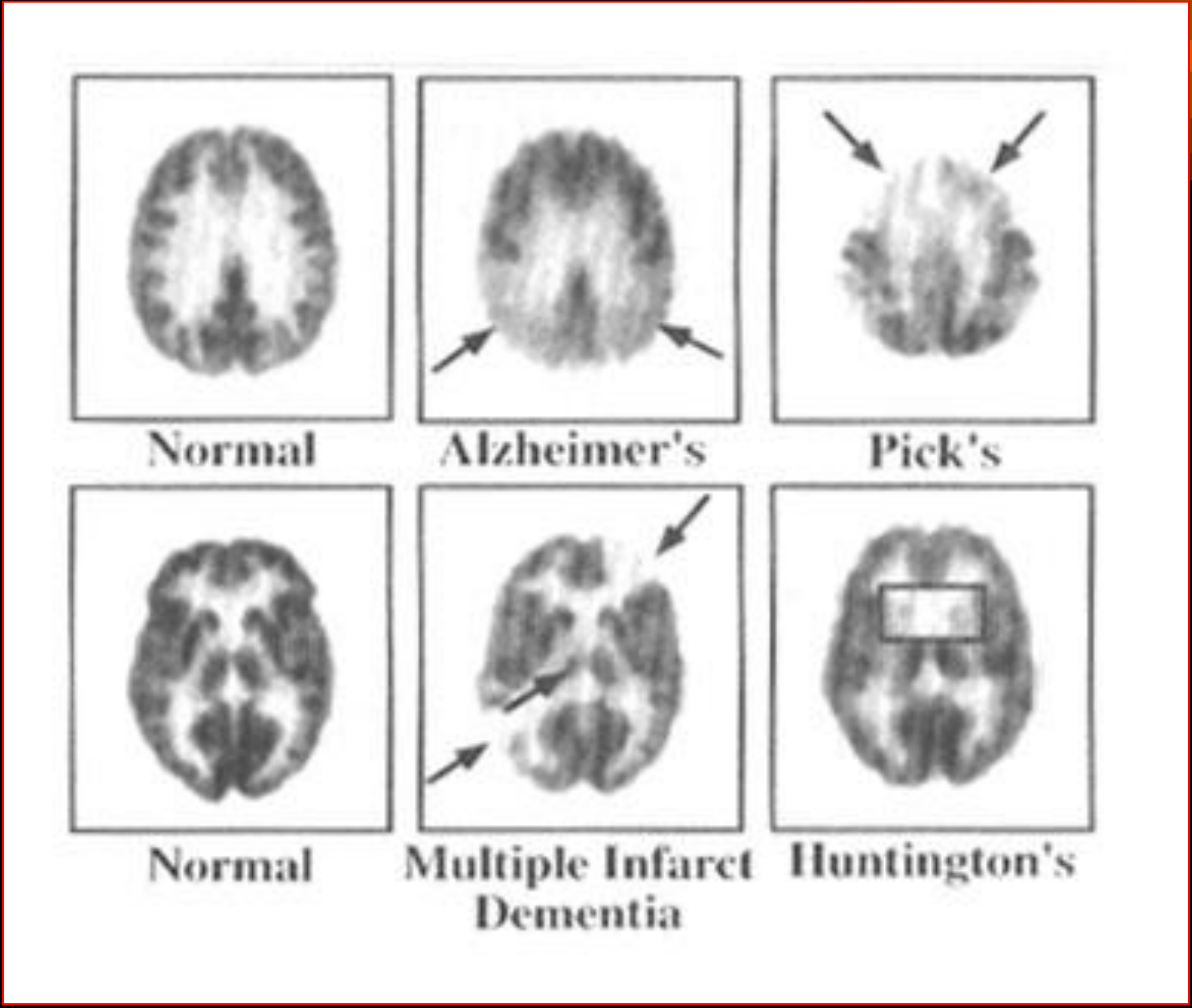
SPECT/CT imaging of brain perfusion



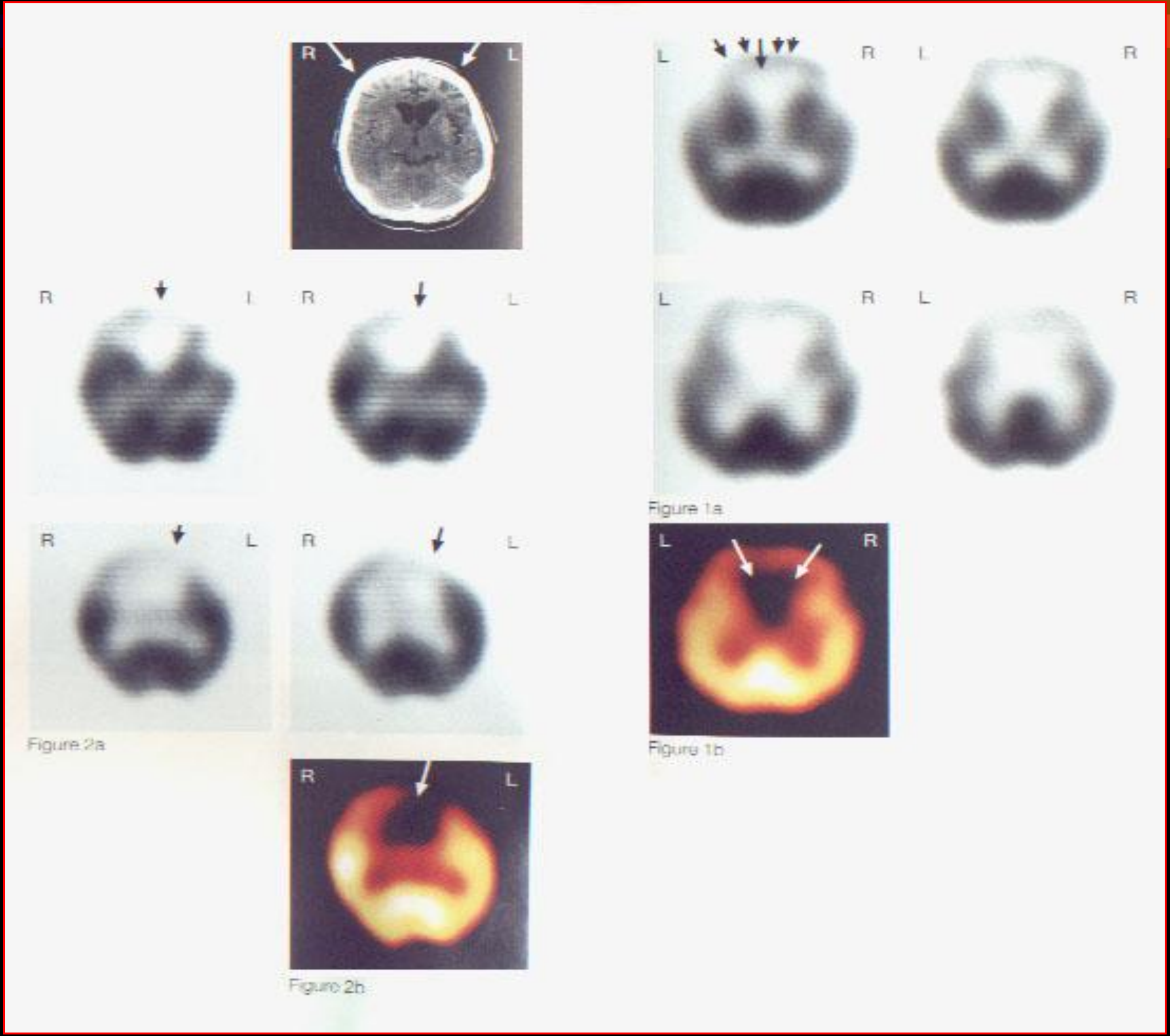




The changes of the brain perfusion in different diseases

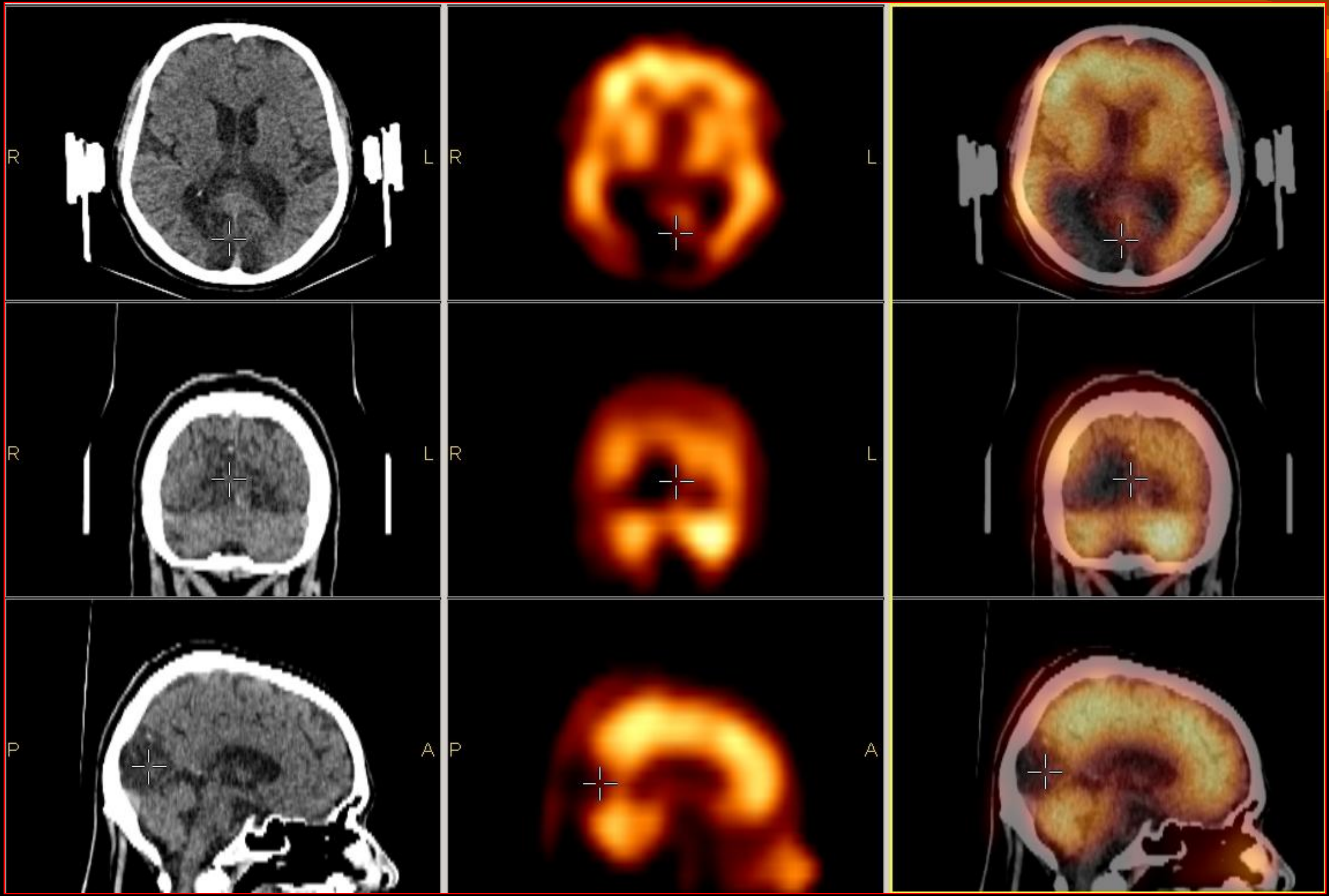


Pick disease: atrophy in both frontal lobes



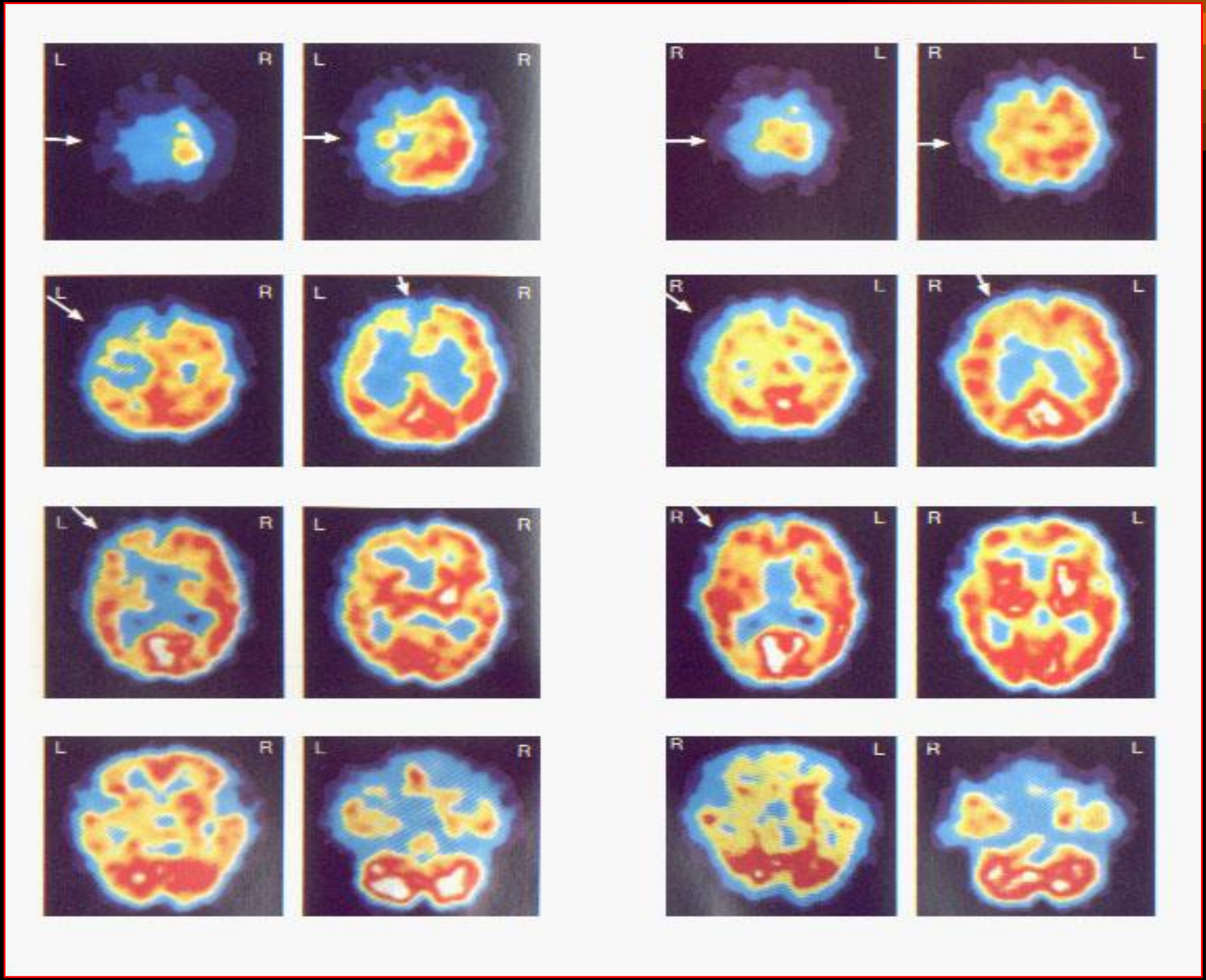
Perfusion defect (stroke) in the right occipital region (produced blindness)

CT | **SPECT** | **SPECT/CT**

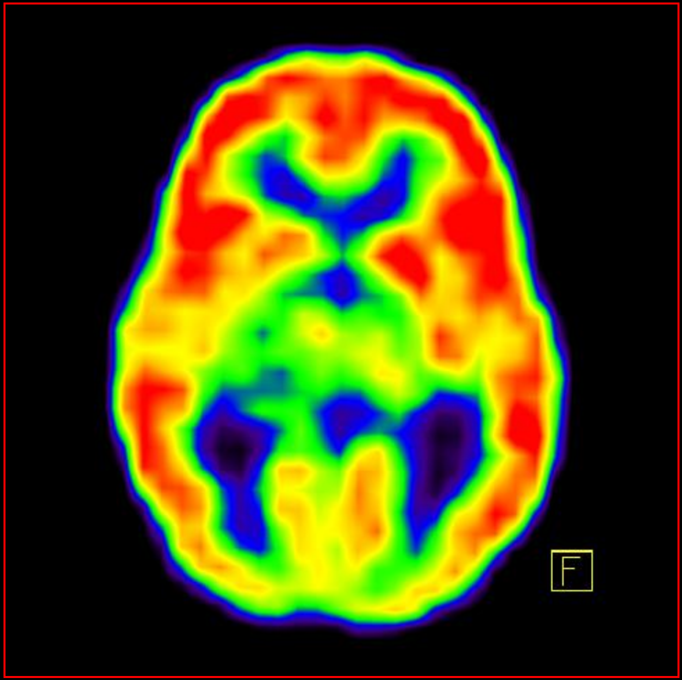


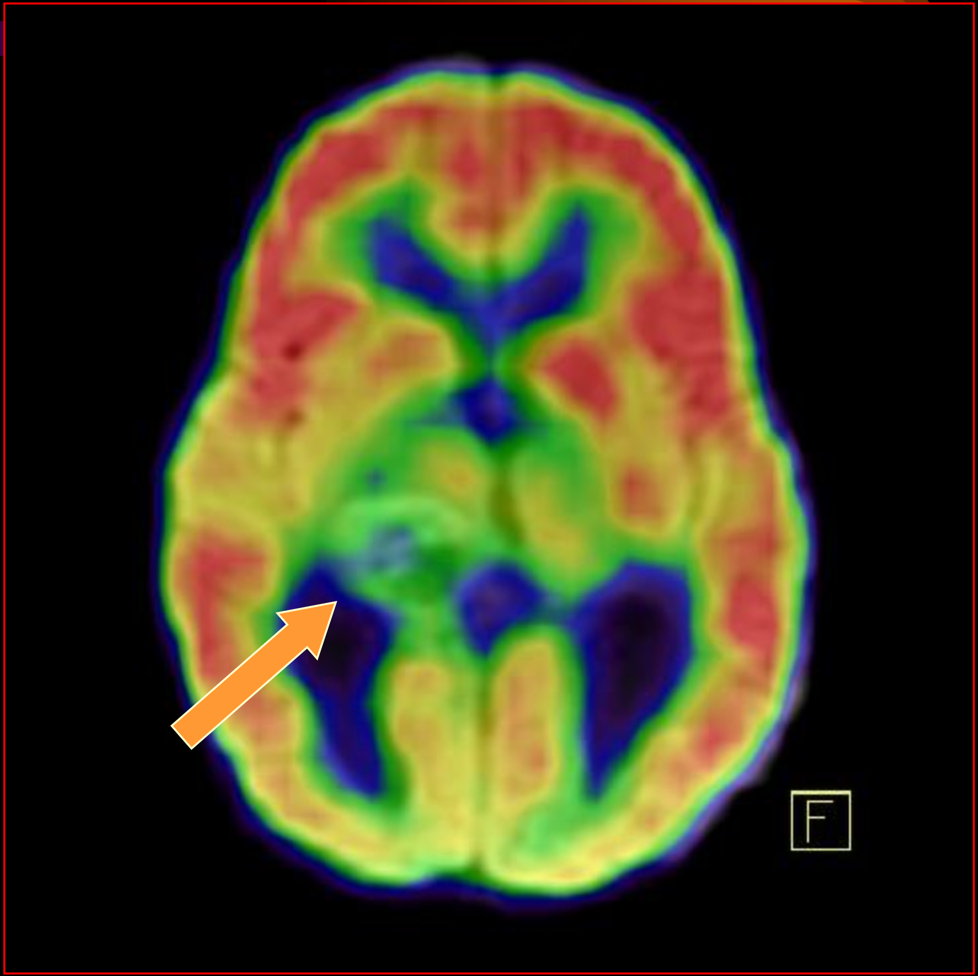
Occlusion of left internal carotis artery

Before operation **After operation**

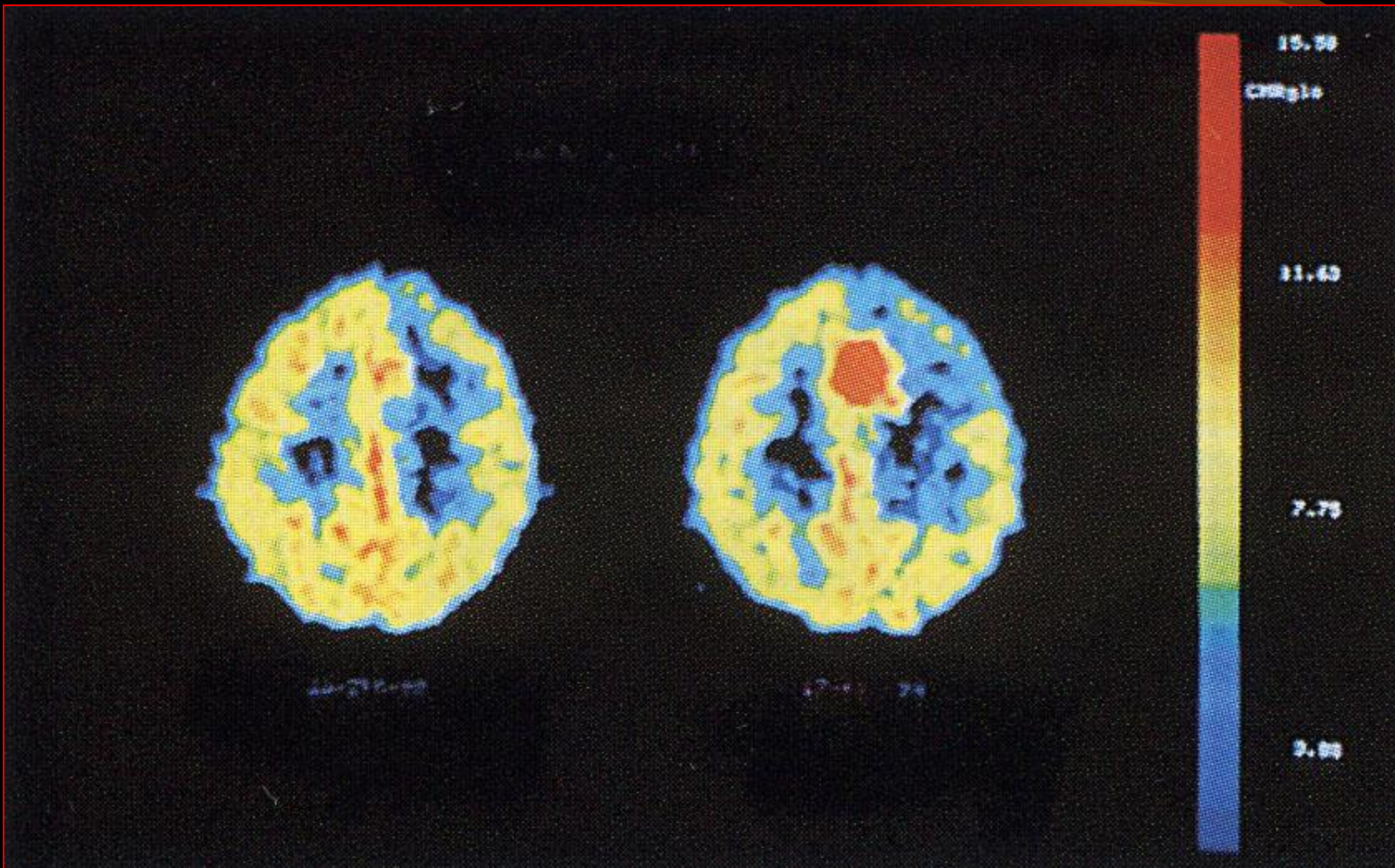


Cerebral glioma by 18-FDG-PET





Recidiv parasagittal meningeoma after operation (18-FDG)




Thank you for your attention!