

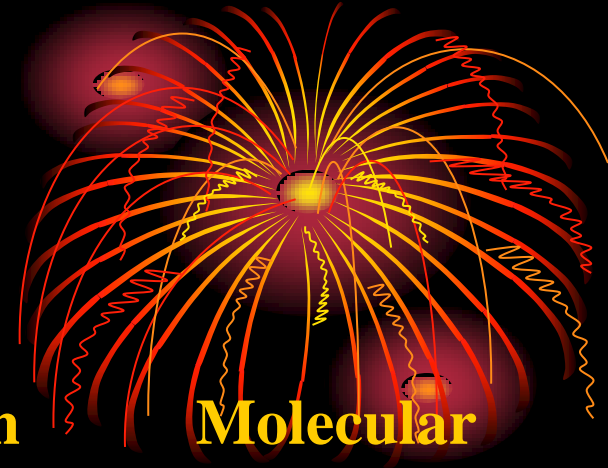


# **Nuclear medicine studies of the digestive system**

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**Department of Nuclear Medicine**

# *Imaging techniques*



**Anatomy**

**Physiology**

**Metabolism**

**Molecular**

**Rtg. / CT**

**PET / SPECT**

**MRI**

**MR spectroscopy**

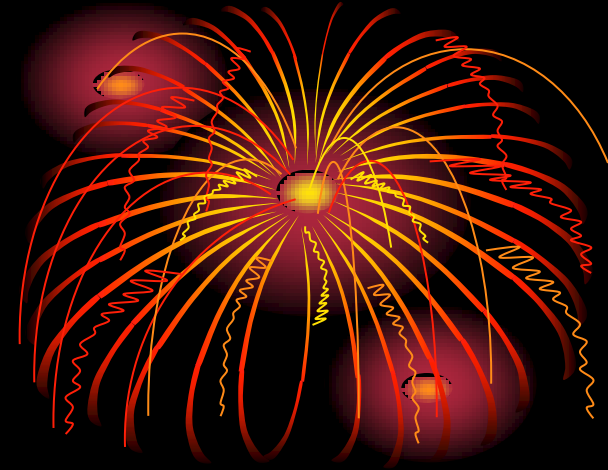
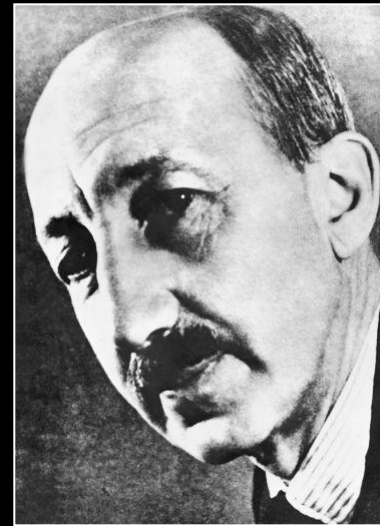
**fMRI**

**Ultrasound**

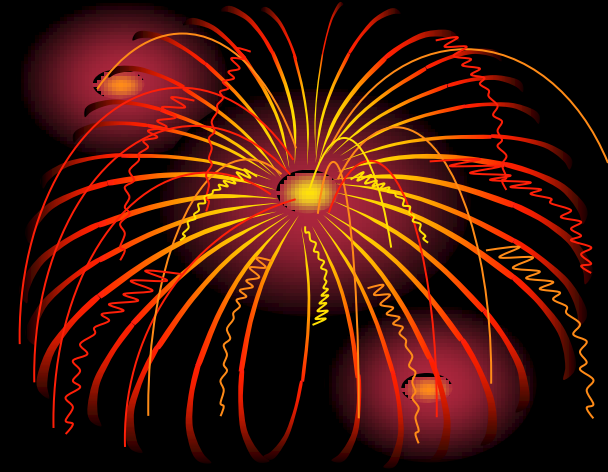
**Hybrid imaging: SPECT/CT, PET/CT, (PET/MRI)**

# The short history of nuclear medicine

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



# Radioactivity



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



# Sub-atomic particles

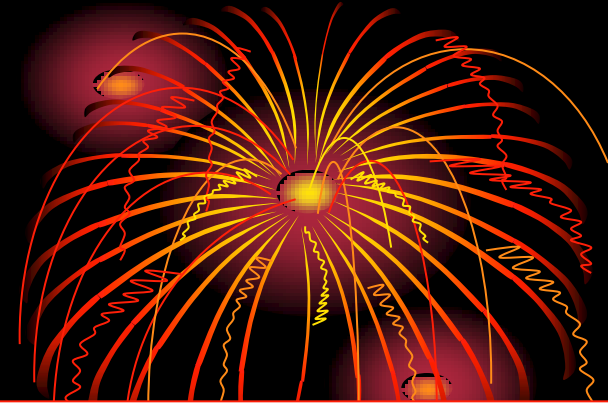
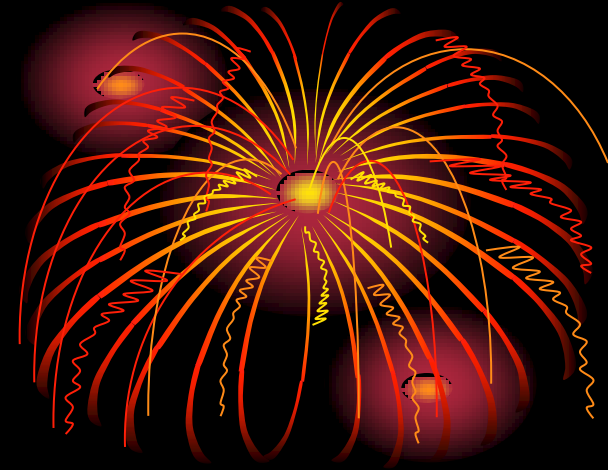


Table 1.1. PHYSICAL PROPERTIES OF SUB-ATOMIC PARTICLES

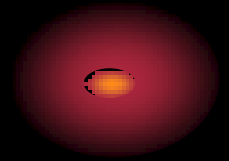
Particle	Electric Charge	Weight		Location
		Grams	a.m.u.	
Proton	+1	$1.66 \times 10^{-24}$	1.0	Nucleus
Neutron	neutral	$1.66 \times 10^{-24}$	1.0*	Nucleus
Electron	-1	$9.1 \times 10^{-28}$	0.00054	Around nucleus

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

# Radioactive isotopes



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



**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.**



## The activity

of a radioactive element is usually given in disintegrations per second or minutes, 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*)

# 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:  $1/T_{\text{eff}} = 1/T_{\text{phys}} + 1/T_{\text{biol}}$

# Energy

is emitted during the decay, constant for the several radioactive atoms.

eV, keV (*used in diagnostics*) or MeV  
(1 eV is extremely small!)



# Three kind of the radioactive radiation

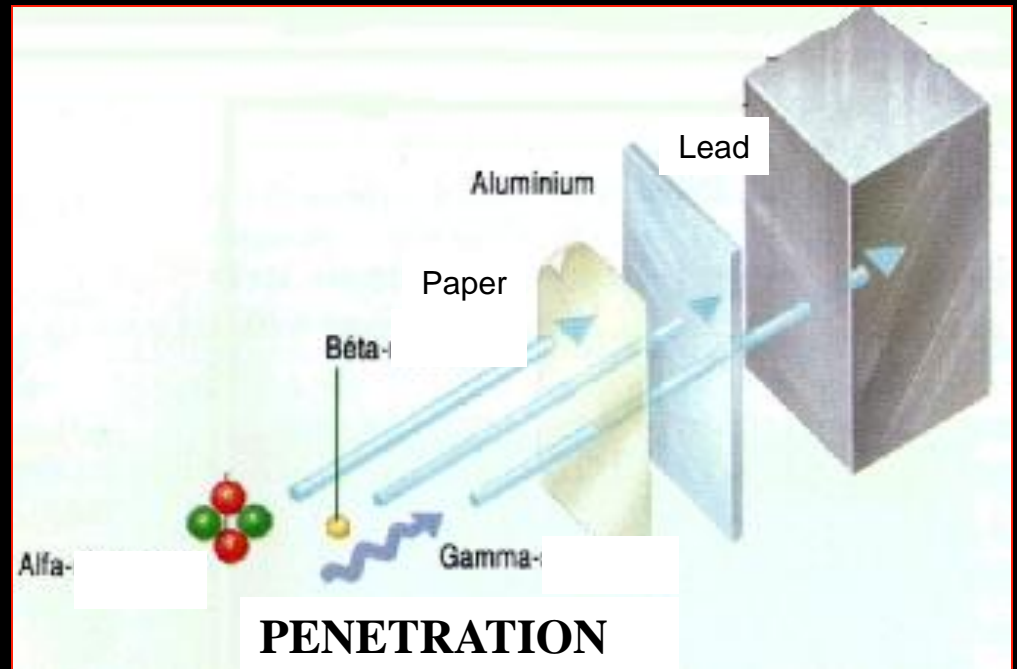
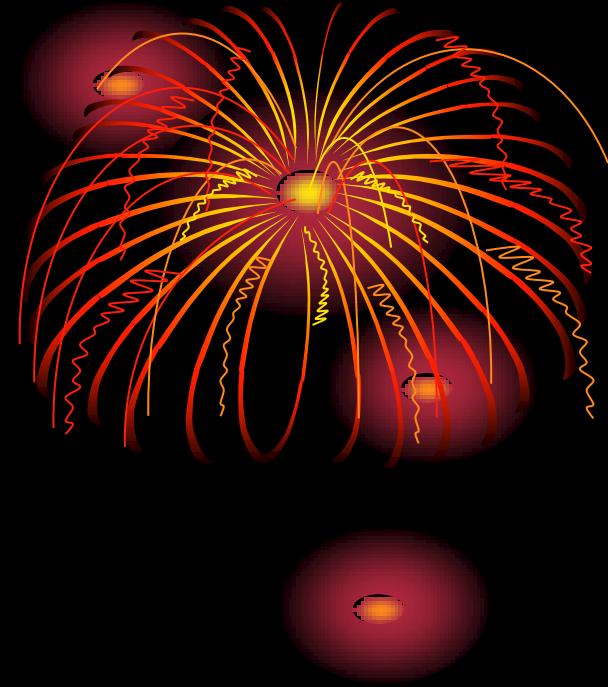
## 1. Corpuscular

**alpha**

**-beta, +beta (positron)**

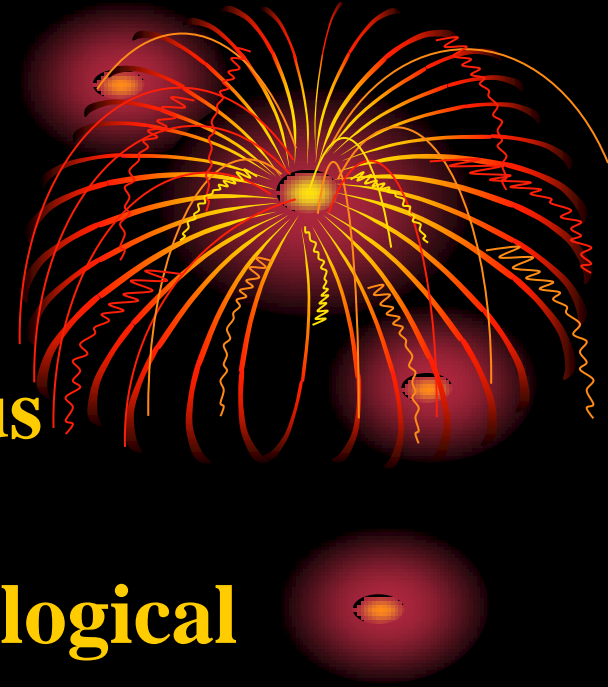
## 2. Electromagnetic

**gamma**



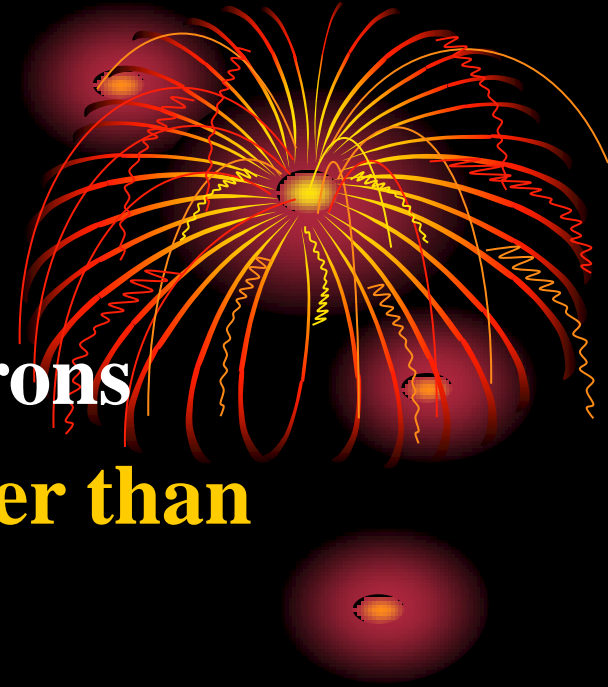
# Alpha radiation

- the emission of a helium nucleus  
(2 protons + 2 neutrons)
- the ionizing property and biological effectivity is great
- range in tissue is with in a few micrometers
- cannot be detected outside!
- e.g.  $^{226}\text{Radium}$  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.  $^{131}\text{I}$  Iodine for thyroid ablation



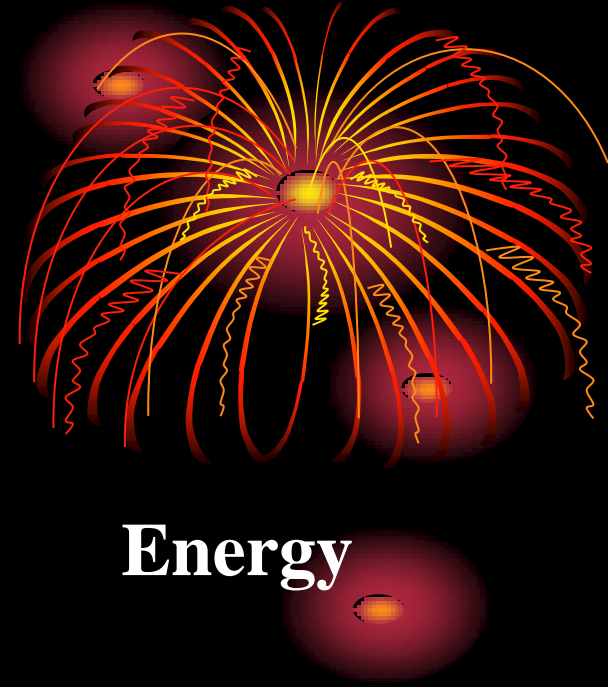


# Gamma radiation

- really electromagnetic radiation
- physically similar to X-rays, but it comes from the nucleus of the atom
- very penetrated and easily pass through tissue
- it can be detected externally well!
- e.g.  $^{99\text{m}}\text{Tc}$  for the diagnosis



# The most commonly used isotopes:

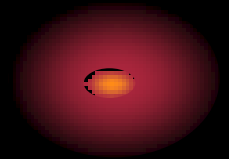


Isotope	Radiation	Half-time	Energy
99m-Tc	$\gamma$	6 hours	140 kev
131-iodine	$\gamma$	8 days	364 keV
	$\beta$		180 keV
123-iodine	$\gamma$	13.2 hours	159 keV
111-indium	$\gamma$	2.8 days	172.2 keV
201-thallium	$\gamma$	3 days	76 keV(95%)

# Equipments I.

## Gamma-camera

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



# Layout of the gamma-camera

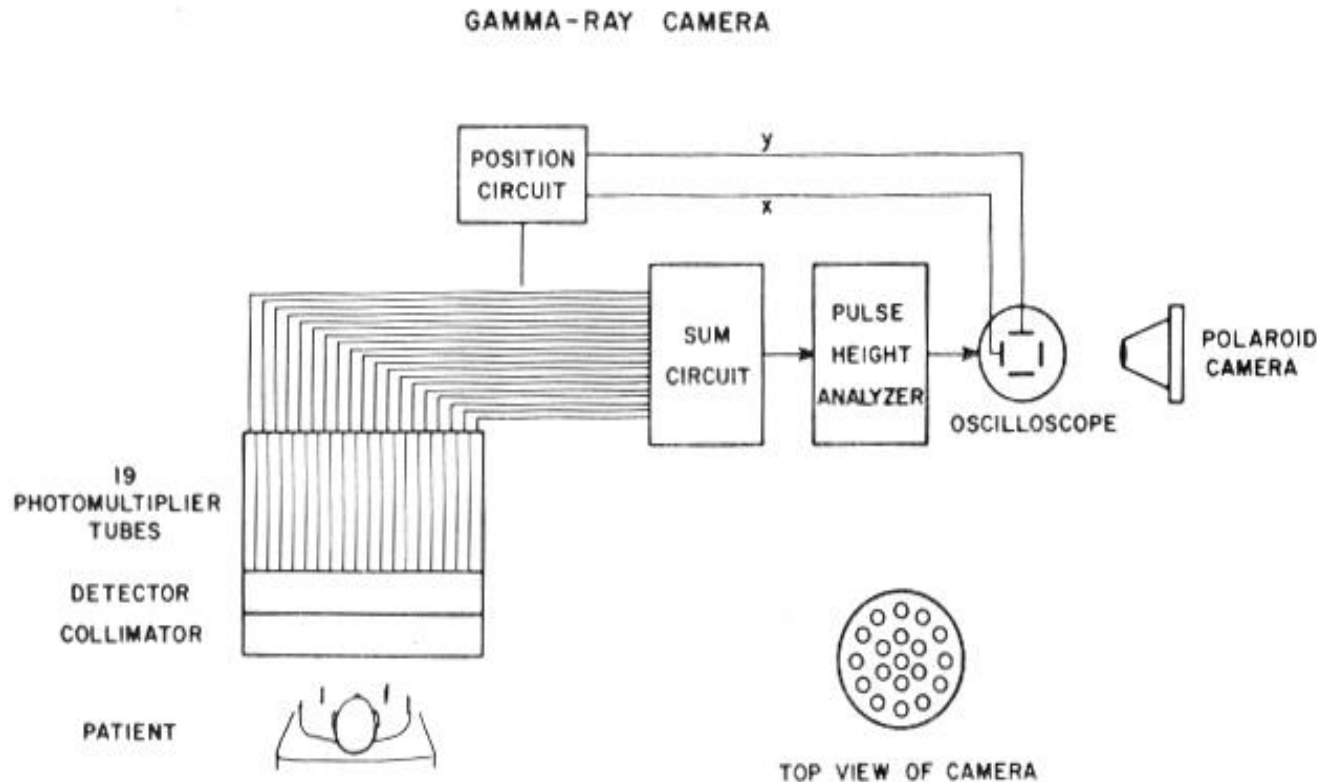
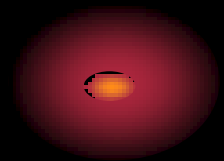
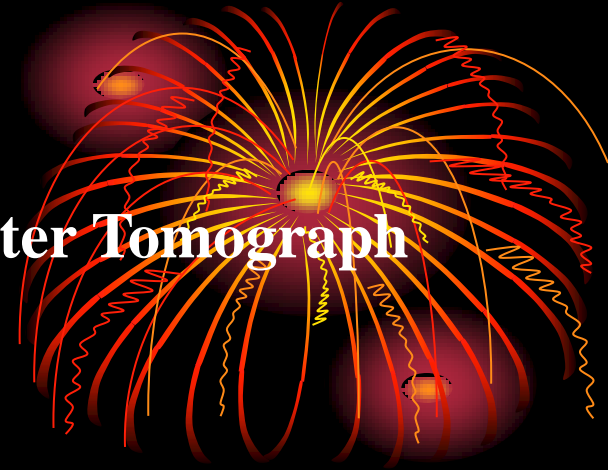


Fig. 1.11. The basic components of an Anger  $\gamma$ -ray camera. There is a one-to-one correspondence between the location of  $\gamma$ -ray interactions in the scintillation crystal and the location of the dot flashed on the oscilloscope screen.

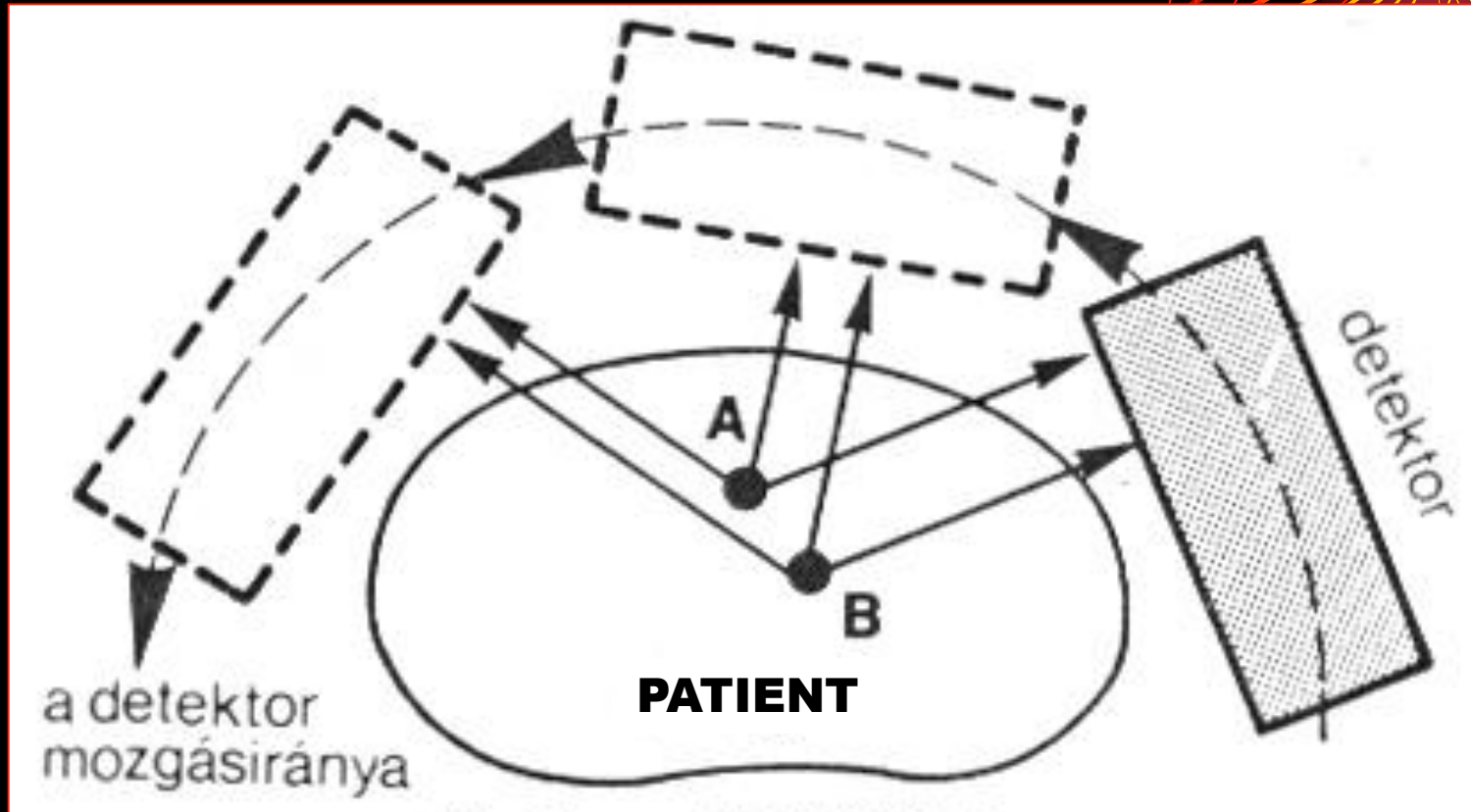
# Equipments II.

**SPECT Single Photon Emission Computer Tomograph**  
**SPECT/CT: multimodality!**

- the computer program reconstruates the transversal, sagittal and coronal slices of the organ  
+ fused image



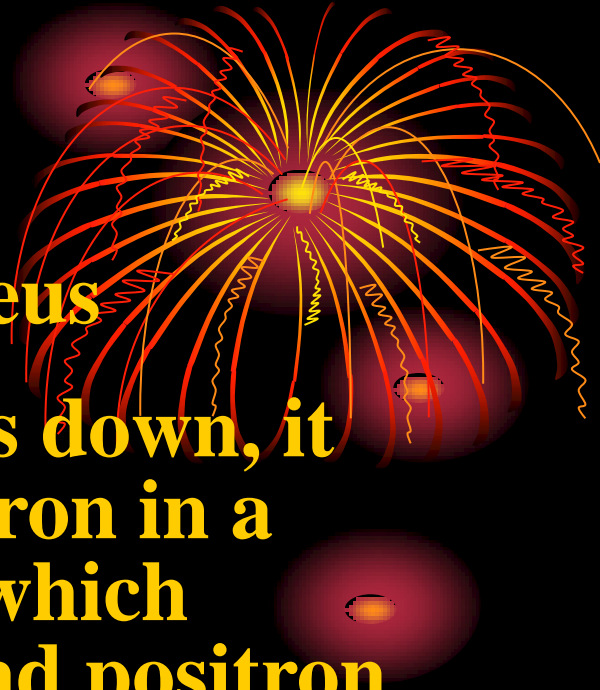
# The principle of the SPECT



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 reconstructed 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 destroys 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.  $^{18}\text{F}$ -FDG for glucose metabolic studies

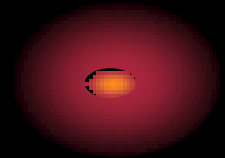
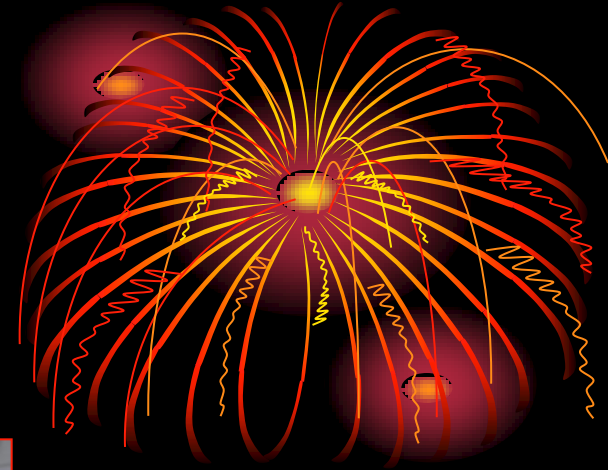




# Equipments III.

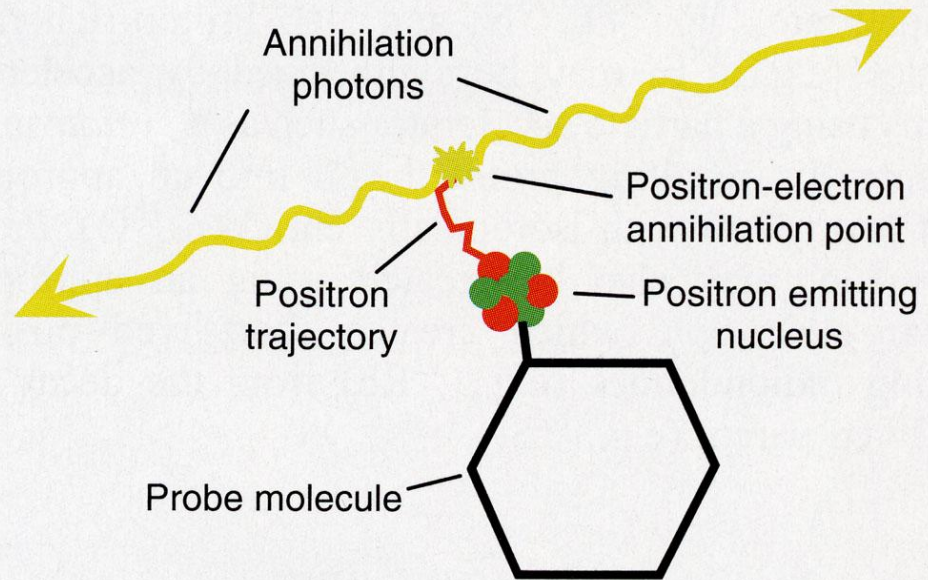
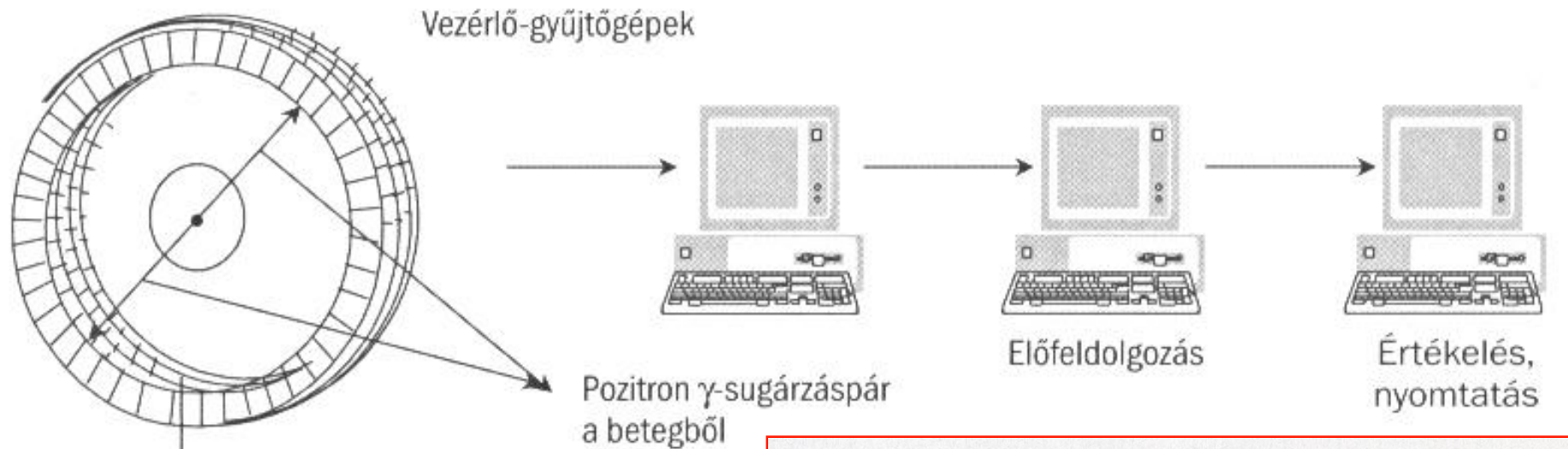
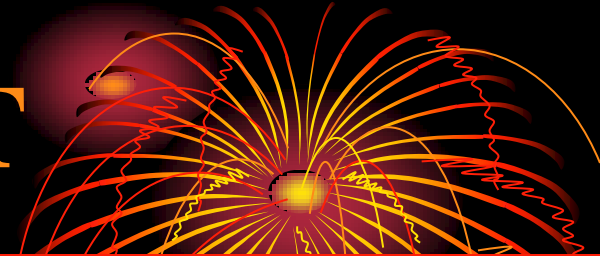
**PET: Positron Emission Tomograph**

**PET/CT: multimodality!**

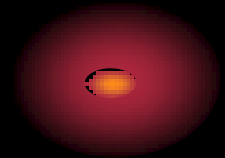
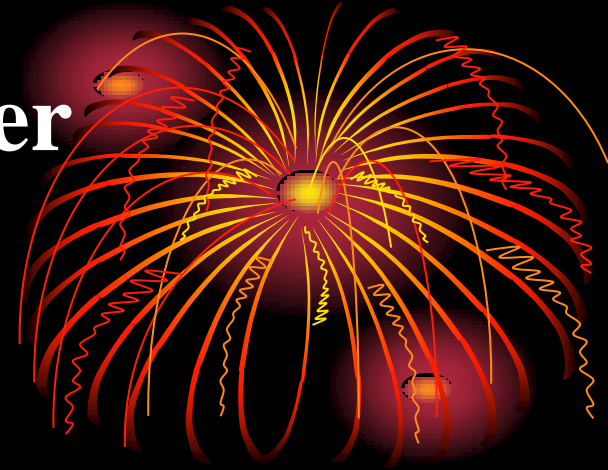
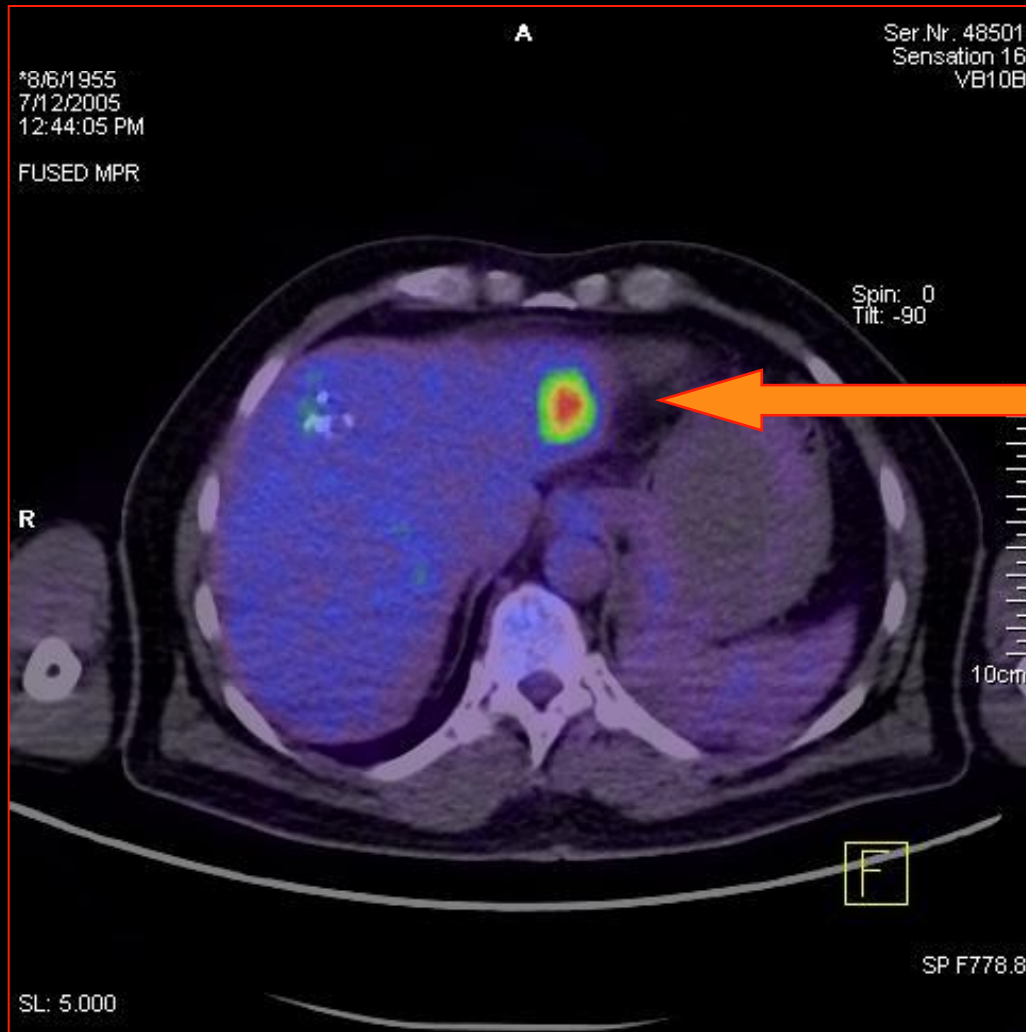




# The principle of the PET

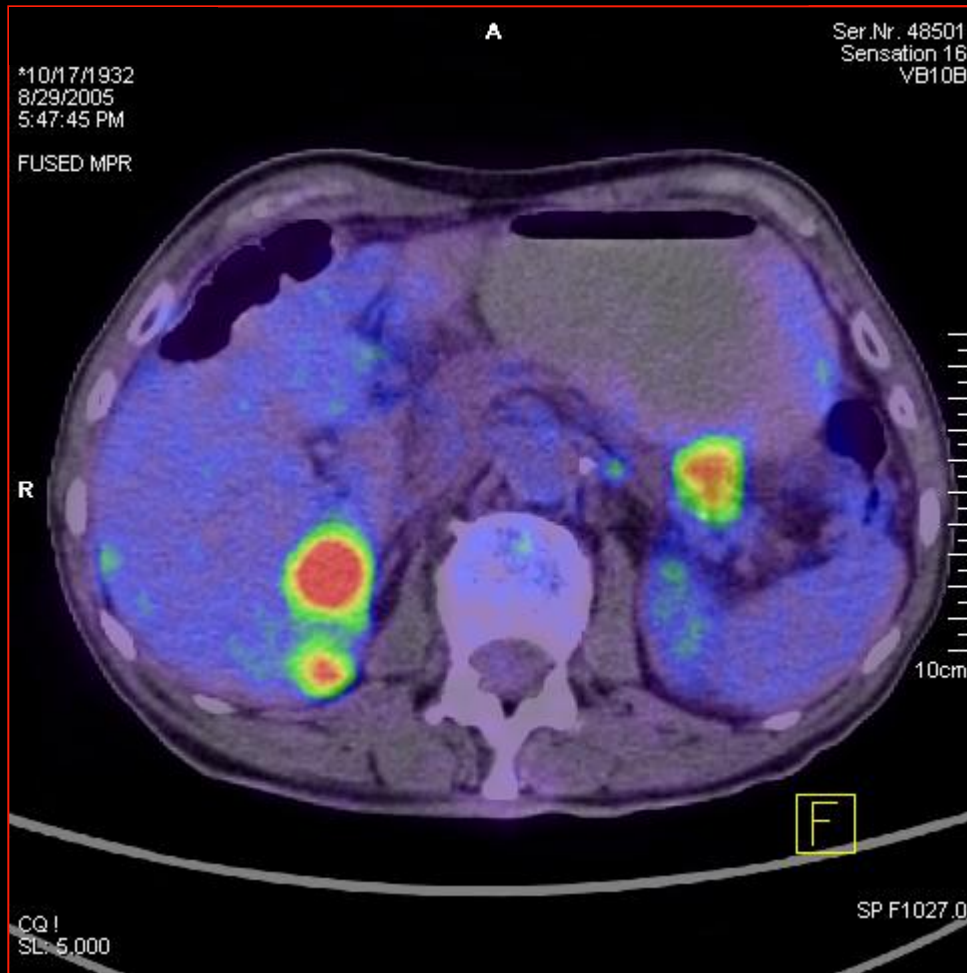
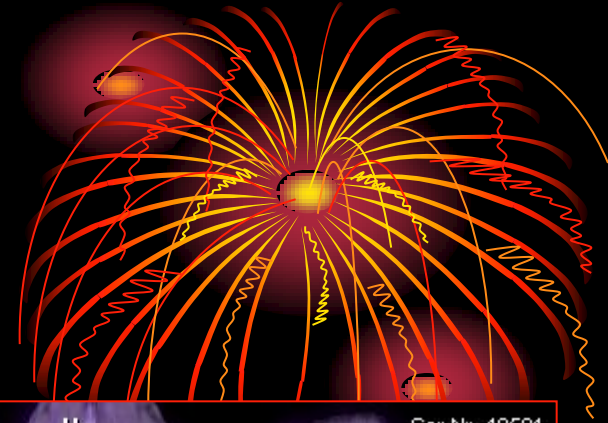


# Liver metastasis of rectal cancer by 18F-FDG PET/CT fused image



**Increased  
glucose  
metabolism  
in the  
metastasis**

# Multiplex metastases of pancreas tail cancer by $^{18}\text{F}$ -FDG PET/CT fused image



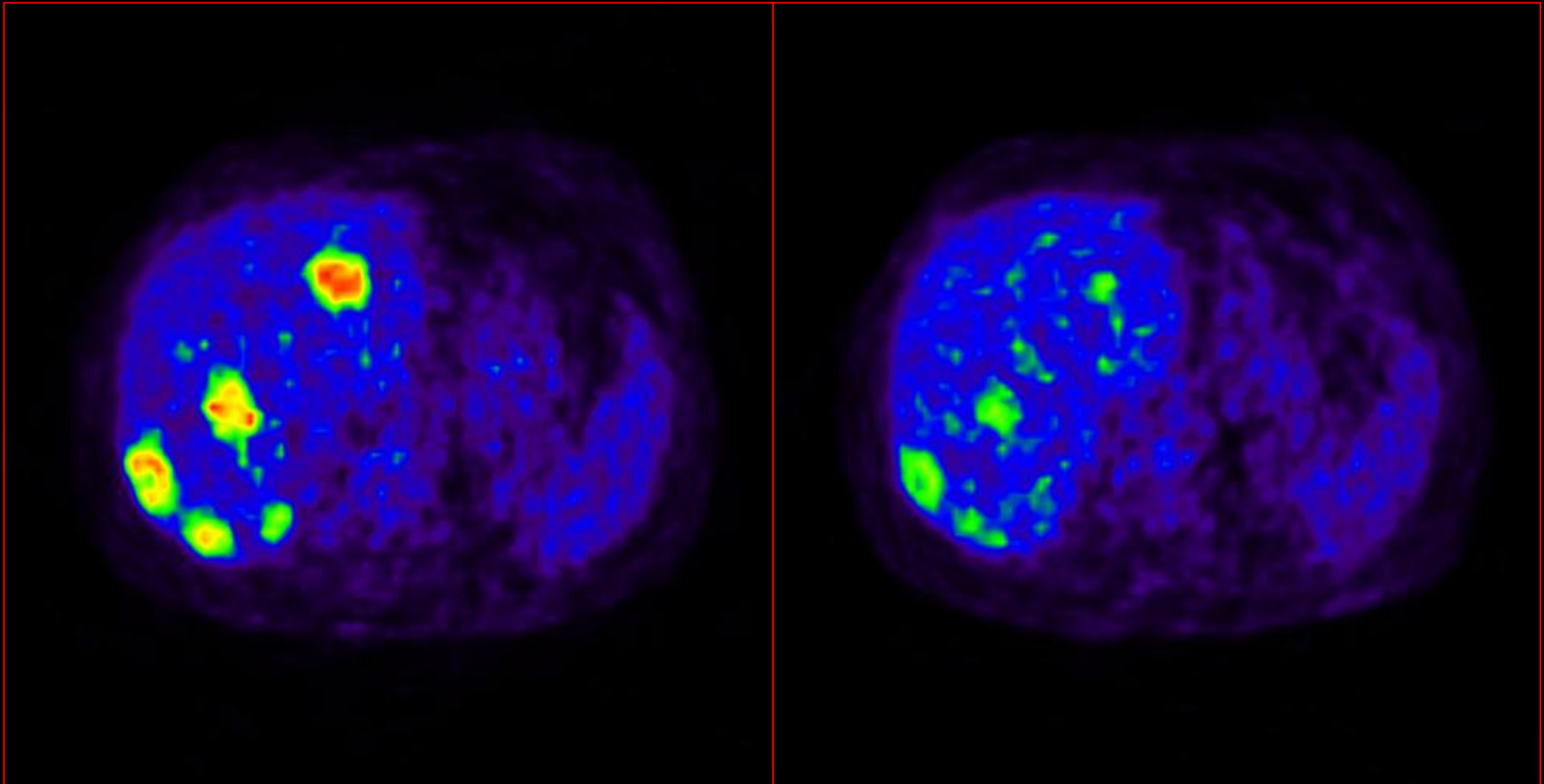


# Therapeutic changes of multiplex liver metastases of sigmoid tumor by $^{18}\text{F}$ -FDG PET

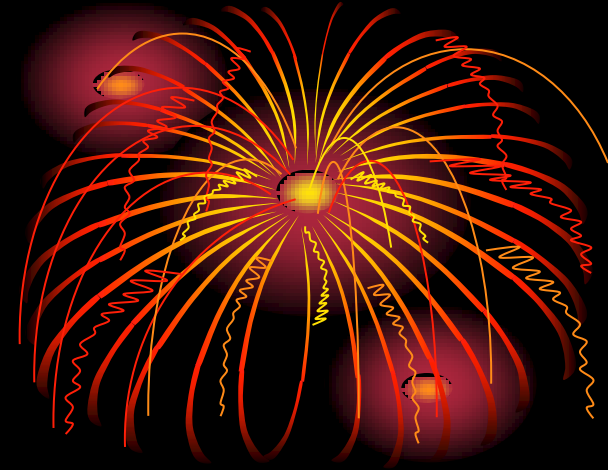


**Before therapy**

**After therapy**



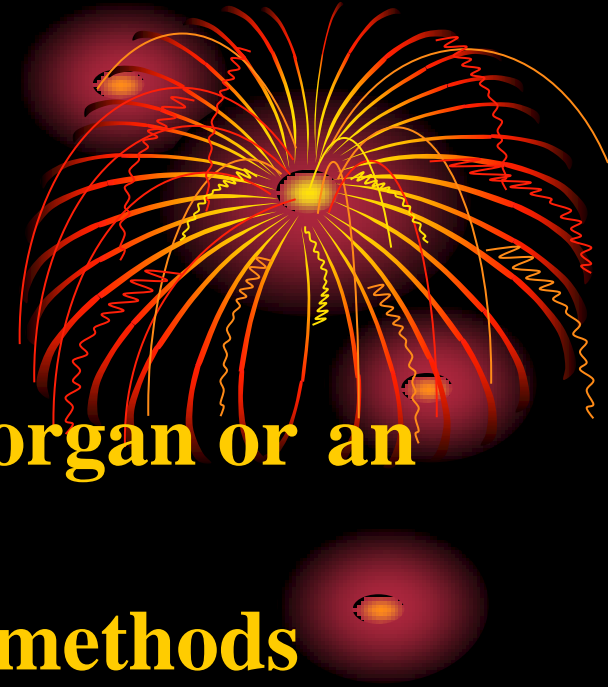
# Radiation exposure



- principle of **ALARA** (as low as reasonable achievable) 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
- only one organ or tissue is examined
- 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
- the delayed times are different before the examinations
- imaging by scintillation detector



## Static examination (scintigraphy)

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

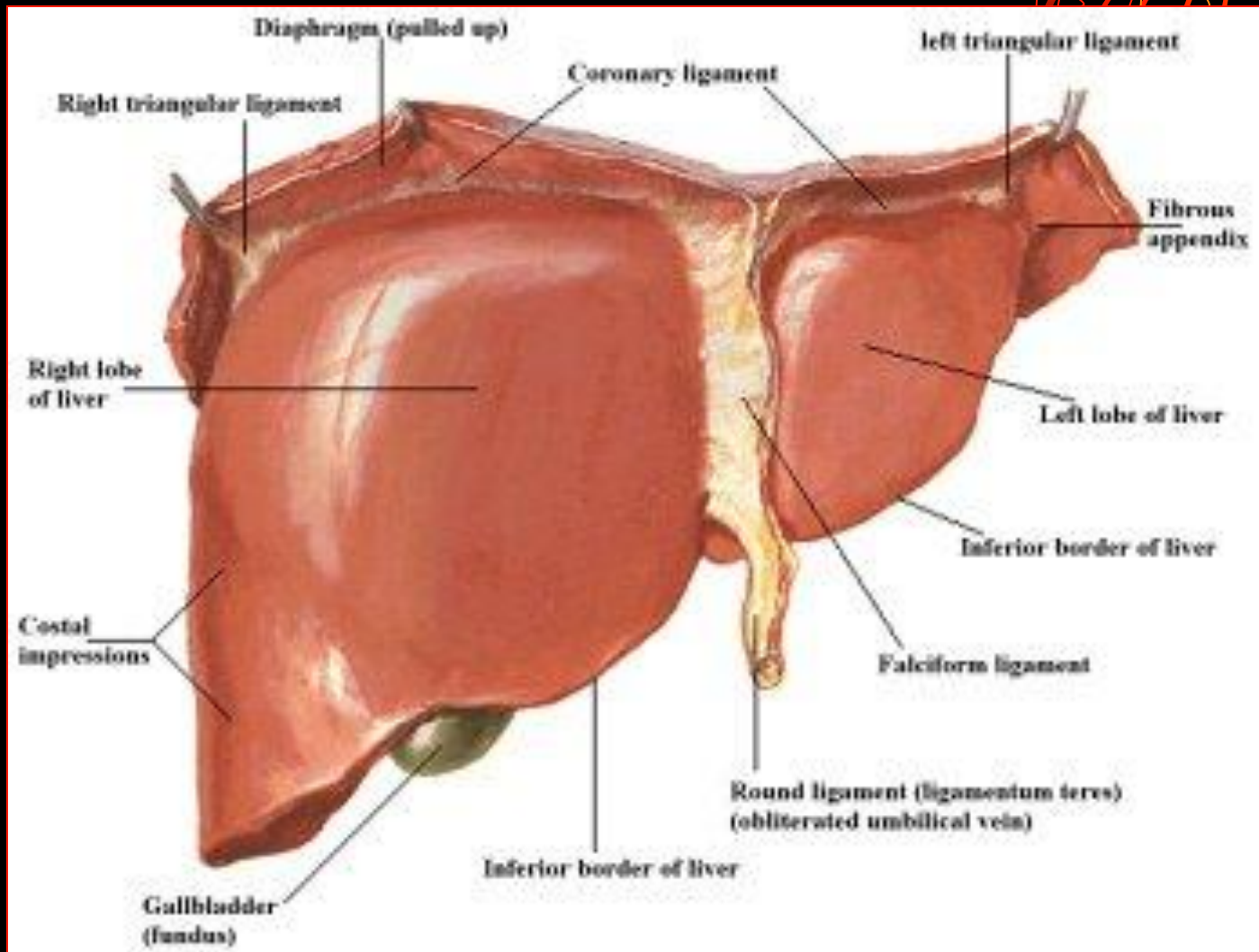
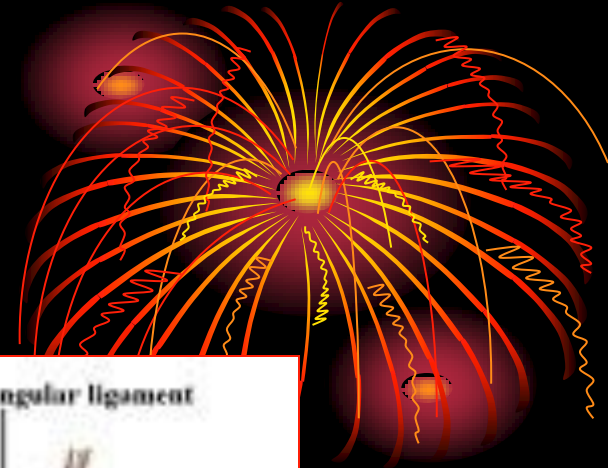
## Dynamic study

- **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**





# Anatomy of the liver



# Liver scintigraphy

The labelled colloid (200 MBq  $^{99m}\text{Tc}$ -Eytan)  
is enhanced in the RES-cells of the liver

Static imaging (after 20 minutes) from  
6 directions + SPECT or SPECT/CT  
examination is very useful

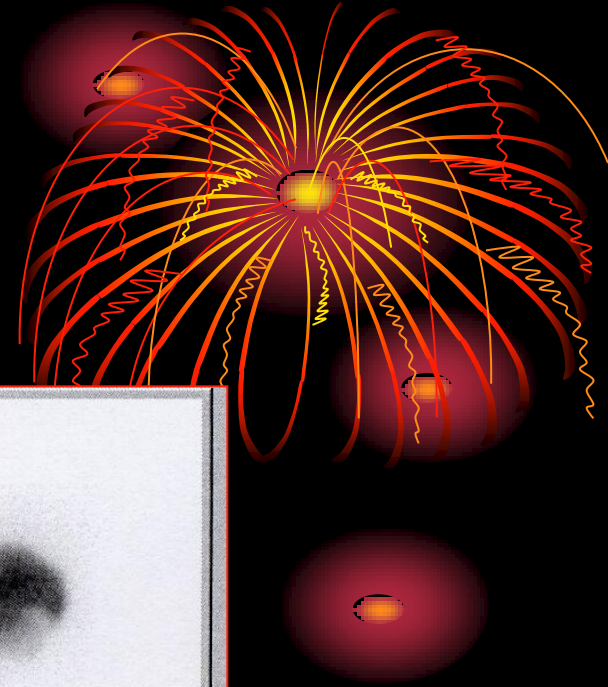
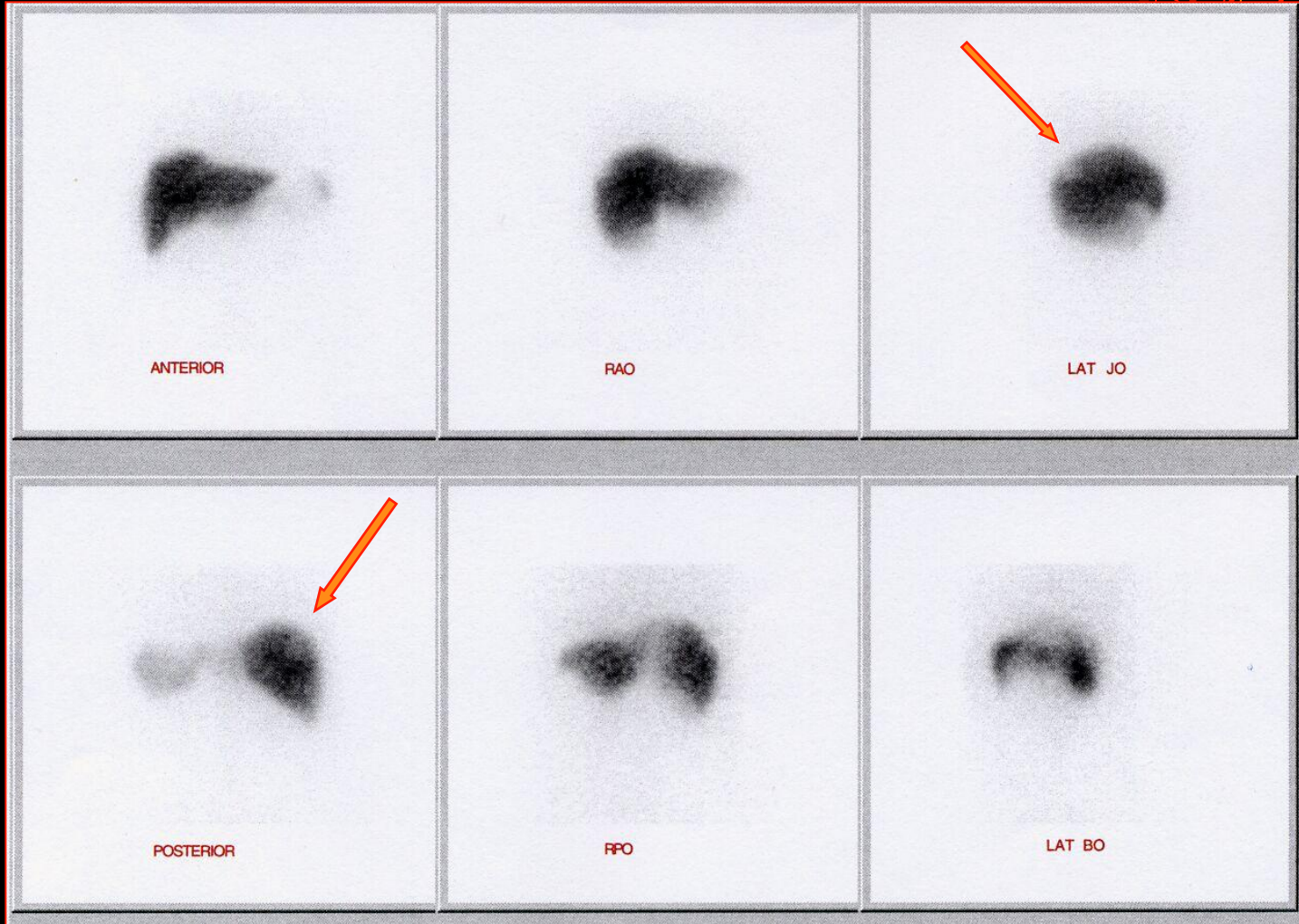
The focal defect is signed by the decreasing  
and/or the lack of the activity

Indications: primary tumors, metastases,  
cysts, *haemangioma*, *FNH*



# Focal parenchymal defect

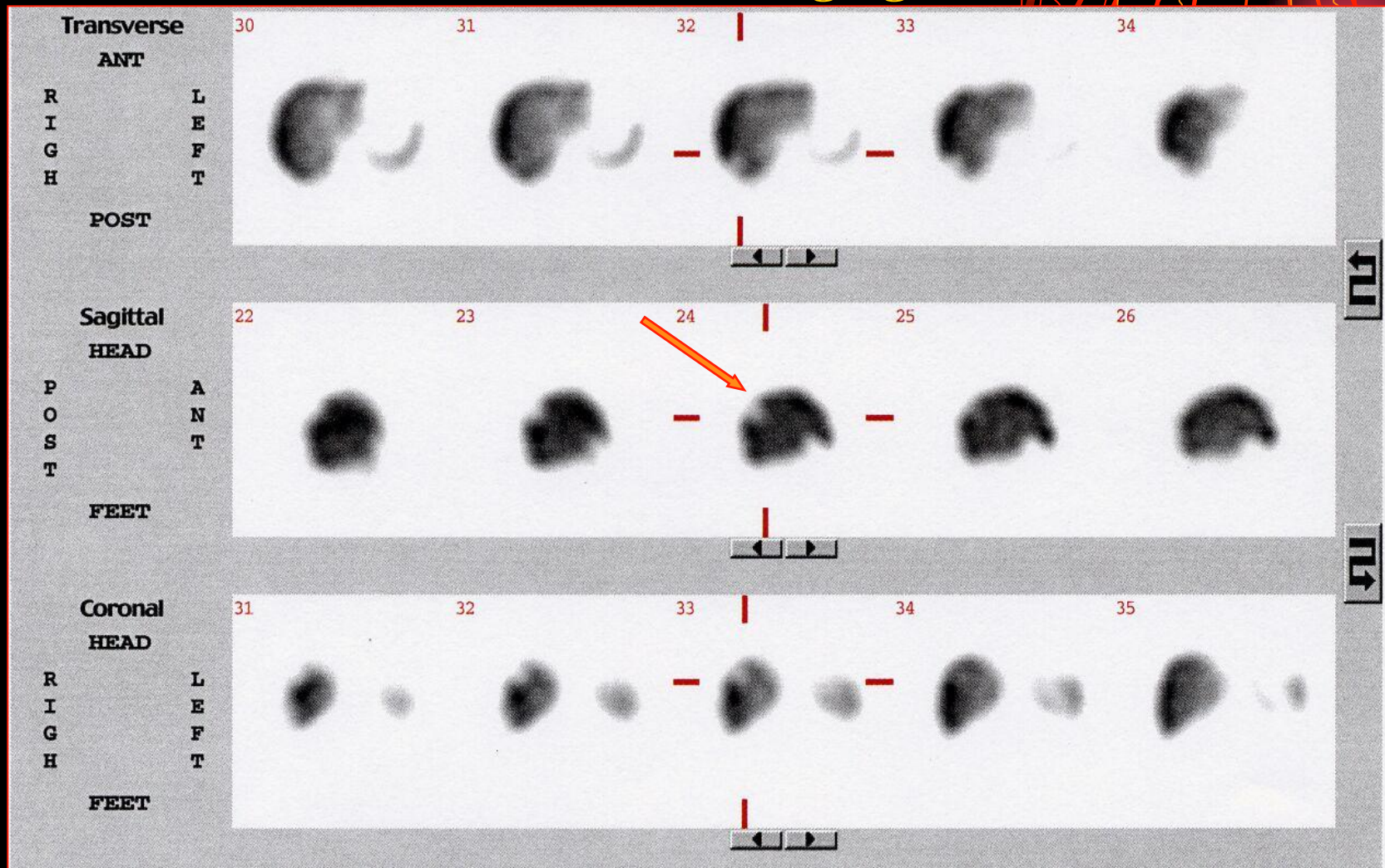
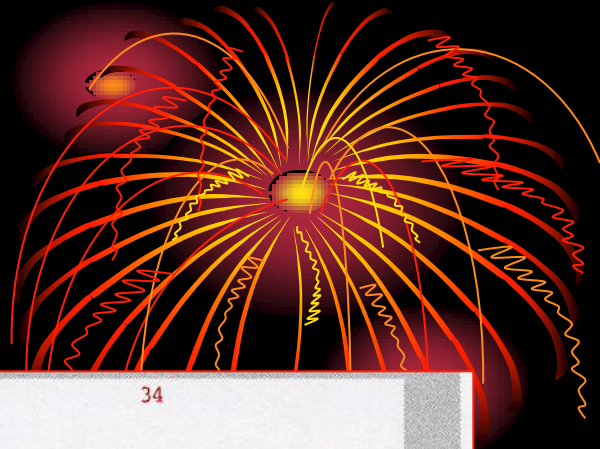
## Static imaging



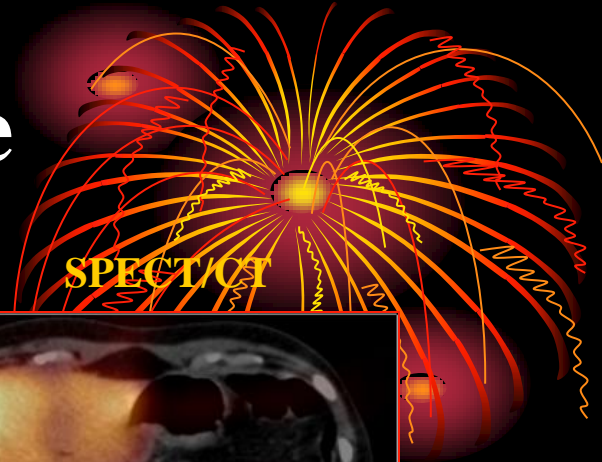


# Focal parenchymal defect

## SPECT imaging



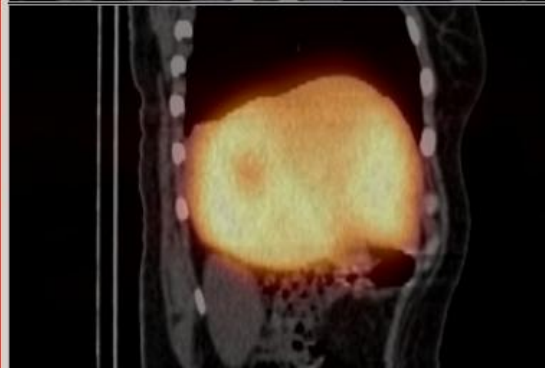
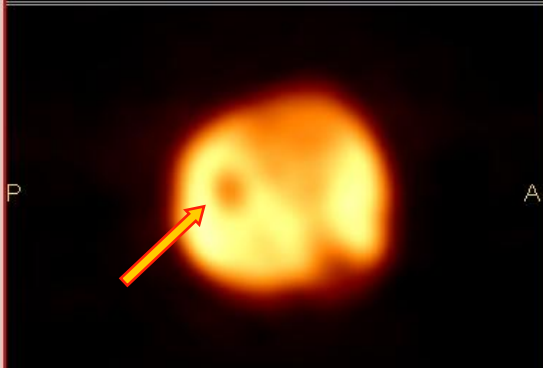
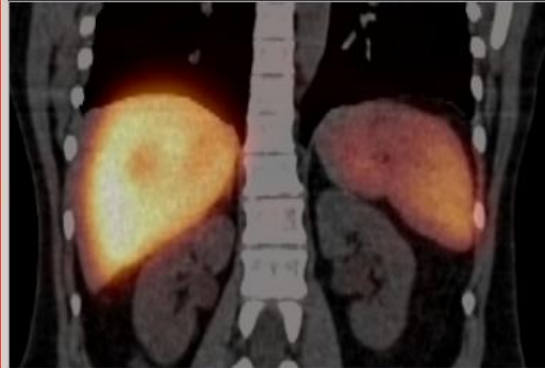
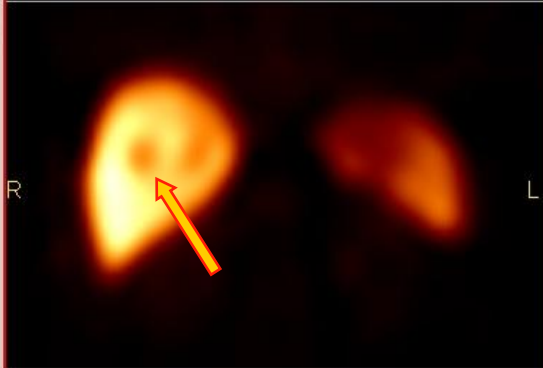
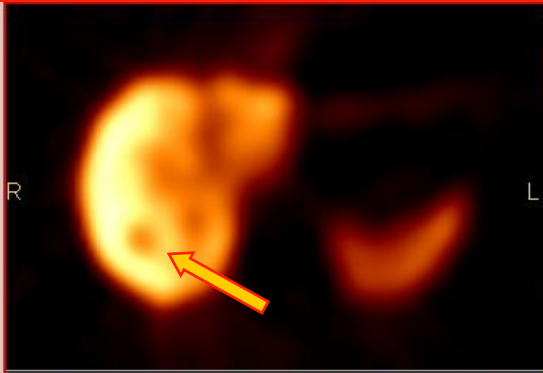
# Liver SPECT/CT fused image



CT

SPECT

SPECT/CT



# Liver blood-pool scintigraphy



**The blood-pool of the liver is labelled by  $^{99m}\text{Tc}$ -pyrophosphate-red blood cells:**

**At first inactive pyrophosphate is injected i.v.,  
20 minutes later 500 MBq  $^{99m}\text{Tc}$ -pertechnetate  
is injected i.v., too**

**Imaging is performed in equilibrium from 6  
directions (similar to colloid scan) + SPECT  
or SPECT/CT**

**Haemangioma is seen by increased activity**

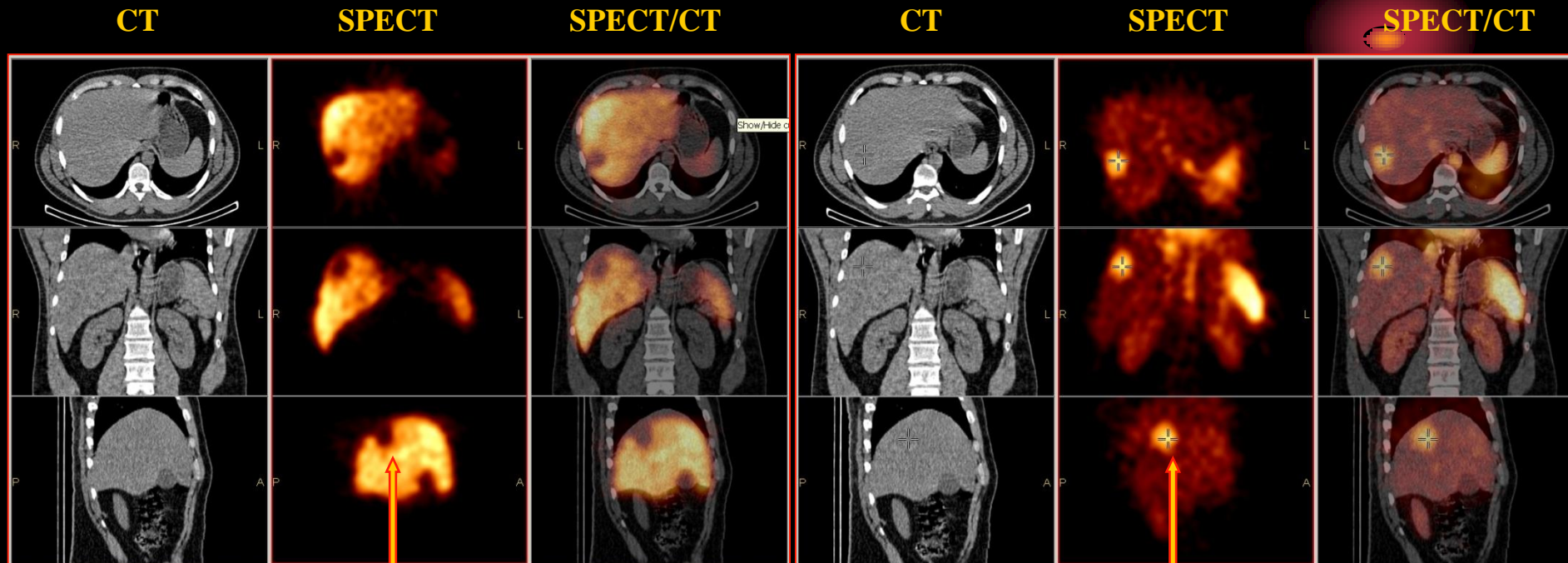


# Liver colloid and blood-pool SPECT/CT fused image in haemangioma



**Colloidal scintigraphy**

**Blood-pool scintigraphy**



**Focal parenchymal defect**

**Increased blood pool**

# Hepatobiliary scintigraphy I.



**The goal of the examination:**

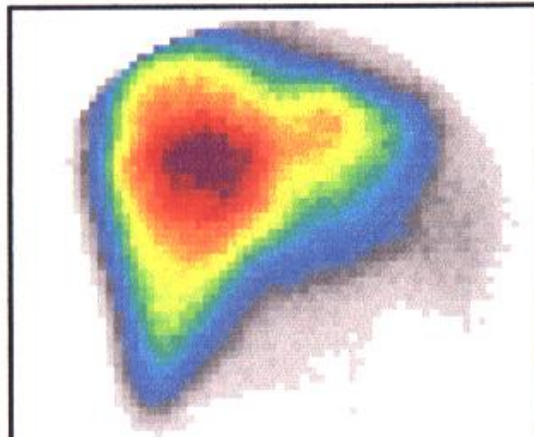
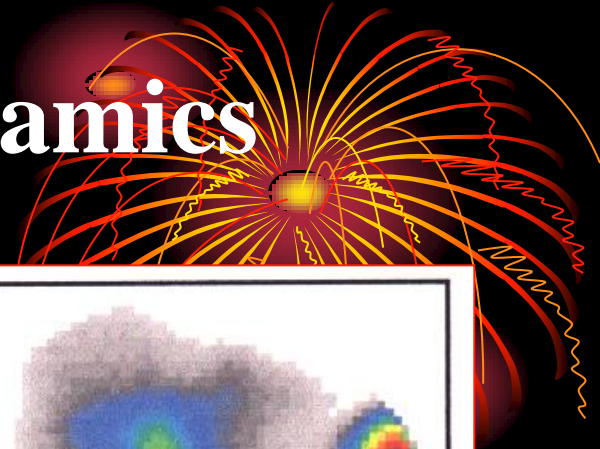
- **secretion function of the liver from the blood**
- **excretion function of the bile through the liver cells**
- **function of the gall bladder (contraction by Sorbitol, ejection fraction)**

**The way of the radioactive agent -  $^{99m}\text{Tc}$ -HIDA - from the blood to the bowels:**

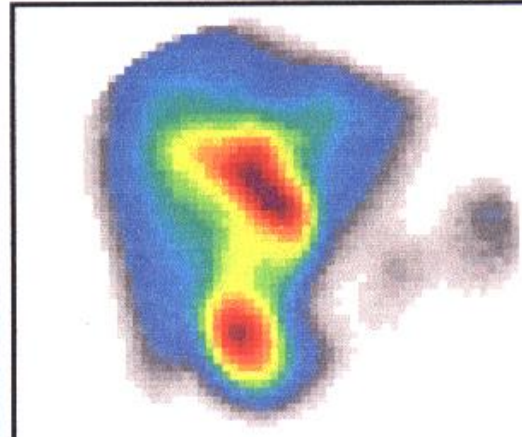
- **parenchymal part of the liver**
- **ductus hepaticus**
- **ductus choledochus**
- **cholecysta**
- **bowels**



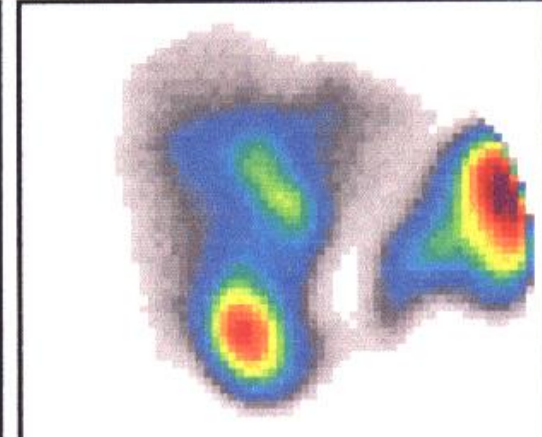
# Normal hepatobiliary dynamics



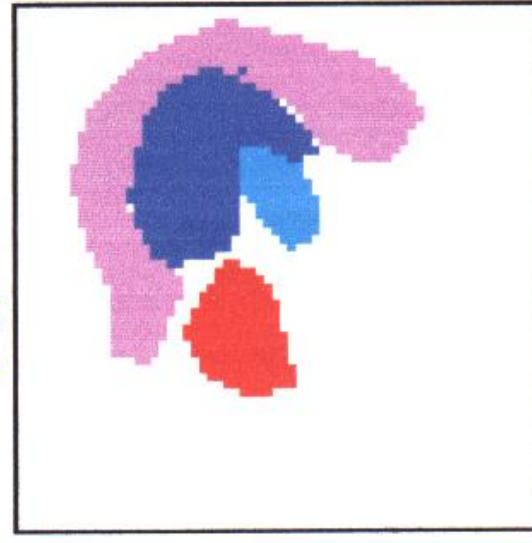
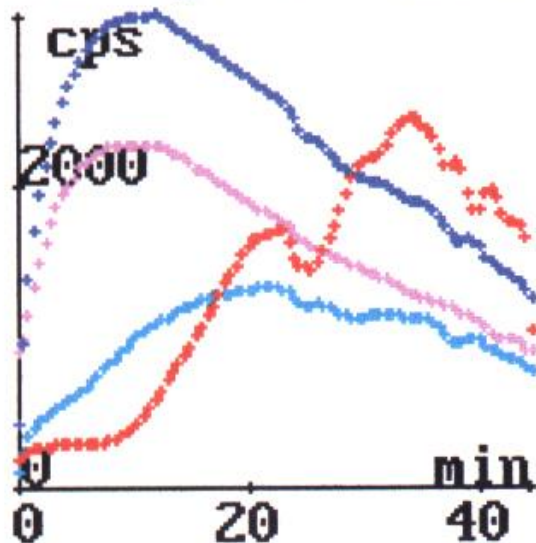
összeg: 3 - 15



összeg: 35 - 50



összeg: 75 - 89



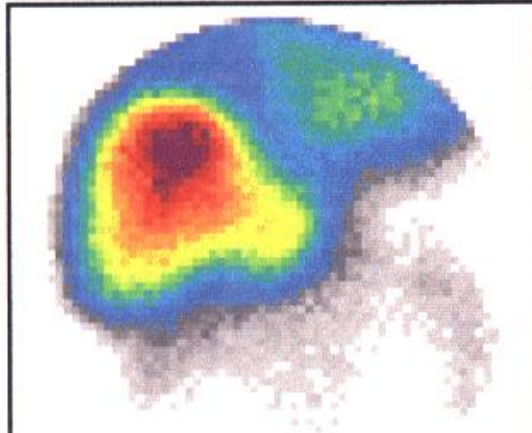
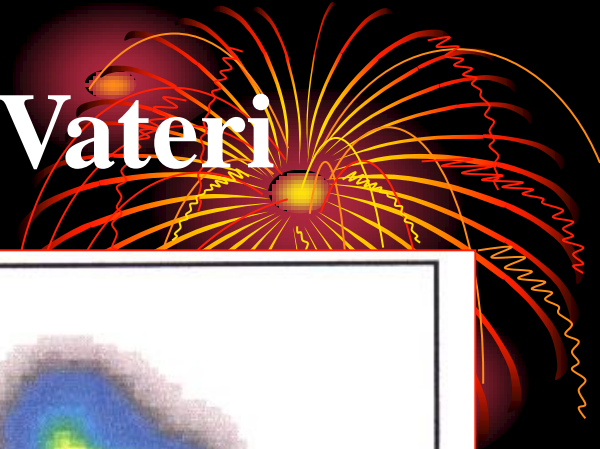
# Hepatobiliary scintigraphy II.



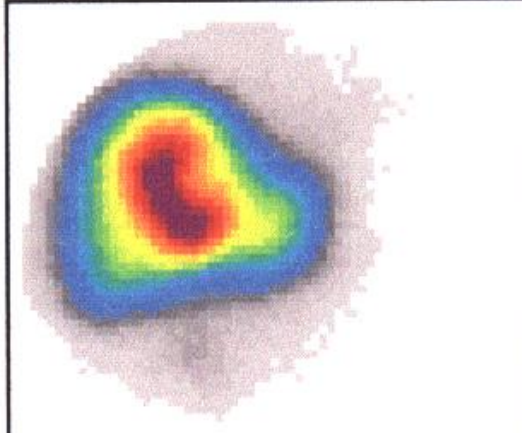
## Indications:

- **Post - cholecystectomical syndrome**
- **Bile excretion disorders**
- **Acute or chronic cholecystitis**
- **Cholecysto dyskinesia**
- **Focal nodular hyperplasia**
- **Flow of the bile to the abdominal cavity**
- **Atresia of the ductus hepaticus or choledochus**
- **Transplantation of the liver**

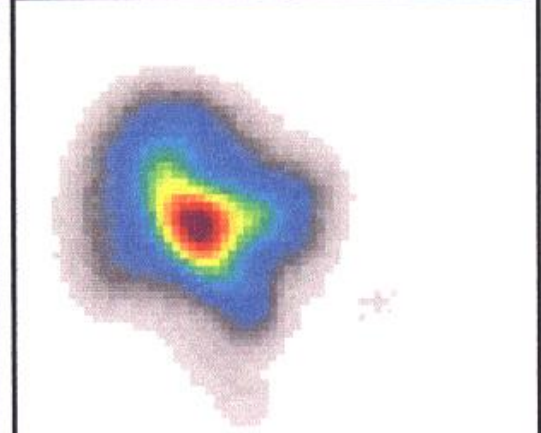
# Obstruction of the papilla Vateri



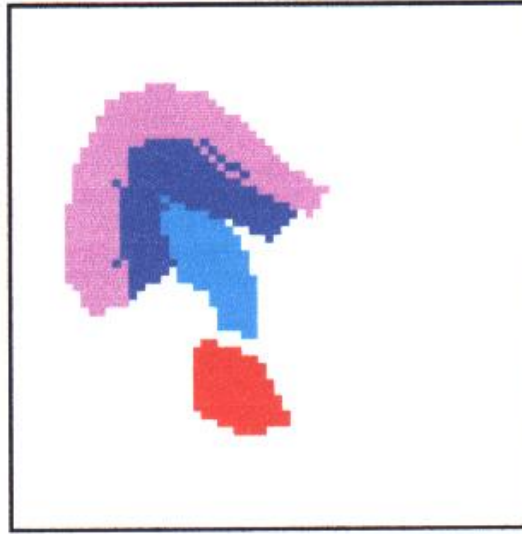
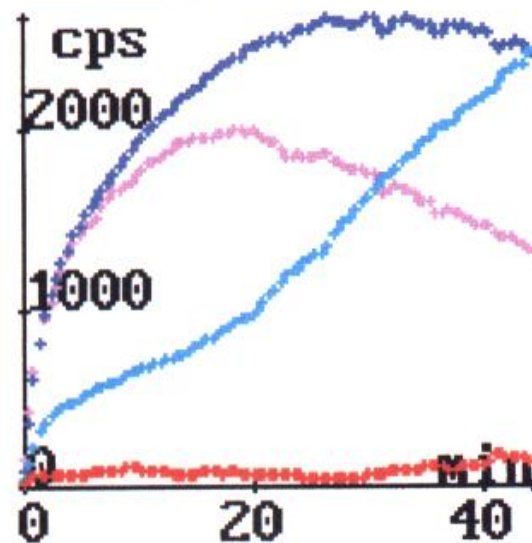
Összeg: 0 - 10



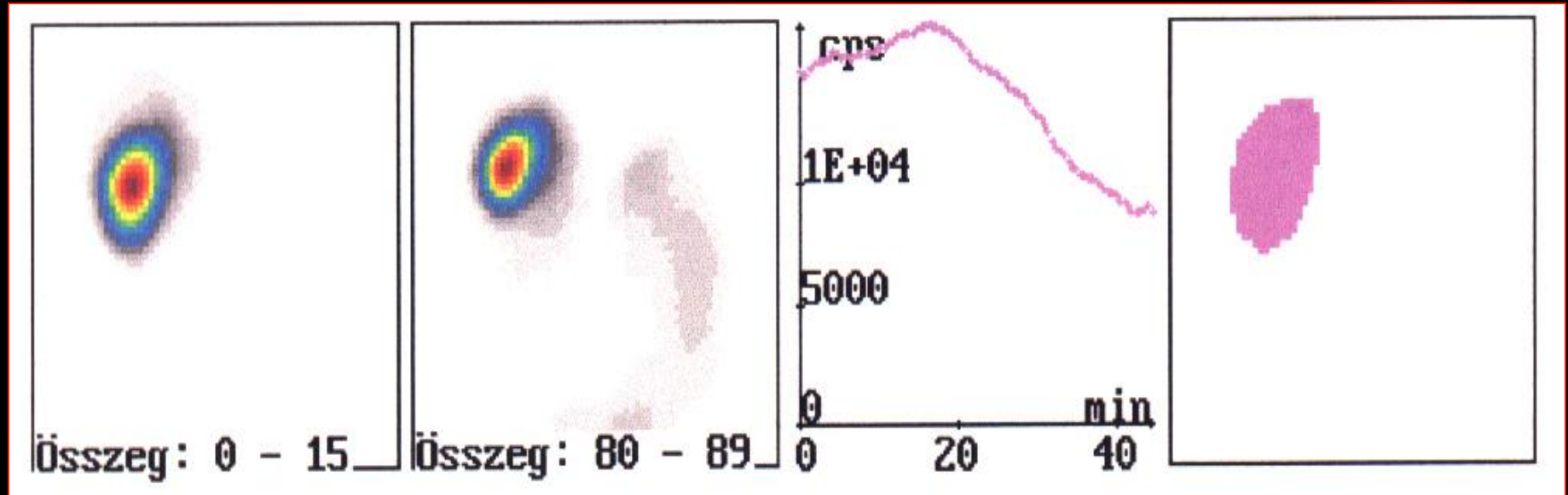
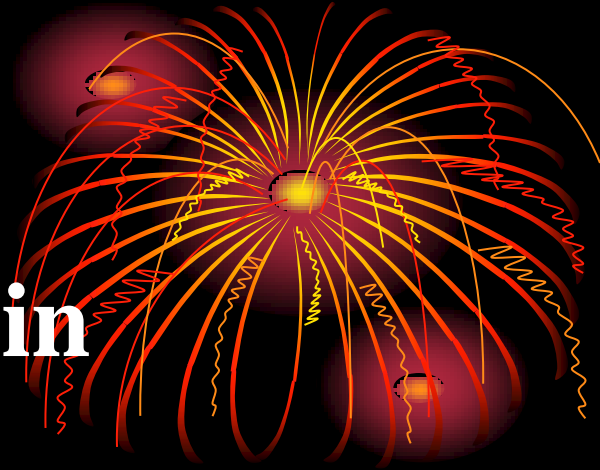
Összeg: 40 - 50



Összeg: 80 - 89

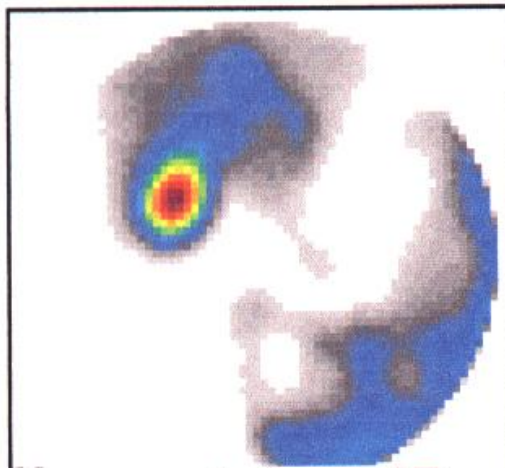
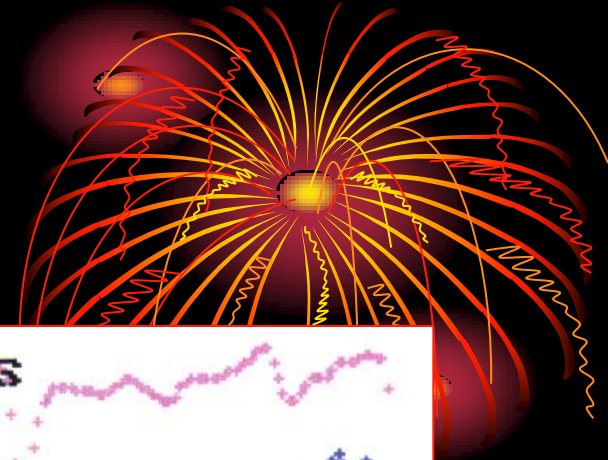


# Normal ejection fraction of the gall bladder: $>1\%/min$

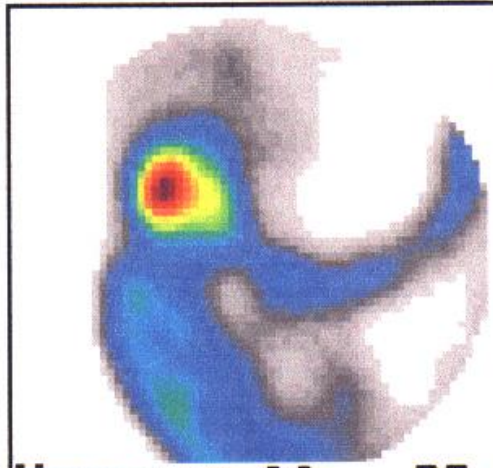




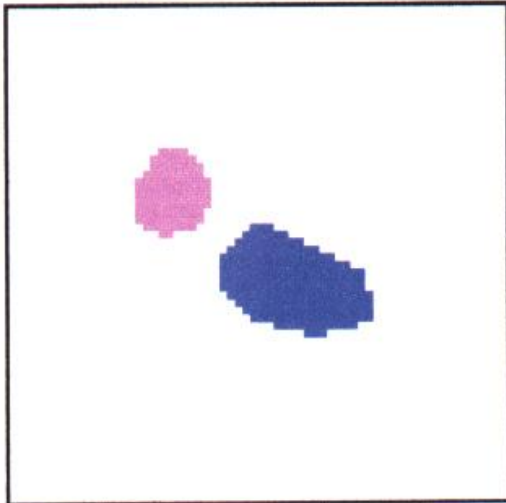
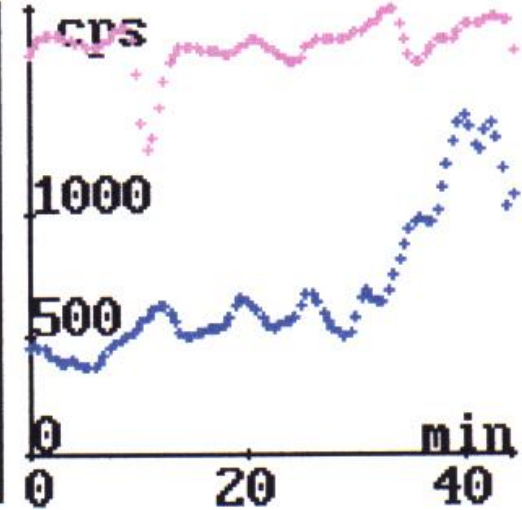
# Failed contraction of the gall bladder



Összeg: 0 - 18

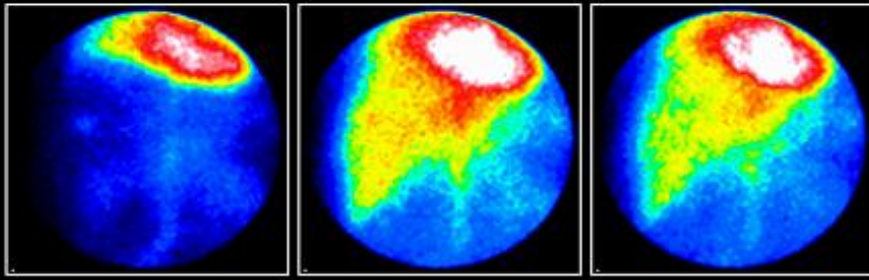


Összeg: 60 - 89

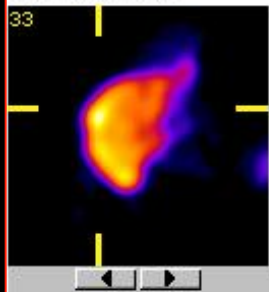


**Fig. b**

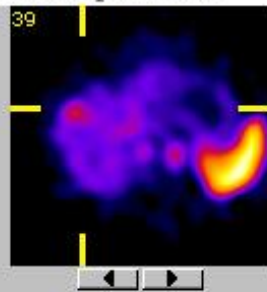
Perfusion



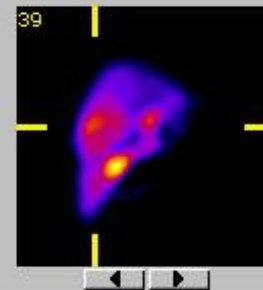
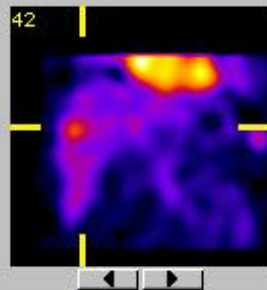
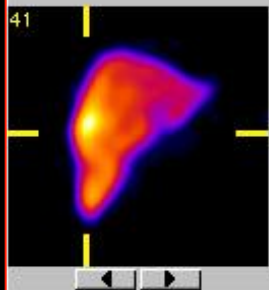
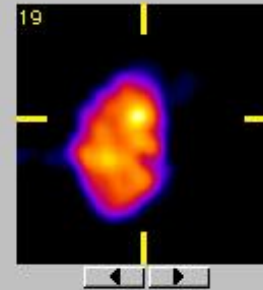
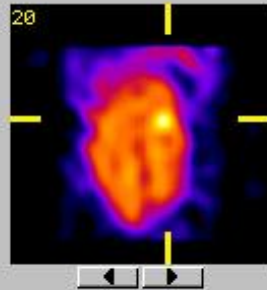
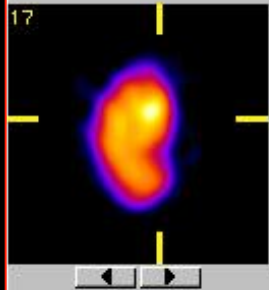
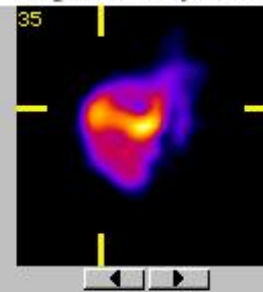
Colloid scan



Blood pool scan

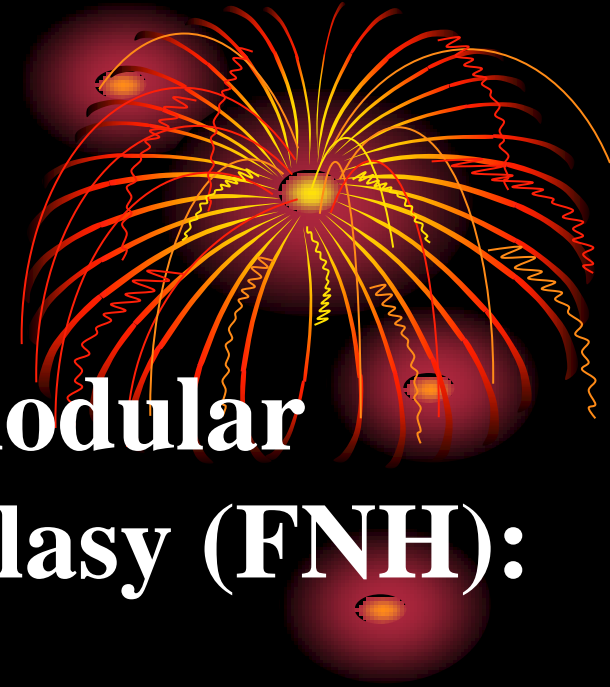


Hepatobiliary scan



# Focal nodular hyperplasia (FNH):

- higher perfusion
- normal or higher colloid activity
- higher blood-pool activity
- higher hepatobiliary activity



# Somatostatin receptor scintigraphy



Injected subject: **111-Indium-pentetreotide**  
(somatostatin analog peptide are binding to the receptors overexpressed on the surface of tumor cells)

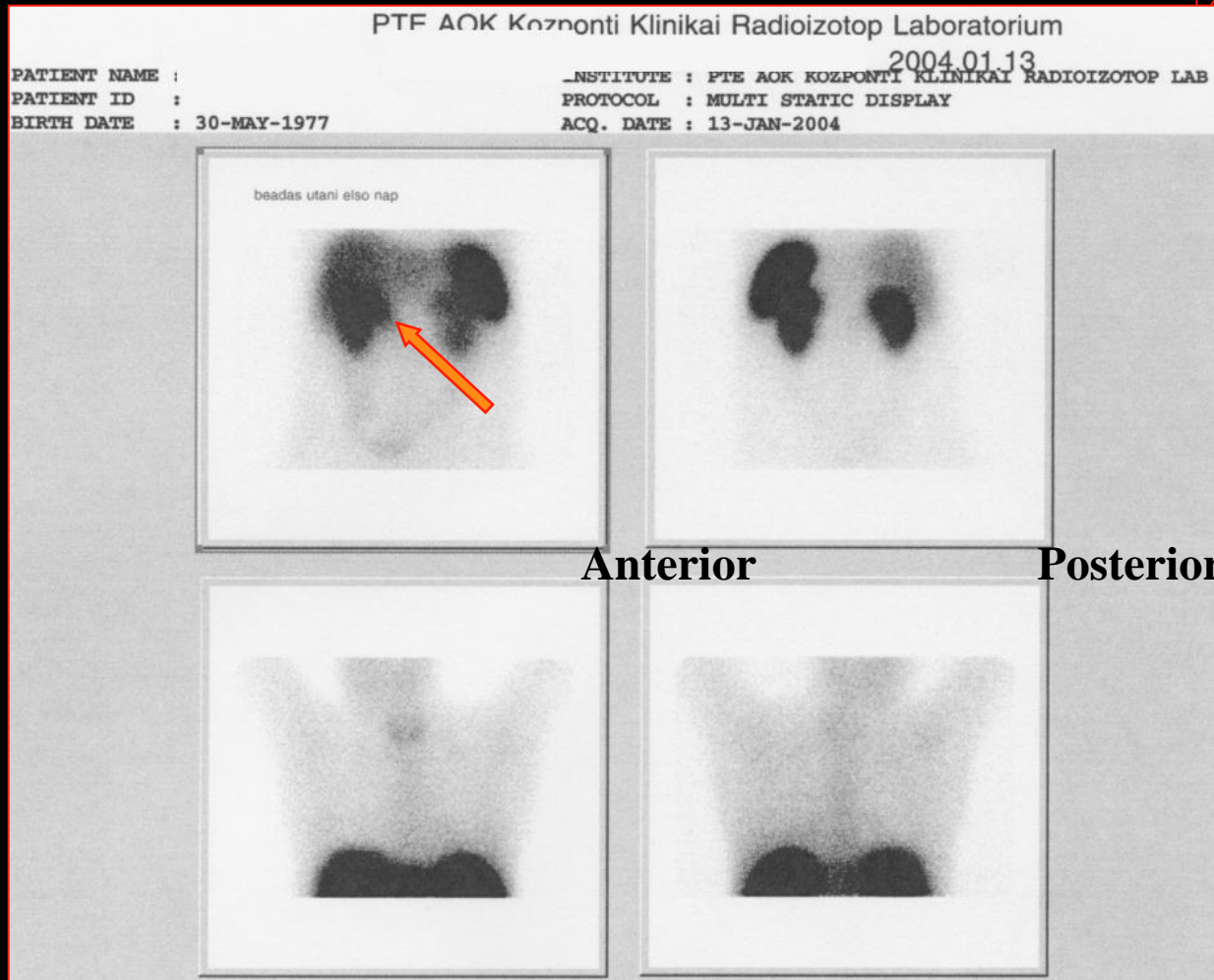
Imaging time: **24 and 48 hours after the intravenous injection**, SPECT/CT at the delayed time

Indications: - **carcinoid**  
- **GEP tumors**



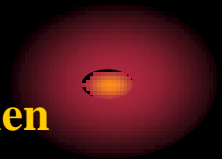
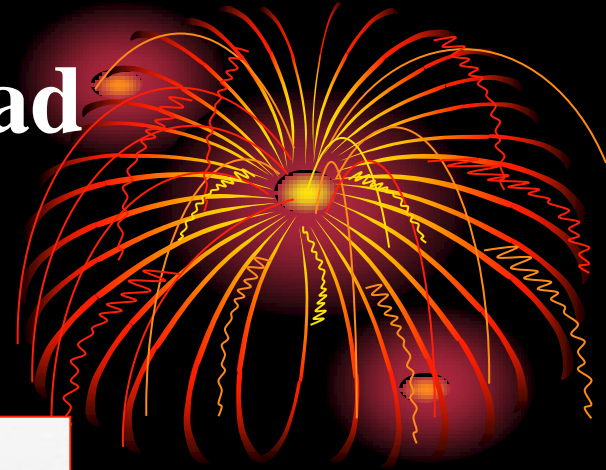
# Carcinoid in the pancreas head by $^{111}\text{In}$ -pentetreotide

## Static imaging



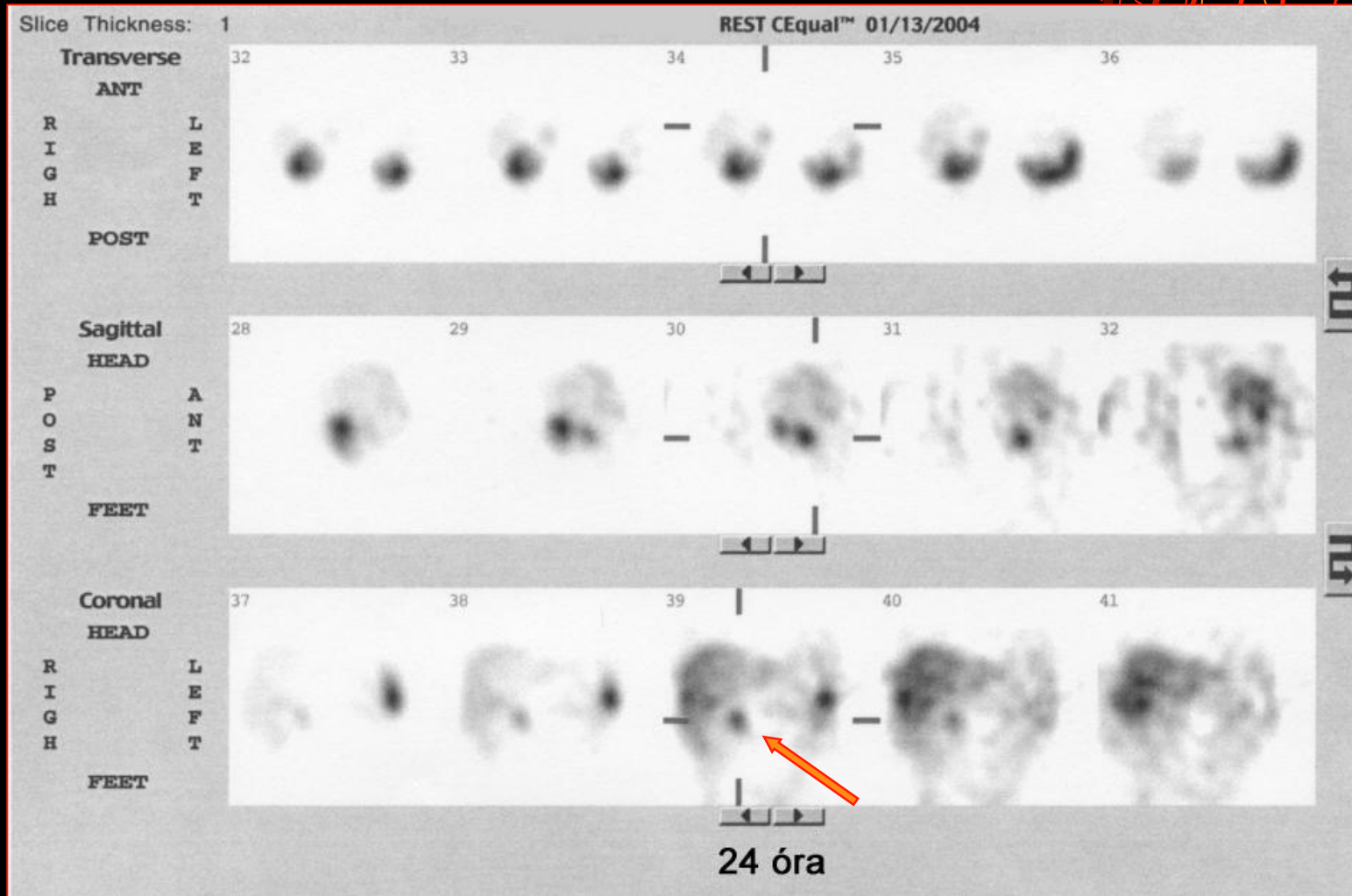
Abdomen

Chest



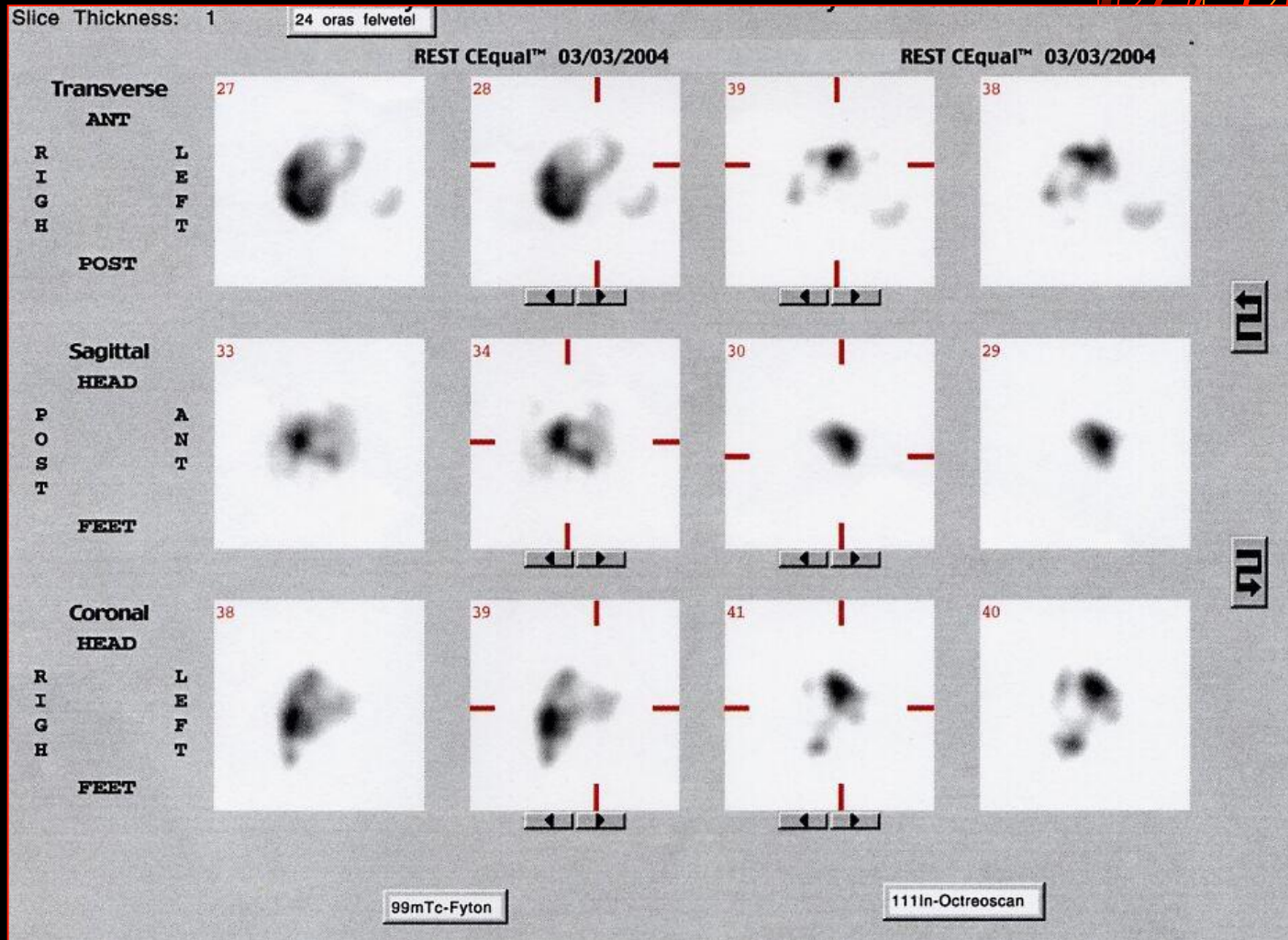
# Carcinoid in the pancreas head by $^{111}\text{In}$ -pentetreotide

## SPECT imaging



# Carcinoid metastasis in the liver by $^{99m}\text{Tc}$ -colloide and $^{111}\text{In}$ -pentetreotide

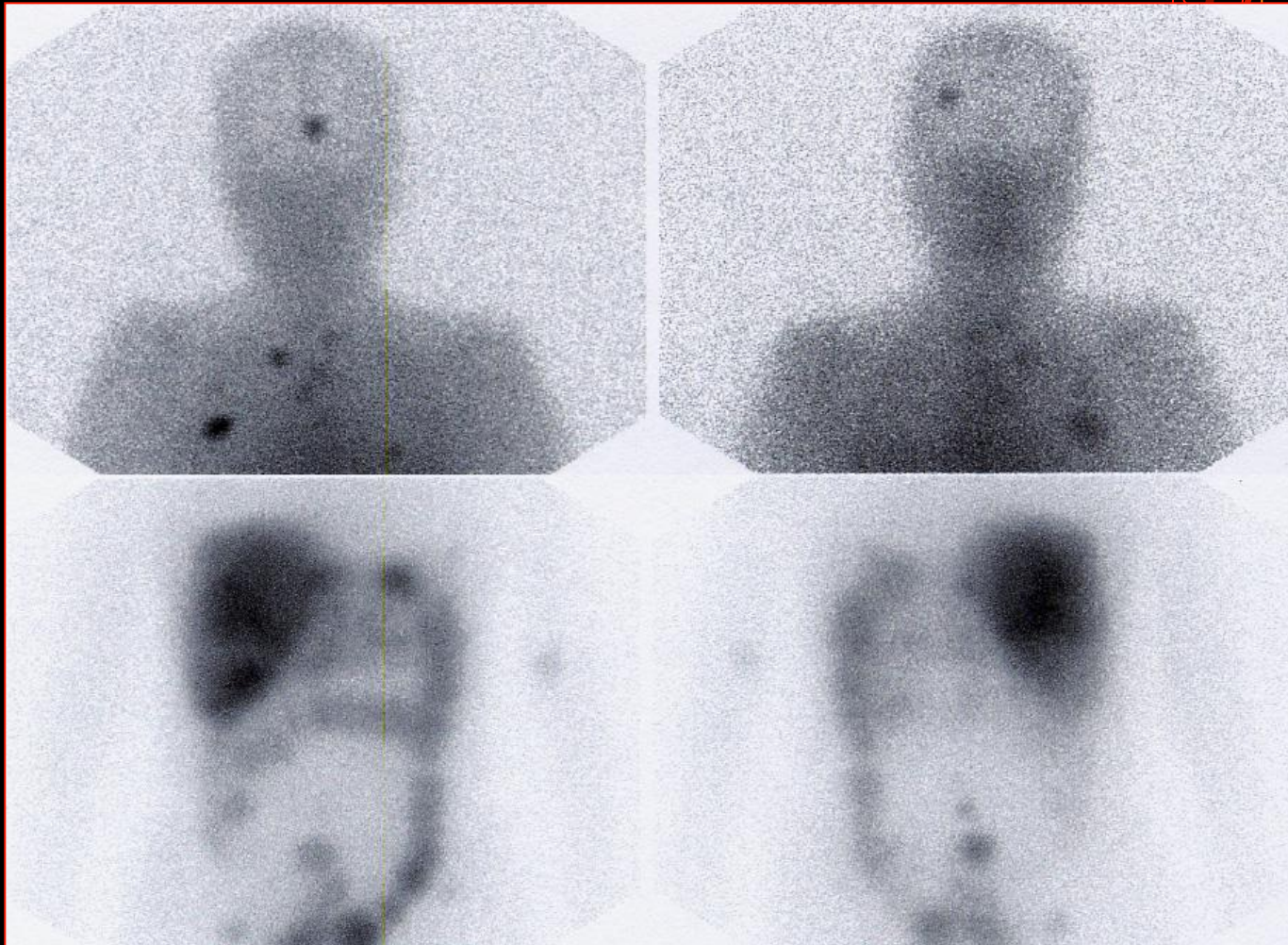
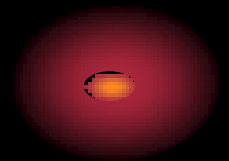
## SPECT imaging





# Carcinoid in the pancreas head, st. p. surgery, metastases?

**Static imaging by  $^{111}\text{In}$ -pentetreotide**



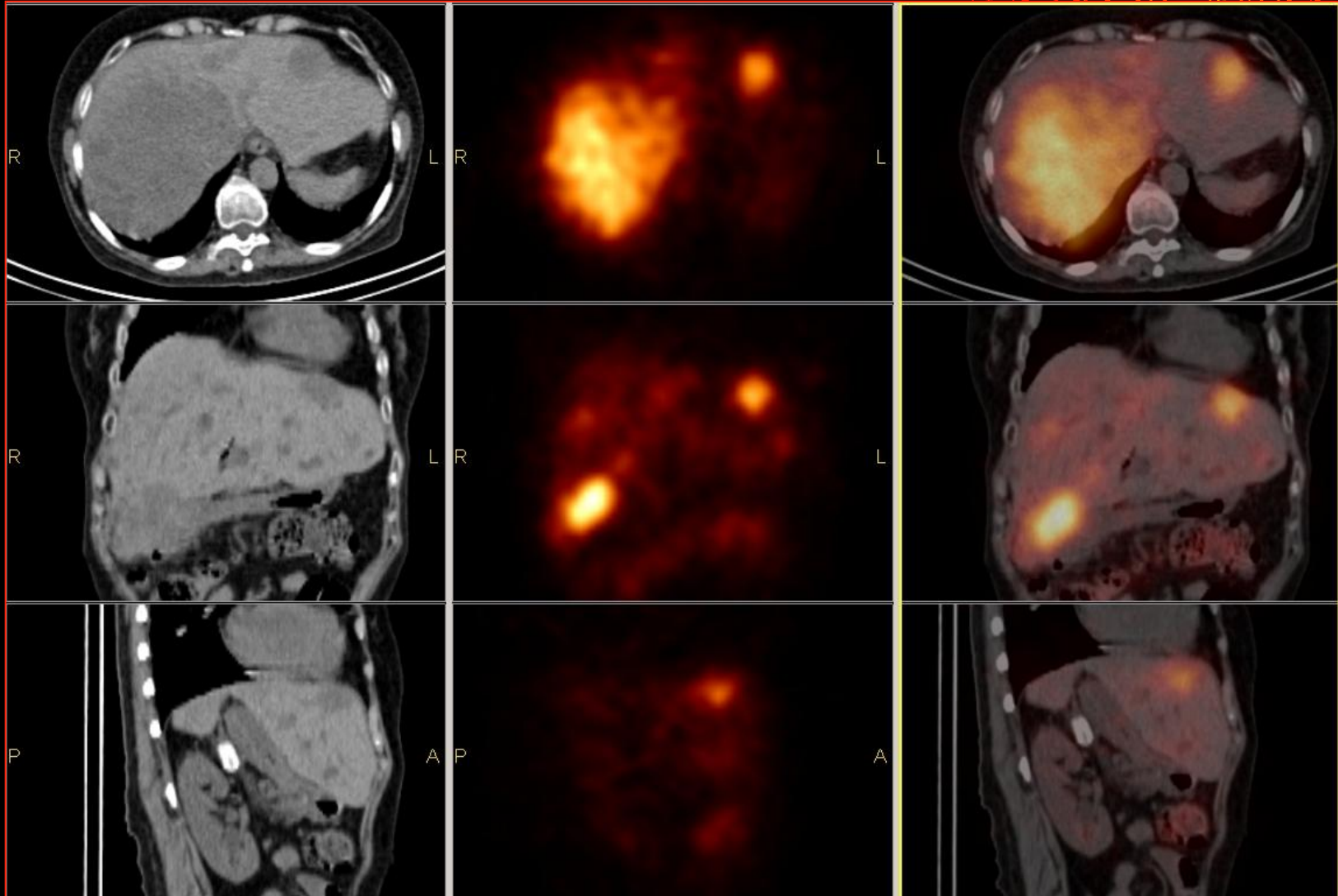
# Multiplex carcinoid metastases in the liver by $^{111}\text{In}$ -pentetreotide



CT

SPECT

SPECT/CT

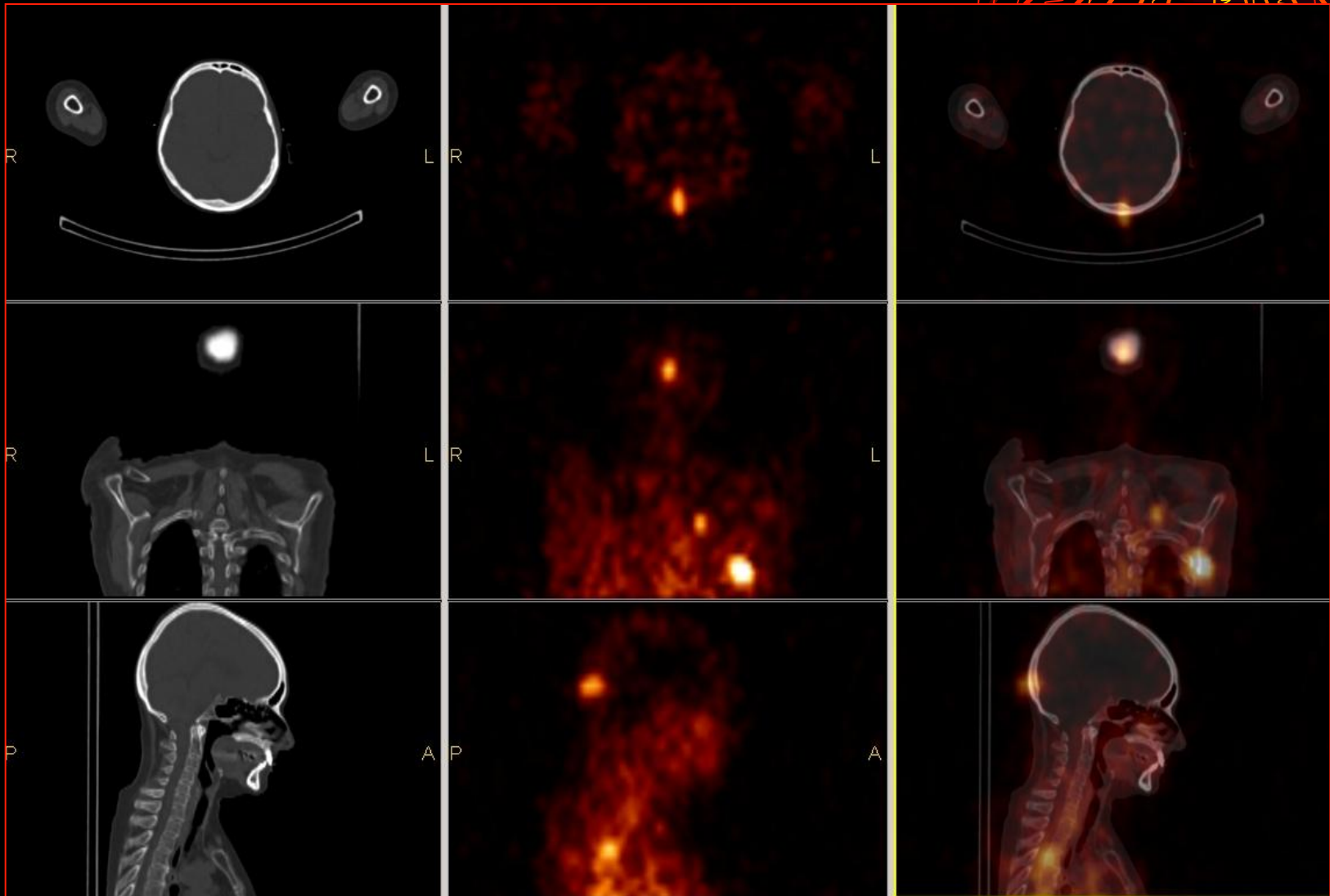


# Multiplex carcinoid metastases in the bones by $^{111}\text{In}$ -pentetreotide

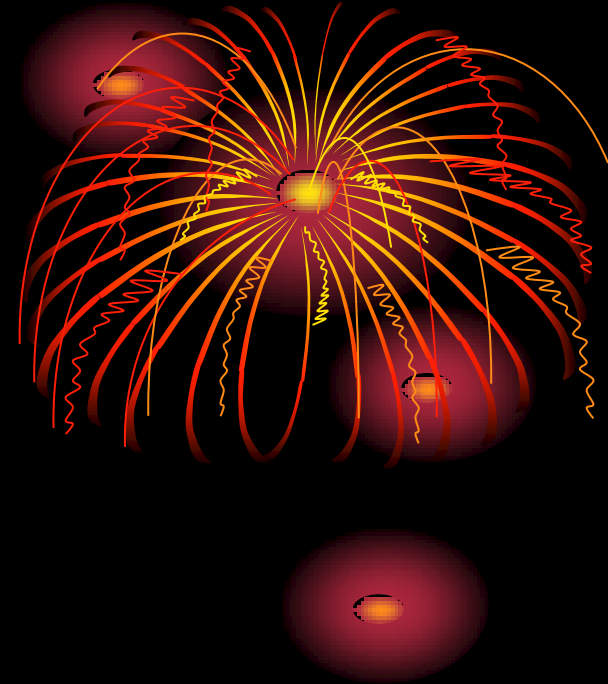
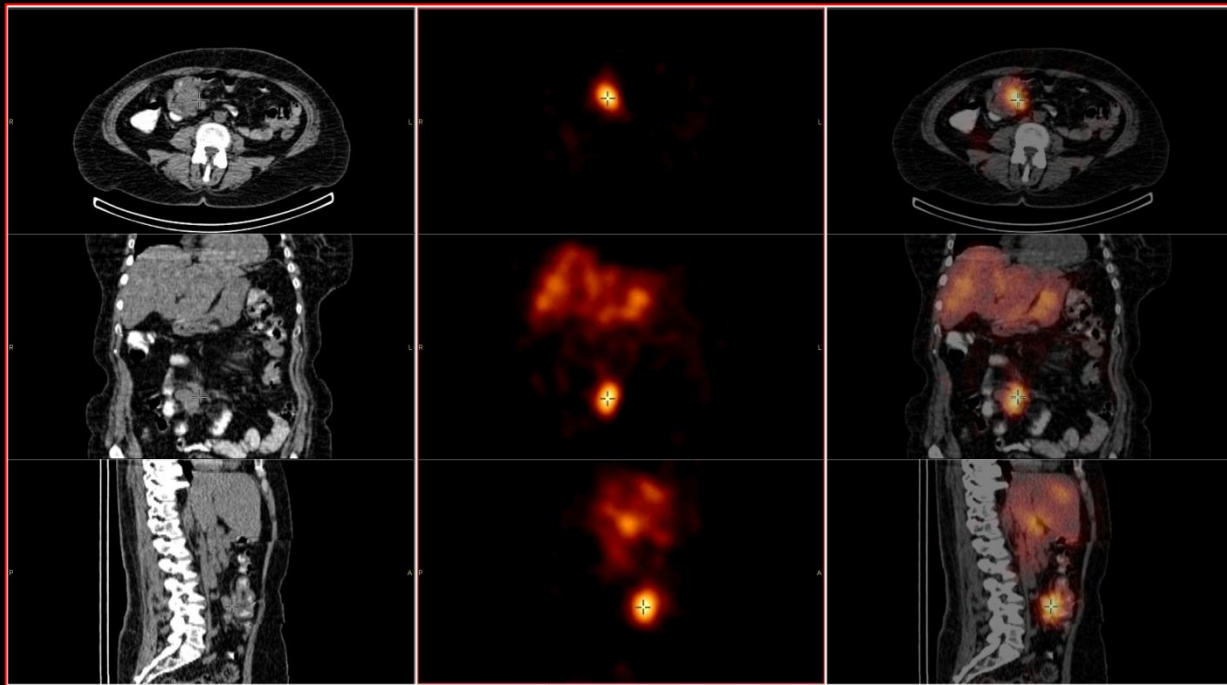
CT

SPECT

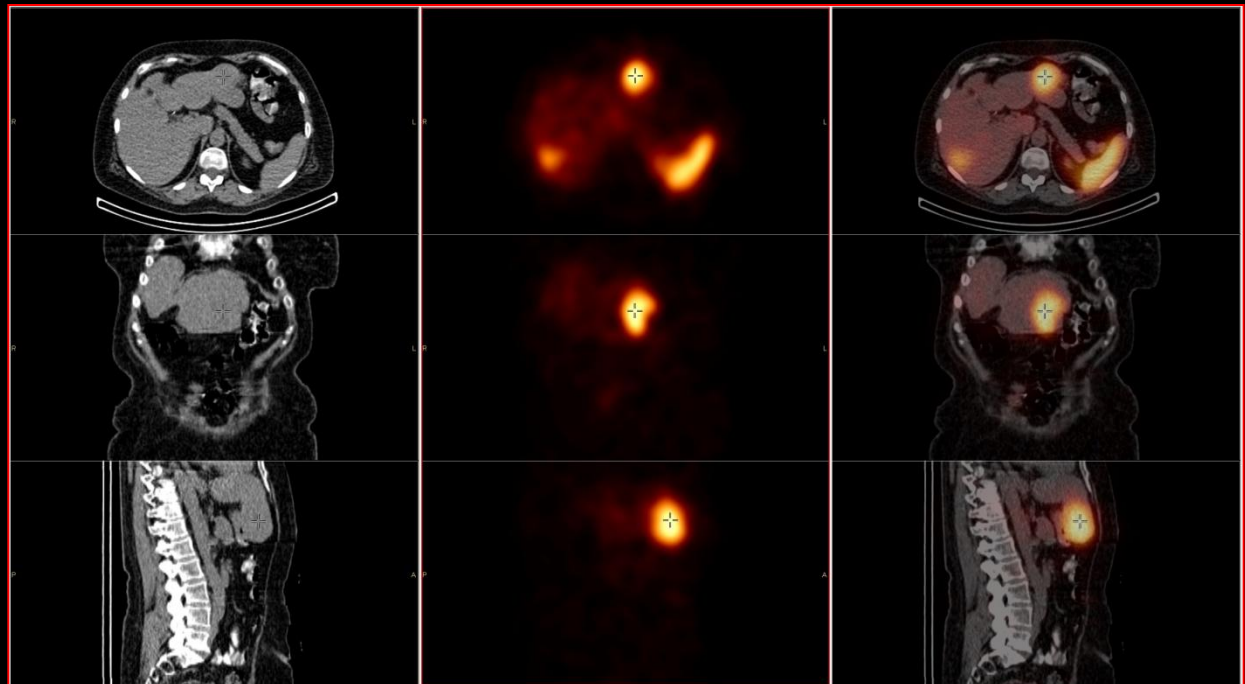
SPECT/CT







**NET in the small  
intestine with  
multiplex liver  
metastases  
by  $^{111}\text{In}$ -  
pentetreotide**





# Adrenerg receptor scintigraphy

Injected subject:  **$^{123}$ -iodine or  $^{131}$ -iodine-MIBG** (metaiodobenzyl-guanidine) is binding to adrenerg receptors

Imaging time: **6 and 24 or 24 and 48 hours** after the intravenous injection, SPECT/CT at the delayed time

Indications:

- **neuroendocrin tumors**
- **pheochromocytoma**
- **neuroblastoma**



# Liver metastases of GEP tumor

## by $^{123}\text{I}$ -MIBG

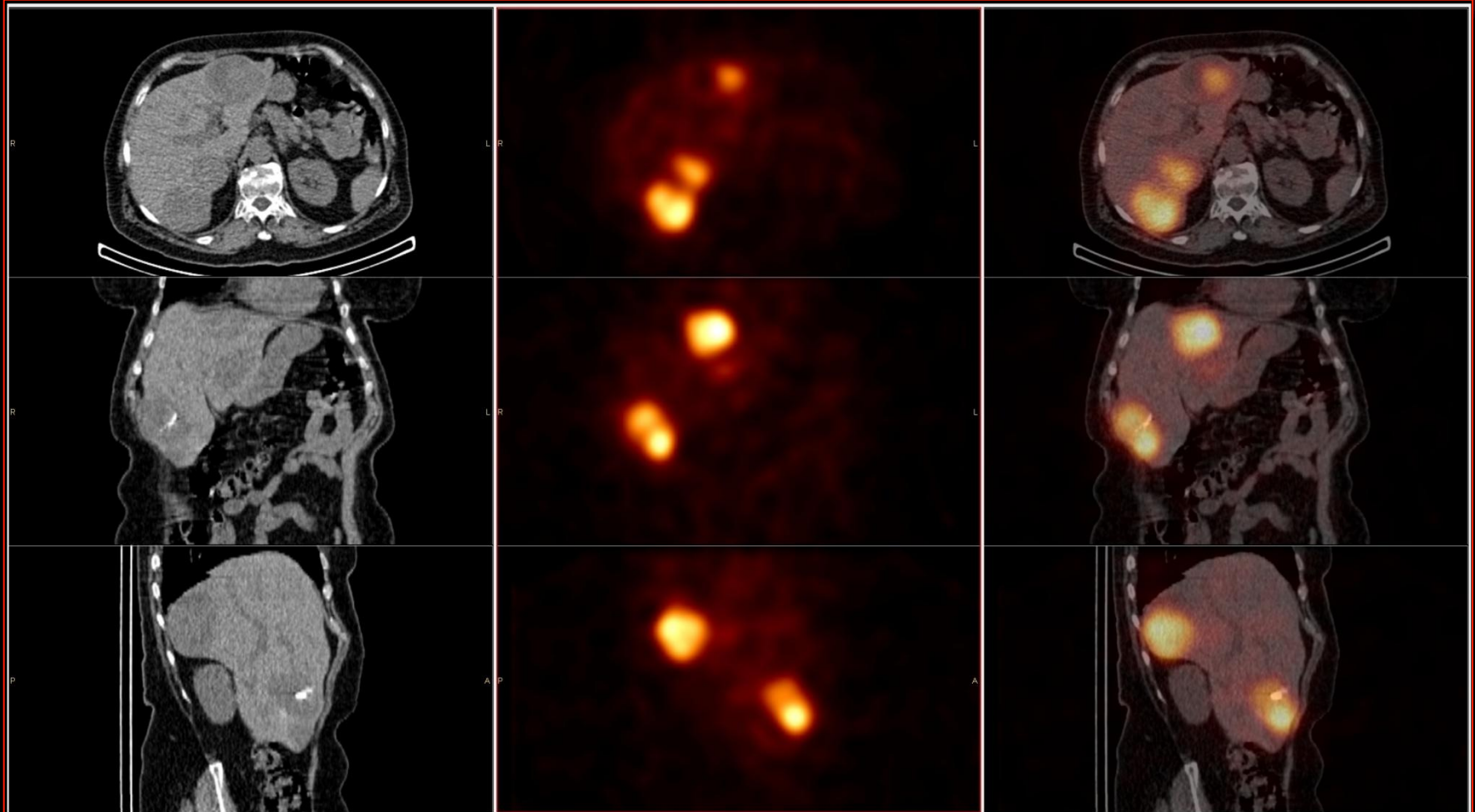
*(examination before  $^{131}\text{I}$ -MIBG therapy)*



CT

SPECT

SPECT/CT



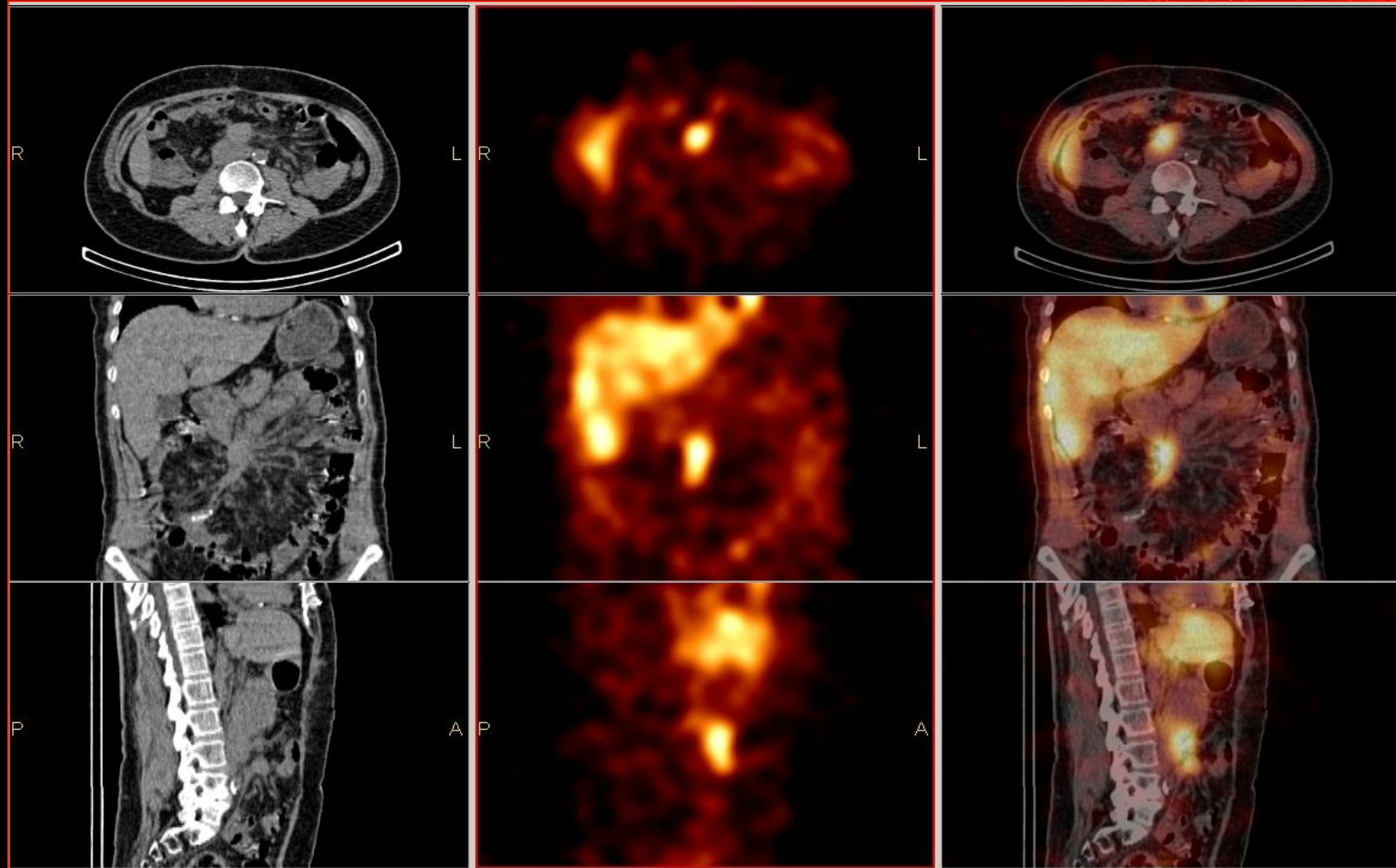
# Paraaortic lymph node metastasis after operation of NET of small intestine by $^{123}\text{I}$ -MIBG



CT

SPECT

SPECT/CT



# Oesophagus scintigraphy and gastric emptying study



**Radiopharmaceutical:** the patient drink water for oesophagus study and/or eat a meal in which a solid component of the meal (scrambled egg), a liquid component of the meal (water), or both for gastric emptying study, are mixed with a small amount of radioactive material 40-80 MBq  $^{99m}\text{Tc}$ -DTPA

**Dynamic examination** is started immediately

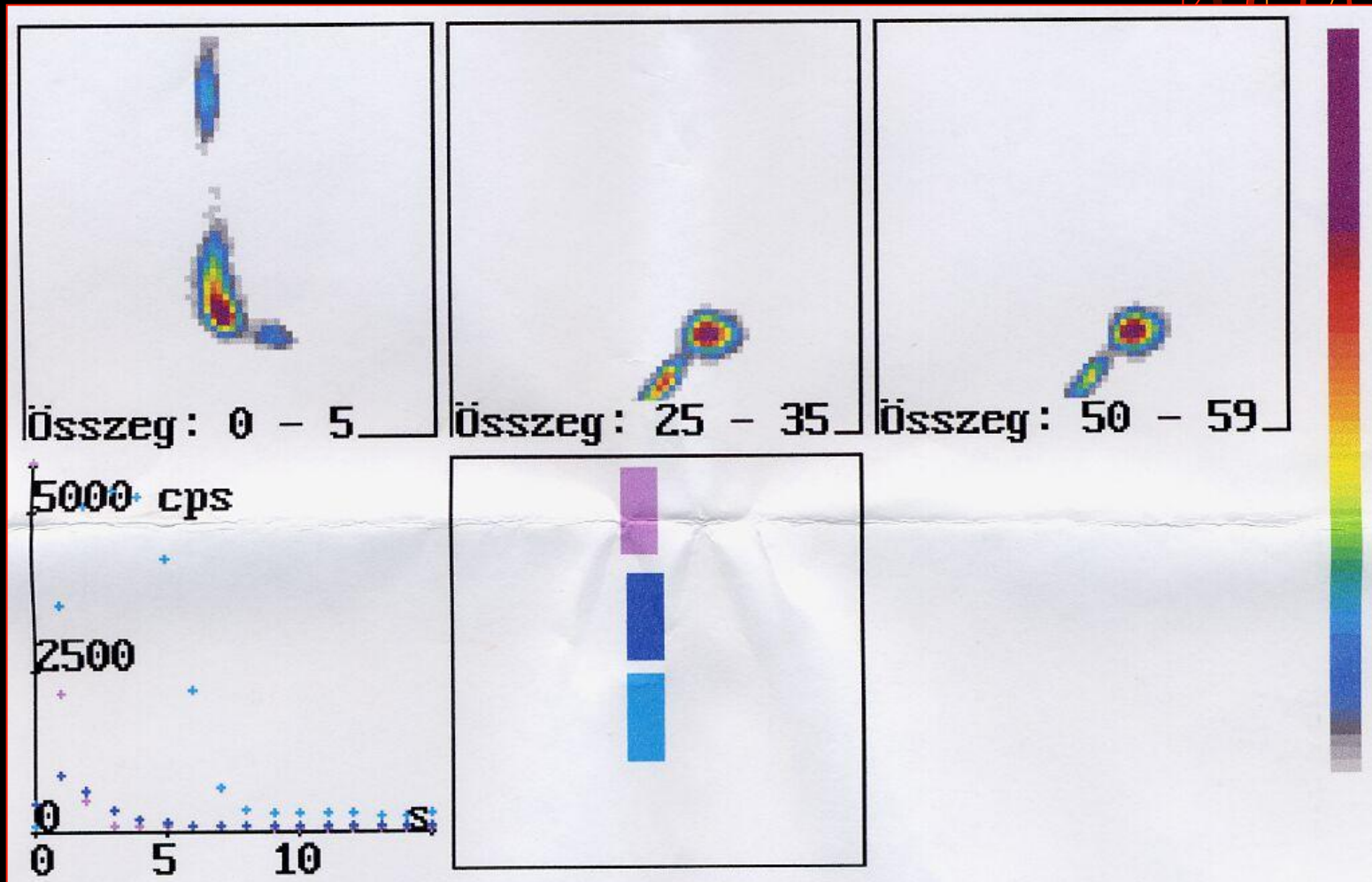
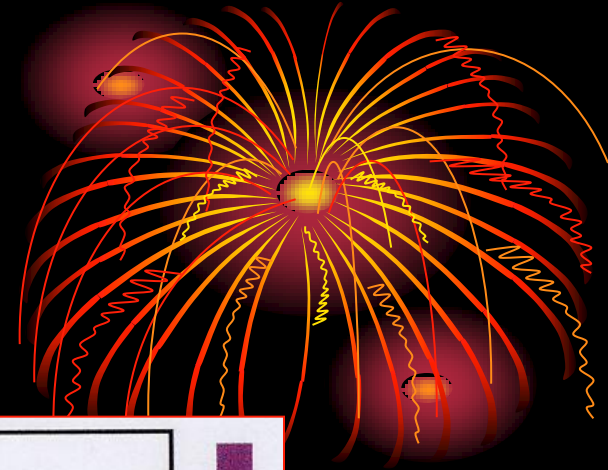
**Generation of time-activity curves** by software program

**Calculation of parameters:** half time, emptying speed of the radioactive meal through to the stomach and bowels

**Indications:** motility failures of oesophagus and/or stomach, cardiac and pyloric stenosis, tumors



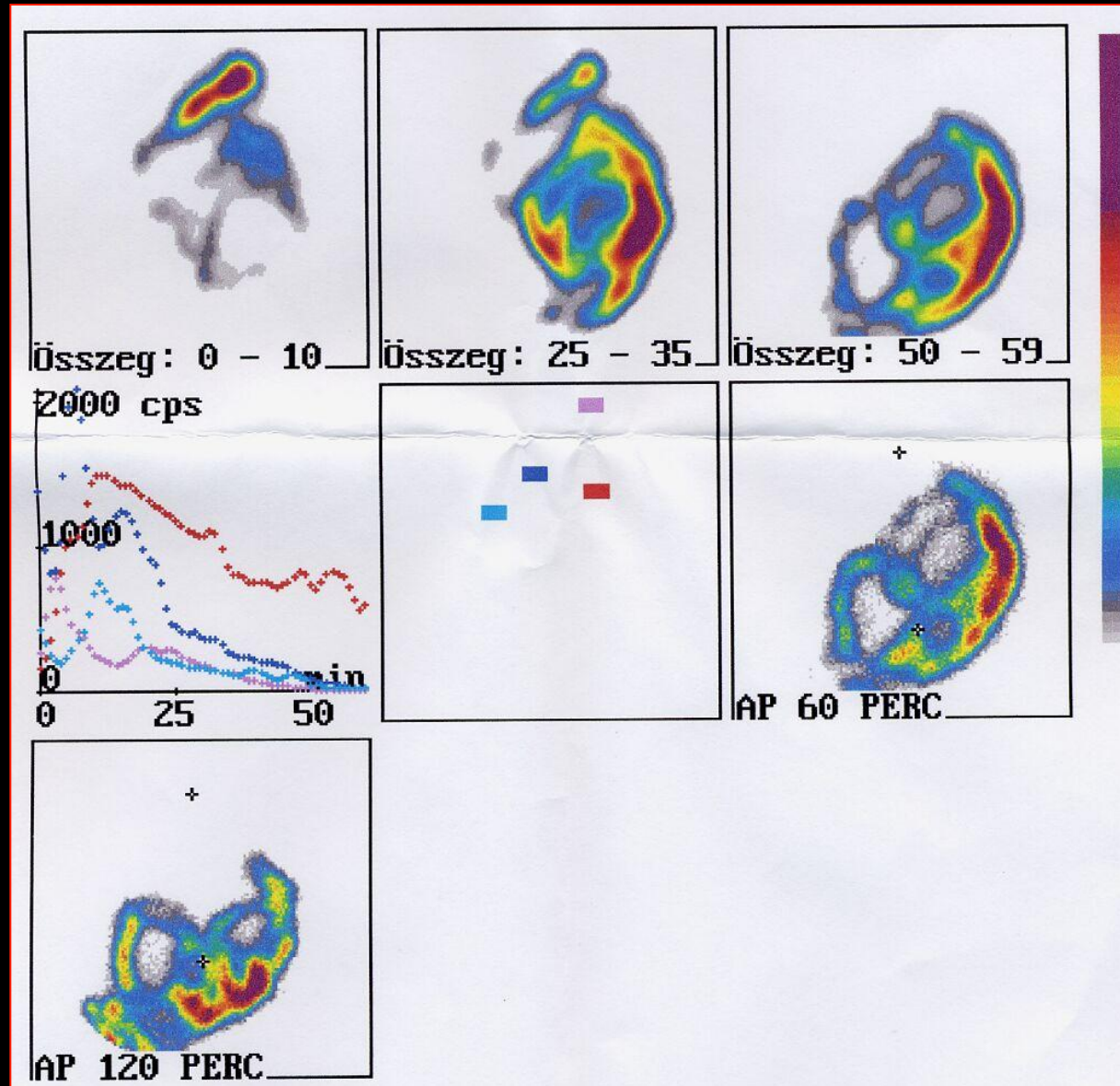
# Gastro-oesophageal stenosis



**Slower  
passage  
through the  
oesophagus**

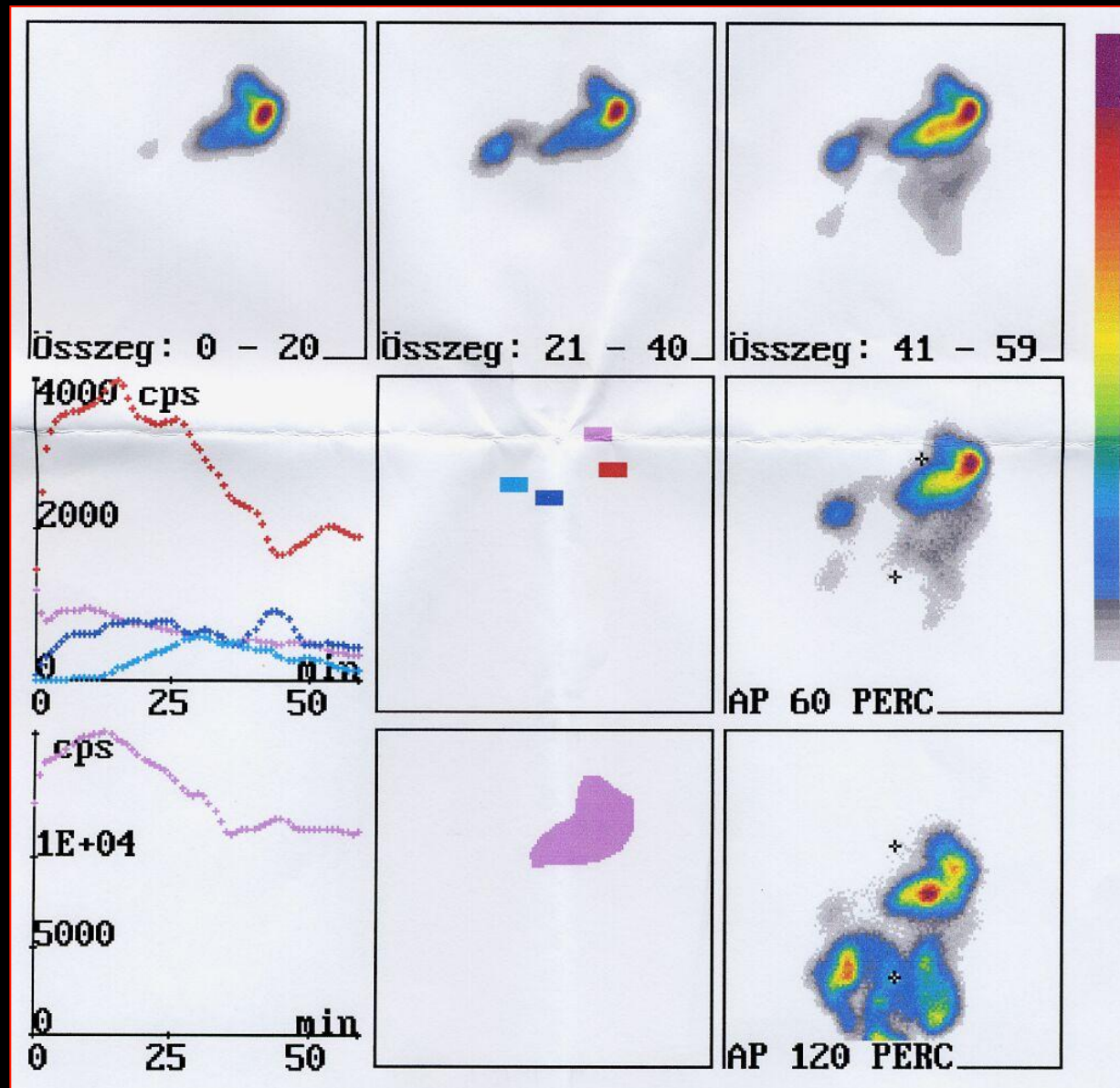
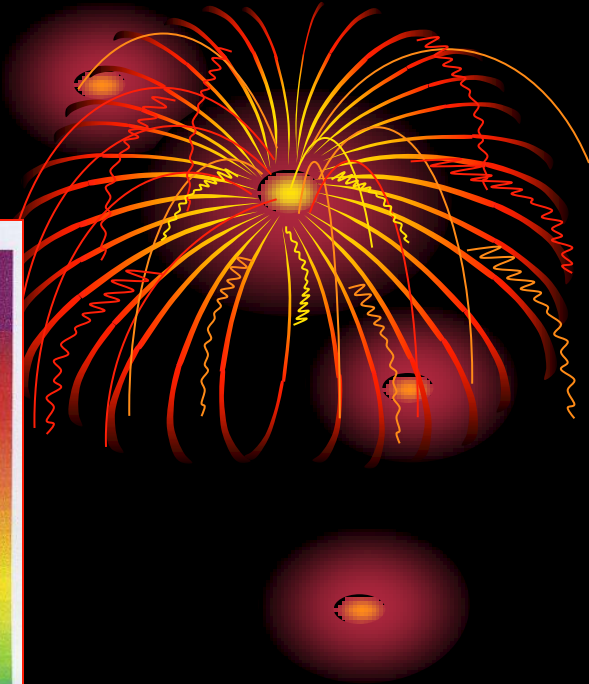


# Gastric emptying study



**Normal  
examination**

# Pyloric stenosis



# Definition of Meckel's diverticulum



**An outpouching from the small intestine, due to failure of obliteration of the yolk stalk (which normally disappears during embryonic life).**

**About 2% of people have a Meckel's diverticulum. It is usually located about 2 feet (60 cm) above the junction of the small intestine with the colon (the large intestine).**

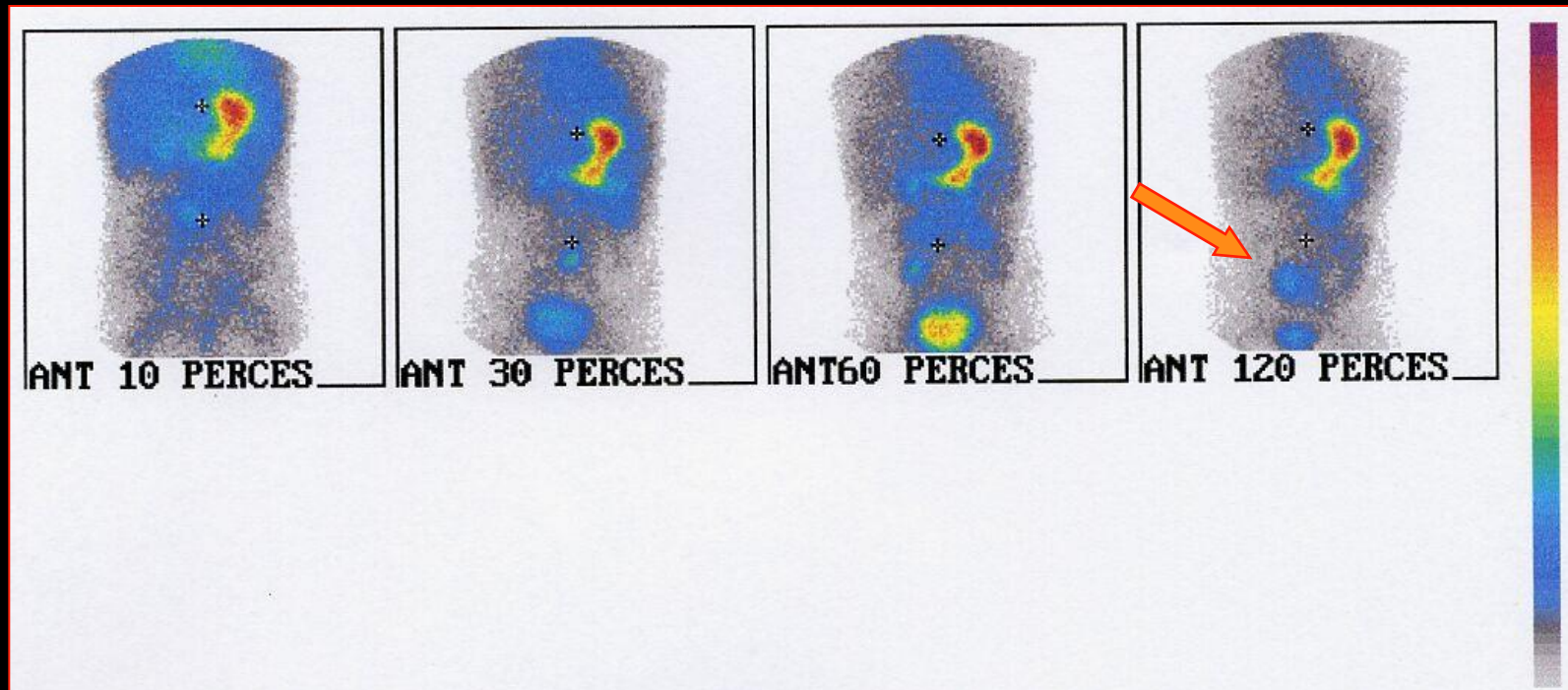
**A Meckel's diverticulum can become inflamed, ulcerate, bleed, perforate or cause obstruction of the small bowels. If it is inflamed or perforated, it is usually removed by surgery.**

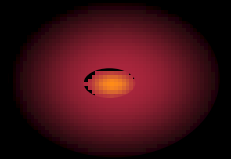
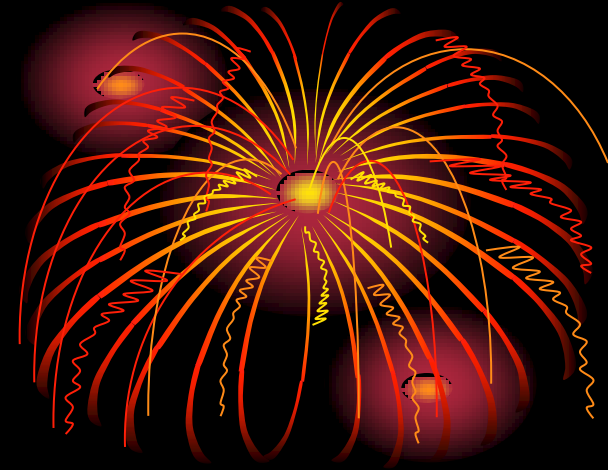


# Examination of Meckel's diverticulum

Radiopharmaceutical:  $^{99m}\text{Tc}$ -pertechnetate i.v.  
Anterior static imaging 10, 30, 60, 120 minutes  
after the injection

Pathological increased activity in the region of  
bowels





**Thank you  
for your  
attention!**