# Nuclear medicine static and dynamic studies

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# Imaging tehniques

Anatomy | Physiology | Metabolism | Molecules

X-ray/ CT

PET / SPECT

MRI

MR spectroscopy

fMRI

Ultrasound

**Hybrid imaging: SPECT/CT, PET/CT, (PET/MRI)**

# Radioactivity

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

**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 combination of protons and neutrons are stable, the other ones are radioactive, which become stable form by different radioactive radiations.**

## The activity

- of a radioactive element is usually given in
  disintegrations per second or minute,
  this is the *dps* or *dpm*

## The unit of the activity

- 1 Bq (Bequerel) = 1 disintegration/second
- 1 kBq = $10^3$ disintegrations/sec
- *1 MBq =* $10^6$ *disintegrations/sec* (used in diagnostics)

## Measurement

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

# The half-life

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

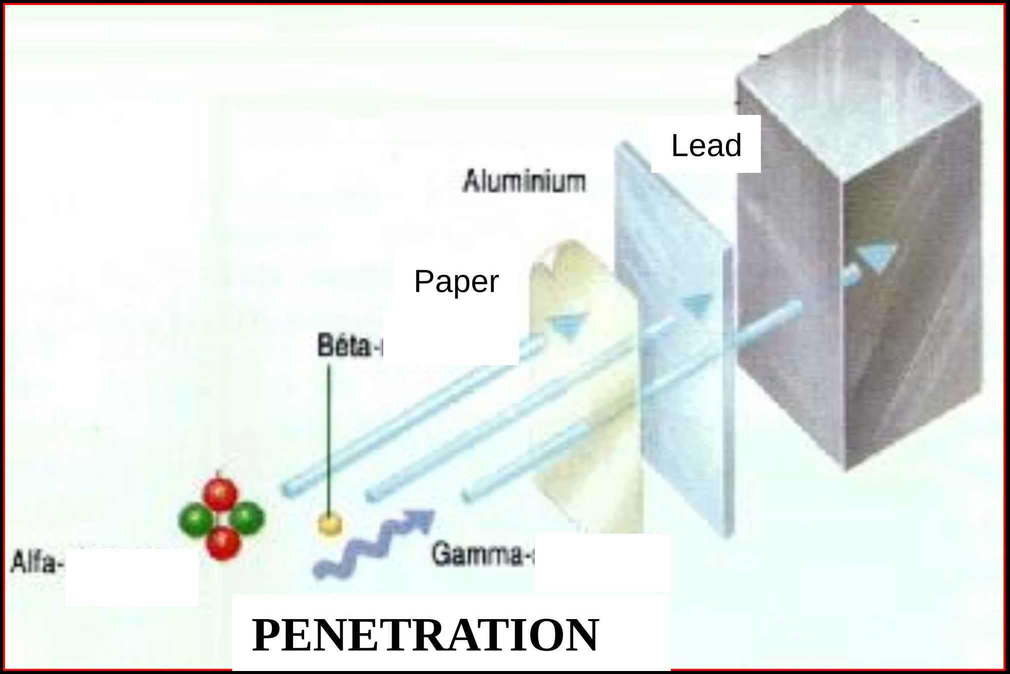
**- Physical half-life is characteristic for an element, independent on the external conditions**
**- Biological half-life depends on the physiological conditions (e.g. increased fluid input)**
**- Effective half-life: $1/T_{eff} = 1/2T_{phys} + 1/2T_{biol}$**

# Energy

**comes out of the nucleus during the radiation, constant for the several radioactive atoms.**
**- eV or keV (used in diagnostics) or MeV**
**1 eV is extremly small!**

# 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 with in a few micrometers
– cannot 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 almost impossible
- the biological damage to tissues is high
- very suitable for radiotherapy
- e.g. $^{131}$Iodine for thyroid ablation

# 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
– it can be detected externally well!
– e.g. 99mTechnetium for the diagnosis

# The most commonly used isotopes

| Isotope | Radiation | Half-time | Energy |
|---|---|---|---|
| 99m-Tc | 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 | 172.2 keV |
| 201-thallium | γ | 3 days | 76 keV(95%) |

# Equipments I.

## Gamma-camera

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

# Layout of the gamma-camera

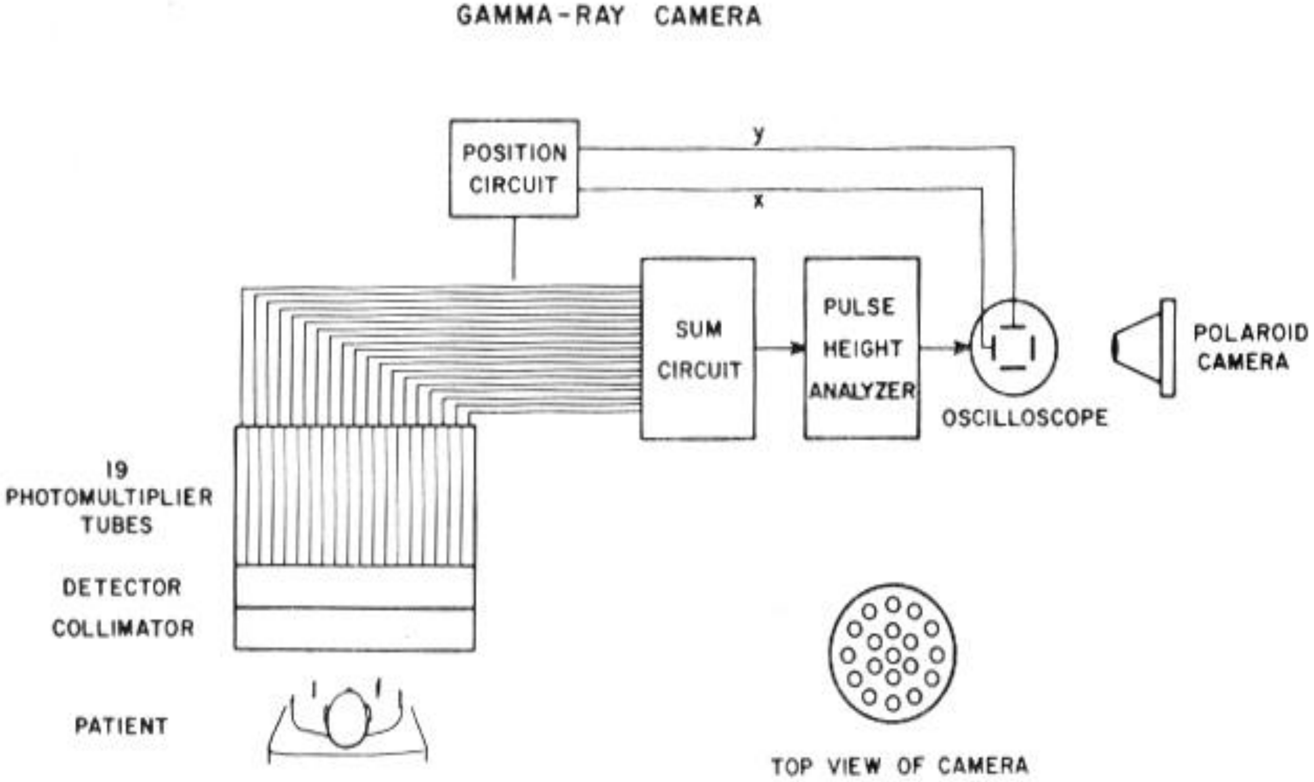



Fig. 1.11. The basic components of an Anger $\gamma$-ray camera. There is a one-to-one correspondence between the location of $\gamma$-ray interactions in the scintillation crystal and the location of the dot flashed on the oscilloscope screen.

# Equipments II.

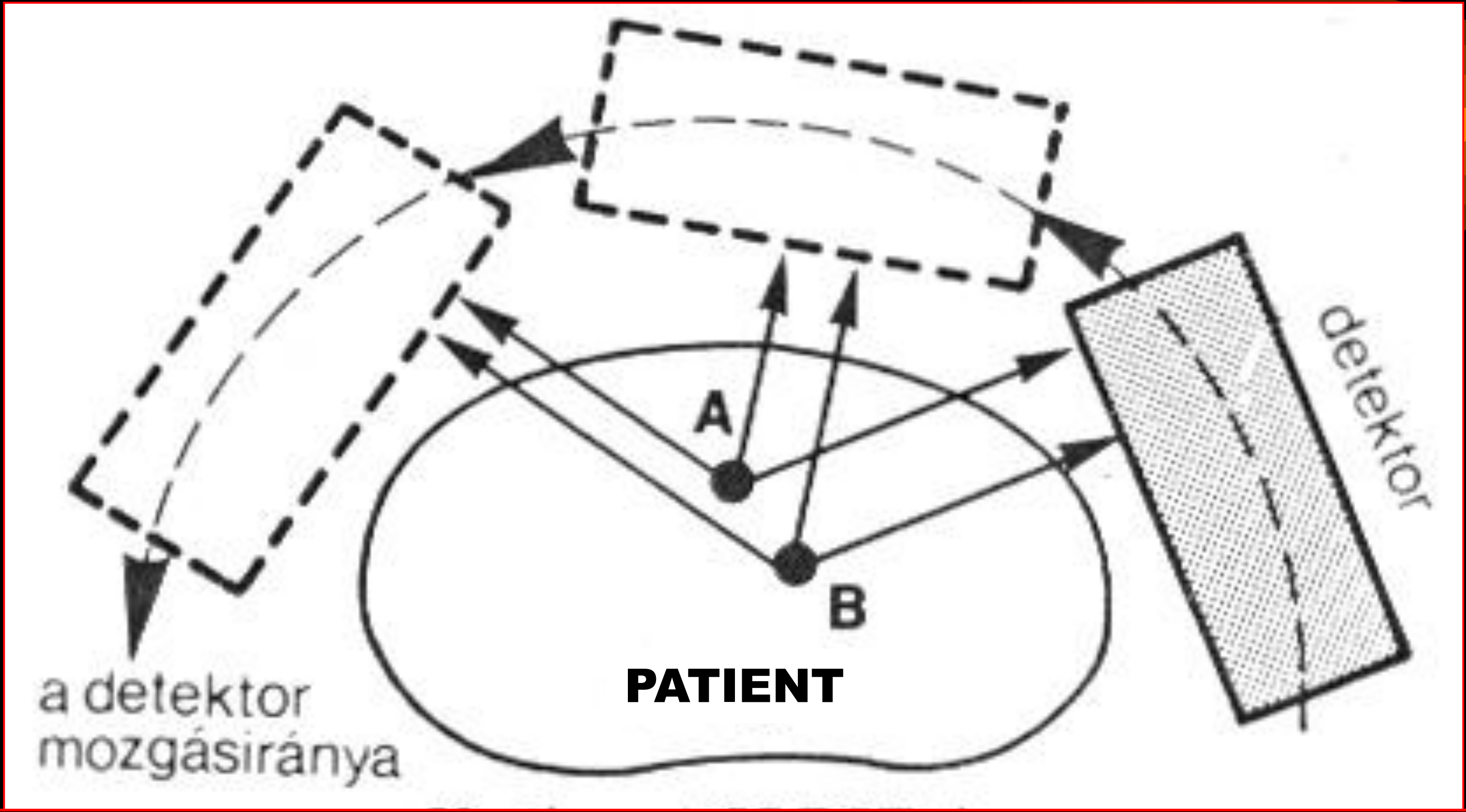
**SPECT Single Photon Emission Computer Tomograph**

**SPECT/CT: multimodality!**

**- the computer program reconstruates the transversal, sagittal and coronal slices of the organ**

**+ fused 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

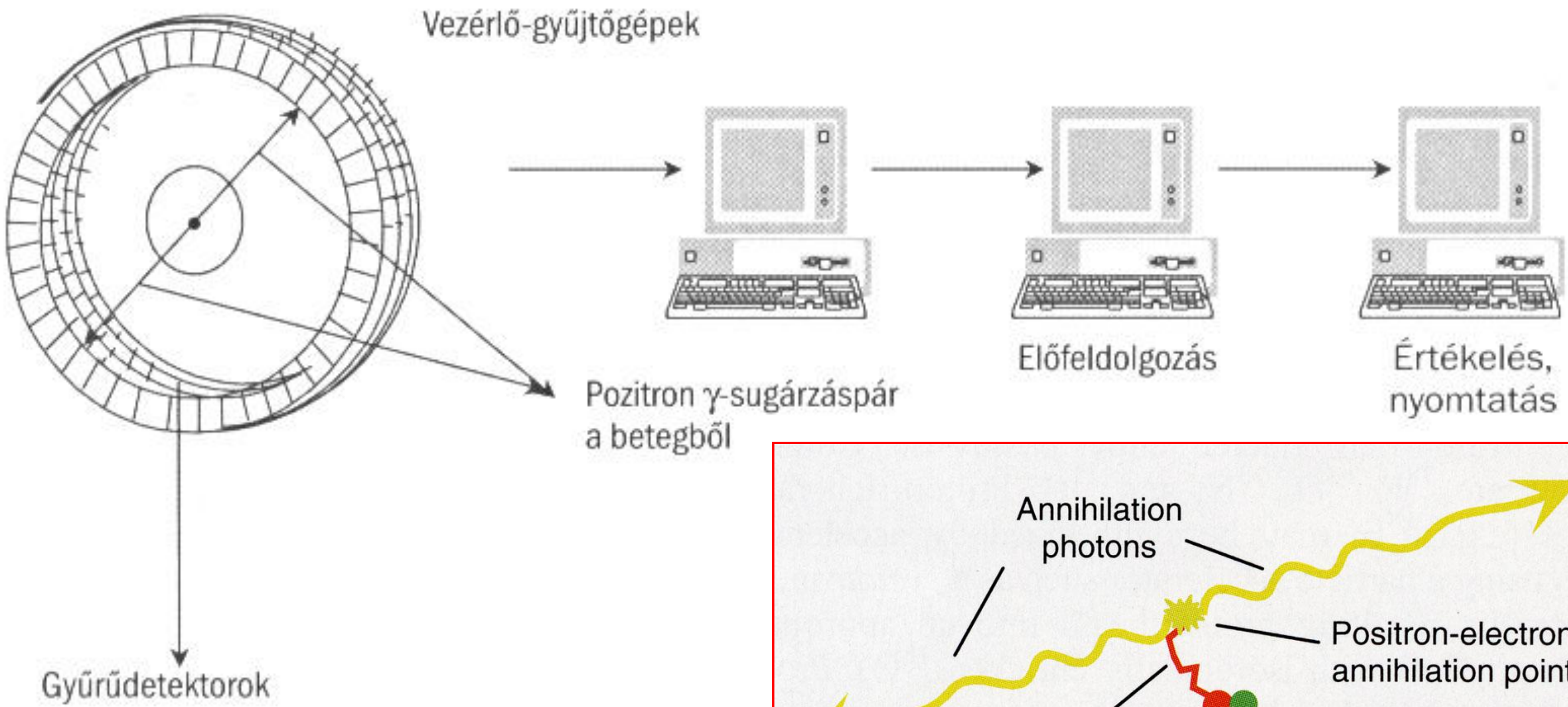
- too many protons are in the nucleus
- its life is very short, when it slows down, it combines with a normal electron in a process known annihilation, which destroyes both the electron and positron and produces two energetic photons each with 511 keV
- they are used for PET examinations
- the metabolic changes of the tumors, the brain and the heart can be detected
- e.g. 18F-FDG for glucose metabolic studies

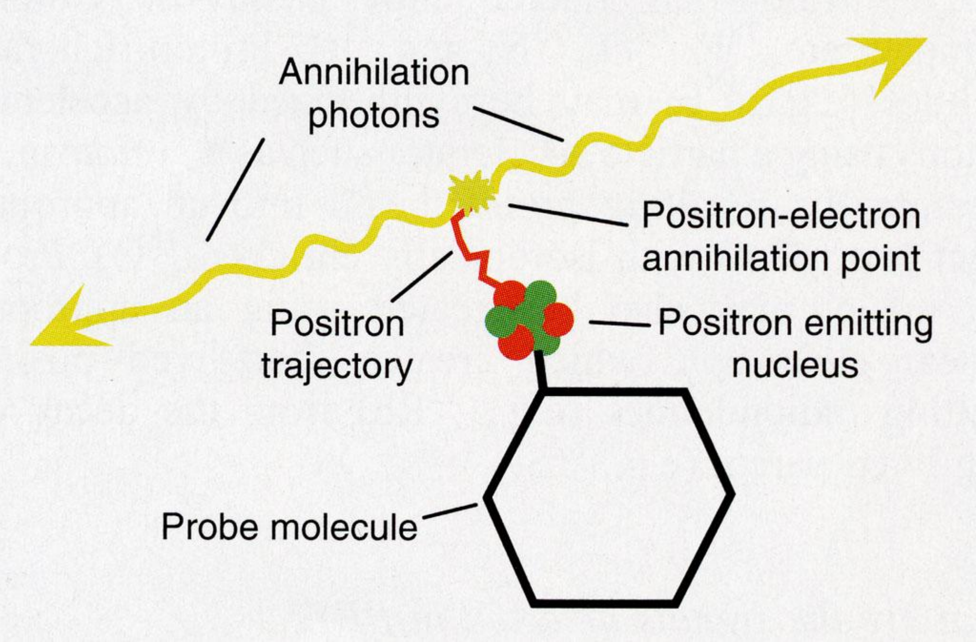
# Equipments III.

**PET:** Positron Emission Tomograph

**PET/CT:** multimodality!

# 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

# 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 any premedication
- are not associated with any morbidity and complication, have only minimal risk
- are very good for screening studies

# 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

# The types of the in vivo examinations

## Static examinations (scintigraphies):

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

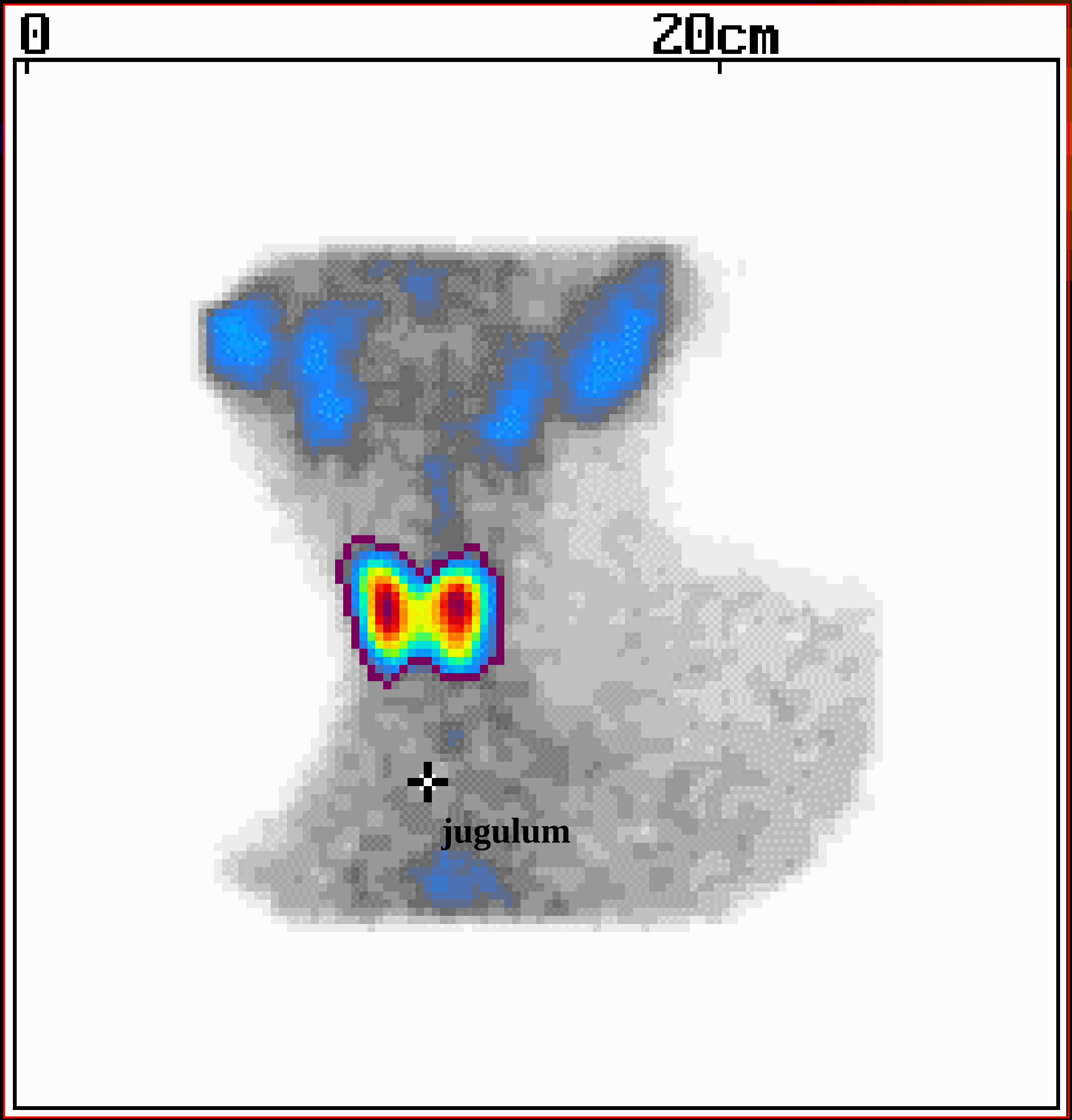
## Dynamic studies:

- 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

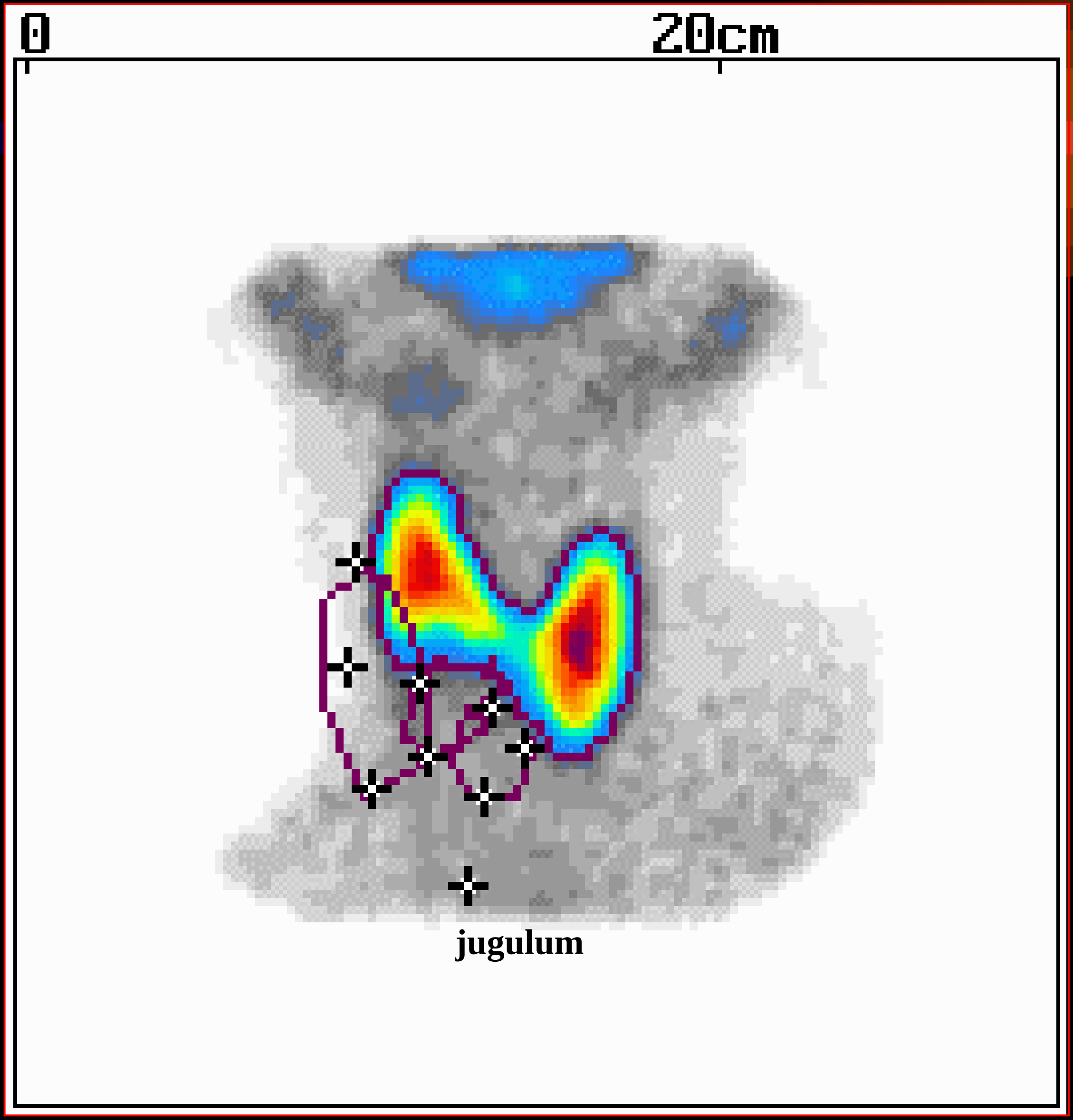
# Thyroid scintigraphy

- The function and the morphology of the thyroid and the nature of the palpable nodules can be evaluated
- Radiopharmaceutical: 40-50 MBq 99mTc-pertechnetate i.v. is used
- Imaging: 20 minutes later, from anterior view of the neck

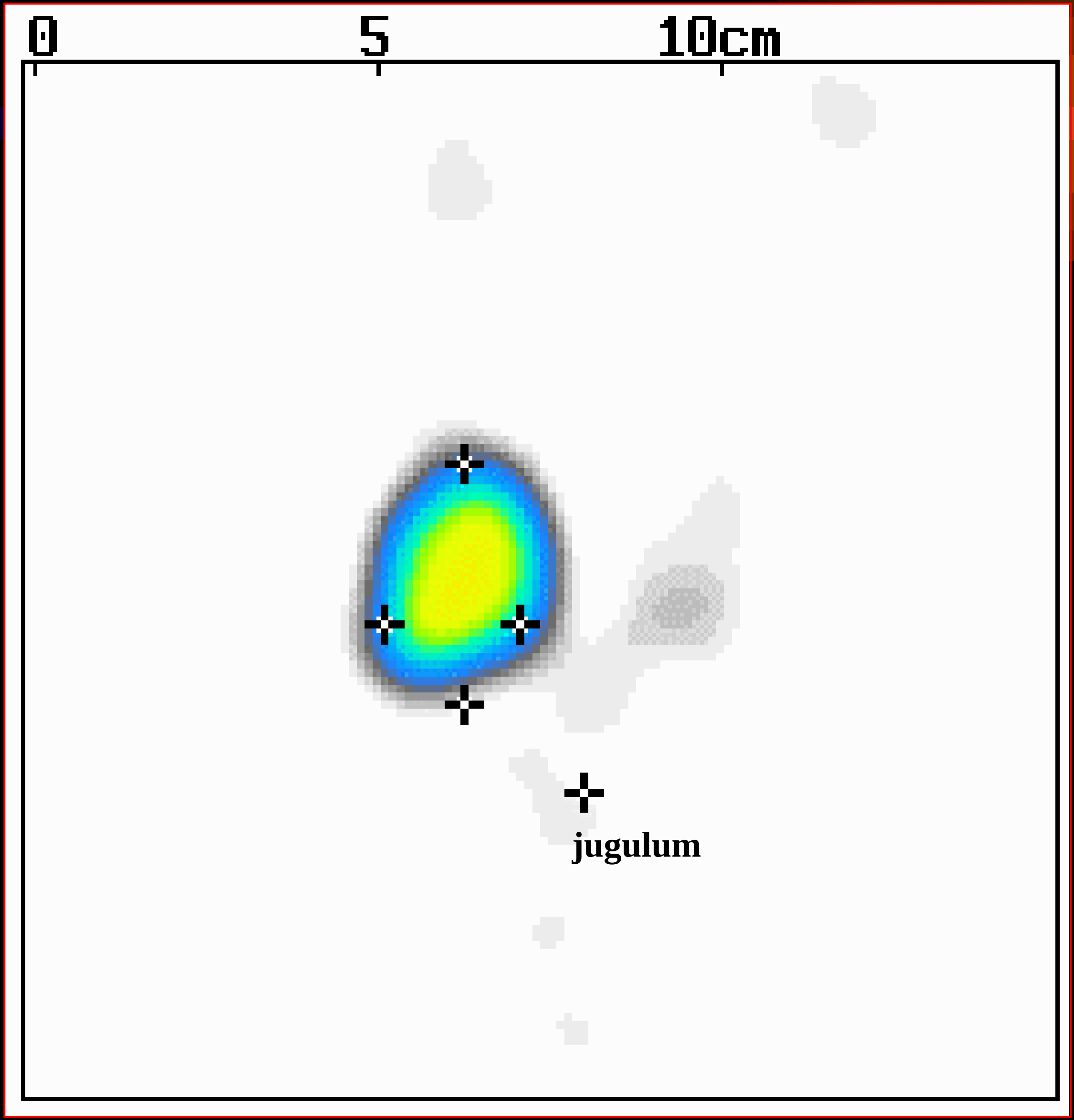
# Normal thyroid scintigraphy



# Cold nodules



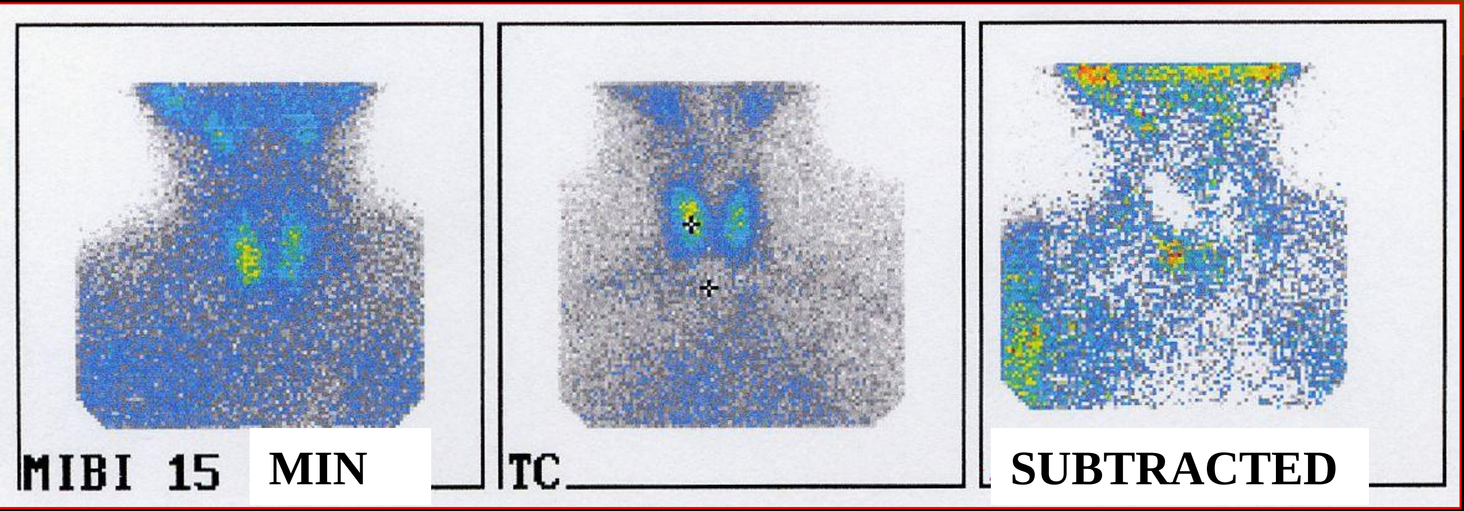
# Hot nodule



# Parathyroid scintigraphy

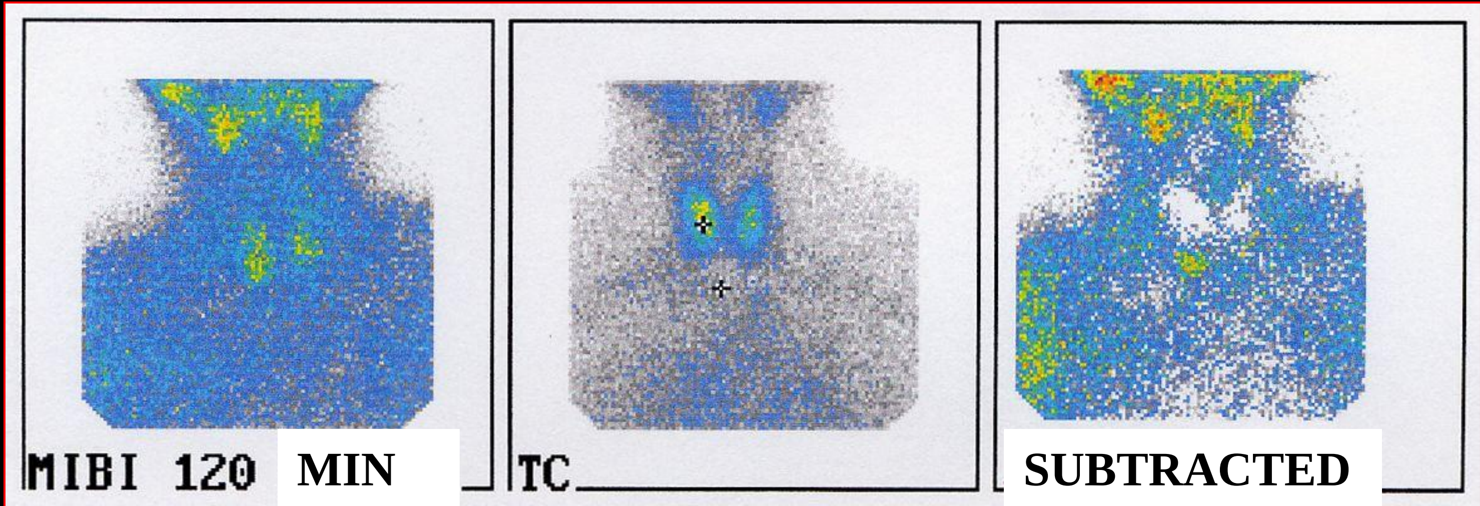
- **99mTc-sestamibi allows detection of hyperplastic glands (mitochondria), although with less sensitivity than adenomas**
- **Dual-phase or double-phase imaging refers to utilizing 99mTc-sestamibi and acquiring early and delayed images (wash out)**
- **Dual-isotope or subtraction studies refer to protocols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

# Parathyroid adenoma by subtraction „wash-out" technique

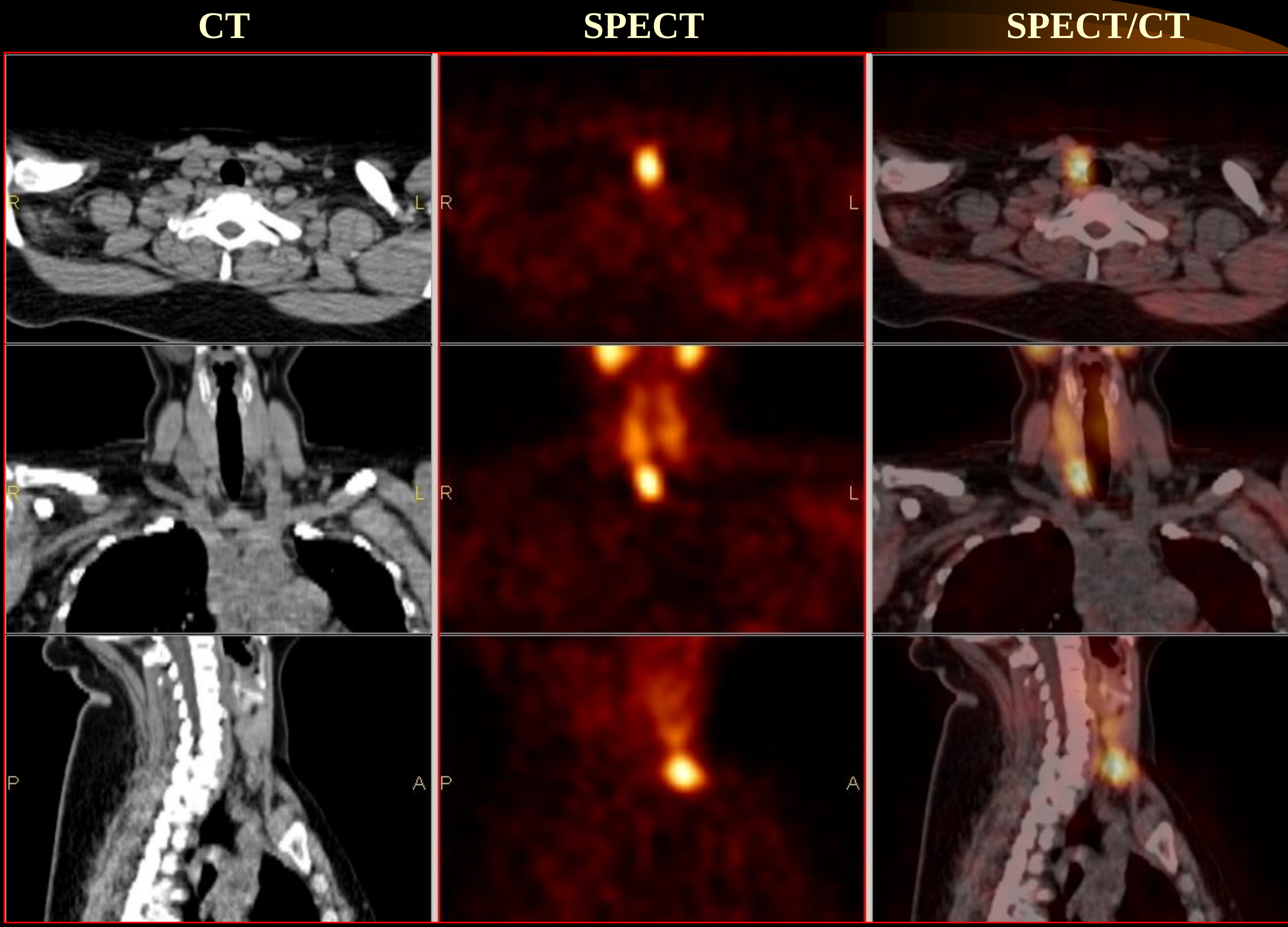



Early phase

Delayed phase



# Parathyroid adenoma by SPECT/CT



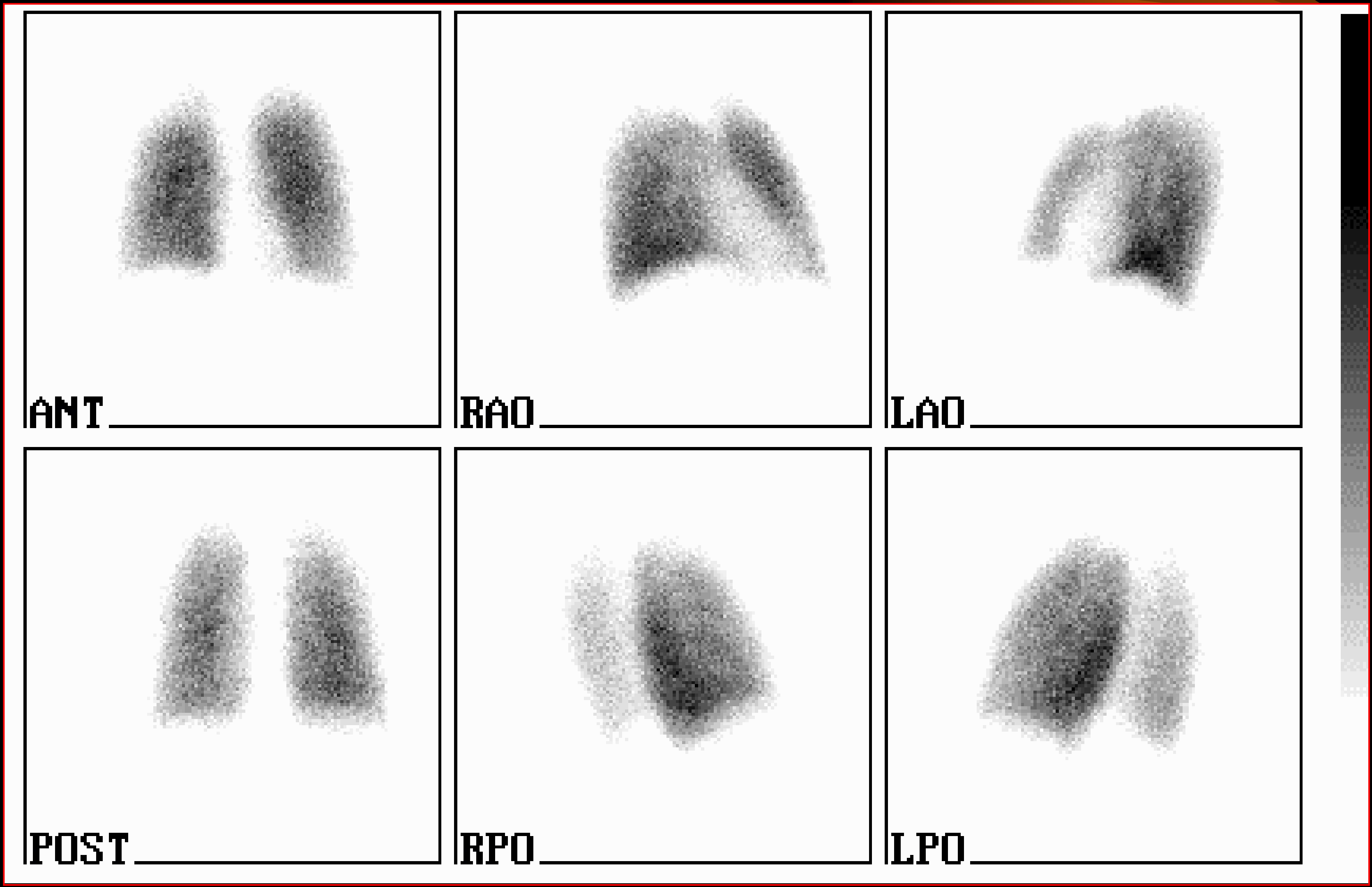
# Perfusion lung scintigraphy

- **Injected subject:** 99mTc-macroaggregate albumin (MAA) with mean particles size of about 30 micrometer
  - it blocks the precapillary arterioles depends on the blood supply, but only less than 0.1 % of them and it is not permanent
- **Administration:** intravenously in lying position
- **The study can be started immediately**

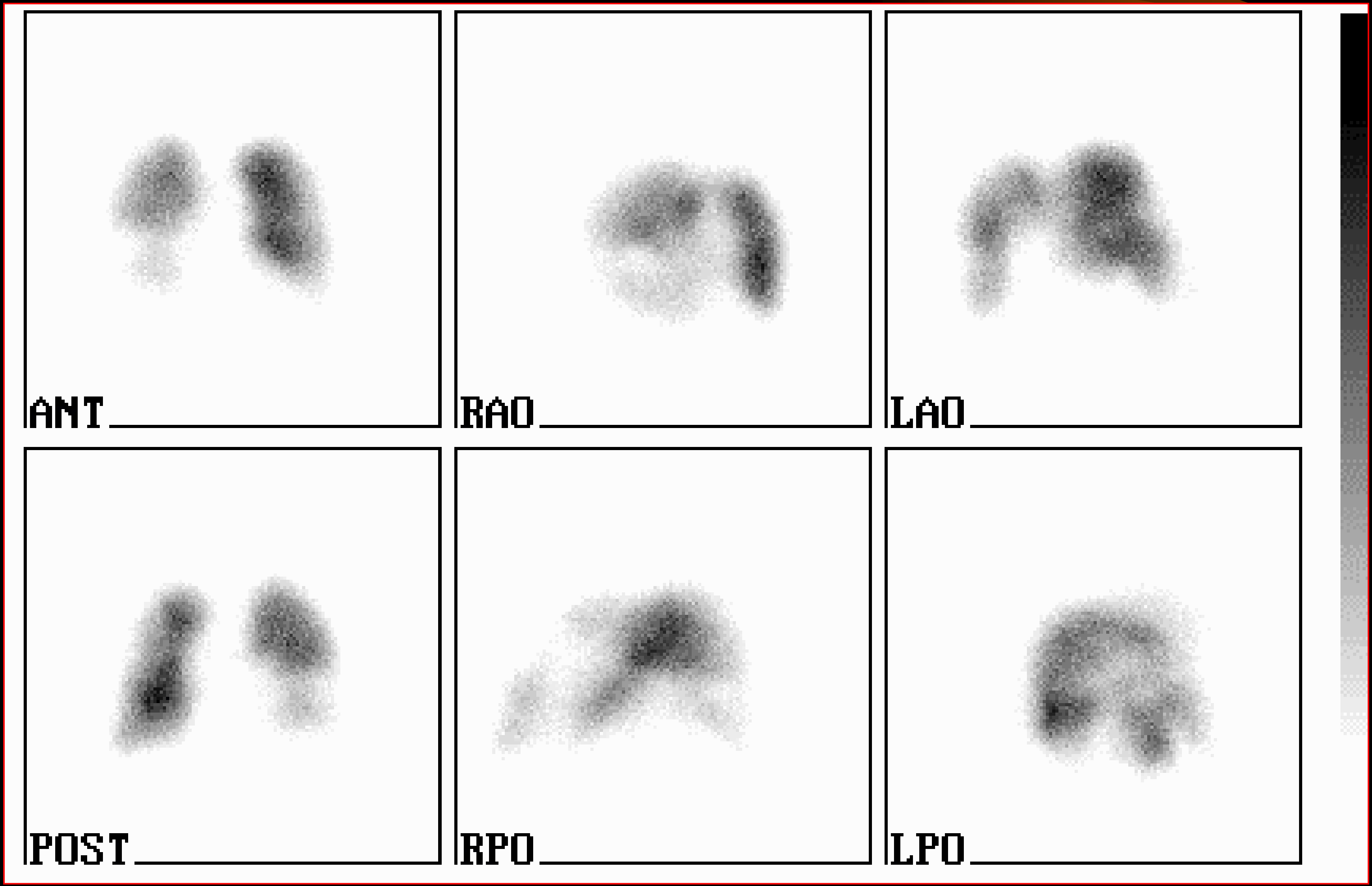
# Indications:

- Verify to pulmonary embolism (couple of the chest X-ray!)
- Evaluation of regional lung function in patients with lung tumour before the operation
- Evaluation of regional lung function in asthmatic and obstructive lung diseases
- Assesement of regional lung function after the therapy

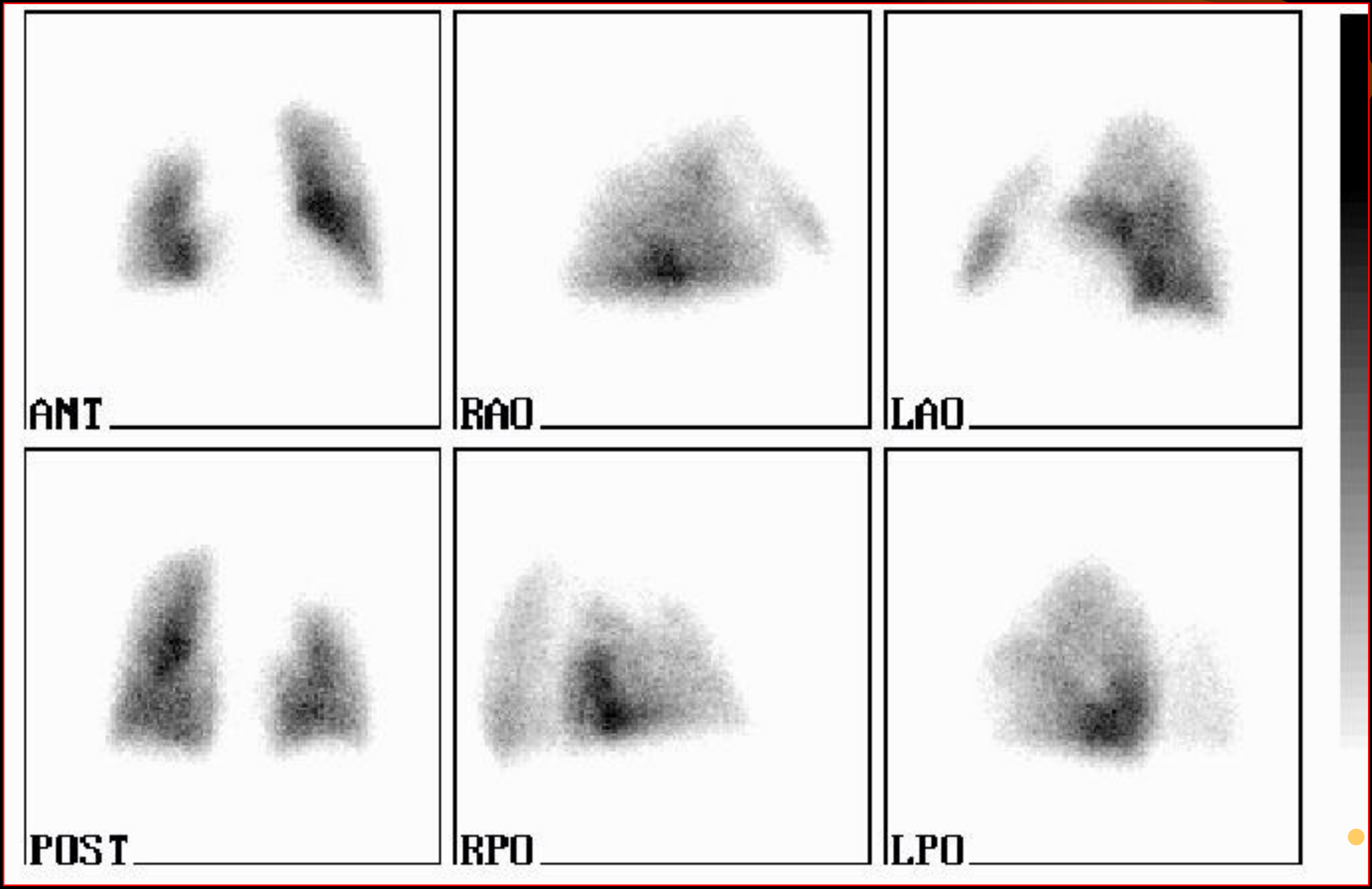
# Normal perfusion lung scan



# Perfusion defects on the lung scan

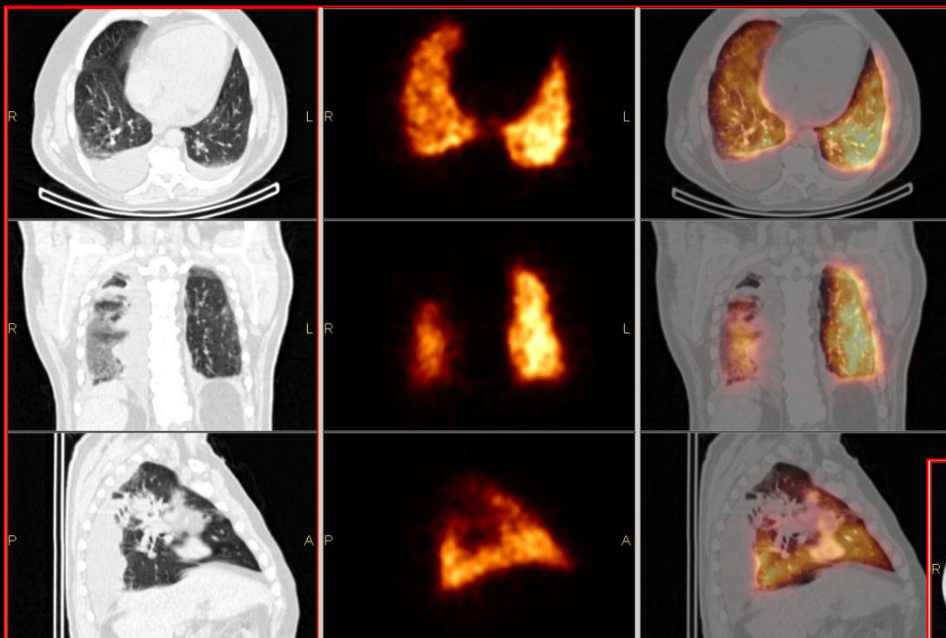


# Lung cancer in right upper lobe, embolism in the left lung?

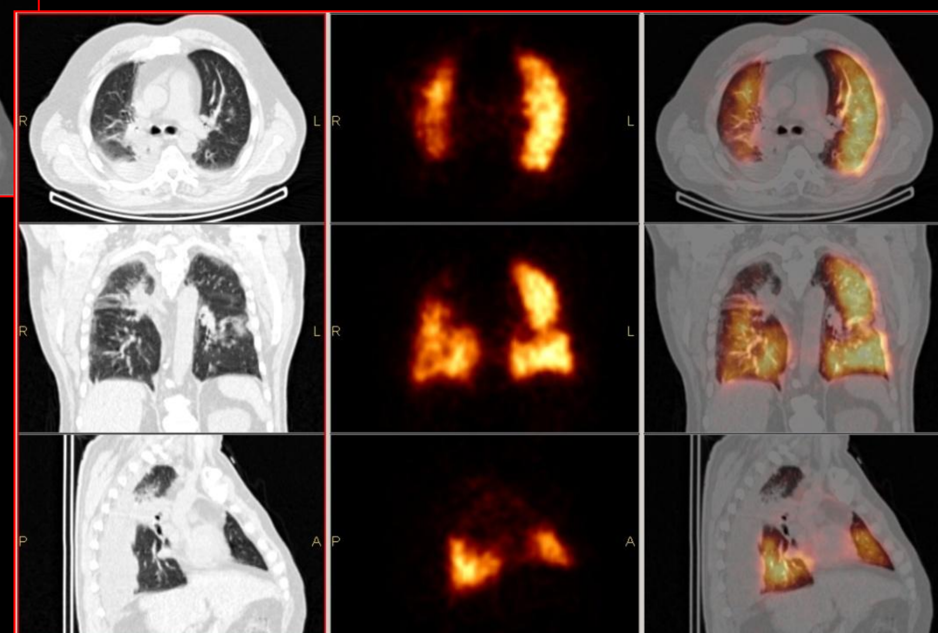


# Lung cancer in right upper lobe, no embolism, BUT metastasis in the left lung

CT SPECT SPECT/CT



CT SPECT SPECT/CT



# Inhalation or ventillation study

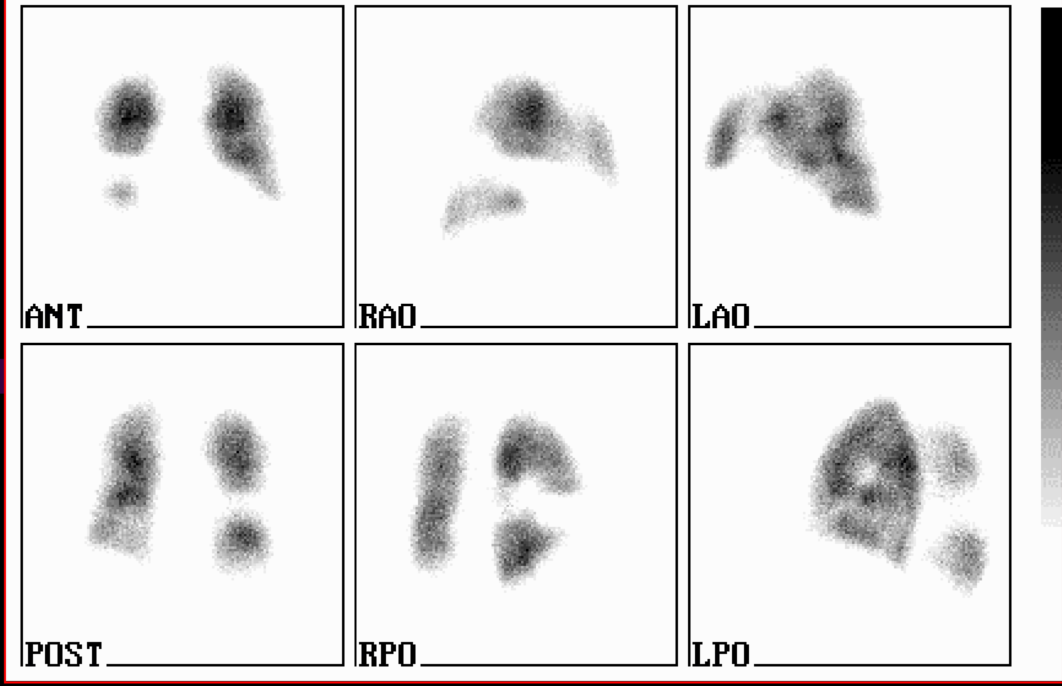
- **Inhaled subject: 99mTc-DTPA aerosol,**
  **or 133-Xe gas**

**The examination can be started immediately**

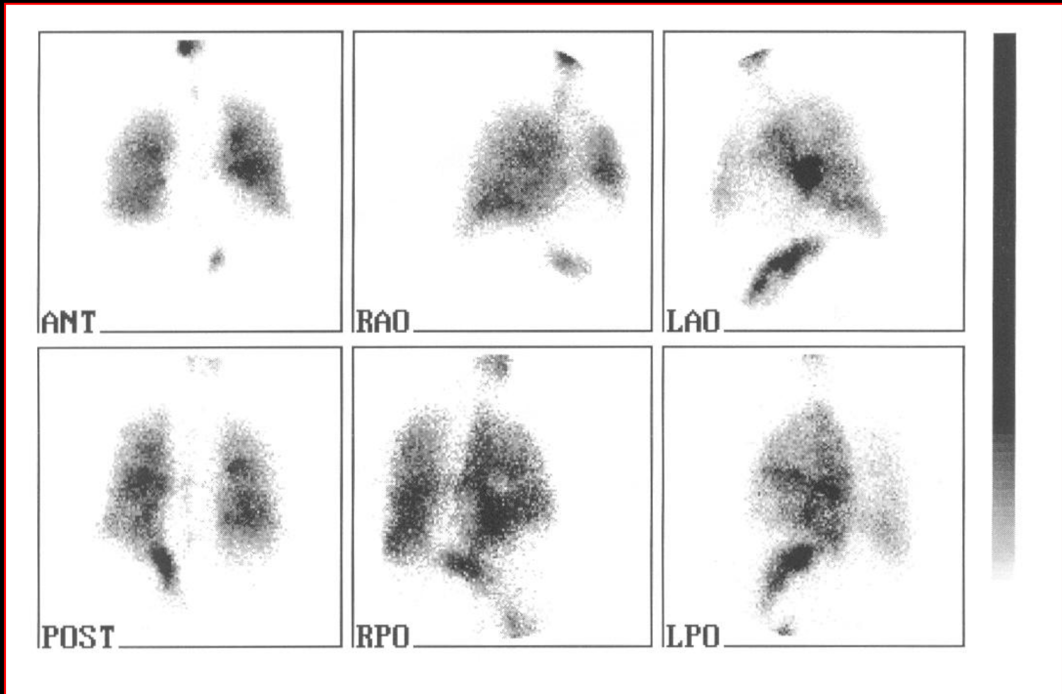
- **Indications:**
  - **pulmonary embolism**
    **(with perfusion study: „mismatch”)**
  - **lung tumor**
    **(with perfusion study: „match” )**
  - **obstructive lung diseses**
    **accumulation of the radiopharmaceutical in the central bronchii**

# Perfusion/inhalation „mismatch” in pulmonary embolism

Perfusion scintigraphy




Inhalation scintigraphy

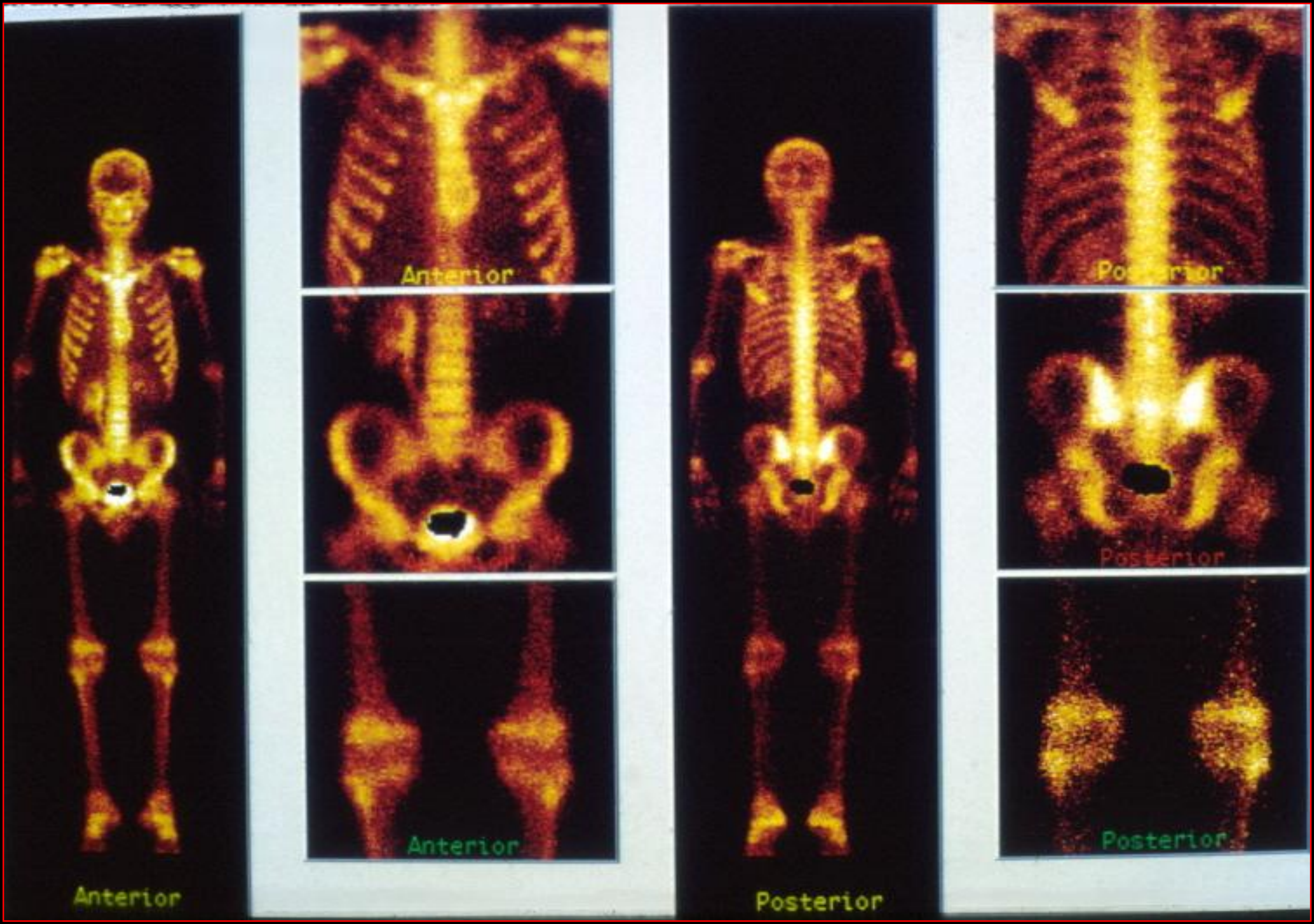


# Bone scintigraphy

Bone tissue has high activity for the intravenously injected phosphate agents. The effectivity of the incorporation depends on the blood supply and on the calcium and phosphorus metabolism of the bone. The method is very sensitive, which becomes positive in the earliest stage of the bone disorders. The increased bone metabolism already can be shown 6 months earlier than the changing of bone structure in the X-ray.

- Injected subject: 800 MBq 99mTc-phosphate (MDP, EDP, Pyrophosphate) intravenously
- The study can be started 2-3 hours later
- Important: rich fluid input!

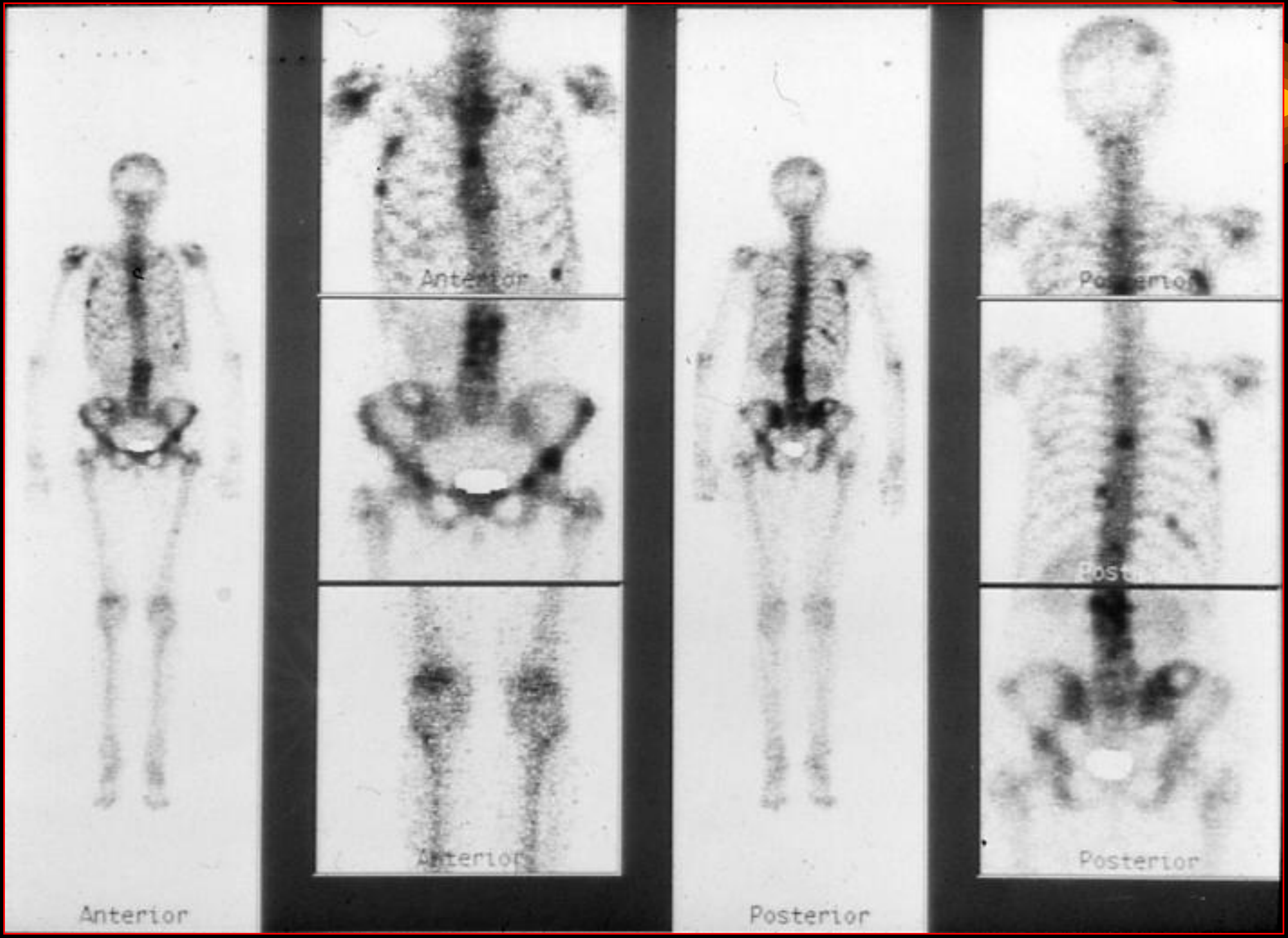
# Normal whole body bone scan



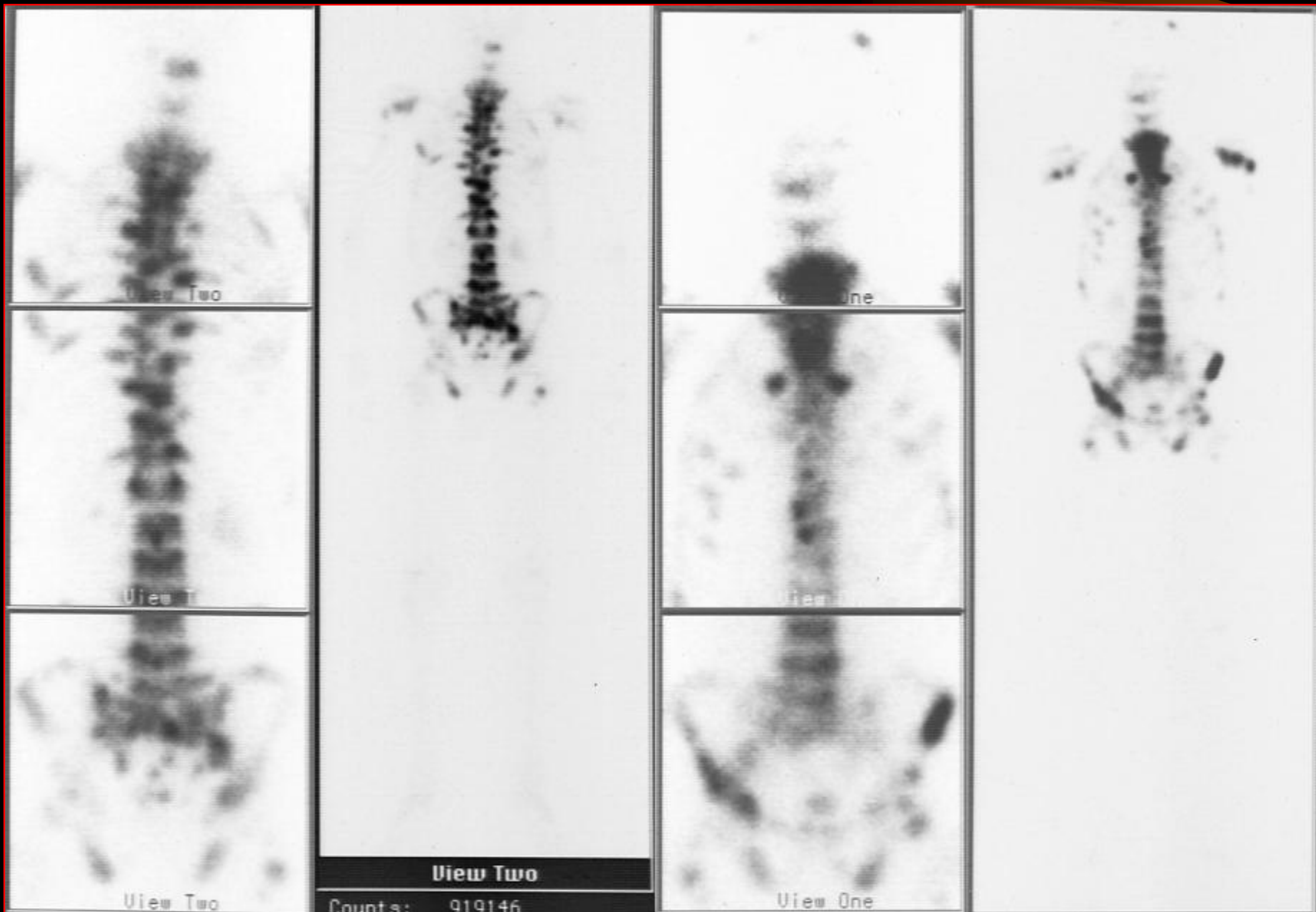
# Indications:

- Metastases of the bone
  (mamma cc., prostatic cc, lung cc, malignant melonoma, and so on)
- Primary bone tumors
- Osteomyelitis, other inflammatory diseases
- Fractures (pathologic and stress fracture)
- Metabolic diseases (e.g. Paget disease)
- Osteonecrosis (e.g. M. Perthes)

# Multifocal metastases in breast cancer

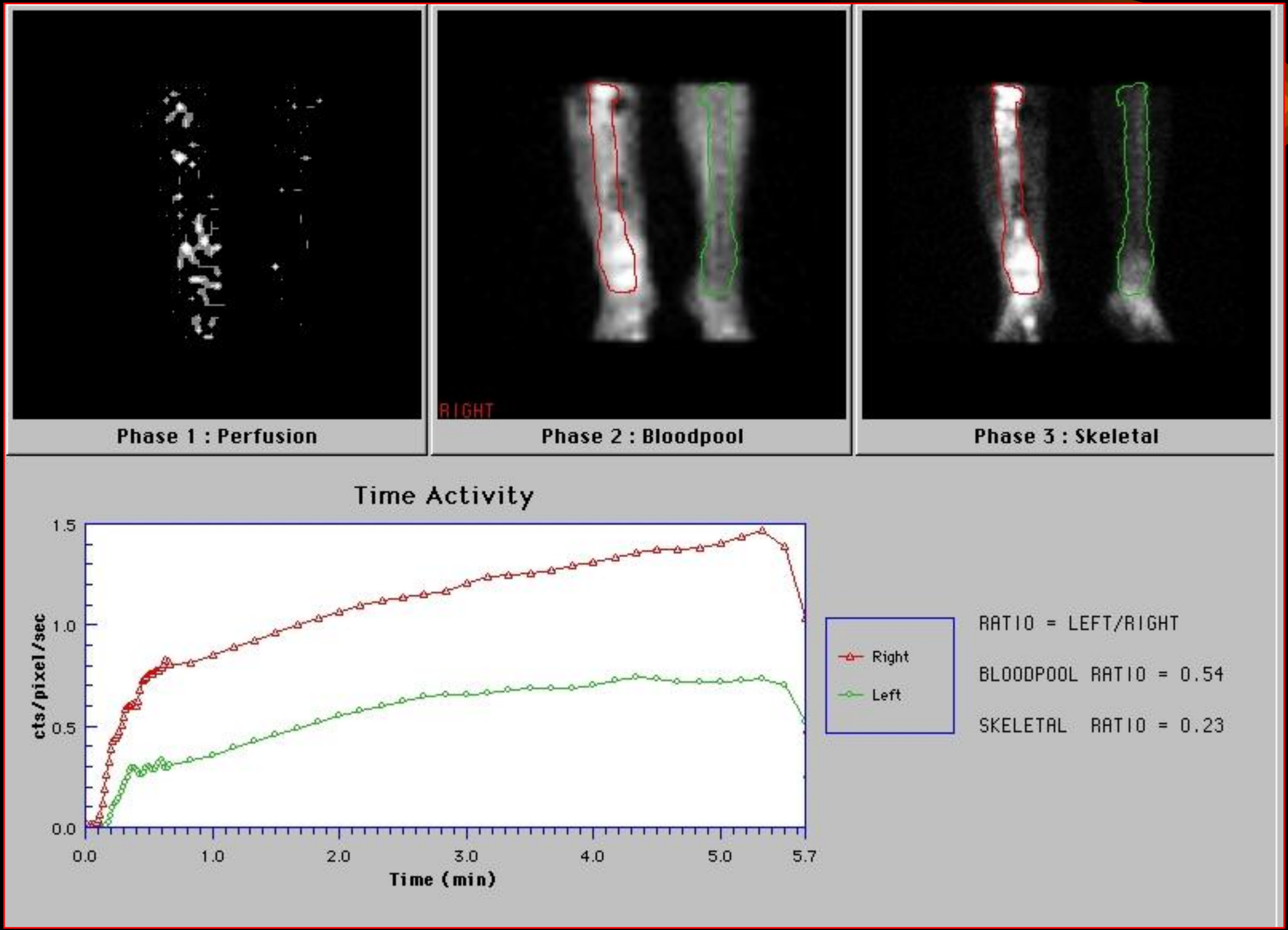


# Multifocal hot-spots in prostatic cancer

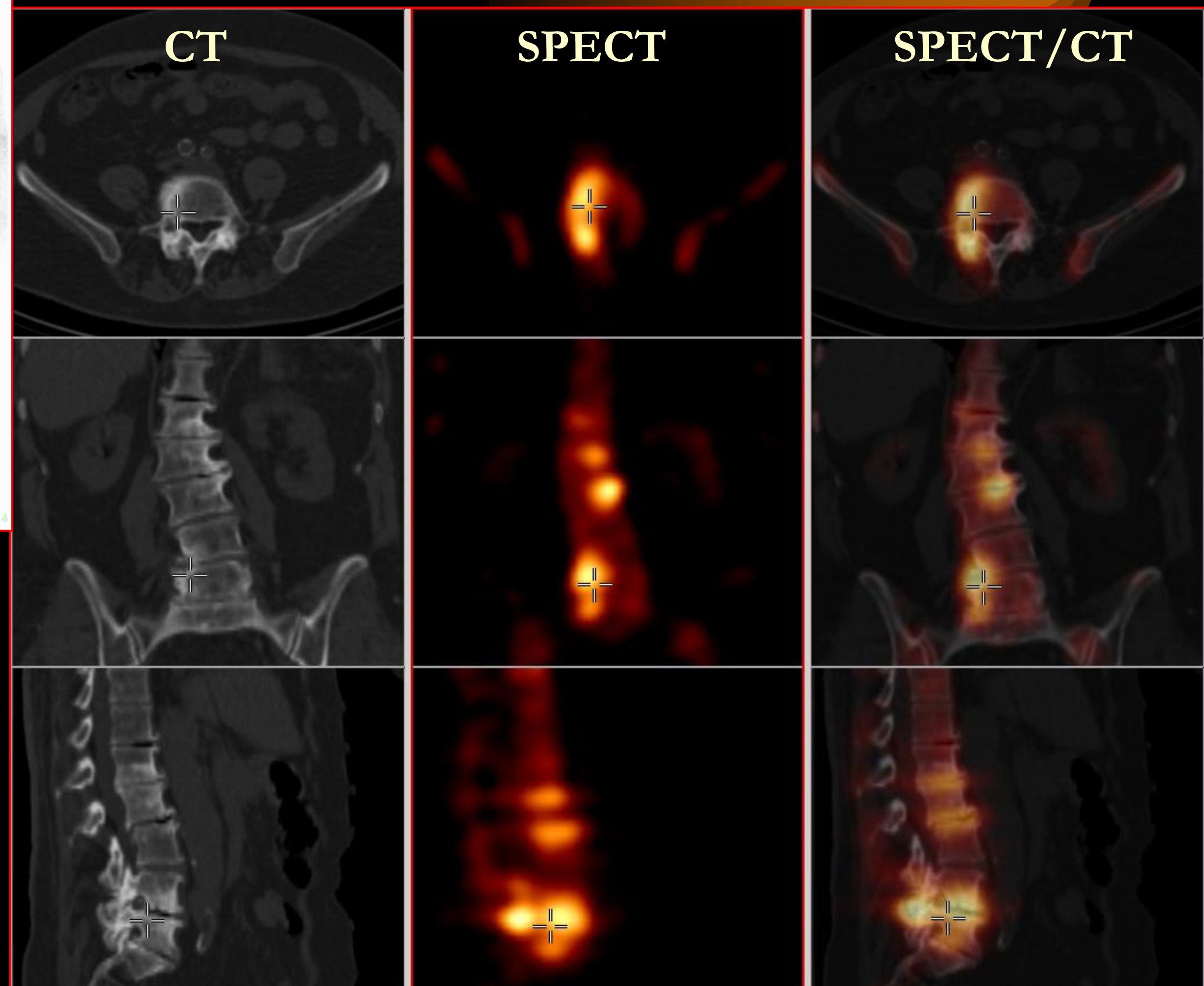


# Osteomyelitis tibiae l.d.

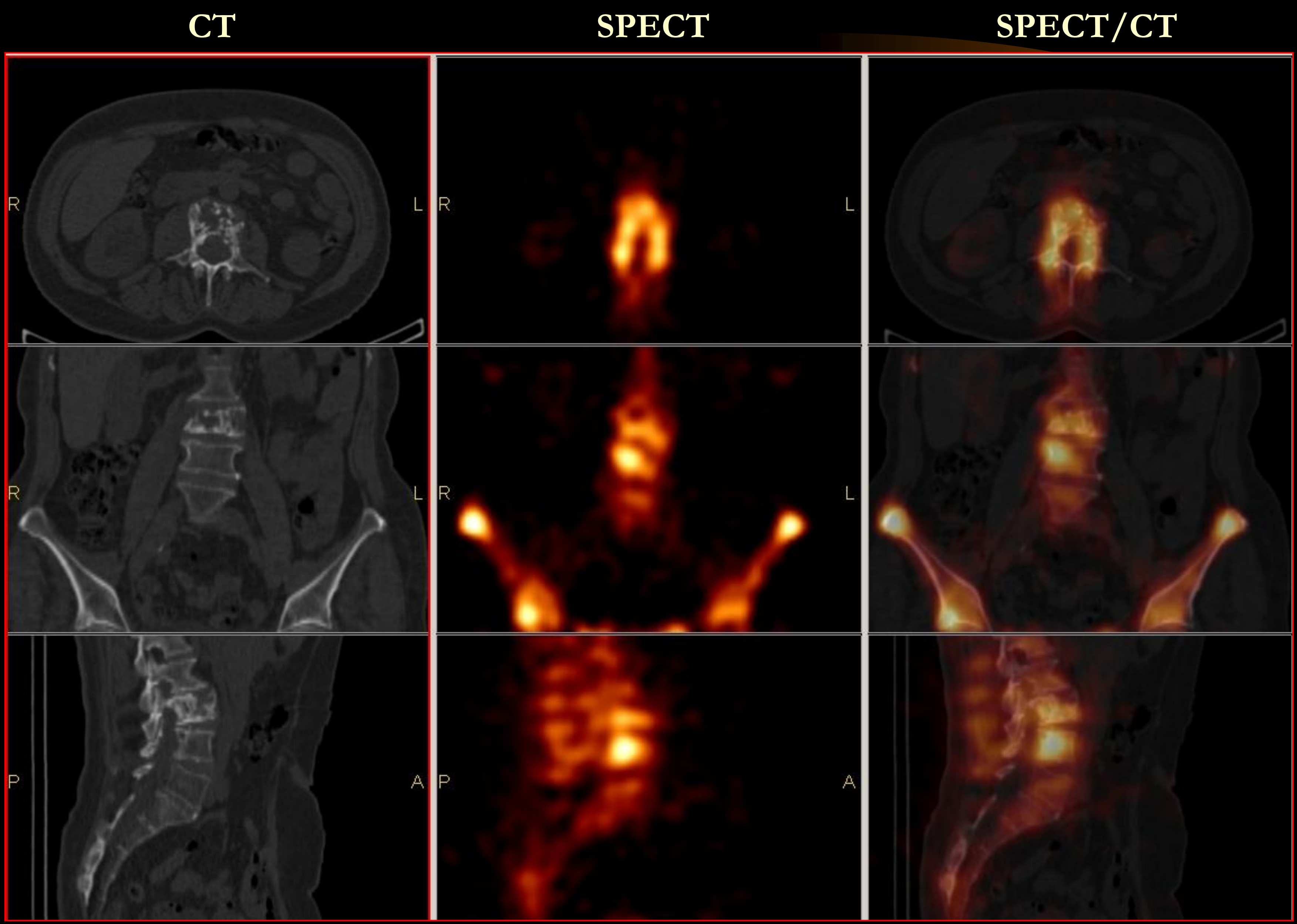
# Osteomyelitis tibiae l.d. - 3-phase bone scan



# Hot spots in the vertebras: no metastases BUT degenerativ disorders



# Bone metastases in the lumbal vertebras

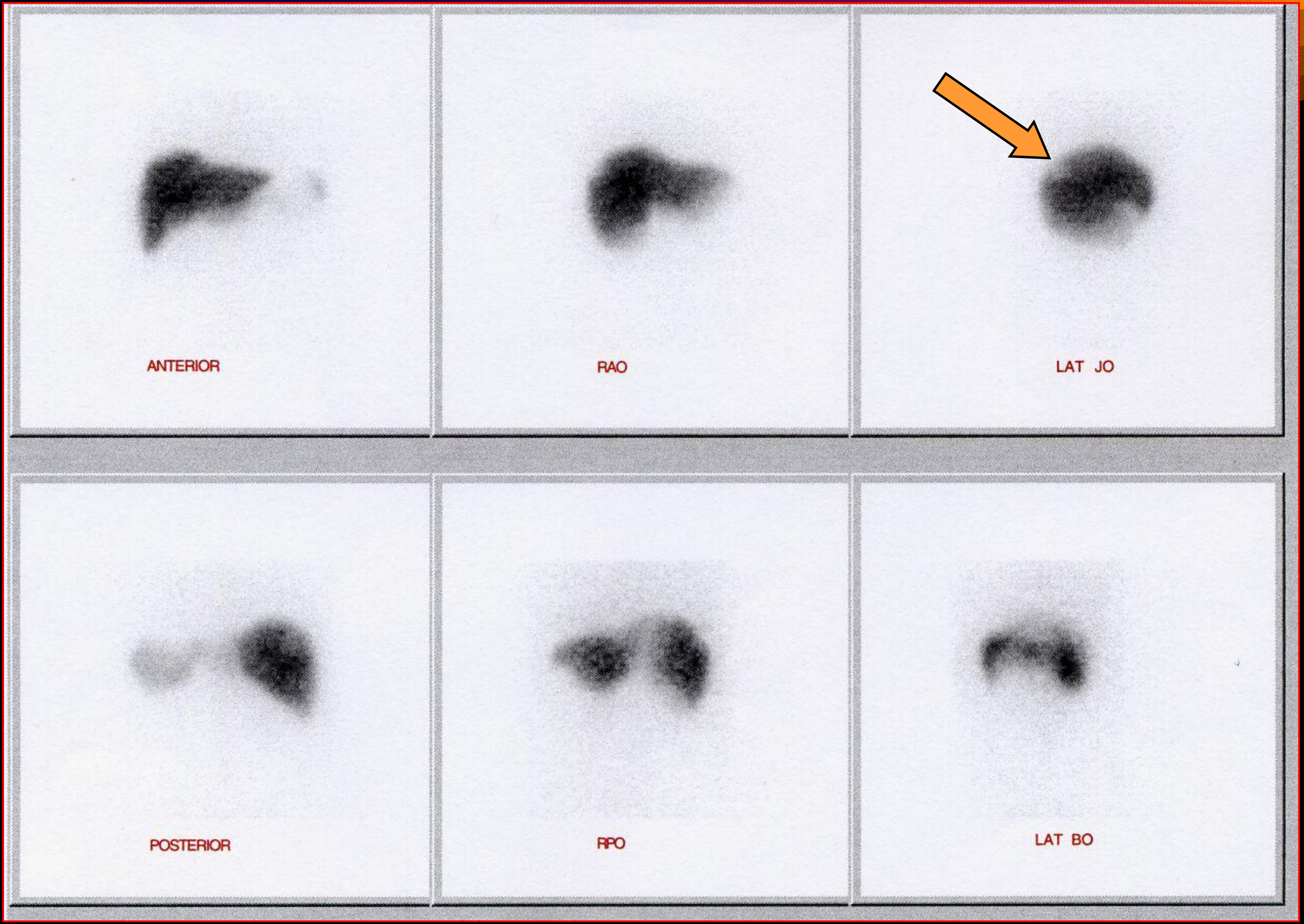


# Liver scintigraphy

- The labelled colloid (200 MBq 99mTc-Fyton) is enhanced in the RES-cells of the liver
- Static imaging (20 minutes after the i.v. injection) from 6 directions + SPECT examination is very useful
- The focal defect is indicated by the decreasing and/or the lack of the activity (primary tumors, metastases, cysts, haemangiomas)

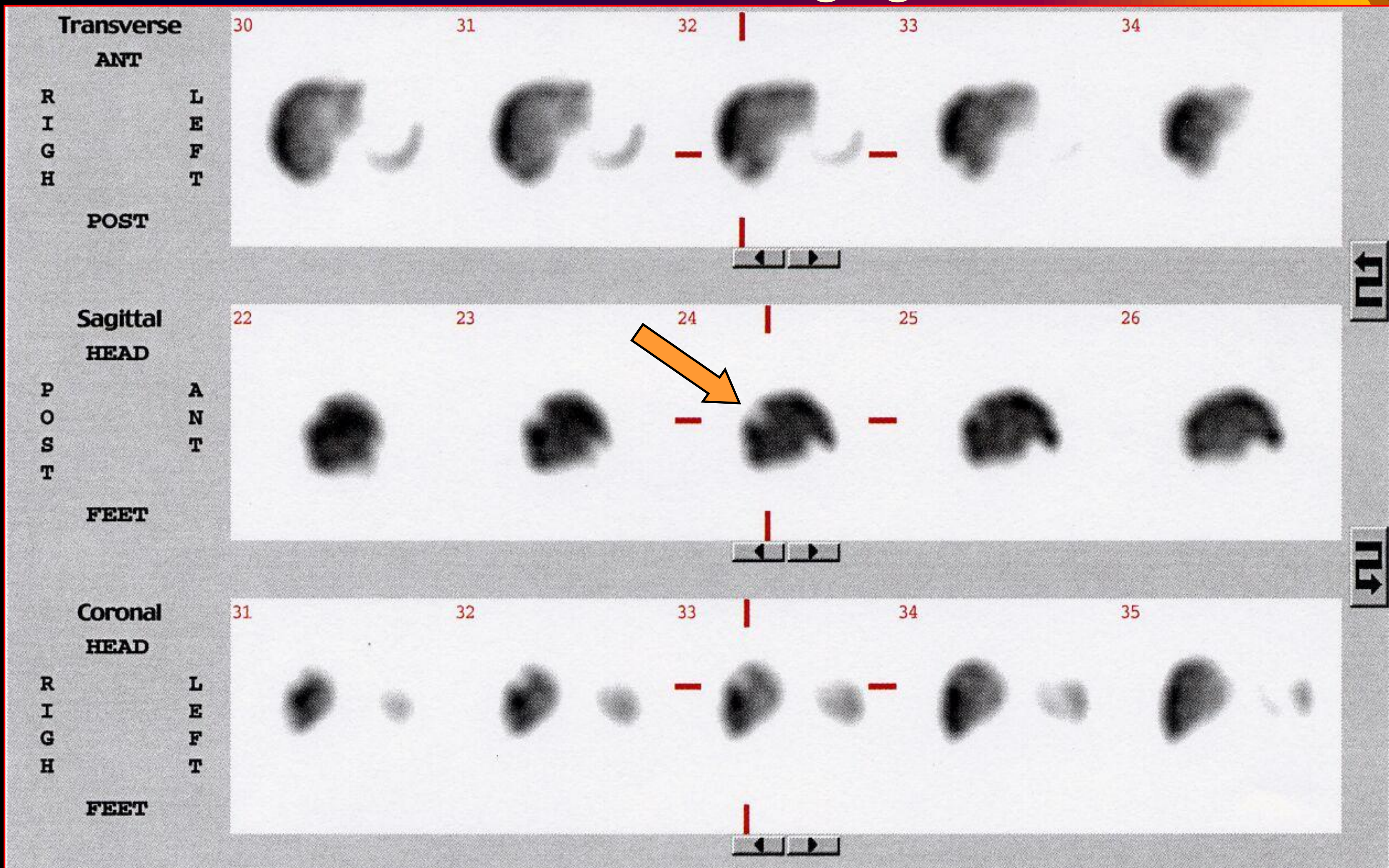
# Focal parenchymal defect

## Static imaging

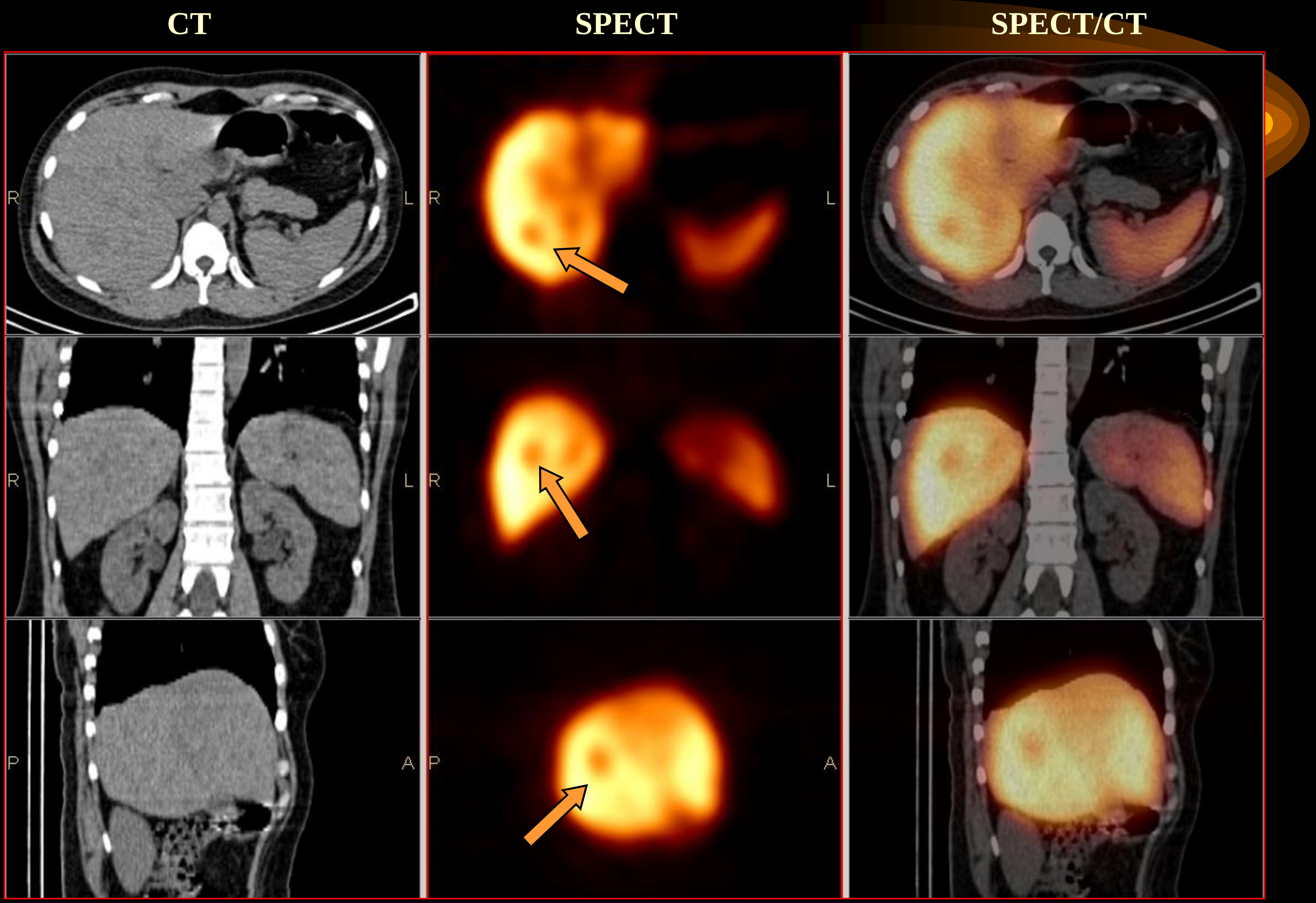


# Focal parenchymal defect

## SPECT imaging



# Liver SPECT/CT imaging in haemangioma



# Liver blood-pool scintigraphy

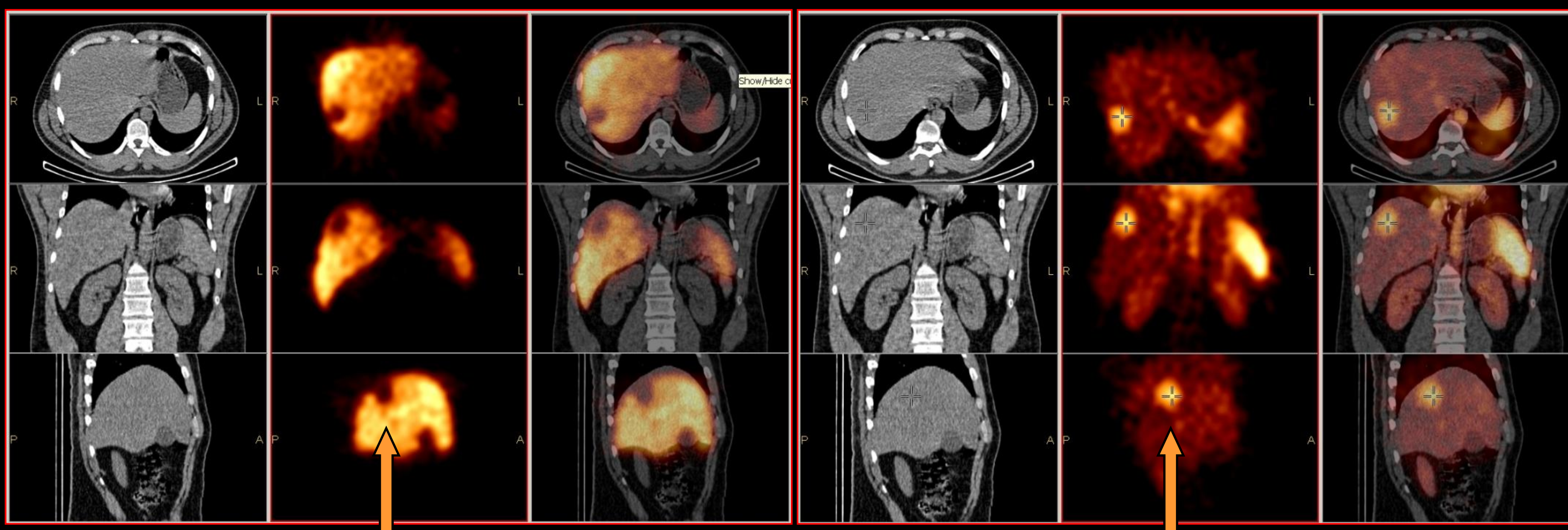
The blood-pool of the liver is labelled by 99mTc-pyrophosphate-red blood cells:

- Inactive pyrophosphate is injected i.v. at first
- 20 minutes later 500 MBq 99mTc-pertechnetate is injected i.v., too
- Imaging is performed in equilibrium from 6 directions (similar to colloid scan) + SPECT
- Haemangioma is indicated by increased activity

# Liver and blood-pool SPECT/CT imaging in haemangioma

**Colloidal scintigraphy** **Blood-pool scintigraphy**

| CT | SPECT | SPECT/CT | CT | SPECT | SPECT/CT |
|---|---|---|---|---|---|



Focal parechymal defect

Hot spot

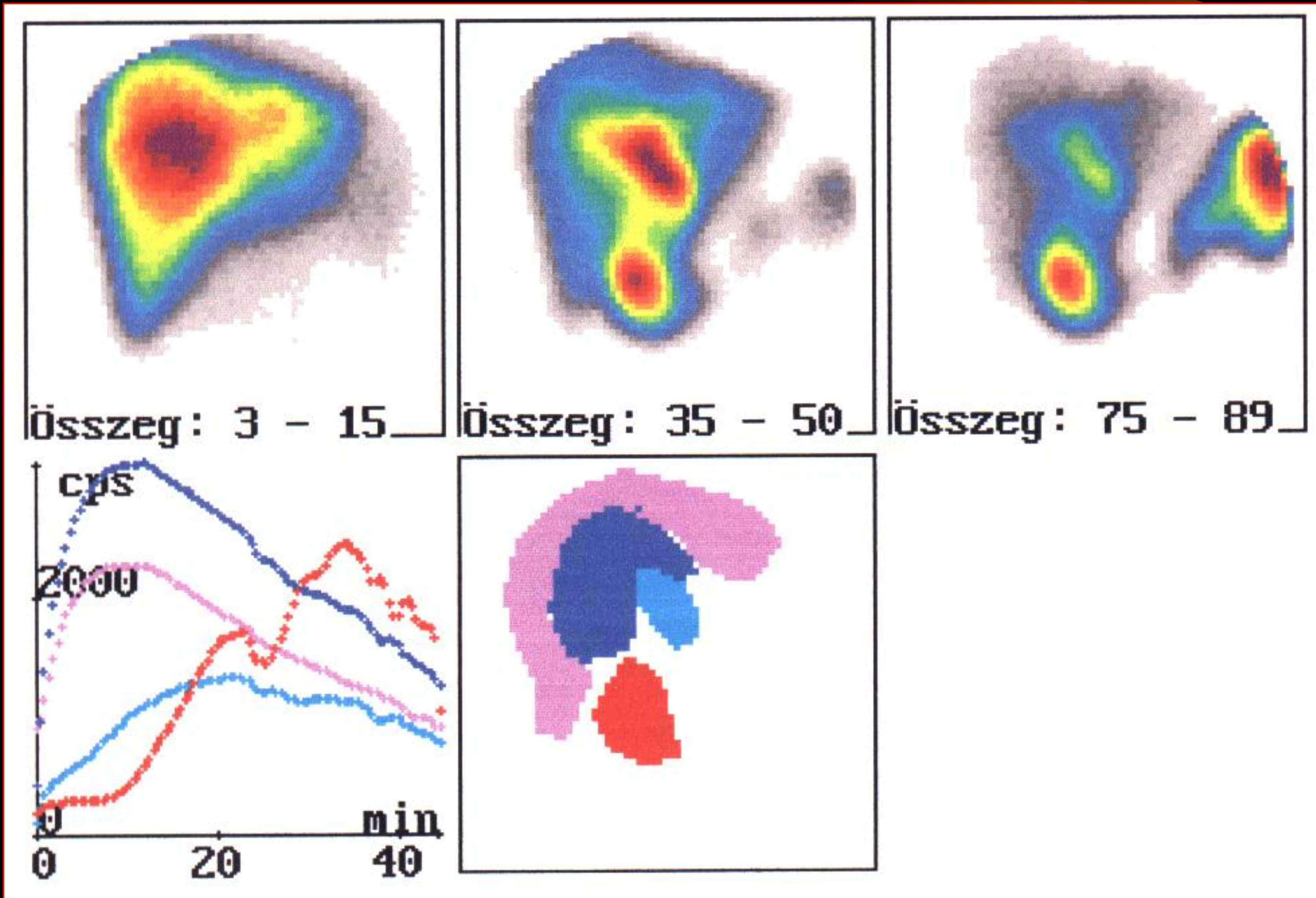
# Dynamic studies

- Follow up the physiological or patho-physiological function of an organ or an organ system by radioactive agents
- Gamma-camera-computer system
- ROI (region of interest) technique
- Time-activity curves, T maximum, T 1/2

# Hepatobiliary scintigraphy I.

- The aim of the examination to study:
  - secretion function of the liver from the blood
  - excretion function of the bile through the liver
  - function of the gall bladder (contraction, ejection fraction)
- The way of the radioactive agent (99mTc-HIDA) from the blood to the bowels:
  - parenchymal part of the liver
  - ductus hepaticus
  - ductus choledochus
  - cholecysta
  - bowels

# Normal hepatobiliary function

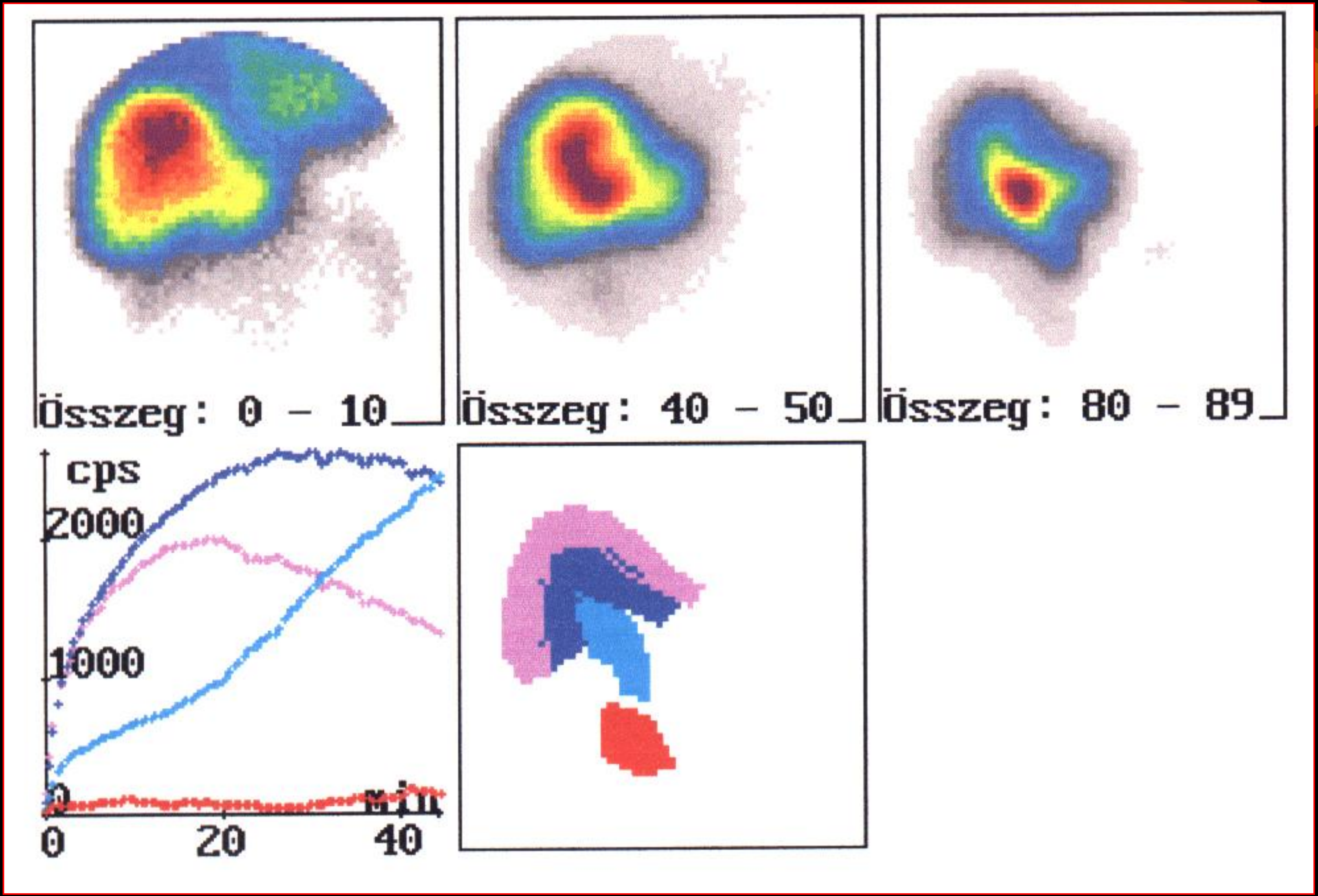


# Hepatobiliary scintigraphy II.

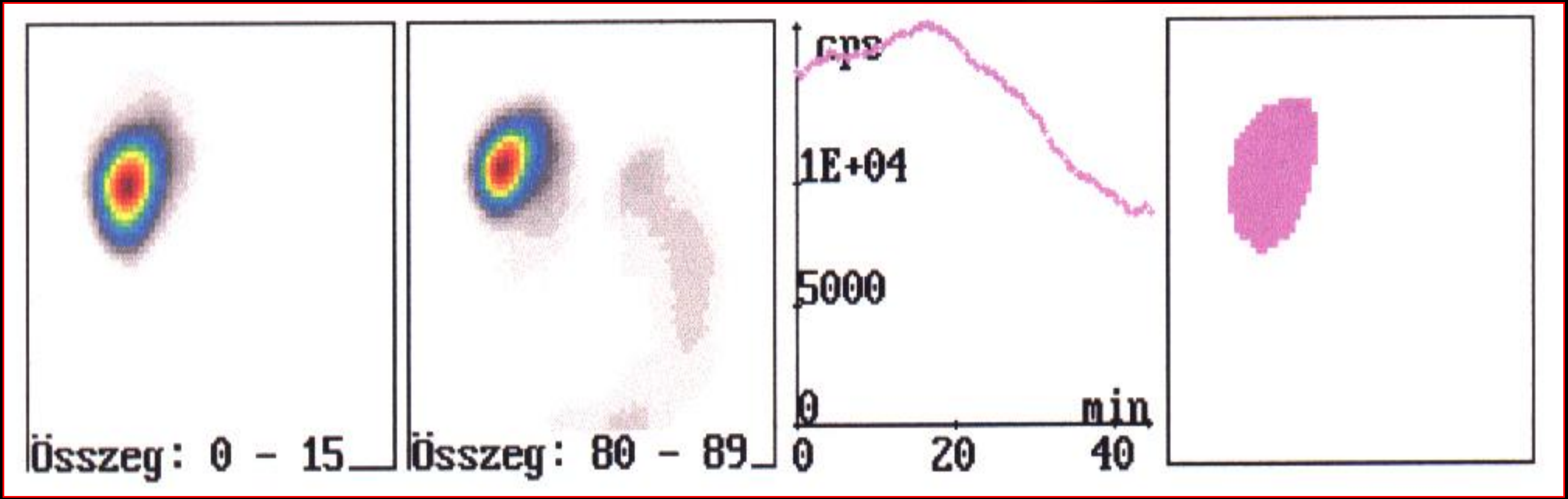
## Indications:

- Post - cholecystectomical syndrome
- Bile excretion disorders
- Acut or chronic cholecystitis
- Cholecysta dyskinesis
- Flow of the bile to the abdomen cavity
- Atresie of the ductus hepaticus or choledochus
- Transplantation of the liver

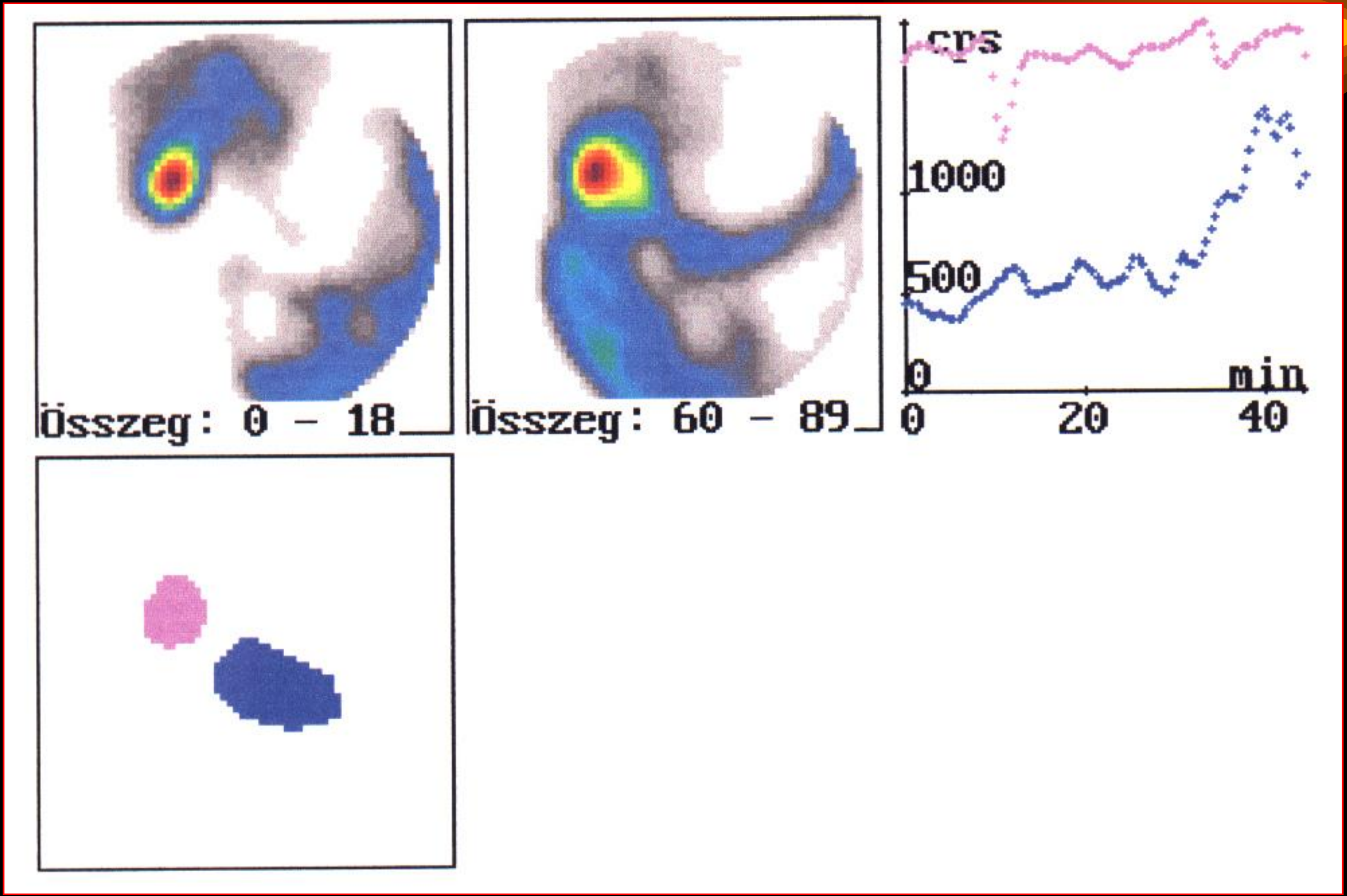
# Stenosis of the papilla Vateri



# Normal ejection fraction (> 1%/min) of the gall bladder after Sorbitol

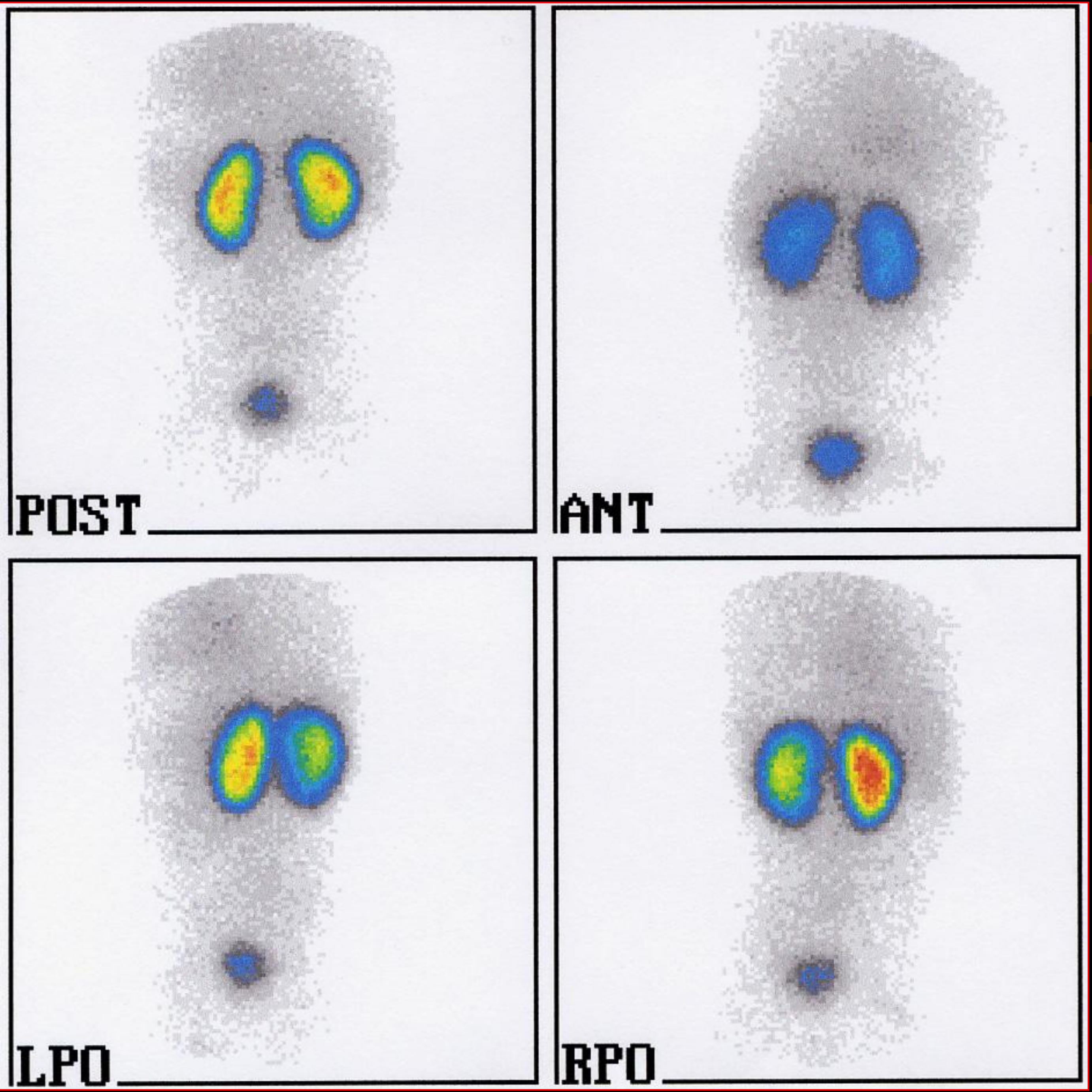


# Failed contraction of the gall bladder in chronic cholecystitis after Sorbitol



# Renal scintigraphy I.

- **Radiofarmaceutical:** **37-74 MBq 99mTc-DMSA (dimercaptosuccinic acid is enhanced in the proximal tubular cells)**
- **Acquisition time:** **120 minutes after the injection**
- **Planar imaging** **from 4 different directions:**
  - **- anterior, posterior**
  - **- RPO (right posterior oblique)**
  - **- LPO (left posterior oblique)**
- **Evaluation:** **focal parenchymal defect (≤ 1.5 cm)**

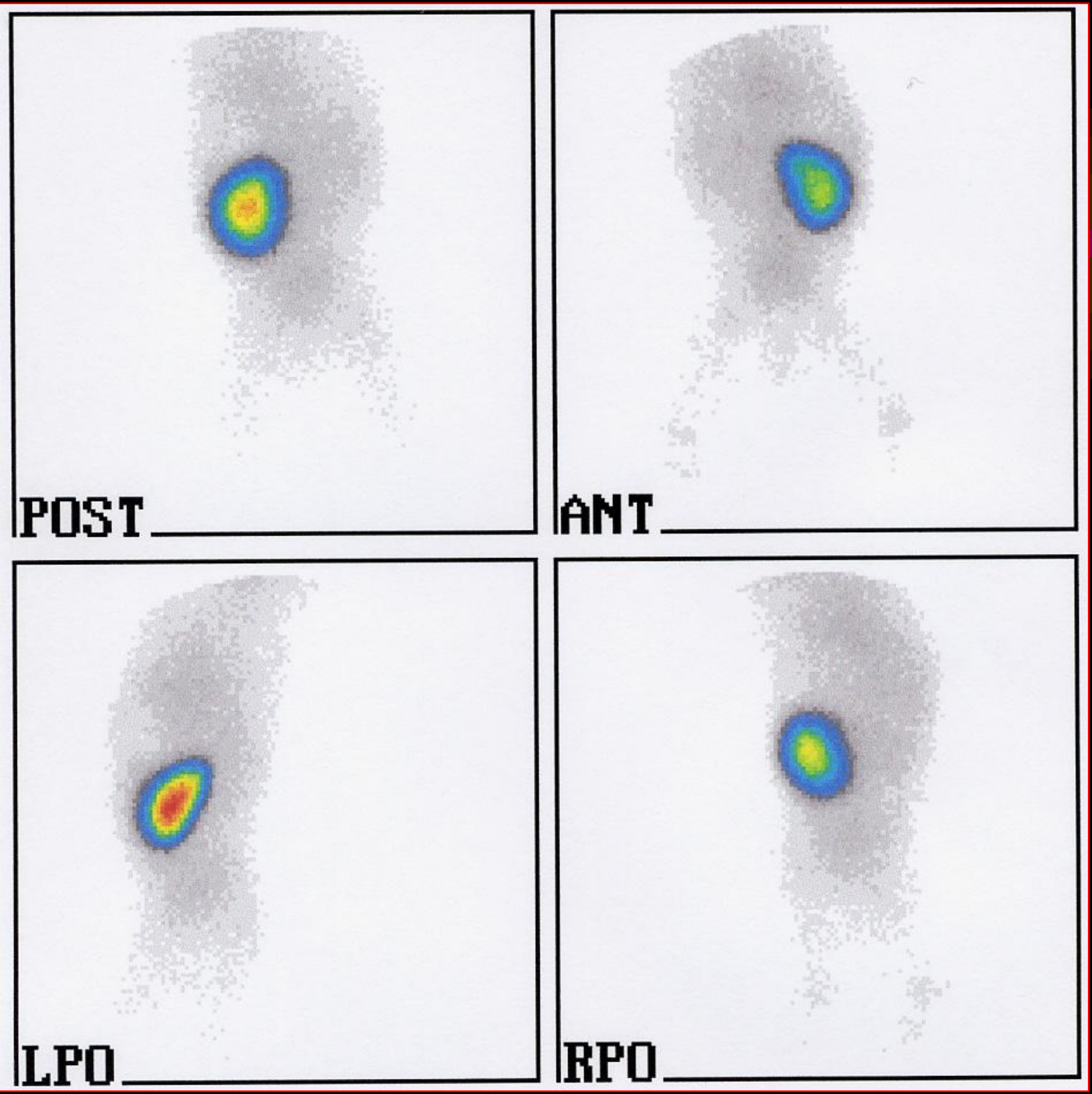



Normal renal scintigram

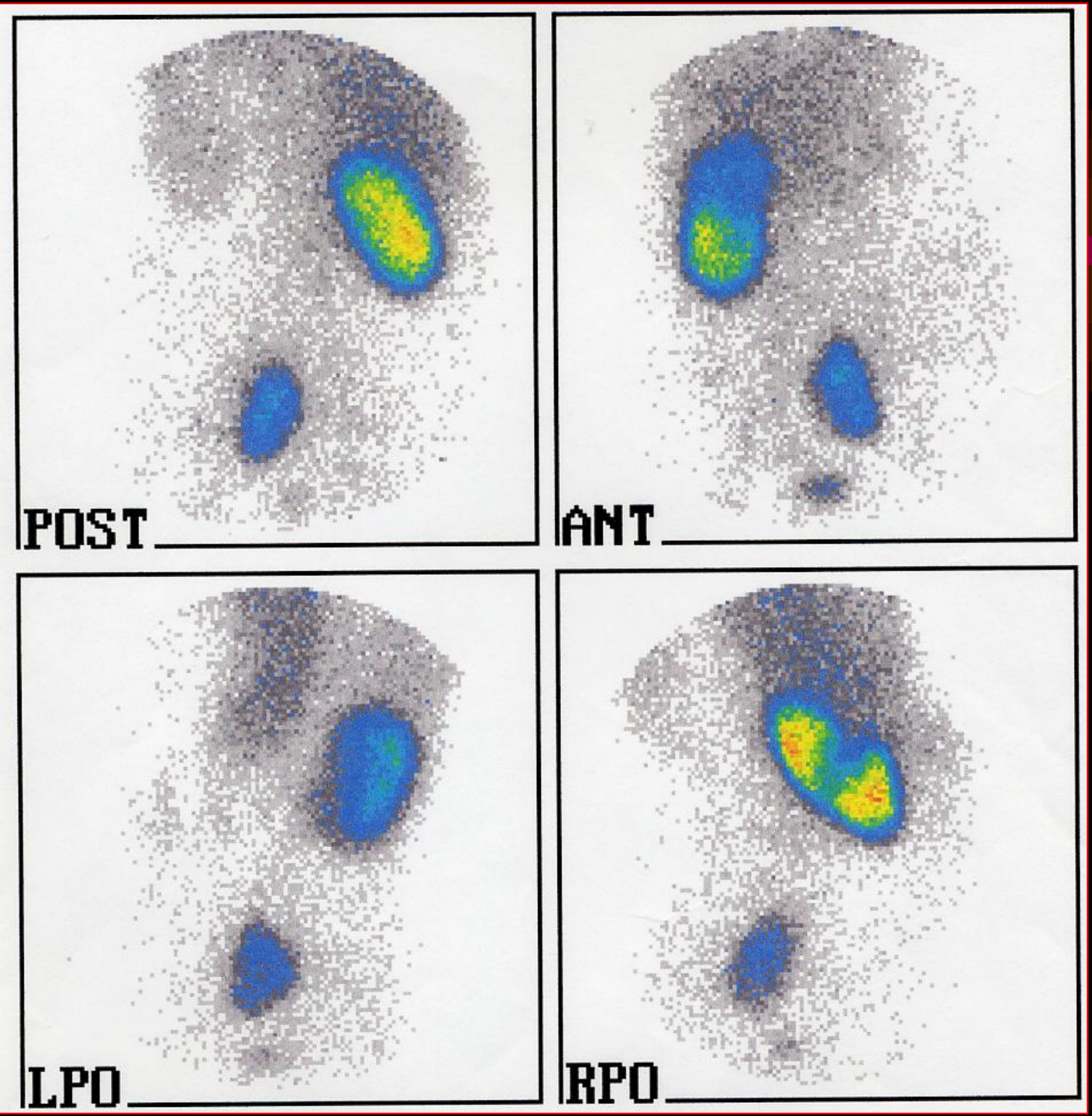
# Renal scintigraphy II.

## Indications:

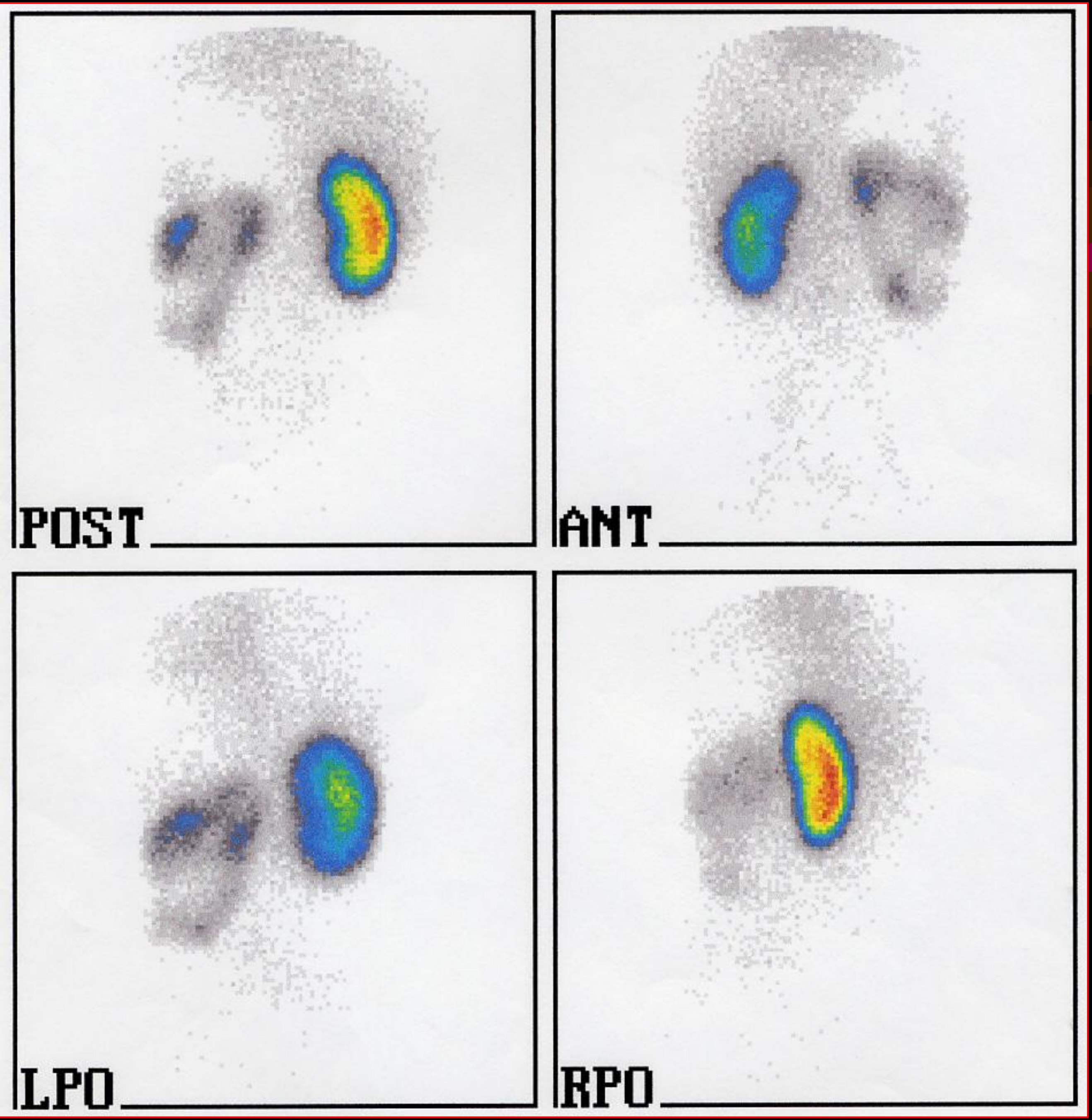
- Determine relative (differential) renal function in the left and right kidneys
- Pyelonephritis
- Renal ectopia
- Infarction
- Hypertension
- Horseshoe kidney
- Acute renal failure
- Multicystic dysplastic kidneys
- Trauma
- Tumors and metastases




Solo kidney on the left side in a newborn

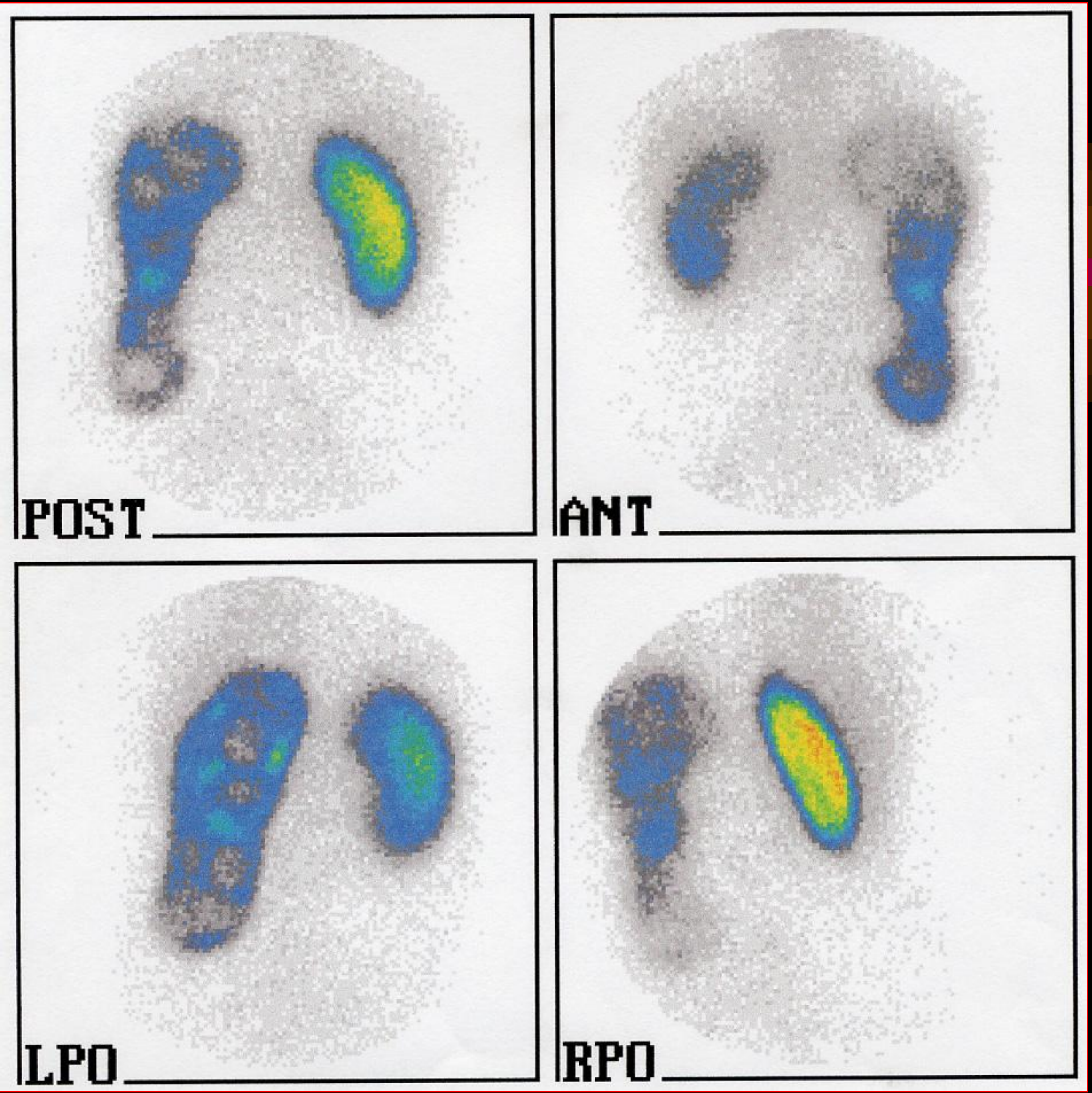



**Ptotic kidney with failed parenchyma on the left side, focal parenchymal defect on the right side**

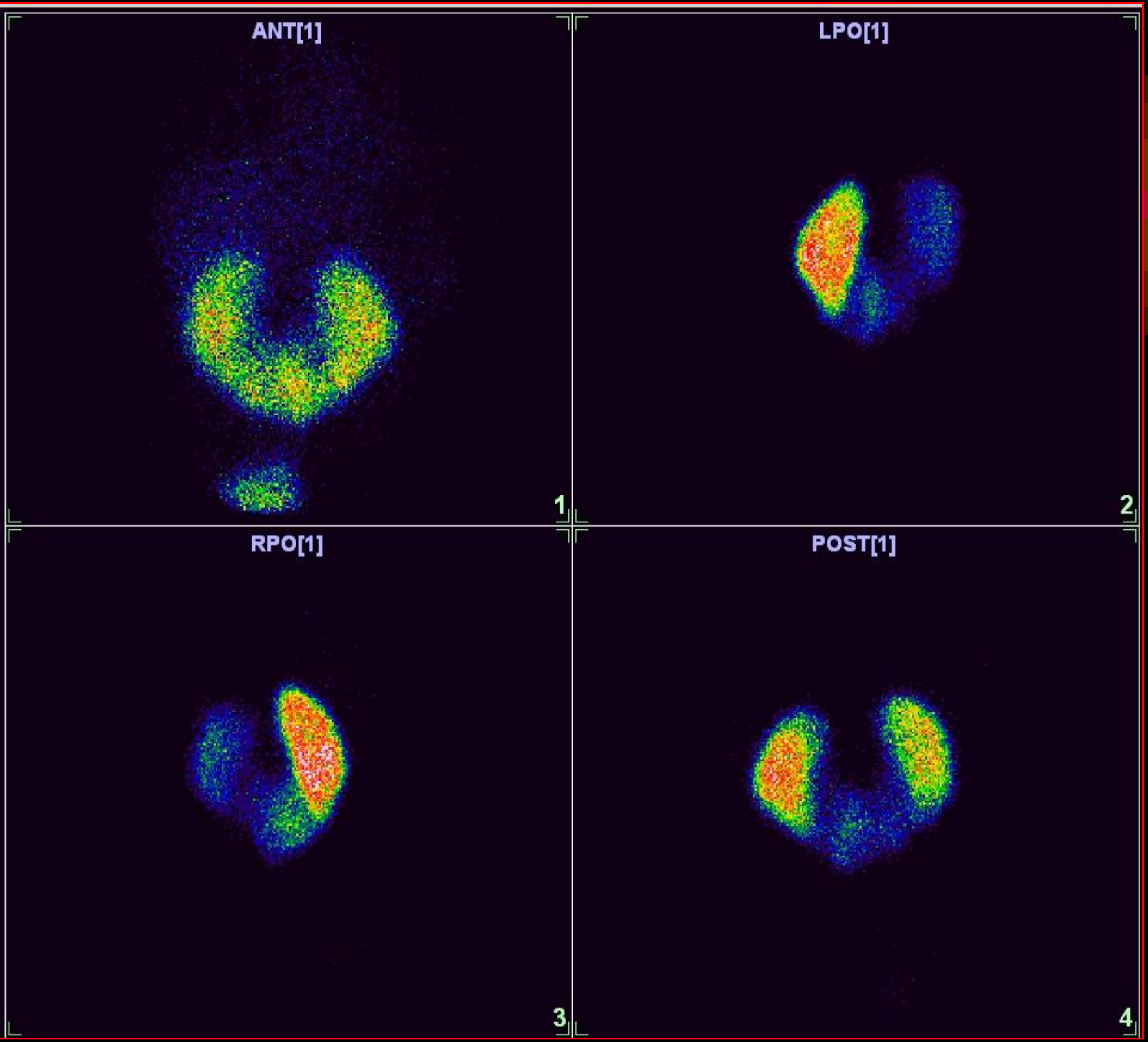



Hydro - nephrosis on the left side

parenchymal failure




**Multicystic disease on the left side**




# Horseshoe kidney

# Renal scintigraphy III.

**Determine relative renal function in the left and right kidney from the DMSA imaging:**

- **Posterior view: ROI of the left and the right kidney**
- **Anterior view: ROI of the left and the right kidney again**
- **Calculating of the parameters by computer**
- **It is very important in children with congenital kidney failures**

# Normal ratio

**Relative ratio of the kidney function:**

**Posterior view:**

**left kidney: 48.4%**

**right kidney: 51.6%**

**Anterior view:**

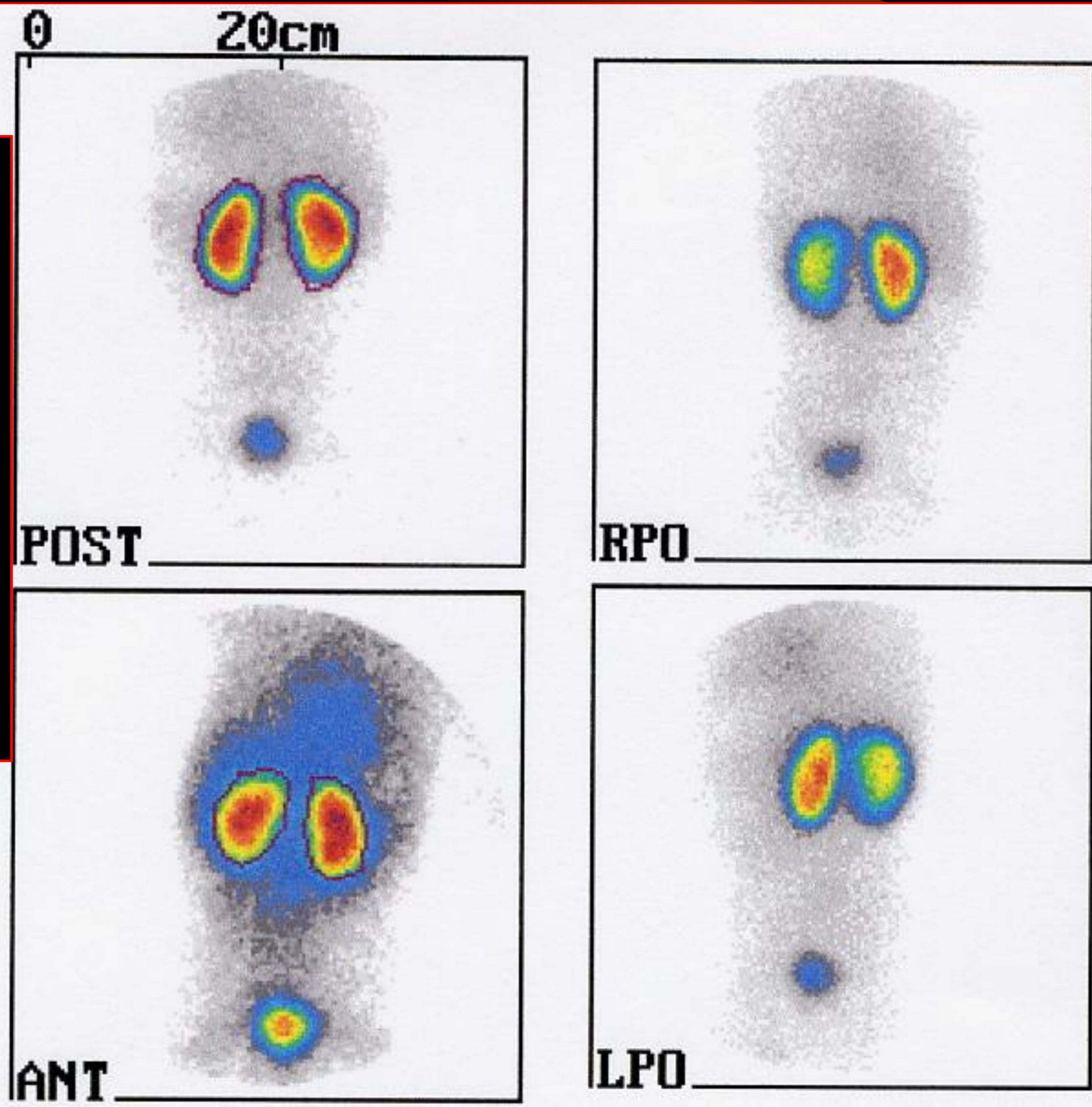
**left kidney: 50.7%**

**right kidney: 49.3%**

**Average:**

**left kidney: 49.5%**

**right kidney: 50.5%**

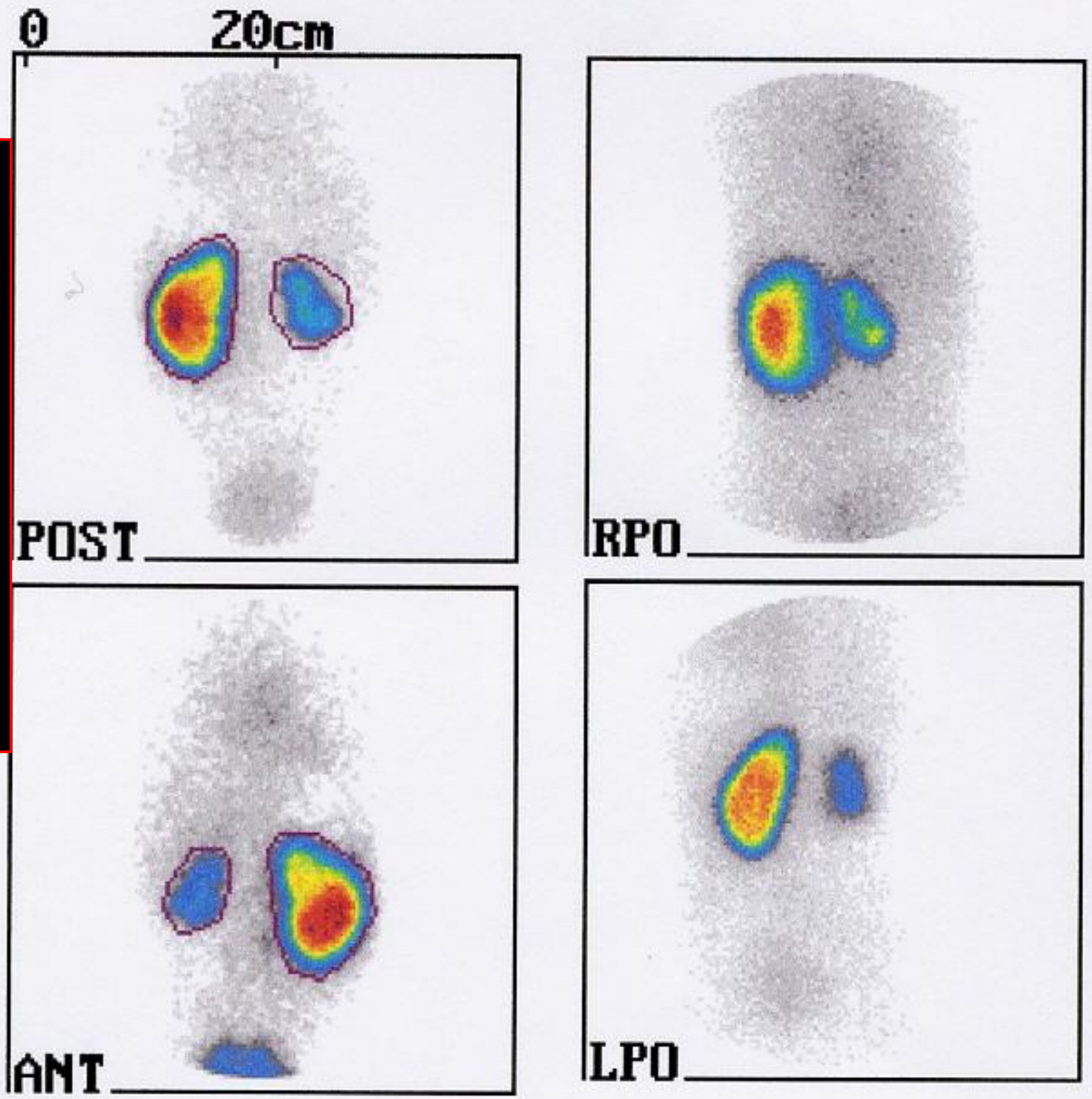


# Ratio of failed parenchyma on the right side

**Relative ratio of the kidney function:**

**Posterior view:**
  **left kidney: 83.8%**
  **right kidney: 16.2%**
**Anterior view:**
  **left kidney: 88.5%**
  **right kidney: 11.5%**
**Average:**
  **left kidney: 86.3%**
  **right kidney: 13.7%**

**Operation is absolutly indicated under 10%!**



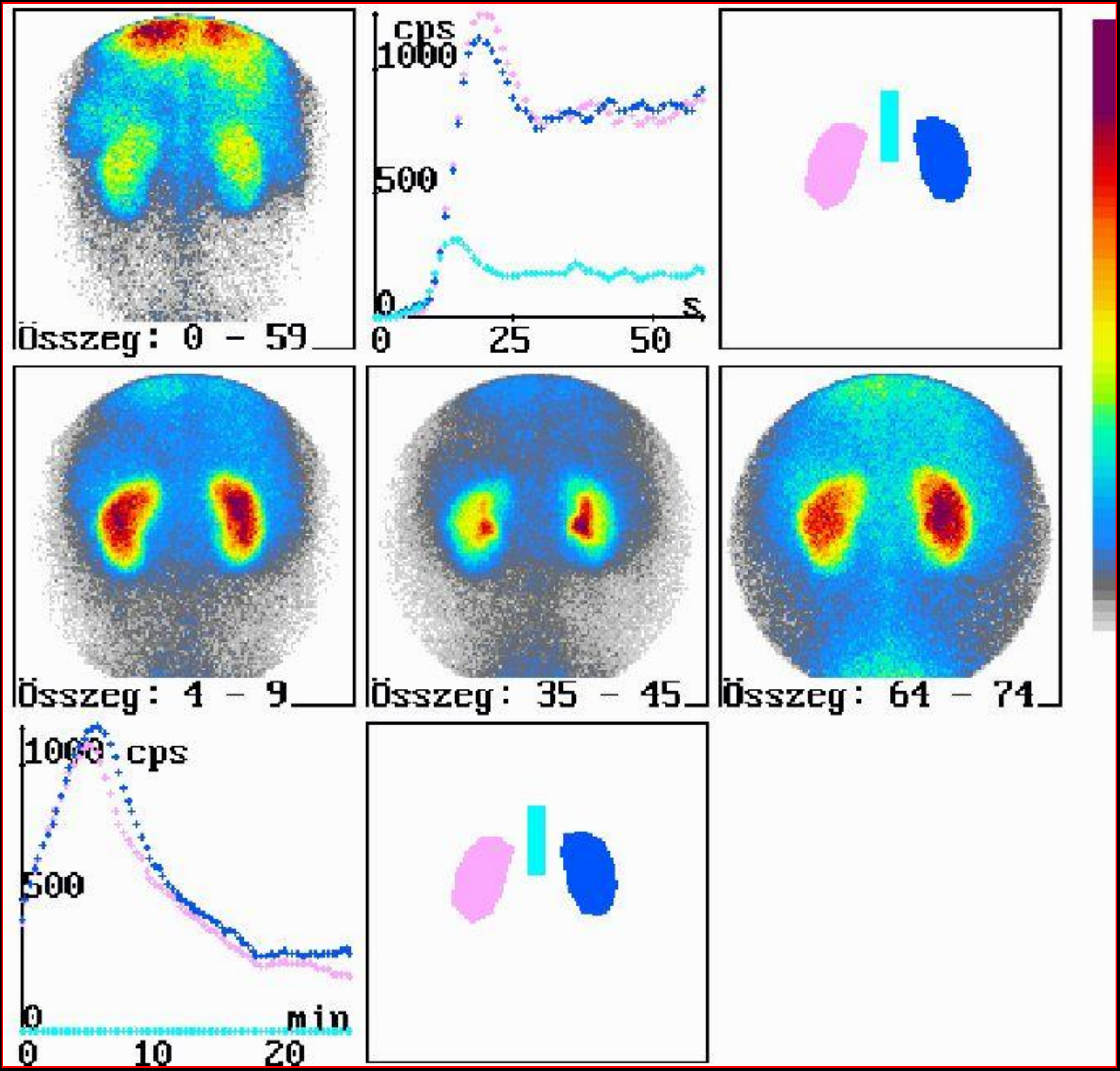
# Camera-renography I.

- Glomerular or tubular function of the kidneys are investigated (99mTc-DTPA, 99mTc-EC, 99mTc-MAG3)
- Time-activity curve = renogram
  - Phase I. = perfusion
  - Phase II. = filtration or secretion function
  - Phase III. = excretion function

Perfusion

# Normal function of the kidneys

Renography

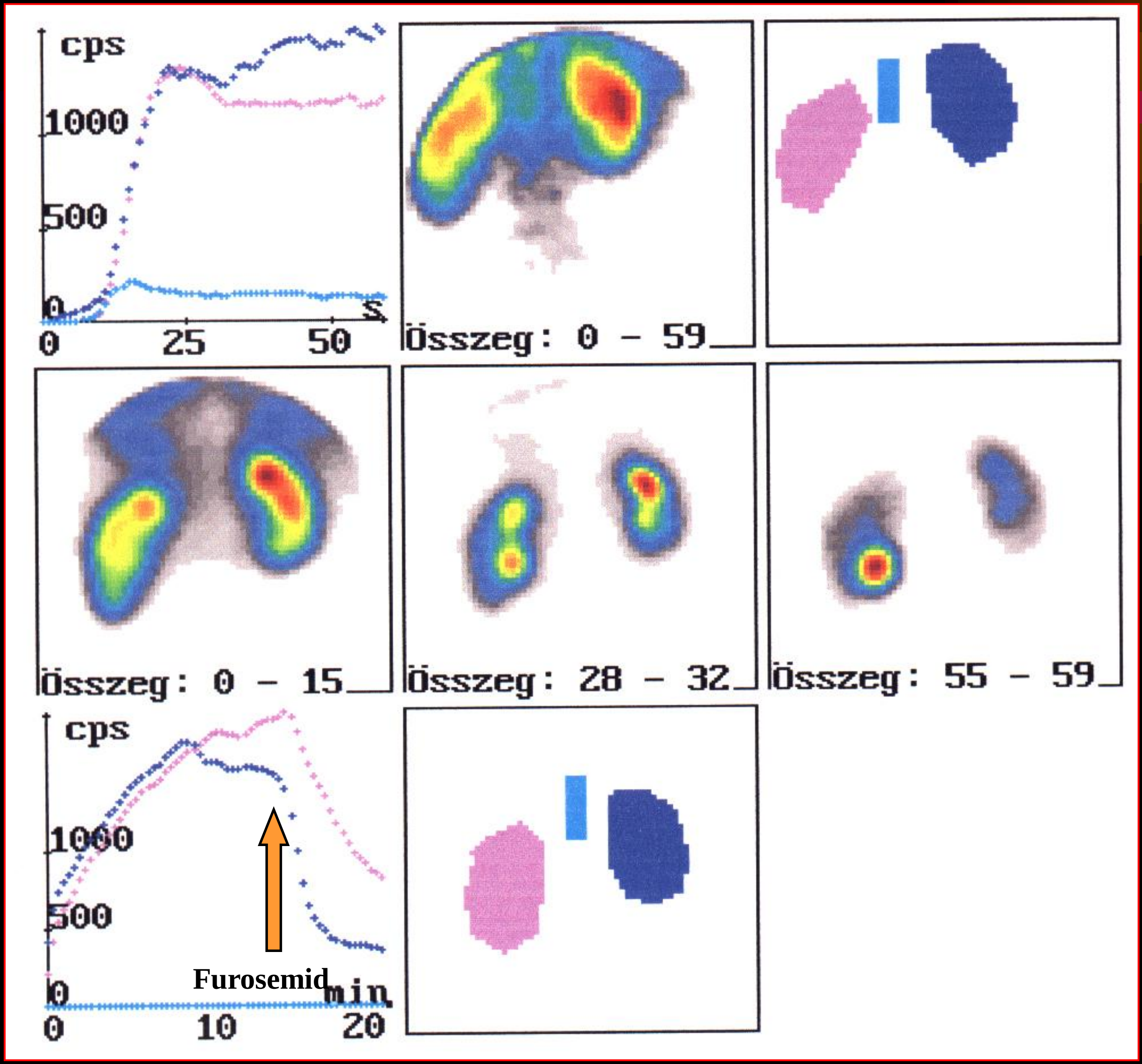


# Camera-renography II.

## Indications:

- *Functional or organical obstructions*
- *Hypertension – renal perfusion*
- One-side kidney diseases (nephrolithiasis, pyelonephritis)
- Clearence-studies (GFR)
- Vesico-ureteral reflux
- Kidney transplantation

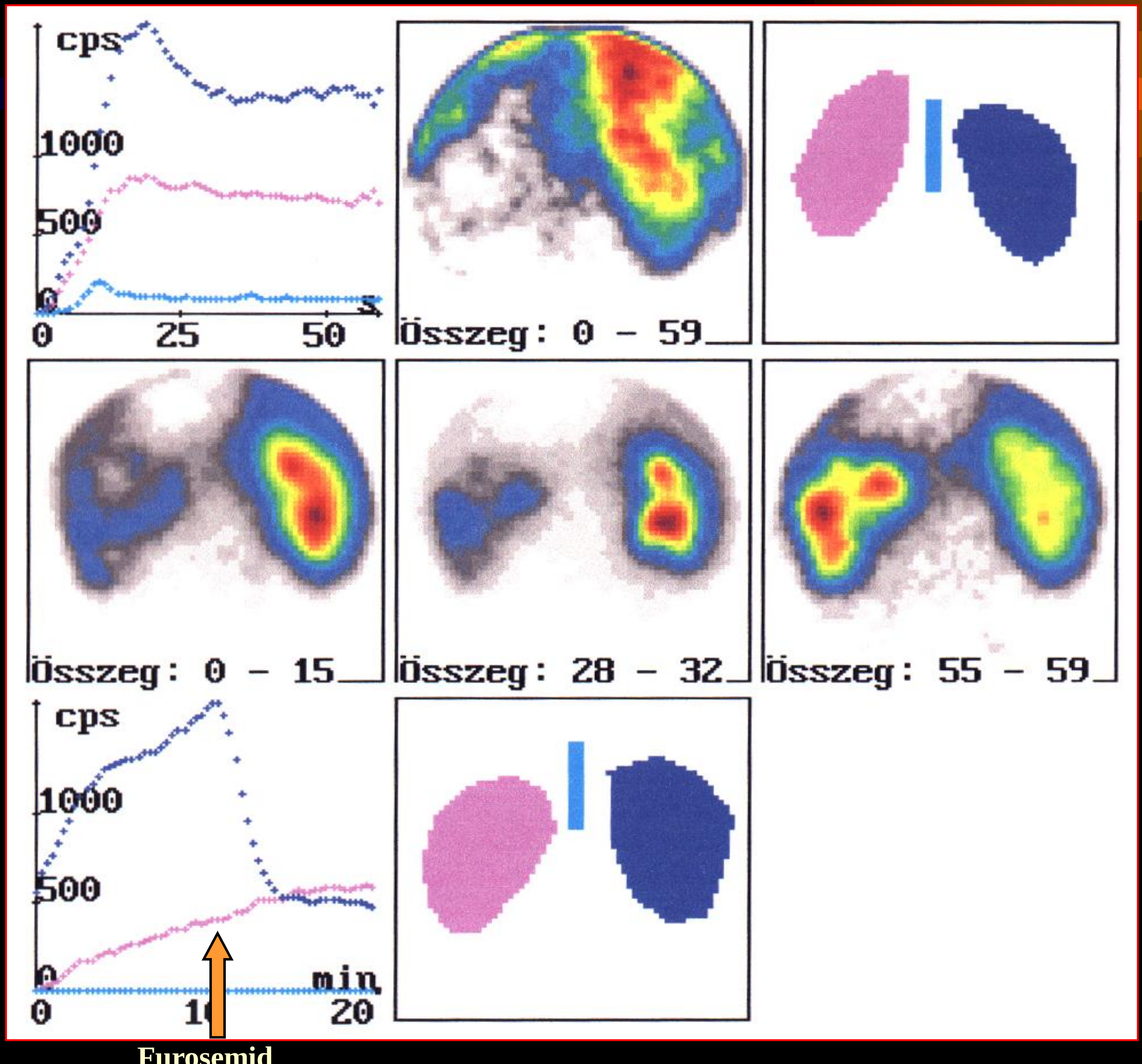
# Bilateral failed function + good excretion by diuretic - Furosemid




Perfusion phase

Renography phase

# Bilateral failed function + no excretion by Furosemid in the left side




Thank you for the attention!