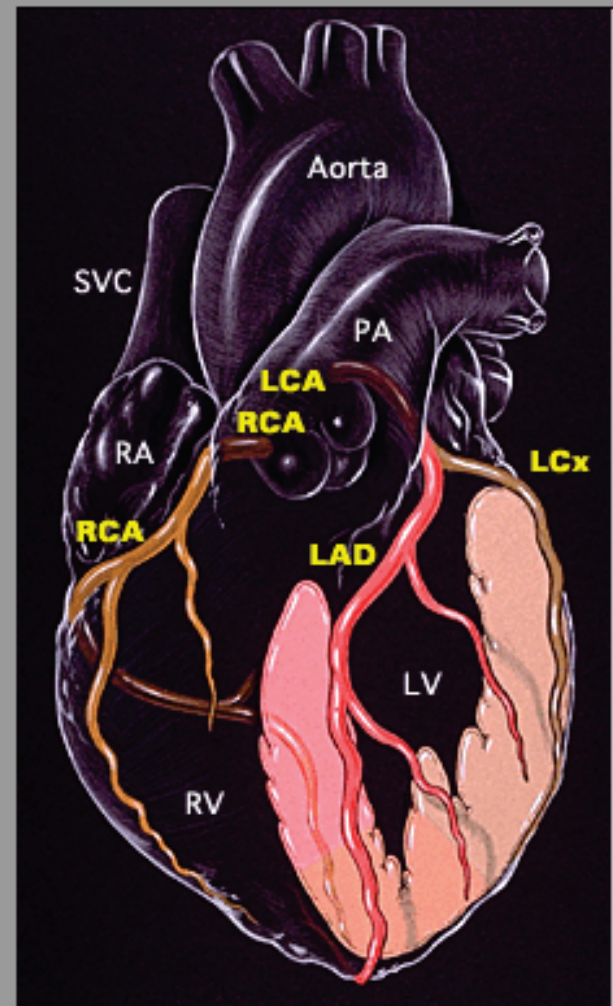
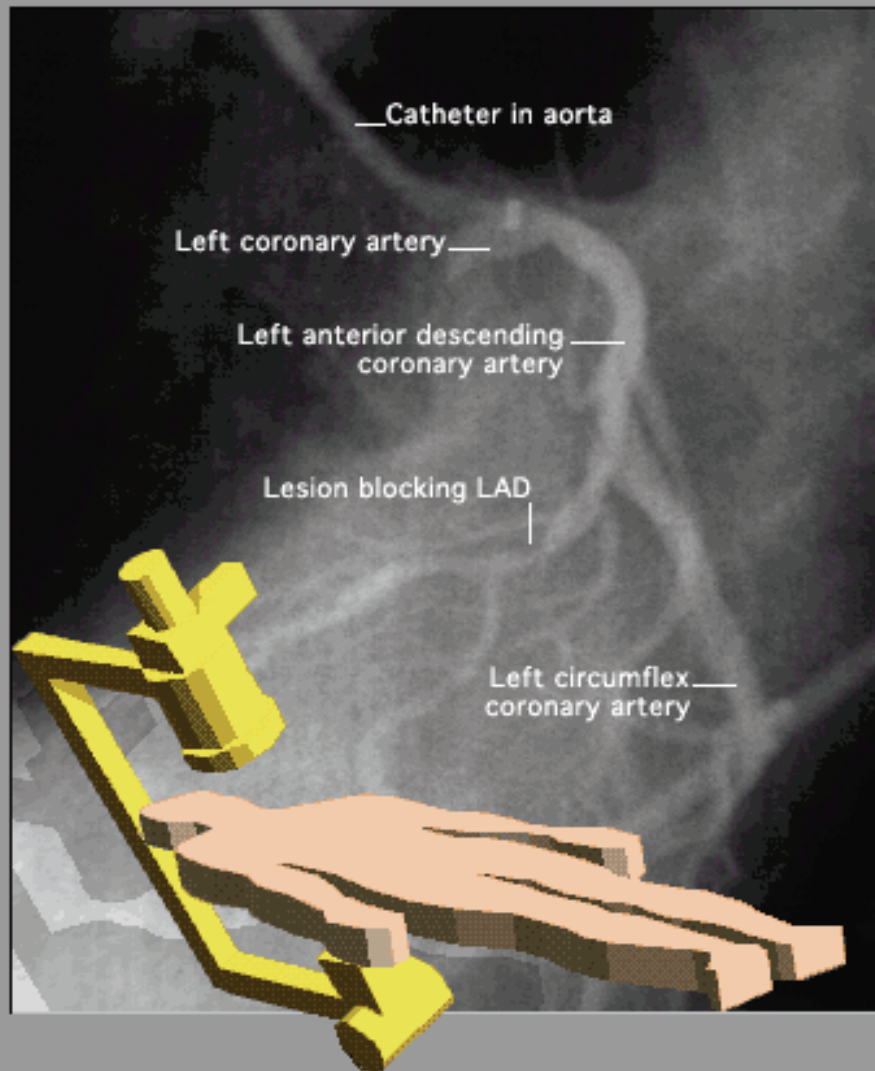




Myocardial Perfusion Imaging (MPI)

Multi-modality Survey

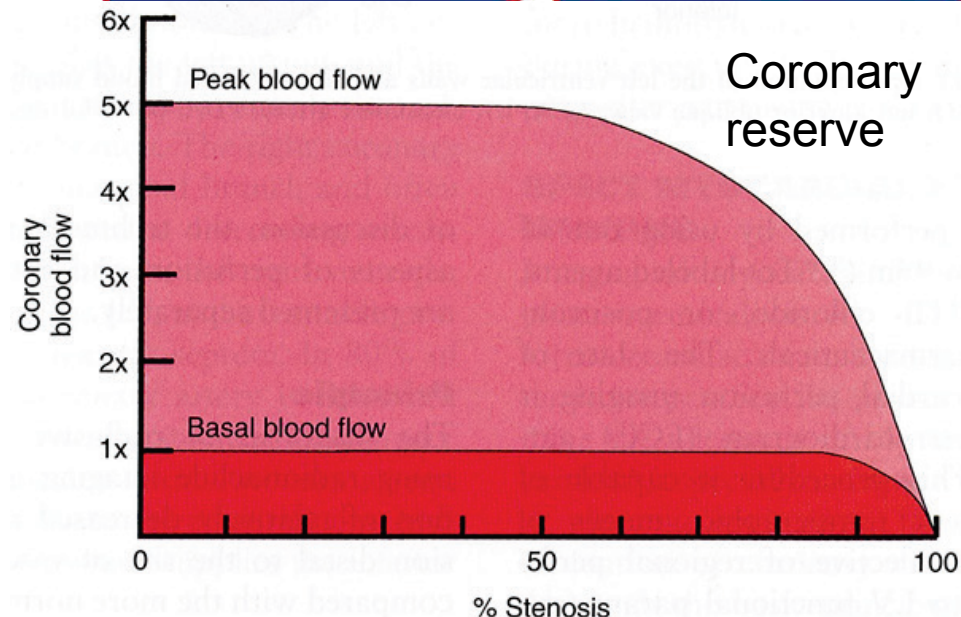
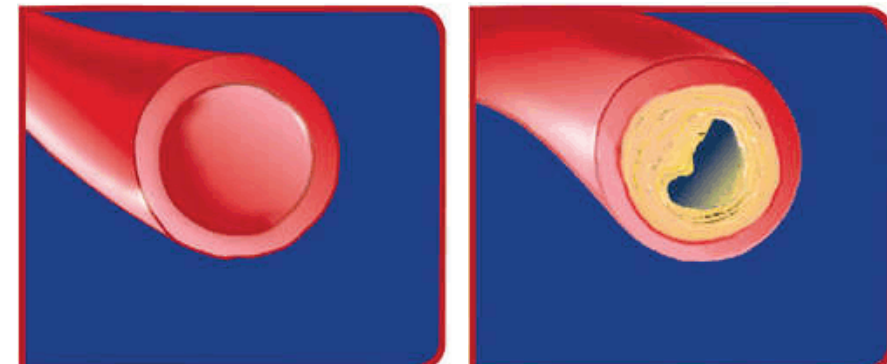


Indication

- Detect **CAD** or **restenosis**
 - Location (territory and segment)
 - Severity (treatment plan: medical or intervention?)
 - Other evidence (VD, RV, ITLU etc...)
- Ventricular function
- Myocardial viability
- Risk assessment

Myocardial Perfusion

- Normal coronary artery can dilate and provide about **5x more blood flow** at max exercise than at rest
- Stenotic coronary artery dilates at rest and provides less increased blood flow at max exercise





Stress Methods

- Exercise
 - **Treadmill**
 - Bicycles
- Pharmacological
 - Adenosine
 - **Dipyridamole**
 - **Dobutamine**
 - Regadenoson (Lexiscan[®]) (2008 US FDA approval)

Exercise Stress

- Peak exercise (target heart rate)
 - [Male: **85%**, female: **90%**] of max heart rate
 - Max heart rate = $220 - \text{Age}$

Table 78.1 The standard Bruce protocol for dynamic treadmill exercise

Stage	Duration (min)	Speed (miles/h)	Grade (%)
1	3	1.7	10
2	3	2.5	12
3	3	3.4	14
4	3	4.2	16
5	3	5.0	18
6	3	5.5	20
7	3	6.0	22



Contraindications of Exercise Stress

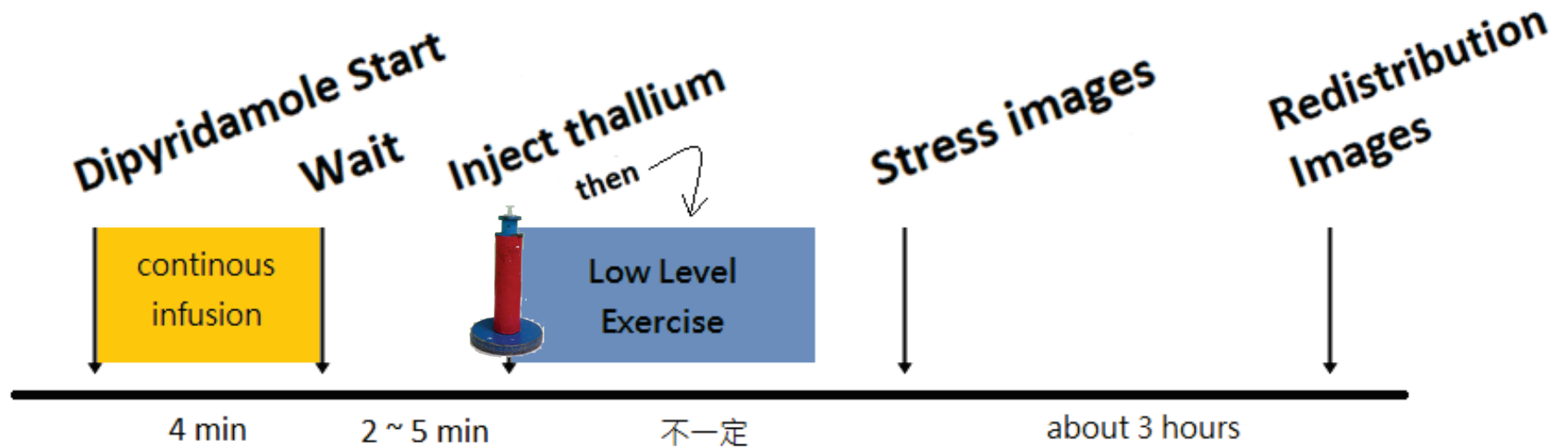
- Unstable angina with recent (<48 h) angina or congestive heart failure
- Documented acute MI within 2–4 days of testing
- Uncontrolled systemic (systolic > 220 mm Hg, diastolic < 120 mm Hg) or pulmonary hypertension
- Untreated life-threatening arrhythmias
- Uncompensated congestive heart failure, advanced
- AV block (without a pacemaker)
- Acute myocarditis
- Acute pericarditis
- Severe mitral or aortic stenosis
- Severe obstructive cardiomyopathy
- Acute systemic illness



Pharmacological Stress

- Vasodilator
 - Adenosine
 - 0.14 mg/kg/min for 4-6 min (total: 0.56-0.84 mg/kg)
 - Dipyridamole
 - 0.568 mg/kg iv over 4 min in 20 mL of normal saline
- Beta-1 agonist (inotropic agent)
 - Dobutamine (escalating rate)
 - initial: 5 ug/kg/min
 - q3-5 min increase up to maximum of 15-30 ug/kg/min
- Selective A2A receptor agonist
 - Regadenoson

Pharmacological Stress



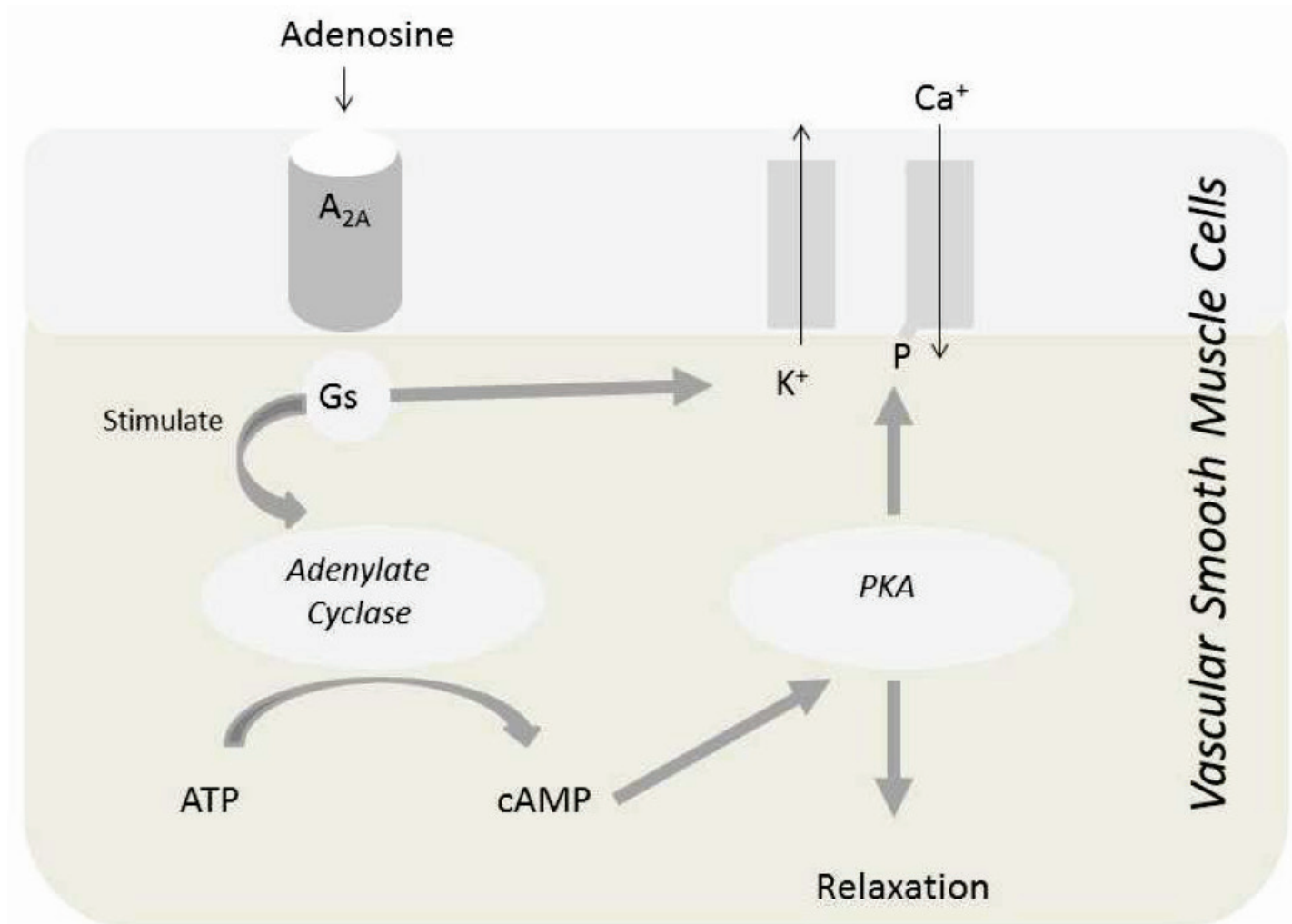
Dipyridamole dose:
0.568 mg/kg, IV infusion



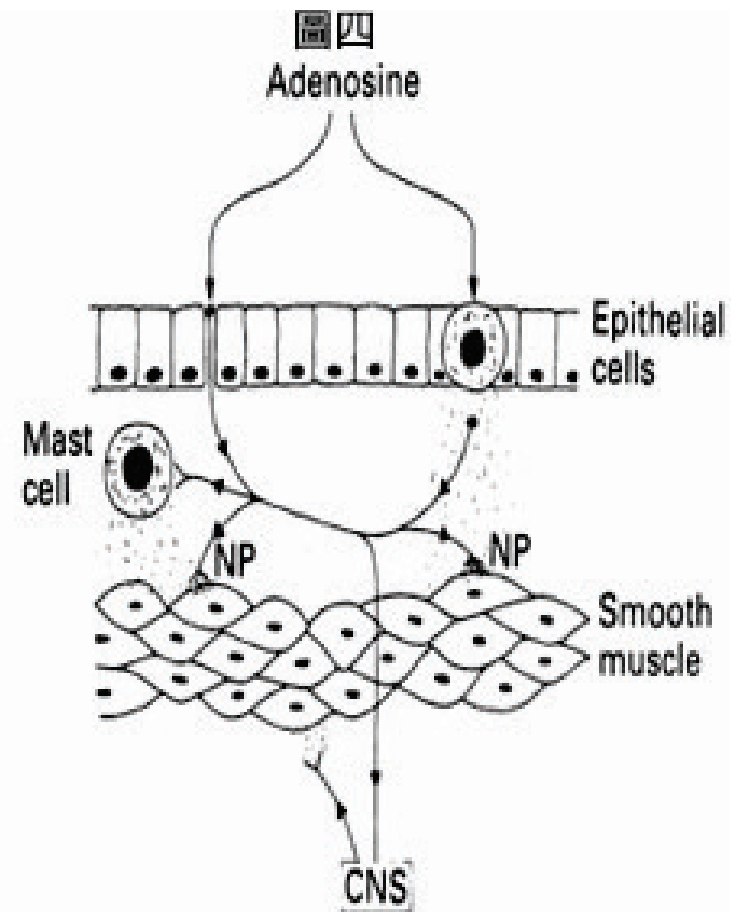
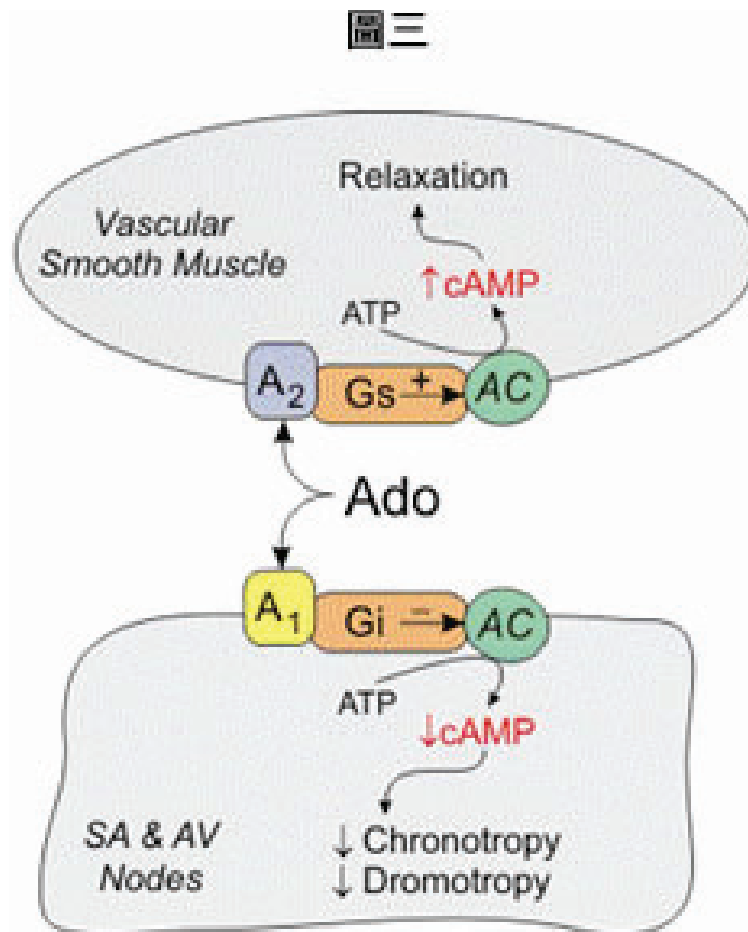
Adenosine

- CNS
 - inhibitory neurotransmitter (A1)
- Heart
 - **inhibitory effect in AV node (A1)**
 - negative inotropic and chronotropic effect
 - **relax of smooth muscle in arteries (A2A)**
- Lung
 - **bronchospasm (A2B, A3)**
- Inflammatory cells
 - anti-inflammatory effect (A3)
 - T-cell v.s. tumor ?

Adenosine



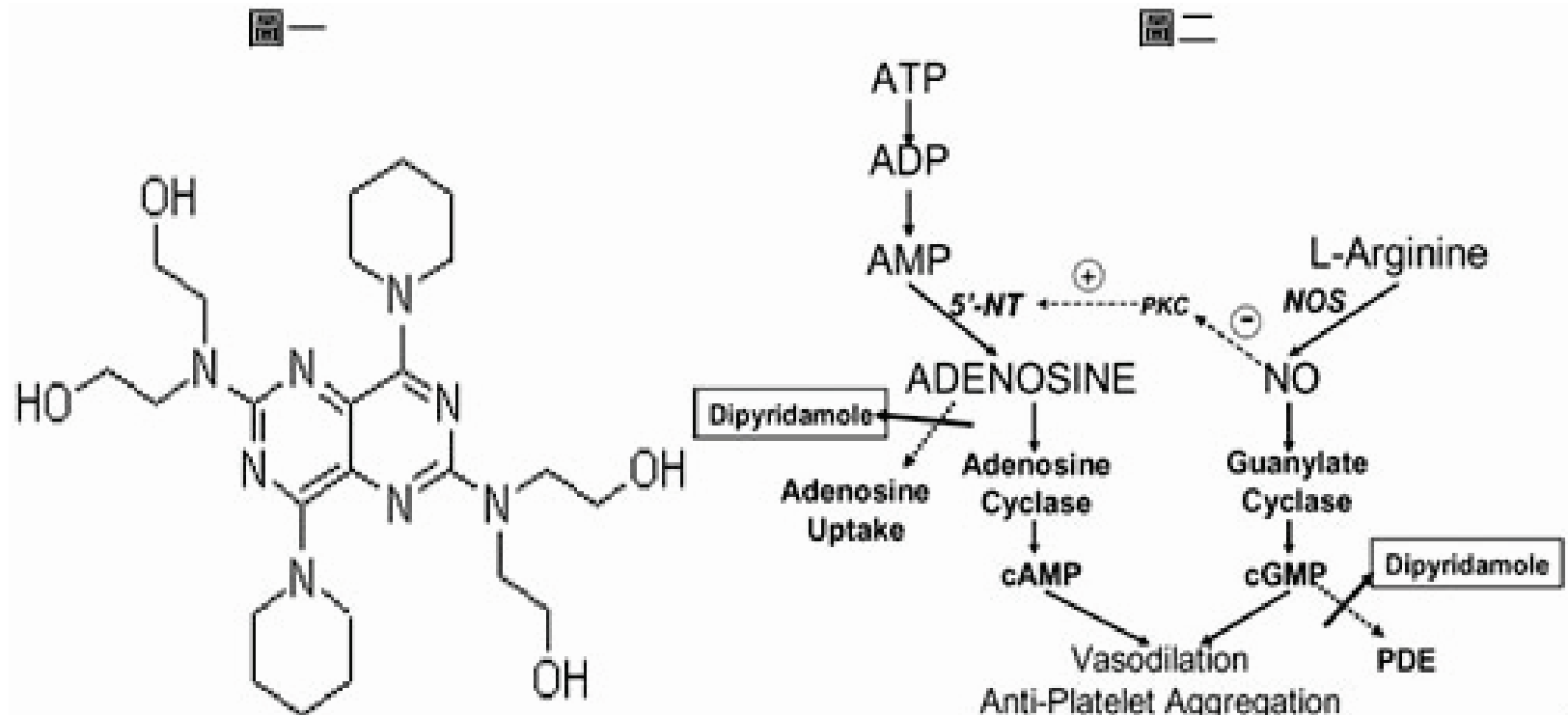
Adenosine



Dipyridamole

- Inhibit adenosine re-uptake
- Inhibit phosphodiesterase
- Inhibit adenosine deaminase
- Inhibit thromboxane synthase, thromboxane receptor
- $T^{1/2}$: 40-80 minutes

Dipyridamole



Adenosine, Dipyridamole and Aminophylline

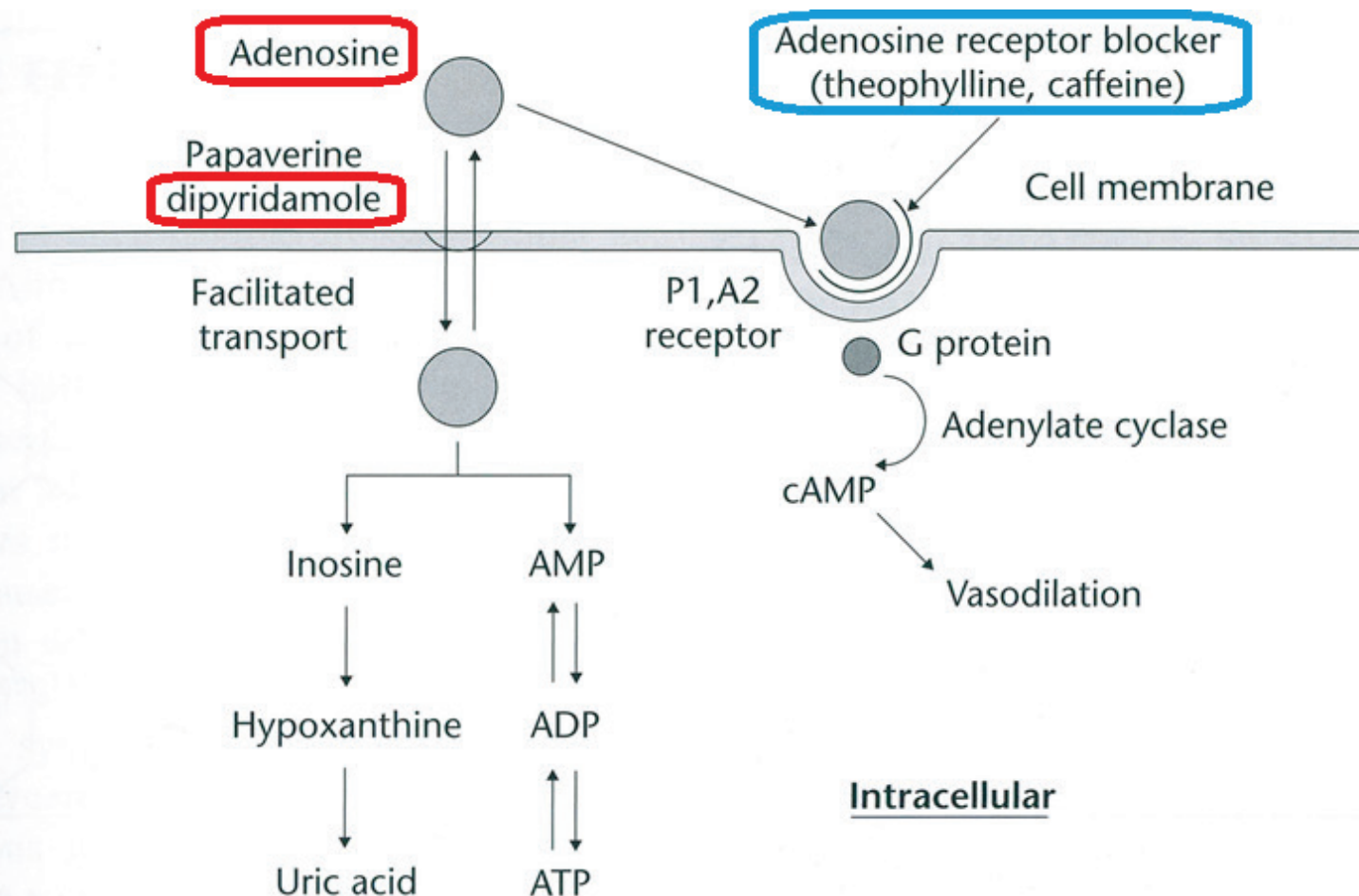


Fig. 78.5 The action of adenosine on the A2 receptor. The intracellular mediator is cyclic AMP.



Contraindications of Adenosine

- SSS, 2nd / 3rd AV block (without pacemaker)
- WPW syndrome with Af or AF
- QT prolong
- Acute coronary syndrome
- Heart failure, severe hypotension (SBP <90 mmHg)
- Asthma, severe COPD
- Pregnant, lactating

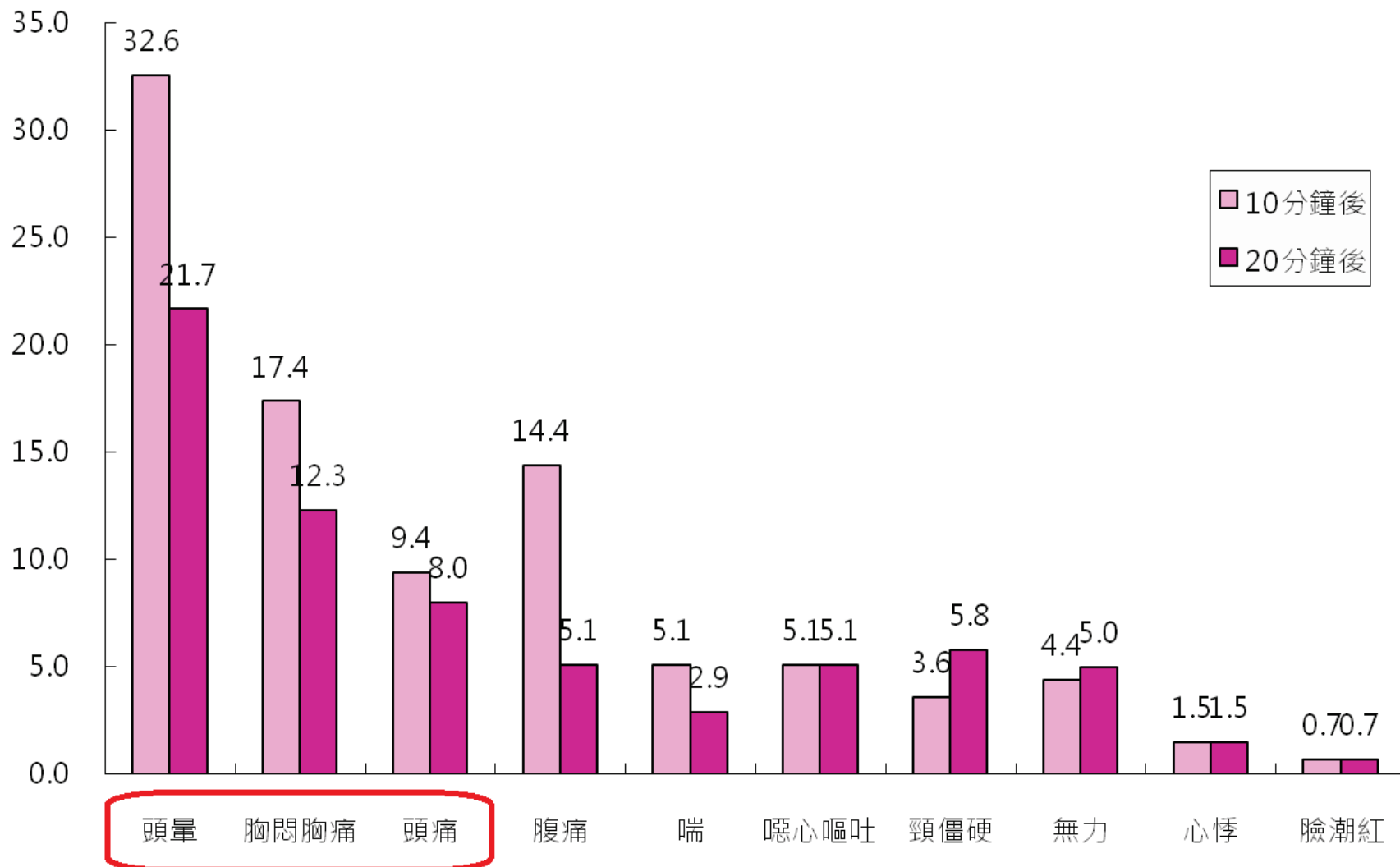
Side Effects of Pharmacological Stress

 Incidence (%) of Occurrence in 3911 Patients	
Event Description	
Chest pain/angina pectoris	19.7
Headache	12.2
Dizziness	11.8
Electrocardiographic Abnormalities/ ST-T changes	7.5
Electrocardiographic Abnormalities/ Extrasystoles	5.2
Hypotension	4.6
Nausea	4.6
Flushing	3.4
Electrocardiographic Abnormalities/ Tachycardia	3.2
Dyspnea	2.6
Pain Unspecified	2.6
Blood Pressure Lability	1.6
Hypertension	1.5
Paresthesia	1.3
Fatigue	1.2



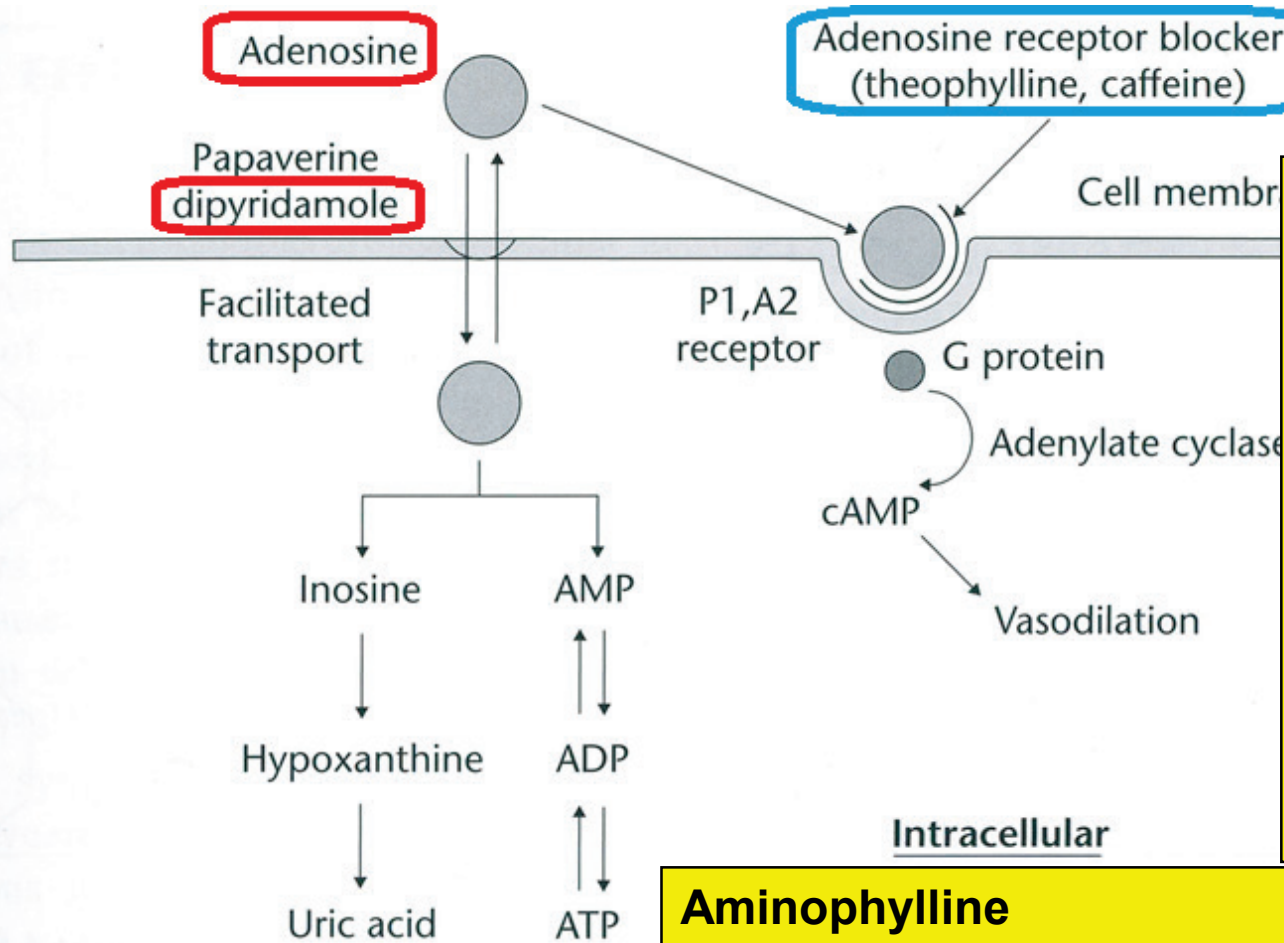
Side Effects of Pharmacological Stress

注射Dipyridamole 10分鐘及20分鐘後不適之比率(%)



Data from Nuclear Medicine Department of VGHKS

Reversal of Side Effect



Aminophylline
125 mg
IV slow push

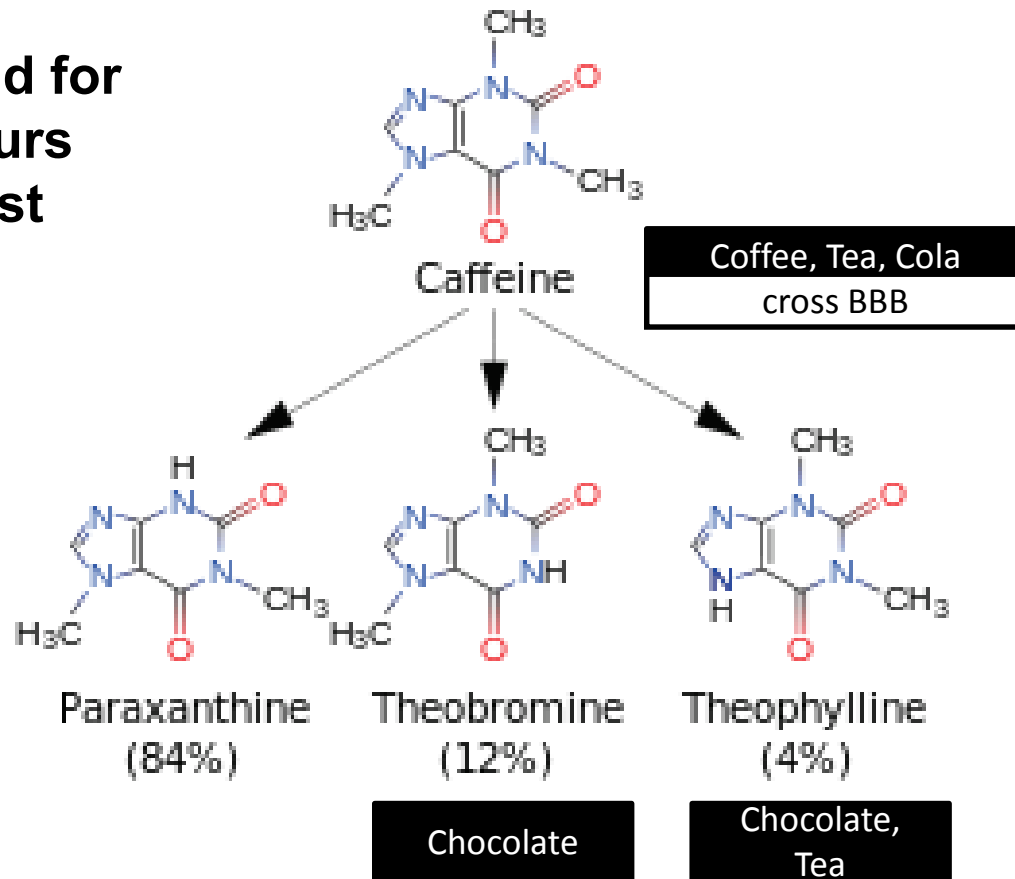
Other:
◆ **Coffee**
◆ **Tea**
◆ **Water**

Aminophylline
= theophylline with ethylenediamine in 2:1 ratio

Fig. 78.5 The action of adenosine on the A2 receptor. The intracellular mediator is cyclic AMP.

Xanthine Derivatives

Should be held for
at least **24** hours
prior to the test



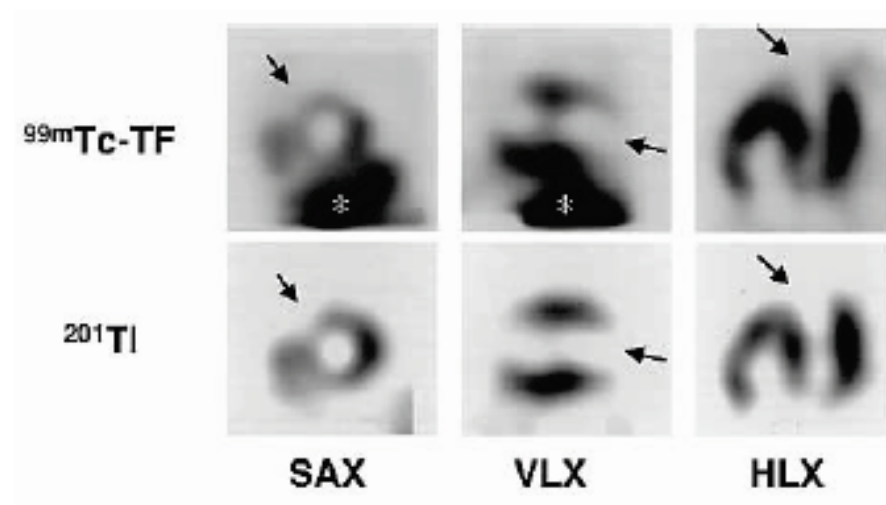


Other Precautions

- If possible, it is preferable to have patients **withhold beta-blockers** at the time of MPI.
- **Phosphodiesterase use within 24-48 h** is a contraindication for NTG administration.
- **Dipyridamole-containing medications** must be withheld for **48 h** before pharmacologic stress.

Radiopharmaceuticals

- **Thallium-201**
- Technetium-99m-labeled tracers: **MIBI**, tetrofosmin
 - Better imaging quality and radiation dosimetry
 - Slow liver clearance

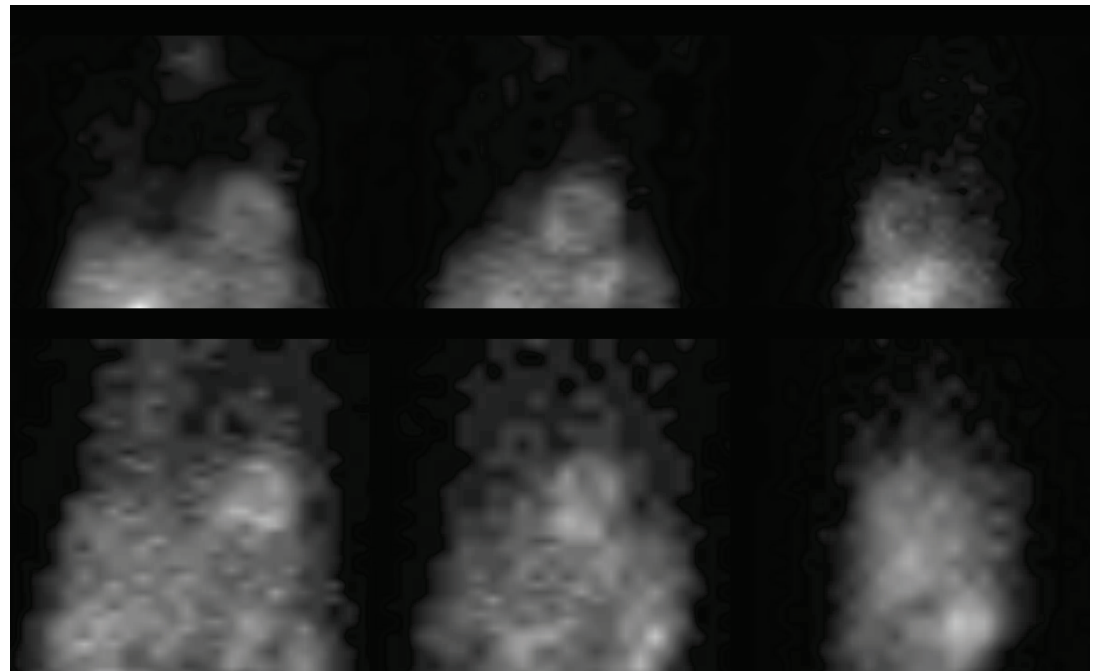




Tc-99m MIBI
(post PCI)

Stress

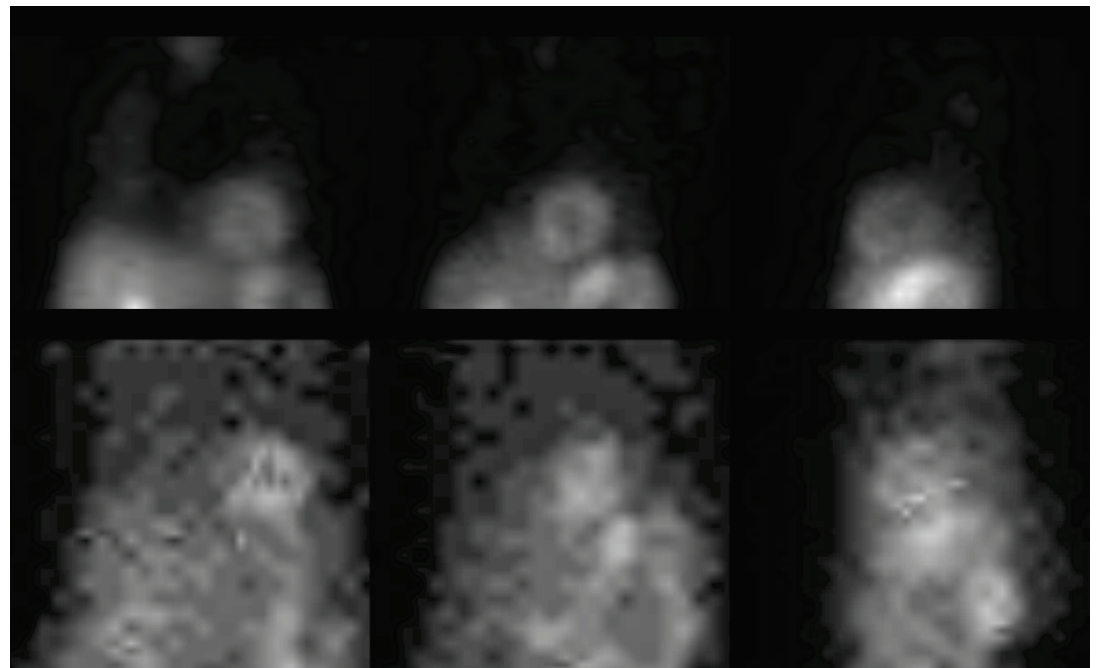
Tl-201
(pre PCI)



Tc-99m MIBI
(post PCI)

Rest / Redistribution

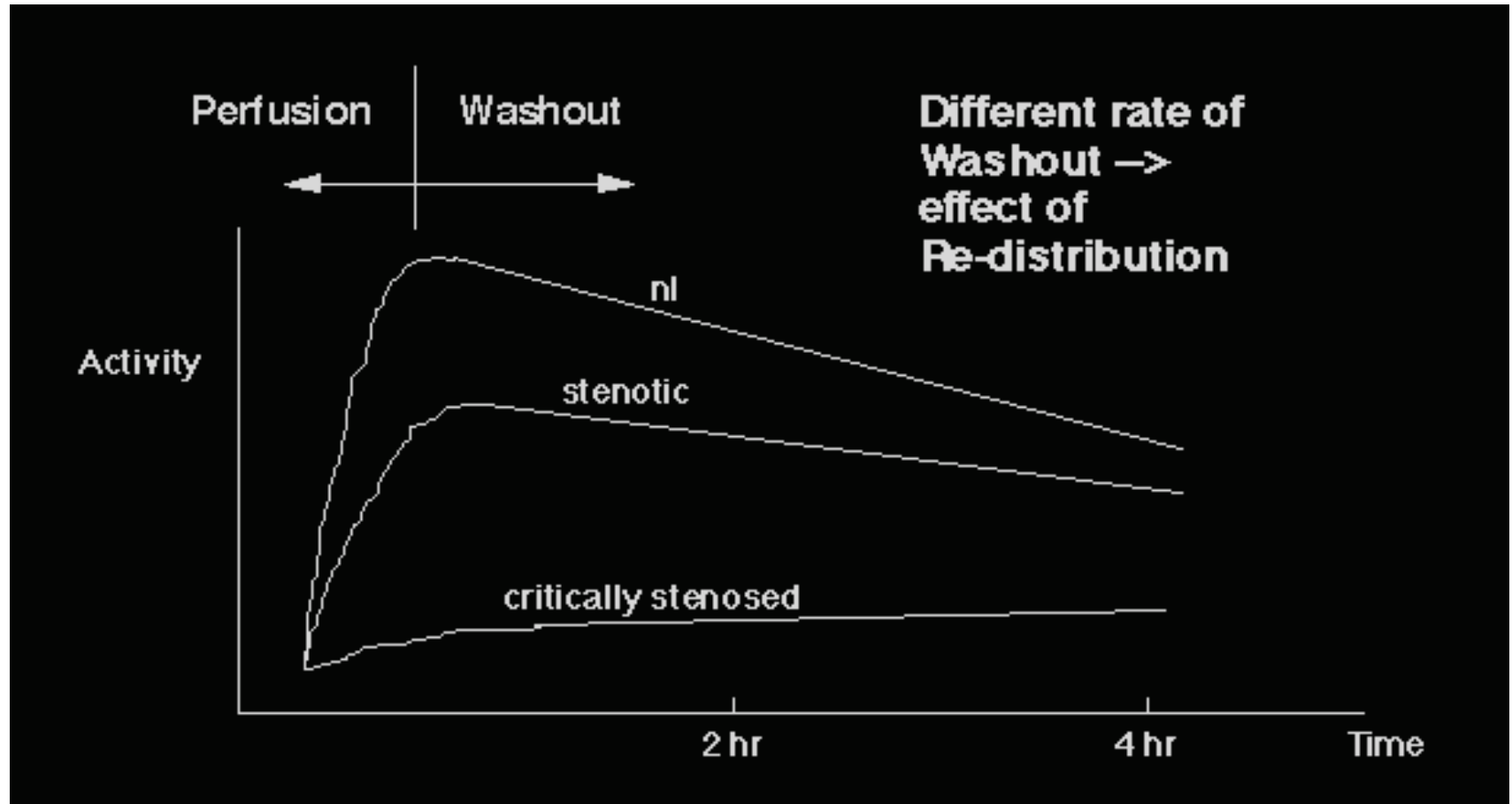
Tl-201
(pre PCI)



Mechanism of Thallium

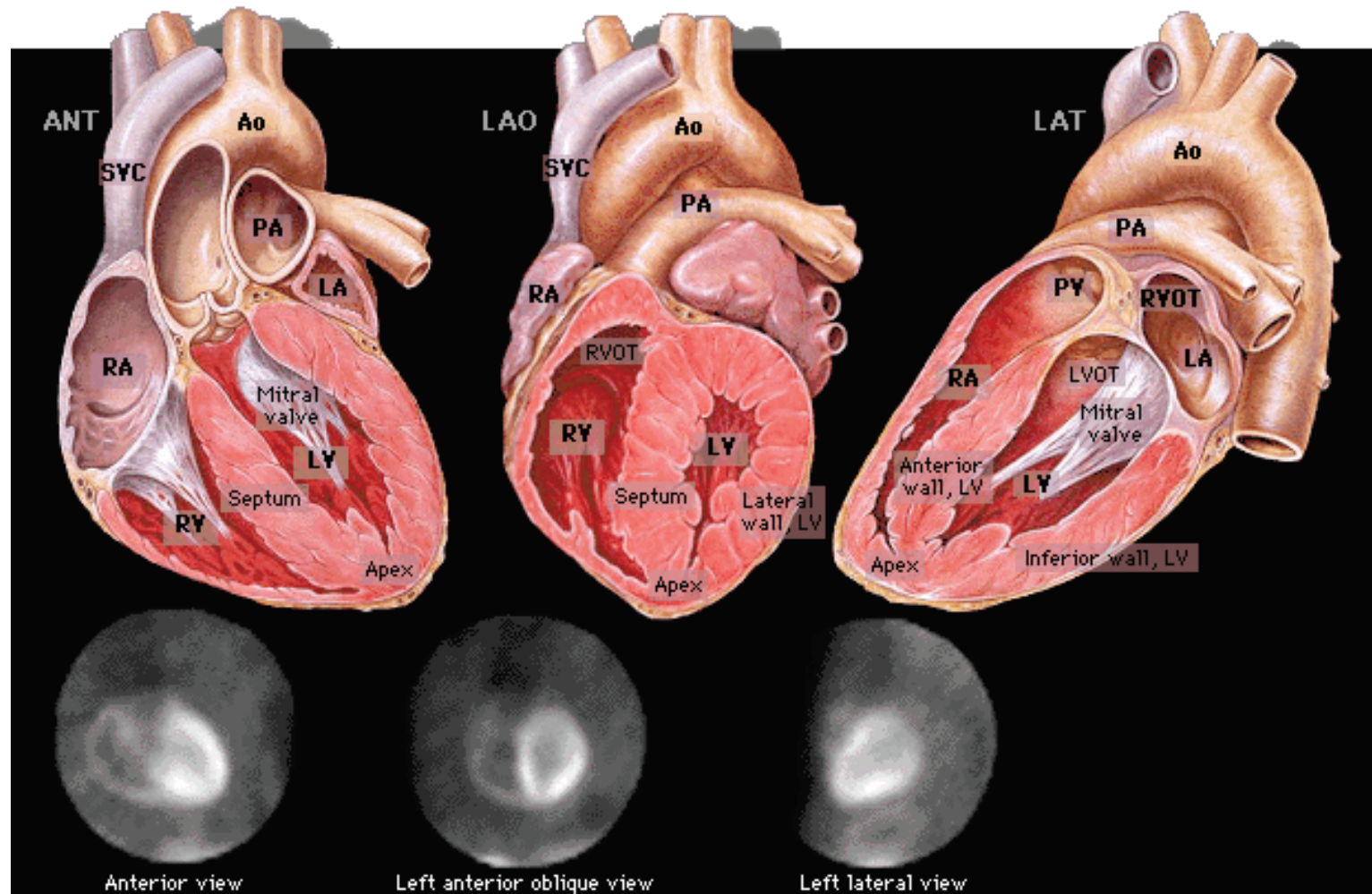
- Tl-201 is a **monovalent cation-potassium analog**
- Myocardial uptake of Tl-201 is by active transport based on **Na/K-ATPase pump**
- After IV injection, the Tl-201 uptake is proportional to **regional blood flow**
- Insulin, glucose
- $T^{1/2}$: 73 hr, EC, **main: X-ray 69-81 keV**,
minor: gamma-ray 135(2%), 167(8%)

Redistribution

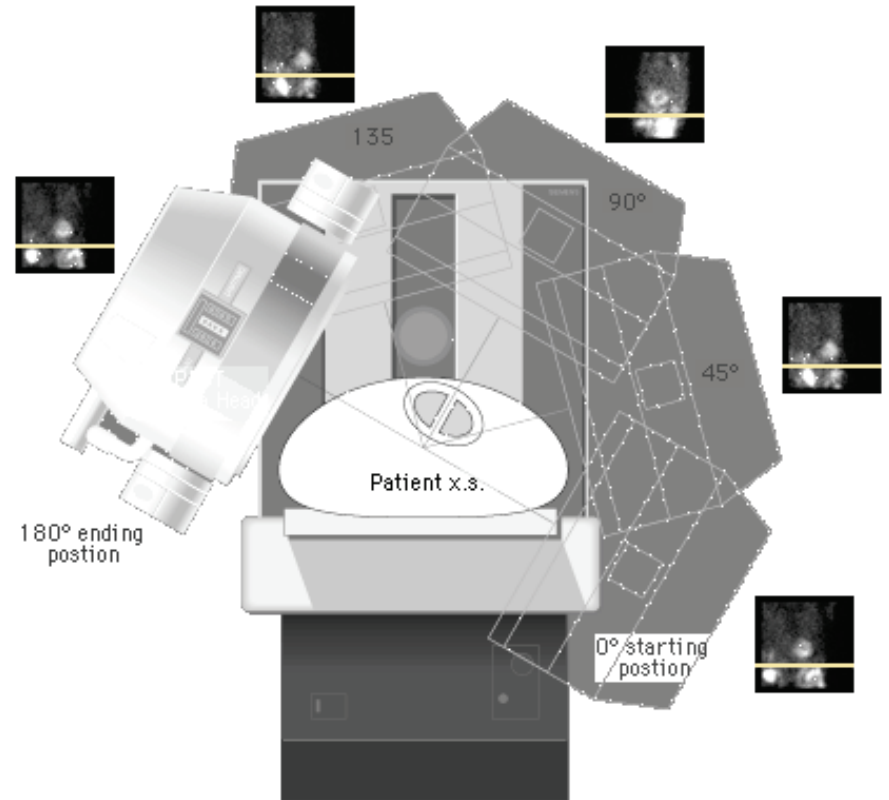


wash out: ischemic area < normal area

Planar Imaging



SPECT

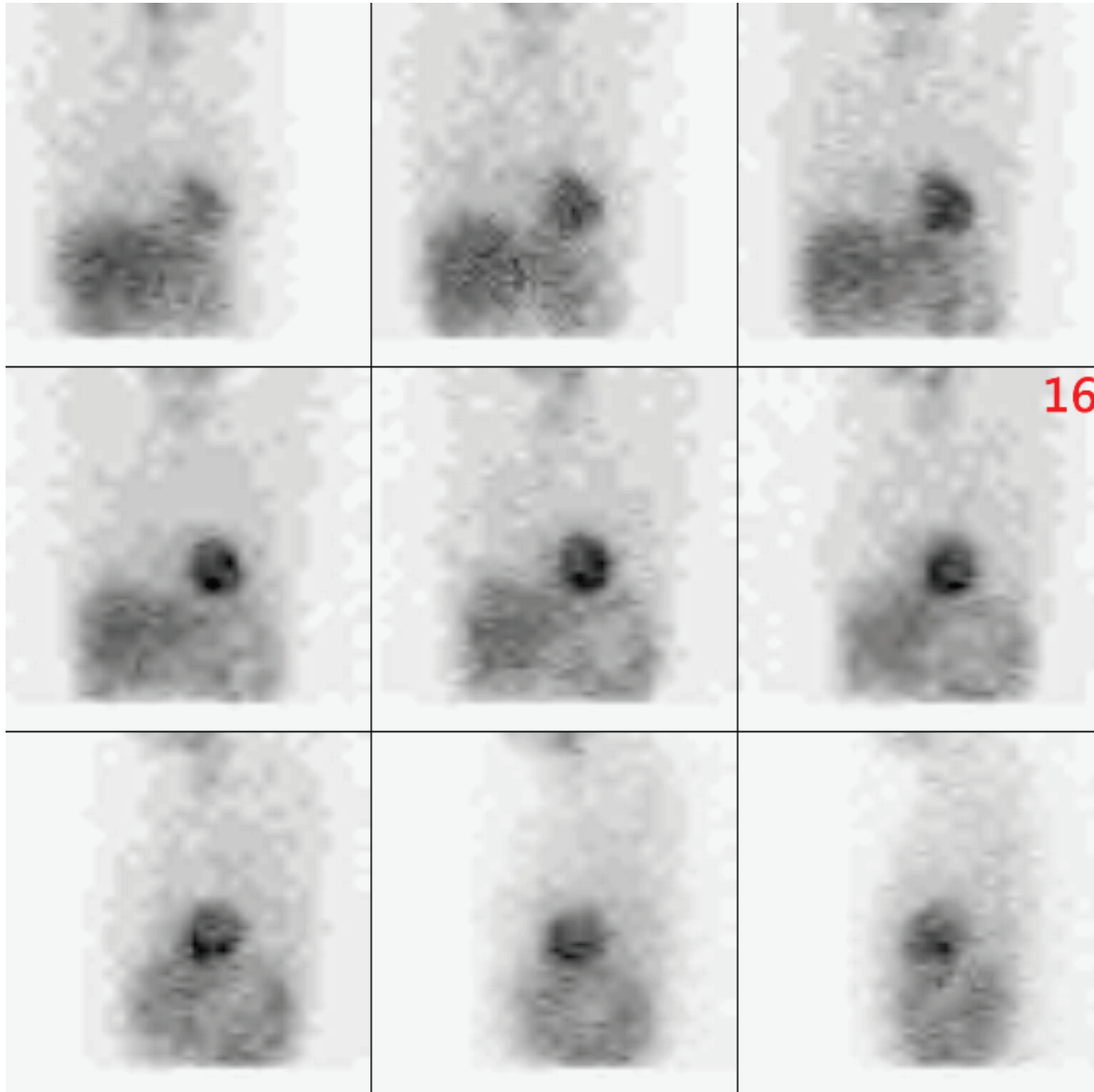


SPECT raw data shown with inverted gray scale

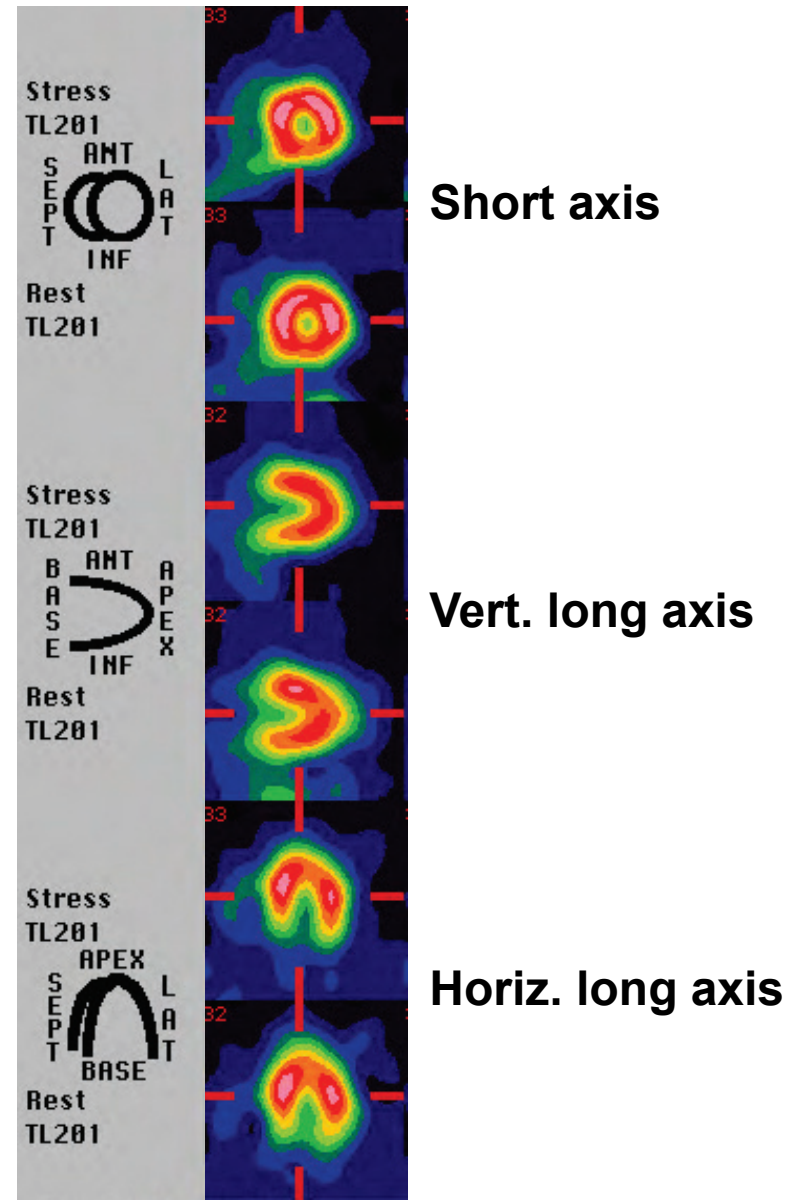
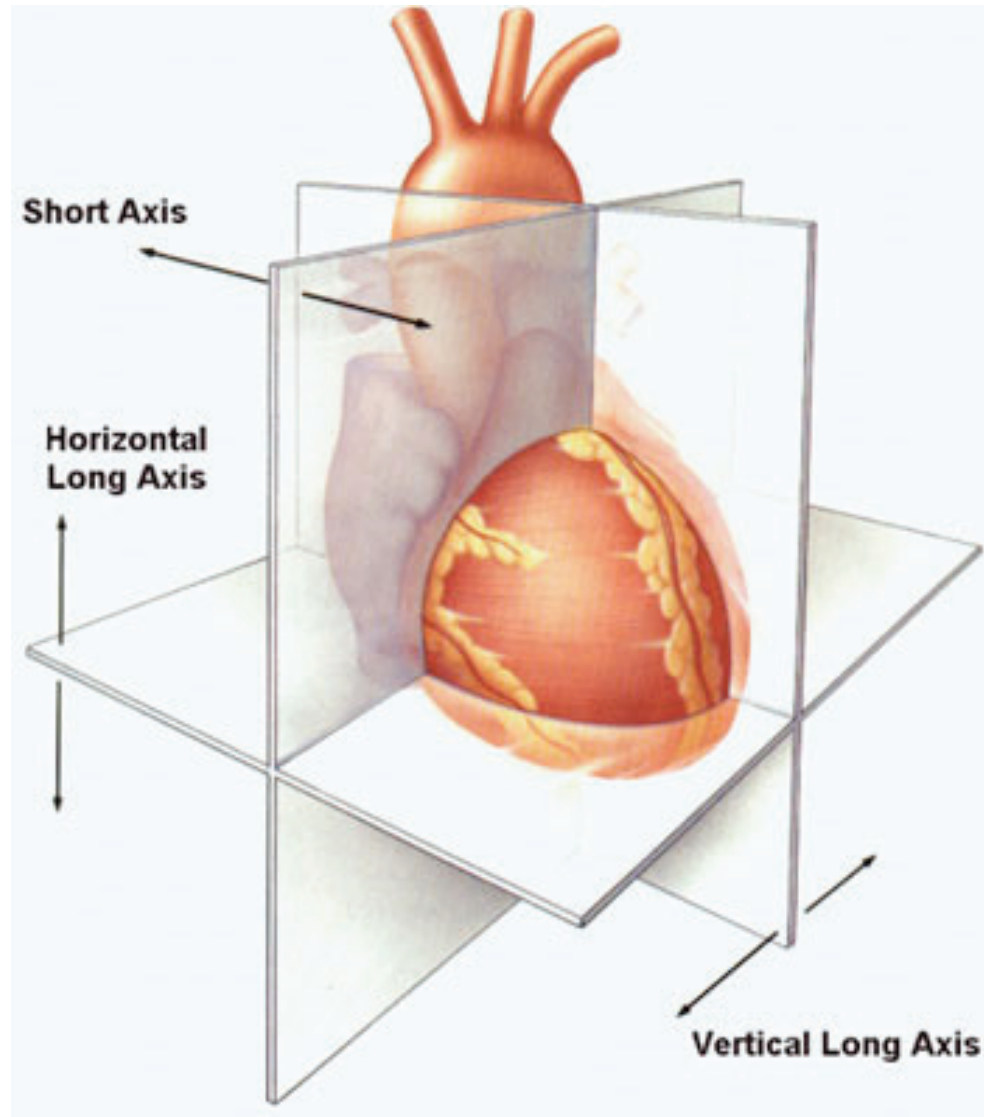
Patient Mr. A

Different angles of projections

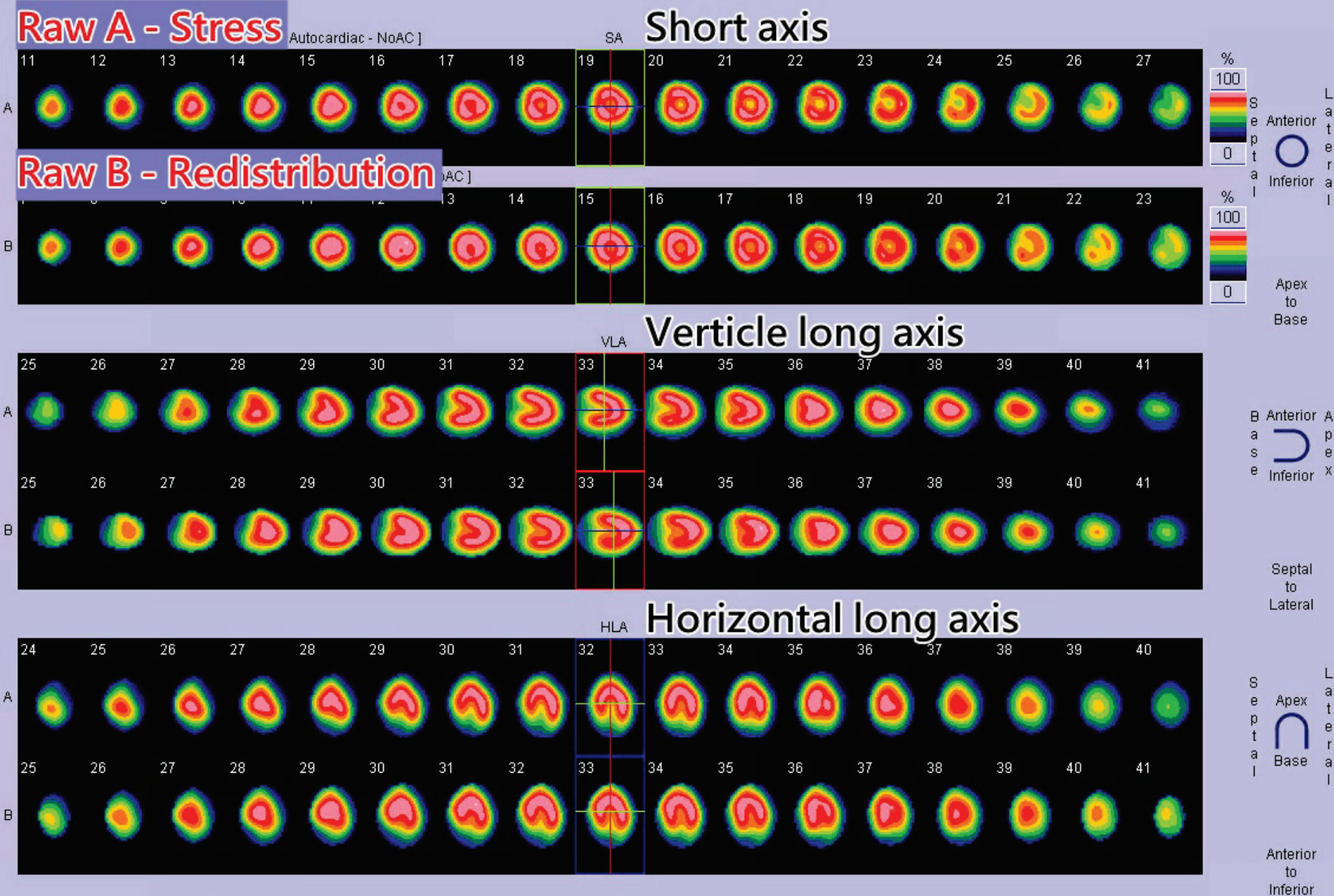
RAO 45°
↓
LPO 45°



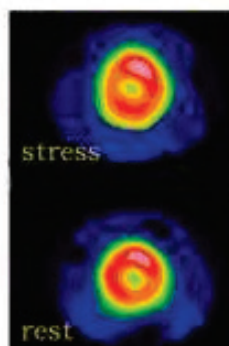
Slicing



SPECT display with color scale

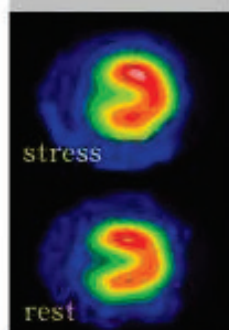


正常影像



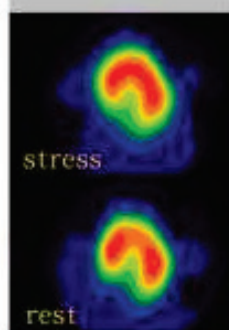
短軸斷層影像
(Short Axis Slices)

灌注正常



垂直長軸斷層影像
(Vertical Long Axis Slices)

灌注正常

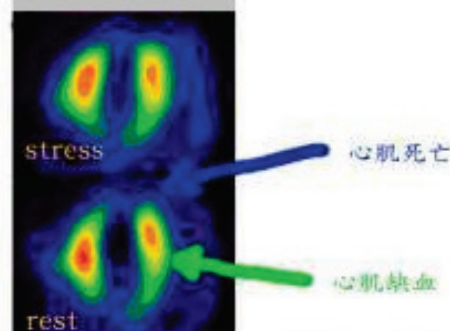
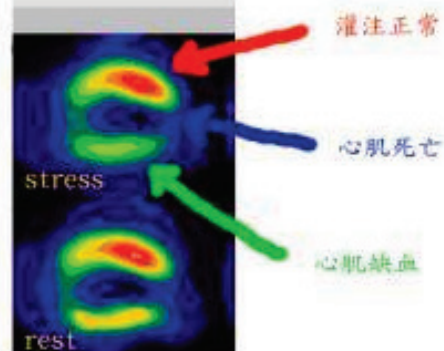
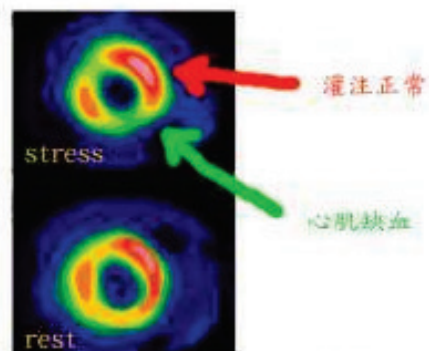


水平長軸斷層影像
(Horizontal Long Axis Slices)

灌注正常

顏色越亮 (越紅) 表示放射活性越高

缺血影像

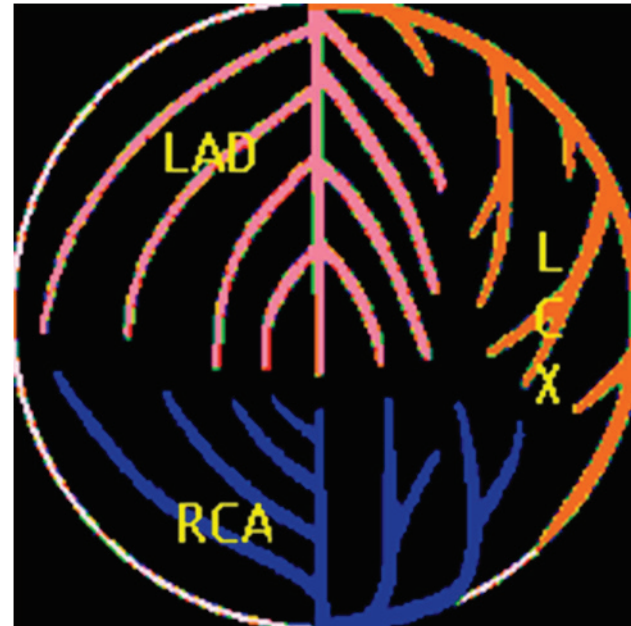
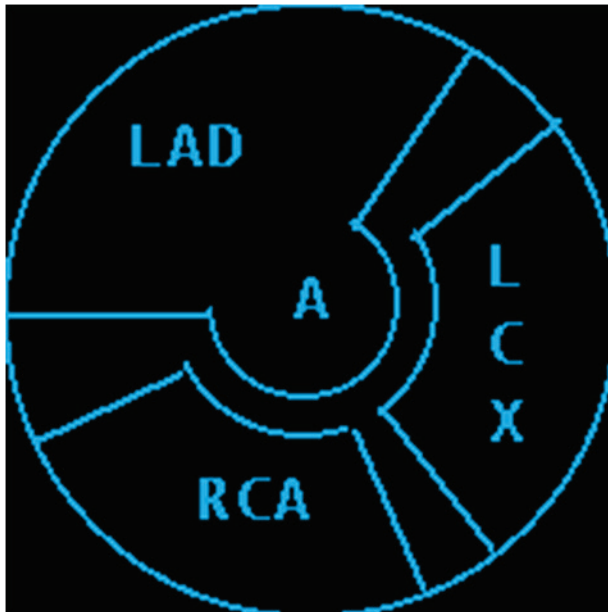


顏色越亮 (越紅) 表示放射活性越高

Color scale



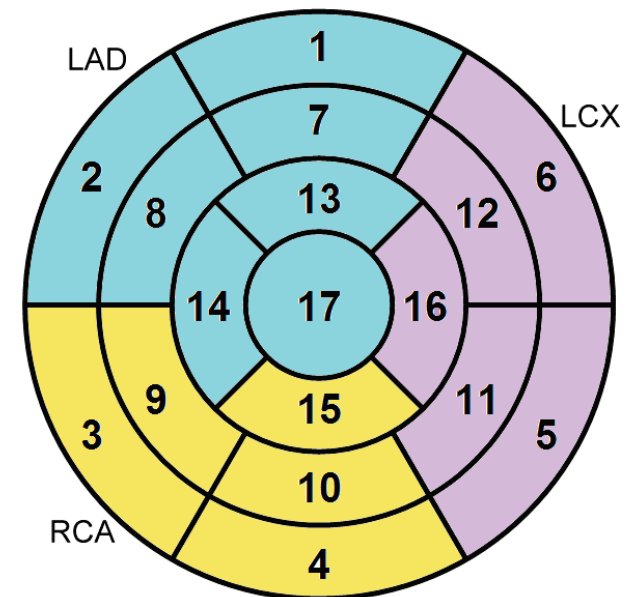
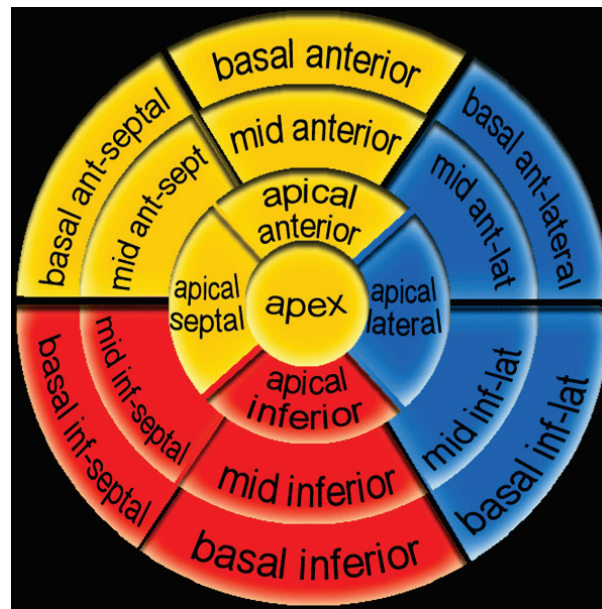
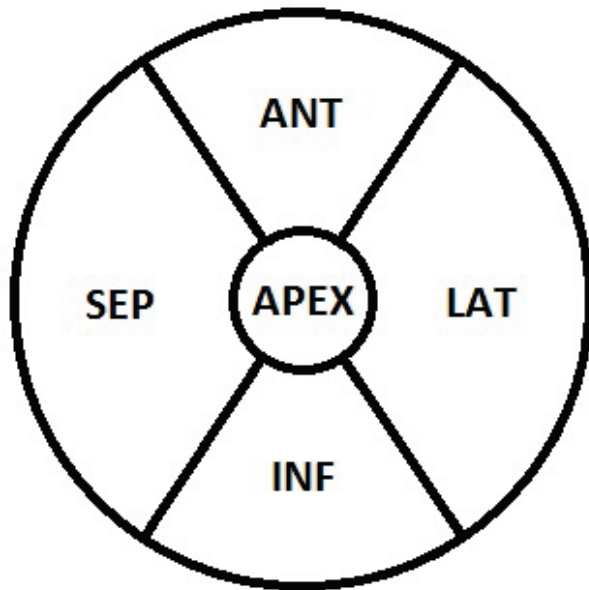
Polar Map (Bull's Eye Map)





LV Wall

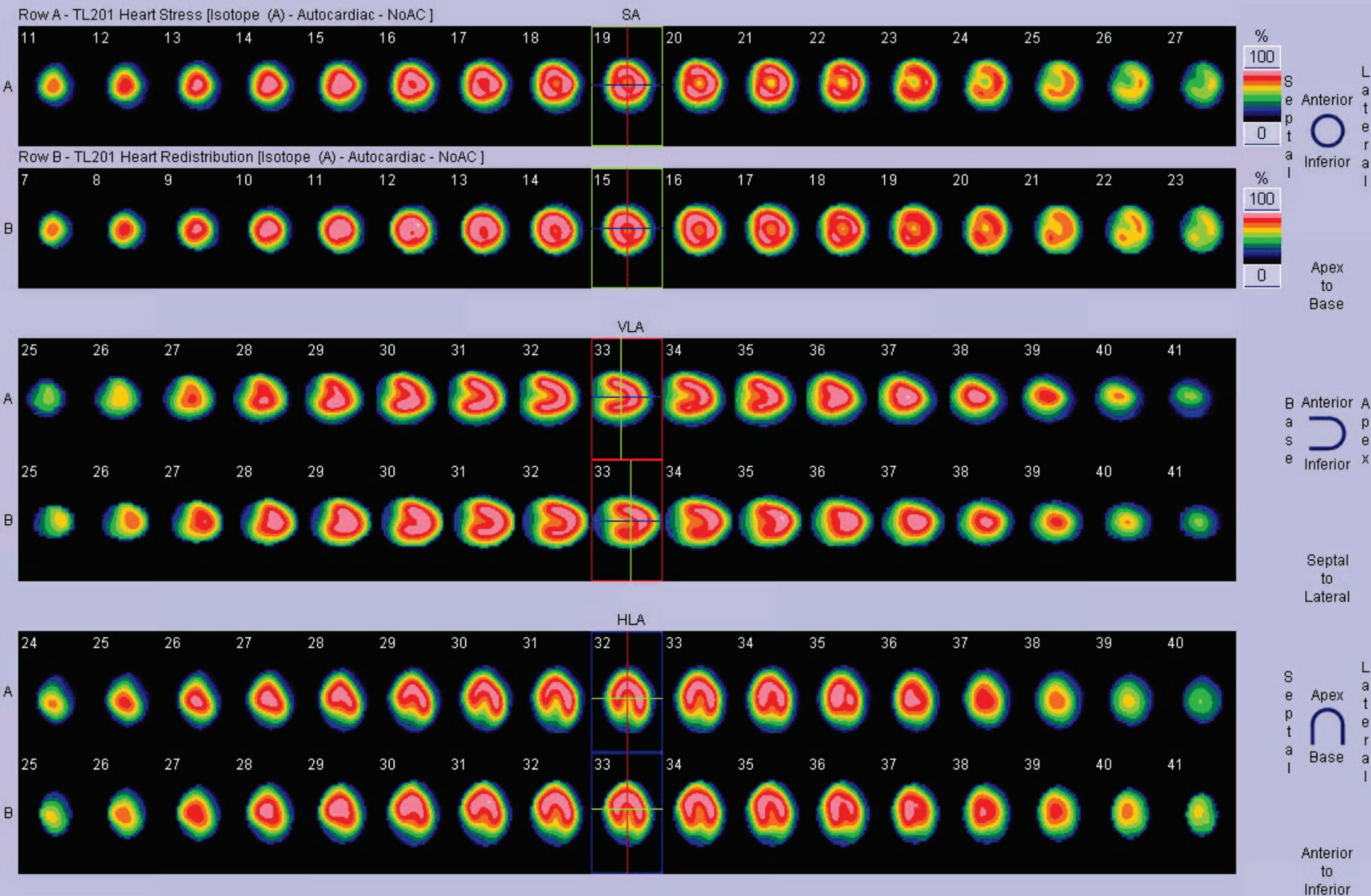
AHA 17 segment



Interpretation Models

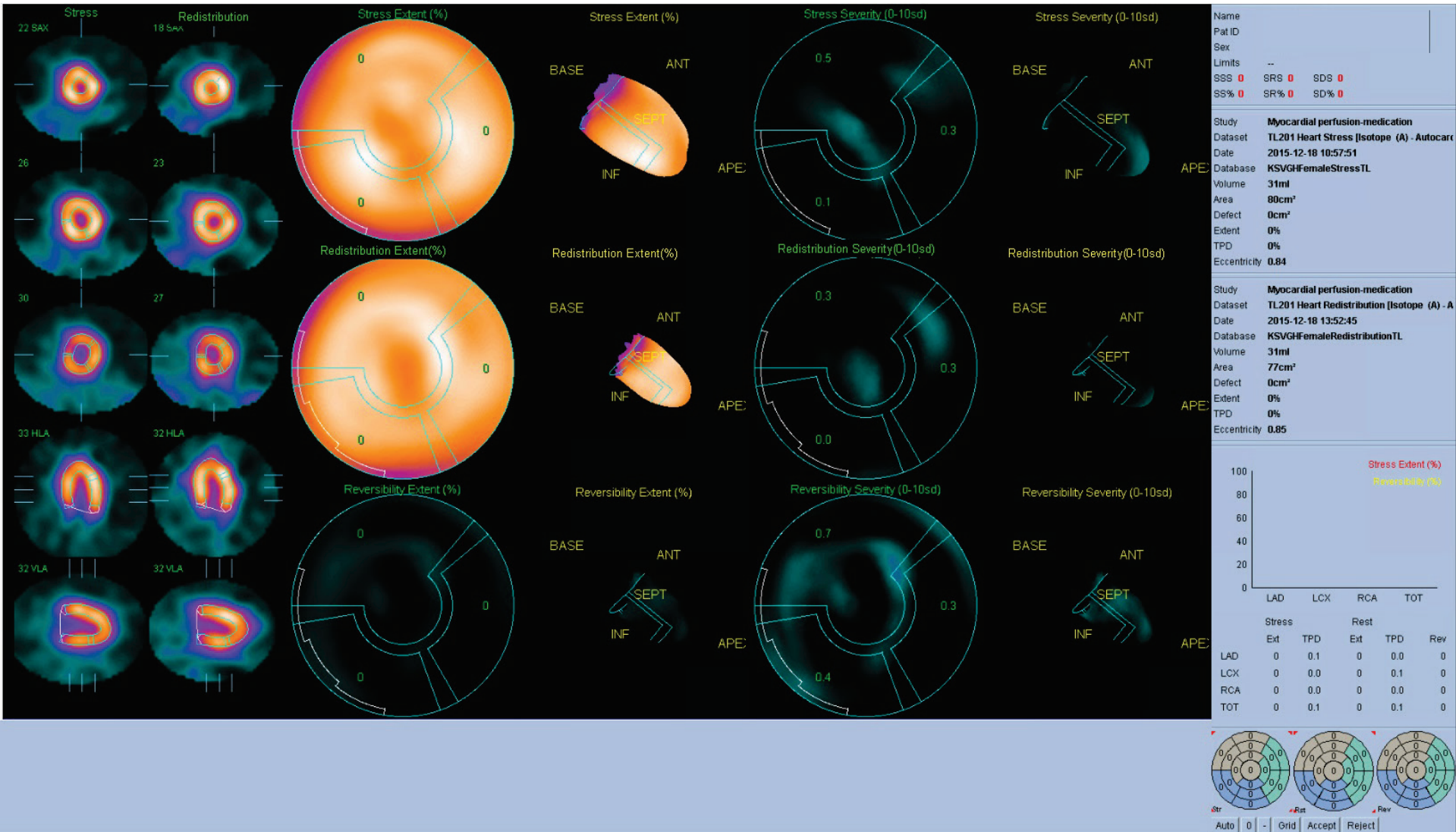
- Visual interpretation
 - Slicing after tomographic reconstruction
 - Color scale
- Semiquantitative method
 - Polar Map

Patient Mr. A

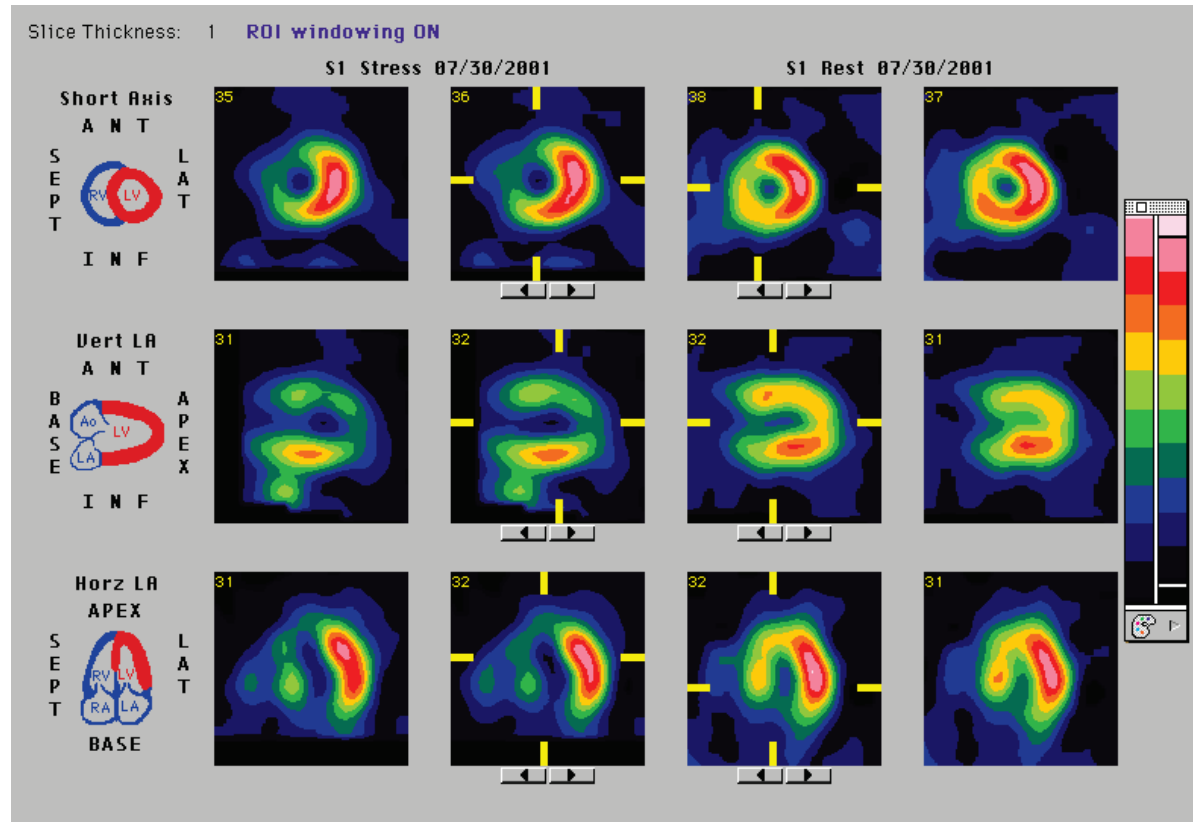


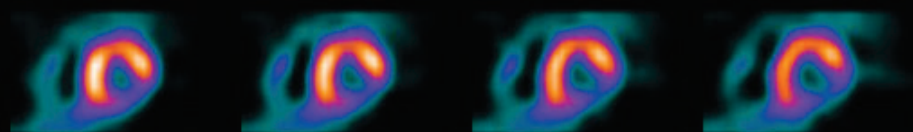
Normal myocardial perfusion

Patient Mr. A

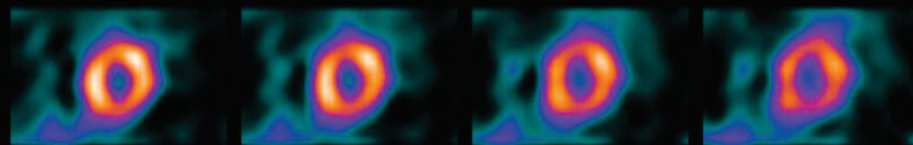


- 

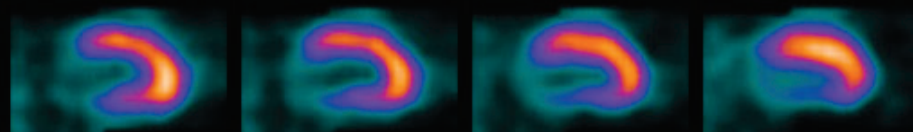




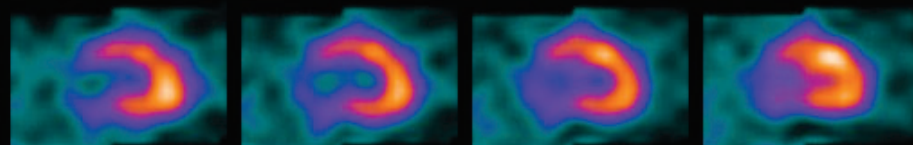
SHORT AXIS-STR



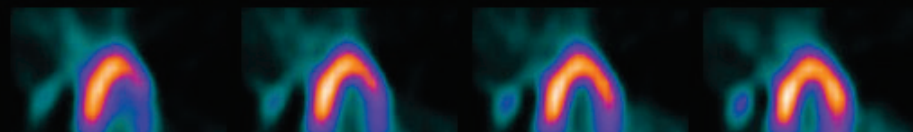
SHORT AXIS-DLY



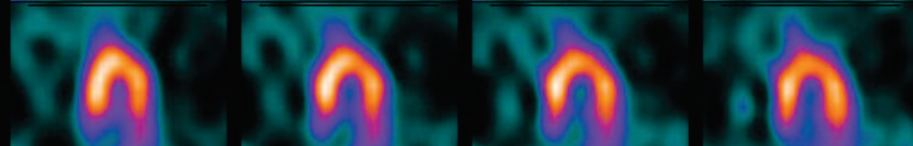
VERTICAL-STR



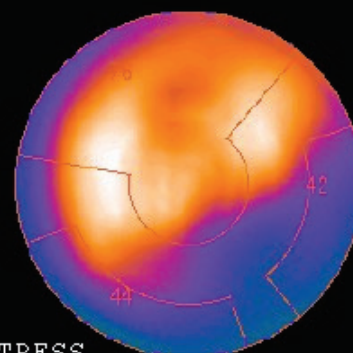
VERTICAL-DLY



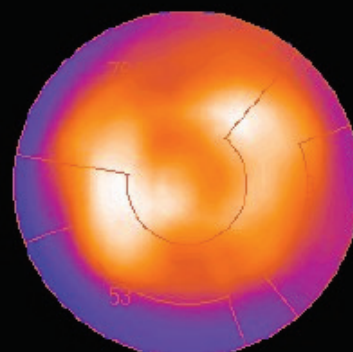
HORIZONTAL-STR



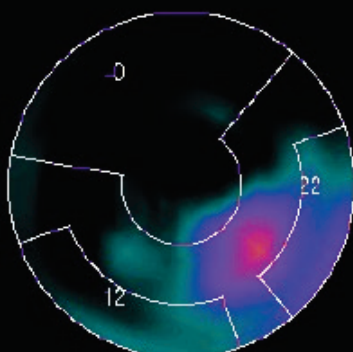
HORIZONTAL-DLY



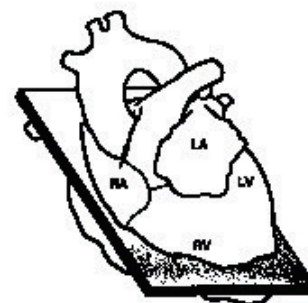
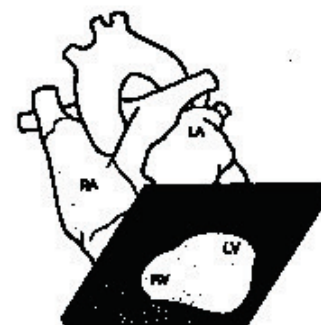
STRESS

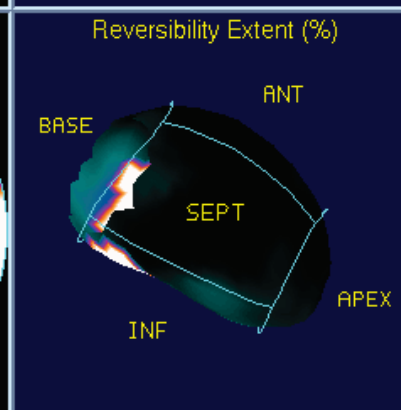
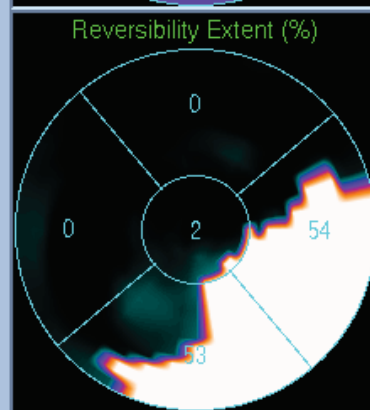
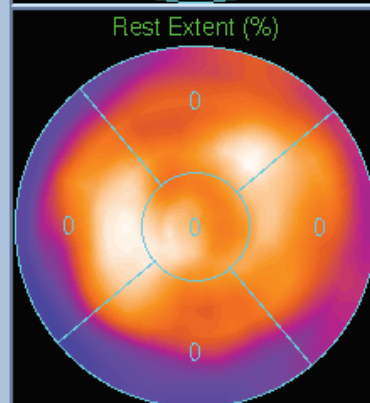
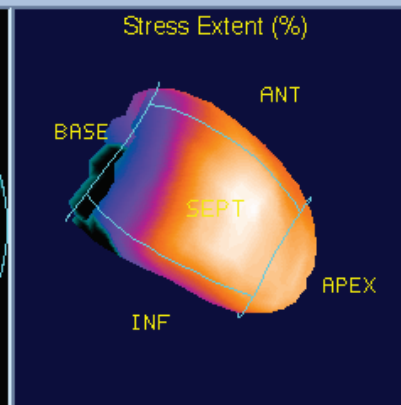
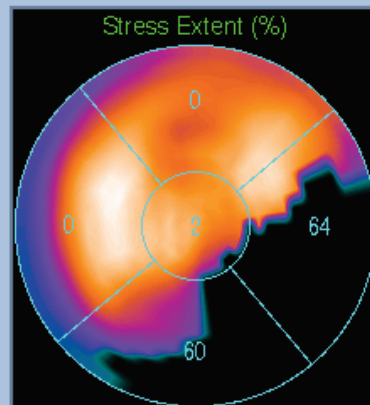
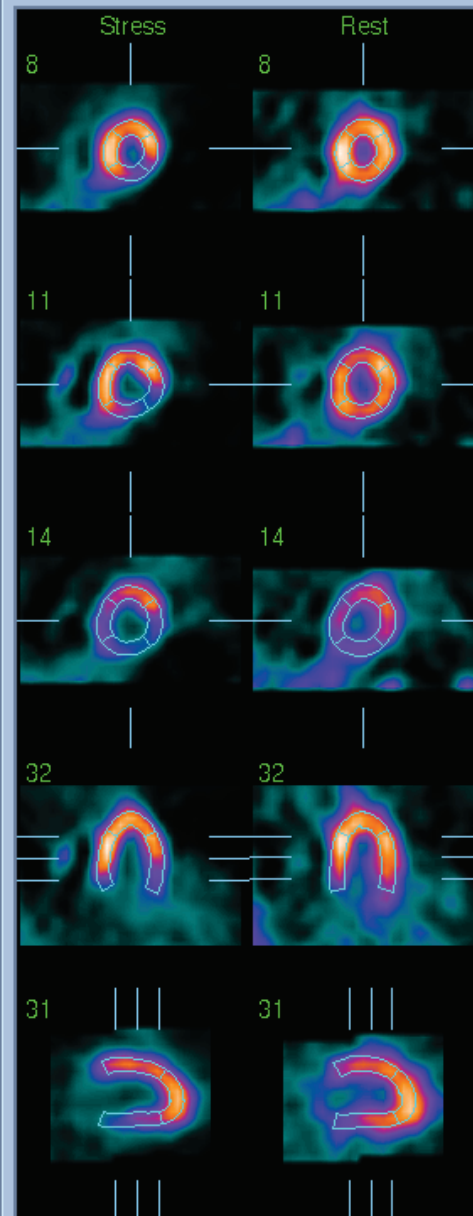


REST



EXTENT

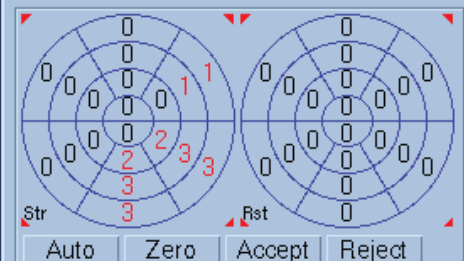




Name AUTOQUANT ABNORM
Pat ID 123456789
Sex MALE
Limits A:SepdualMale
TID 1.03
LHR 0.41
SSS 18 SRS 0 SDS 18

Proc ID GATED RST TL & STR
View ID SAX
Date 04/07/1999 12:11:37
Chamber 65ml
Wall 135ml
Defect 37ml
Extent 27%

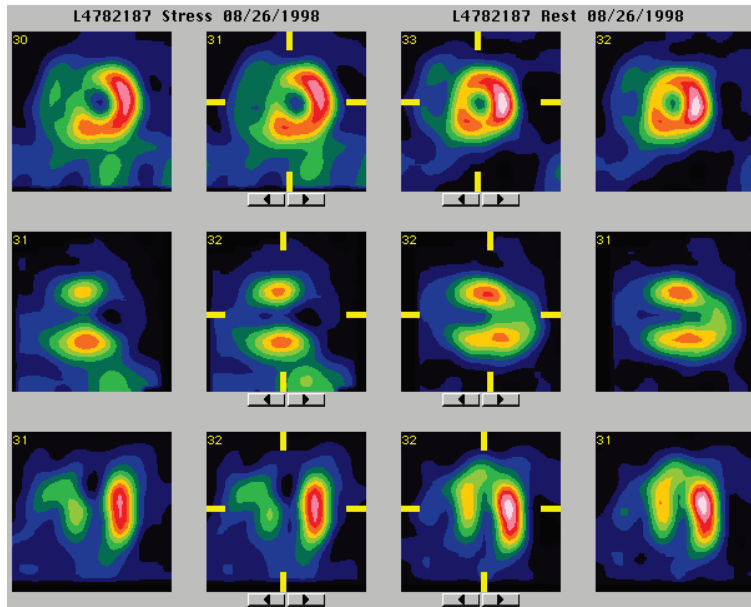
Proc ID GATED RST TL & STR
View ID SAX
Date 04/07/1999 10:19:30
Chamber 63ml
Wall 155ml
Defect 0ml
Extent 0%





Stress

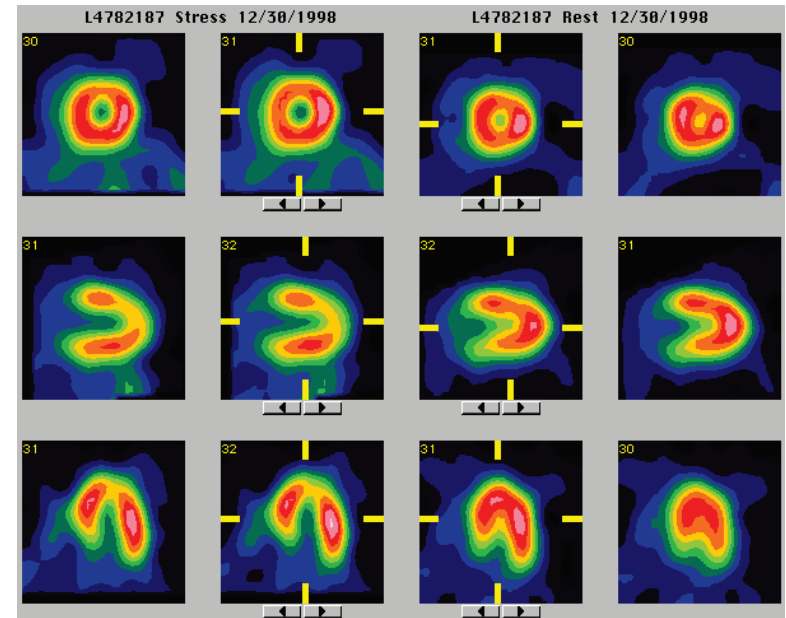
Redistribution



Before PTCA & STENT

Stress

Redistribution



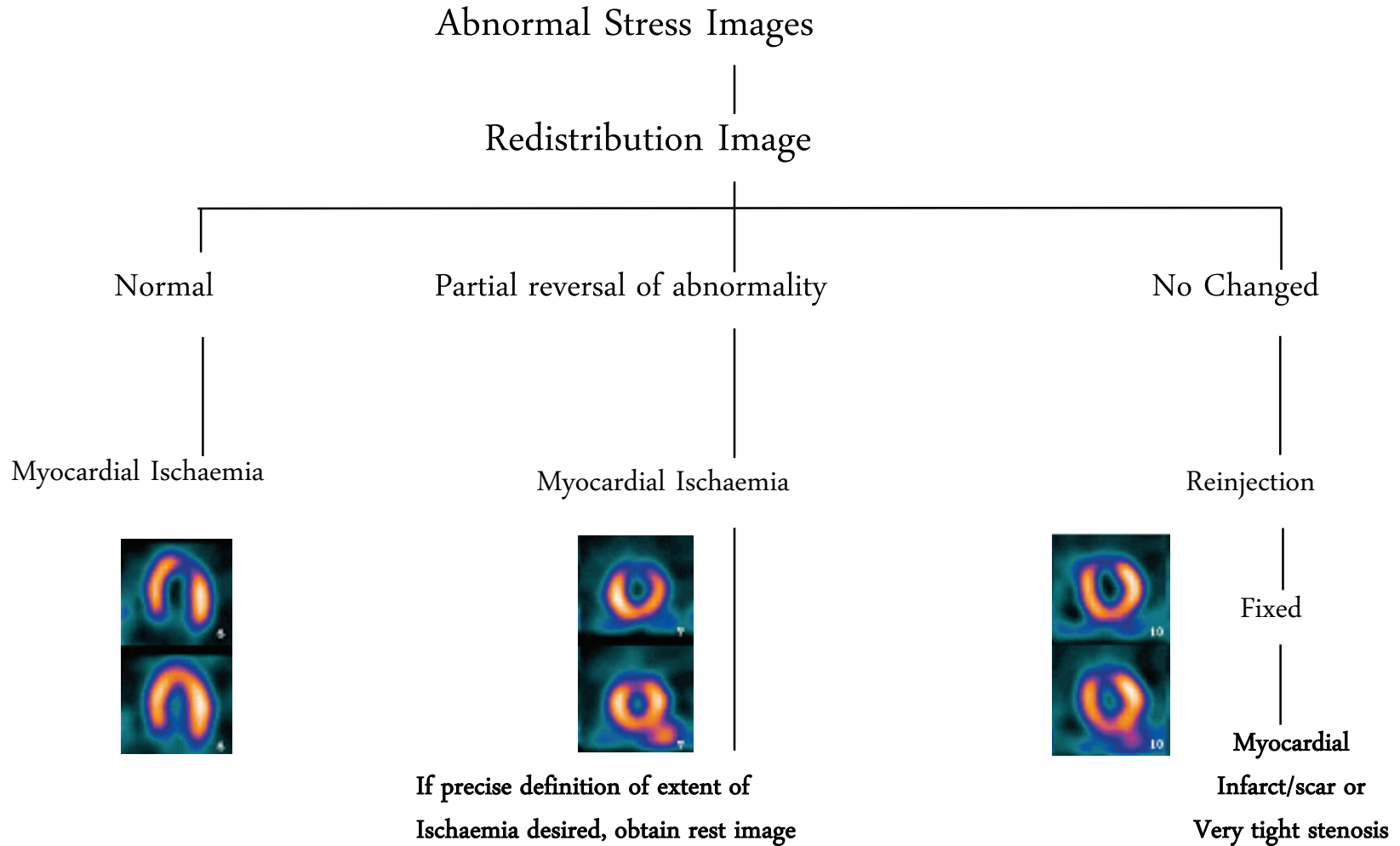
4m after PTCA & STENT

Viability Types

- **Reversible defect (RD)**
 - 40% decrease → normal
- **Partial reversible defect (PRD)**
 - 60% decrease → 40% decrease
- **Persistent defect (PD)**
 - 50% decrease → 50% decrease
- **Reverse redistribution (RR)**
 - Type A: normal → 30% decrease
 - Type B: 30% decrease → 50% decrease



Myocardial Viability



Myocardial Viability

- Reversibility --- Ischemia
 - Reversible defect
 - Partial reversible defect
- Irreversible defect
 - About **50%** of the fixed defect on stress-redistribution images are viable

Myocardial Viability

- Differential Diagnosis of Persistent Defect
 - Scar formation (old infarction)
 - Hibernating caused by chronic ischemia
 - Artifact ...

Risk Assessment

- Risk factors
 - **Ischemic extent and severity**
 - Increased lung thallium uptake
 - Left ventricle dilation
 - Reduced ejection fraction
 - Late defect reversibility

Risk Assessment

- Individual segment score
- QPS: 5-point scoring system
 - 0 – normal perfusion
 - 1 – mild reduced
 - 2 – moderate reduced
 - 3 – severe reduced
 - 4 – absence of uptake
- Summed Stress Score (SSS): adding the individual scores derived from 17 segments during stress
 - 0 – 3: normal
 - 4 – 8: mildly abnormal
 - 9 – 13: moderately abnormal
 - >13: severely abnormal

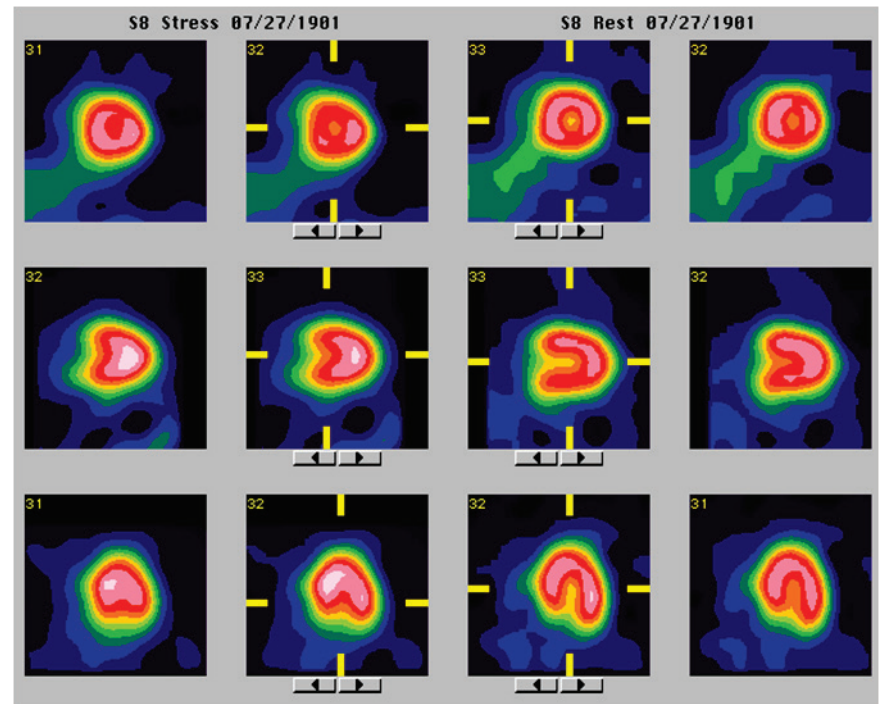
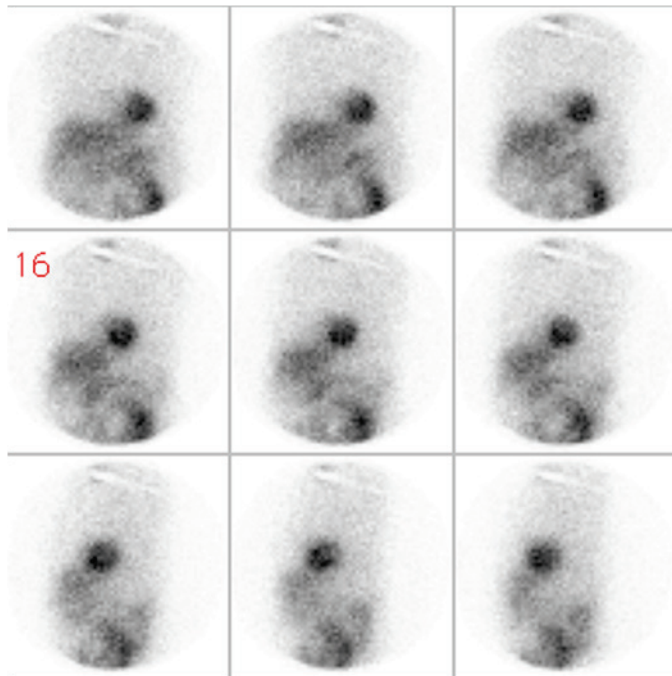


Risk Assessment

- In a 2700 patients study
 - Group 1 (**low risk**), only 2% underwent cath and 2% of them underwent revas, no cardiac event during a 3 year FU
 - Group 2 (**high risk**), 33% underwent cath and 33% of them underwent revas, 15% cardiac event during a 3 year FU

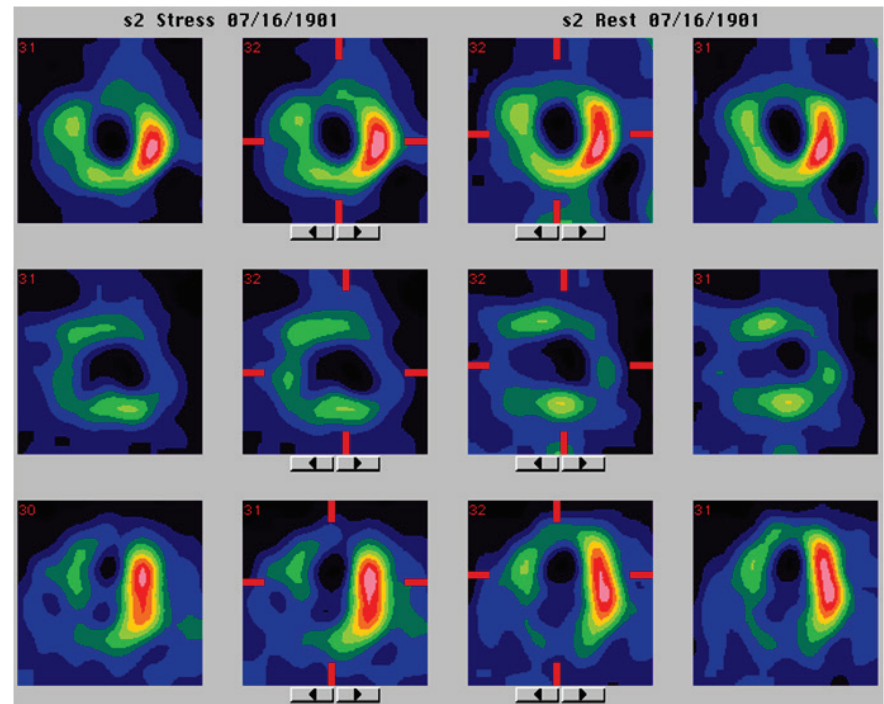
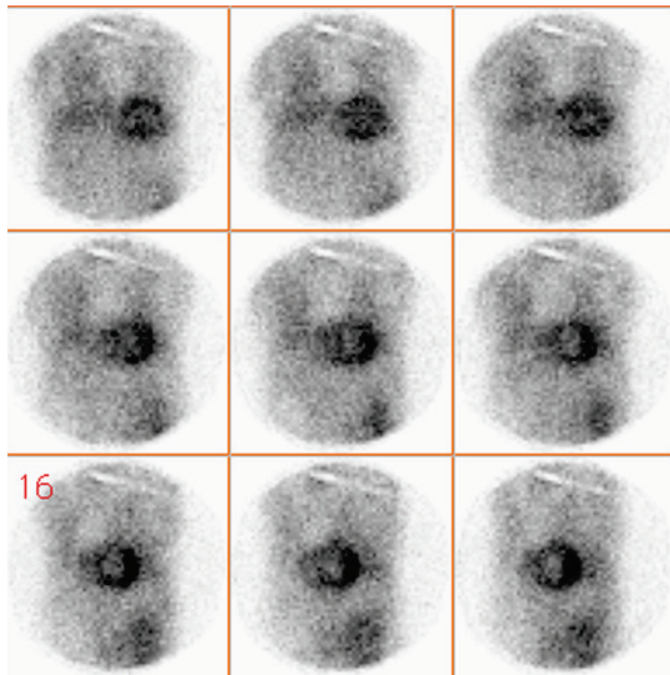
Risk Assessment

- Low risk

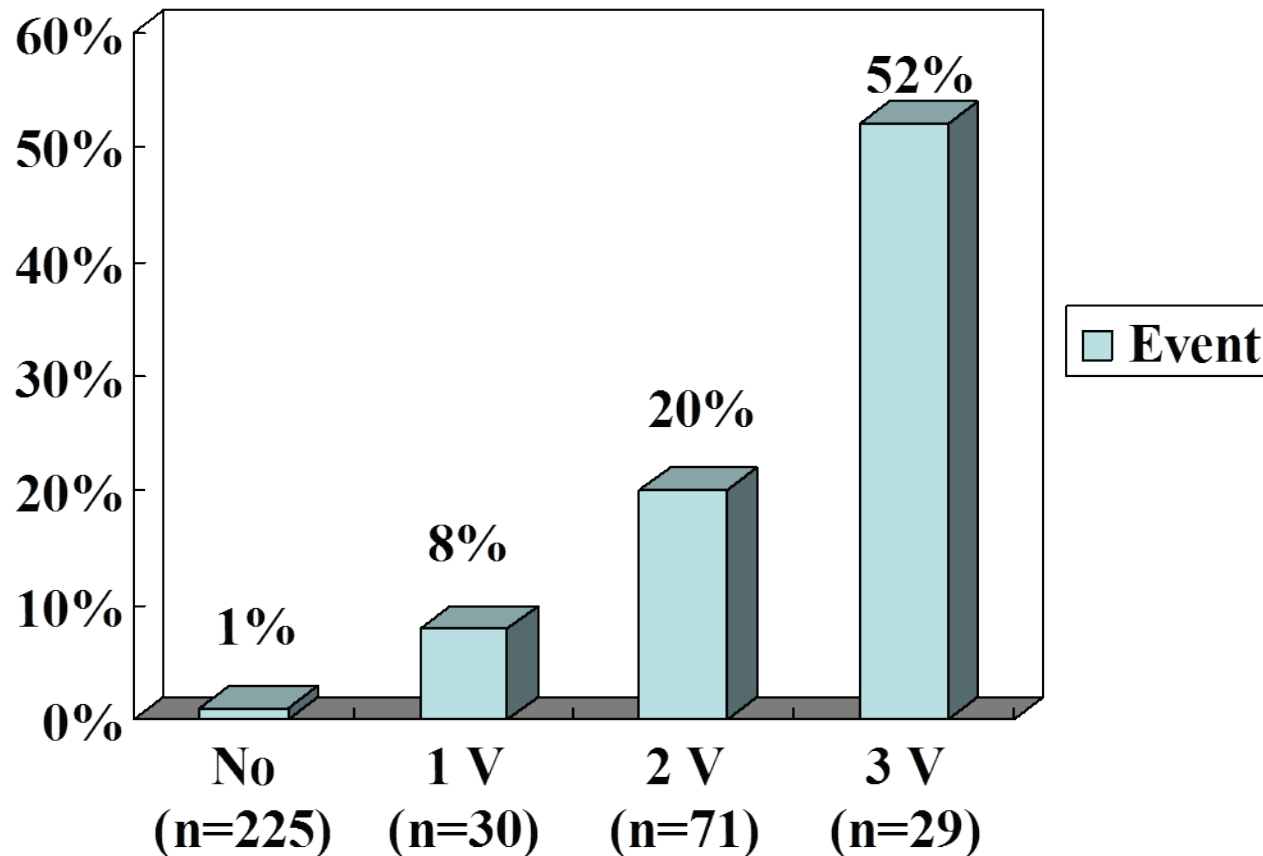


Risk Assessment

- High risk



Cardiac risk for elective noncardiac surgery



Pitfalls of Thallium Scan

- Sensitivity ↓ (false negative)
 - Inadequate pharmacological stress; **coffee, tea**
 - Inadequate exercise: <85 or 90% of predicted maximal heart rate
 - Balanced ischemia
 - Collateral circulation

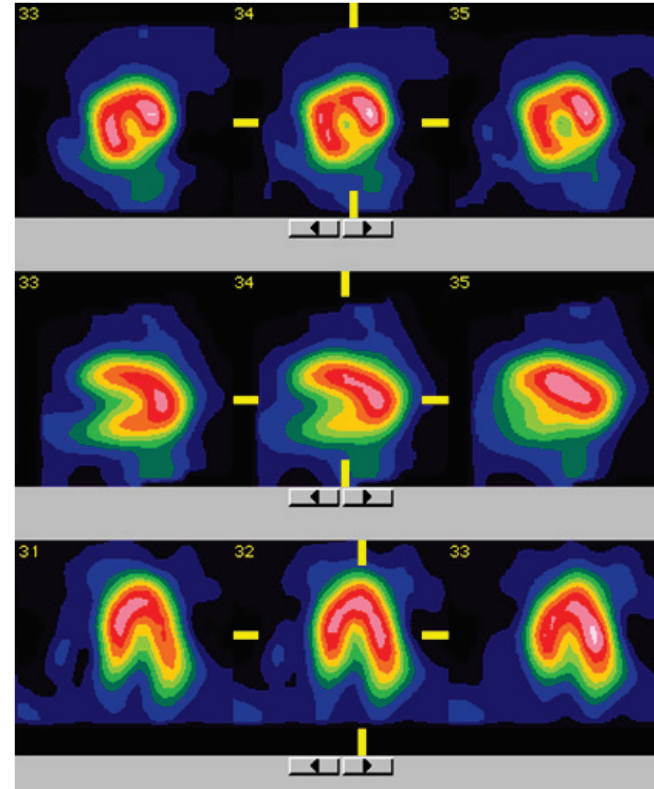
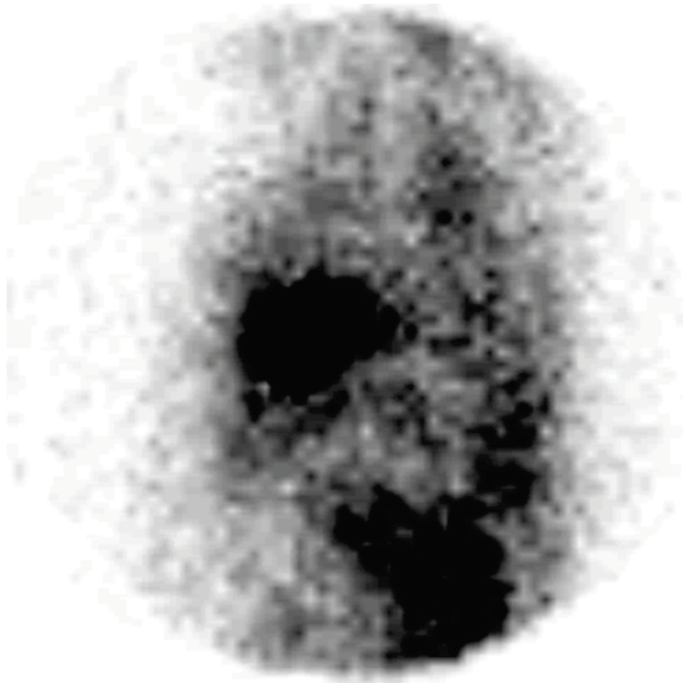
Pitfalls of Thallium Scan

- Specificity ↓ (false positive)
 - Attenuation effect
 - Microvascular disease
 - Non-coronary disorders
 - Motion
 - Normal variant

Pitfalls of Thallium Scan

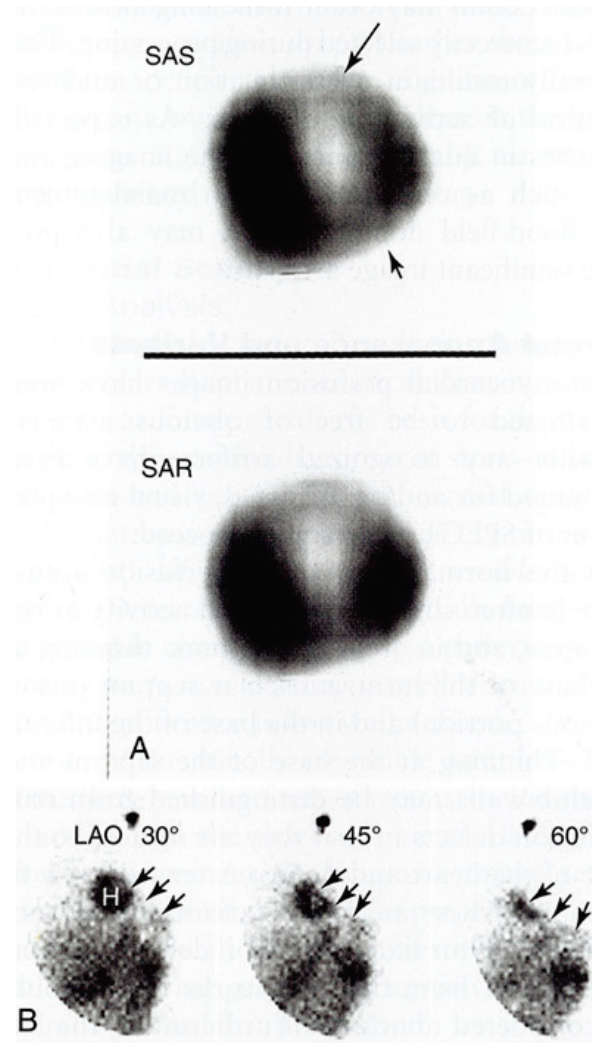
- Attenuation effect
 - Diaphragm : inferior wall
 - Breast : anterior wall
 - Over-weight : lateral wall
 - Intestine : inferior wall
 - Foreign body

Diaphragm Attenuation



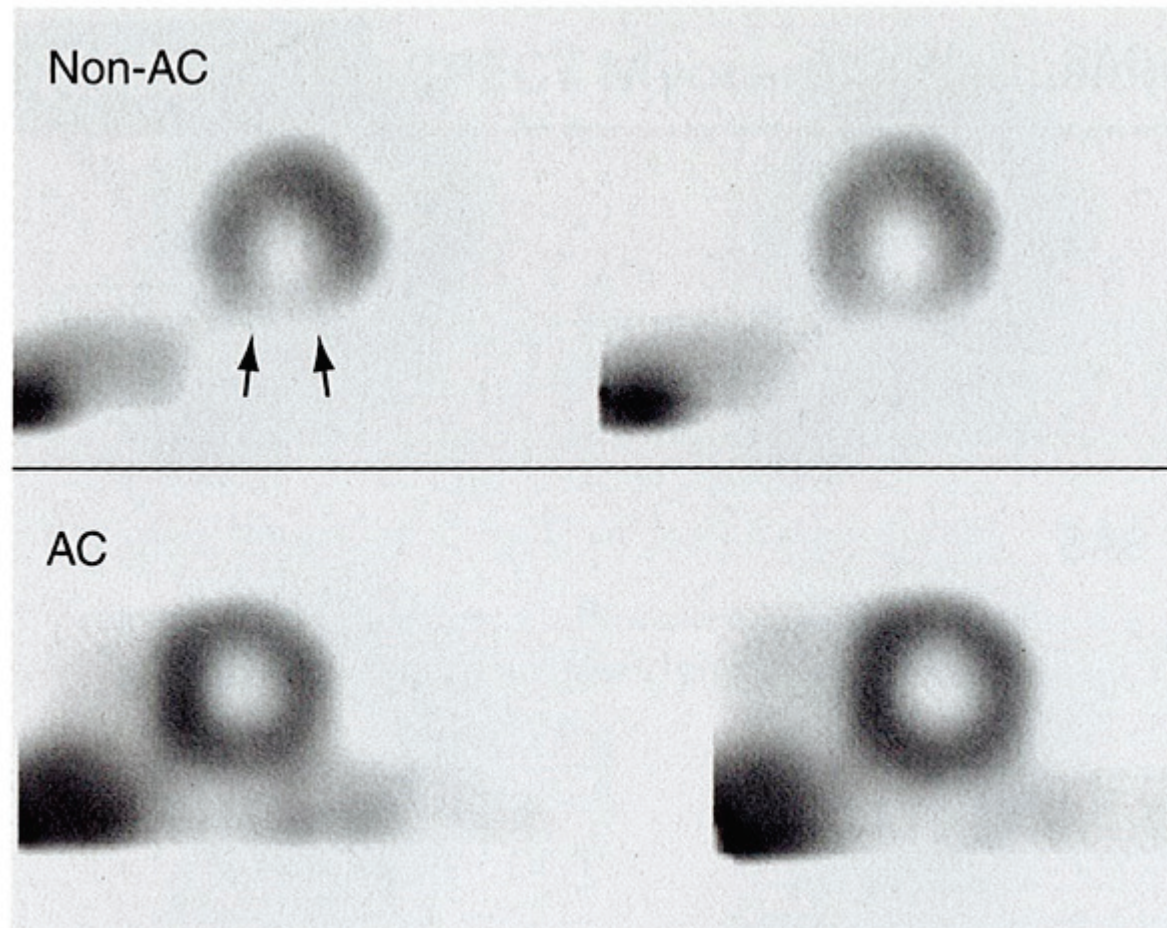
Inferior wall defect
(30% reduction)

Breast Attenuation





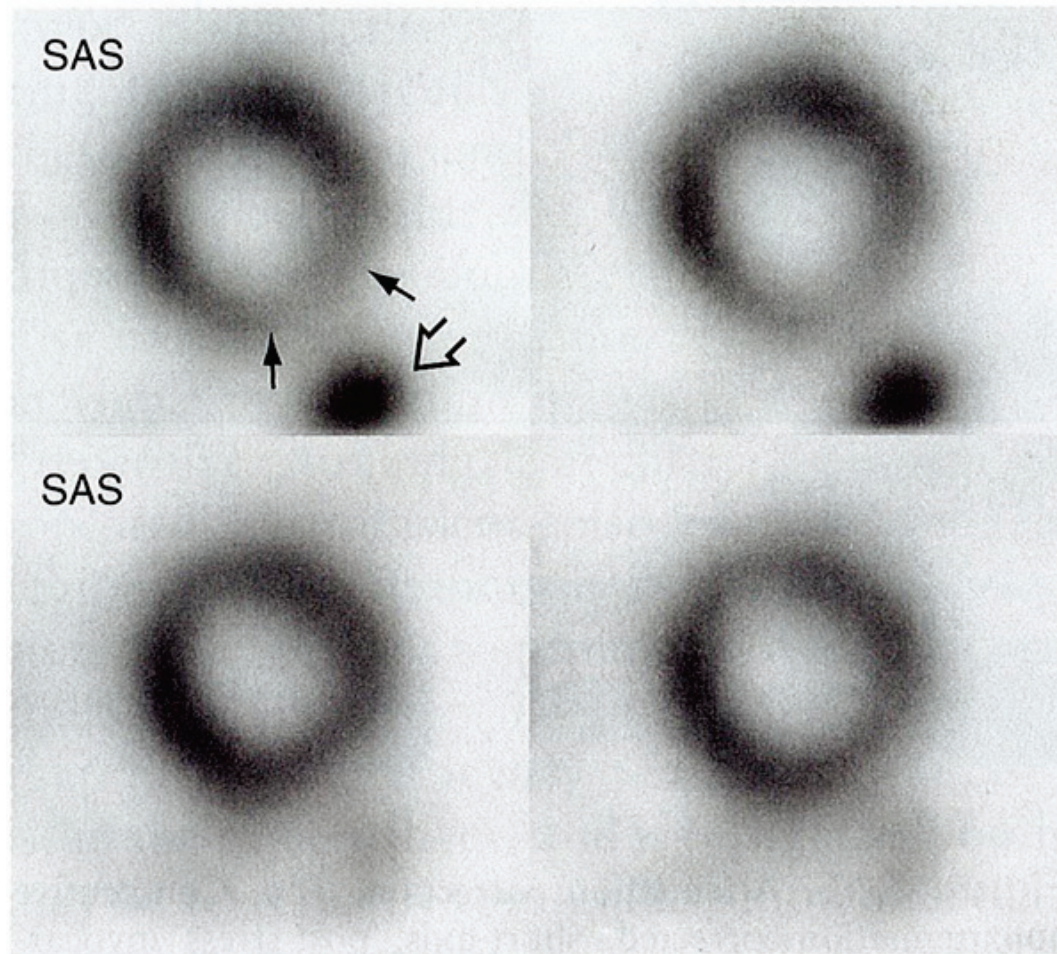
Attenuation Correction



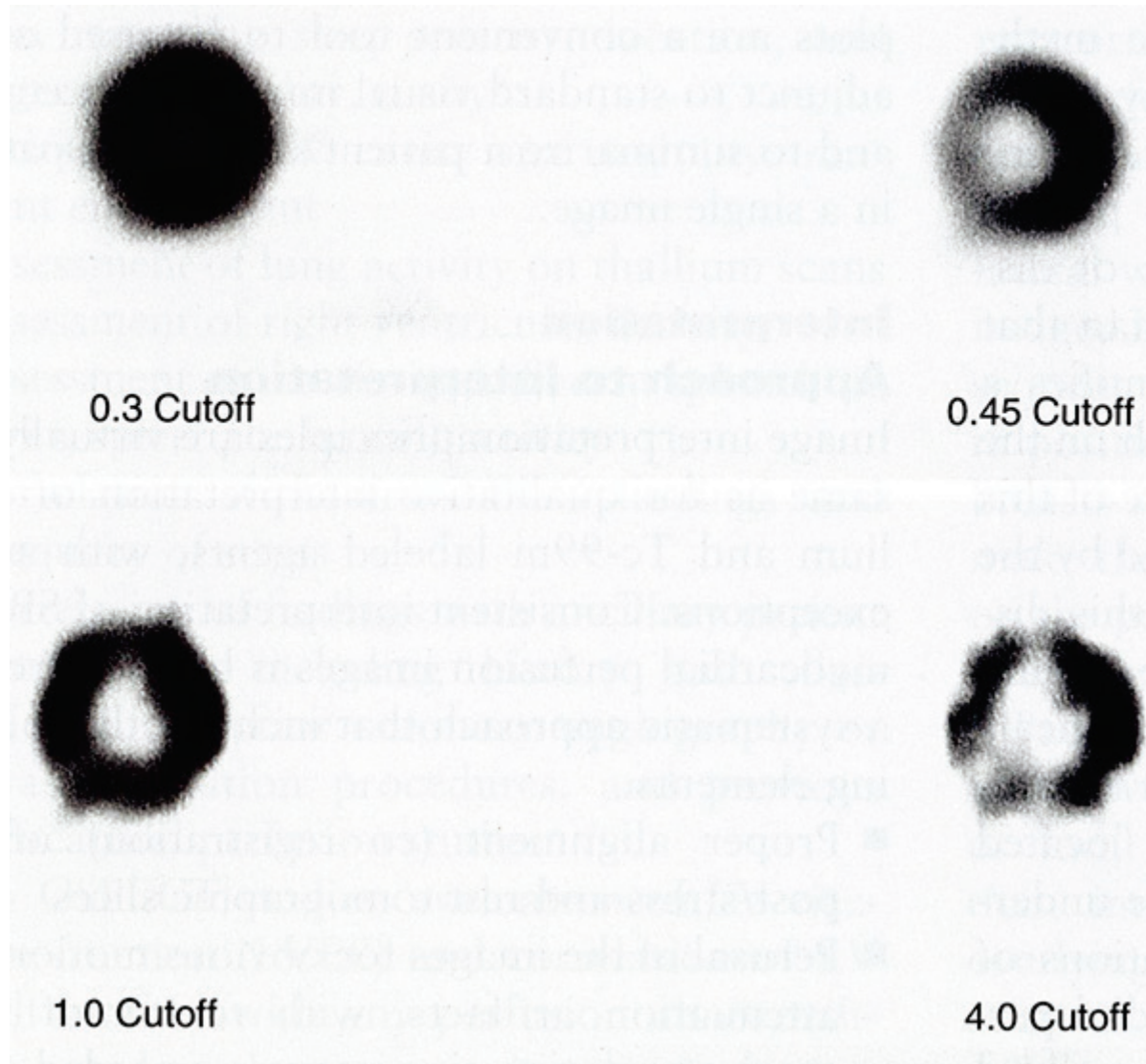


Reconstruction Artifact

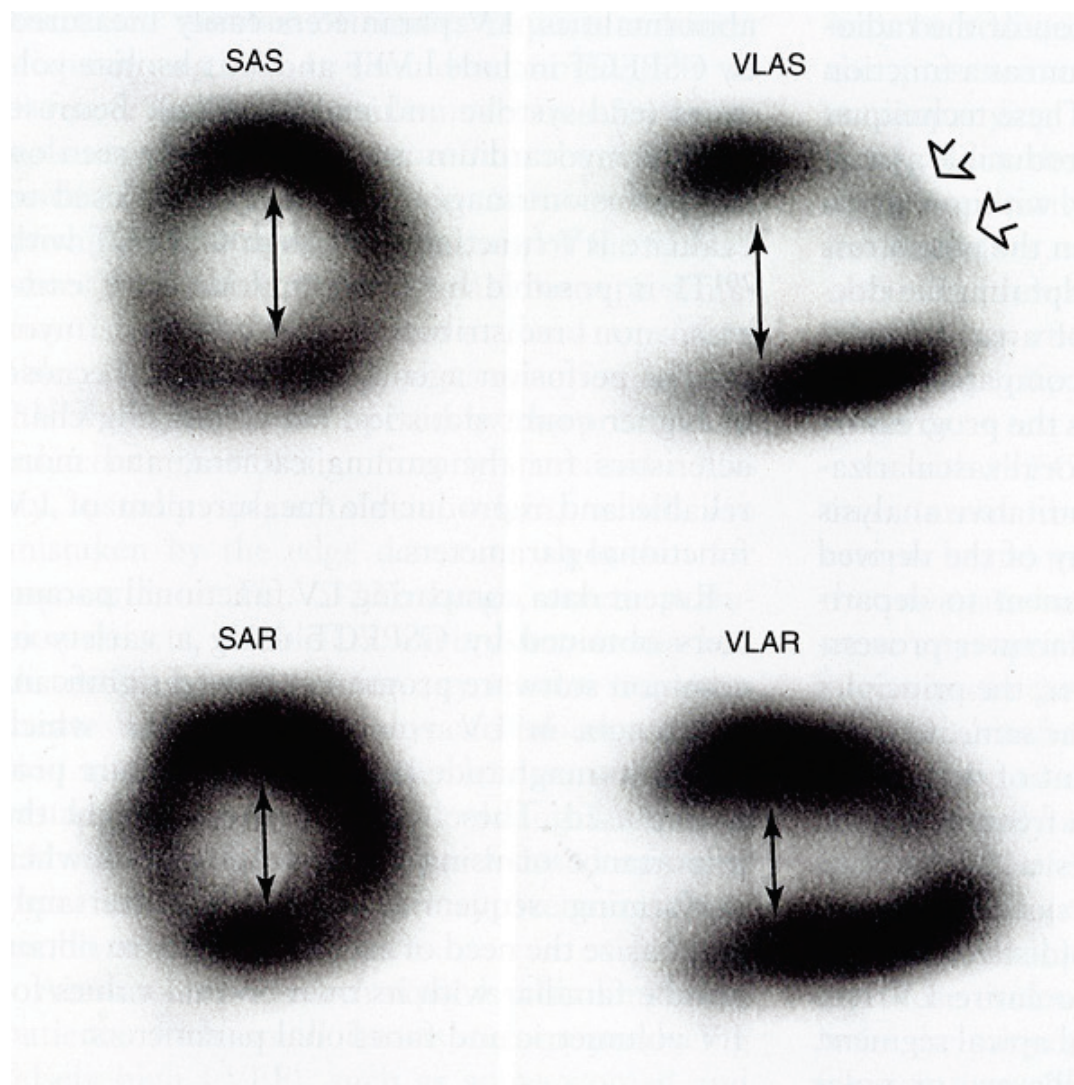
caused by GI uptake



Reconstruction Filter

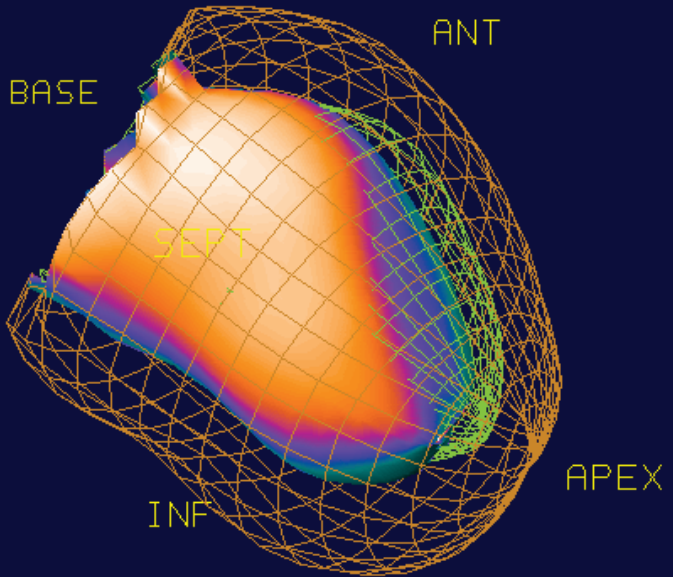
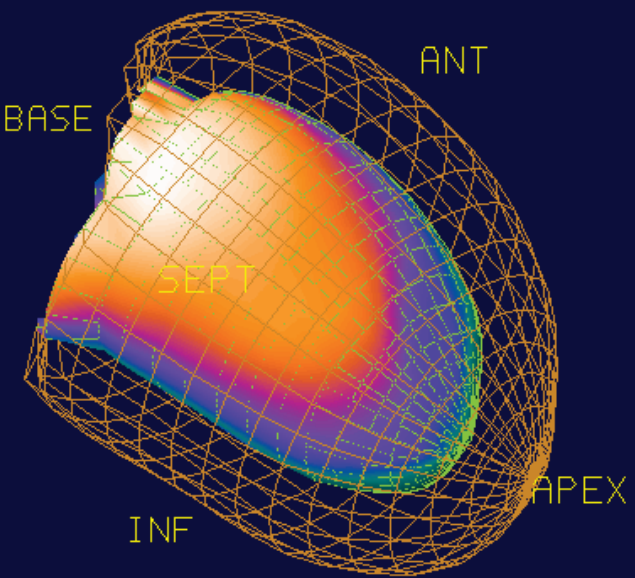


Transient Ischemic Dilation



Gated SPECT

Label Box **ED** Gate Spin Surface Both Interval 1 Interval 1 Scale 1.0 Rate 14

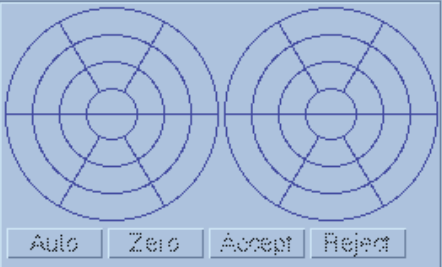


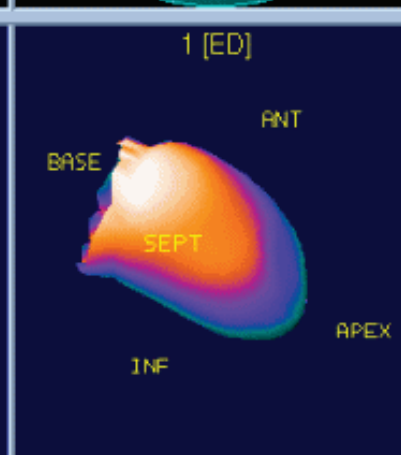
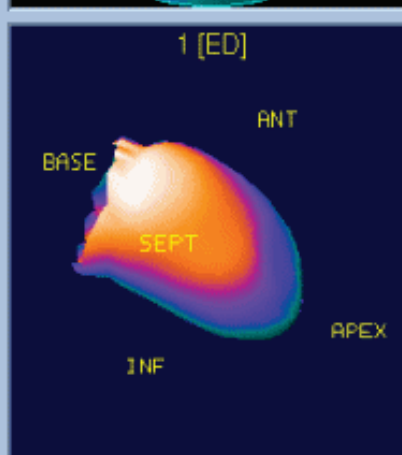
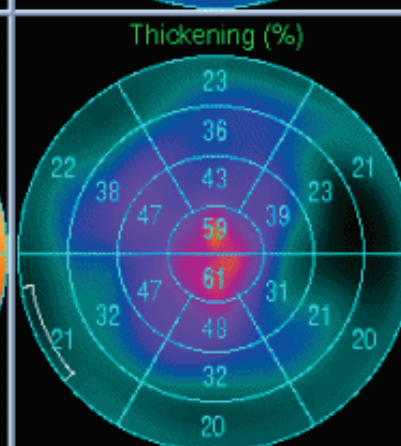
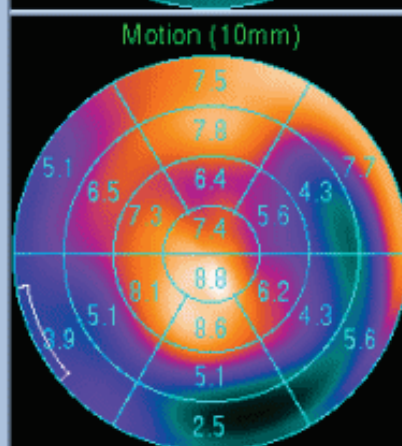
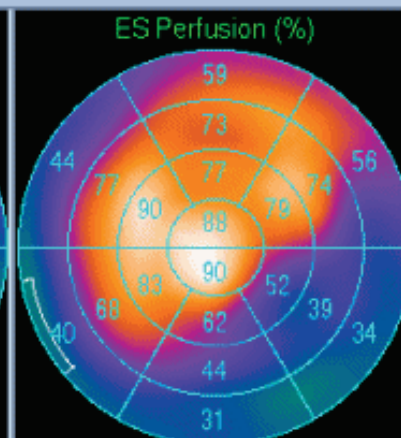
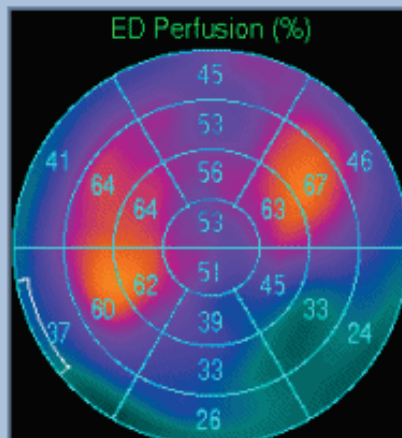
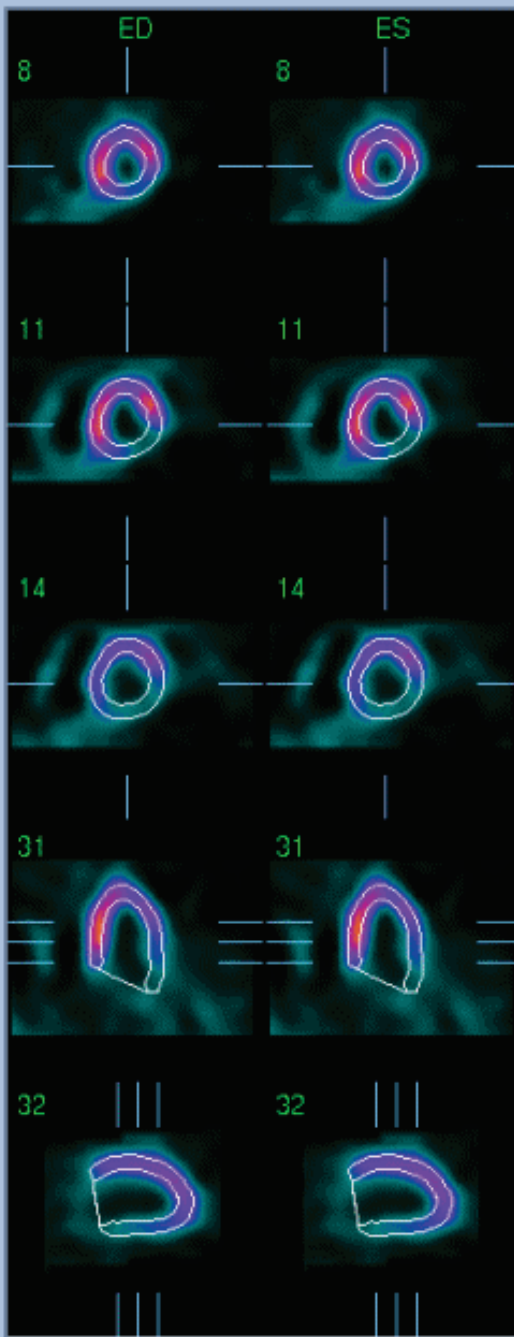
ANT LAT INF SEPT APEX BASE LAO RAO ECHO ANT LAT INF SEPT APEX BASE LAO RAO ECHO

Name AUTOQUANT ABNORM
Pat ID 123456789
Sex MALE
Limits A:SepdualMale
TID 1.03
LHR 0.41
SSS 18 **SRS** 0 **SDS** 18

Proc ID GATED RST TL & STR
View ID SA Gated Stress
Date 04/07/1999 12:11:37
Volume 86ml [1]
EDV 86ml [1]
ESV 41ml [4]
EF 52%

Proc ID GATED RST TL & STR
View ID SA Gated Rest
Date 04/07/1999 10:19:30
Volume 77ml [1]
EDV 82ml [7]
ESV 39ml [4]
EF 52%



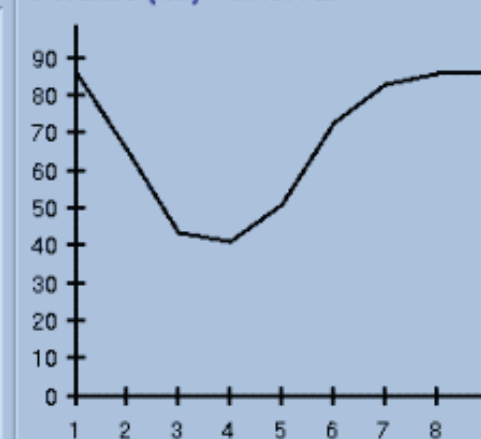


Name AUTOQUANT ABNORM
Pat ID 123456789
Sex MALE
Limits A:SepdualMale
TID 1.03
LHR 0.41
SSS 18 **SRS** 0 **SDS** 18

Proc ID GATED RST TL & STR
View ID SA Gated Stress
Date 04/07/1999 12:11:37
Matrix 64x64
Slices 25
Intervals 8
Mm/Vox 6.47

Volume 86ml [1]
EDV 86ml [1]
ESV 41ml [4]
SV 45ml
EF 52%

Volume (ml) / Interval



Extra-cardiac Uptake

Box 10-1 Radiopharmaceutical Affinity for Various Tumors

Gallium-67 Citrate

Hodgkin disease
Non-Hodgkin lymphoma (especially high-grade)
Hepatoma
Bronchogenic carcinoma
Melanoma
Seminoma
Rhabdomyosarcoma

Thallium-201 Chloride

Gliomas (high-grade)
Thyroid carcinoma
Benign tumors (usually fade over 2 hr)
Osteosarcoma
Lymphoma (especially low-grade)
Kaposi sarcoma (gallium-negative)

Technetium-99m Sestamibi

Cancer metastases
Breast cancer
Parathyroid adenoma
Gliomas
Lymphoma
Thyroid

Indium-111 Pentetreotide

APUD cell tumors
Pancreatic islet cell
Pituitary adenoma
Pheochromocytoma

Neuroblastoma
Paraganglioma
Carcinoid
Gastrinoma
VIPoma
Medullary carcinoma of thyroid
Small-cell lung cancer
Meningioma

Fluorine-18 Fluorodeoxyglucose

Most tumors (see Chapter 11)
Head and neck cancer
Esophageal cancer
Non-small-cell lung cancer
Melanoma
Lymphoma
Colorectal cancer
Breast cancer
Poorly differentiated neuroendocrine tumors

Iodine-123 or 131 Sodium Iodide

Thyroid cancer

Iodine-123 or 131 Metaiodobenzylguanidine

Pheochromocytoma
Neuroblastoma
Paraganglioma

Monoclonal Antibodies

Lymphoma