

Nuclear cardiology

Zámbó Katalin

Department of Nuclear Medicine

Imaging techniques

Morphology

Physiology

Metabolism

Molecules

X-ray / CT

NM - SPECT/ PET

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 - in which the number of protons and neutrons are not stable - and various type of radiation (α , $-\beta$, $+\beta$, γ) comes out from the nucleus.

Number of protons

= elemental identity number

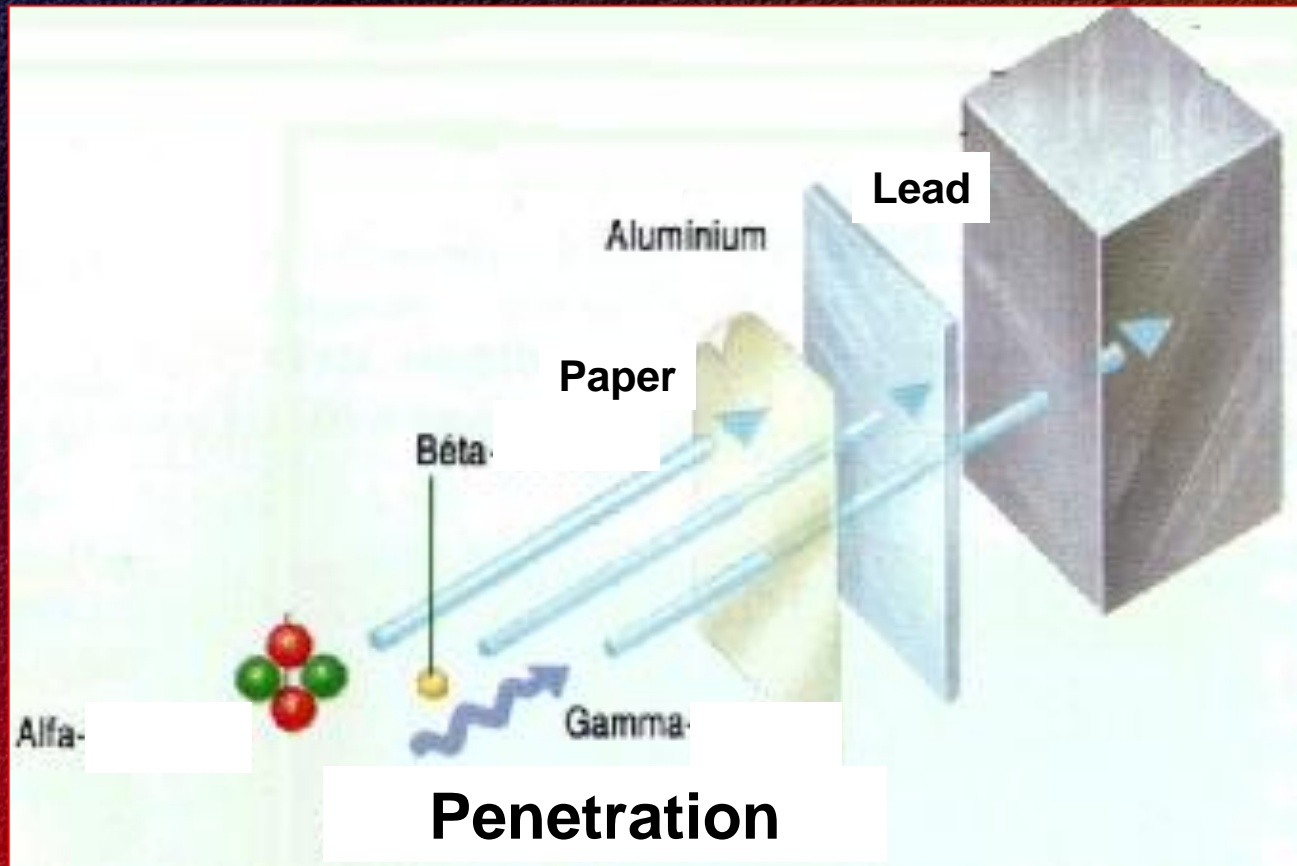
Number of protons and neutrons

= 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 atom is the same as the stable form in every conditions.*
- *Using the radioactive material as a tracer (Hevesy György 1923).*

Rays of radioactive decay

- **Corpuscular rays (α , $-\beta$, $+\beta$)**
- **Electromagnetic ray (γ)**



Gamma radiation

- really electromagnetic radiation
- physically similar to X-rays, but it comes out from the nucleus of the atom
- very penetrated and easily pass through tissue
- SO: it can be detected externally well, it can be used for diagnostics
- 99mtechnetium (artificial)

Equipments I.

Gamma-camera

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



Gamma-camera

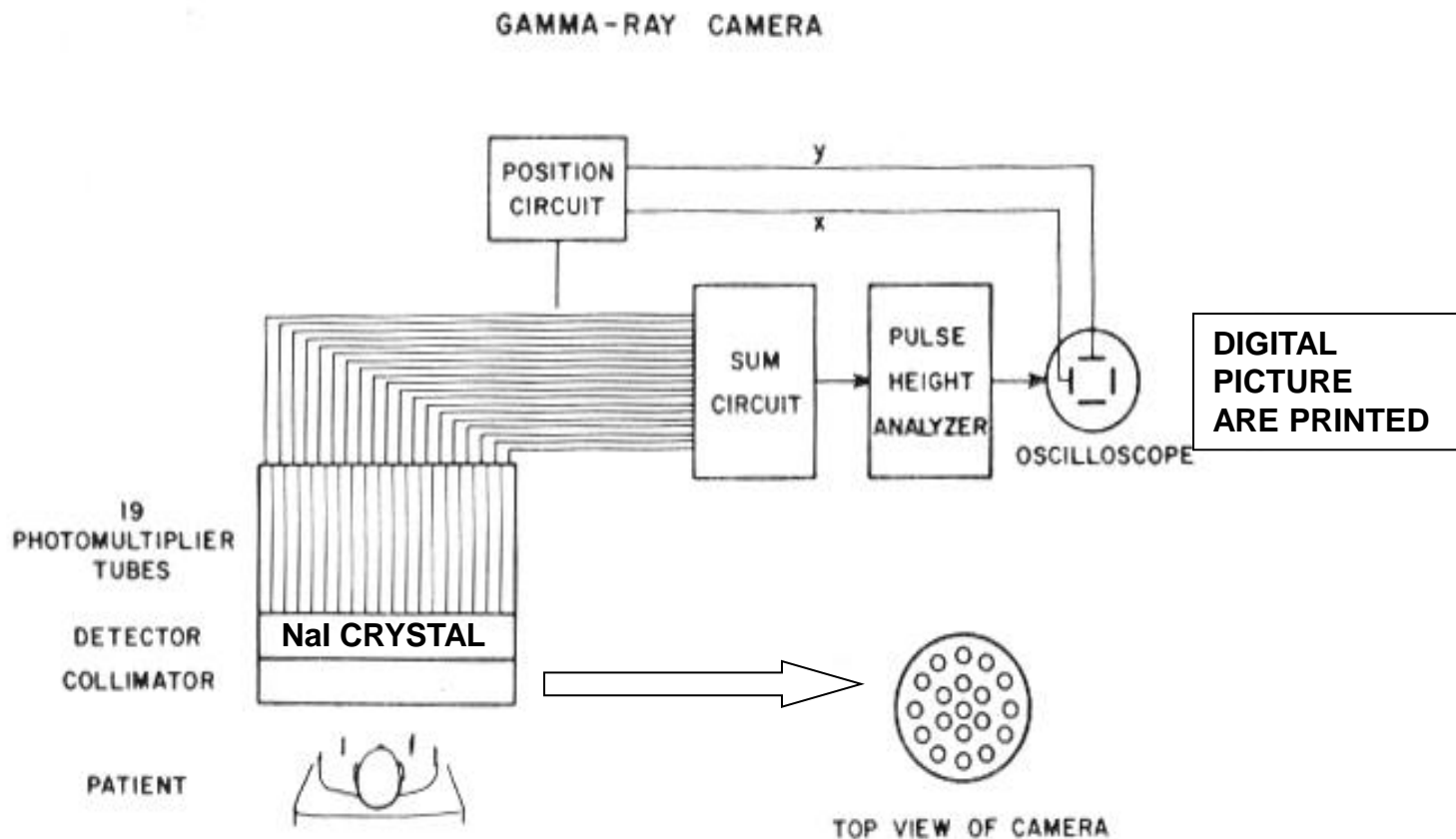


Fig. 1.11. The basic components of an Anger γ -ray camera. There is a one-to-one correspondence between the location of γ -ray interactions in the scintillation crystal and the location of the dot flashed on the oscilloscope screen.

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

Nuclear medicine methods

Static examinations (scintigraphy):

- an optimal time-period after the subject administration is delayed and several photos (or SPECT slices) 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**

Dynamic studies

Follow up the physiological or pathophysiological 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, $T_{1/2}$

Nuclear cardiology

1. „First passage” examination
2. Radionuclide ventriculography (RNV), multigated analysis (MUGA)
3. Rest myocardial perfusion study
4. Stress/rest myocardial perfusion study (viability, PET/CT)

„First passage” study

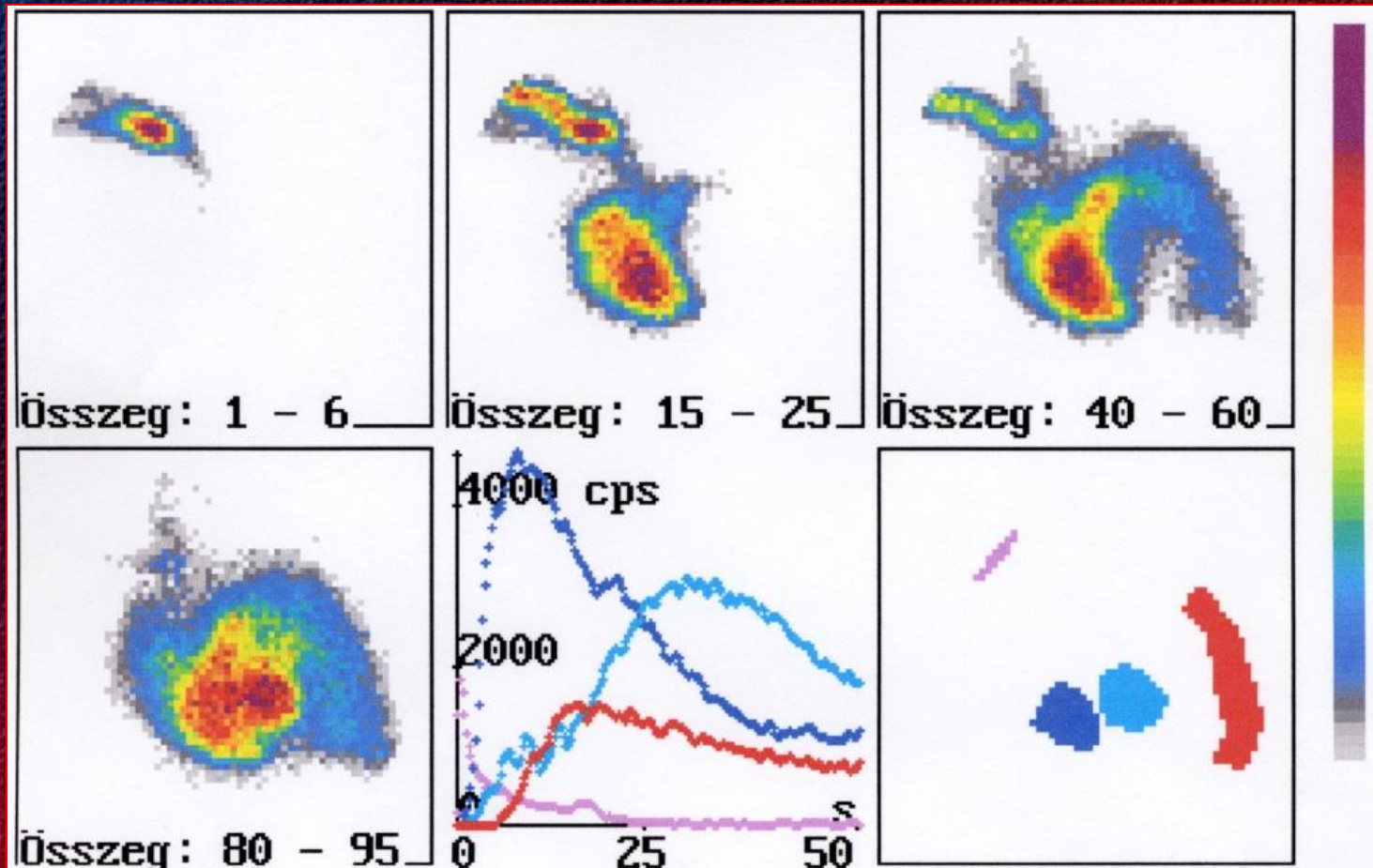
- The radioactive subject: **^{99m}Tc -DTPA** (rapid movement from the body through the kidneys)
- **Fast circulation** through the heart and the lung
- „**Bolus**” of the injection (rapid administration in a small volume) is important
- **Cardio-pulmonary** circulation times, **cardiac output**, **stroke volume**
- **Indications:** **cor pulmonale**, **primer pulmonary hypertony**, **myocardial infarction**, **hyperkinetic circulation**, **intracardial left-to-right shunt**

The way of the bolus

sup. v. cava

right ventricle

pulm. artery+lungs

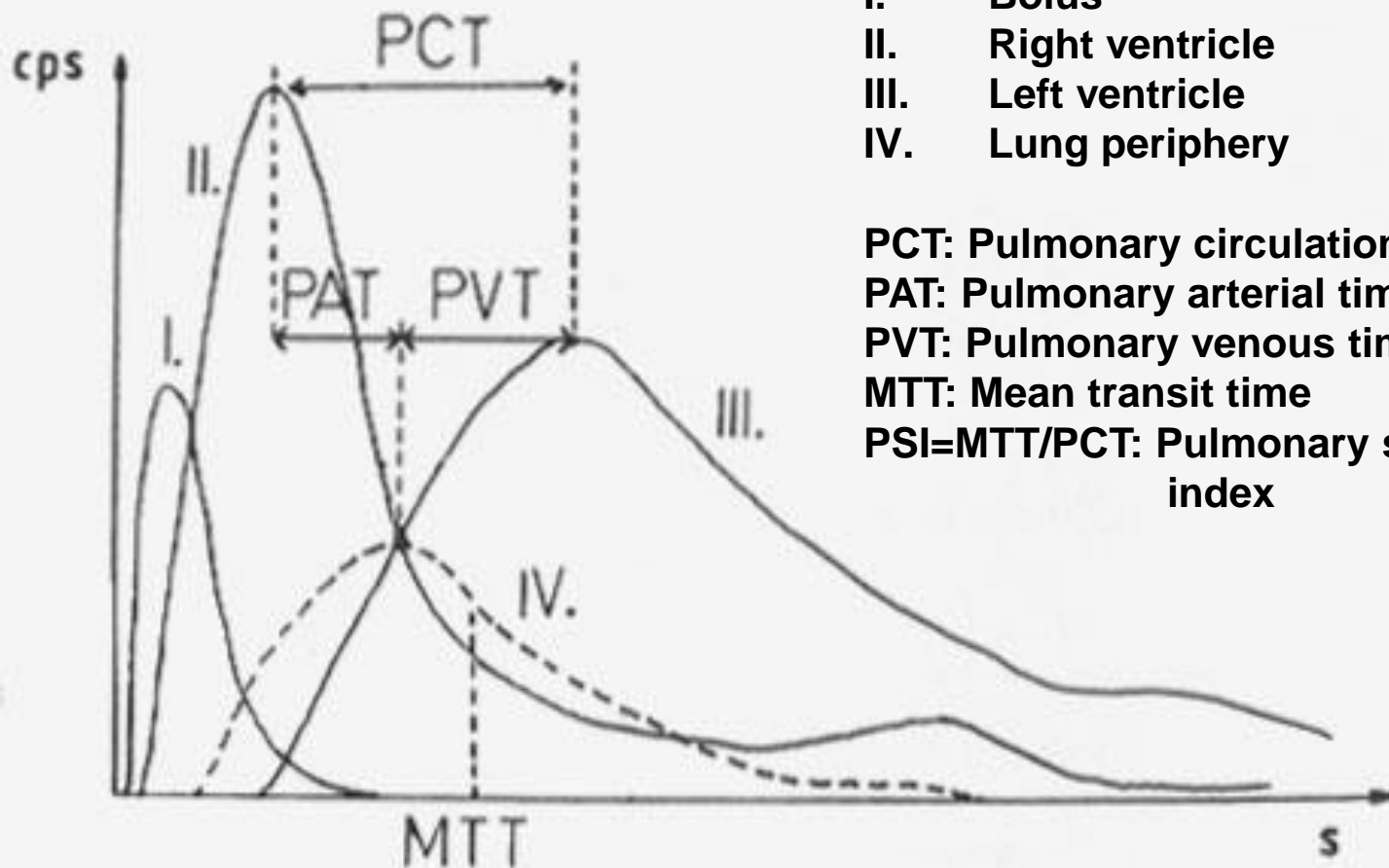


left ventricle

curves

ROIs

Time-activity curves and circulation times



- I. Bolus
- II. Right ventricle
- III. Left ventricle
- IV. Lung periphery

PCT: Pulmonary circulation time
PAT: Pulmonary arterial time
PVT: Pulmonary venous time
MTT: Mean transit time
 $PSI = MTT / PCT$: Pulmonary stagnation index



Átlagos tüdőátfolyási idő vizsgálat lelete

PÉCSI TUDOMÁNYEGYETEM ÁLTALÁNOS ORVOSTUDOMÁNYI KAR
Központi Klinikai Radioizotóp Laboratórium
7624 Pécs, Ifjúság útja 13. Tel.: (72) 536-386
Intézővezető: dr. Zámbo Katalin

Report

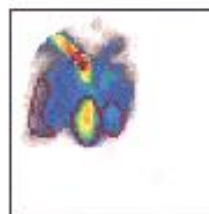
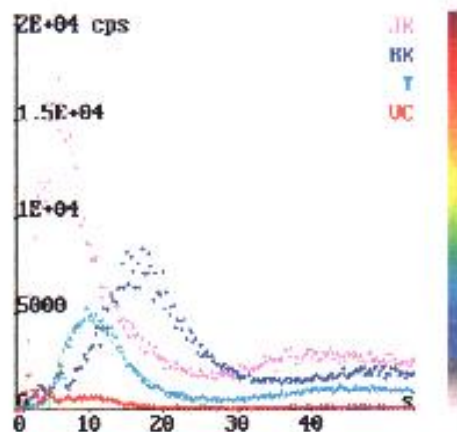
FIRST PASSAGE VIZSGÁLAT

BETEGADATOK

Kódszám	FP0008
Patient ID	006421140
Birth date	1.26.34
Referring Ph	VERI
Height	- 180 cm
Weight	- 90 kg
Dosage	- 550 MBq TC-99M-DTPA

SZIV TRANZITIDŐK

Bolus max	: 2.10 s
T(25%)	: 2.10 s
J→B tranzit	: 11.70 s
Tudo MTT	: 0.25 s
MTT / J→B	: 0.71
Perfúziós index	: 1.60
Artériás fázis	: 4.20 s
Vénás fázis	: 7.50 s
Art.vénás idő	: 0.56



Intracardial left-to-right shunt

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7624 Pécs, Ifjúság útja 13. Tel.: (72) 536-386

Intézetvezető: dr. Zámbó Katalin

„First passage“ vizsgálat

Név : **INTRACARDIALIS BAL-JOBB SHUNT**

Kódszám : FP0001

Patient ID : 000000000

Birth date : 3.27.83

Referring Ph: II.B.

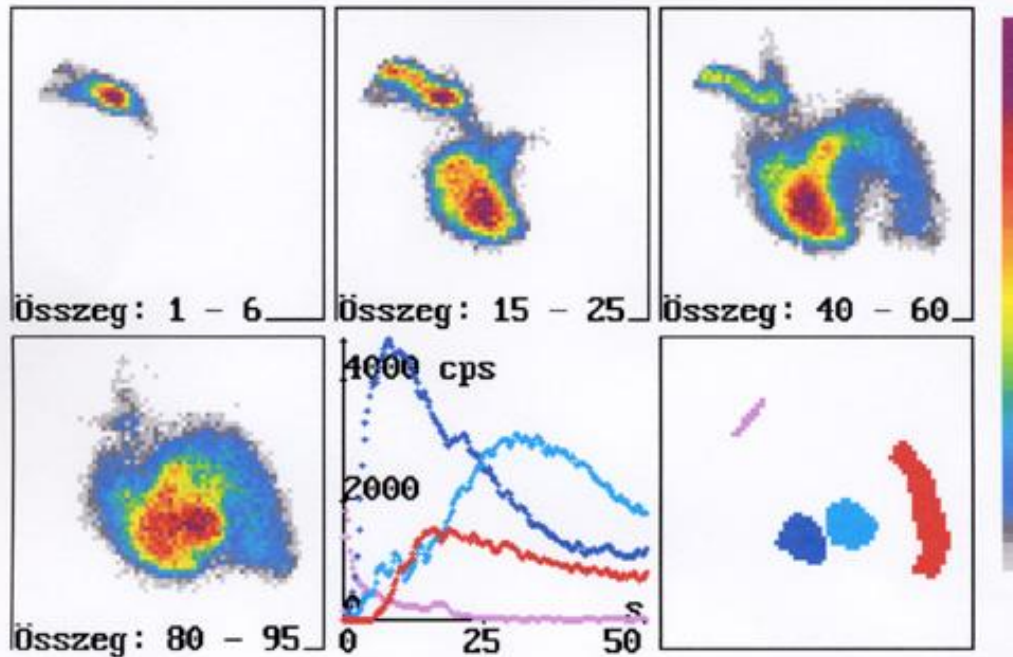
Height : 184 cm

Weight : 130 kg

Dosage : 555 MBq TC-99m-DTPA

Dátum : 2004.03.05

Pulzus: 120/perc



Bolus:

Tmax=0.9 s

T25%=5.1 s

PCT = 20.4 s

MTT = 27.5 s

PSI = 1.35

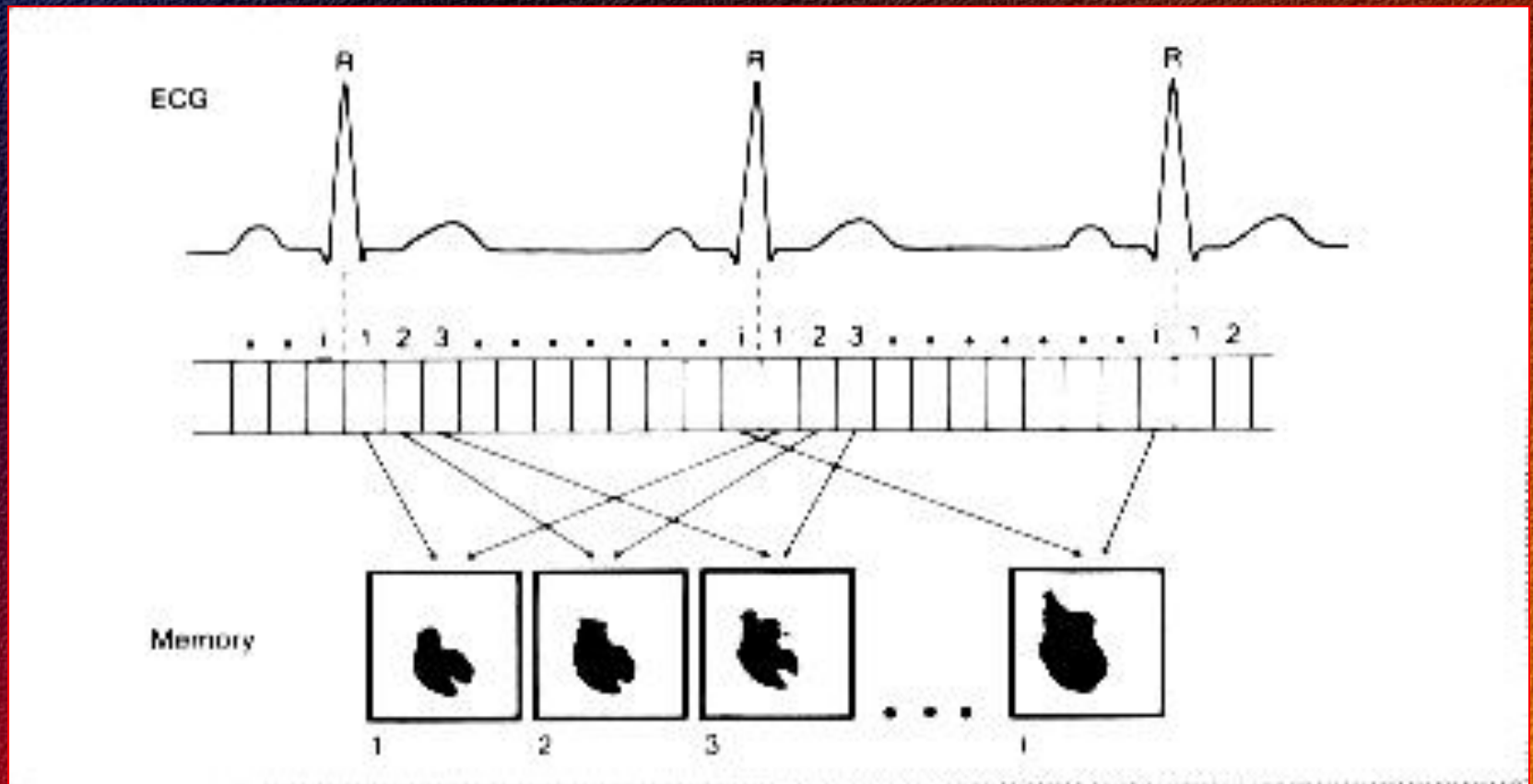
PI = 1.14

Radionuclide ventriculography (RNV), or multigated analysis (MUGA)

- The blood-pool of the heart is labelled by isotope (^{99m}Tc -pyrophosphate-RBC), and study is performed in equilibrium
- Gamma-camera-computer-R wave monitor system synchronizes the acquisition to R wave of ECG
- EF: ED-ES/ED-BG (LAO 30° projection)
- Wall-motion is analysed by parametric pictures (LAO 30° and LAO 70° projections)
- Indications: myocardial infarction, cardiomyopathy

A representative cycle

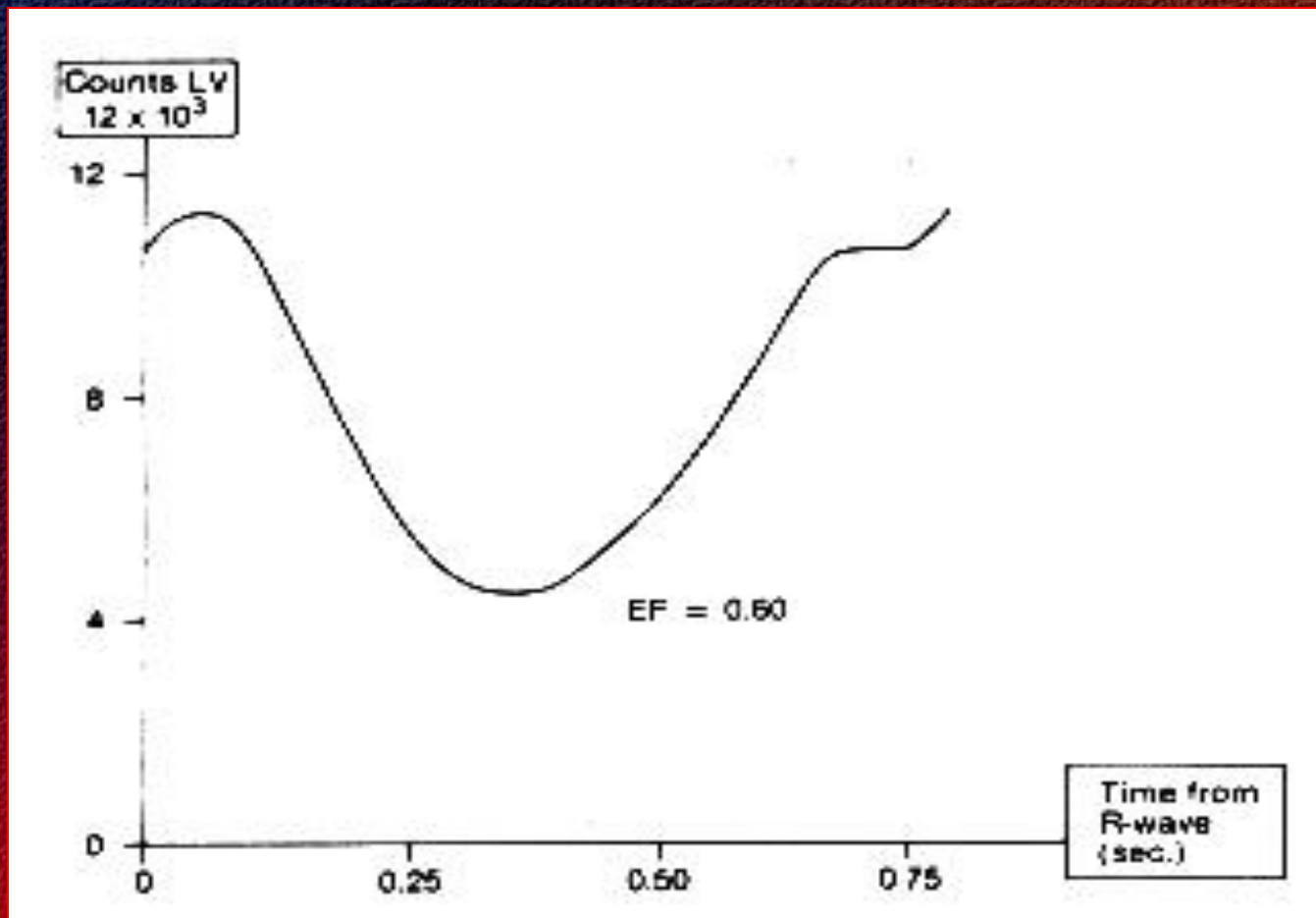
300-600 cardiac cycles are collected within each R-R interval and an average cycle is generated by computer from ED to ED. 16 or 32 frames are made from this cycle.



The ejection fraction curve

LAO 30 the chambers are separated well

EF = ED-ES/ED-BG (%)

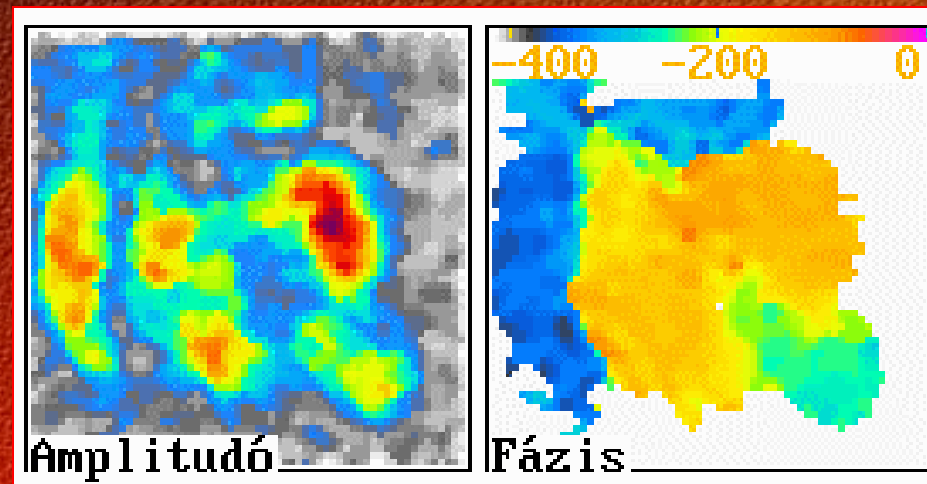
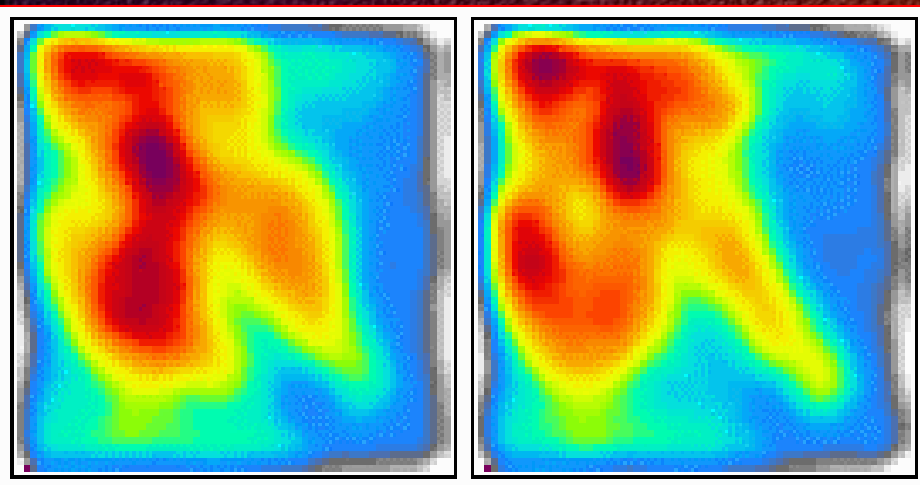


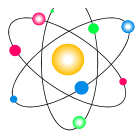
Parametric pictures

Activity picture: the colours represent the activity of the pixels

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
7624 Pécs, Ifjúság útja 13. Tel.: (72) 326-222/1229
Intézetvezető: dr. Zámbó Katalin

NORMAL FUNCTION OF THE LEFT VENTRICLE

Kódszám: KE0351

Szül.: 450515

Beküldő 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

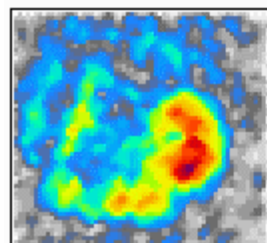
seb.: 2.18 EDV/s

PFR/PER: 0.87

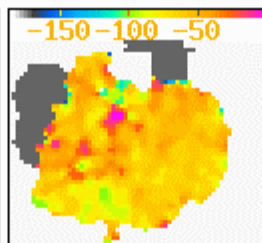
Ciklusidő: 944 ms

Frekvencia: 64/min

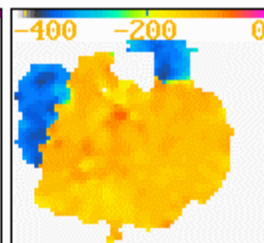
Infl. pont: 768 ms



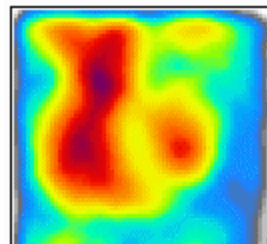
Amplitudó



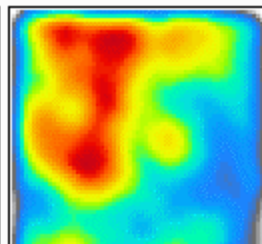
Nyújtott fázis



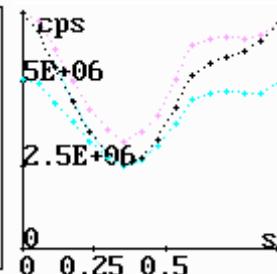
Fázis



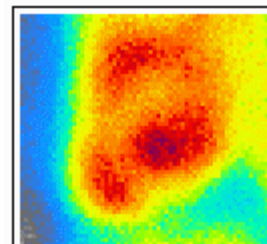
Végdiasztole



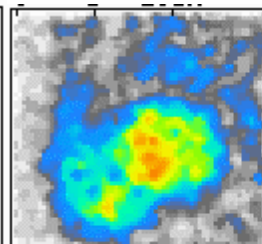
Végshizstole



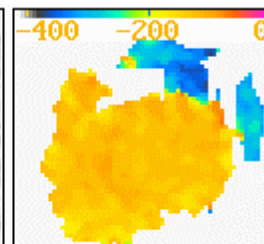
Lao30



Összeg: 0 - 15



Amplitudó



Fázis

Lao70



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Központi Klinikai Radioizotóp Laboratórium

7624 Pécs, Ifjúság útja 13. Tel.: (72) 326-222/1229

Intézetvezető: dr. Zámbo Katalin

POSTERO-BASALIS HYPOKINESIS

Kódszám: KE0152

Szül.: 590606

Beküldő int.: Szig.Kh.Bel.

Diagnosis: Ang.pect.

Értékelte: dr.Schmidt

Dátum: 2000.04.18

:

SZIVKAMRA-GÖRBE ELEMZÉSE

EF: 49,4 %

ES ideje: 378 ms

PER

ideje: 188 ms

seb.: -2.12 EDV/s

PIR

ideje: 492 ms

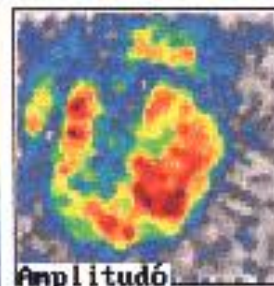
seb.: 1.95 EDV/s

PIR/PER: 0.92

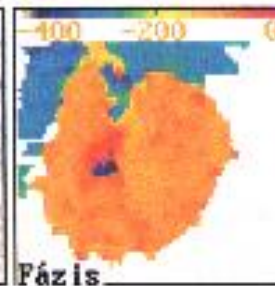
Ciklusidő: 1072 ms

Frekvencia: 56/min

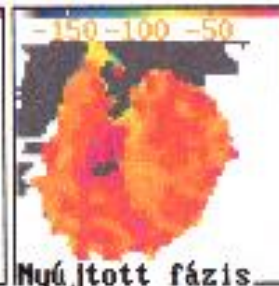
Inf. pont: 821 ms



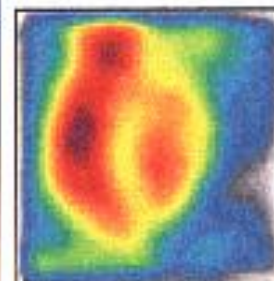
Amplitudó



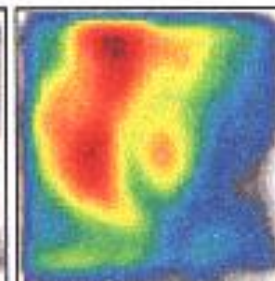
Fázis



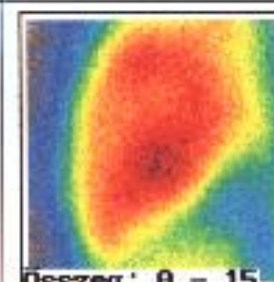
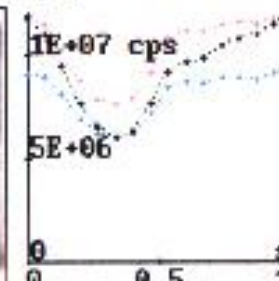
Nyújtott fázis



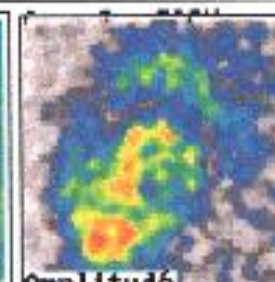
Lao30



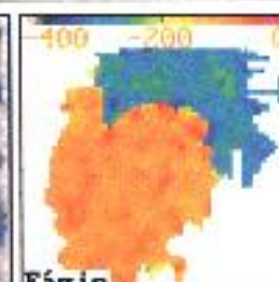
Lao70



Összeg: 0 - 15



Amplitudó



Fázis



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PÉCSI TUDOMÁNYEGYETEM ÁLTALÁNOS ORVOSTUDOMÁNYI KAR

Központi Klinikai Radioizotóp Laboratórium

7624 Pécs, Ifjúság útja 13. Tel.: (72) 326-222/1229

Intézetvezető: dr. Zámbo Katalin

POSTERO-INFERO-LATERALIS HYPOKINESIS

Kódszám: KE0082

Szül.: 50.12.08.

Beküldő int.: Szigetvár Kard.Szagr.

Diagnosis: St.p.AMI

Értékelte: dr.Udvaros

Dátum: 2000.03.01

:

SZIVKAMRA-GÖRBE ELEMZÉSE

EF: 52.6 %

ES ideje: 378 ms

PIR

ideje: 190 ms

seb.: -2.53 EDV/s

PTR

ideje: 544 ms

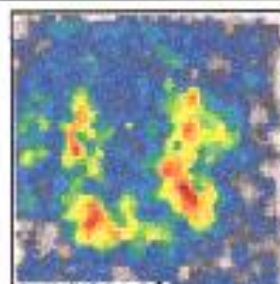
seb.: 1.34 EDV/s

PTR/PTR: 0.53

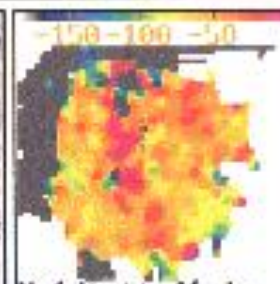
Ciklusidő: 1024 ms

Frekvencia: 59/min

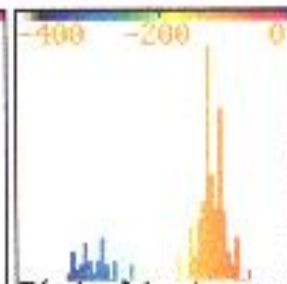
Inf. pont: 803 ms



Amplitudó



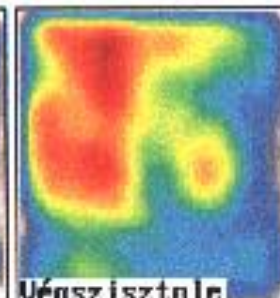
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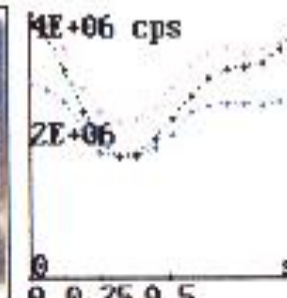
Fázis-hisztogram



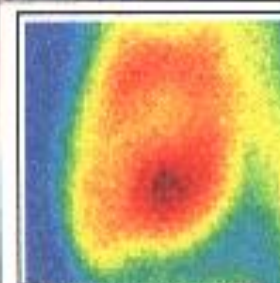
Végdiasztole



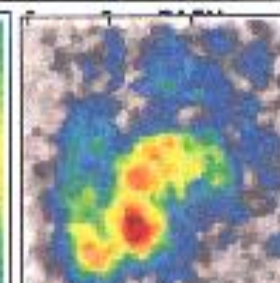
Végszisztole



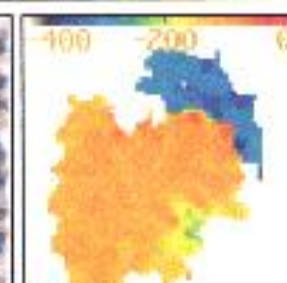
Lao30



Összeg: 0 - 15



Amplitudó



Fázis



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PÉCSI TUDOMÁNYEGYETEM ÁLTALÁNOS ORVOSTUDOMÁNYI KAR

Központi Klinikai Radioizotóp Laboratórium

7624 Pécs, Ifjúság útja 13. Tel.: (72) 326-222/1229

Intézetvezető: dr. Zámbó Katalin

ANTERIOR, ANTERO-SEPTALIS, CSÚCSI HYPOKINESIS

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: 546 ms

PER

ideje: 194 ms

seb.: -1,30 EDV/s

PFR

ideje: 433 ms

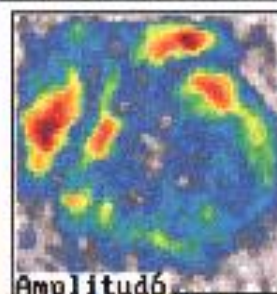
seb.: 0,35 EDV/s

PFR/PER: 0,27

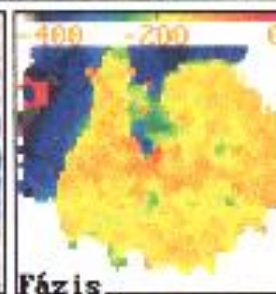
Ciklusidő: 832 ms

Frekvencia: 72/min

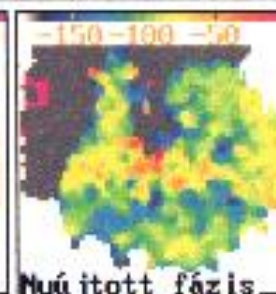
Intl. pont: 659 ms



Amplitudó



Fázis



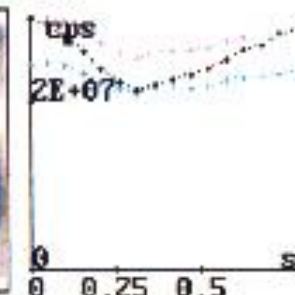
Nyújtott fázis



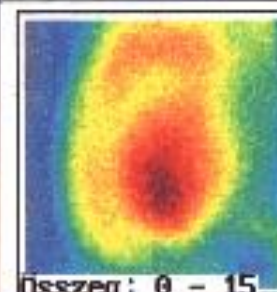
Végdiasztole



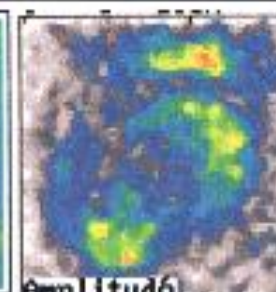
Végshisztole



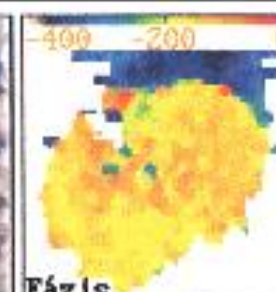
Lao30



Összeg: 0 - 15

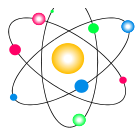


Amplitudó



Fázis

Lao70



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PÉCSI TUDOMÁNYEGYETEM ÁLTALÁNOS ORVOSTUDOMÁNYI KAR

Központi Klinikai Radioizotóp Laboratórium

7624 Pécs, Ifjúság útja 13. Tel.: (72) 326-222/1229

Intézetvezető: dr. Zámbó Katalin

HUGE PARADOX WALL-MOTION ON THE APEX

Kódszám: KE0100

Szül.: 240308

Beküldő 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

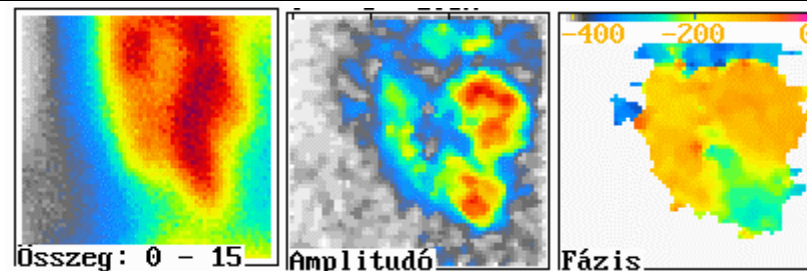
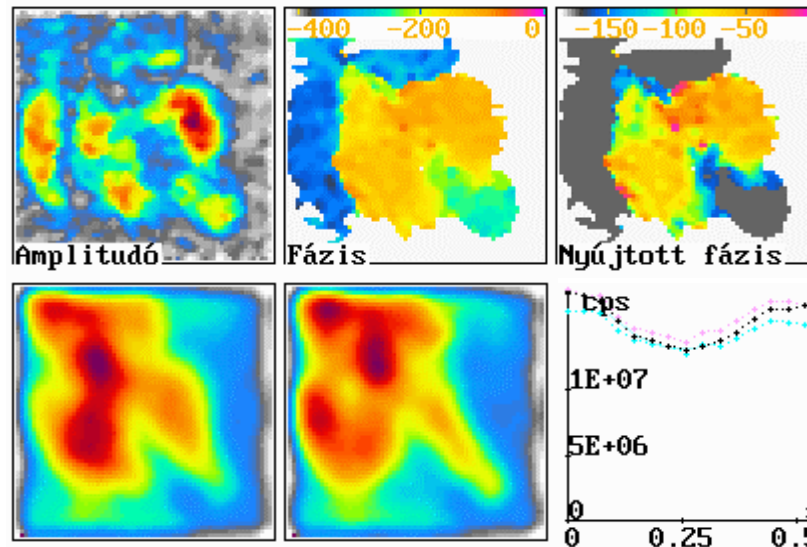
ideje: 392 ms

seb.: 1.26 EDV/s

PFR/PER: 0.79

Ciklusidő: 592 ms

Frekvencia: 101/min



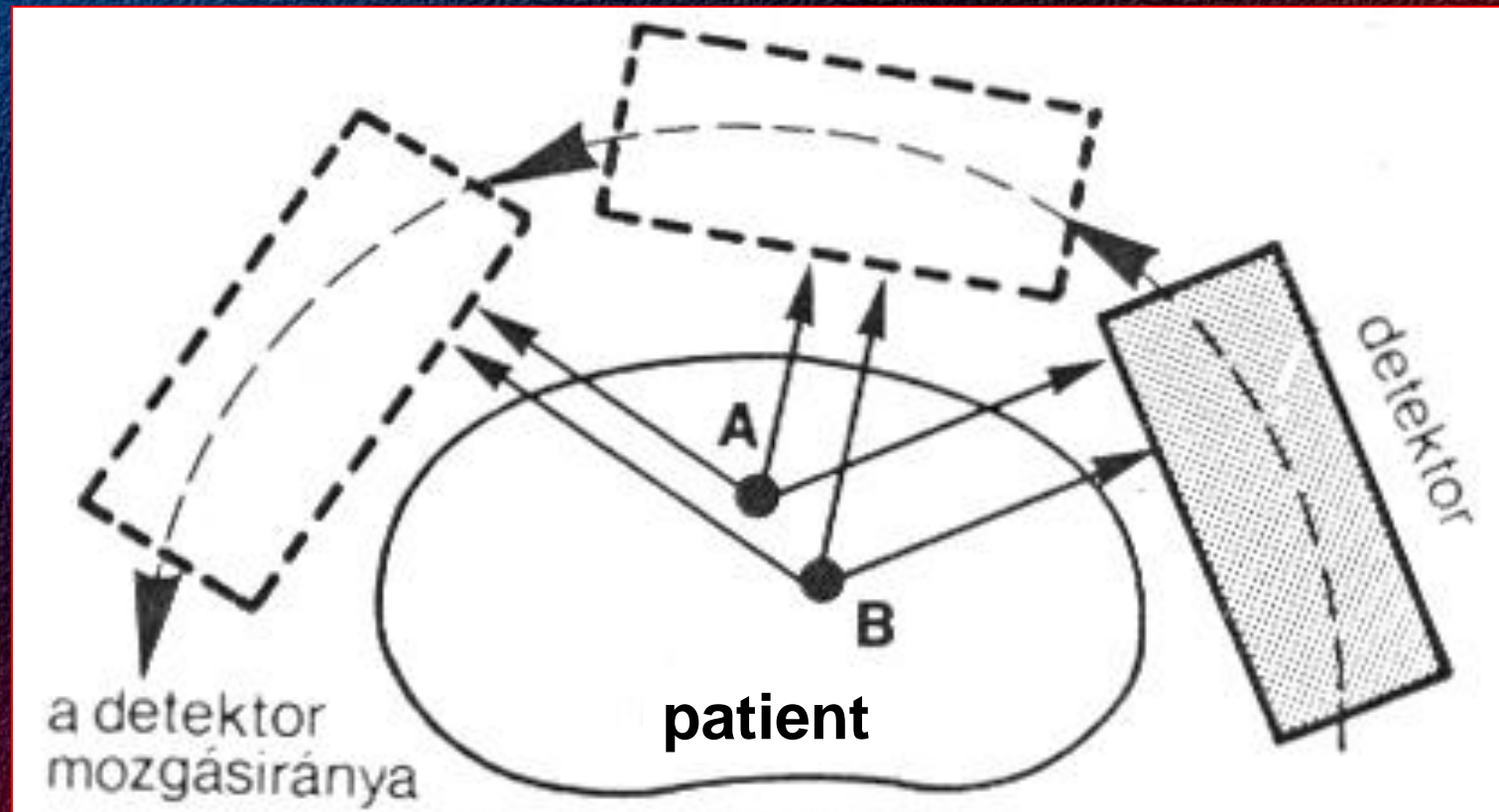
Equipments II.

SPECT

(Single Photon Emission Computer Tomograph)



The principle of the SPECT

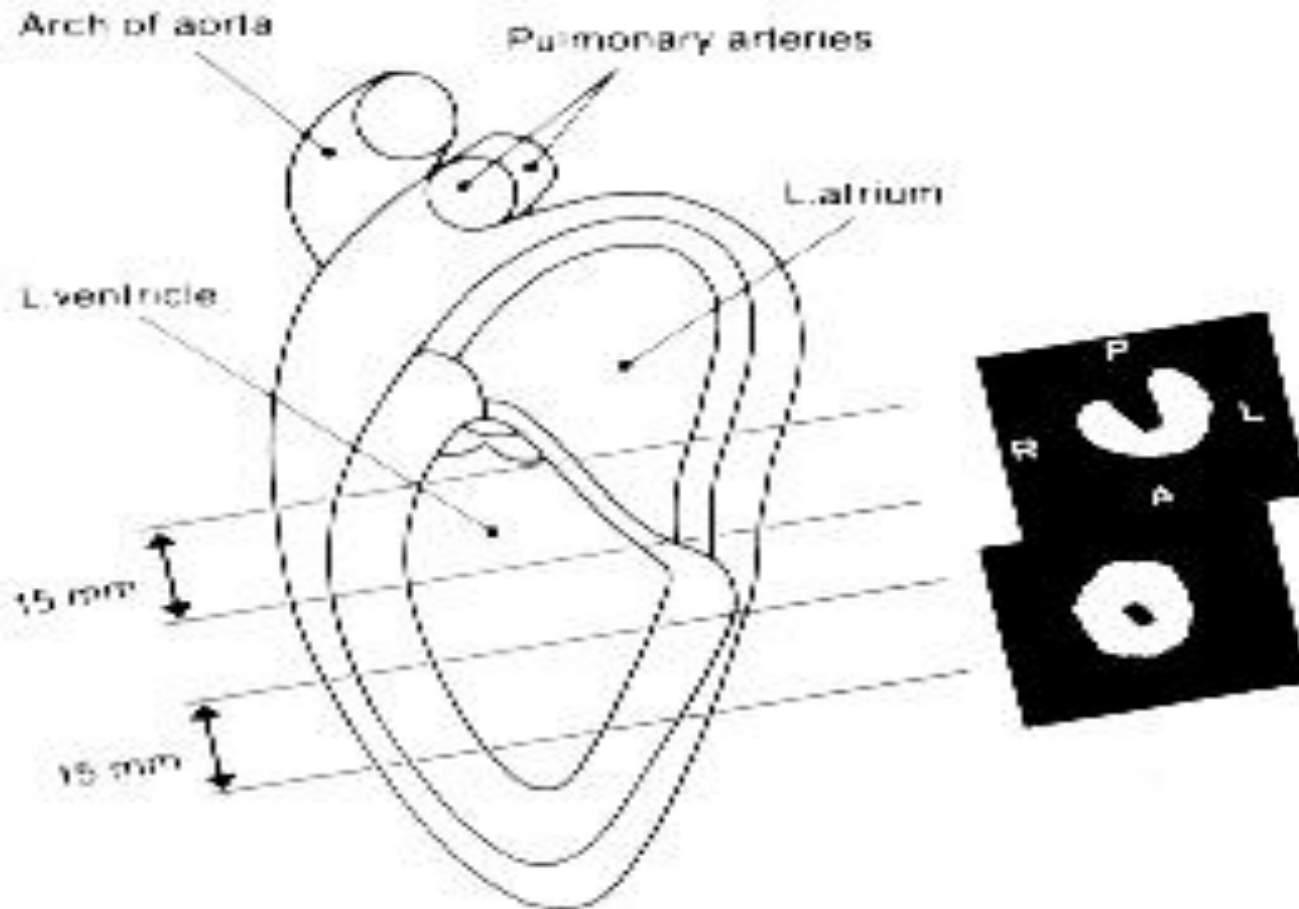


The detectors whirl around the patient and makes pictures from different steps. The transversal, sagittal and coronal slices of the organ are reconstructed and reorientated by computer program.

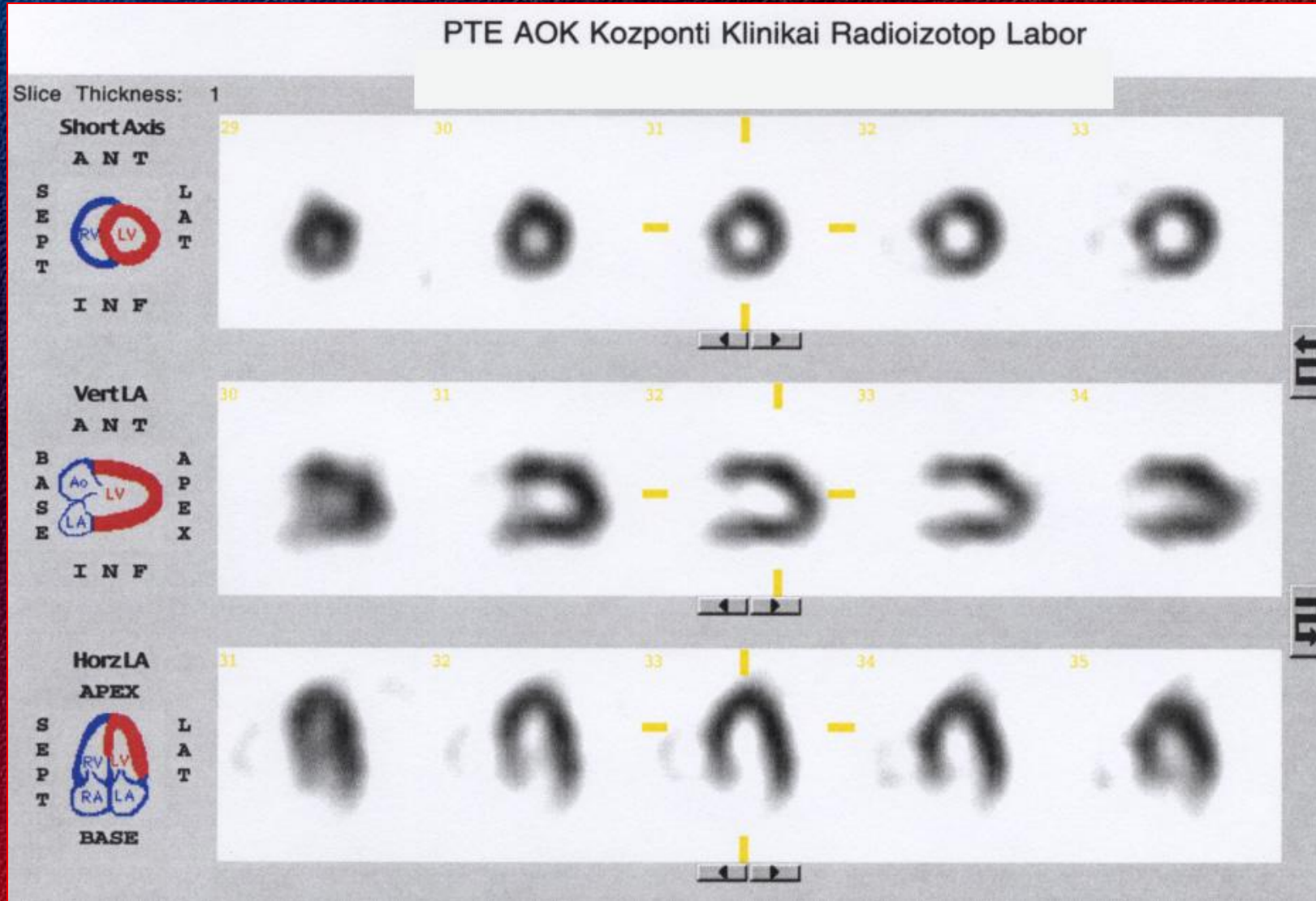
Myocardial perfusion imaging in rest

- The myocardium is labelled by radioactive agent:
 - ^{99m}Tc -MIBI, ^{99m}Tc -tetrofosmin: mitochondria
 - ^{201}Tl -chlorid: Na-K pump
- Reconstructed and reorientated slices are created from the left ventricle by SPECT or SPECT/CT (attenuation correction)
- The impairment of the myocardial perfusion is indicated by decreased activity or lack of the activity
- Indications: myocardial infarction

The slices of the myocardium made by SPECT



The transversal, sagittal and coronal slices of the myocardium



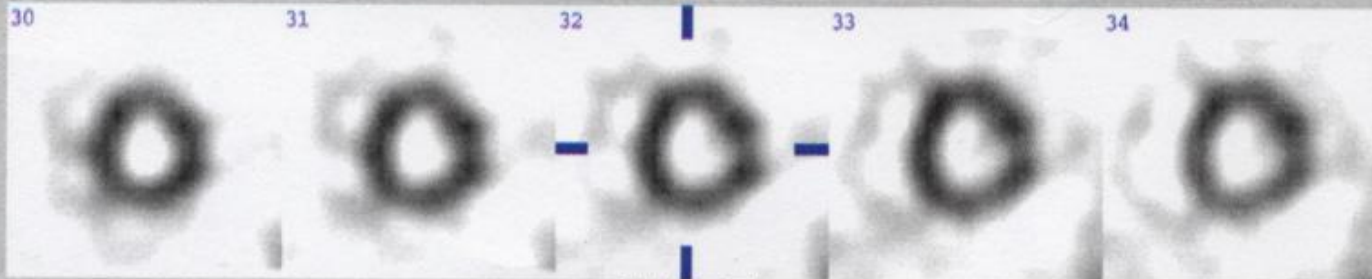
Enlarged left ventricle, increased background

PTE AOK Kozponti Klinikai Radioizotop Laboratorium

Slice Thickness: 1

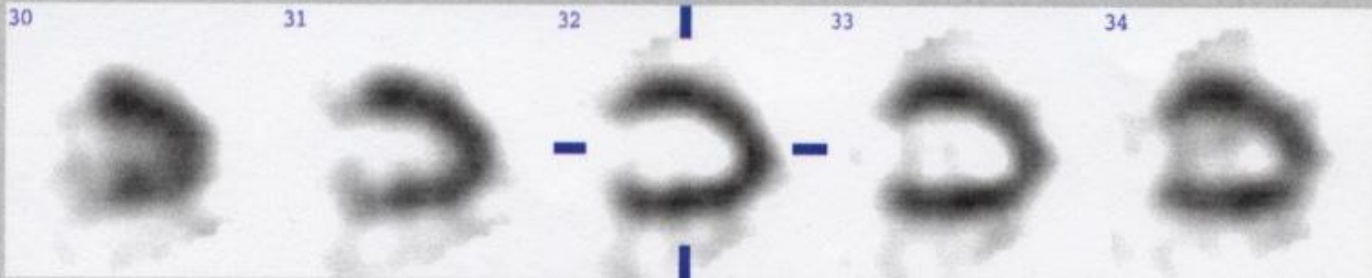
Short Axis

A N T



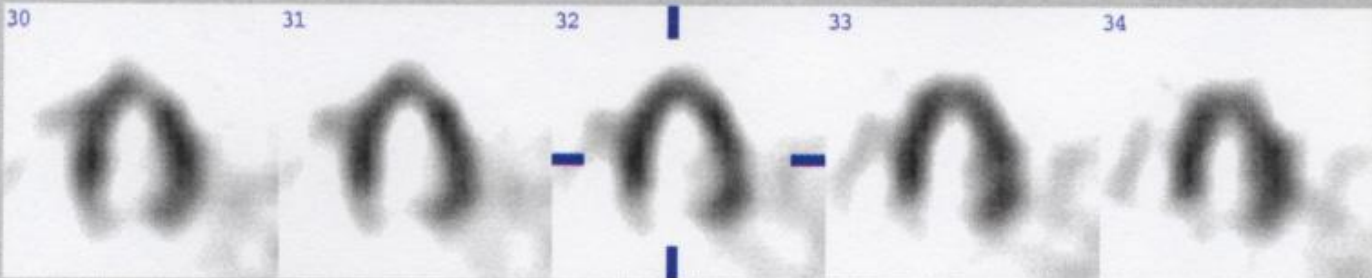
VertLA

A N T

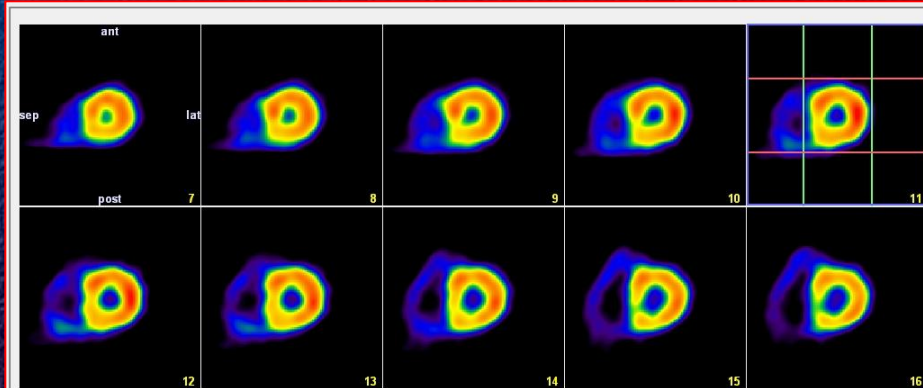


HorzLA

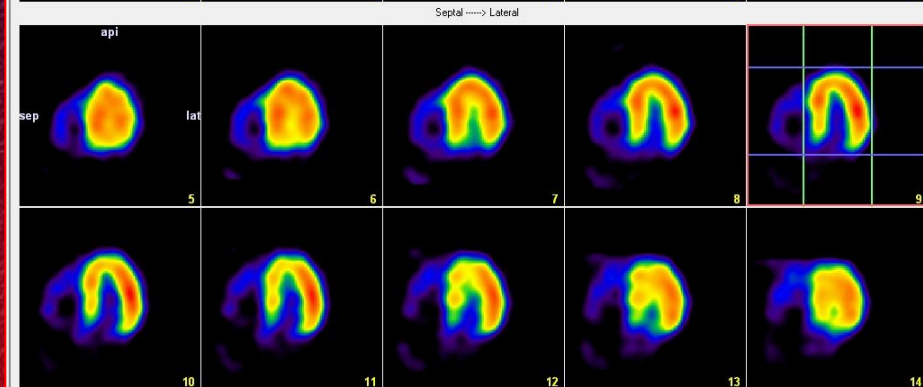
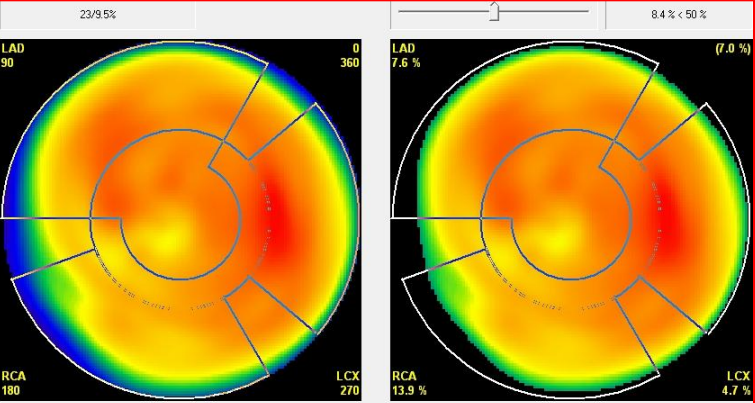
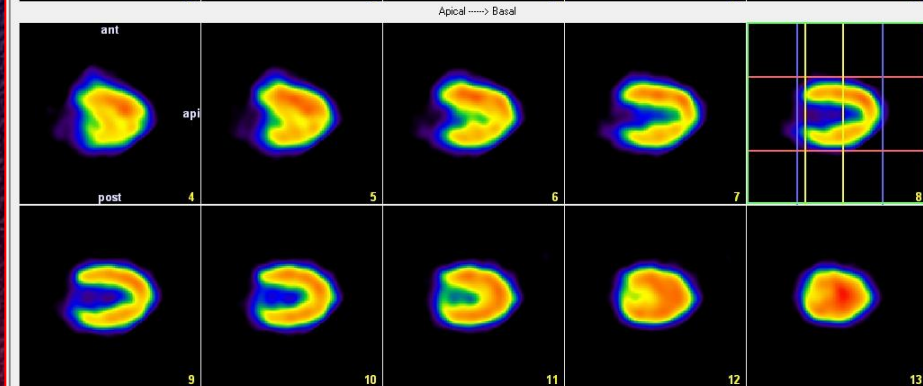
A P E X



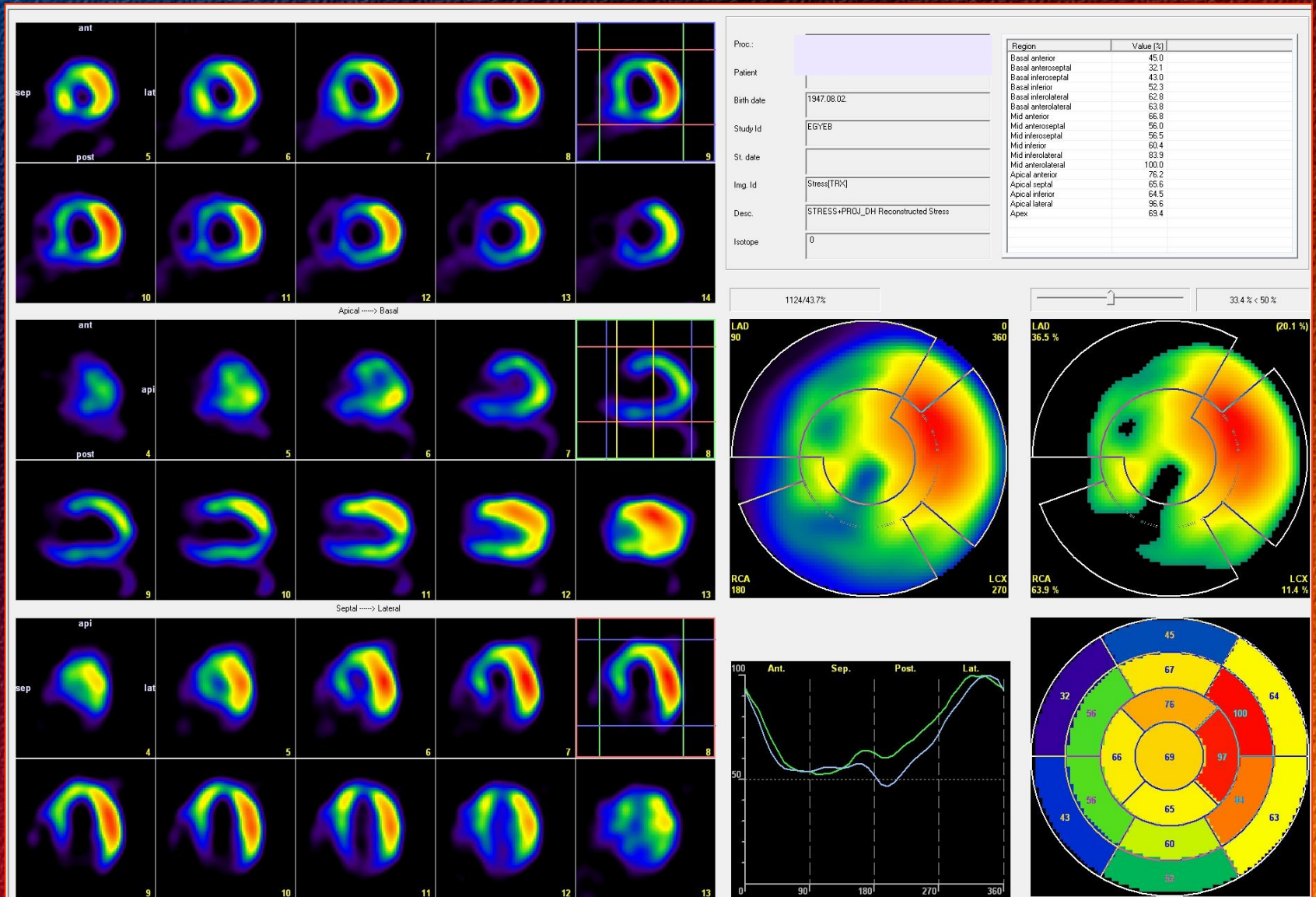
Septal-basal hypoperfusion + right ventricle



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



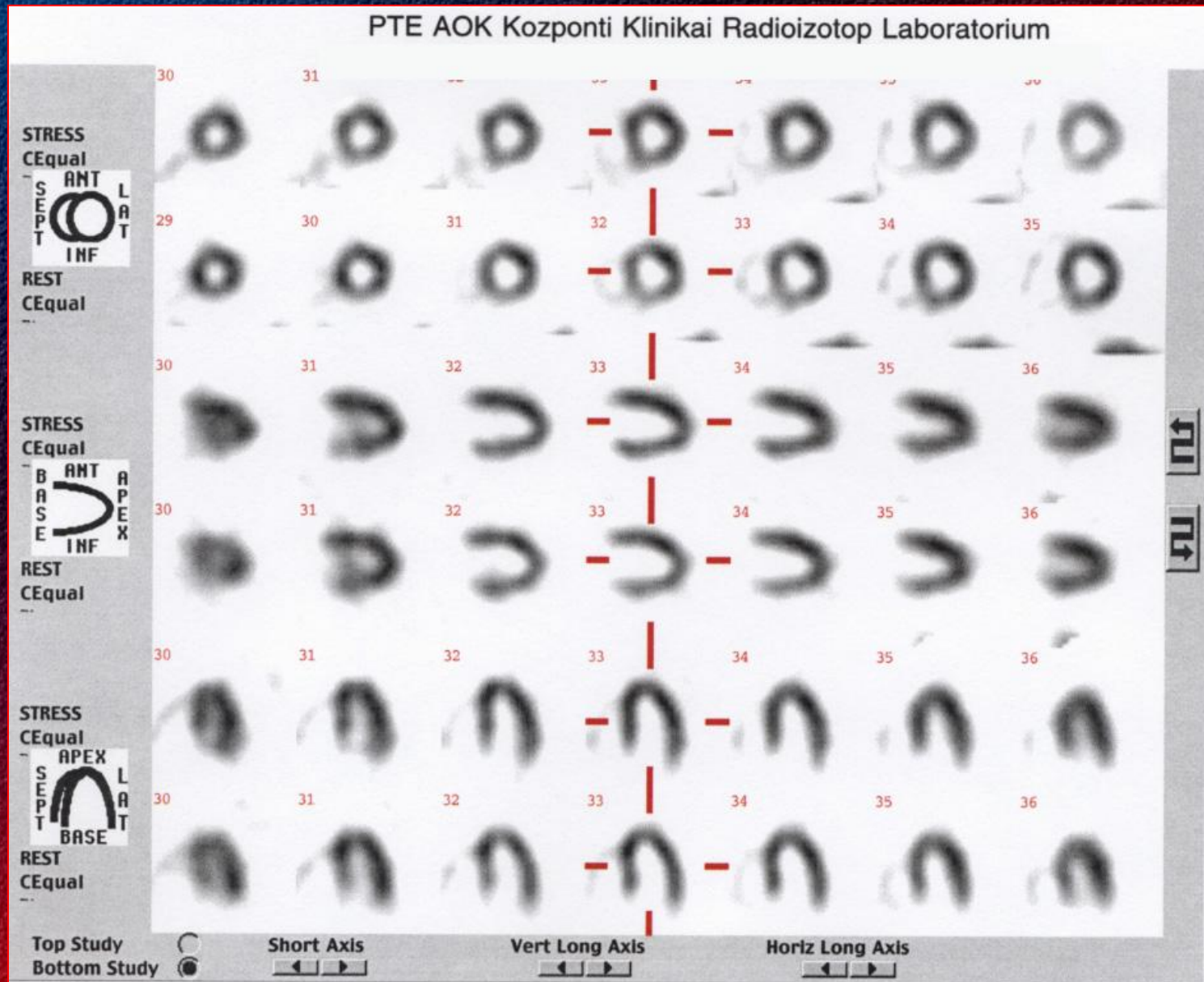
Septal + infero-septal + antero-septal hypoperfusion



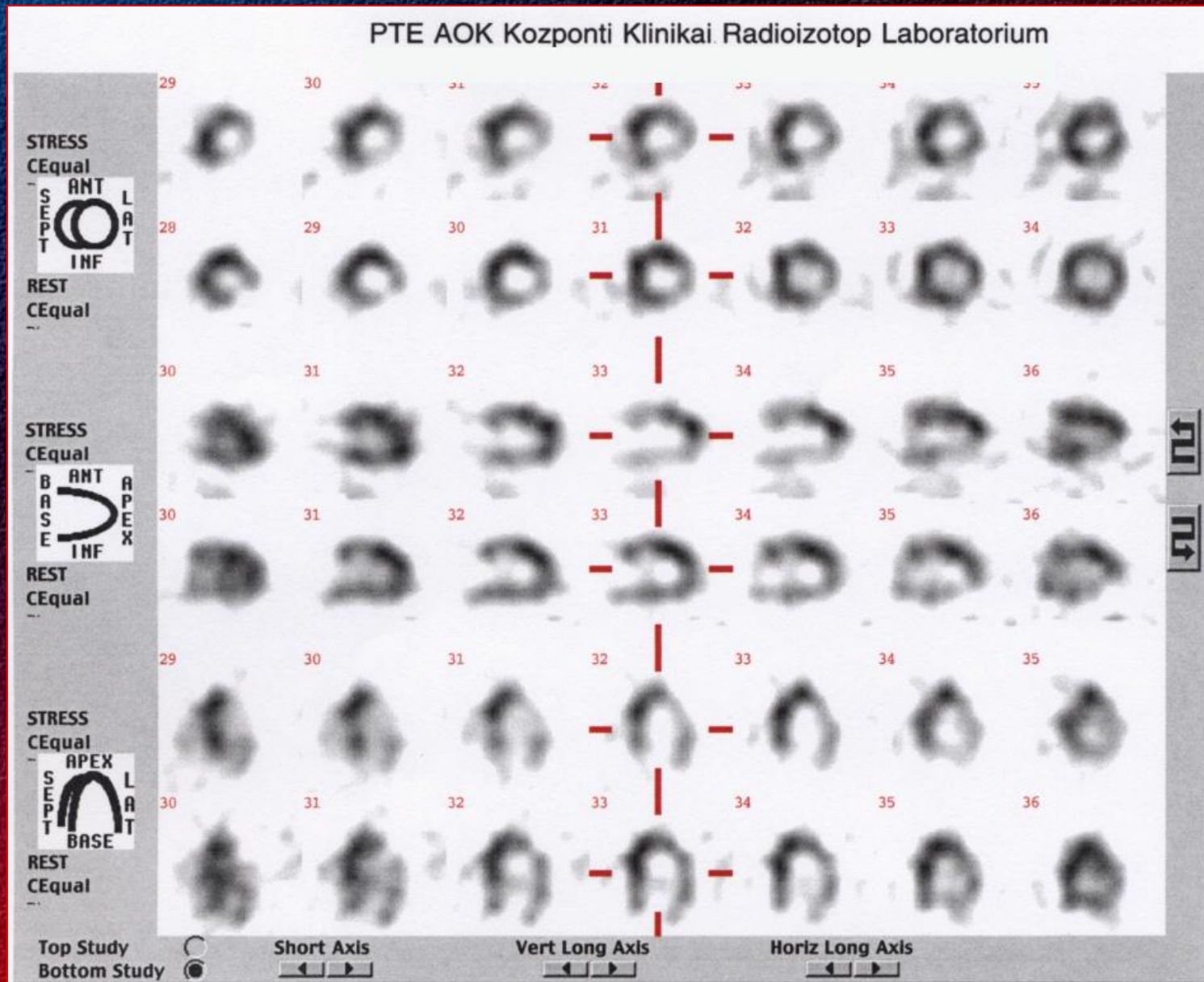
Stress/rest myocardial perfusion study

- Physical or pharmacological stress (Dipyridamol) is applied
- The isotope is administered at peak of the stress » *SPECT-imaging*
- Rest *SPECT-imaging* is on the same day (TI), or one day later (Tc-MIBI)
- Reversible ischaemy: stress/rest mismatch
- Fixed abnormality (scar): stress/rest match

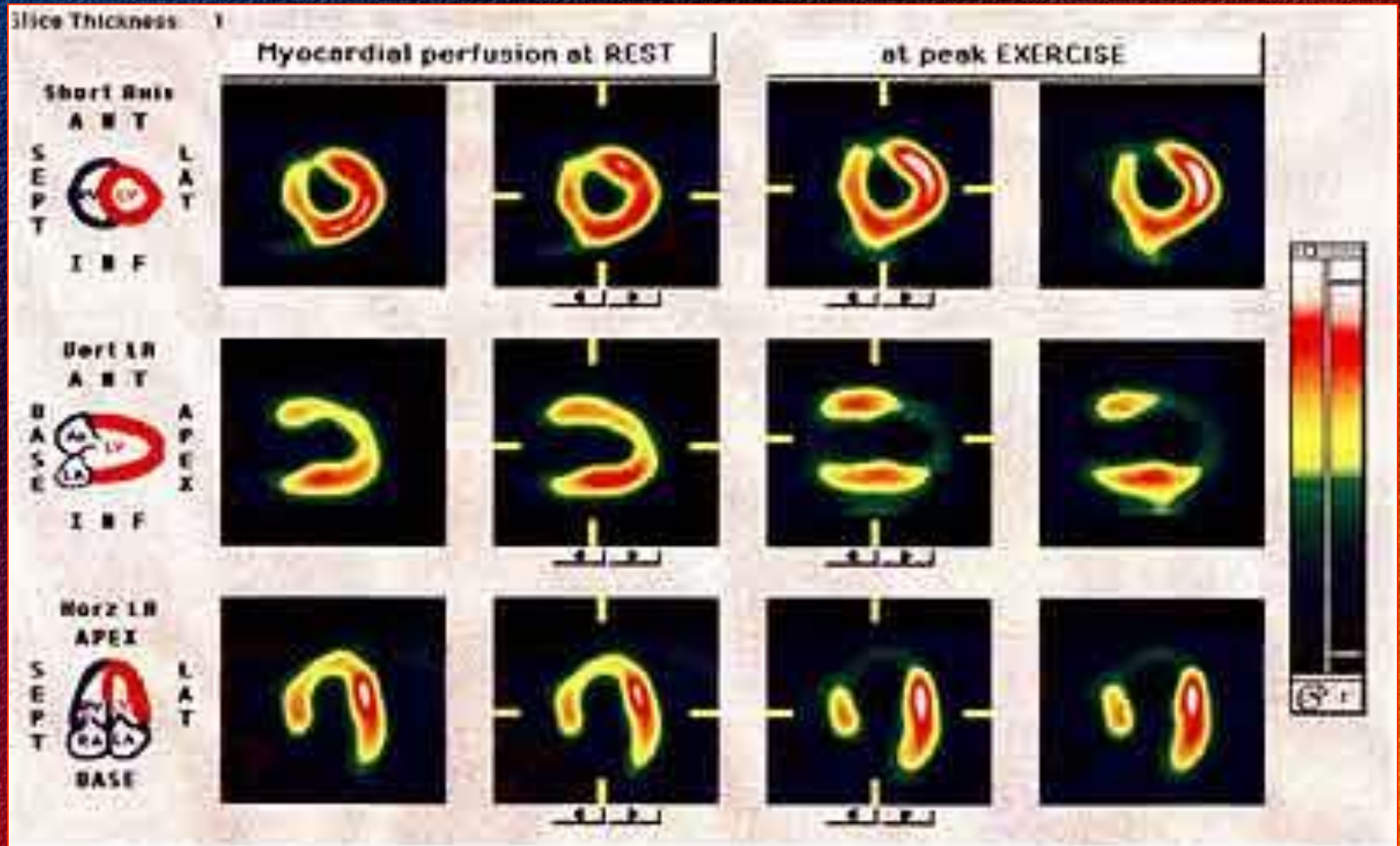
Normal myocardial perfusion



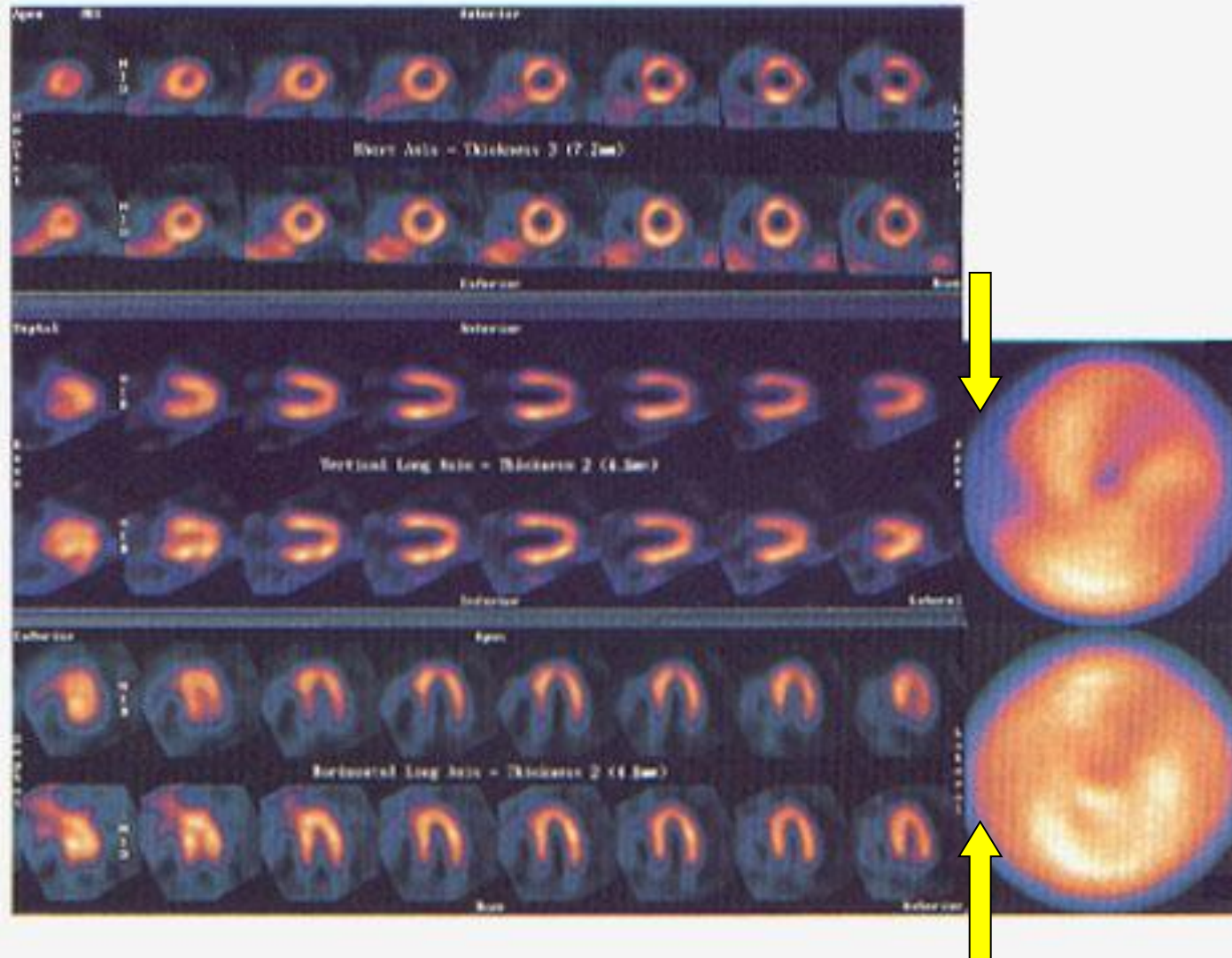
CAD in the infero-lateral wall



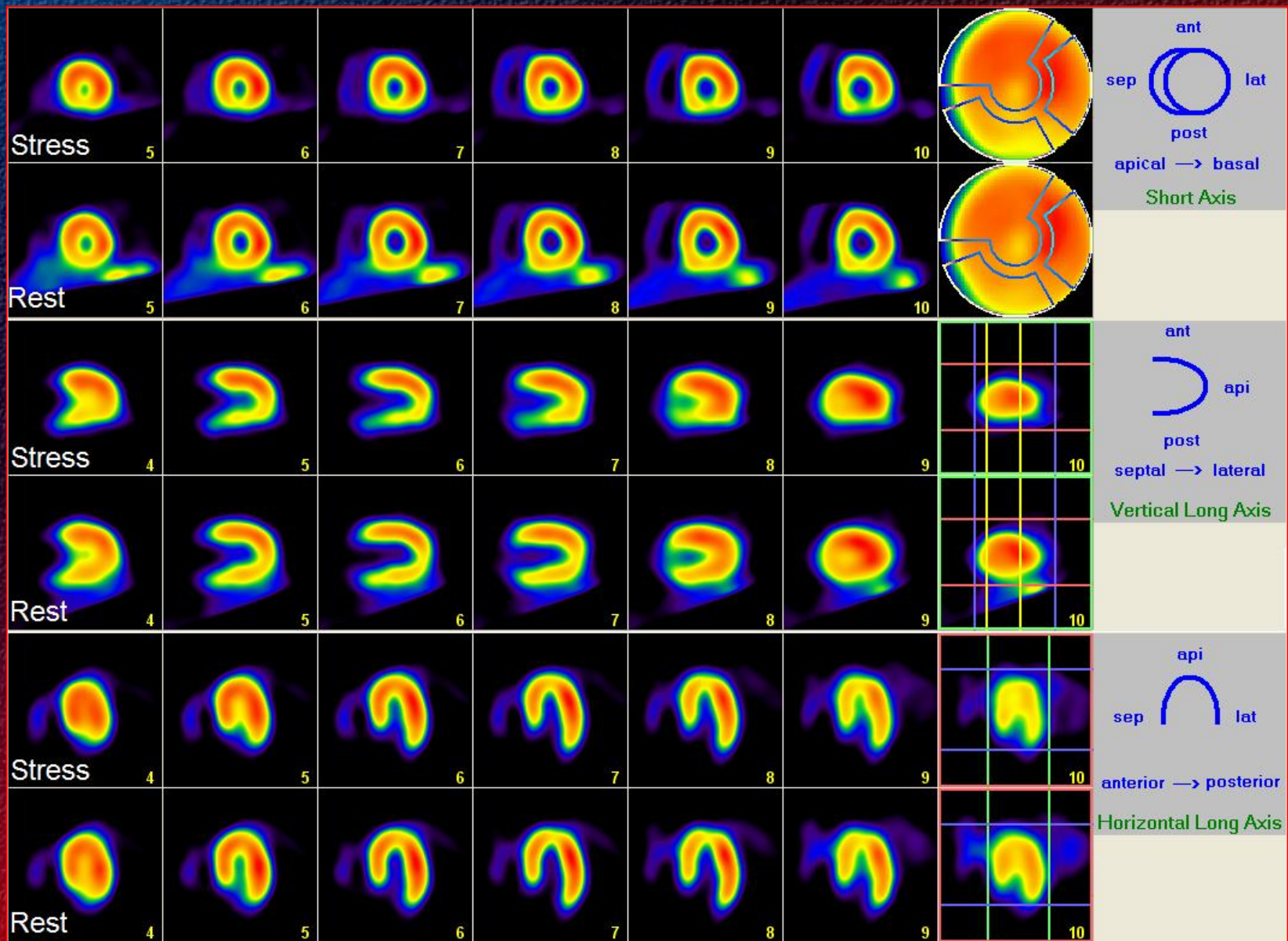
Apical and antero-apical transient ischaemia



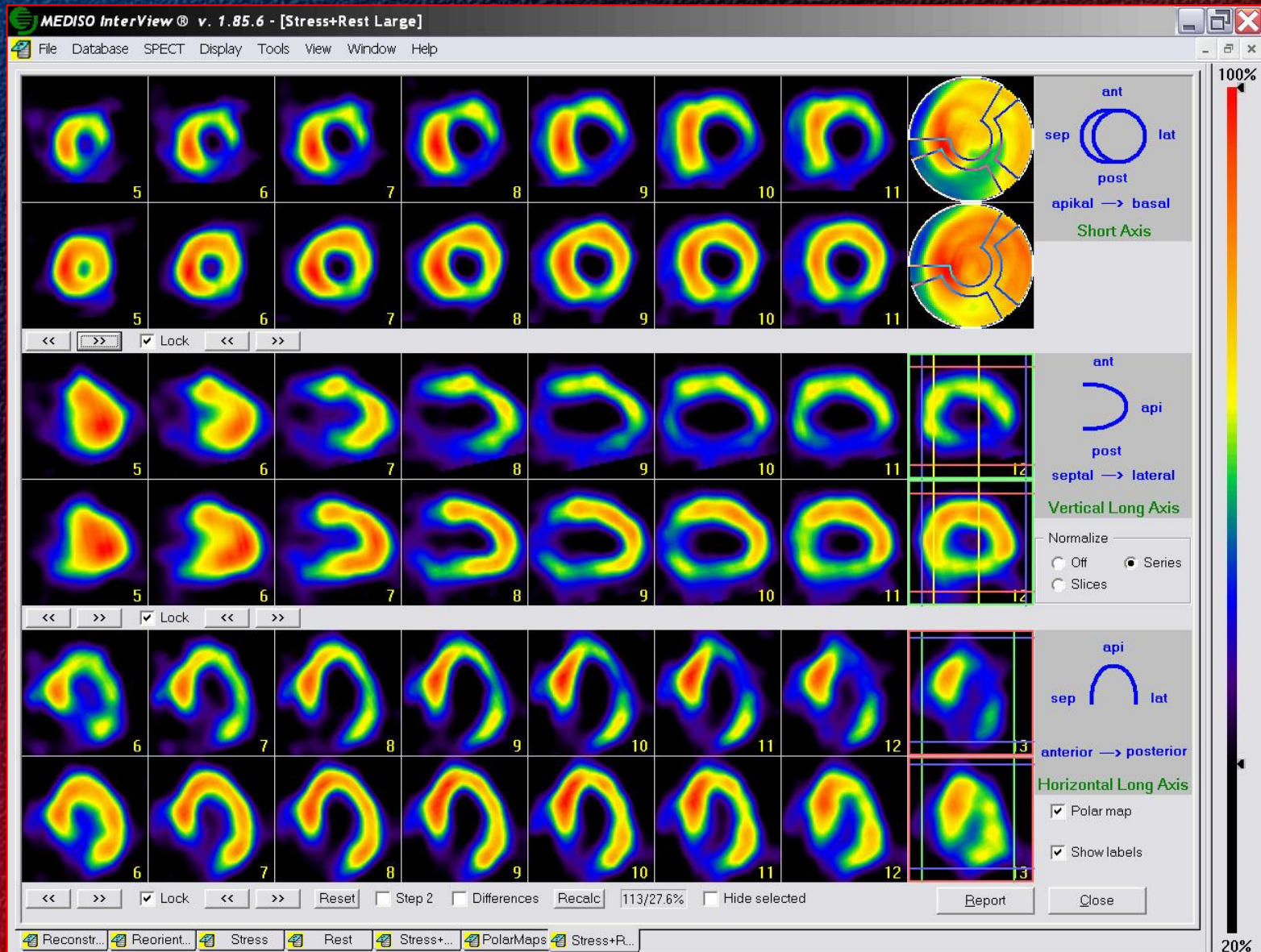
Transient ischaemia in the basal part of the septum



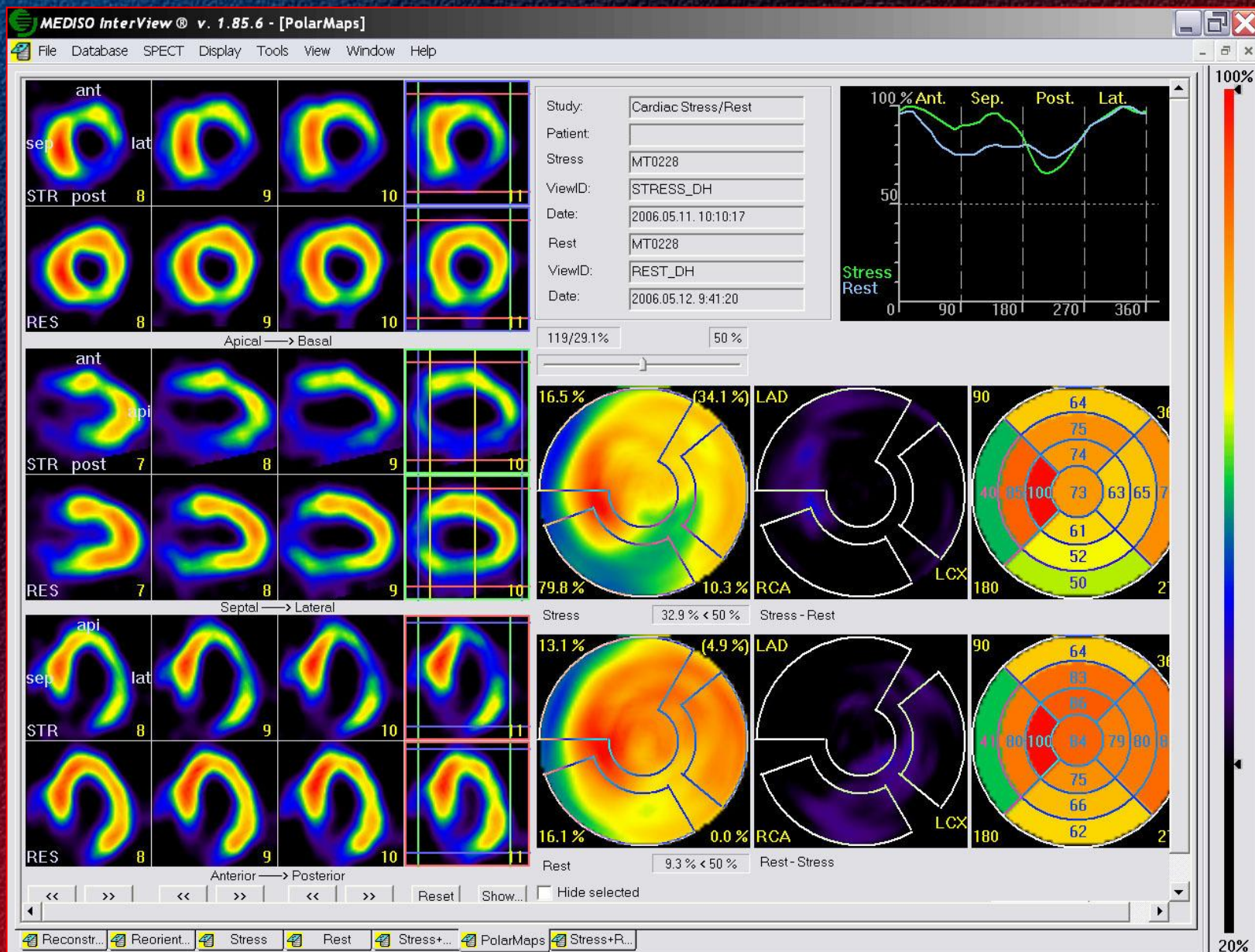
Infero-basal transient ischaemia



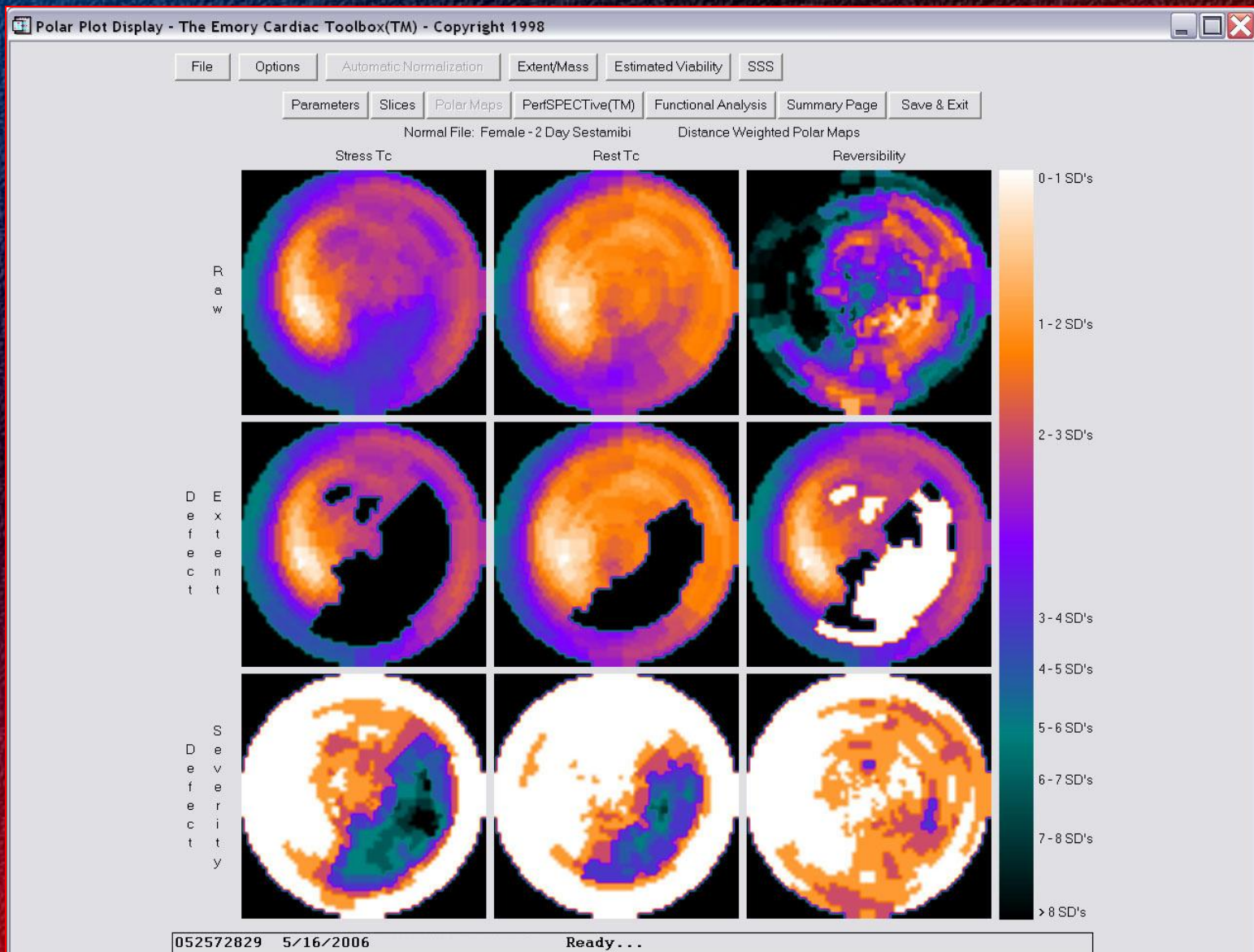
Hudge infero-lateral transient ischaemia



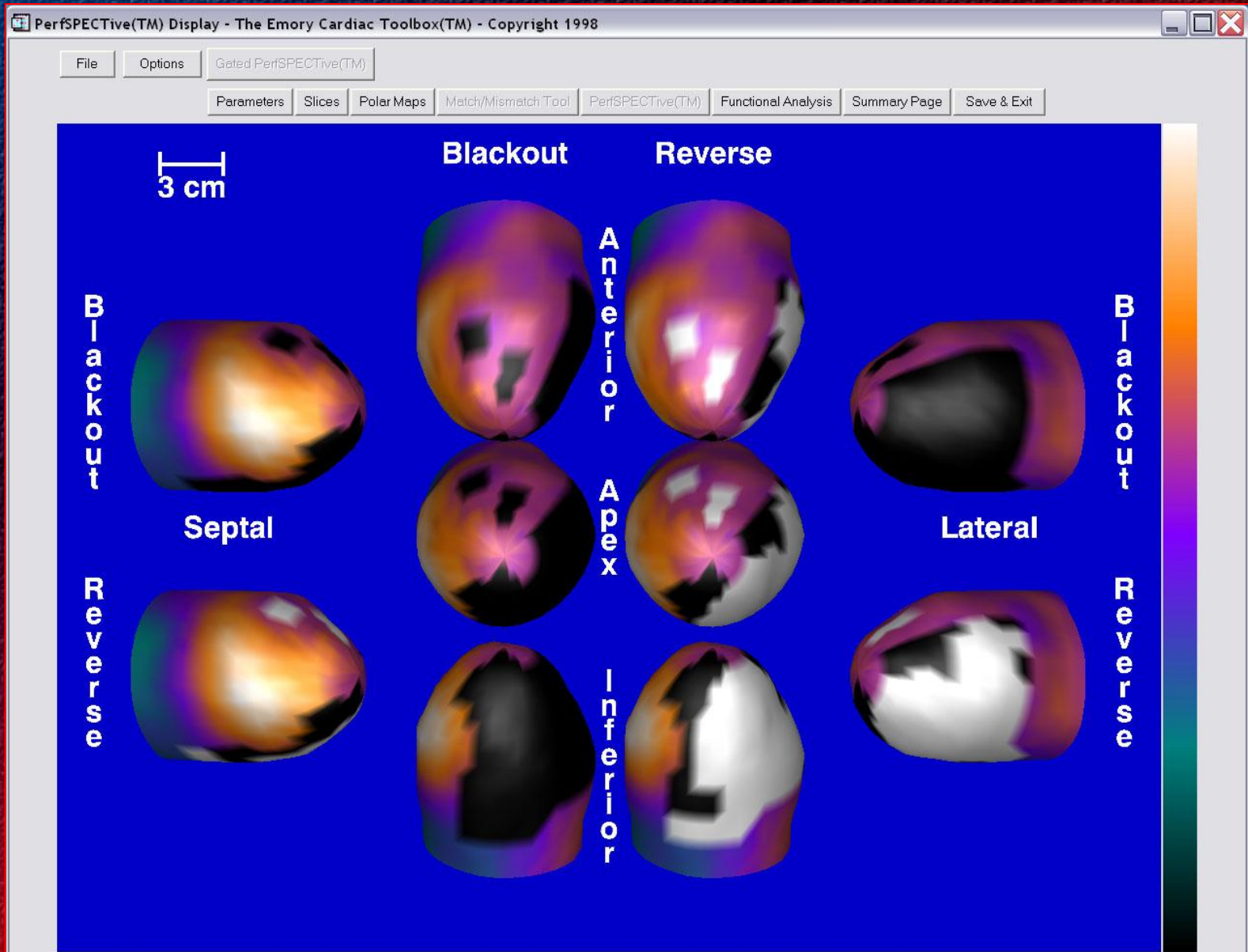
Polar maps, profil-curves



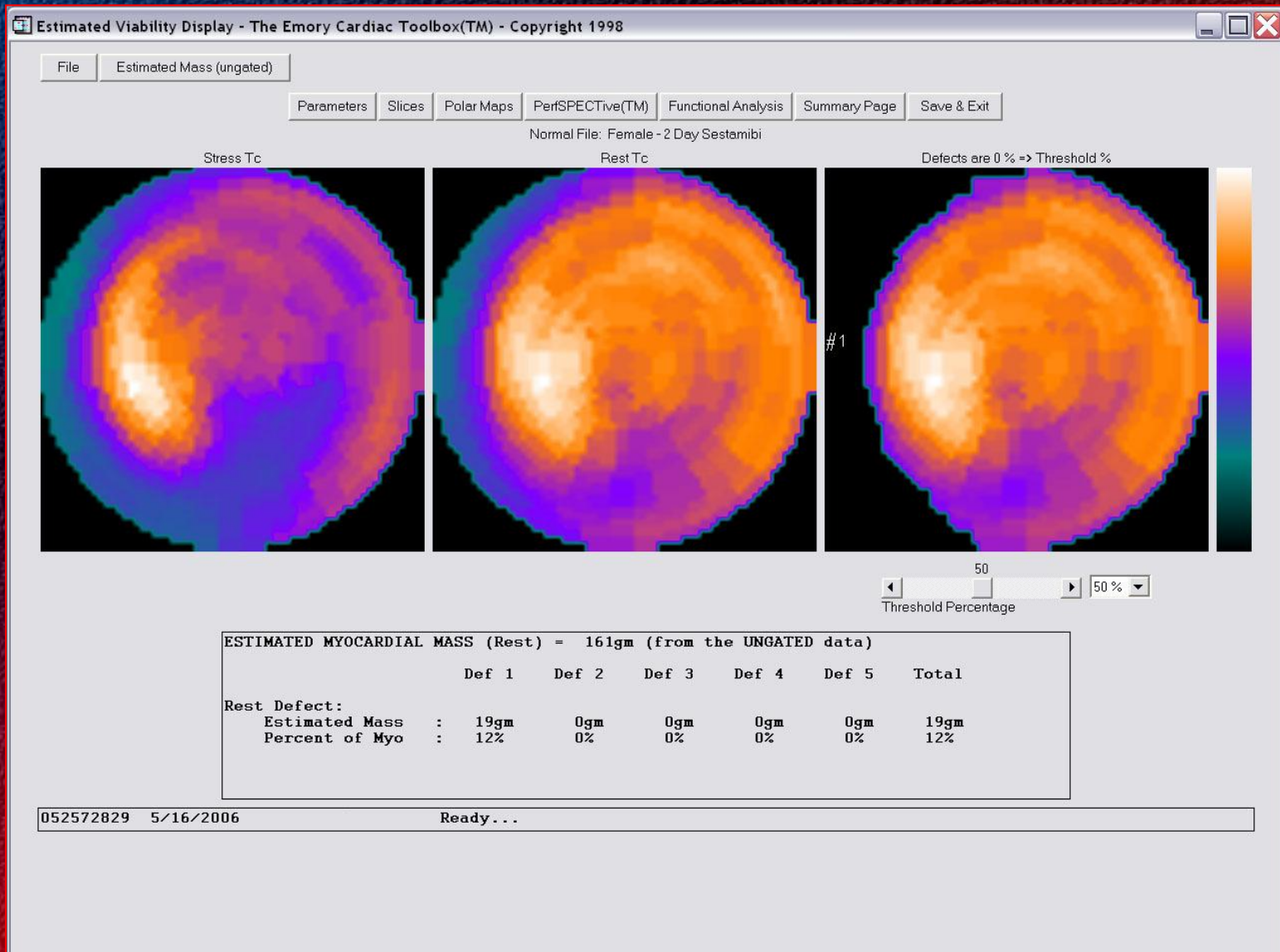
Polar maps of reversibility (Emory toolbox)



3D (three dimension) imaging



Quantitativ evaluation



Report

The Emory Cardiac Toolbox(TM) - Copyright 1998

File

Options

Slices

Polar Maps

Match/Mismatch Tool

PerfSPECTive(TM)

Functional Analysis

Summary Page

PERFEX(TM)

Save & Exit

Summary Page - The Emory Cardiac Toolbox(TM) - Copyright 1998

File

Parameters

Slices

Polar Maps

Match/Mismatch Tool

PerfSPECTive(TM)

Functional Analysis

Summary Page

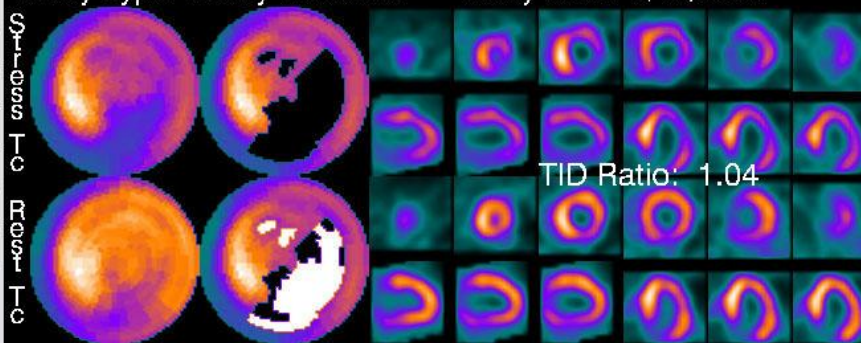
NRP

Save & Exit

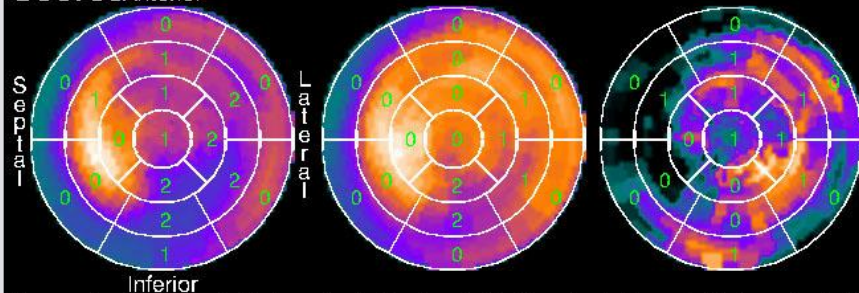
PTE OEC AOK/ Közponi Klinikai Radioizotóp Laboratórium

Patient: ID: 052572829 Age: 77

Study Type: 2 Day Sestamibi Study Date: 5/16/2006



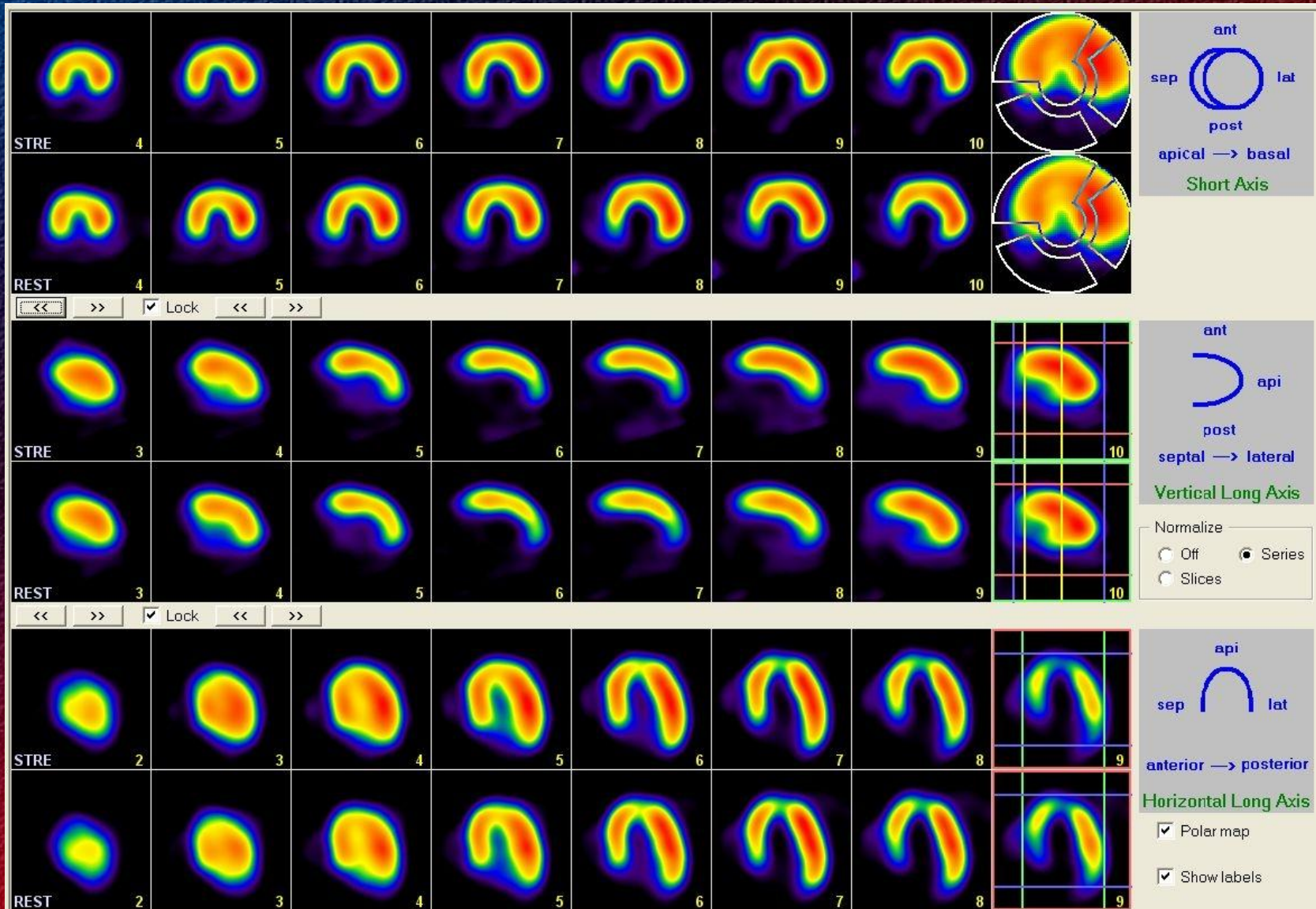
Scores



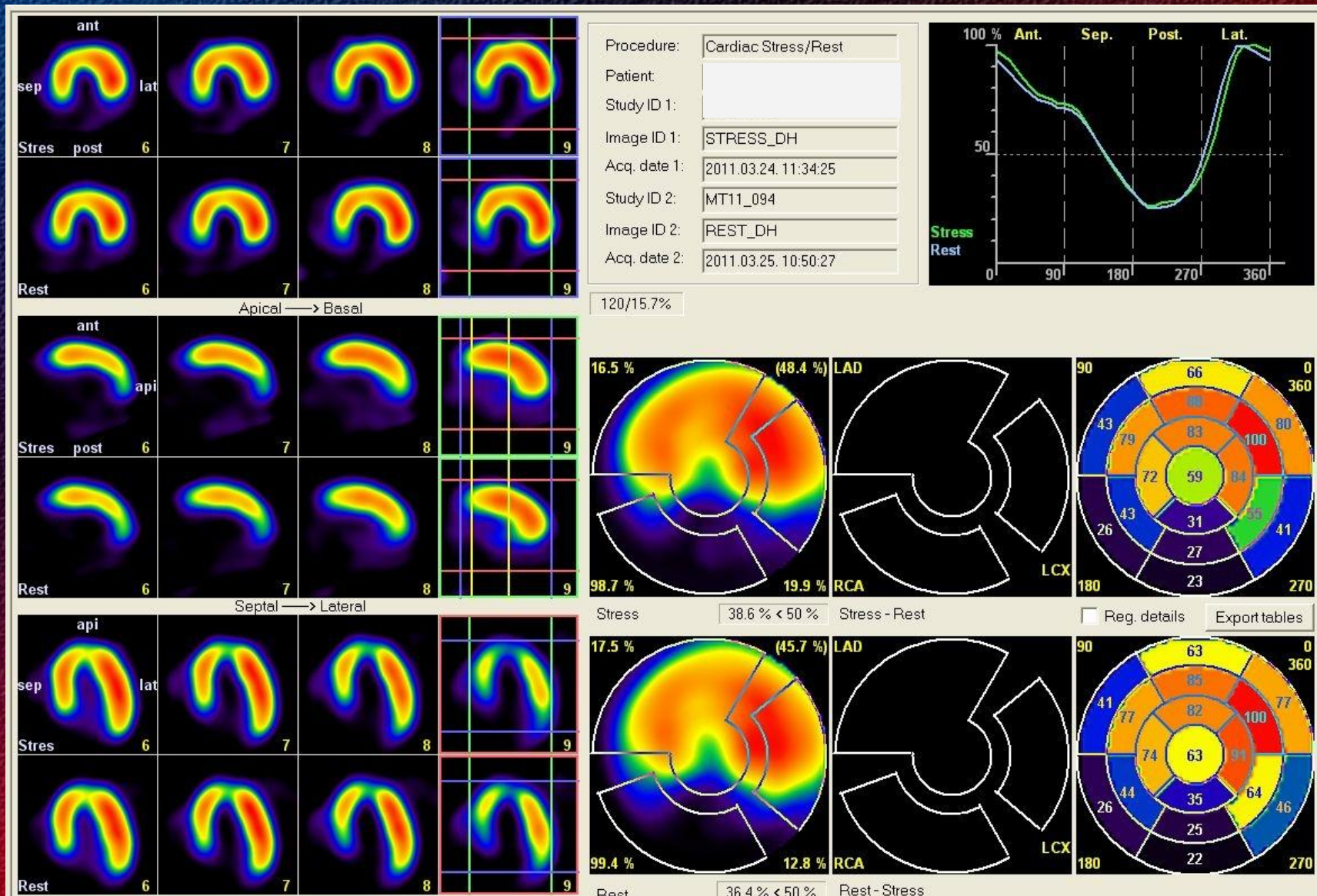
Scores: 0=Normal 1=Equivocal 2=Moderately Reduced 3=Severely Reduced 4=Absent
Summed Stress Score: 15 Summed Rest Score: 7 Summed Difference Score: 8

052572829 5/

Inferior, infero-septal, infero-lateral fix perfusion defect (scar)



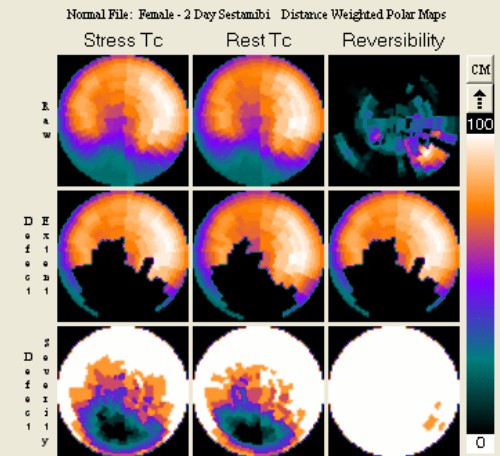
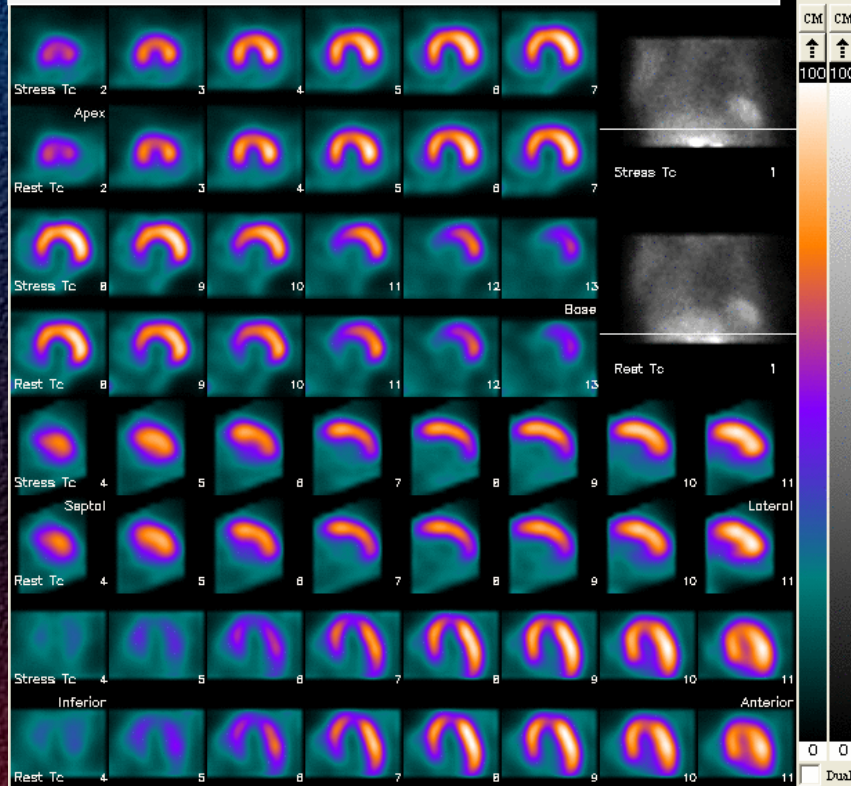
Inferior, infero-septal, infero-lateral fix perfusion defect (scar)



Report (Emory toolbox)

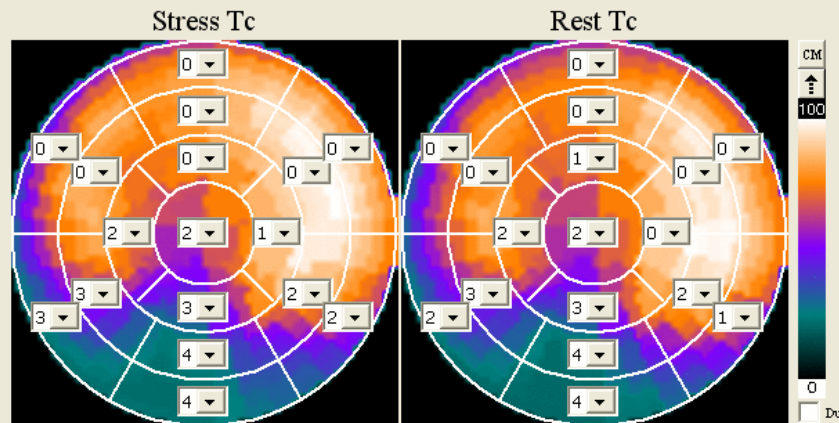
2 Day Sestamibi
3/24/2011 11:34:25

General Hospital / Nuclear Medicine



No Stress Gated Data Available

No Rest Gated Data Available

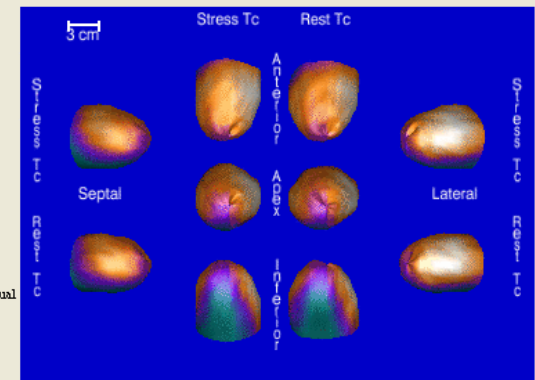


0: Normal 1: Equivocal 2: Moderate Reduction 3: Severe Reduction 4: Absent

Summed Stress Score: 26

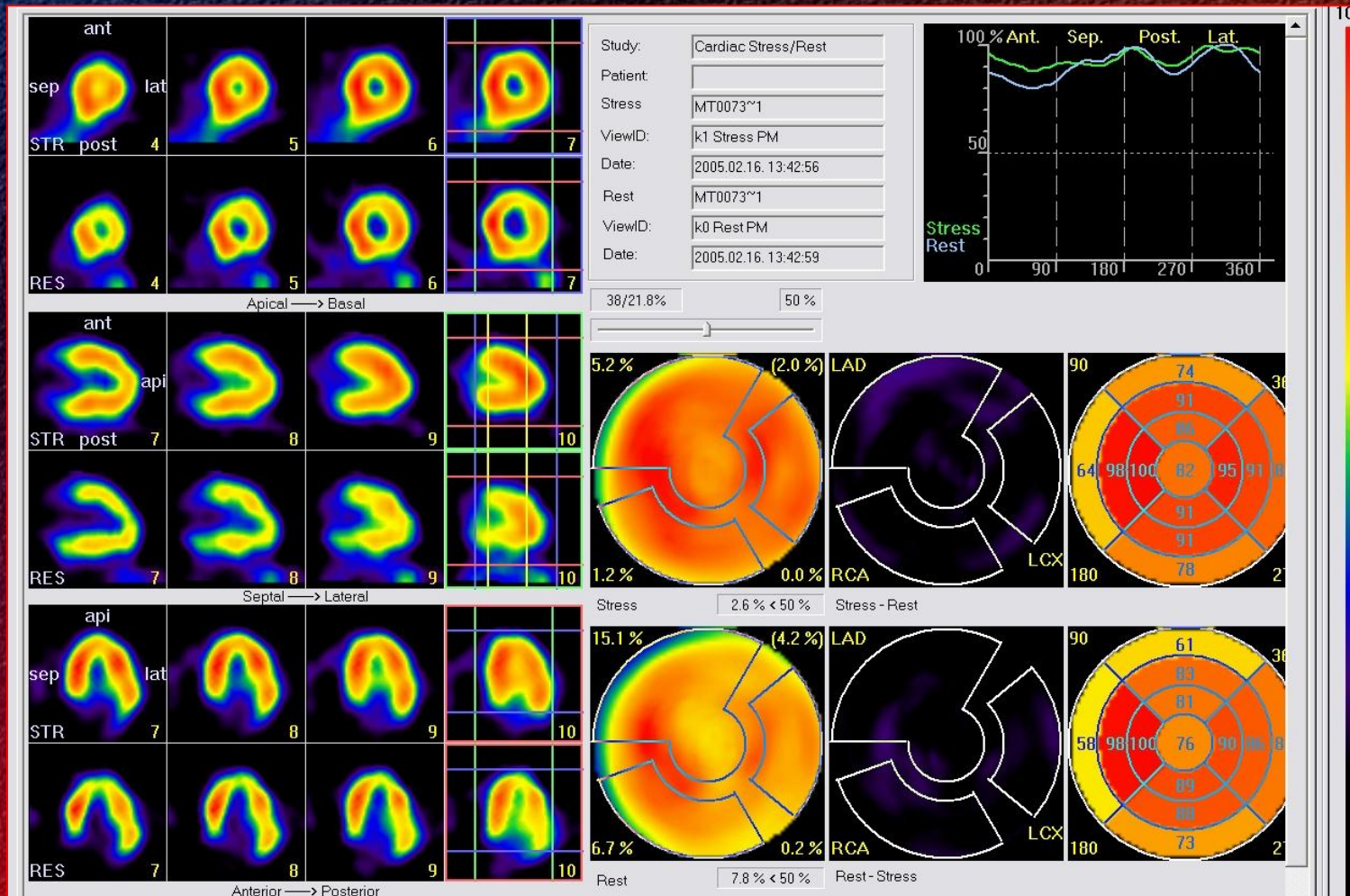
Summed Rest Score: 24

Summed Difference Score: 2

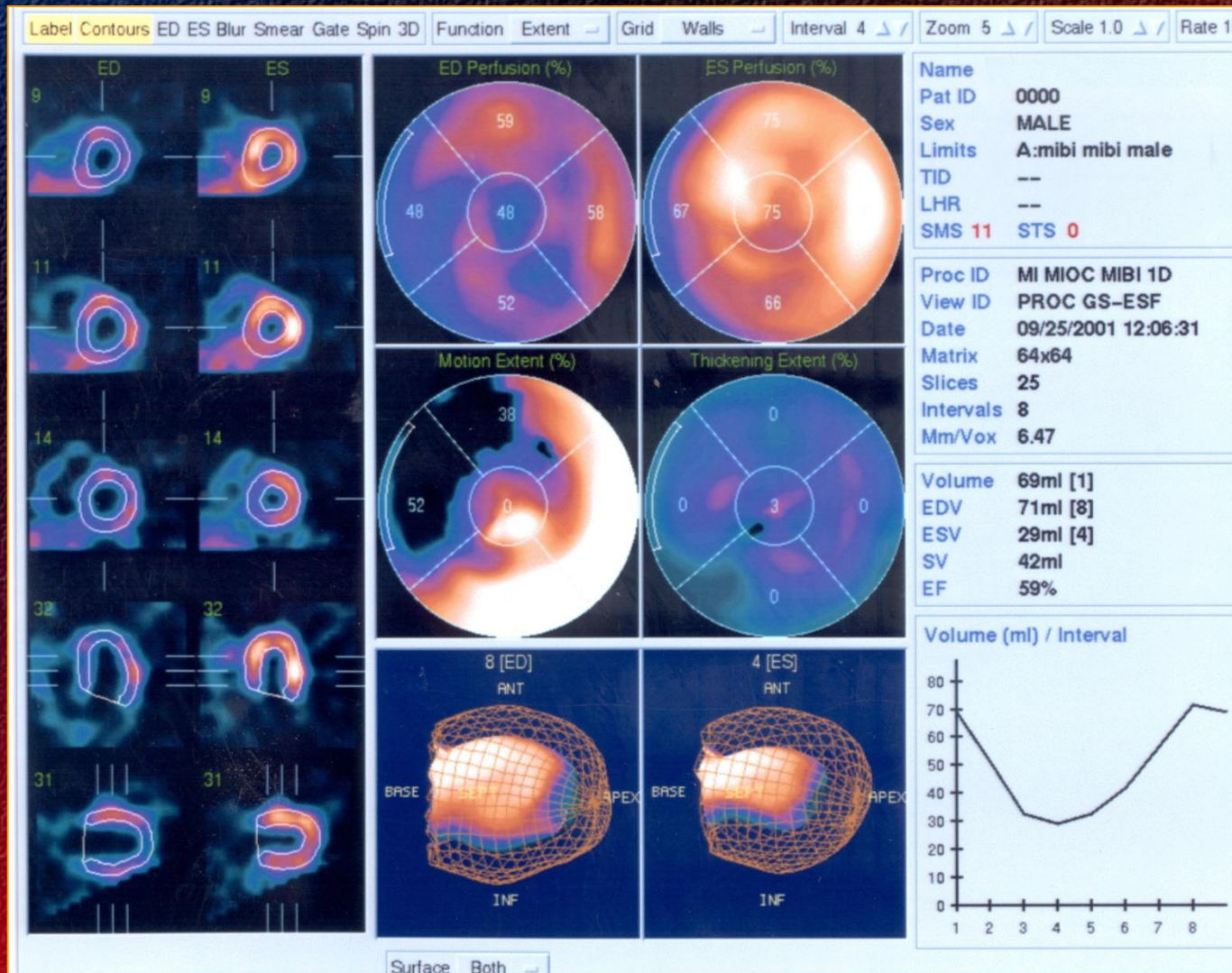


Reverse perfusion: is impaired in rest

- DPD - „steal” mechanism
- X syndrom, myocardial „bridge”



Gated examination: quantitativ evaluation of thickening, global and regional EF

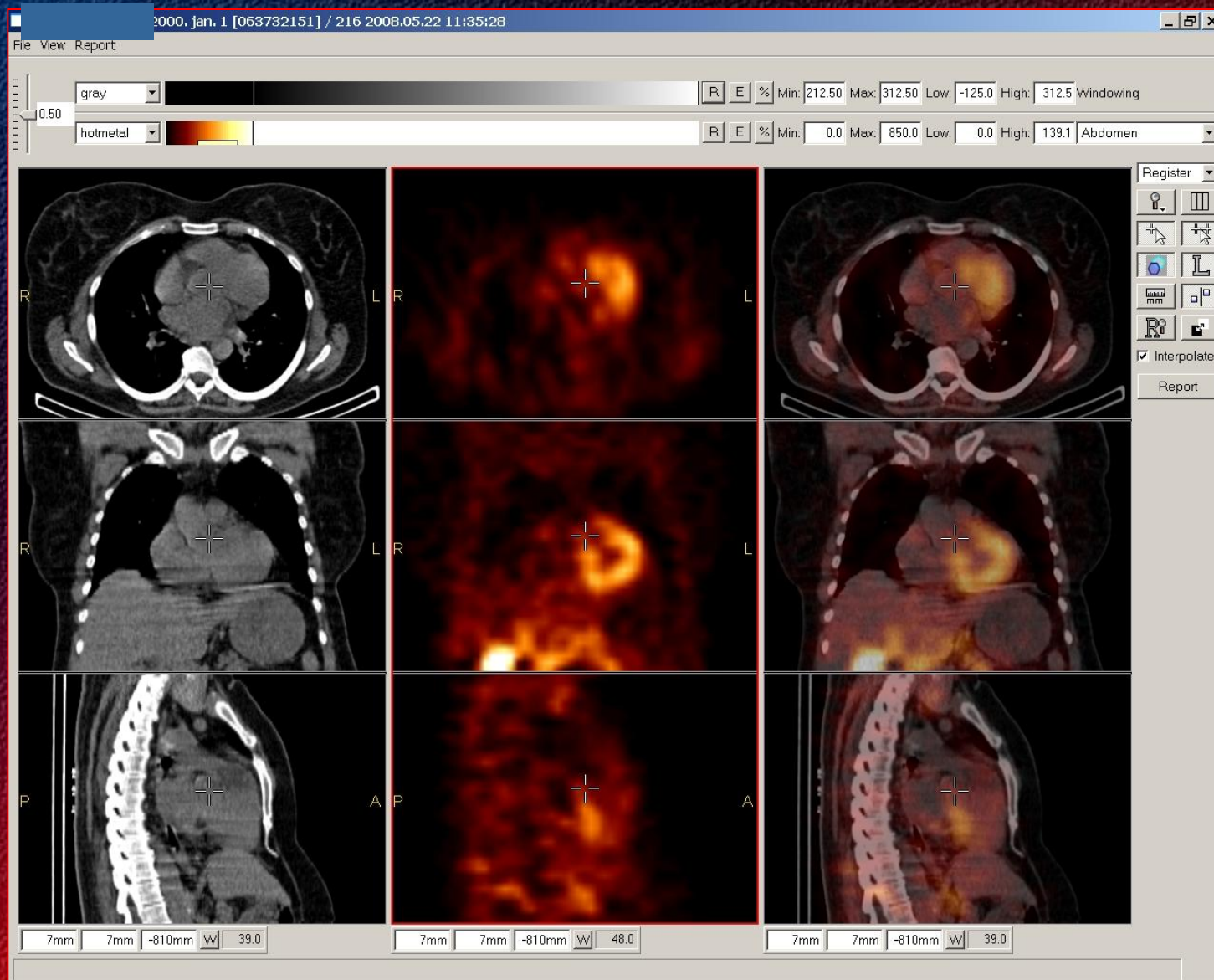


Equipments III.

- SPECT/CT (Single Photon Emission Computer Tomograph) + CT hybrid: multimodality, fused imaging



Myocardium perfusion SPECT/CT study in female



Influence of attenuation correction of the anterior wall in female

Basic

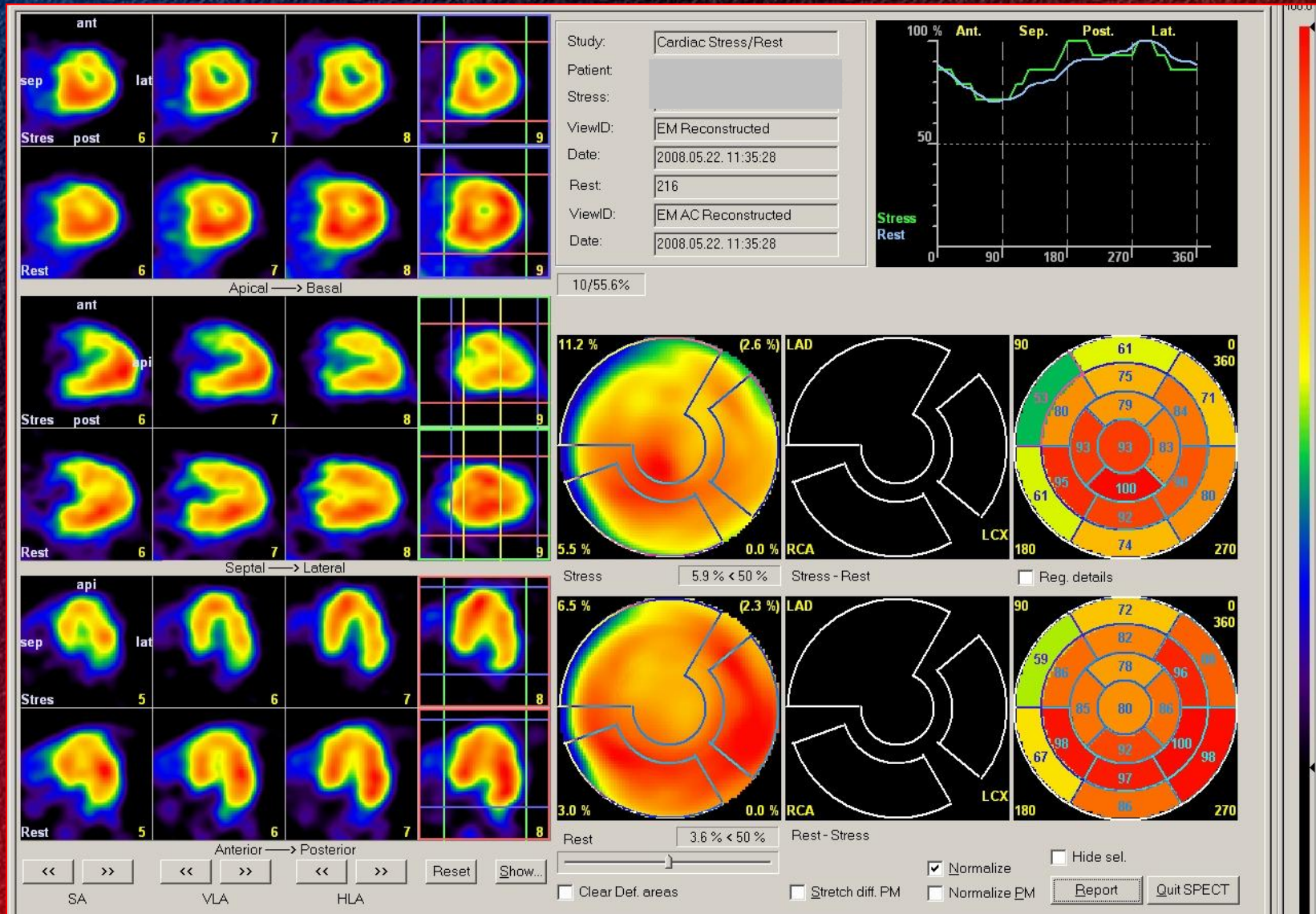
AC

Basic

AC

Basic

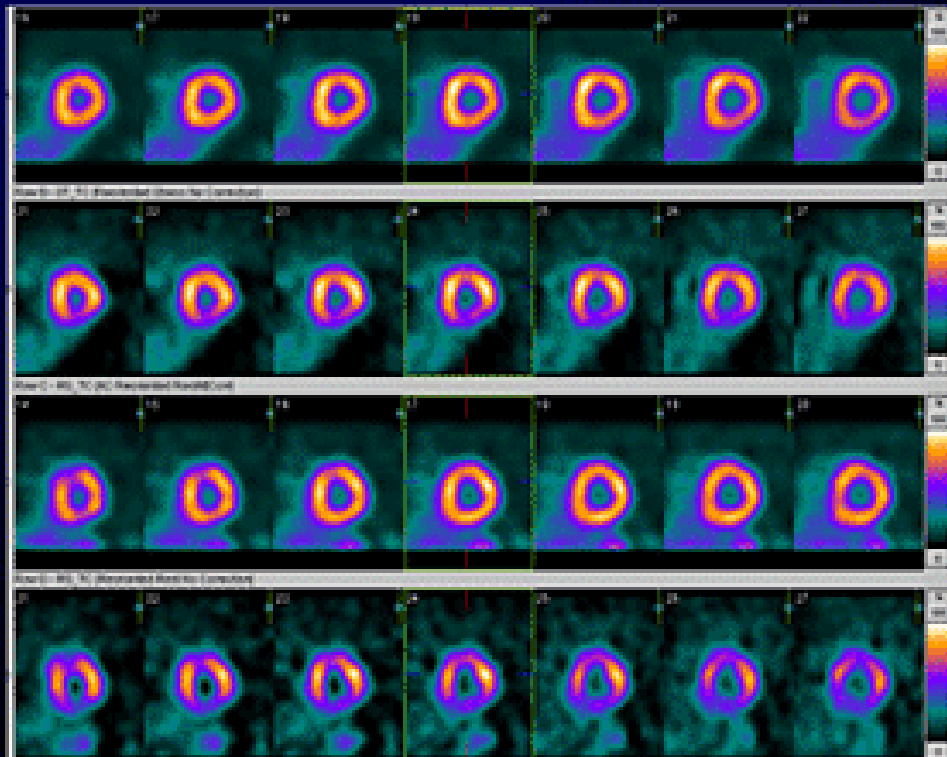
AC



Influence of attenuation correction of the inferior wall in male

SPECT/CT vs Conventional SPECT

- 385-lb male patient—Short Axis



Stress corrected

Stress uncorrected

Rest corrected

Rest uncorrected

3D SPECT/CT imaging:

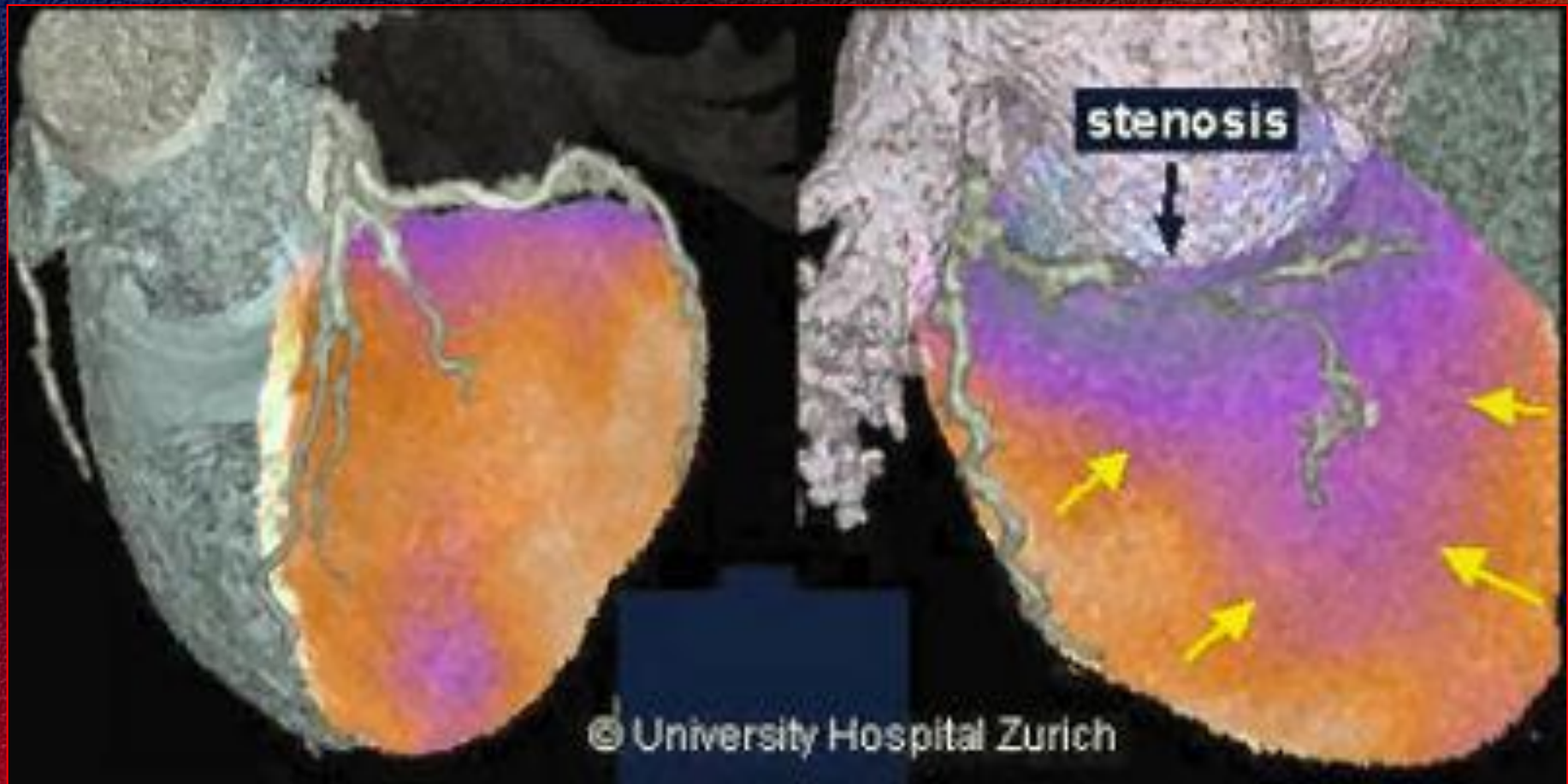
stenosis of circumflexa



**hypoperfusion in the
apical part of the left
ventricle**



3D SPECT/CT imaging:
stenosis of proximal part of the LAD
→ antero-basalis hypoperfusion

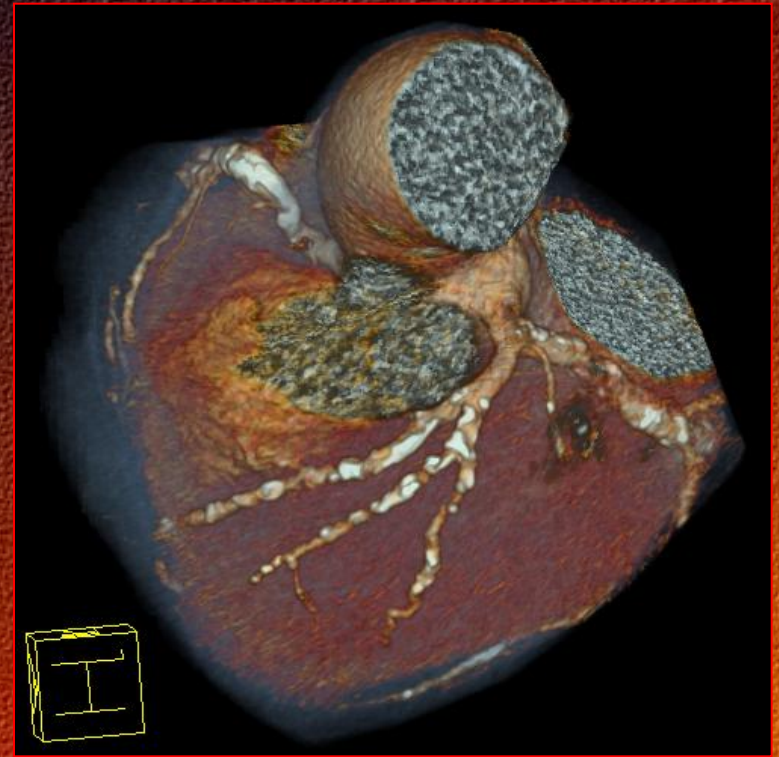
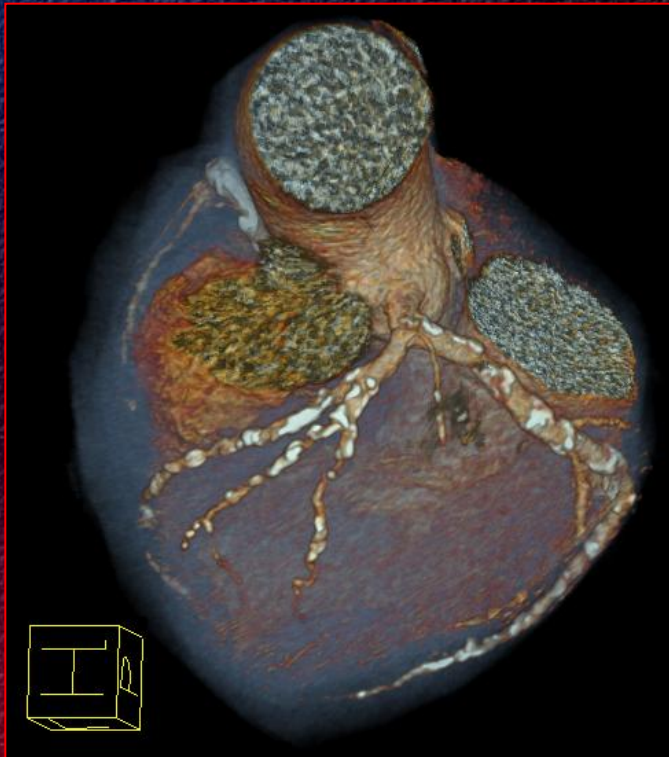


4. pts

MSCT

LAD, Cx, RCA sten. → *significance* ?

Calcium score: LAD - 1717
Cx - 3959
RCA - 1245



*MSCT result questionable: high coron. calcification
saccular dilatation of coronaries*



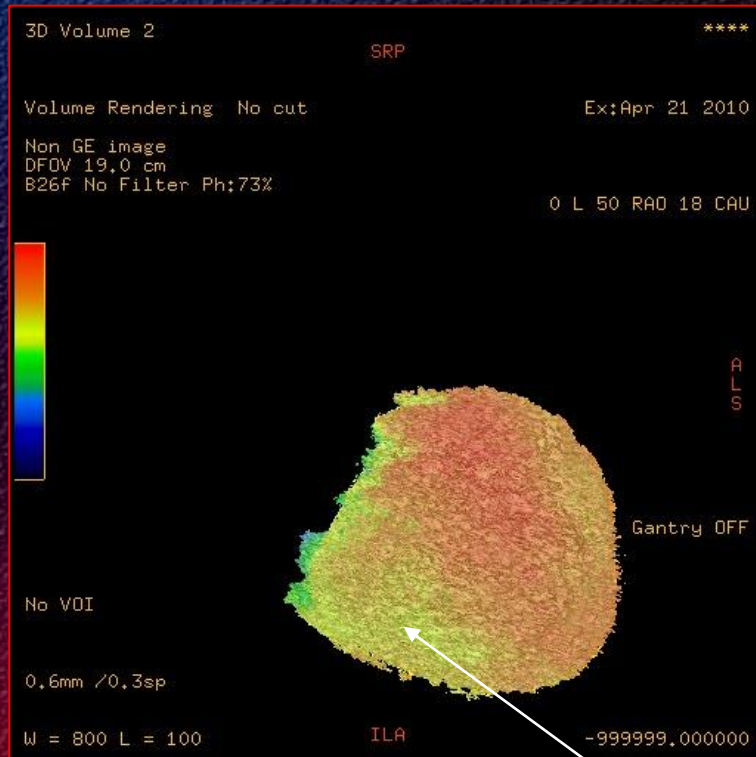
**PET
POZITRON**
DIAGNOSZTIKA Kft.

Kerecsen Gábor

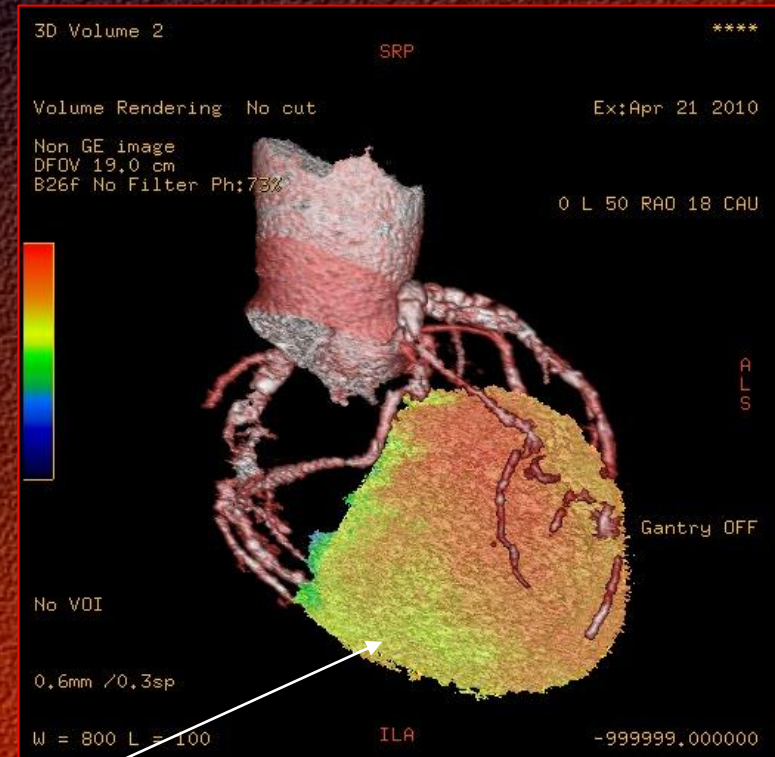
4. pts

Stress MPS + MSCT fusion (GE)

Stress MPS - 3D



Stress MPS + MSCT



Mild ischemia on inferior wall

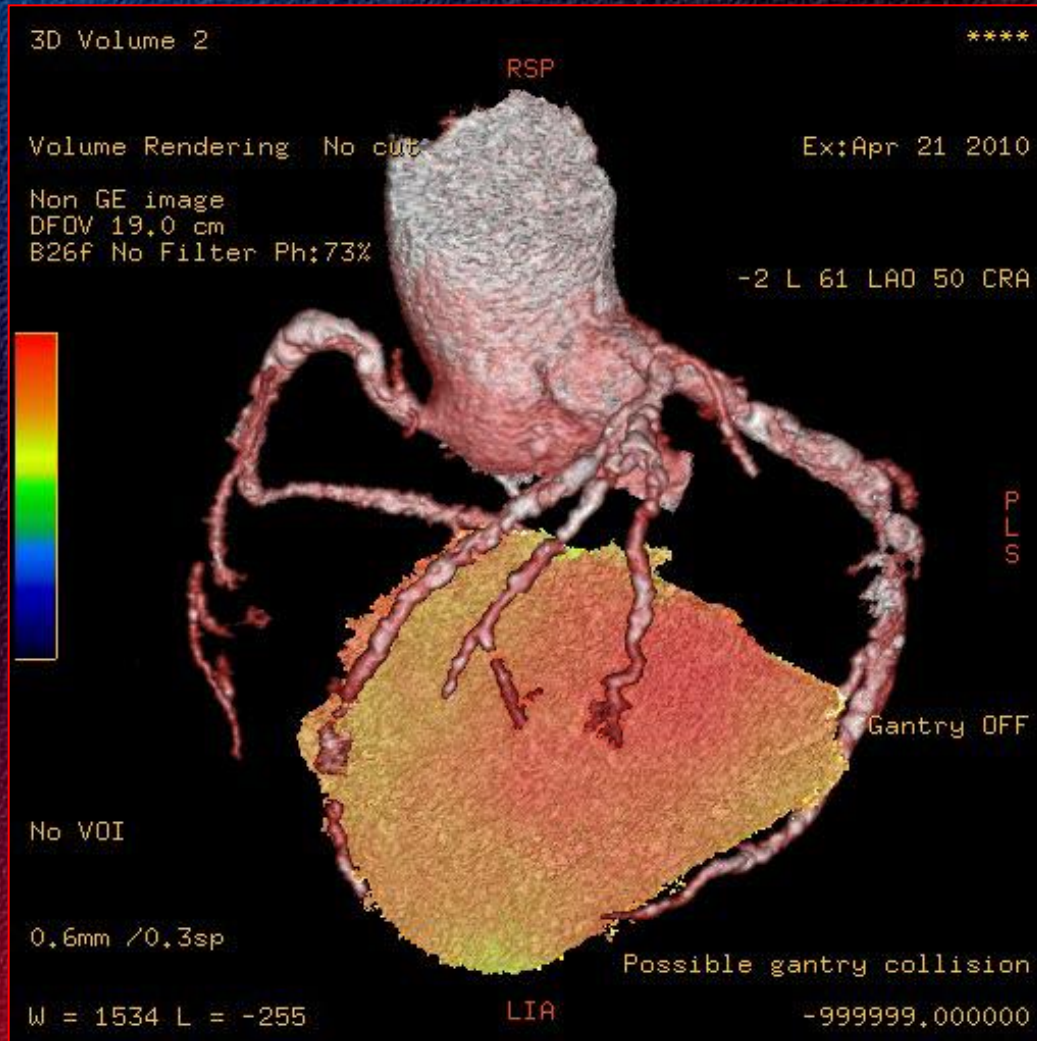
Answer: the ischemia is mild → medical therapy



Balogh Ildikó

4. pts

Stress MPS + MSCT



Balogh I. – Kerecsen G.

Viability examination of the myocardium

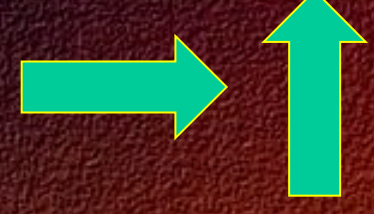
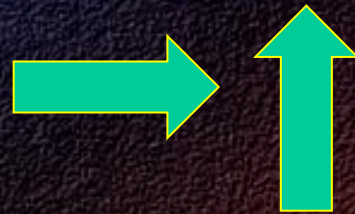
- When similar fix defect is found in stress and rest situation (scar, hibernated, stunned myocardium) to assess the possibility for succesful revascularization.
- ^{201}Ti -chlorid has a specific redistribution pattern after 3-4 hours in rest, which depends on the wash-out from the myocytes.
- After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

Function

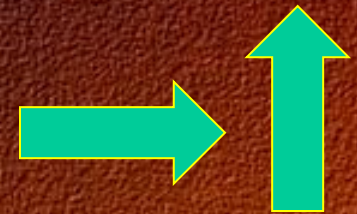
Perfusion

Metabolisme

• **Stunned**



• **Hibernated**



Reversible! → Revascularization

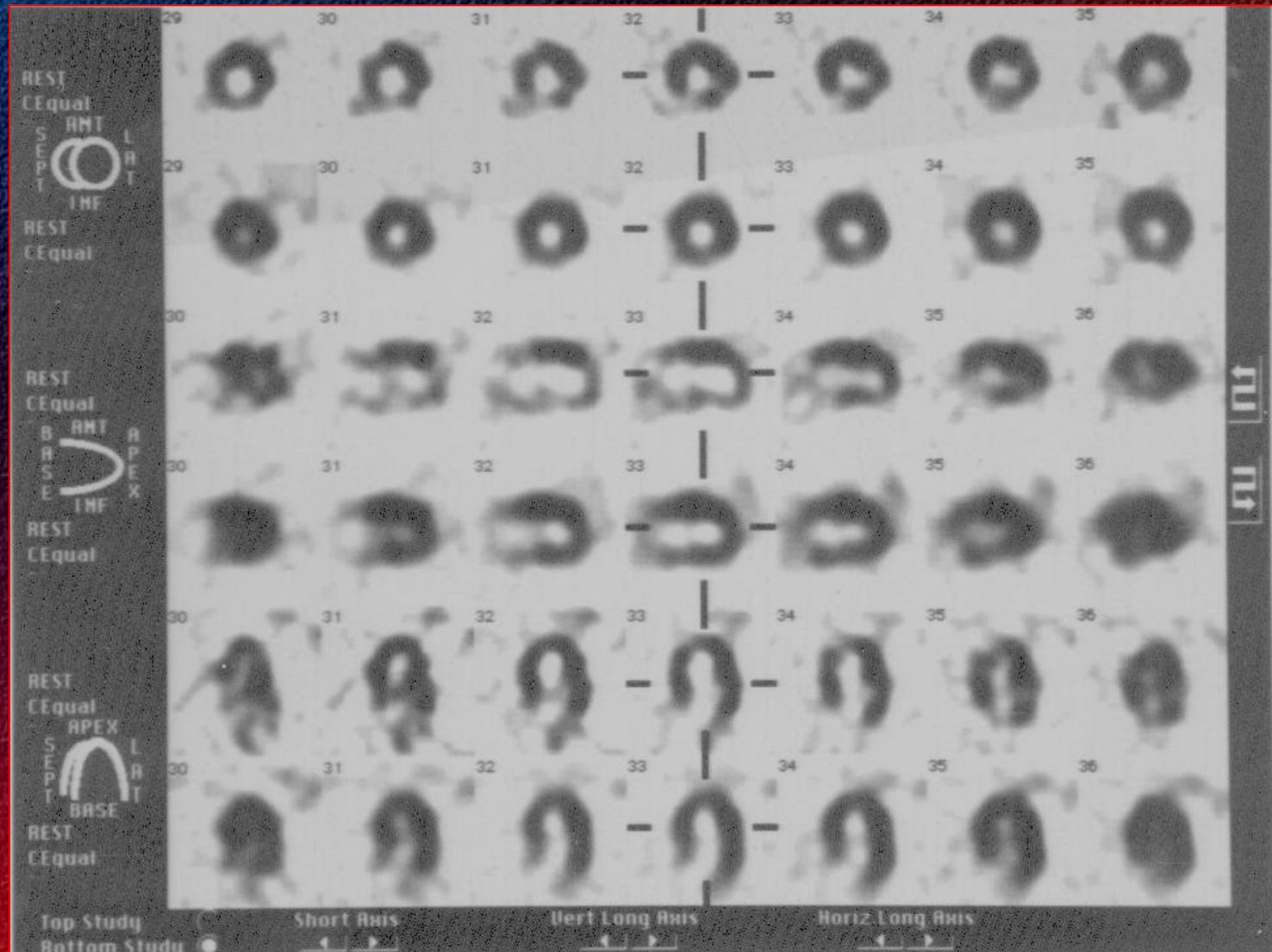
• **Necrosis
(scar)**



Irreversible!

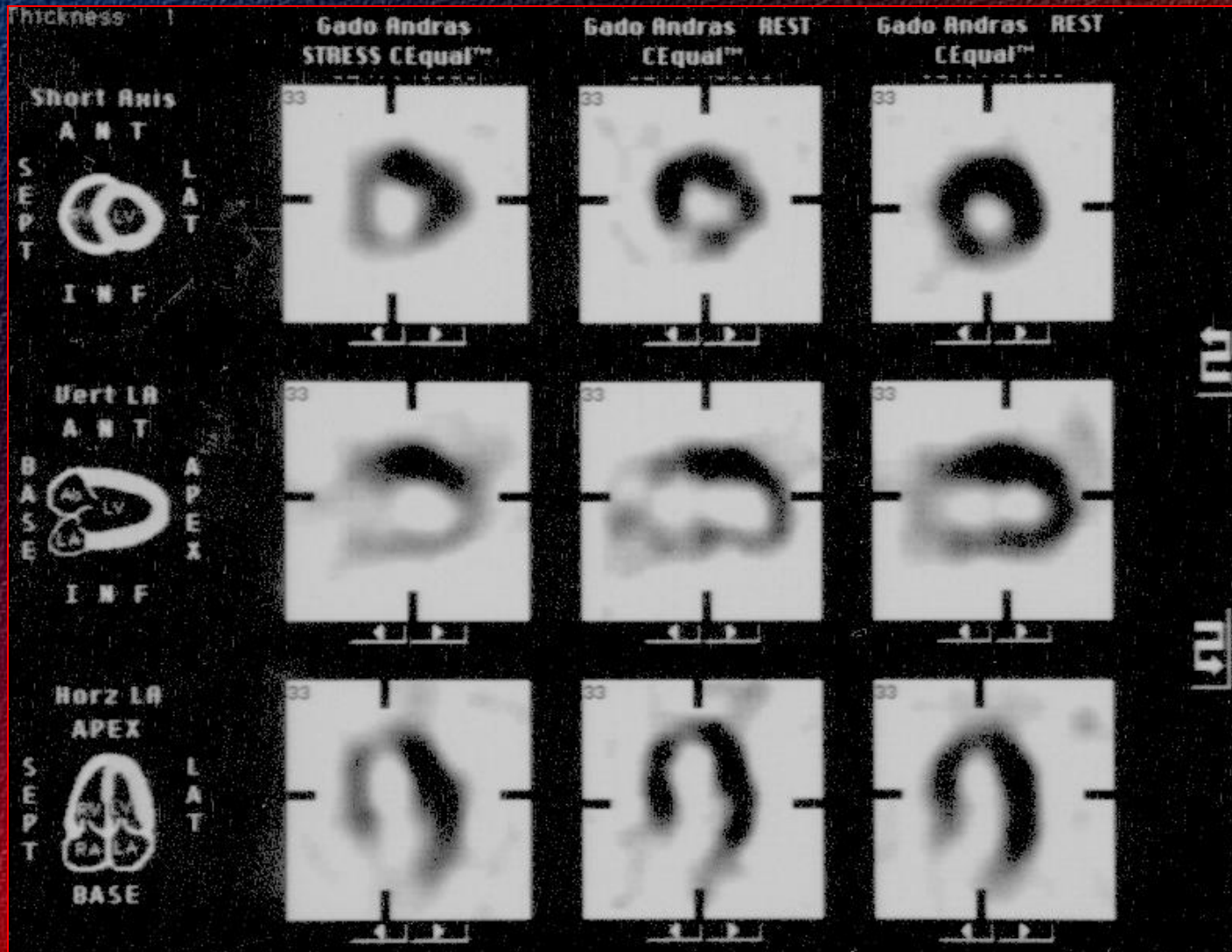
Figure 1 displays a series of 36 short-axis SPECT myocardial perfusion images arranged in a 6x6 grid. The grid is organized into three rows of stress images and three rows of rest images. The columns represent different slices, numbered 30 to 36. The top row of stress images shows normal perfusion. The middle row of stress images shows a large perfusion defect in the anterior wall. The bottom row of stress images shows a large perfusion defect in the inferior wall. The rest images show normal perfusion. The grid is labeled with 'STRESS CEqual', 'REST CEqual', 'ANT', 'INF', 'BASE', 'APEX', 'SEPT', 'LAT', 'Short Axis', 'Vert Long Axis', and 'Horiz Long Axis'.

Viability examination by ^{201}Tl -chlorid: redistribution-reinjection



Viability examination by ^{201}Tl -chlorid

stress redistrib. reinjection



+Beta (positron) radiation

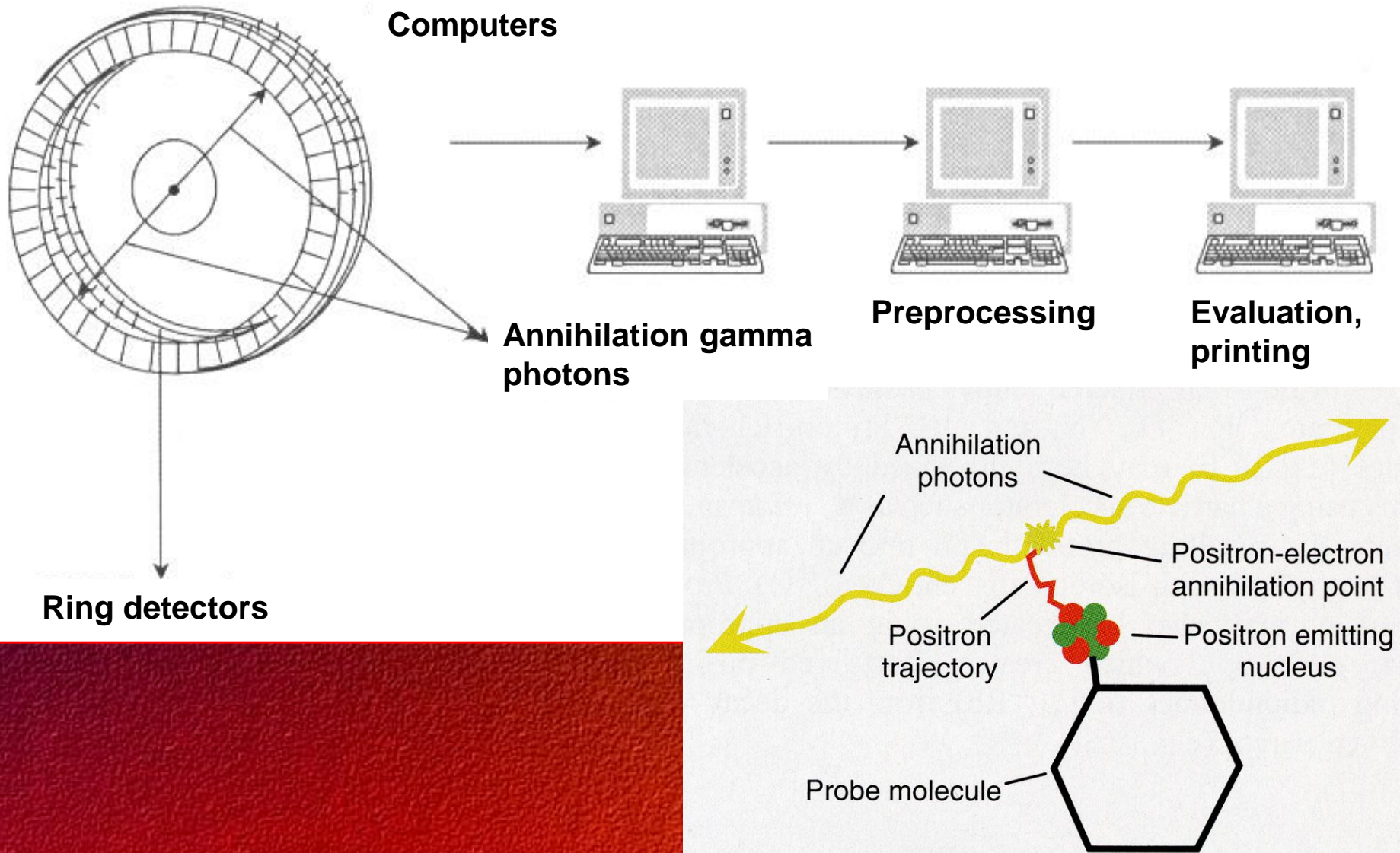
- too many protons are in the nucleus
- its life is very short, when it slows down, it combines with a normal electron in a process known annihilation, which destroys both the electron and positron and produces two energetic photons each with 511 keV
- they are used for PET examinations
- isotopes with ultrashort half-life (^{11}C , ^{15}O , ^{13}N , ^{18}F)
- e.g. ^{18}F Fluor-FDG to study the metabolic changes of the heart, the brain and the various tumors

Equipments III.

PET/CT (Positron Emission Tomograph/CT)



The principle of the PET



PET study
MIBI-FDG
„mismatch”



viability of
myocardium

MIBI

A

FDG

B

S = 100%

VP = 93%

Perfusion-
metabolic
„match”

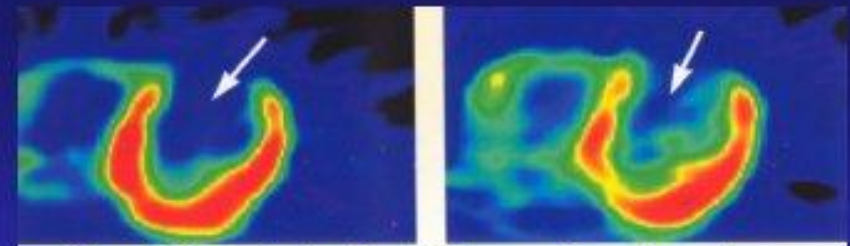


scar

FLUJO: Amonio N13

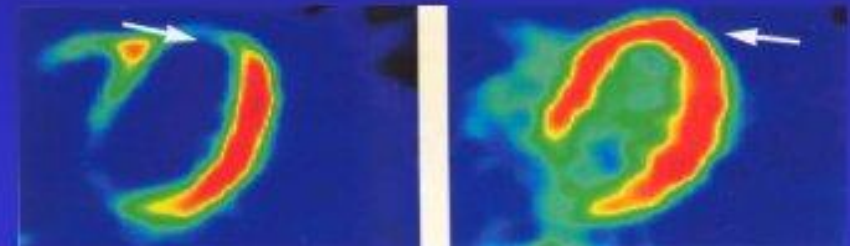
METABOLISMO: FDG

Match
concordancia



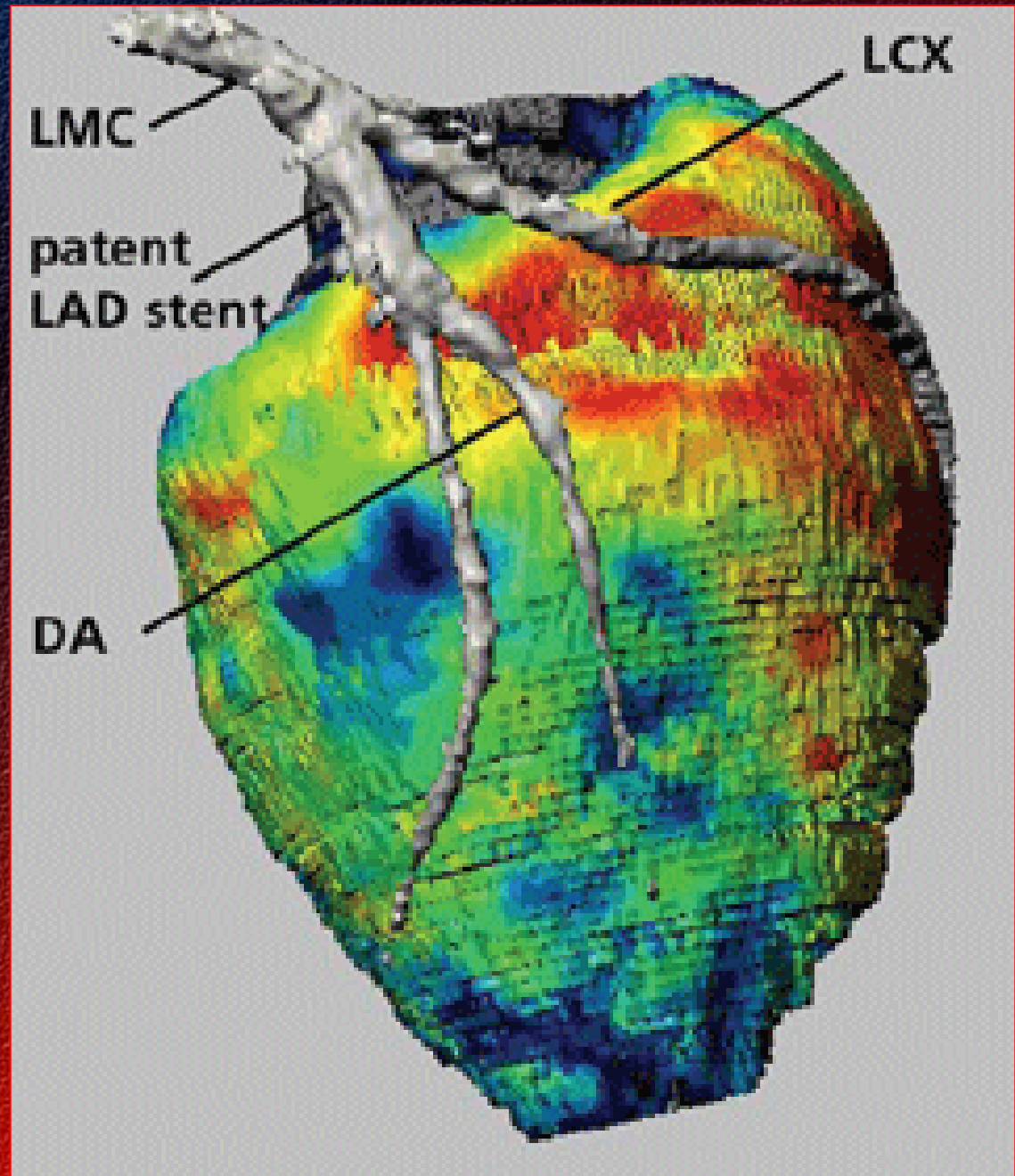
No viable territorio Arteria Descendente Anterior

Mismatch
discordancia

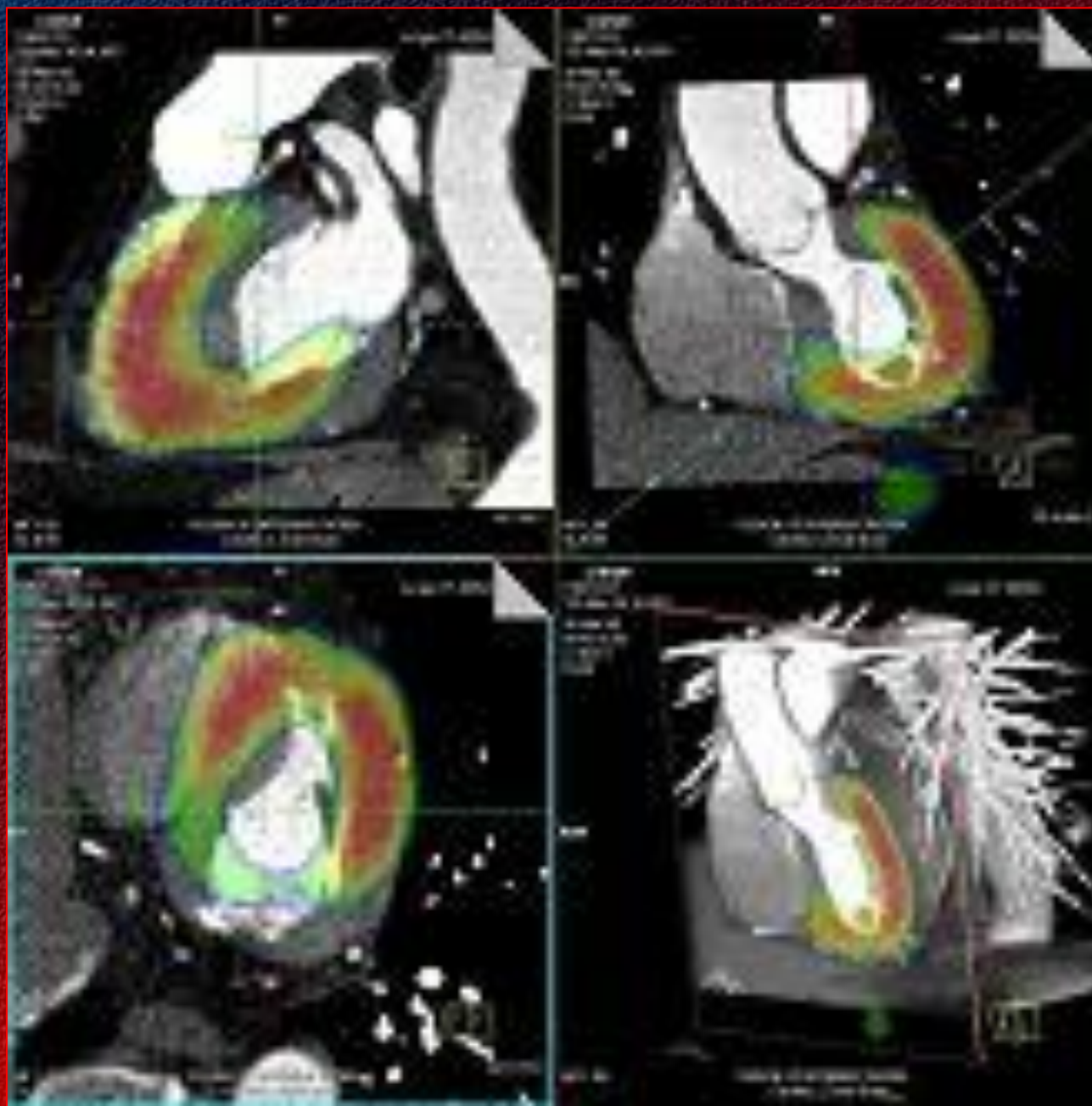


Viable territorio Arteria Descendente Anterior

The coronary angiogram was acquired using CT, while the surface of the myocardium is coloured using the data of the ammonia PET stress perfusion scan done during the PET-CT examination. It can be clearly seen that territories in the distal LAD region are blue, which signifies reduced stress perfusion.



SPECT/MRI fused imaging



Differential diagnosis

- **Intracardial left-to-right shunt, chronic cor pulmonale:**
 - „first passage” study
- **Acute myocardial infarction, myocardial scar, cardiomyopathy:**
 - rest myocardial perfusion study
 - radionuclide ventriculography (MUGA)
- **Pectoral angina, coronary artery disease:**
 - stress/rest myocardial perfusion study
- **Viability before revascularization:**
 - glucose metabolism by PET/CT

Thank you!

