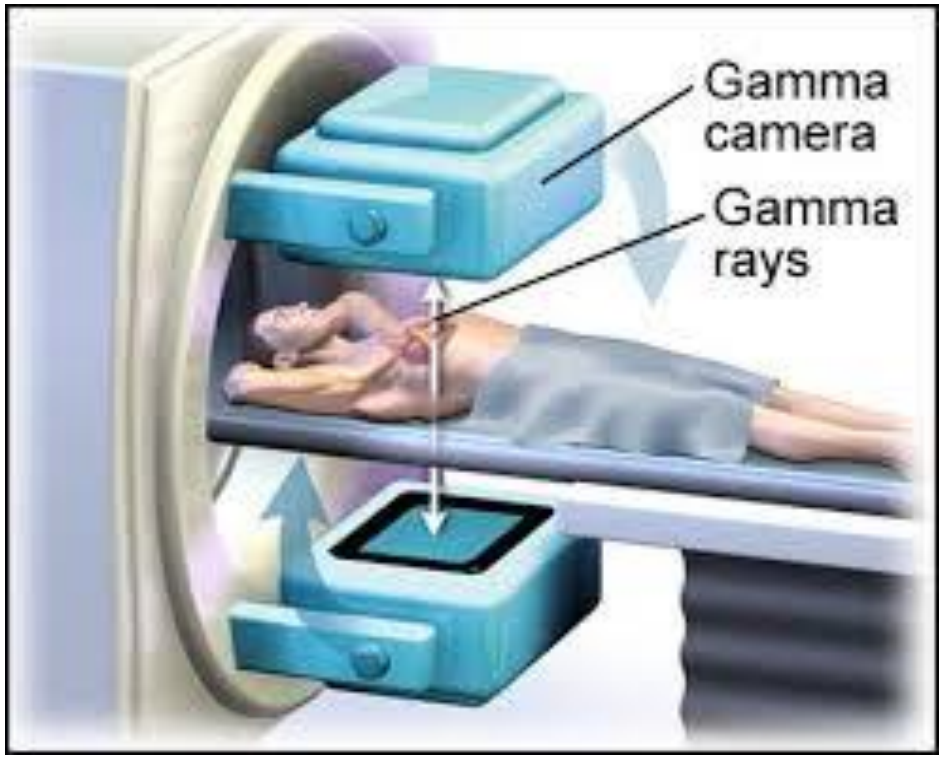
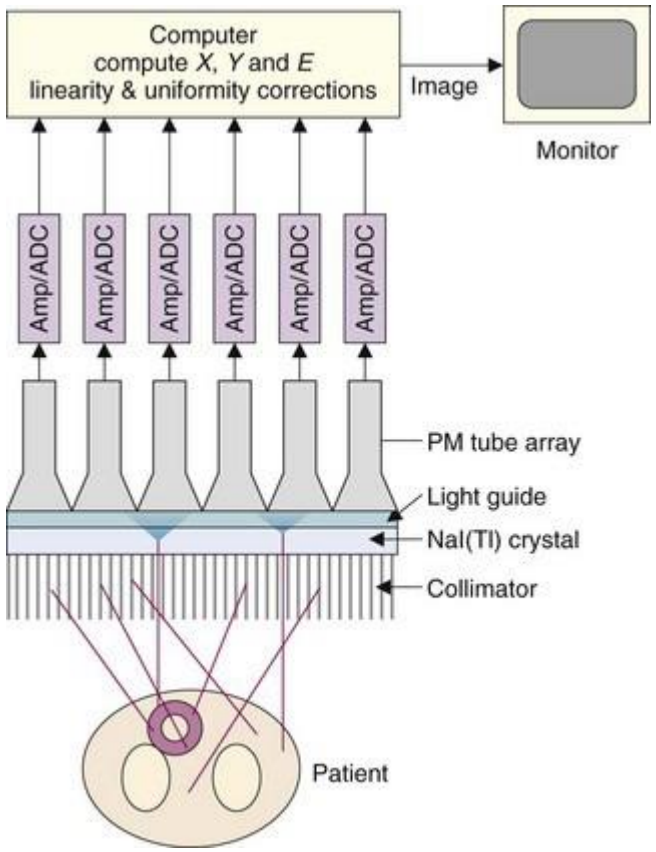
In the name of god

Application of nuclear imaging using PET/SPECT techniques for assessment of CVD

Presented by: Dr. F. Jalali, MD, Assistant professor of Nuclear medicine

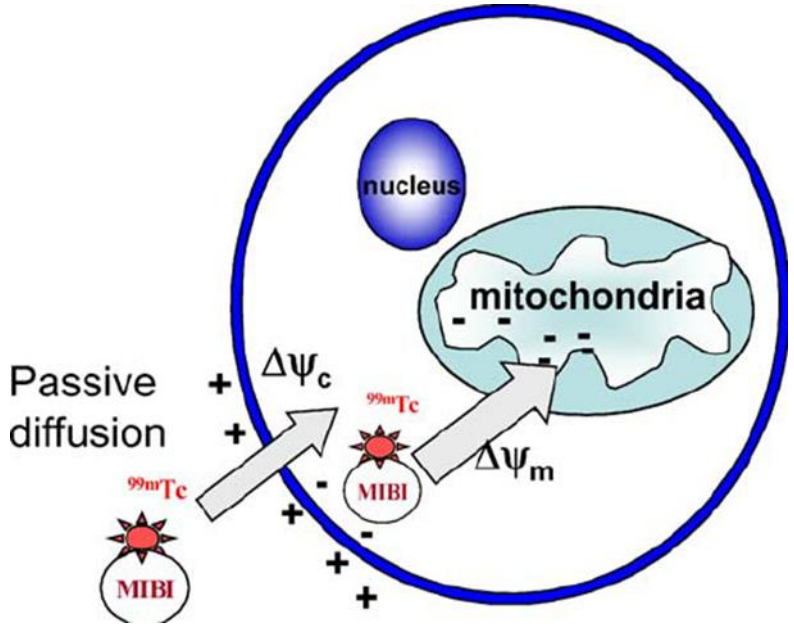

Gamma camera
Gamma rays


Computer
compute X, Y and E
linearity & uniformity corrections
Image
Monitor
Amp/ADC
Amp/ADC
Amp/ADC
Amp/ADC
Amp/ADC
Amp/ADC
PM tube array
Light guide
NaI(Tl) crystal
Collimator
Patient

Commonly used tracers

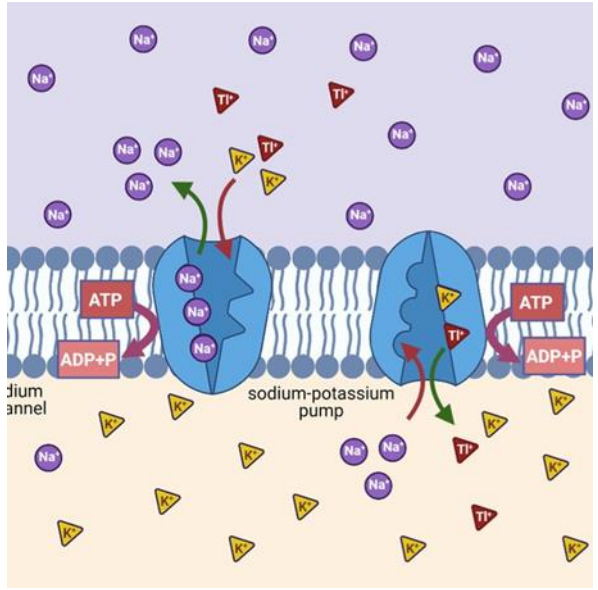
^{99m}Tc-Sestamibi

- Tc-99m is a radioactive compound
- Sestamibi is a lipophilic cation that has been labeled with TC-99m
- passively diffusion into the myocardial cell : because of its lipid solubility
- retain in myocardial cell and no redistribution.
- Half-life: 6hr
- Energy: 140kev
- Better image quality (intrinsically better & inject higher dose since ½ life is shorter



^{201}Tl

- Energy: 69-83kev
- K+ analoge : enter/ exit cell via Na+/K+ ATPase pump.
- Half-life is 73hr (more radio active exposure to the patients)
- Unlike the Tc-99m perfusion agents, it then undergoes redistribution, a process of continual dynamic exchange between myocardial cells and the vascular blood pool.
- Worse imaging characteristics(intrinsically worse and also because need to limit dose to limit radioactive exposure)
- Assessment of viability



Indication of MPI

- Detection of CAD
- Determination of significant of anatomic lesions detected by angiography
- Evaluating prognosis and risk stratification
- Assessing medical therapy of CAD
- Monitoring treatment effect after coronary revascularization
- Assessing cardiac viability
- Detect otherwise undetectable deficiencies (e.g. micro-circulatory)

Risk stratification
Risk of cardiac death or MI

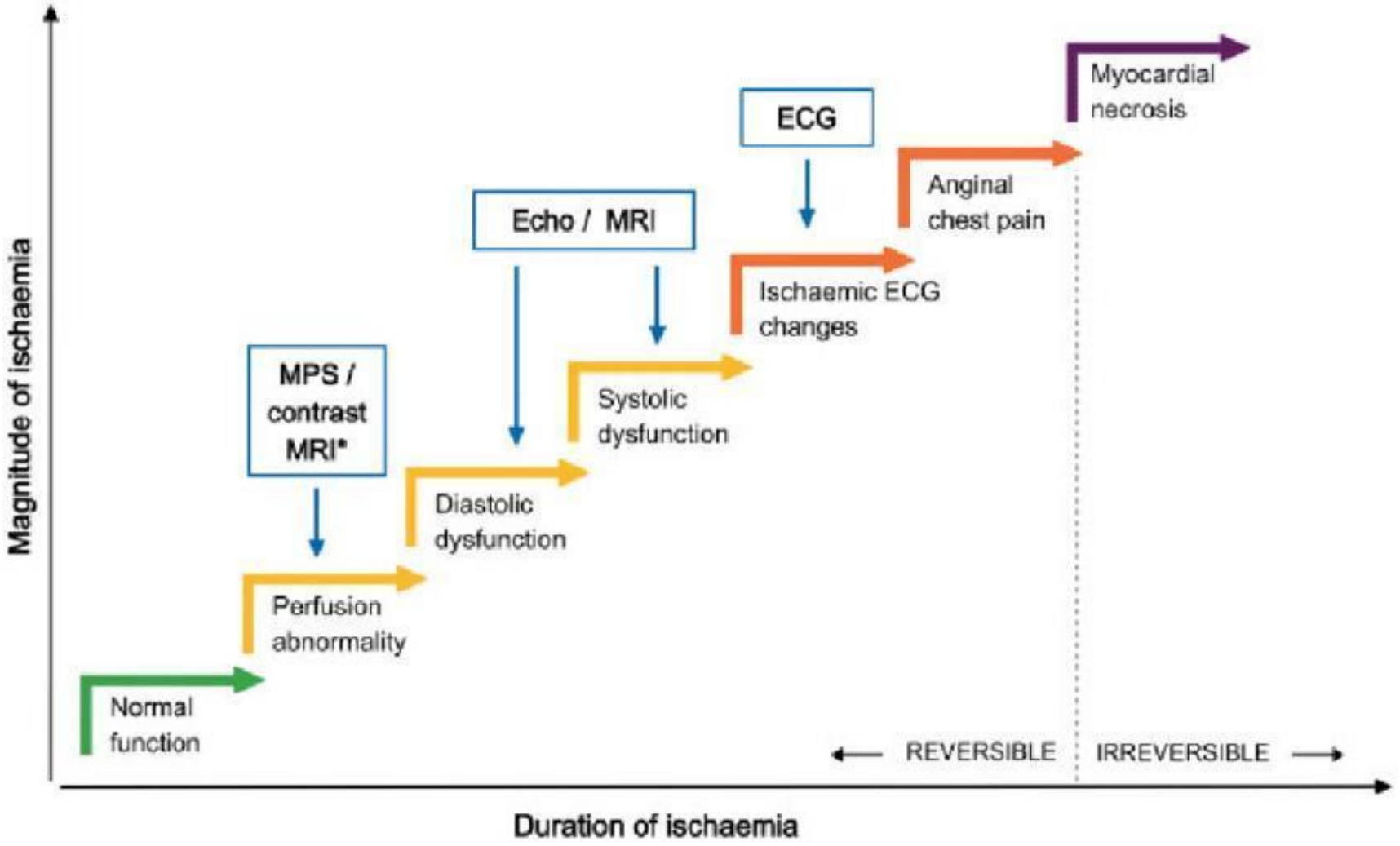
- Low < 1% per year
- Intermediate 1-3% per year
- High > 3% per year

- Normal or near normal exercise MPI even in presence of known angiographic CAD have a very low cardiac event rate (<1%)

-Subgroup where risk of a normal SPECT is >1% → warranty period of normal stress MPI was about 2 years

- Pharmacologic stress
- Diabetics
- Elderly patient
- Patient with non-CAD

Ischemic Cascade

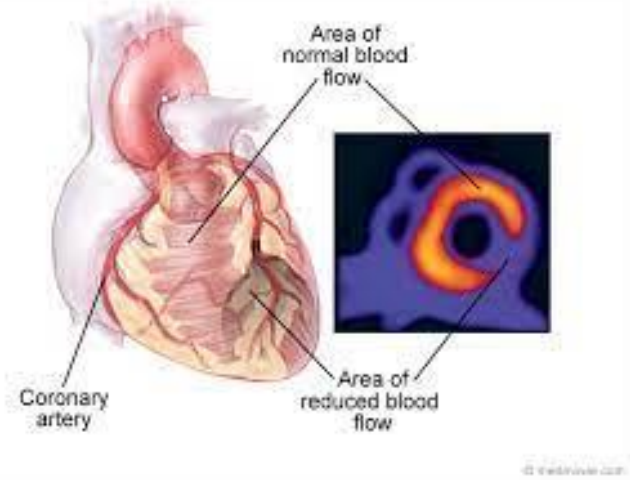


Basic principles of MPI

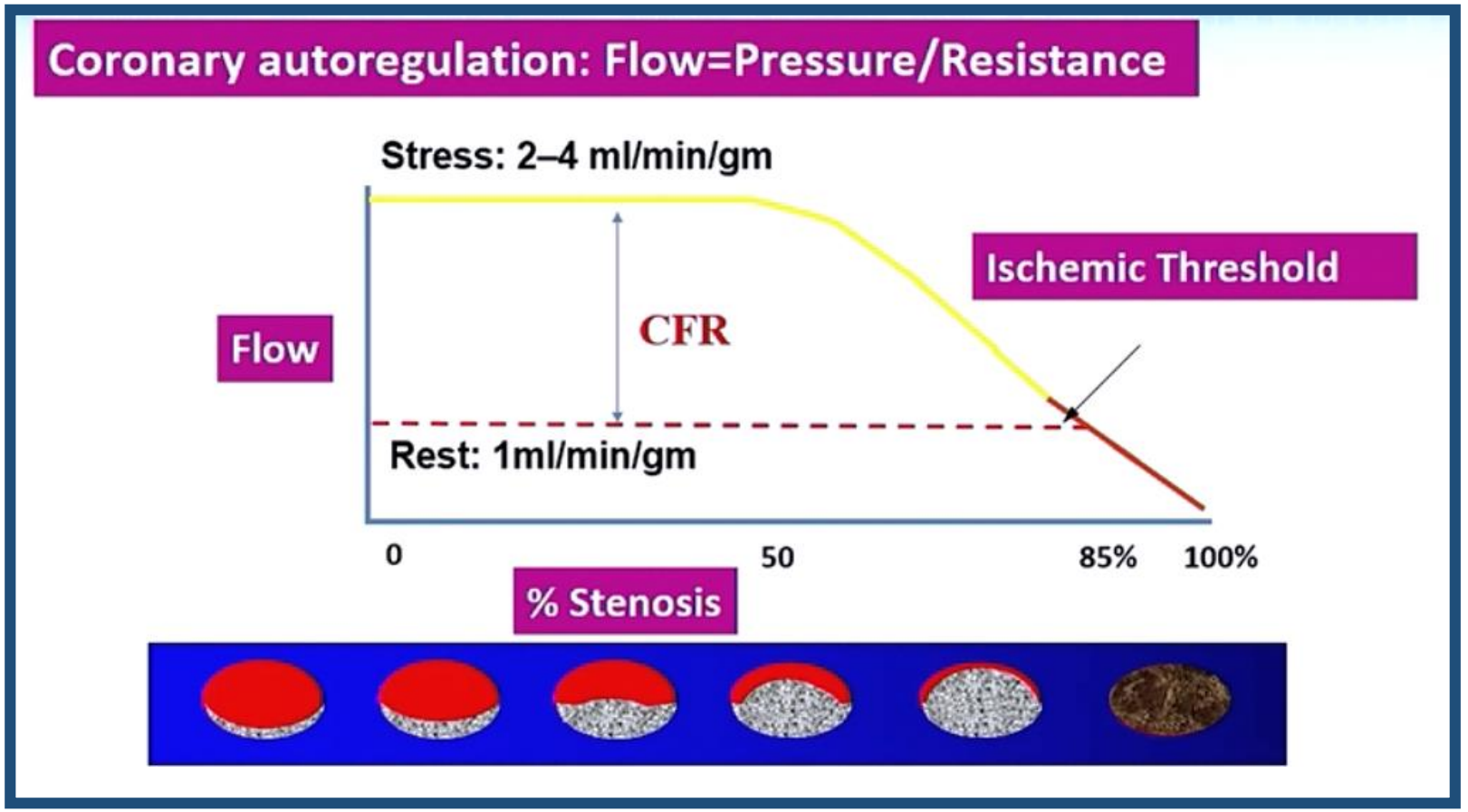
- Inject radioactive tracers whose distribution in the heart are proportional to the amount of blood flow to the area.
- Areas where tracers has been absorbed (normal blood flow) look different from areas that don’t enough absorbed due to decreased blood flow.

- Gamma camera detects the photons given off by the radioactive tracers and thus the relative blood flow to the different areas d

- MPI detects “Relative, not absolute blood flow.

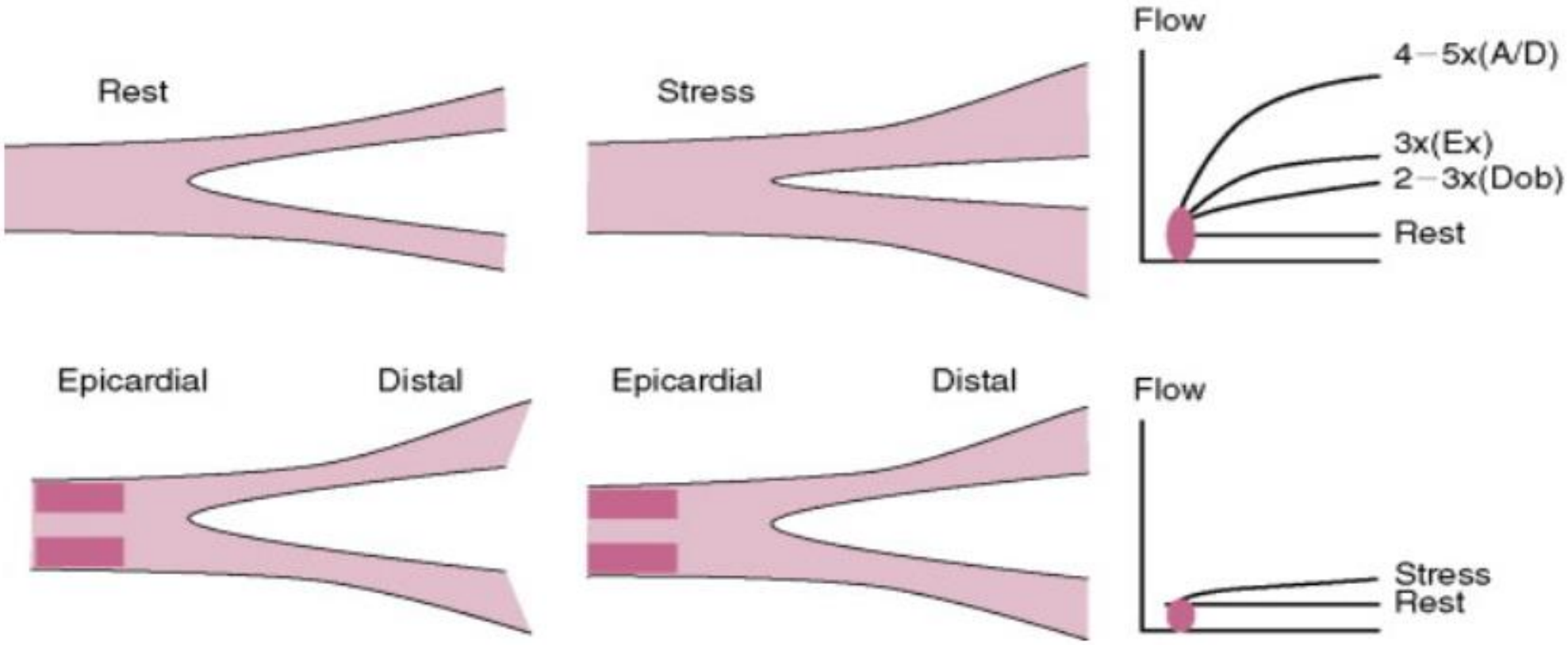


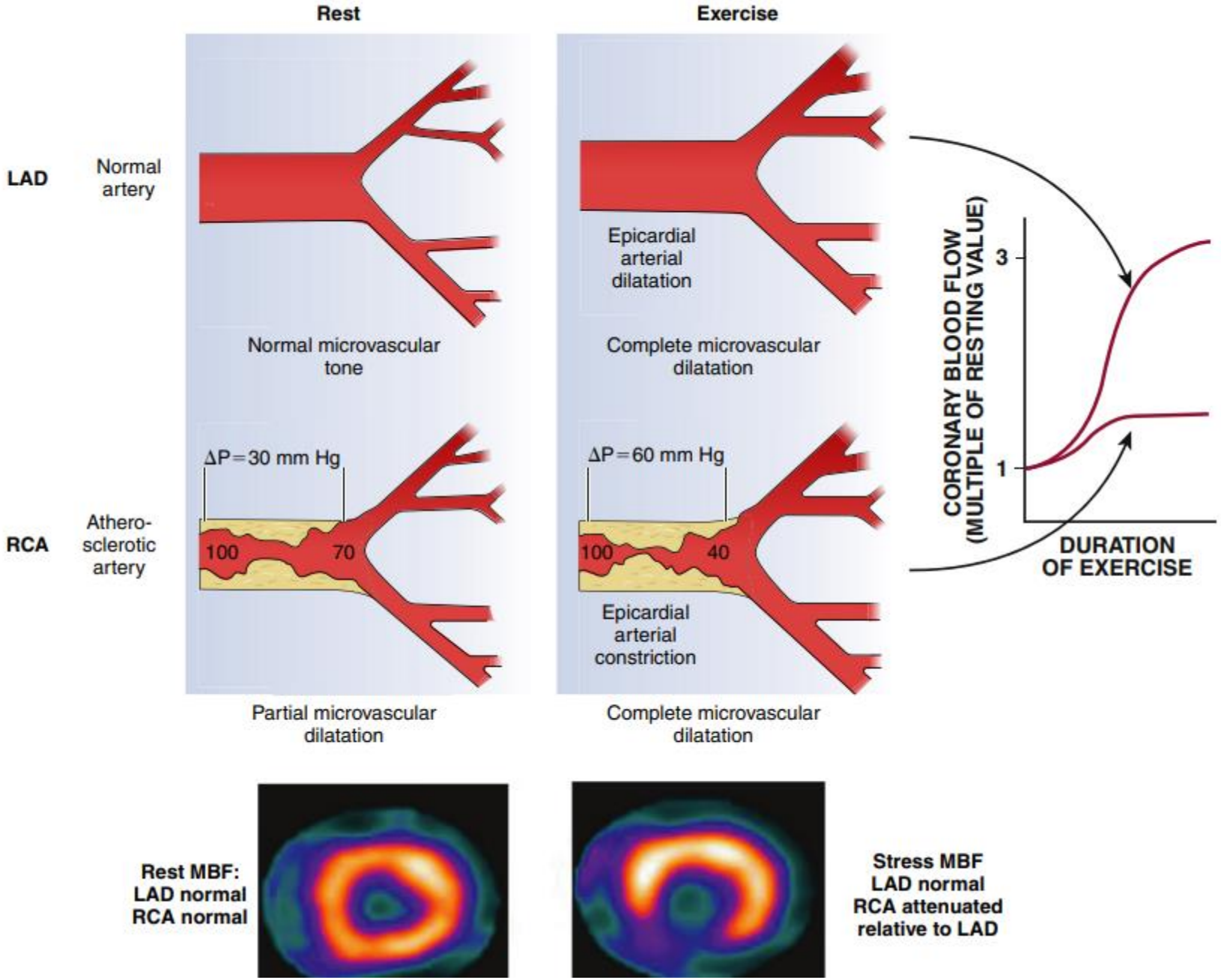
Determinants of ischemia



Relationship between blood flow and severity of coronary stenosis. At rest, myocardial blood flow is not reduced until a coronary stenosis approaches 90%. It then begins to drop off. However, with increased coronary blood flow produced by exercise or pharmacological stress, less severe stenoses (50–75%) result in reduced coronary flow.

Coronary Blood flow rates



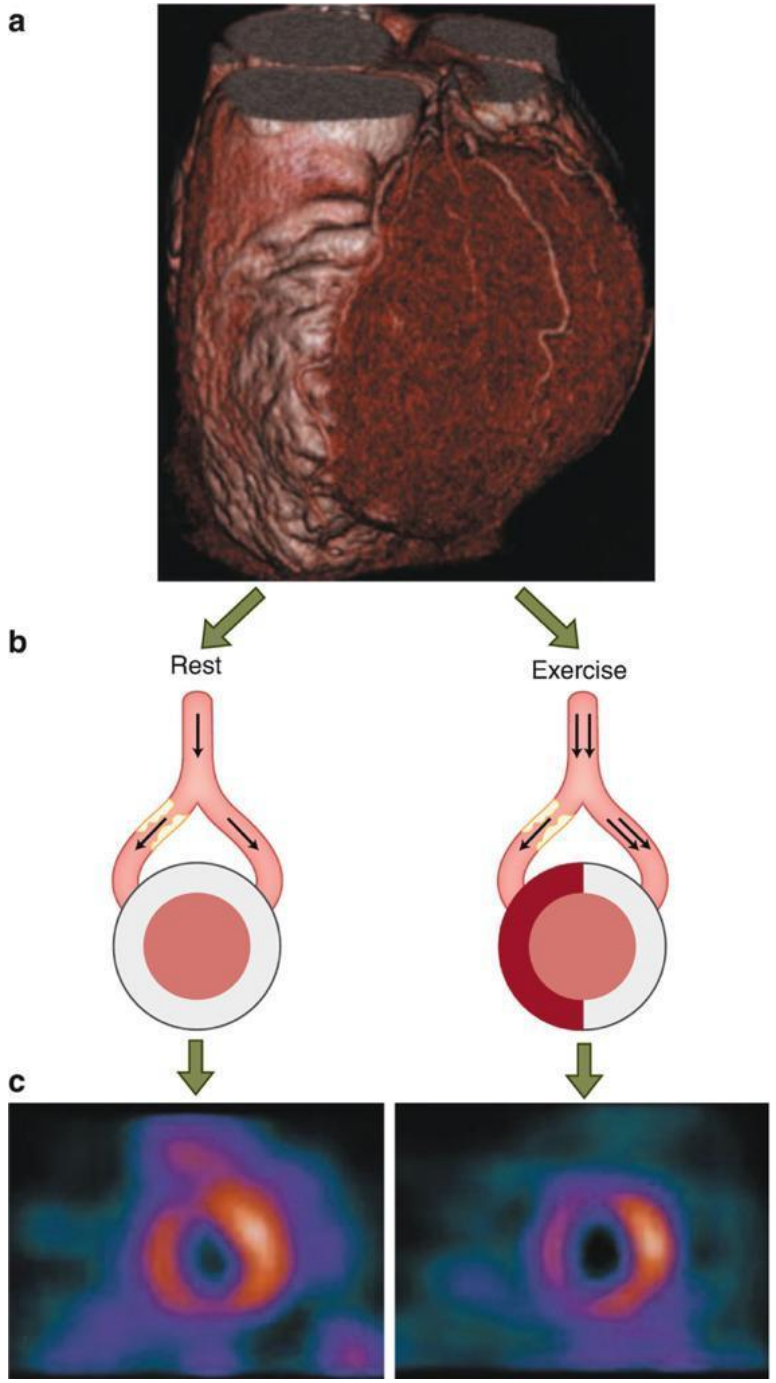

Rest
Exercise
LAD
Normal artery
Normal microvascular tone
Epicardial arterial dilatation
Complete microvascular dilatation
RCA
Athero-sclerotic artery
ΔP=30 mm Hg
100
70
Partial microvascular dilatation
ΔP=60 mm Hg
100
40
Epicardial arterial constriction
Complete microvascular dilatation
CORONARY BLOOD FLOW (MULTIPLE OF RESTING VALUE)
3
1
DURATION OF EXERCISE
Rest MBF: LAD normal RCA normal
Stress MBF LAD normal RCA attenuated relative to LAD

MPI procedure

- MPI is comprised of two parts

Stress phase: Exercise or pharmacologic stress (dipyridamole, adenosine, dobutamine), with ECG monitoring.

Rest phase: When a myocardial perfusion imaging agent is injected at rest, myocardial uptake therefore will be homogenous



Stress Testing

- Exercise stress test

- Pharmacologic Stress Testing
- Vasodilators:

Dipyridamole

Adenosine

Regadenoson

- dobutamine

Preparation for exercise testing

- The patient must fast for 4 to 6 hours before the test to prevent gastric symptoms and minimize splanchnic blood distribution.
- Cardiac medications may be held depending on the indication for the stress test :diagnosis or to determine the effectiveness of therapy.

- Beta-blockers may prevent achievement of maximum heart rate. nitrate ,calcium channel blockers may block or prevent cardiac ischemia, limiting the test's diagnostic value.

- Hold caffeine, Methylxanthines, theophylline and Oral dipyridamole for at least 12-24 hours prior to testing
- Can give IV dipyridamole

In addition to a standard 12-lead electrocardiogram, an intravenous line is kept open.

Stress Testing

- Exercise preferred mode of testing
- Can evaluate:
- Exercise duration (functional capacity)
- Symptoms
- Heart-rate response/recovery
- Blood-pressure response
- EKG response
- Arrhythmia
- treadmill exercise is usually performed according to the Bruce protocol
- degree of stress must be sufficient to unmask underlying ischemia. The adequacy of exercise is critical for interpretation.
- Degree of stress must be sufficient to unmask underlying ischemia.
- The adequacy of exercise is critical for interpretation.
- Patients achieving more than 85% of the age-predicted maximum heart rate (220 – age) are considered to have achieved adequate exercise stress.
- Product of heart rate × blood pressure & metabolic equivalents (METS) & exercise time (minutes) are also used to judge the adequacy of exercise.
- Tests should be symptom limited (not just 85% PMHR)

Contraindications to Exercise testing

-Absolute

- Contraindications Acute myocardial infarction, within 2 days
- High-risk unstable angina
- Uncontrolled cardiac arrhythmia with hemodynamic compromise
- Active endocarditis
- Symptomatic severe aortic stenosis
- Decompensated heart failure
- Acute pulmonary embolism or pulmonary infarction
- Acute myocarditis or pericarditis
- Physical disability that precludes safe and adequate testing

-Relative Contraindications

- Known left main coronary artery stenosis
- Moderate aortic stenosis with uncertain relation to symptoms
- Tachyarrhythmias with uncontrolled ventricular rates
- Acquired complete heart block
- Hypertrophic cardiomyopathy with severe resting gradient
- Mental impairment with limited ability to cooperate

Indication for terminating the exercise

- ST elevation (>1.0 mm) in leads without Q waves due to prior MI (other than aVR, aVL, or V1) •
- Drop in systolic BP of >10 mm Hg, despite an increase in workload, when accompanied by any other evidence of ischemia
- Moderate to severe angina
- Central nervous system symptoms (e.g., ataxia, dizziness, or near syncope)
- Signs of poor perfusion (cyanosis or pallor)
- Sustained ventricular tachycardia or other arrhythmia that interferes with normal maintenance of cardiac output during exercise
- Technical difficulties monitoring the ECG or systolic BP
- Patient’s request to stop Relative Indications
- Marked ST displacement (horizontal or downsloping of >2 mm) in a patient with suspected ischemia • Drop in systolic BP of >10 mm Hg (persistently below baseline) despite an increase in workload, in the absence of other evidence of ischemia
- Increasing chest pain
- Fatigue, shortness of breath, wheezing, leg cramps, or claudication
- Arrhythmias other than sustained ventricular tachycardia, including multifocal ectopy, ventricular triplets, supraventricular tachycardia, atrioventricular heart block, or bradyarrhythmias
- Exaggerated hypertensive response (systolic blood pressure >250 mm Hg and/or diastolic blood pressure >115 mm Hg)
- Development of bundle branch block that cannot be distinguished from ventricular tachycardia

Pharmacological stress testing

- Pharmacologic Stress Testing
- Vasodilators:

Dipyridamole

Adenosine

Regadenoson

- dobutamine

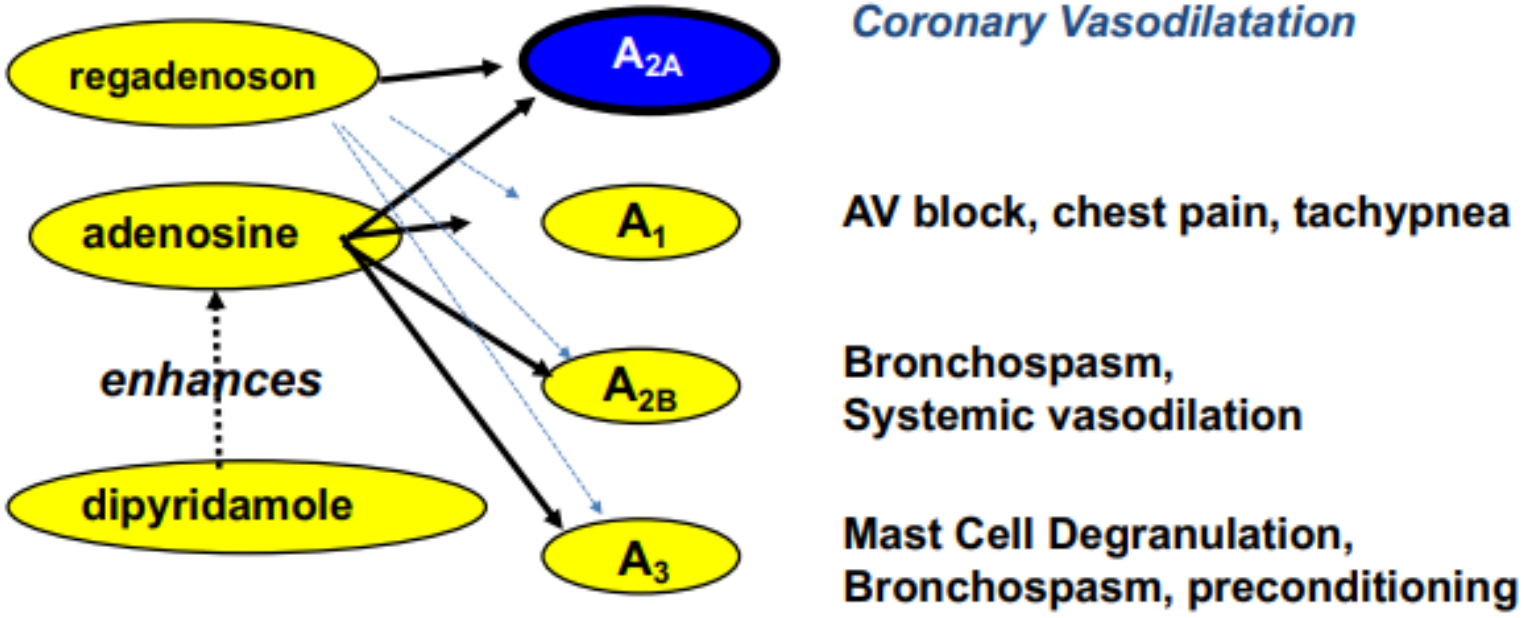
Indication pharmacologic stress testing

- Patient unable/unwilling to exercise
- Contraindications for exercise-abdominal aortic aneurism, severe AS
- LBBB/Pacemaker
- Interfering medications
- Post MI(>=1day) clinically stable patients

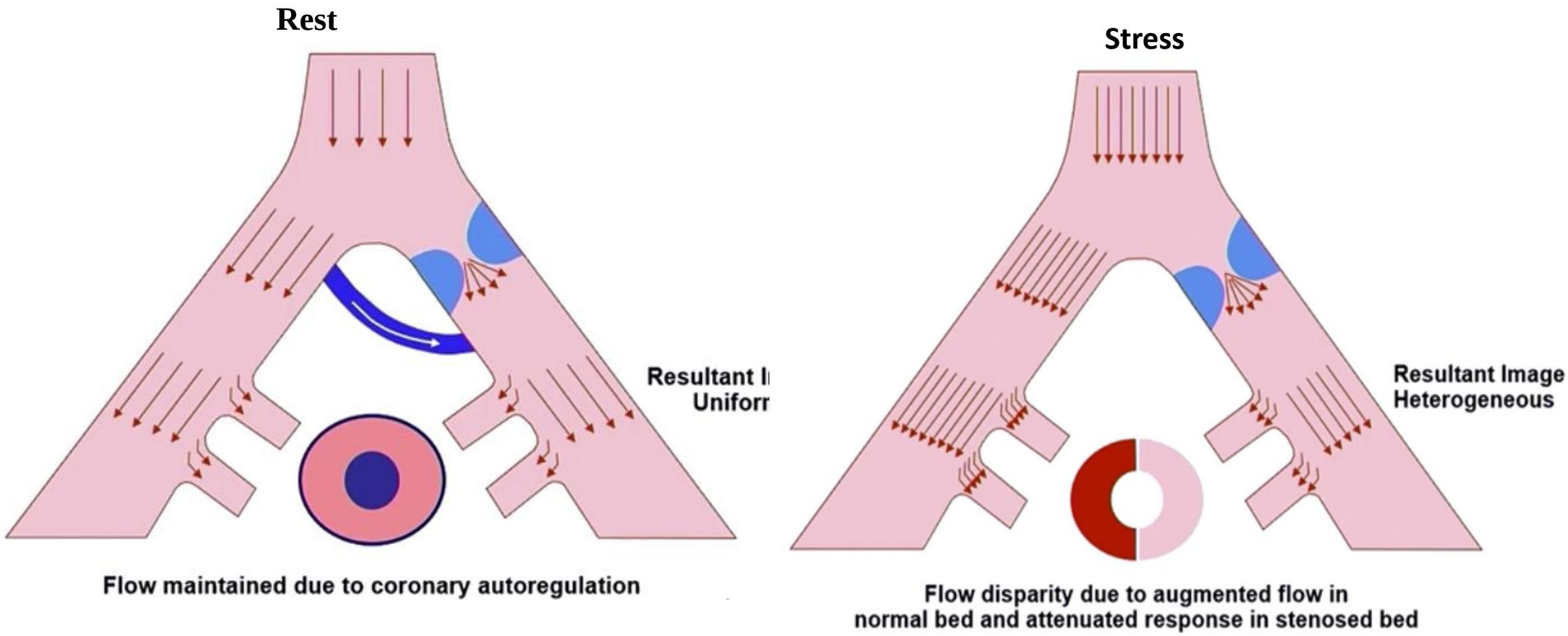
Preparation for pharmacological stress

- Nothing to eat for at least 3 hours
- Hold caffeine, Methylxanthines, theophylline and Oral dipyridamole for at least 12-24 hours prior to testing
- Can give IV dipyridamole

pharmacologic stress testing (vasodilator)



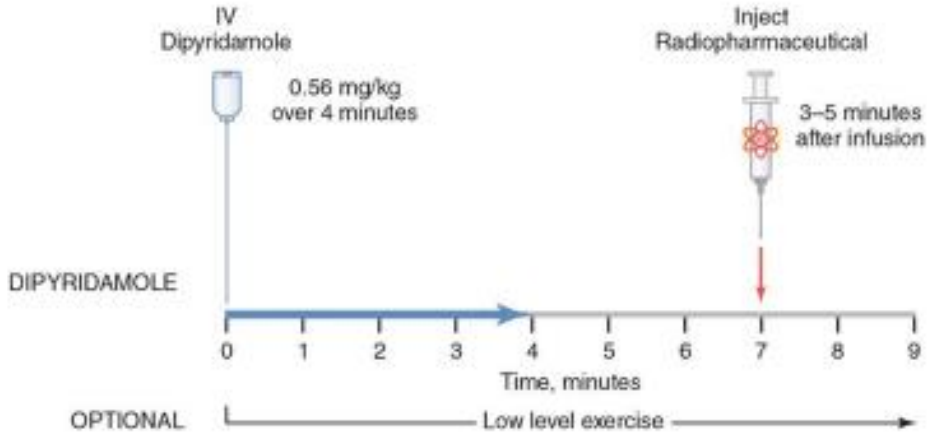
Coronary flow in patient with CAD in



Vasodilators

Dipyridamole

- Indirect coronary artery vasodilator
- Prevents intracellular reuptake of adenosine
- Half-life 33–62 minutes
- Hyperemia >15 minutes



Adenosine

- Coronary vasodilator-activation of cellular adenosine receptors
- A2 receptor on smooth muscle
- vasodilation 3.5-5 x’s blood flow
- Short half-life (2-10s vs.dipyridamole 33-62min)

Regadenoson

- A2a receptor agonist
- Low affinity for A1 (AV block)
- Very weak A2a and A3(Bronchospasm)
- Dose (0.4mg)
- Rapid injections (10s) with immediate flush
- Radionuclide agent 10-20s after flush

Contraindications to Dipyridamole/Adenosine

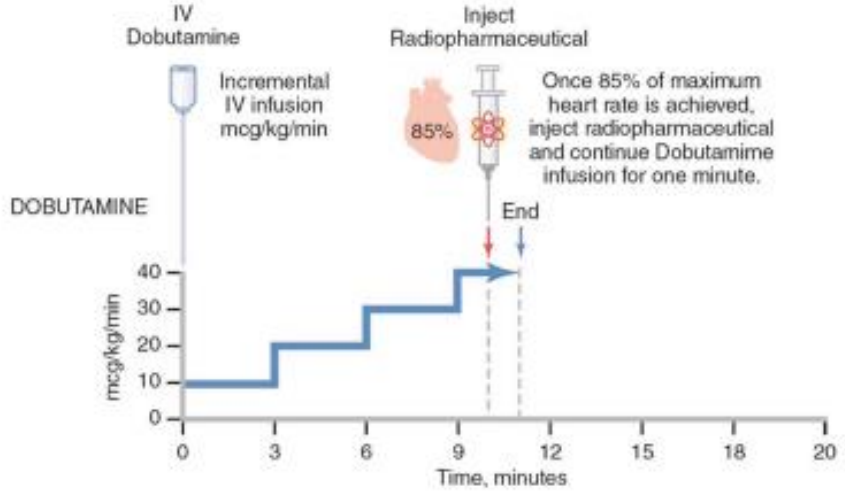
- Patient with bronchospatic lung disease
- Systolic BP less than 90mmHg
- Uncontrolled hypertension (systolic BP> 200mmHg or diastolic BP>110mmHg)
- Ingestion of caffeinated foods or beverages
- Known hypersensitivity to dipyridamole
- Unstable angina, acute coronary syndrome or less than 2 to 4days after an acute myocardial infraction

Dobutamine

- Direct weak β2 and α1 receptor agonist activity and a strong β1 agonist Dobutamine infusion results in direct related increase b1 and b2 stimulation with a dose in heart rate, BP, and myocardial contractility

- Onset of action is within 2 minutes of its infusion.

- Half-life 2-minute



Contraindications for dobutamine

- Unstable angina, acute coronary syndrome, or less than 2 to 4 days after an acute myocardial infarction.
- Hemodynamically significant left ventricular outflow tract obstruction
- Atrial tachyarrhythmias with uncontrolled ventricular response
- Prior history of ventricular tachycardia.
- Uncontrolled hypertension (systolic BP >200 mmHg or diastolic BP>110 mmHg)
- Patients with aortic dissection
- Known hypersensitivity to dobutamine

Image protocols

- 2-days 99mTc-agent protocol
- **same-day** 99mTc-agent protocol
- Dual isotope (^{201}Tl, 99mTc-sestamibi) same day protocol
- ^{201}Tl stress Reinjecion.
- ^{201}Tl redistribution protocol

Imaging protocols

- **One-day protocol**
- Low dose, high dose 99mTc-sestamibi same day protocol
  - Inject low dose of the tracer
  - Acquire image
  - Wait several hours for the tracers to decay
  - Inject a high dose of tracer for the patient
  - Acquire images again
  - Compare the pictures

- **2-days 99mTc-agent protocol**
  - Inject high dose of tracer for rest and stress
  - Wait 1 day between the stress & rest images
  - Better for obese patient

Different imaging protocols

- Dual isotope (^{201}Tl, 99mTc-sestamibi) same day protocol:
  - Inject ^{201}Tl at rest
  - Acquire images
  - Advantage is that ^{201}Tl & 99mTc-sestamibi gives up slightly different energy of photons so pictures from the rest wouldn't contaminate the picture at stress.
  - Problems includes more radioactive exposure and difficulty in comparing ^{201}Tl with ^{99m}Tc images.

- ^{201}Tl redistribution protocol
  - Stress the patient and inject the tracer at peak stress
  - Image the patient immediately
  - Wait 3-4 hours and image the patient again
  - Can wait 24hours to assess viability

Interpretation Sequence

- Review unprocessed data first
- Review myocardial slices: supine and prone breast up and breast down, AC & non-AC
- Quantitation
- ECG gated SPECT data

Raw Data

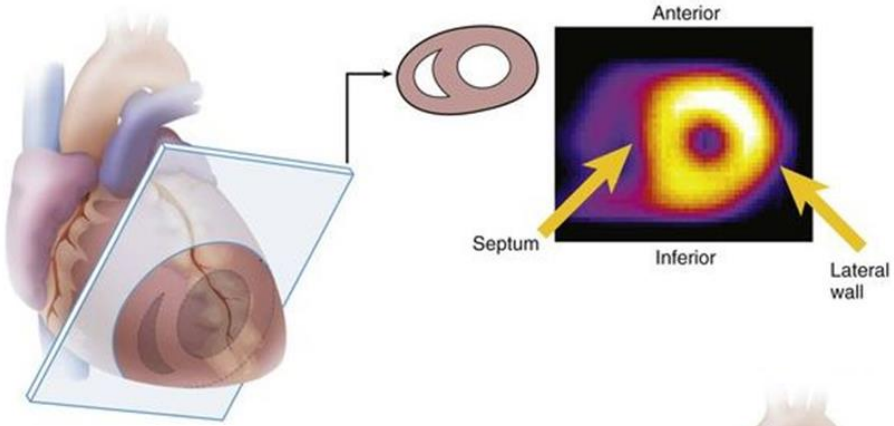
- Patient motion (vertical and horizontal)
- Lung uptake
- Count density
- Attenuation
- Extracardiac activity

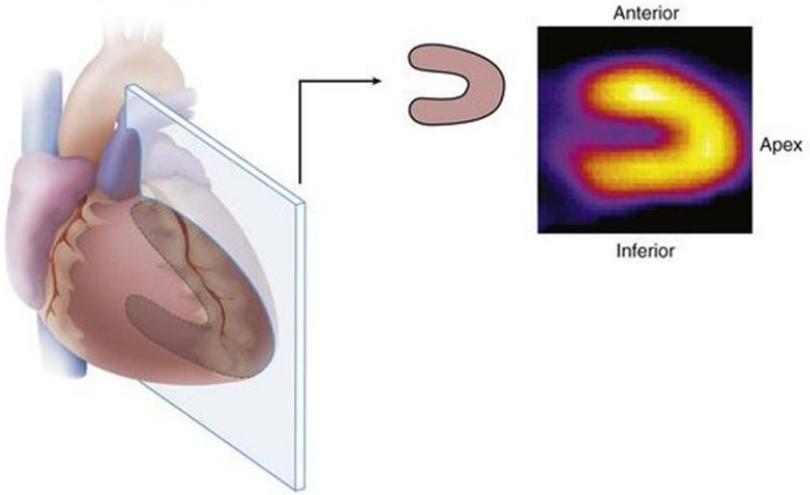
Ready

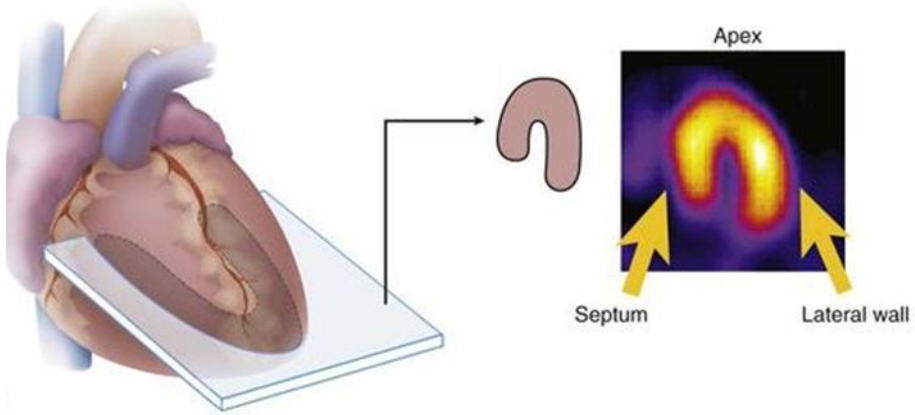
SPECT Images

- Confirm orientation
- Align slices
- Normalize intensity
- Cavity size: Assess dilatation, TID
- Evaluate relative perfusion (including RV)
- Confirm defect in multiple projections
- Determine severity and extent
- High-risk or multi-vessel distribution

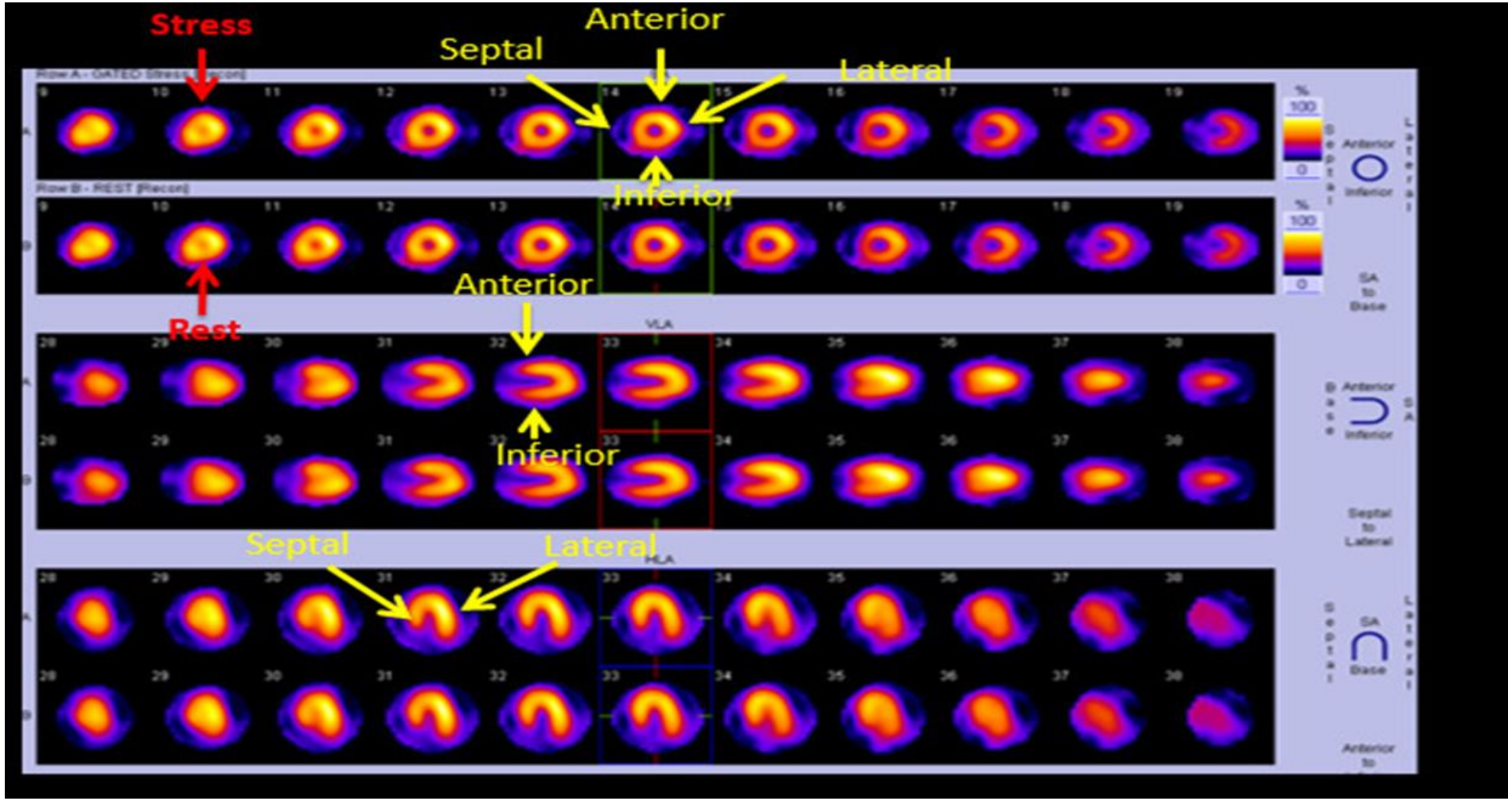
Standard SPECT imaging display



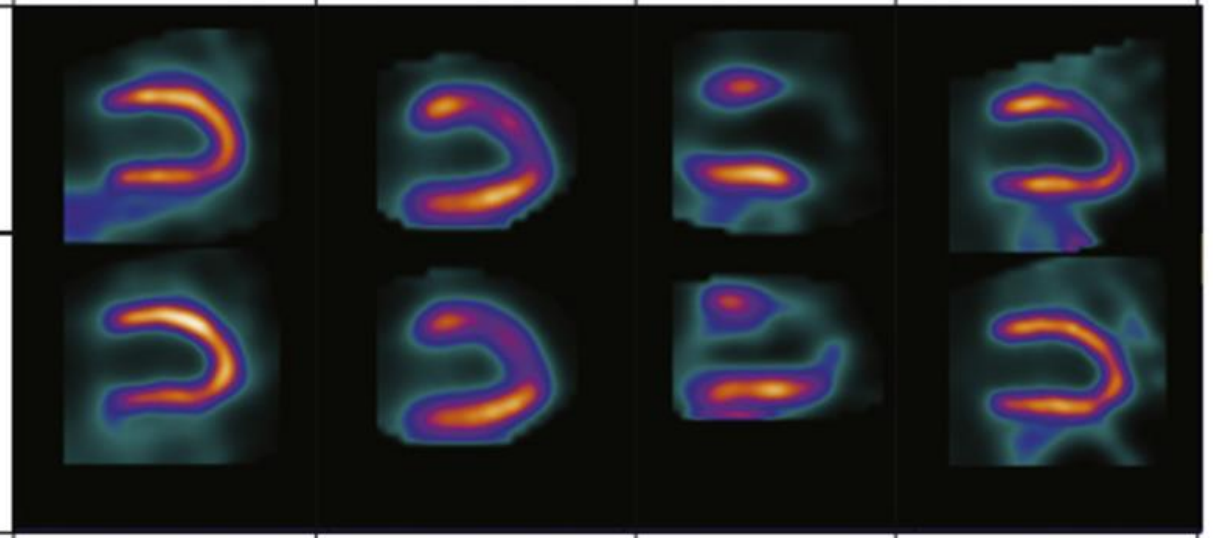




Standard SPECT imaging display



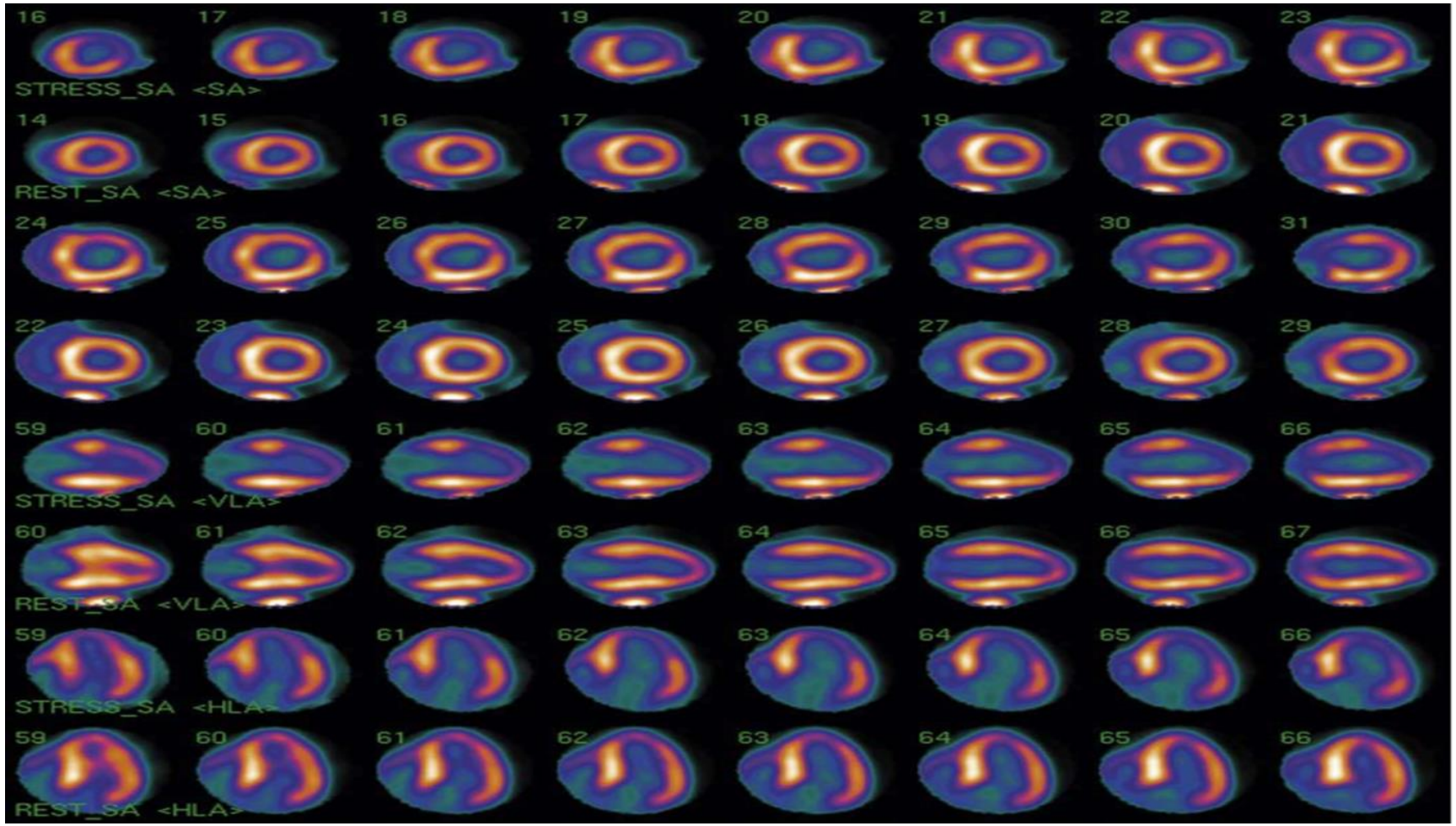
General Principles of interpretation

Interpretation	Normal	Attenuation artifact	Scar	Ischemia
Stress				
Rest				
Perfusion	No defects	Fixed defects	Fixed defects	Reversible defect
Wall motion	Normal	Normal	Abnormal	Normal or abnormal

Interpretation of MPI Images

- Interpretation should include:
  - Location
  - Size
  - Severity
  - Degree of reversibility
  - Number of defects that represent different vascular territories

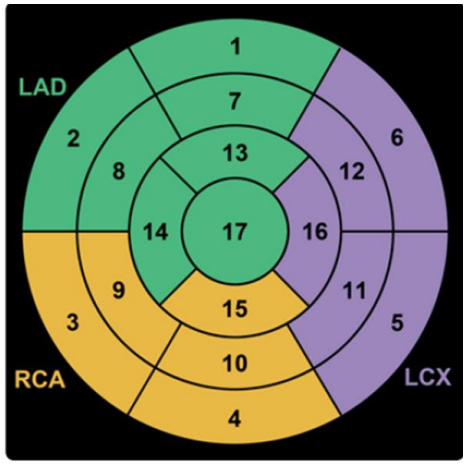
Reversible Ischemia in anterior lateral and apical myocardium



Extent and Severity

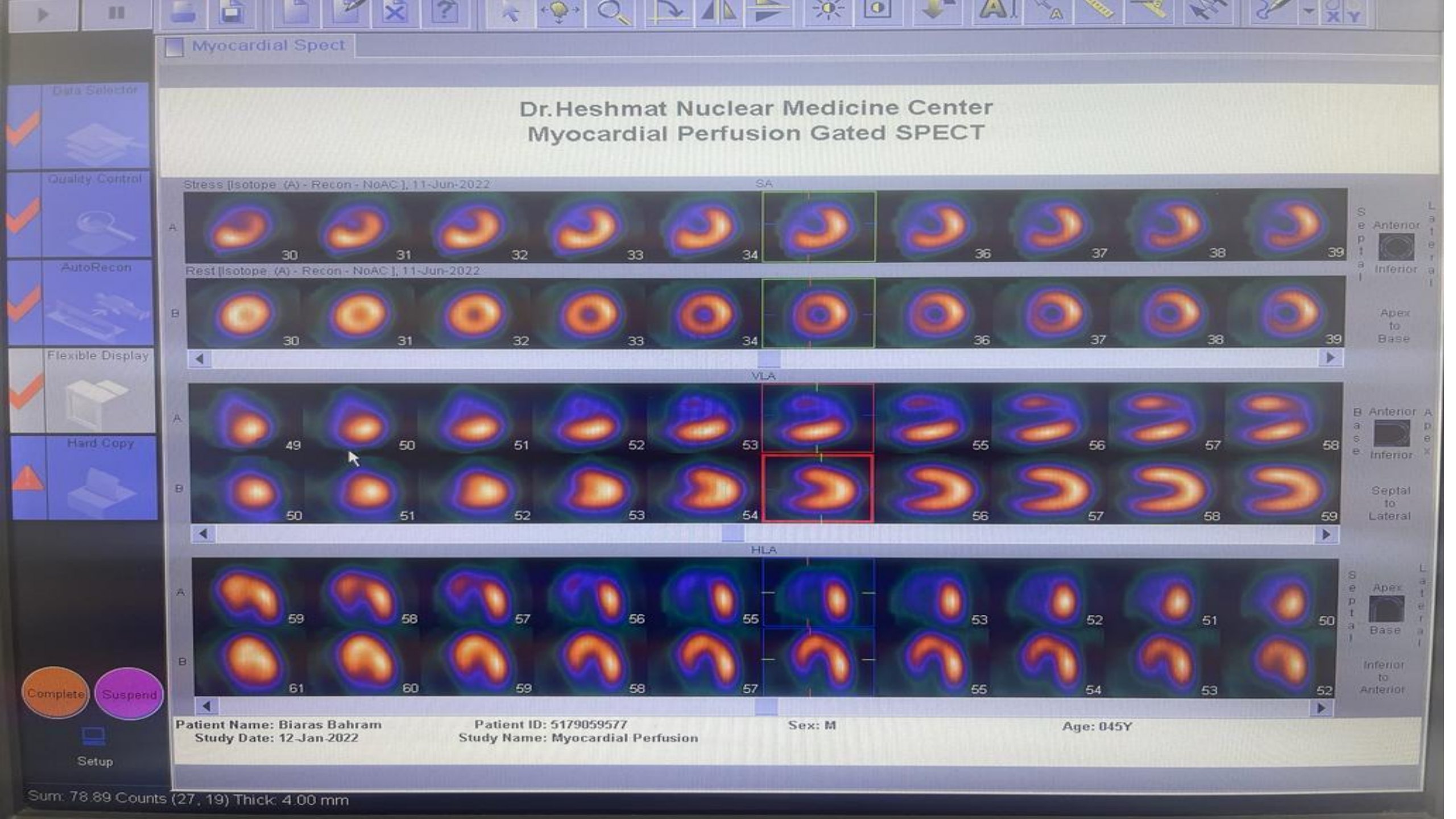
• **Severity qualitative**
– Mild decrease in counts compared to adjacent activity without the appearance of wall thinning
– Moderate: wall thinning
– Severe: defects that approach background activity

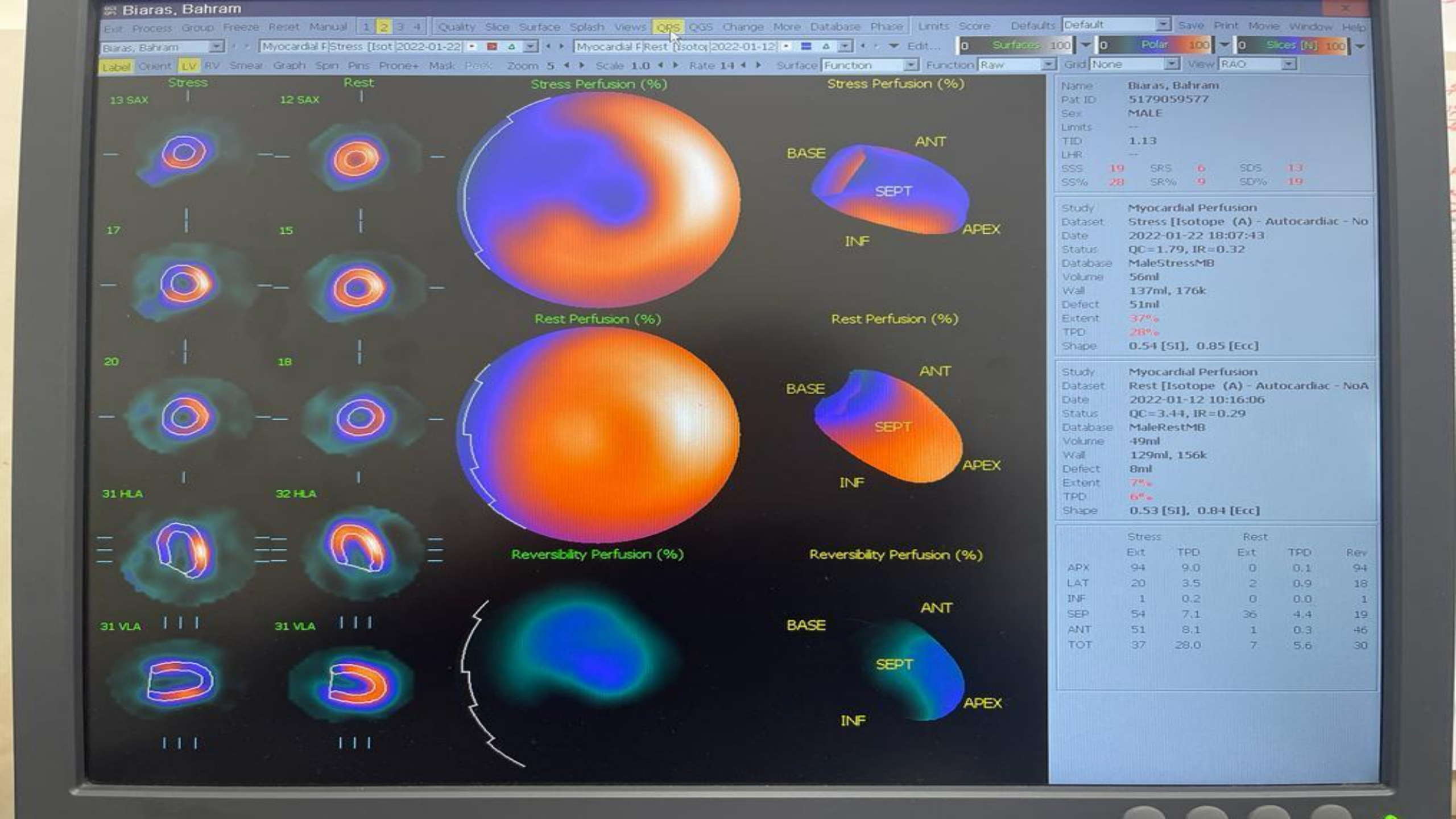
• **Severity semiquantitative**
– Normal perfusion 0
– Mild reduction in counts 1
– Moderate reduction in counts 2
– Severe reduction in counts 3
– Absent uptake 4

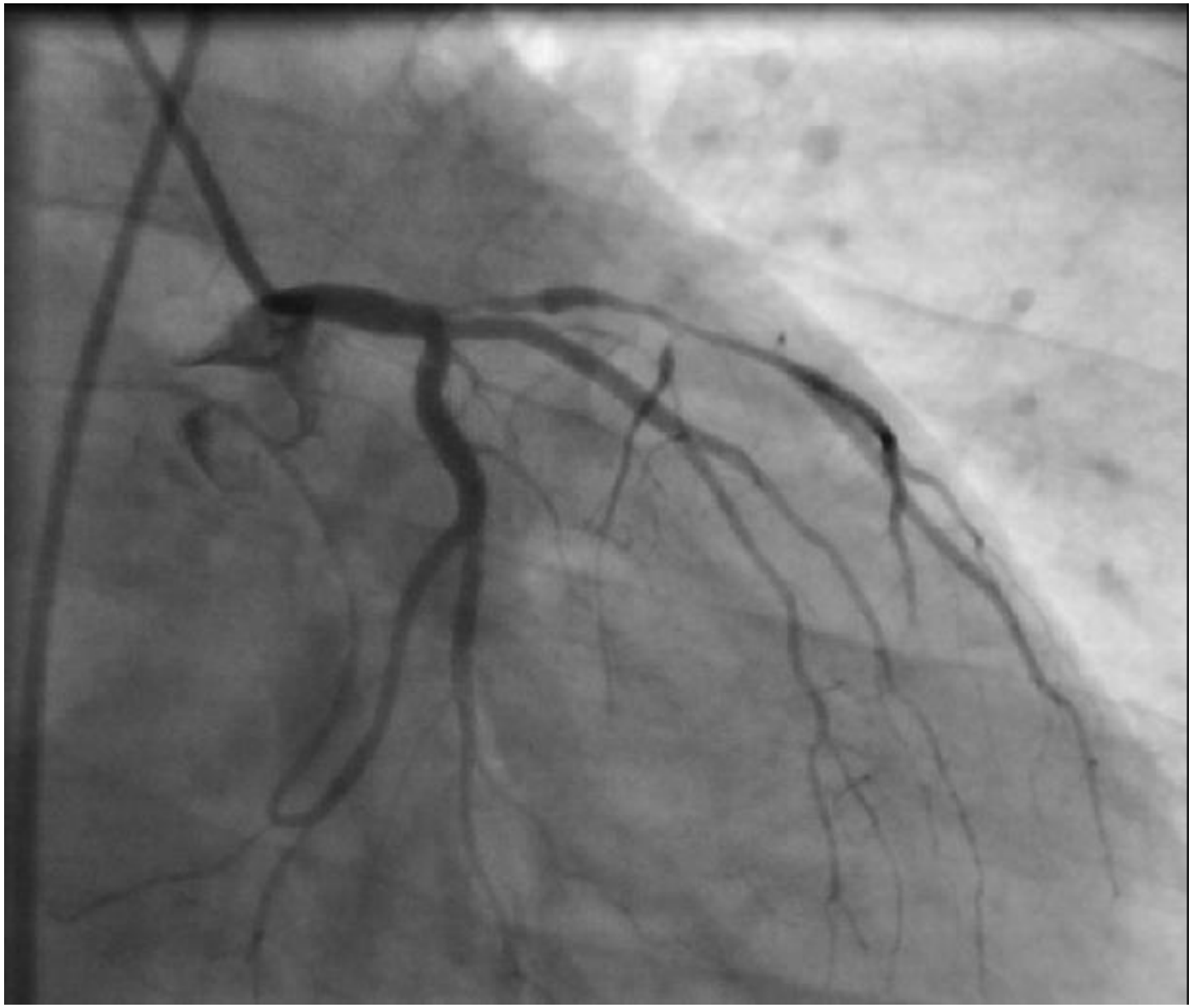


Semiquantitative Analysis

- Summed Stress Score (SSS)
- – Extent and severity of CAD
- – SSS = S stress segmental scores
- • Summed Rest Score (SRS)
- – Extent and severity of infarction
- – SRS = S rest segmental scores
- • Summed Difference Score (SDS)
- – Extent and severity of ischemia/reversibility
- – SDS = SSS – SRS


Myocardial Spect
Data Selector
Quality Control
AutoRecon
Flexible Display
Hard Copy
Complete
Suspend
Setup
Dr.Heshmat Nuclear Medicine Center
Myocardial Perfusion Gated SPECT
Stress [Isotope (A) - Recon - NoAC], 11-Jun-2022
SA
Rest [Isotope (A) - Recon - NoAC], 11-Jun-2022
VLA
HLA
Anterior
Inferior
Septal
Lateral
Apex to Base
Septal to Lateral
Inferior to Anterior
Patient Name: Biaras Bahram
Study Date: 12-Jan-2022
Patient ID: 5179059577
Study Name: Myocardial Perfusion
Sex: M
Age: 045Y
Sum: 78.89 Counts (27, 19) Thick: 4.00 mm

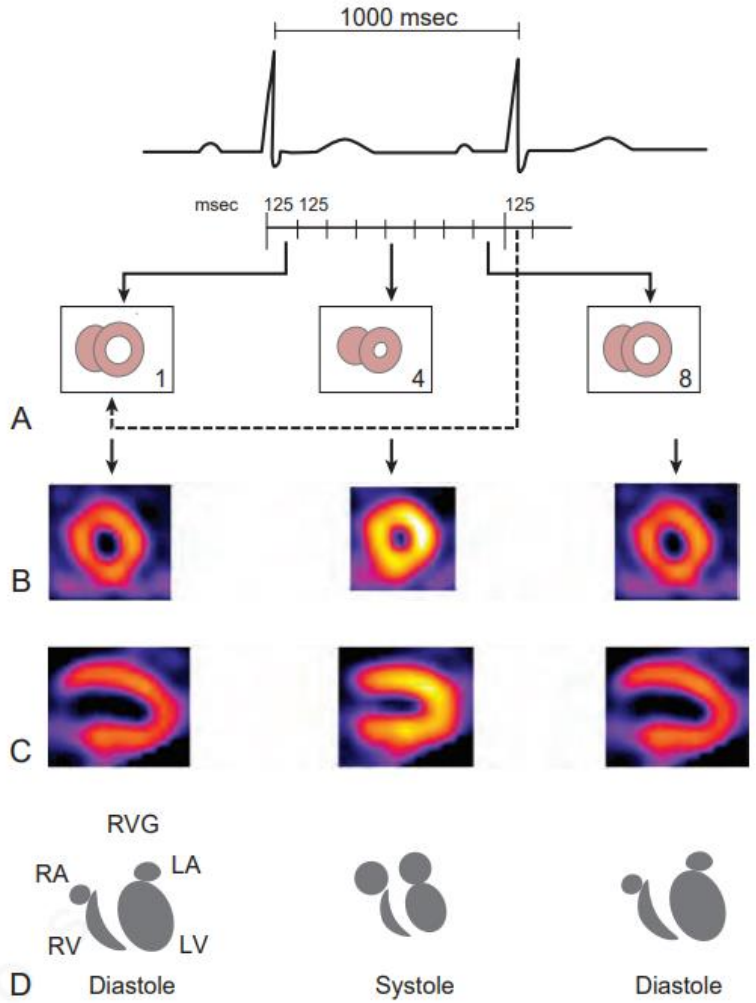

Biaras, Bahram
Stress
Rest
13 SAX
12 SAX
17
15
20
18
31 HLA
32 HLA
31 VLA
31 VLA
Stress Perfusion (%)
Stress Perfusion (%)
BASE
ANT
SEPT
APEX
INF
Rest Perfusion (%)
Rest Perfusion (%)
BASE
ANT
SEPT
APEX
INF
Reversibility Perfusion (%)
Reversibility Perfusion (%)
BASE
ANT
SEPT
APEX
INF
Name Biaras, Bahram
Pat ID 5179059577
Sex MALE
Limits --
TID 1.13
LHR --
SSS 19 SRS 6 SDS 13
SS% 28 SR% 9 SD% 19
Study Myocardial Perfusion
Dataset Stress [Isotope (A) - Autocardiac - No
Date 2022-01-22 18:07:43
Status QC=1.79, IR=0.32
Database MaleStressMB
Volume 56ml
Wall 137ml, 176k
Defect 51ml
Extent 37%
TPD 28%
Shape 0.54 [SI], 0.85 [Ecc]
Study Myocardial Perfusion
Dataset Rest [Isotope (A) - Autocardiac - NoA
Date 2022-01-12 10:16:06
Status QC=3.44, IR=0.29
Database MaleRestMB
Volume 49ml
Wall 129ml, 156k
Defect 8ml
Extent 7%
TPD 6%
Shape 0.53 [SI], 0.84 [Ecc]
Stress Rest
Ext TPD Ext TPD Rev
APX 94 9.0 0 0.1 94
LAT 20 3.5 2 0.9 18
INF 1 0.2 0 0.0 1
SEP 54 7.1 36 4.4 19
ANT 51 8.1 1 0.3 46
TOT 37 28.0 7 5.6 30



Summed Stress Score

SSS	Event rate
<4 normal	0.3%
4–8 (mildly abnormal)	4.7%
9-13 (moderate) >=13 (severely)	10%

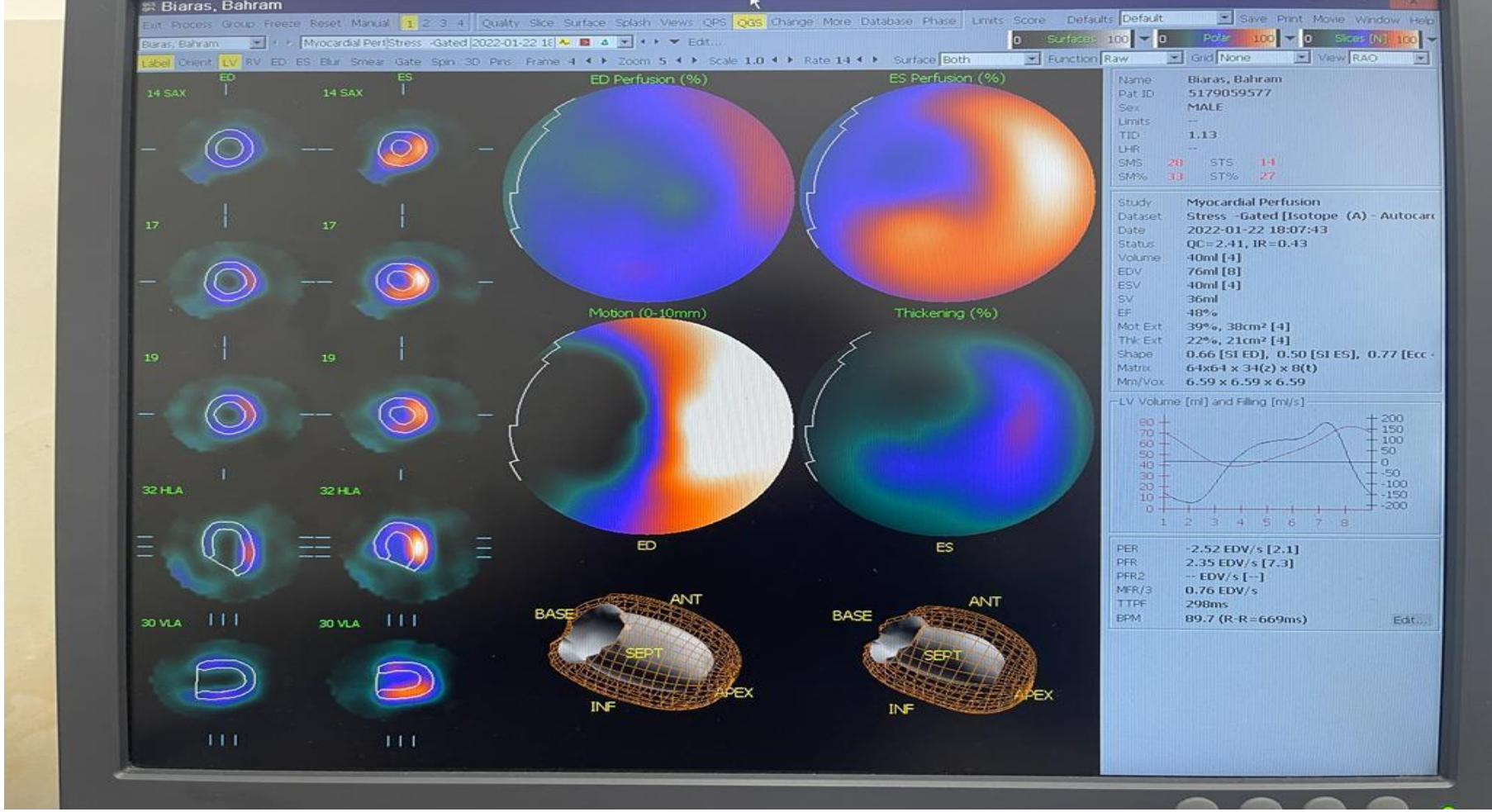
ECG gating


1000 msec
msec
125 125
125
1
4
8
A
B
C
RVG
RA
LA
RV
LV
D
Diastole
Systole
Diastole

Gating data

parameter	Systolic	Diastolic
Global	LVEF: Post stress/optional rest EDV ESV SWM SWT Phase	PFR, TPFR,PER, TPER, TTPF
Regional	WM WT Phase	-

Semiquantetive assessment of wall motion
0 = Normal motion
1 = Mild hypokinesis
2 = Moderate hypokinesis
3 = Severe hypokinesis
4 = Akinesis
5 = Dyskinesis



Semiquantative assessment of wall thickening
0- normal
1= mild reduction
2=Moderate or severe reduction
3= Absence of noticeable thickness increase

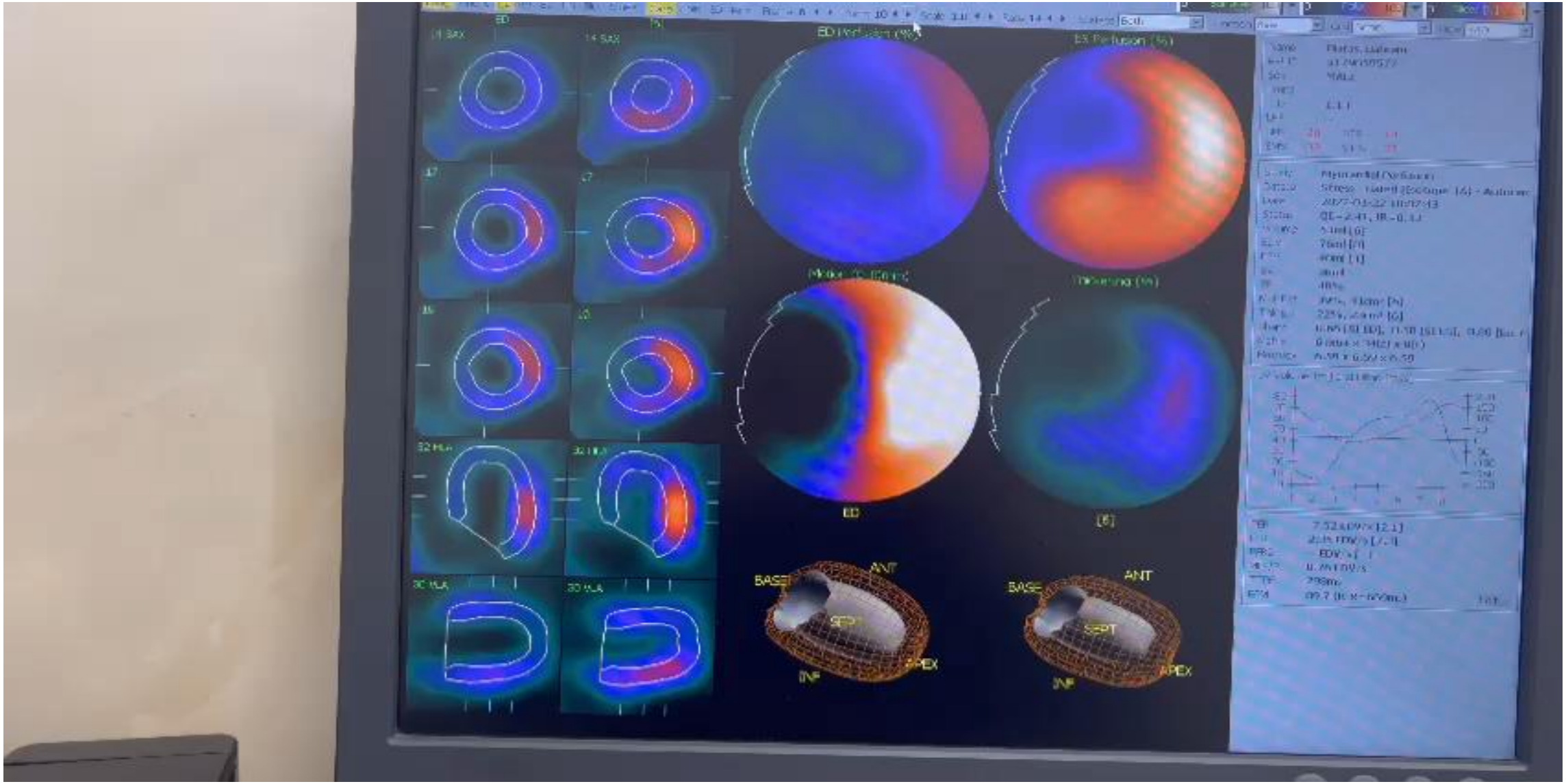

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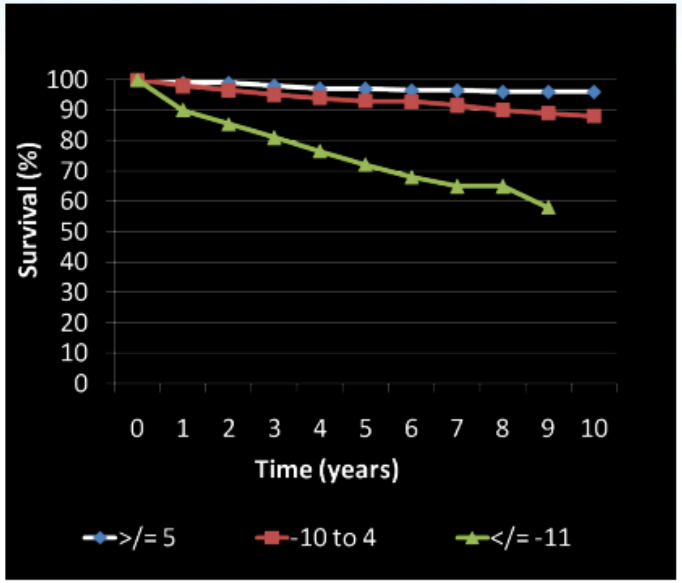
TABLE 18.4 High-Risk Features

Myocardial Perfusion Imaging
Large single or multiterritorial fixed and/or reversible myocardial perfusion defects involving >15% of the LV mass
Transient ischemic dilation of the left ventricle
Stress-induced myocardial stunning with a drop in LVEF poststress
Transient RV tracer uptake
Increased pulmonary tracer uptake
Stress Test
Significant (>3 mm) ST-segment depression
Prolonged ST-segment depression
ST depression at low workload
Multilead ST depression
ST-segment elevation (>1 mm)
Hypotension (>10 mm Hg) with exercise
Sustained ventricular tachycardia

LVEF, Left ventricular ejection fraction; *RV,* right ventricular.

If ST dep <0.5 give 0

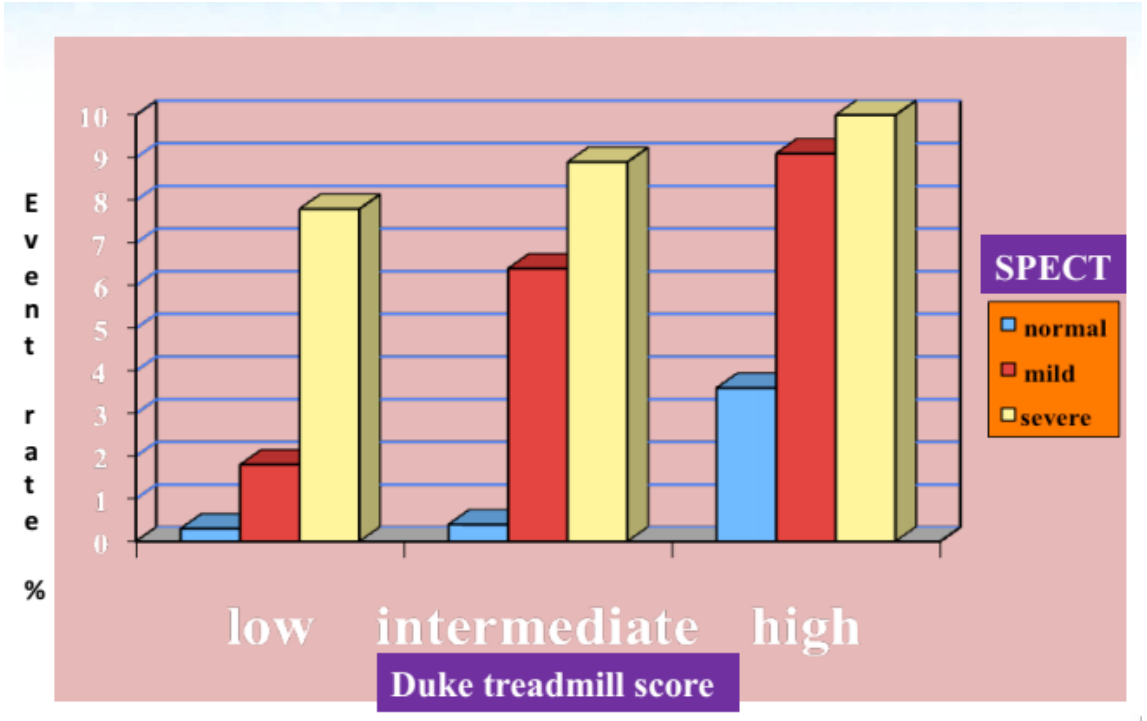


Score ≤-11 = 5 year survival 72%

Score ≥+5 = 5 year survival 97%

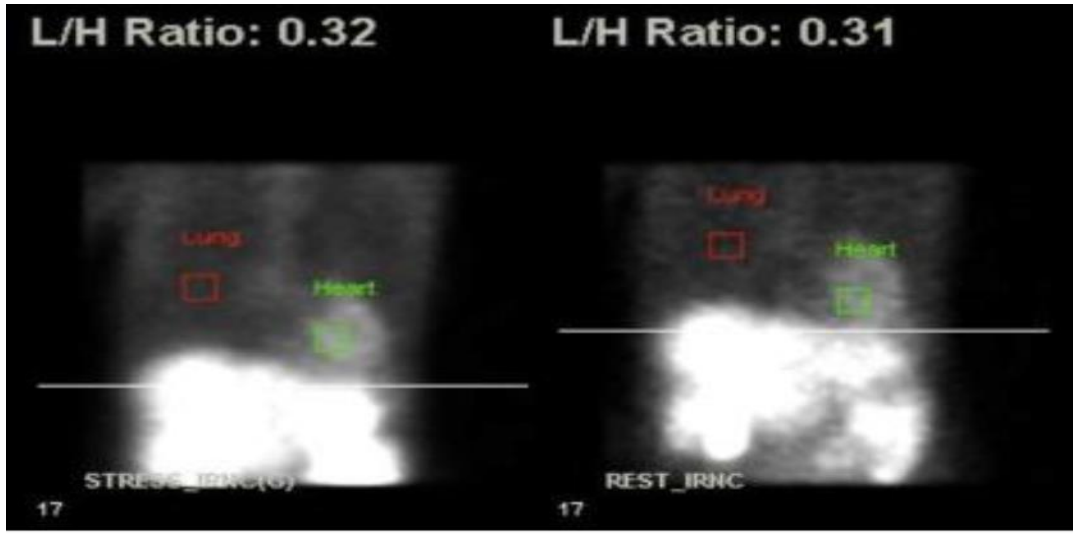
Duke Treadmill Score

= Exercise Time (min) – 5 x Maximal ST depression (mm) – 4 x Angina Index Angina Index (No angina = 0, Angina = 1, Limiting Angina = 2)



Lung uptake

- increased lung uptake (lung -to heart- ratio) > 0.5 for ^{201}Tl and >0.4 for ^{99m}Tc-MIBI
- It is associated with an elevated left ventricular end-diastolic pressure, and indicates exercise-induced ischemia left ventricular dysfunction and severe multi-vessel CAD.
- lung uptake is also observed after pharmacologic stress and has a similar unfavorable significance.
- Not surprisingly, increased lung uptake occurs also in patients with severely decreased resting LVEF, with or without demonstrable exercise-induced ischemia



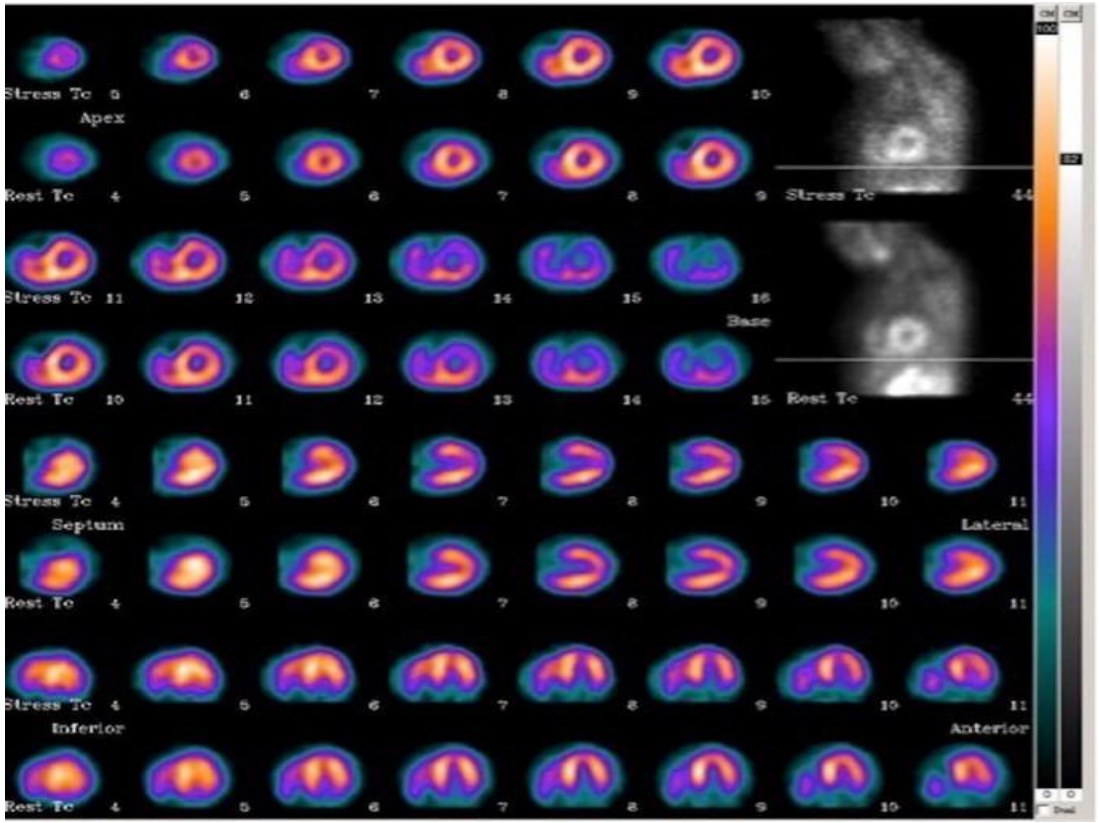
Transient Left Ventricular Dilation

This pattern is more likely caused by apparent thinning of the myocardium by circumferential endocardial ischemia rather than true and persistent dilation of the left ventricular cavity.

At times this image pattern may occur without apparent regional perfusion abnormalities.

Transient Right Ventricular Visualization

- This pattern indicates ischemic left ventricular dysfunction during exercise.
- The mechanism responsible for this indicating remains unknown but may involve either increased right ventricular strain or a relative decrease in count intensity in the left ventricle due to diffuse hypoperfusion.



THANK YOU
FOR YOUR
ATTENTION