Nuclear Cardiology

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Myocardial Perfusion Scintigraphy

- The most commonly performed cardiac nuclear study
- 1/3 of all nuclear medicine procedures done in USA

Myocardial Perfusion Scintigraphy

- **Evaluates two sequential physiological events:**
  - **Myocardial perfusion**
  - **Myocardial viability**

Radiopharmaceuticals

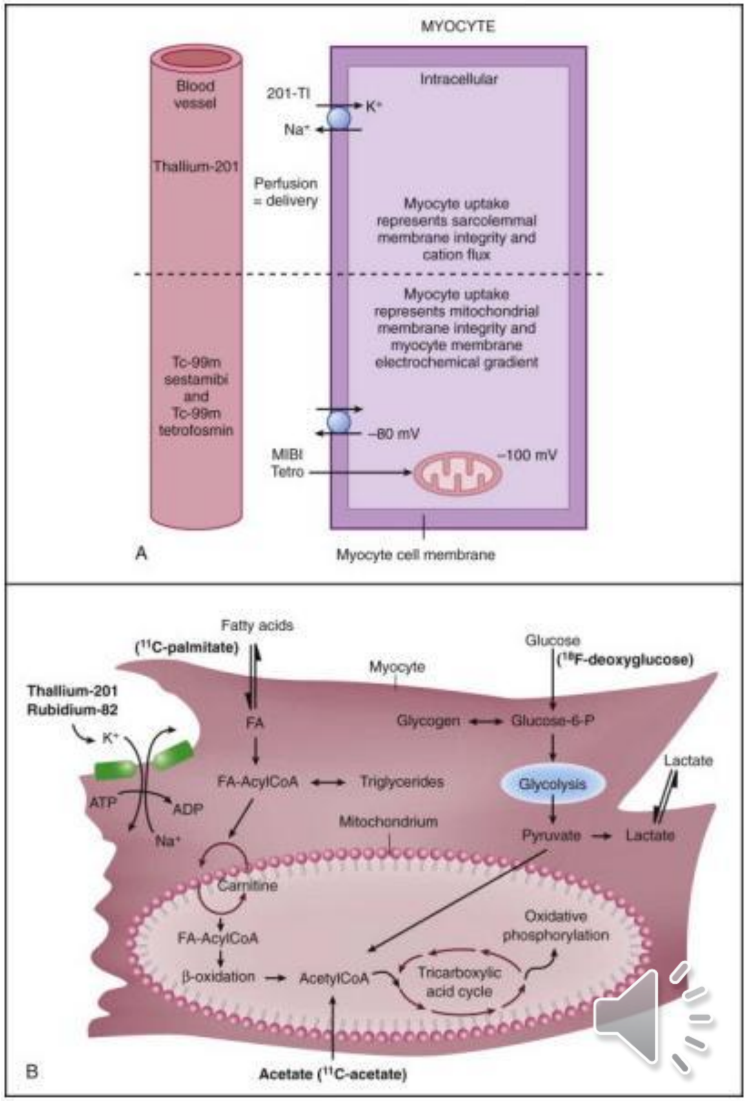
Box 14-1 Physical Characteristics of Thallium-201 and Technetium-99m (Sestamibi and Tetrofosmin)

Physical Characteristic	Thallium-201	Tc-99m (Sestamibi and Tetro-fosmin)
Mode of decay	Electron capture	Isomeric transition
Physical half-life	73 hours	6 hours
Principal emissions (abundance)*	Mercury x-rays 69–83 keV Gamma rays 167 keV (10%) 135 keV (2.7%)	Gamma rays 140 keV (89%)

*Abundance is the percentage of time each emission type that occurs with each decay.

Tc-99m Sestamibi (Cardiolite)
Mechanism of Localization and Uptake

- Lipid soluble
- Diffuses from the blood into the myocardial cell
- Retained in the region of mitochondria because of its negative transmembrane potential
- The first-pass extraction fraction is lower than that of Tl-201, approximately 60%.
- As with Tl-201, extraction is proportional to coronary flow and is underestimated at high flow rates and overestimated at low flow.



Scintigraphic Methodology

- Planar Imaging (Two dimentional)
- Tomographic imaging (SPECT)

Normal Planar Scan

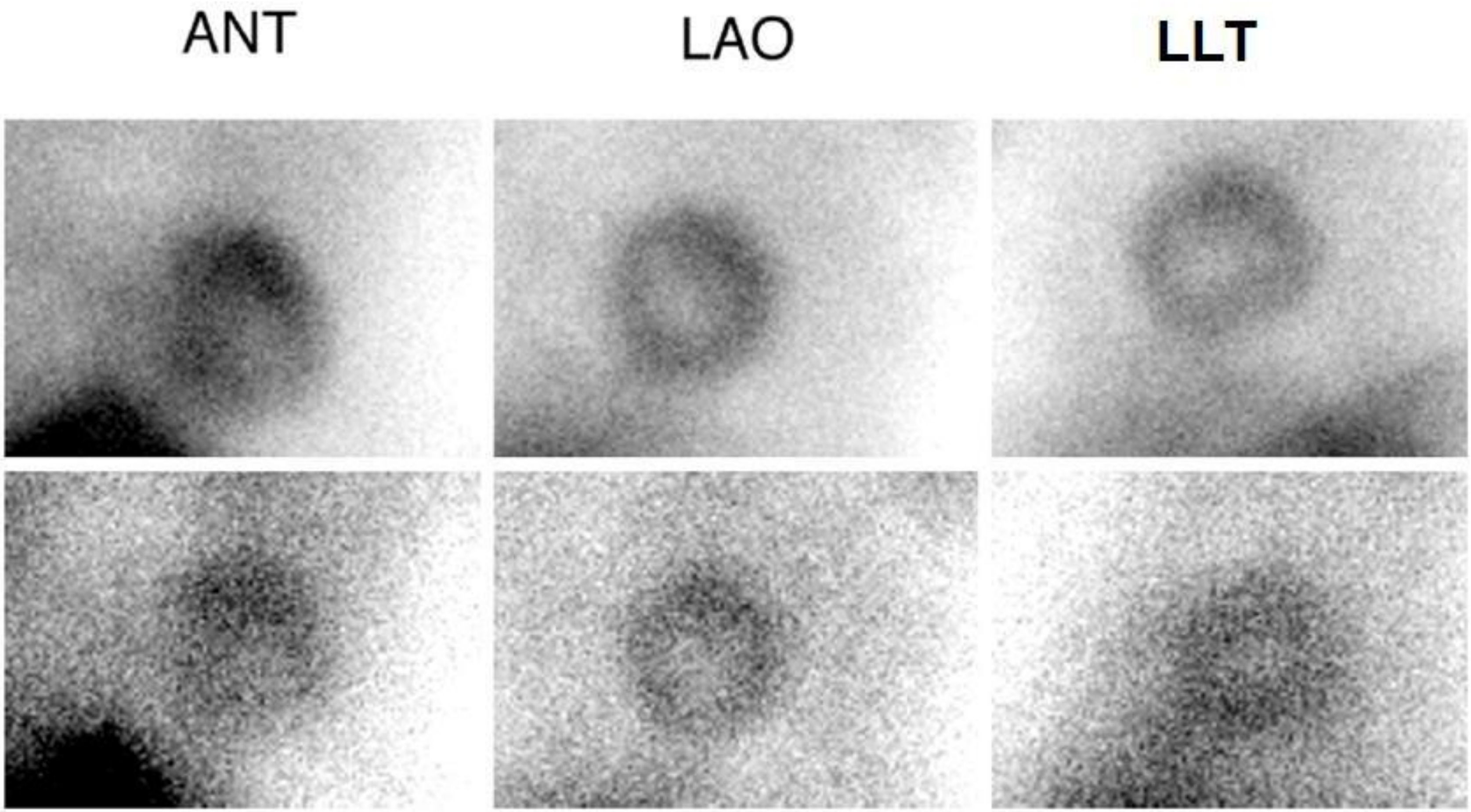
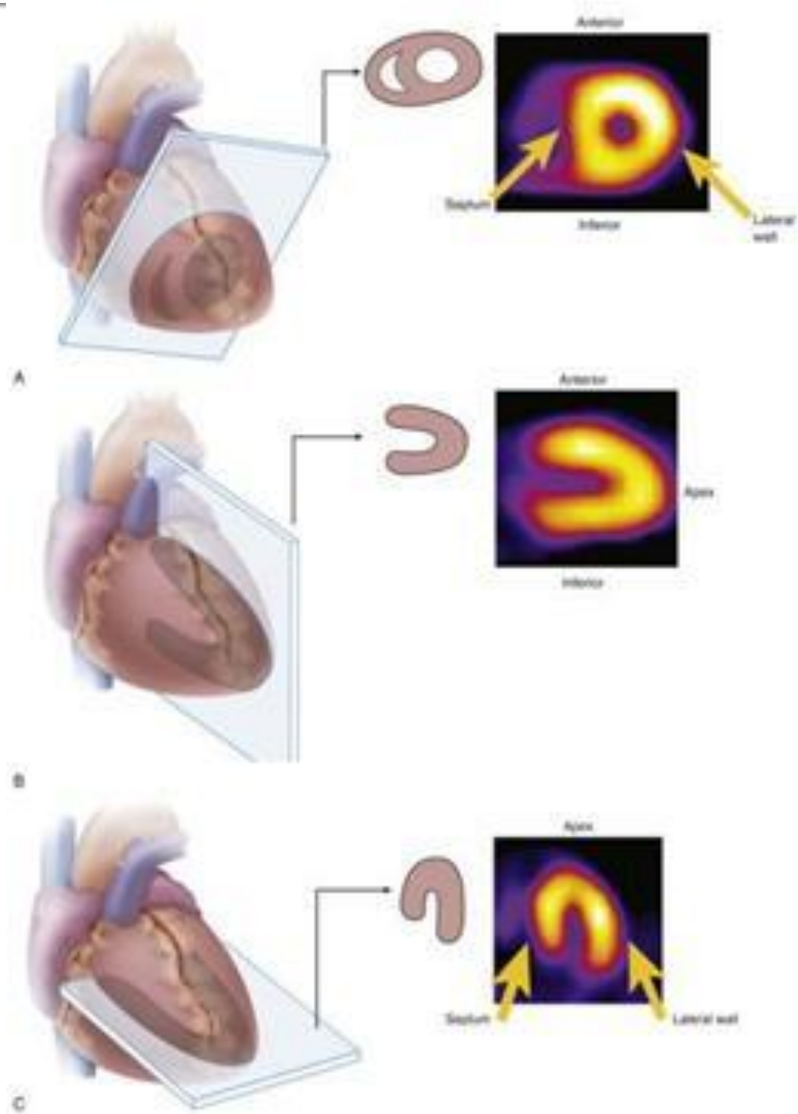


Figure 14-5 Planar stress and rest Tc-99m sestamibi scintigraphy. The rest images are considerably noisier because of the lower administered dose (8 mCi) compared to the stress images (25 mCi). The images should be acquired so that the three planar views (anterior, left anterior oblique, left lateral) are identical for optimal comparison. This study was interpreted as normal.

Standard LV Walls Slices in MPS



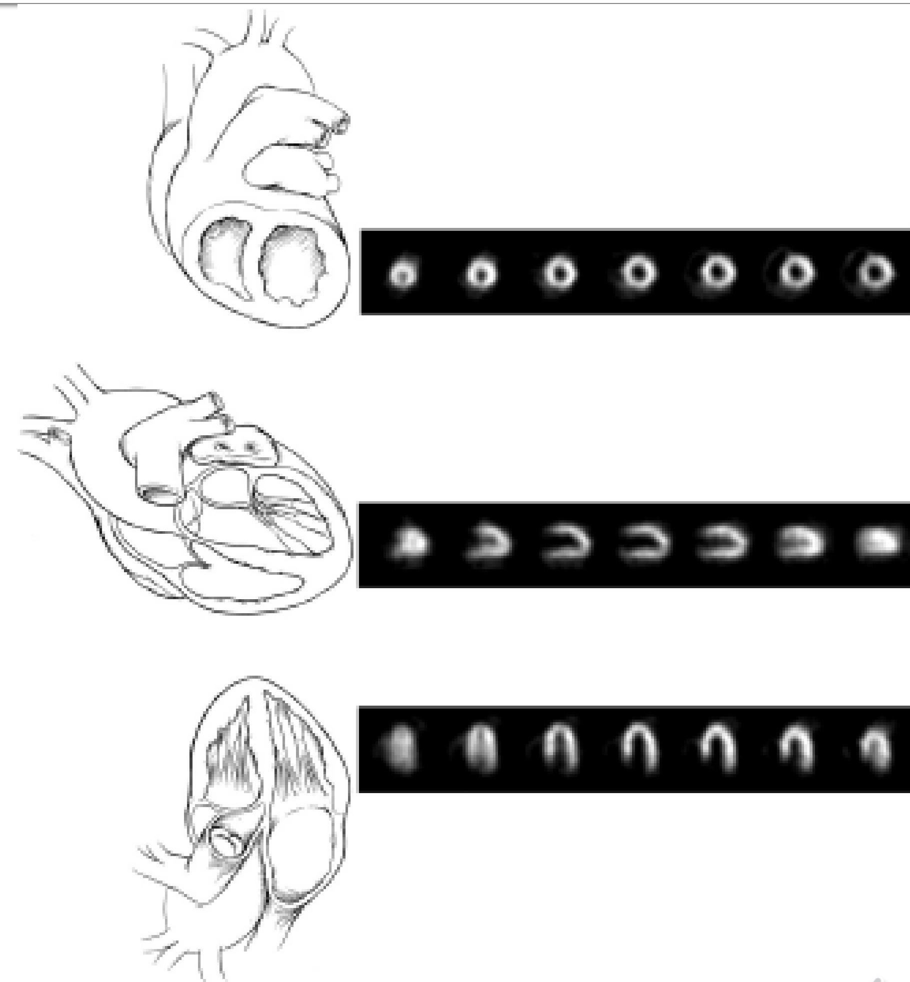


Figure 14-11 Standard display of SPECT cross-sectional images correlated with cardiac anatomy. The planes are cut along the short and long axis of the heart, top (short-axis), middle (vertical long axis), bottom (horizontal long axis). The left ventricle is best seen due to its greater myocardial mass; the right ventricle is less well seen and the display emphasizes the left ventricle. Atria are not visualized.

17 Segment Map of LV walls

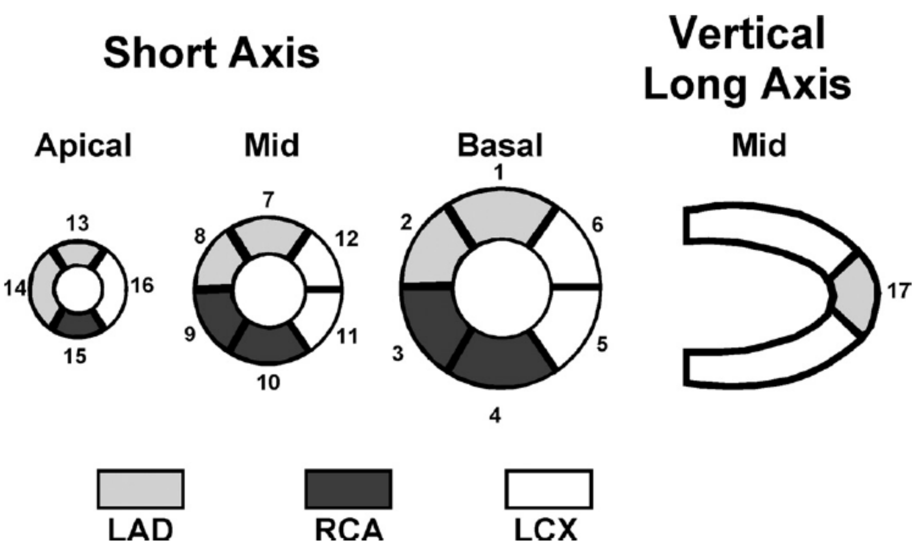


Figure 14-12 Standardization of SPECT myocardial segments. This is the method recommended and published in *Circulation* and the *Journal of Nuclear Cardiology* in an attempt to standardize the regions of the myocardium into 17 regions for all cardiac imaging. The diagram also correlates coronary artery anatomy with regional perfusion. However, some computer software systems use a different number of regions. (Modified with permission from Cerqueira MD, Weissman J, Dilsizian V, et al: J Nucl Card 2:240–245, 2002.)

Box 14-4 Scintigraphic Patterns for Specific Vascular Distributions: Stenosis and Obstruction

Coronary Artery	Scintigraphic Perfusion Defects
Left anterior descending	Septum, anterior wall, apex
Left circumflex	Lateral wall, posterior wall, posterior inferior wall, apex
Right coronary	Inferior wall, posterior inferior wall, right ventricular wall
Left main coronary	Anterior wall, septum, posterolateral wall
Multiple-vessel disease	Multiple vascular bed perfusion defects
	Post stress ventricular dilatation and increased Tl-201 lung uptake

Gated SPECT

- Gated SPECT adds a cinematic three dimensional display of the contracting myocardium.
- Data collection is triggered from the R-wave of the ECG.

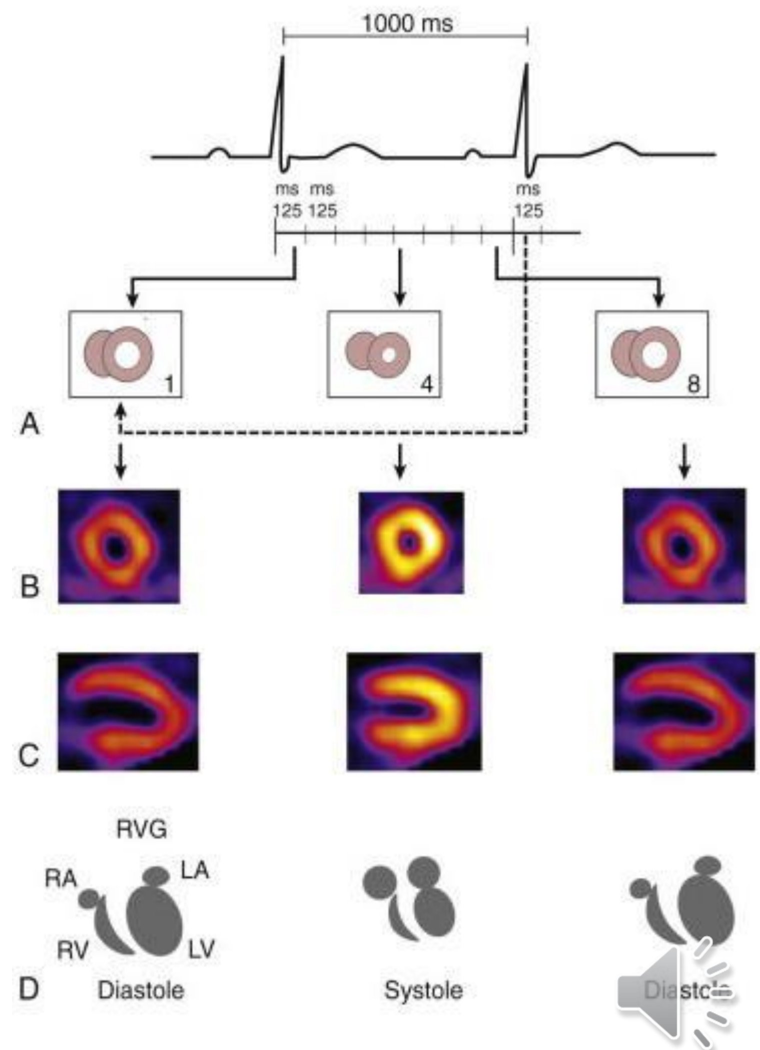
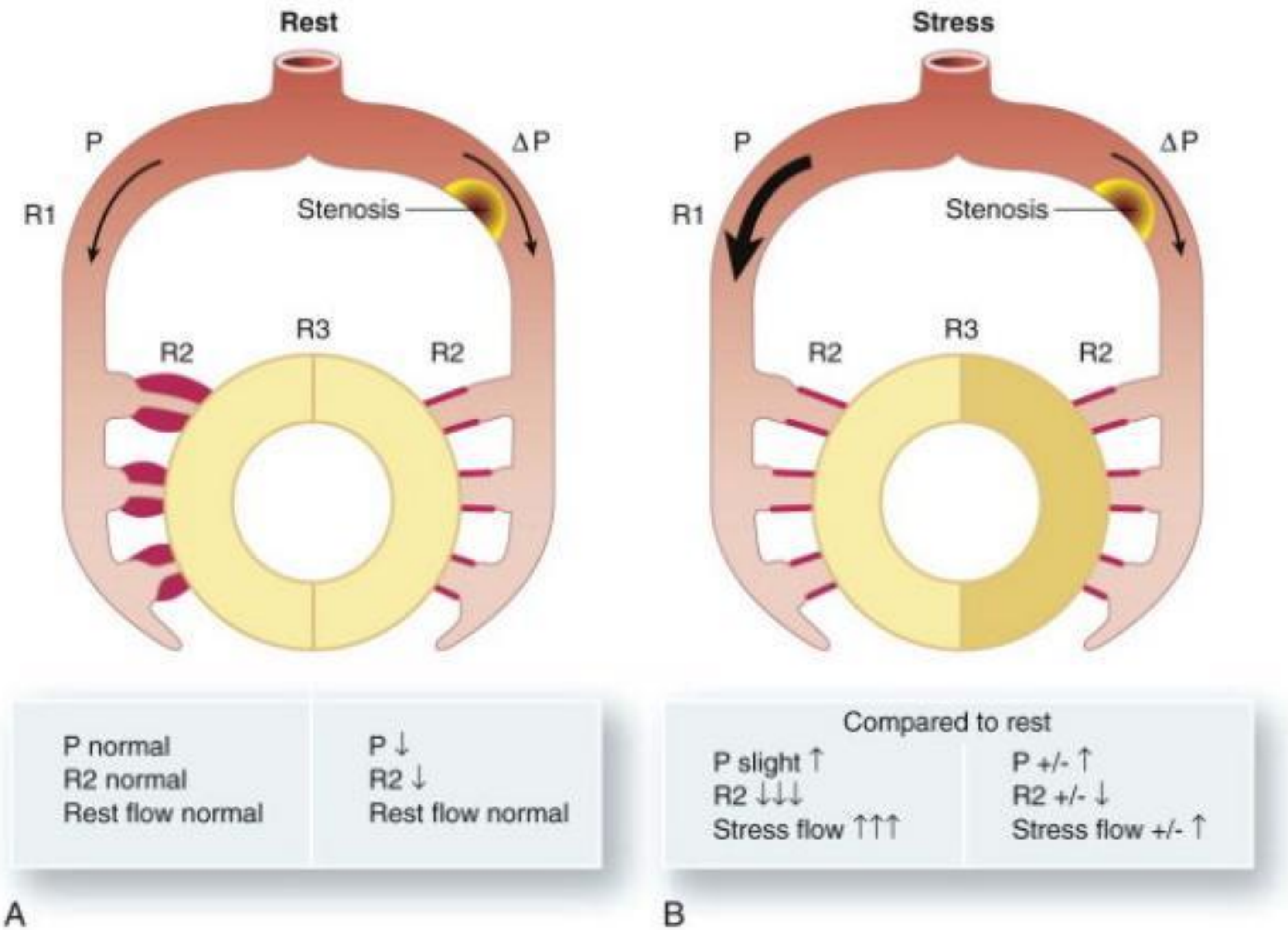


FIGURE 17-16 Basis for the technique of ECG gating. A, The scintigraphic a

Autoregulation of Arteriolar Blood Flow



Basis of Stress Imaging

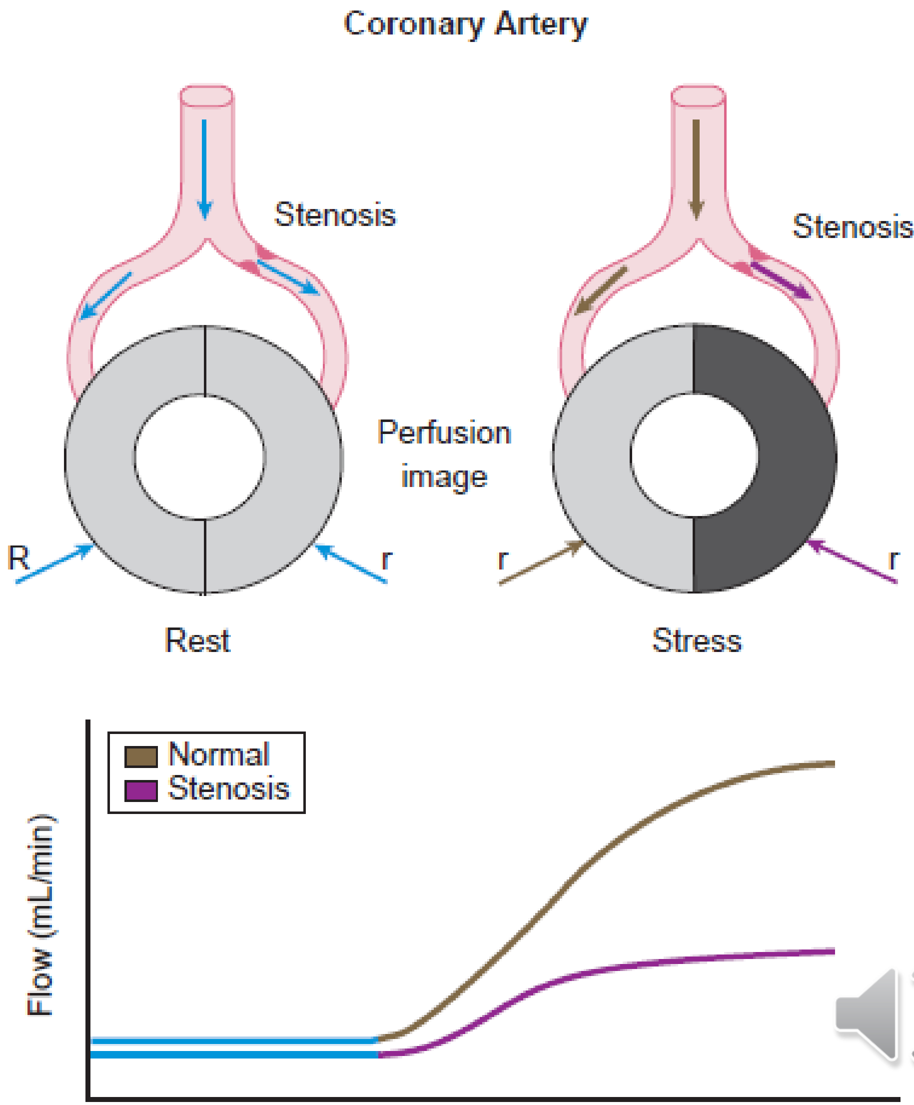
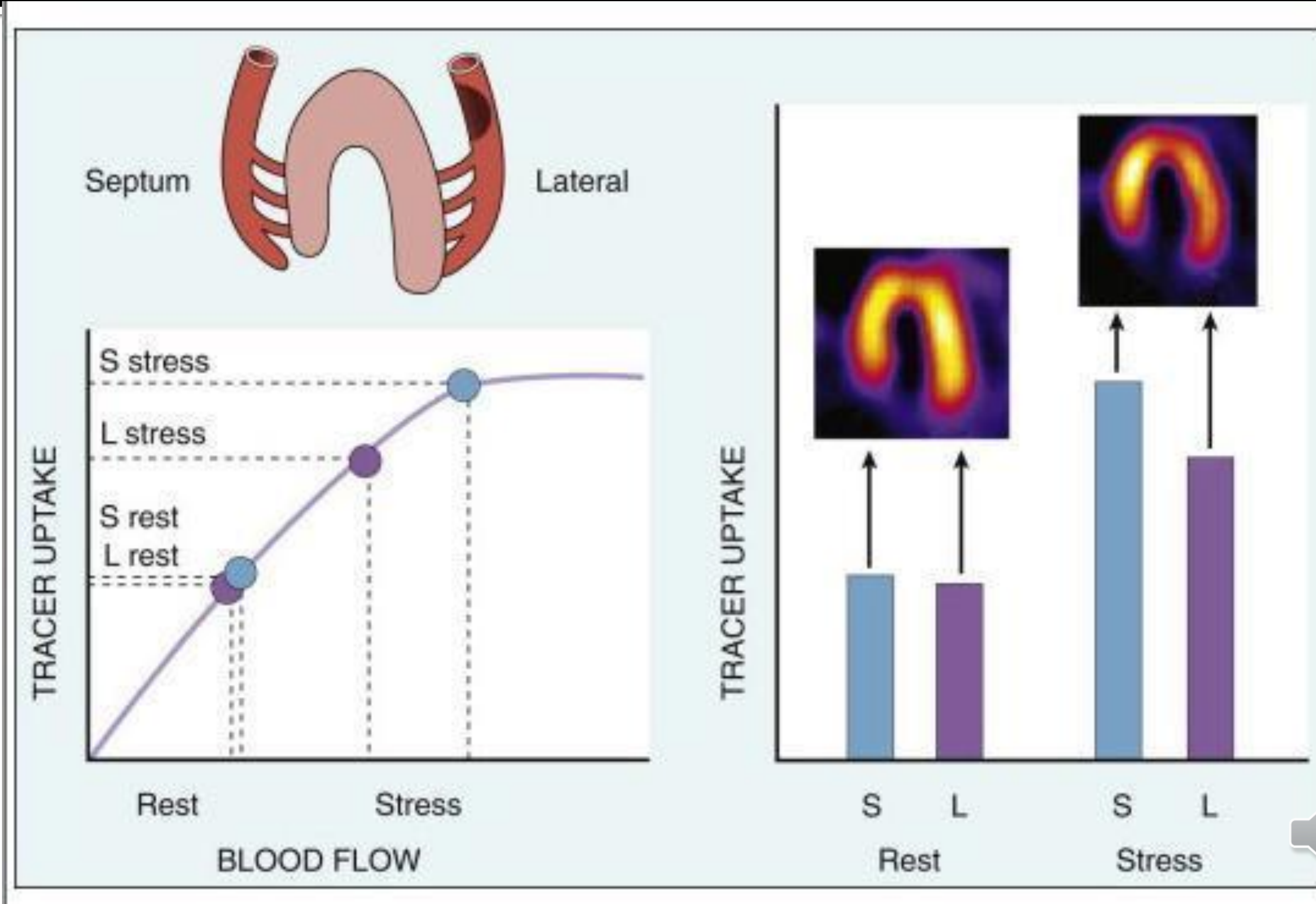


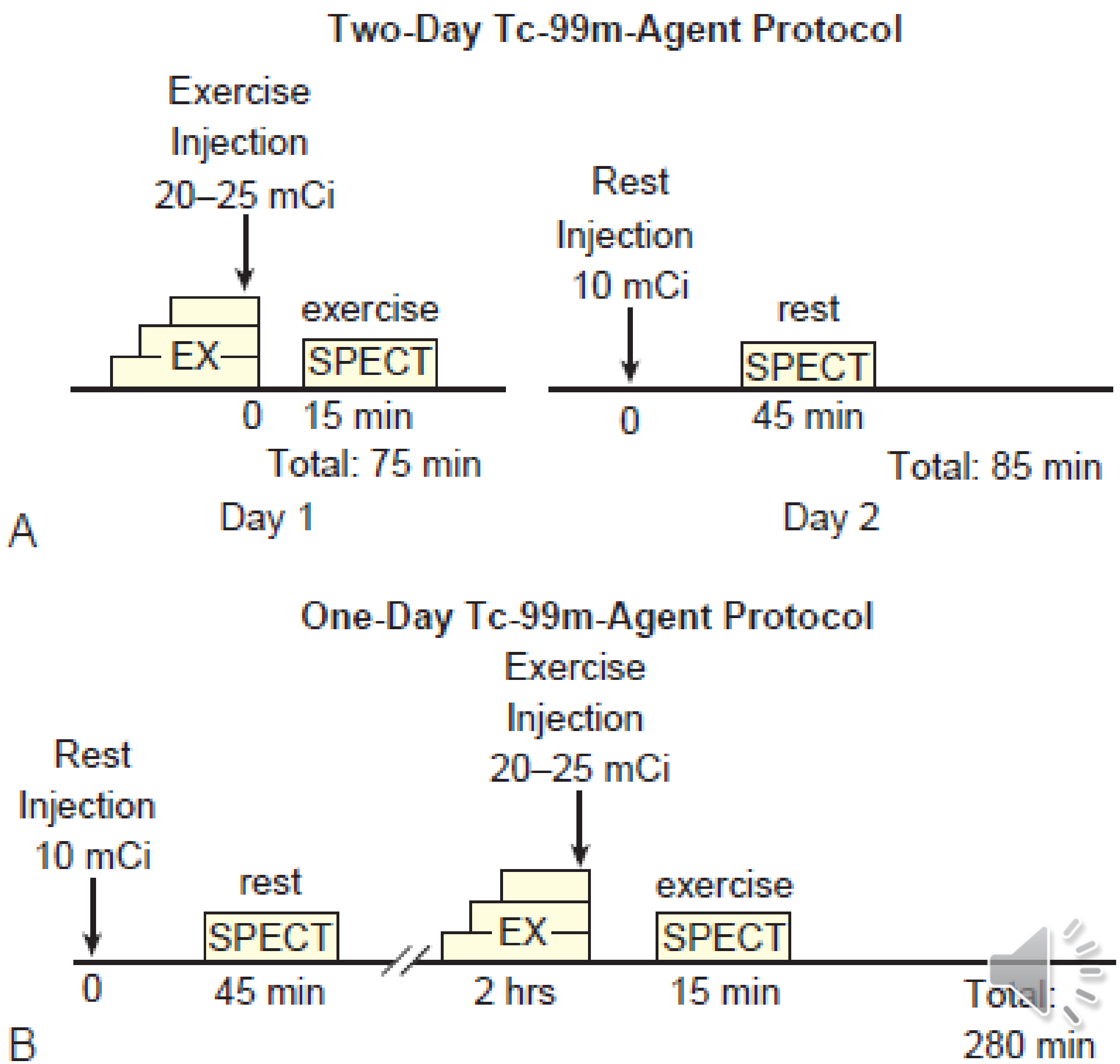
Figure 14-2 Schematic representation of the principle of rest/stress myocardial perfusion imaging. *Top*: Two branches of a coronary artery are schematically shown; the left branch is normal, and the right branch has a significant stenosis. *Middle*: Rest and stress myocardial perfusion images of the territories supplied by the two branches. *Bottom*: Schematic representation of coronary blood flow in the coronary branches at rest and during stress. At rest, myocardial blood flow is similar in both coronary artery branches. Coronary blood flow in the abnormal vascular bed was maintained through autoregulatory mechanisms that lower vascular resistance (r) distal of a significant stenosis. When a myocardial perfusion imaging agent is injected at rest, myocardial uptake therefore will be homogenous *(normal image on the left)*. During stress, peripheral vascular resistance (R) decreases in the normal bed (r), resulting in a 2 to 2.5-fold increase of blood flow over baseline. In the abnormal bed, distal from the stenosis, peripheral vascular resistance (r) cannot decrease much further. This creates heterogeneity of regional myocardial blood flow that can be visualized with thallium-201- or technetium-99m-labeled agents as an area with relatively decreased radiotracer uptake *(darker left area on stress image)*. *(Modified from Wackers FJ: Exercise myocardial perfusion imaging, J Nucl Med 35:726–729, 1994.)*

Blood Flow Rezerve



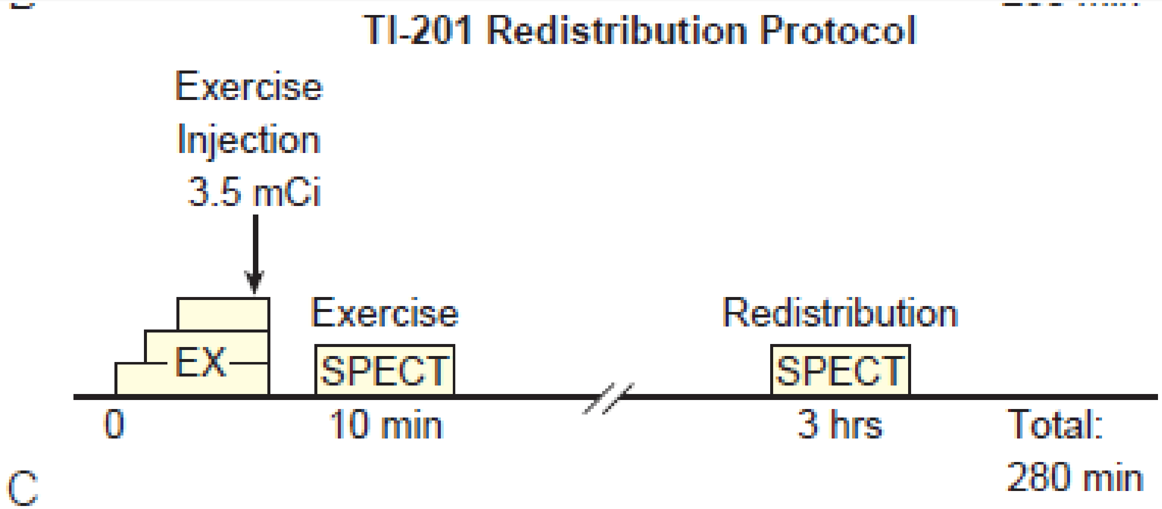
Imaging Protocols
^{99m}Tc-based

- **A, Two-day imaging protocol used for 99mTc-based radiotracer stress/rest imaging, typically used in obese patients.**
- **B, One-day imaging used for Tc-99m-based radiotracer stress/rest imaging, typically used in nonobese patients.**

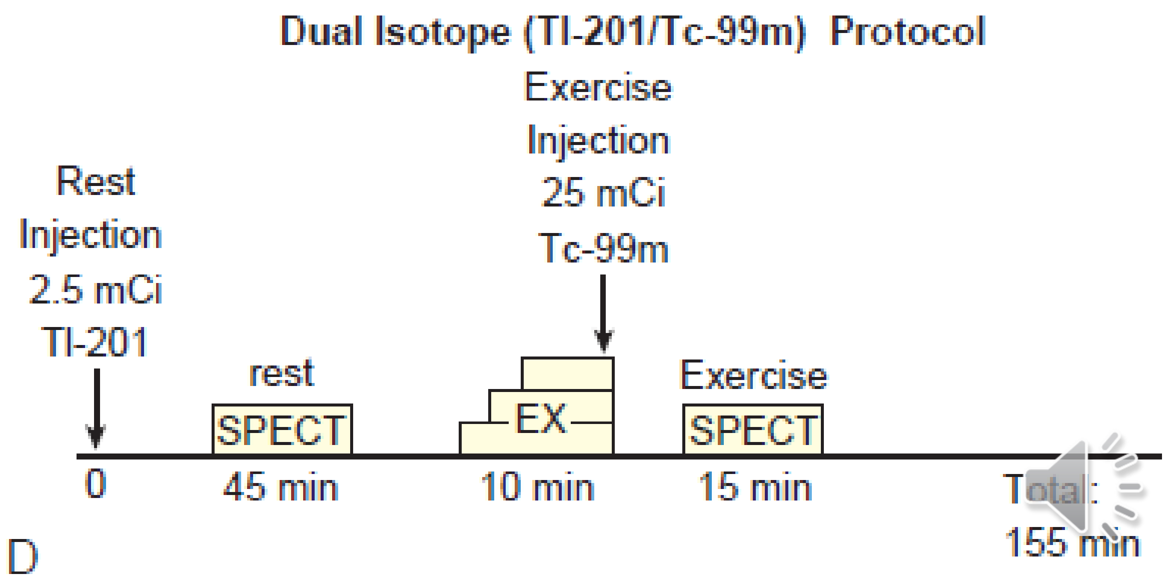


Imaging Protocols
Thallium-201

- C, One-day, stress-redistribution imaging protocol used for thallium-201 imaging



- D, One-day, dual-isotope imaging protocol



Stress Test

- Exercise Test
- Pharmacologic Stress

Exercise Test

- *Graded treadmill exercise*
- Accuracy for the diagnosis of CAD is modest = 75%
- Numerous false negatives and false positives.
- Specificity is particularly poor in:
  - Women
  - Patients with resting ECG ST-T changes
  - Left ventricular hypertrophy
  - Bundle branch block
  - Patients on digoxin
- These patients often require MPS to confirm or exclude the diagnosis of CAD

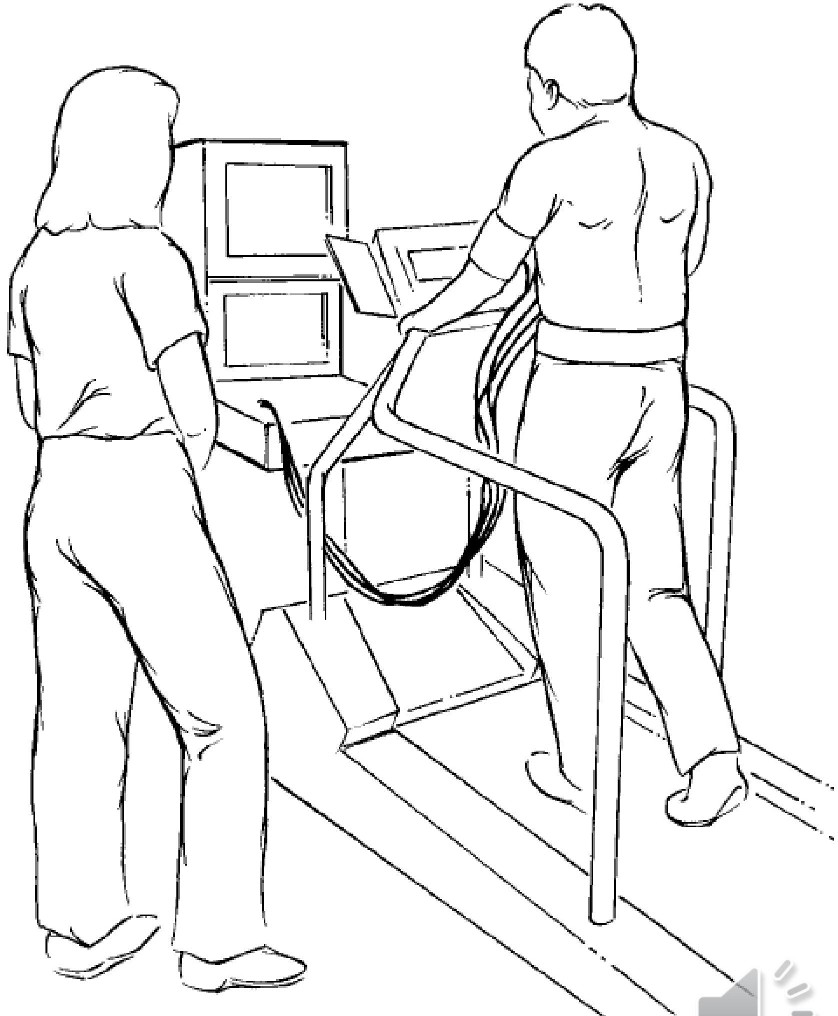


Figure 14-14 Treadmill exercise. Treadmill graded exercise with ECG, blood pressure, and heart rate monitoring.

Pharmacologic Stress

- Vasodilators
  - Adenosine
  - Dipyridamole
- Inotrope Positives
  - Dobutamine

Potential Applications for Chest Pain

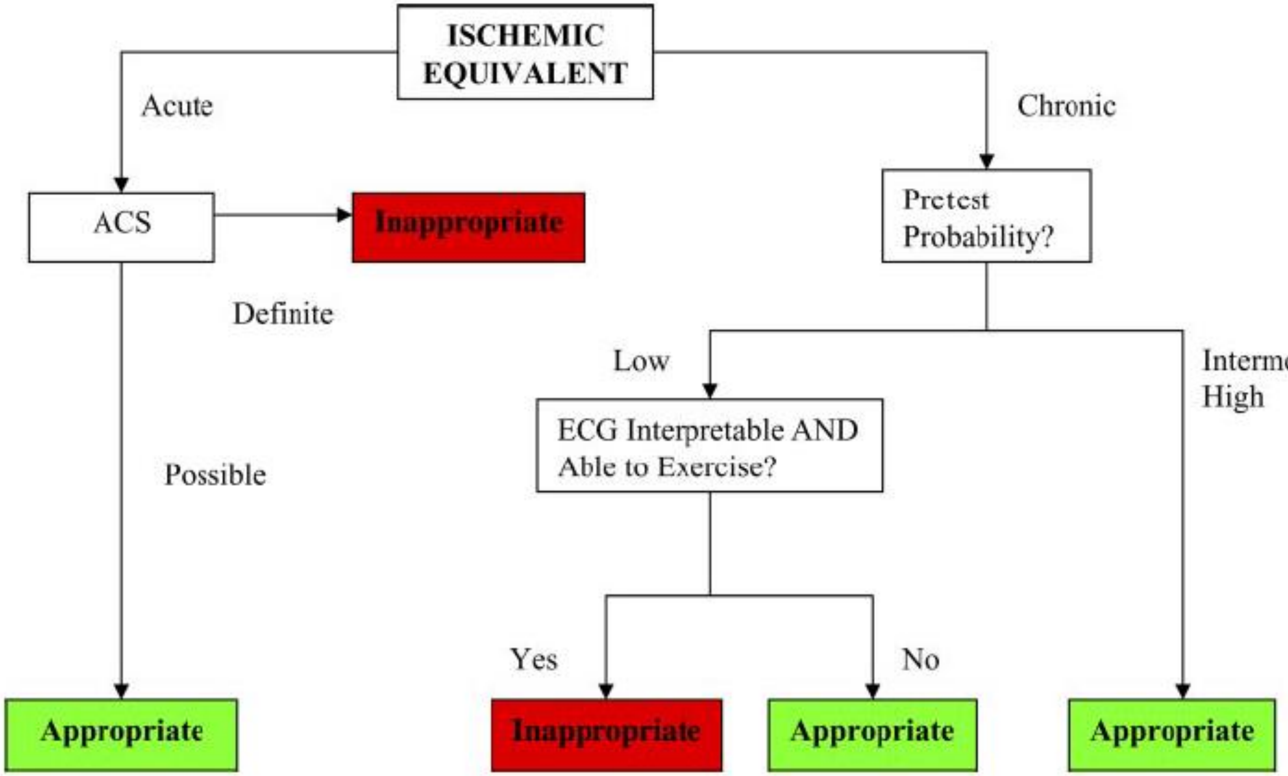


Figure 2. Potential Applications for Chest Pain. Patients with an ischemic equivalent, consisting of symptoms associated with CAD or ECG findings, were divided based on the likelihood of CAD. If patients had an intermediate or high likelihood for CAD, RNI was appropriate. RNI was also appropriate for patients at low likelihood if they were unable to exercise or had an uninterpretable ECG. For patients with a suspected ACS, RNI was appropriate irrespective of the TIMI score or whether or not their troponin levels were elevated.

Potential Applications for Asymptomatic Patients

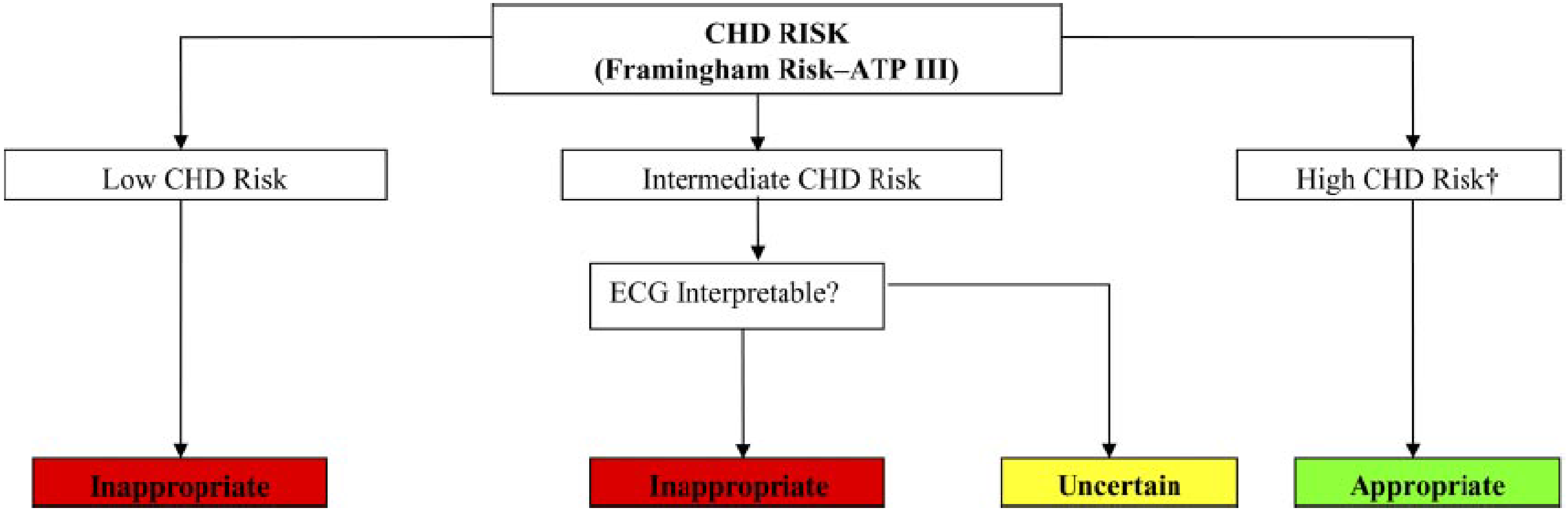


Figure 3. Potential Applications for Asymptomatic* Patients. Only in high CHD risk patients was RNI felt to be appropriate, although those with intermediate CHD risk with an uninterpretable ECG were uncertain. The presence of syncope did not alter the appropriateness of patients separate from their CHD risk, with low-risk patients being inappropriate and high-risk patients being appropriate.
*Asymptomatic patients exhibiting the following clinical indications are appropriate (or uncertain) for RNI and do not require risk assessment by either step: 1) new-onset or newly diagnosed heart failure with LV systolic dysfunction without ischemic equivalent who have not had a prior CAD evaluation AND have no planned coronary angiography (Appropriate); 2) ventricular tachycardia (Appropriate); 3) elevated troponin without additional evidence of acute coronary syndrome (Appropriate); 4) new-onset atrial fibrillation (Uncertain).
†Includes diabetes mellitus or the presence of other clinical atherosclerotic disease, including peripheral arterial disease, abdominal aortic aneurysm, carotid artery disease, and other likely forms of clinical disease (e.g., renal artery disease).

Perioperative Evaluation

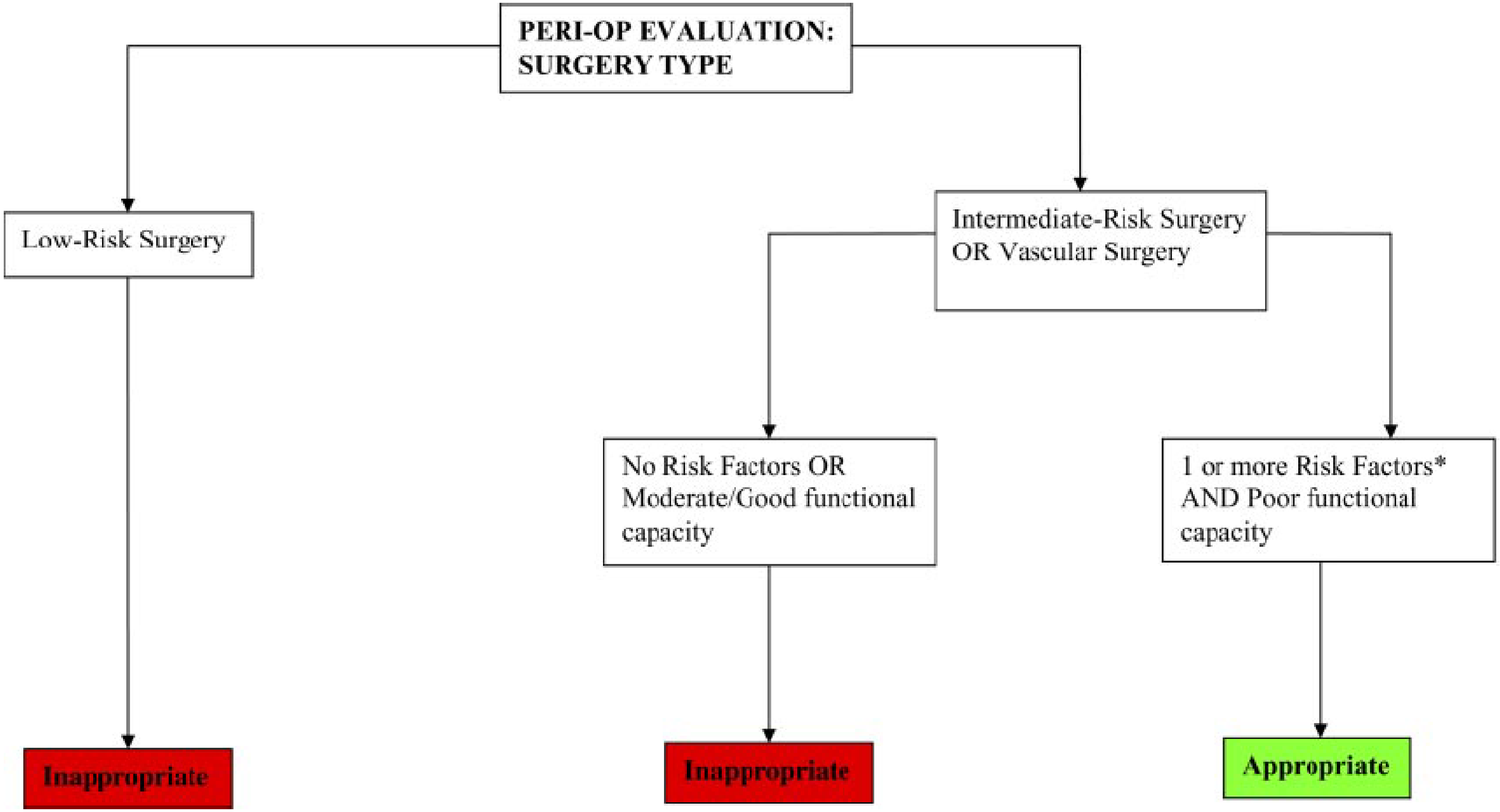


Figure 5. Perioperative Evaluation. RNI was felt to be inappropriate for preoperative risk assessment except in the setting of intermediate risk or vascular surgery when at least 1 risk factor is present and the patient has poor or unknown functional capacity. Additionally, patients who are asymptomatic up to 1 year postnormal catheterization, noninvasive test, or previous revascularization in the setting of intermediate risk or vascular surgery were also rated as inappropriate for RNI. *History of ischemic heart disease, compensated or prior heart failure, cerebrovascular disease, diabetes mellitus (requiring insulin), or renal insufficiency (creatinine >2.0).

Postrevascularization

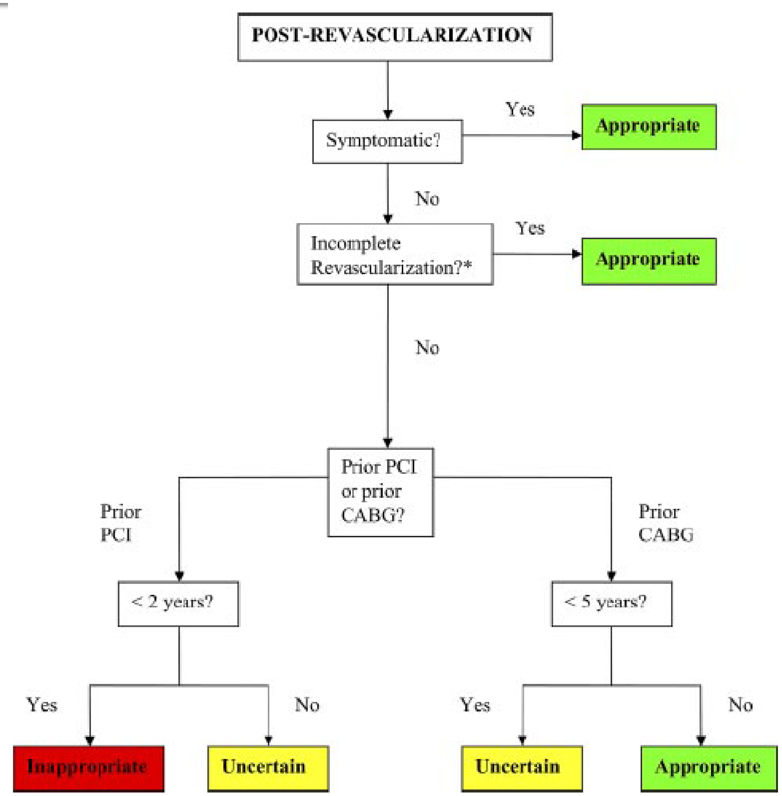


Figure 6. Postrevascularization. Following revascularization with PCI or CABG in a more chronic (>3 months) setting, recurrence of symptoms or the presence of suspected incomplete revascularization were felt to be appropriate indications for RNI. For asymptomatic patients less than 2 years after a PCI, RNI was rated inappropriate. For asymptomatic patients at less than 5 years after CABG or those at greater than or equal to 2 years after PCI, RNI was rated uncertain. If CABG was performed more than 5 years ago, RNI is appropriate. *Assumes that additional revascularization is feasible.

Diagnostic MPI Indications

- Diagnosis or exclude CAD in patients at intermediate or low-intermediate risk for CAD
- Diagnosis or exclude CAD for patients at low risk for CAD who have an abnormal or inconclusive ETT.
- Diagnose CAD in patients presenting in the emergency room with acute chest pain and are found to have a normal or inconclusive ECG.
- Assess cardiac risk for preoperative patients having major surgery who are at risk for CAD
- Determine hemodynamic significance of borderline coronary stenosis and appropriateness of revascularization in patients who have had coronary angiography.
- Follow-up of symptomatic patients after coronary artery interventions.

Sensitivity for detection of Ischemia

- ETT sensitivity for myocardial ischemia: 60%
- MPI sensitivity for myocardial ischemia > 90%

Diagnosis of CAD

- Detection of CAD
- Location of CAD
- Severity of CAD
- Extent of CAD

Scan interpretation

- Normal scan= Homogenous distribution
- Ischemia= Reversible defect
- Scar tissue= Fixed defect

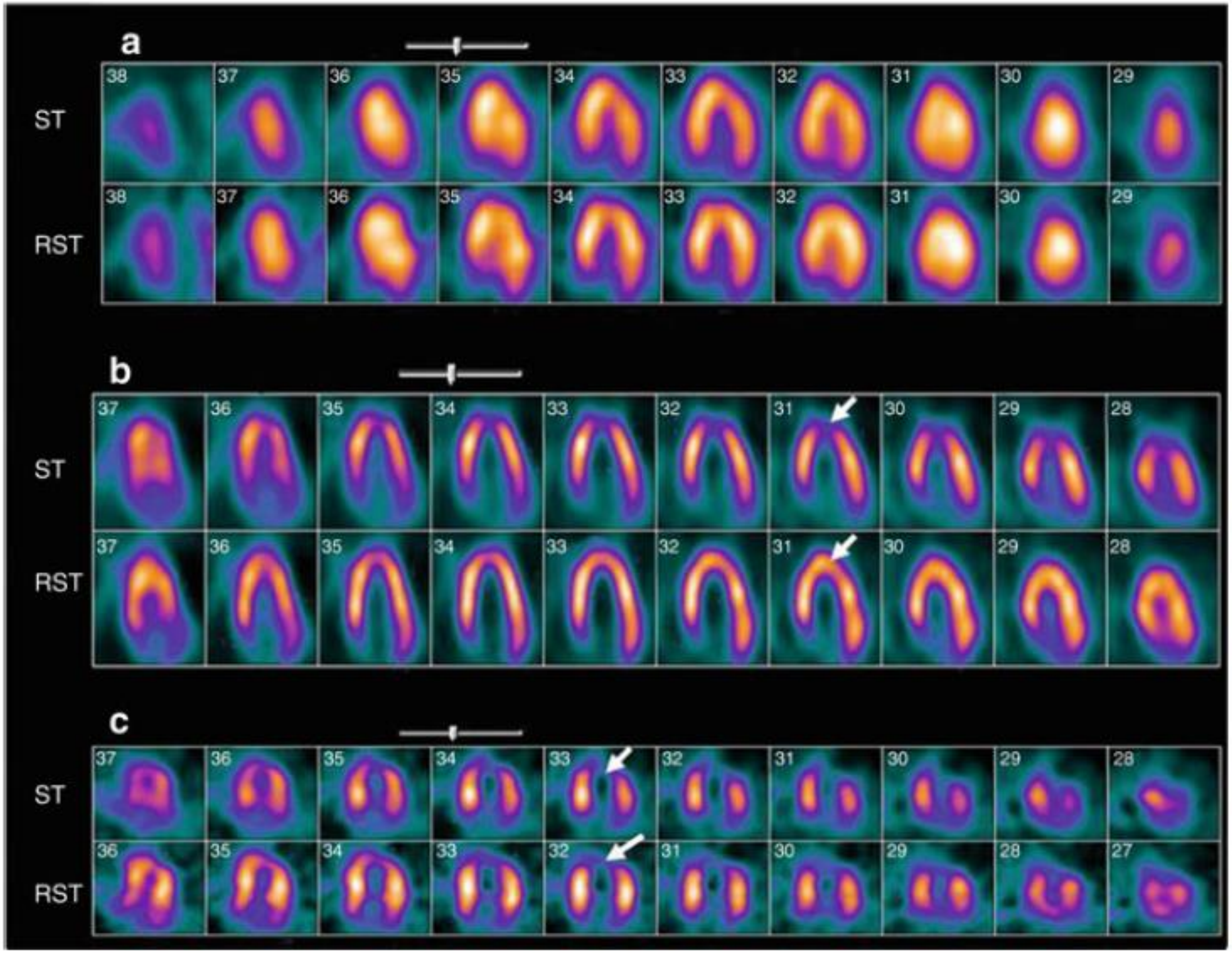
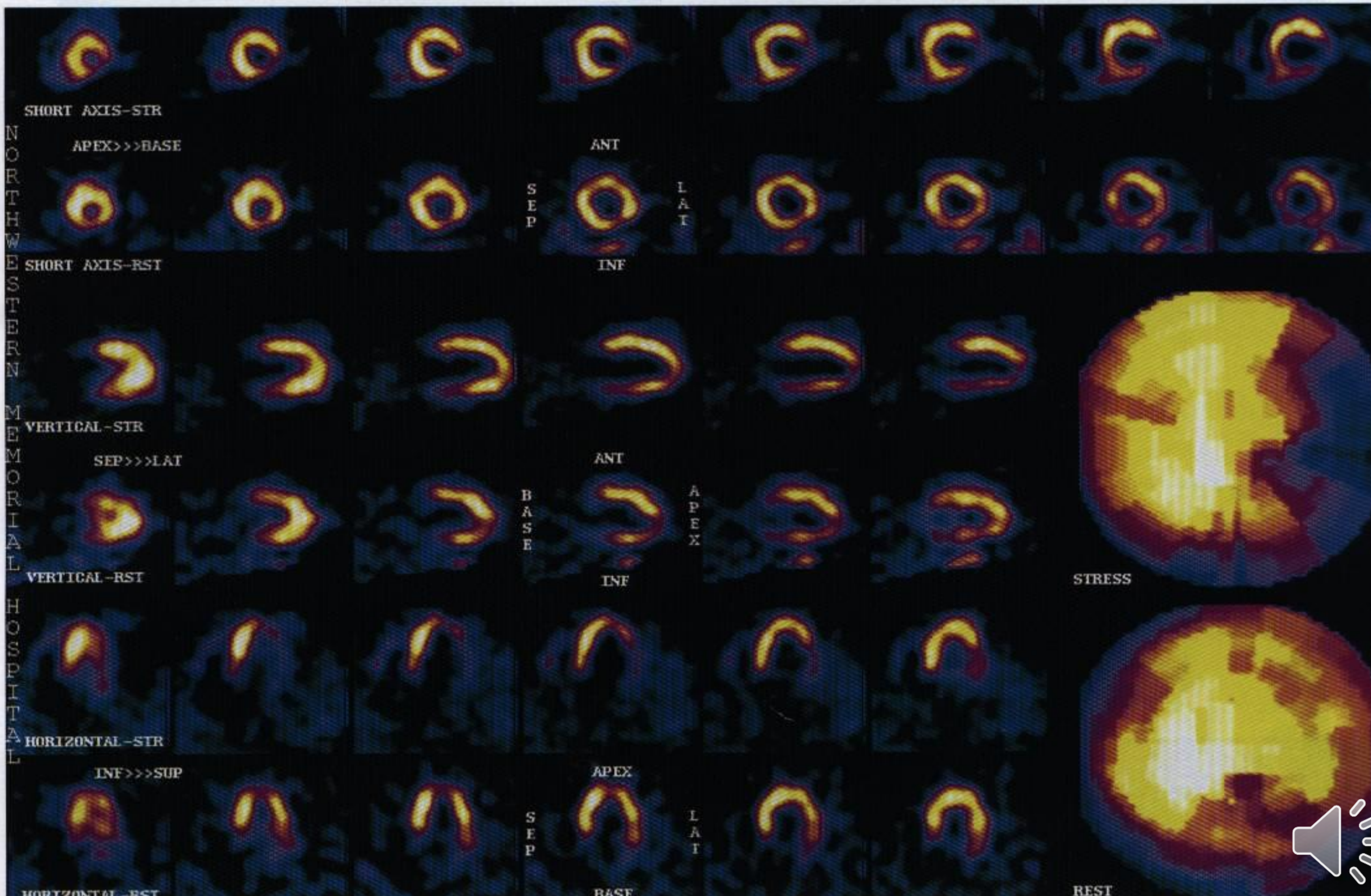


FIGURE 13.30. Attenuation corrected coronal (*horizontal long axis*) SPECT myocardial images of different patients obtained with ^{99m}Tc tetrofosmin at rest and after stress. (**a**) Normal. (**b**) Apical ischemic defect. (**c**) Apical infarct.



NORTHWESTERN MEMORIAL HOSPITAL
SHORT AXIS-STR
APEX>>>BASE
ANT
SEP
LAT
SHORT AXIS-RST
INF
VERTICAL-STR
SEP>>>LAT
ANT
BASE
APEX
VERTICAL-RST
INF
STRESS
HORIZONTAL-STR
INF>>>SUP
APEX
SEP
LAT
HORIZONTAL-RST
BASE
REST

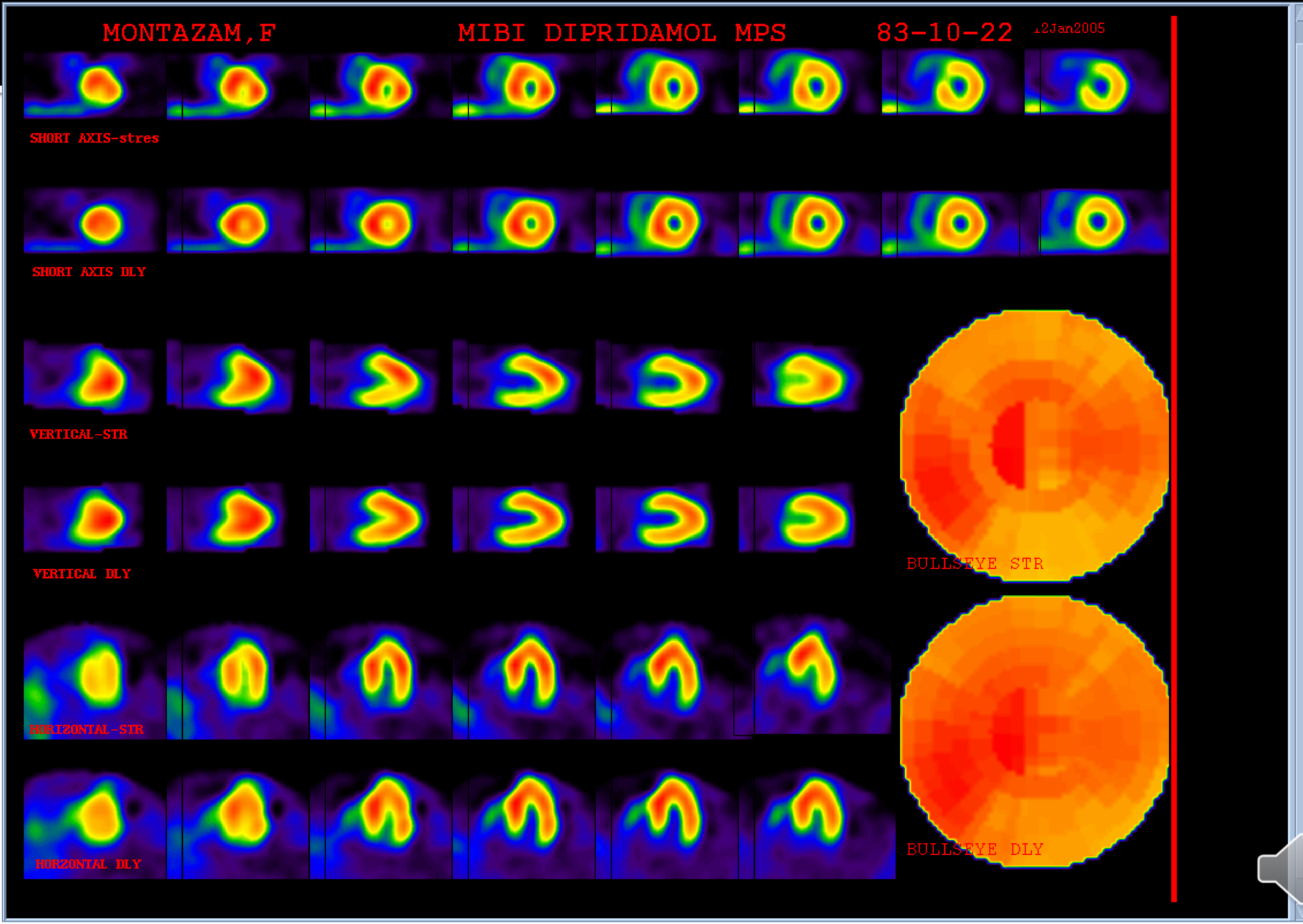
Myocardial viability

- Hibernation
  - Severe ischemia at rest
- More than 20% viable tissue
  - Benefits from bypass surgery
- ^{18}F-FDG (Fluro-Desoxy-Glucose) PET
  - Best method for evaluation of viability

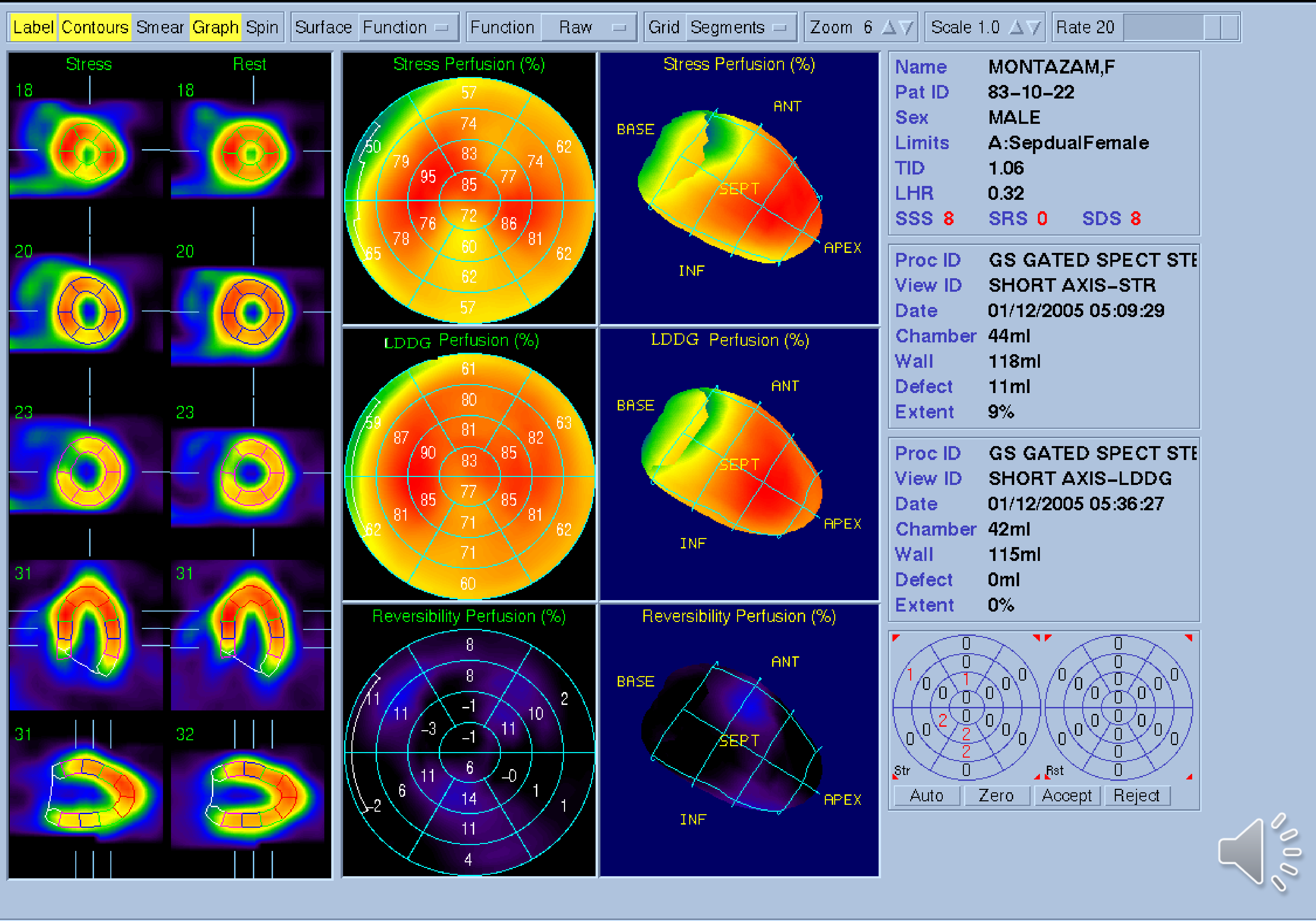
Prognosis of CAD

- High risk scan group:
  - Large size reversible defect
  - Multiple reversible defects
  - Increased ^{201}Tl lung uptake
  - Transient ischemia induced LV dilatation

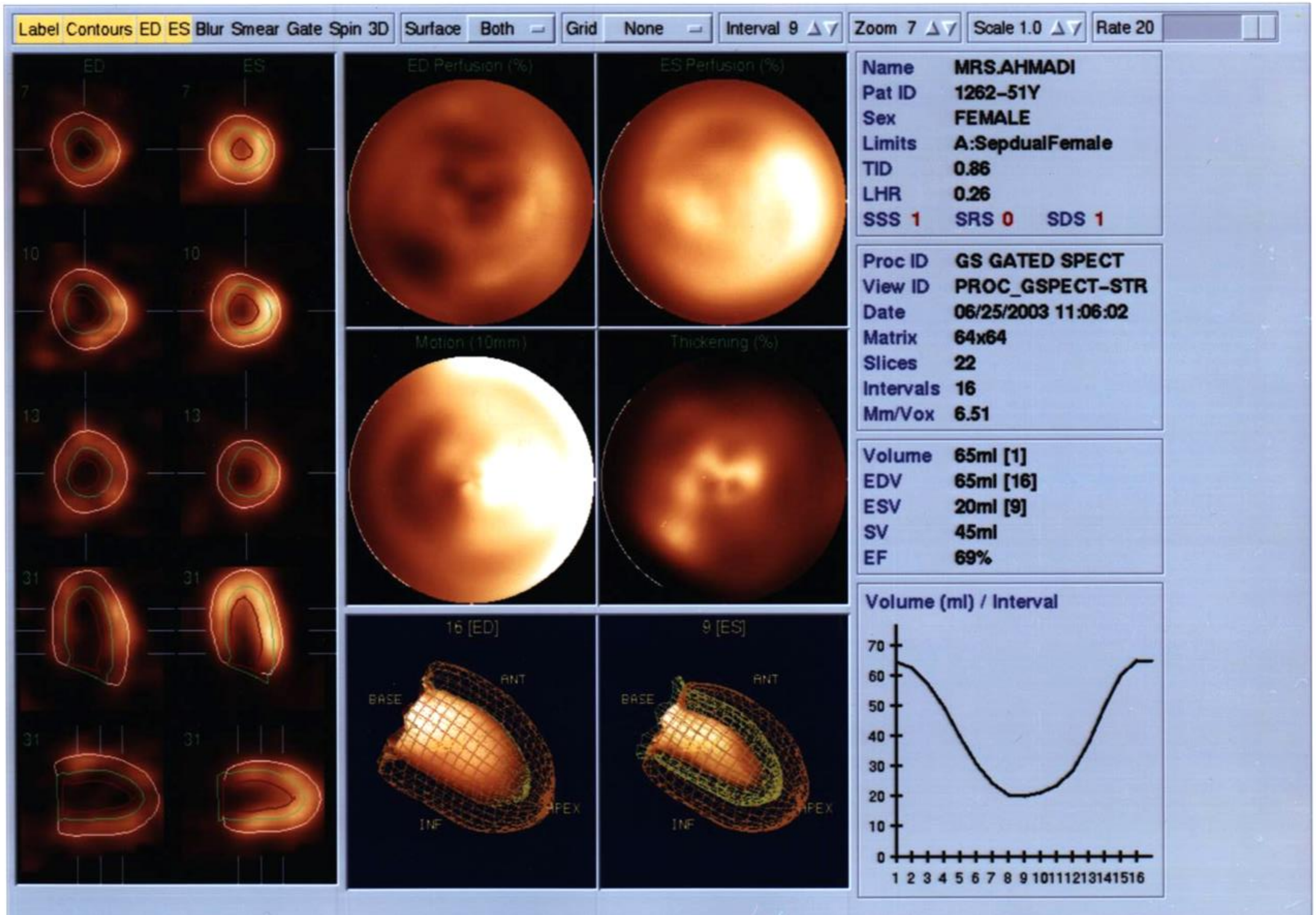
Inferior and anterolateral walls ischemia



Quantitative Perfusion SPECT



Gated SPECT



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ES
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ES Perfusion (%)
Motion (10mm)
Thickening (%)
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9 [ES]
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APEX
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LHR 0.26
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ESV 20ml [9]
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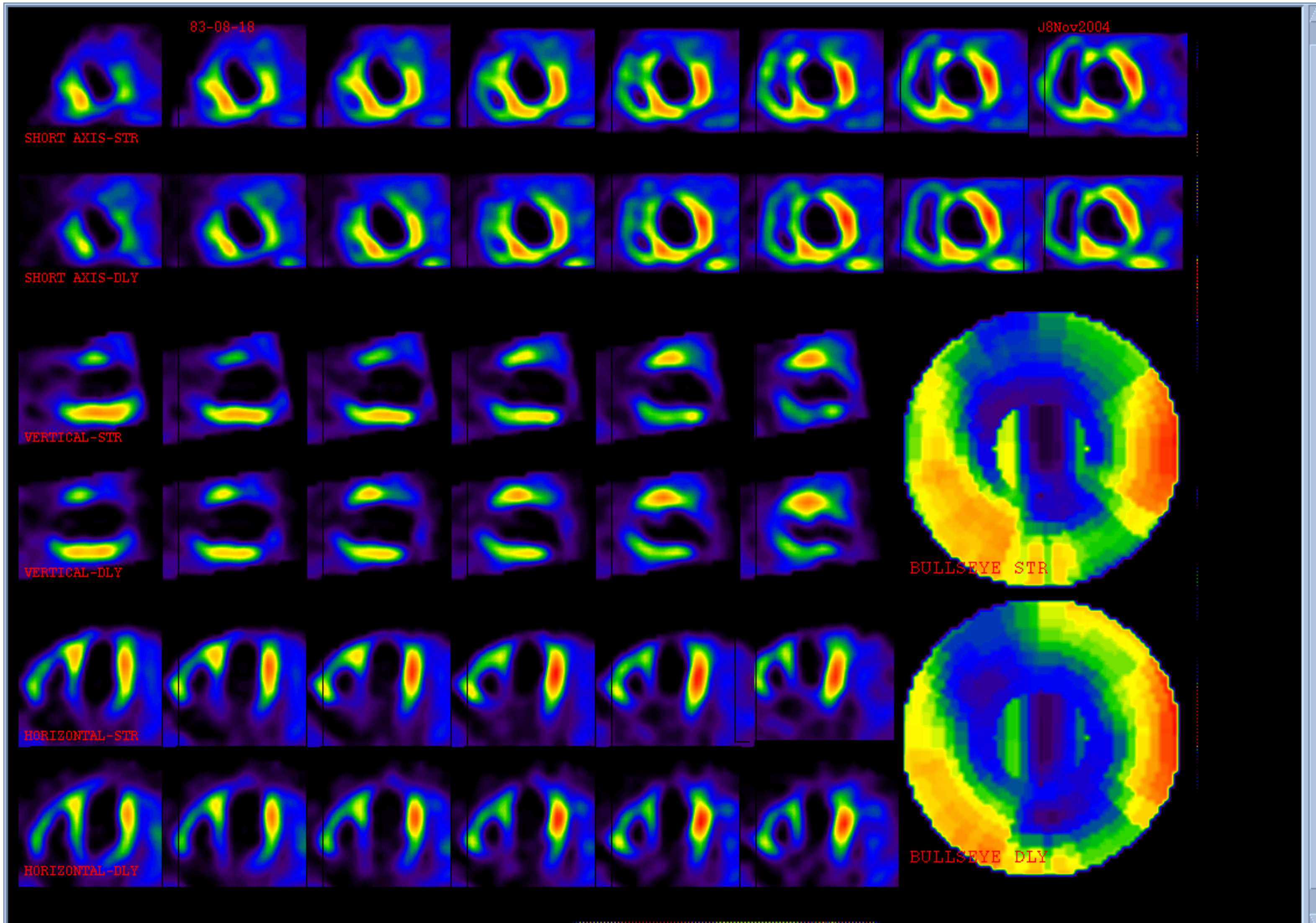
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J8Nov2004
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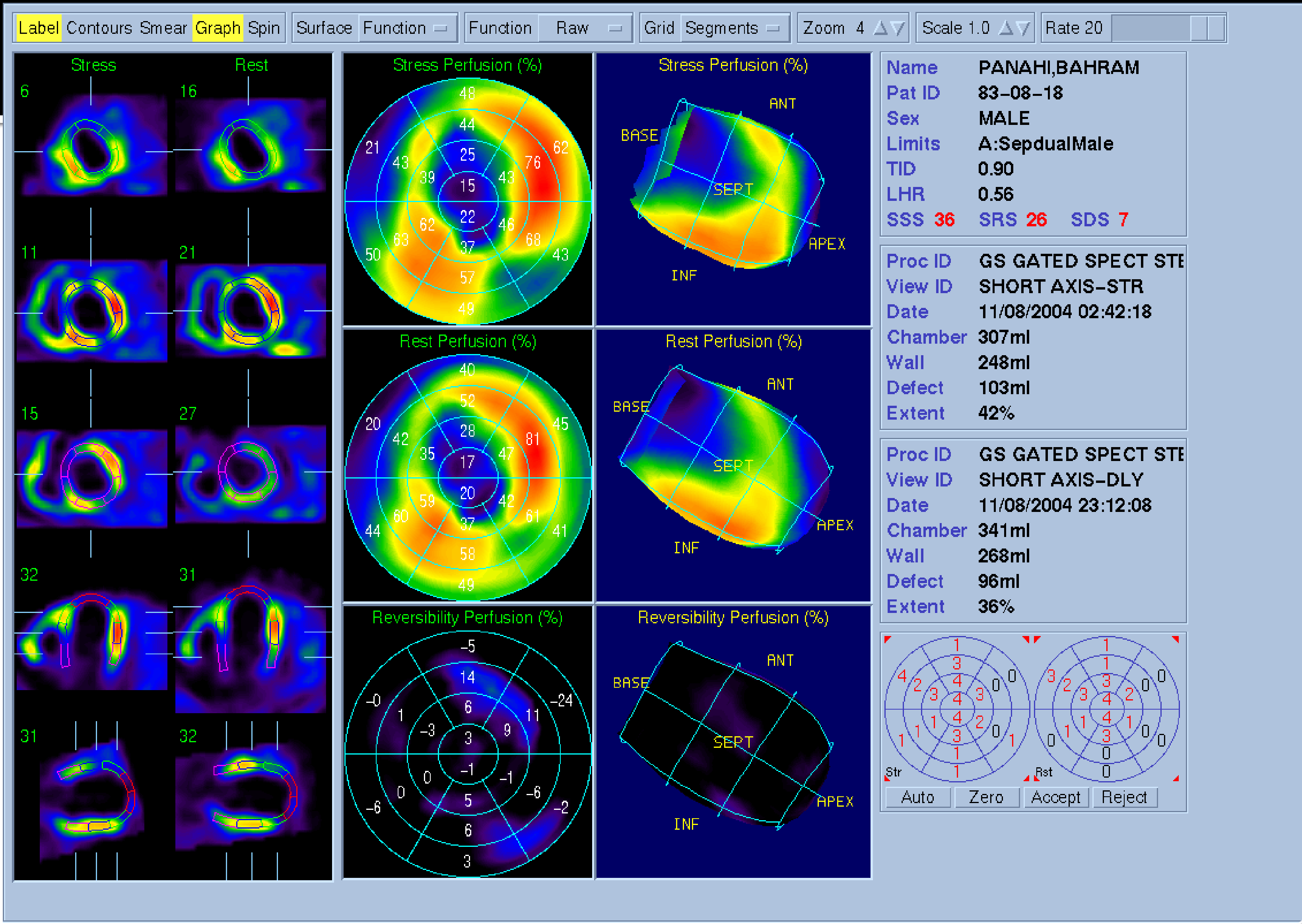
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Rate 20
Stress
Rest
6
16
11
21
15
27
32
31
31
32
Stress Perfusion (%)
48 44 25 15 22 37 57 49
21 43 39 62 63 50
62 76 43 46 68 43
Stress Perfusion (%)
BASE
ANT
SEPT
APEX
INF
Rest Perfusion (%)
40 52 28 17 20 37 58 49
20 42 35 59 60 44
45 81 47 42 61 41
Rest Perfusion (%)
BASE
ANT
SEPT
APEX
INF
Reversibility Perfusion (%)
-5 14 6 3 -1 5 6 3
-0 1 -3 0 0 -6
-24 11 9 -1 -6 -2
Reversibility Perfusion (%)
BASE
ANT
SEPT
APEX
INF
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Pat ID 83-08-18
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Limits A:SepdualMale
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LHR 0.56
SSS 36 SRS 26 SDS 7
Proc ID GS GATED SPECT STE
View ID SHORT AXIS-STR
Date 11/08/2004 02:42:18
Chamber 307ml
Wall 248ml
Defect 103ml
Extent 42%
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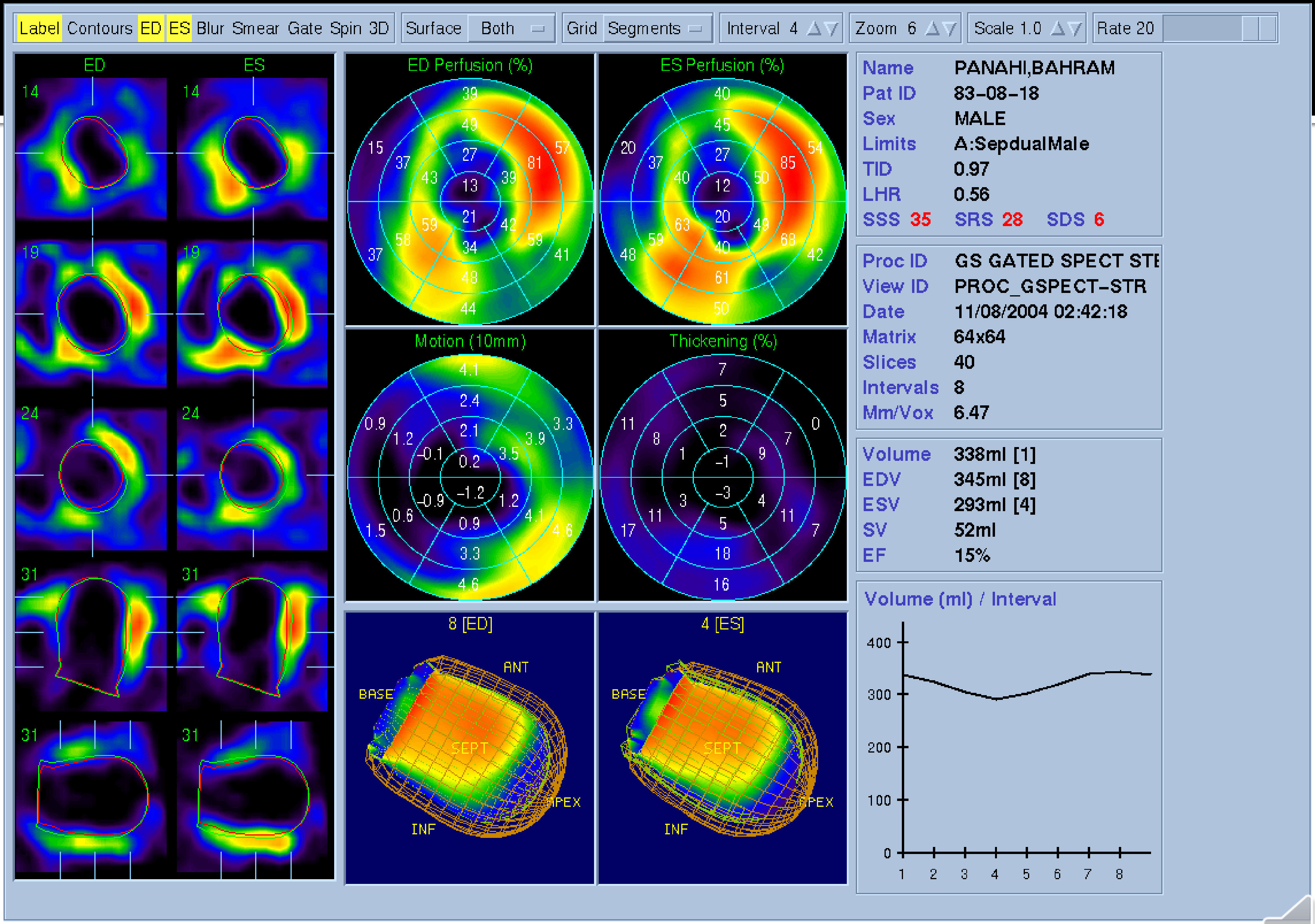
Str
Rst
Auto Zero Accept Reject



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Zoom 6
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ES
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ES Perfusion (%)
Motion (10mm)
Thickening (%)
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4 [ES]
ANT
BASE
SEPT
APEX
INF
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Pat ID 83-08-18
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LHR 0.56
SSS 35 SRS 28 SDS 6
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View ID PROC_GSPECT-STR
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Intervals 8
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Volume (ml) / Interval

First Pass scan

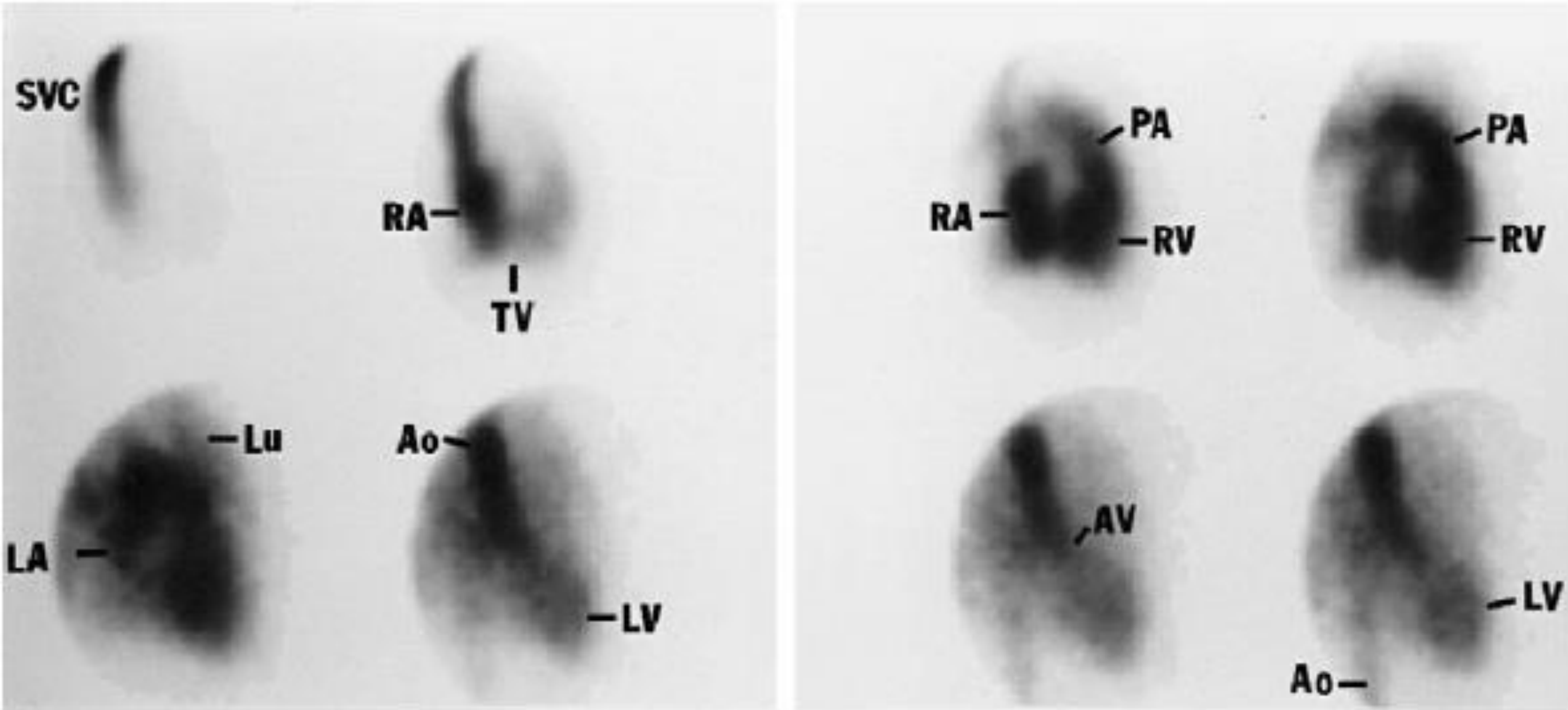

Figure 14-42 First-pass radionuclide angiogram. Cardiac structures are sequentially visualized as the bolus passes through the right side of the heart into the lungs and then returns to the left side. *Ao*, Aorta; *AV*, aortic valve; *LA*, left atrium; *Lu*, lung; *LV*, left ventricle; *PA*, pulmonary artery; *RA*, right atrium; *RV*, right ventricle; *SVC*, superior vena cava; *TV*, tricuspid valve.

Gated Blood Pool

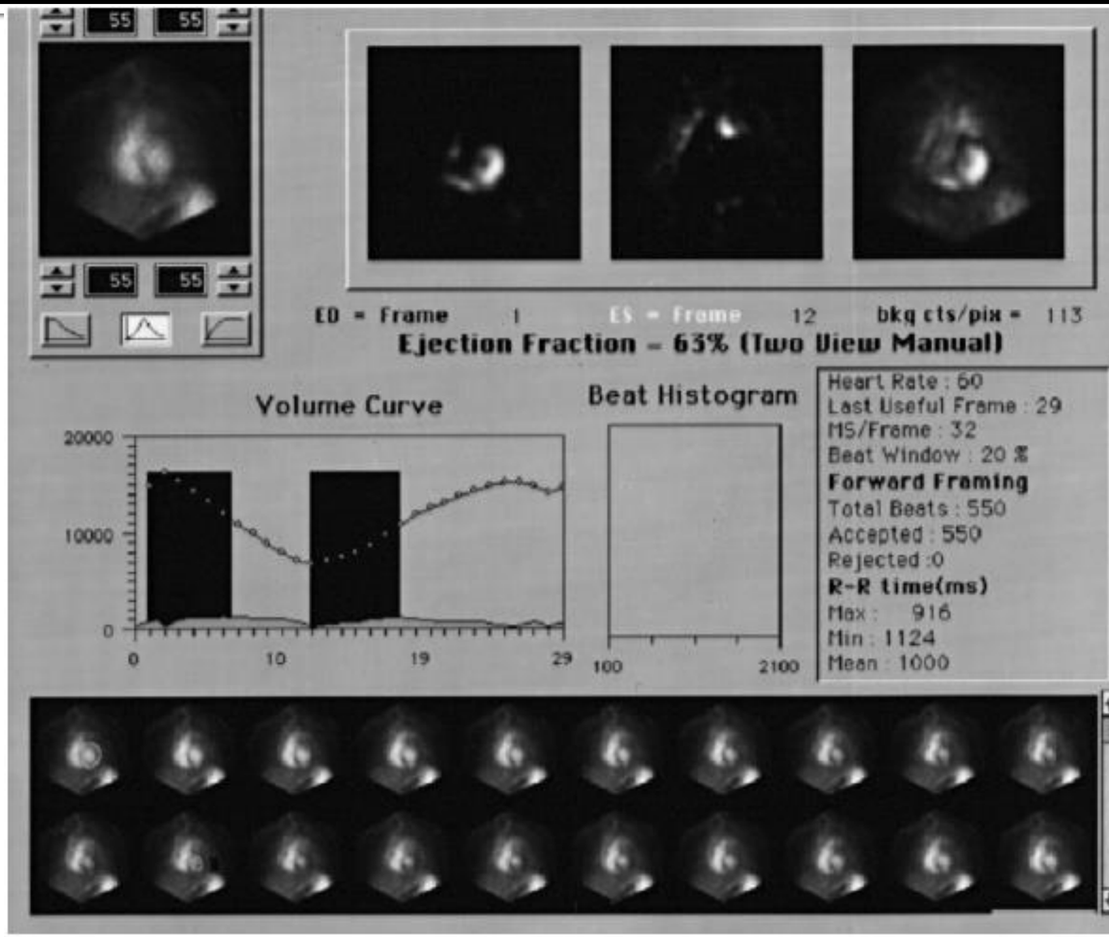

Figure 14-49 Composite computer-generated display: analysis of gated radionuclide ventriculogram. The sequential left anterior oblique views are displayed across the bottom. The end-diastolic and end-systolic regions of interest are indicated, along with the crescent-shaped background region of interest adjacent to the left ventricle at end-systole (*bottom row, second image from right*). The three parametric images in the upper right-hand corner represent ejection fraction (ES – ED), paradox (ES – ED), and amplitude. The LVEF of 63% is normal.

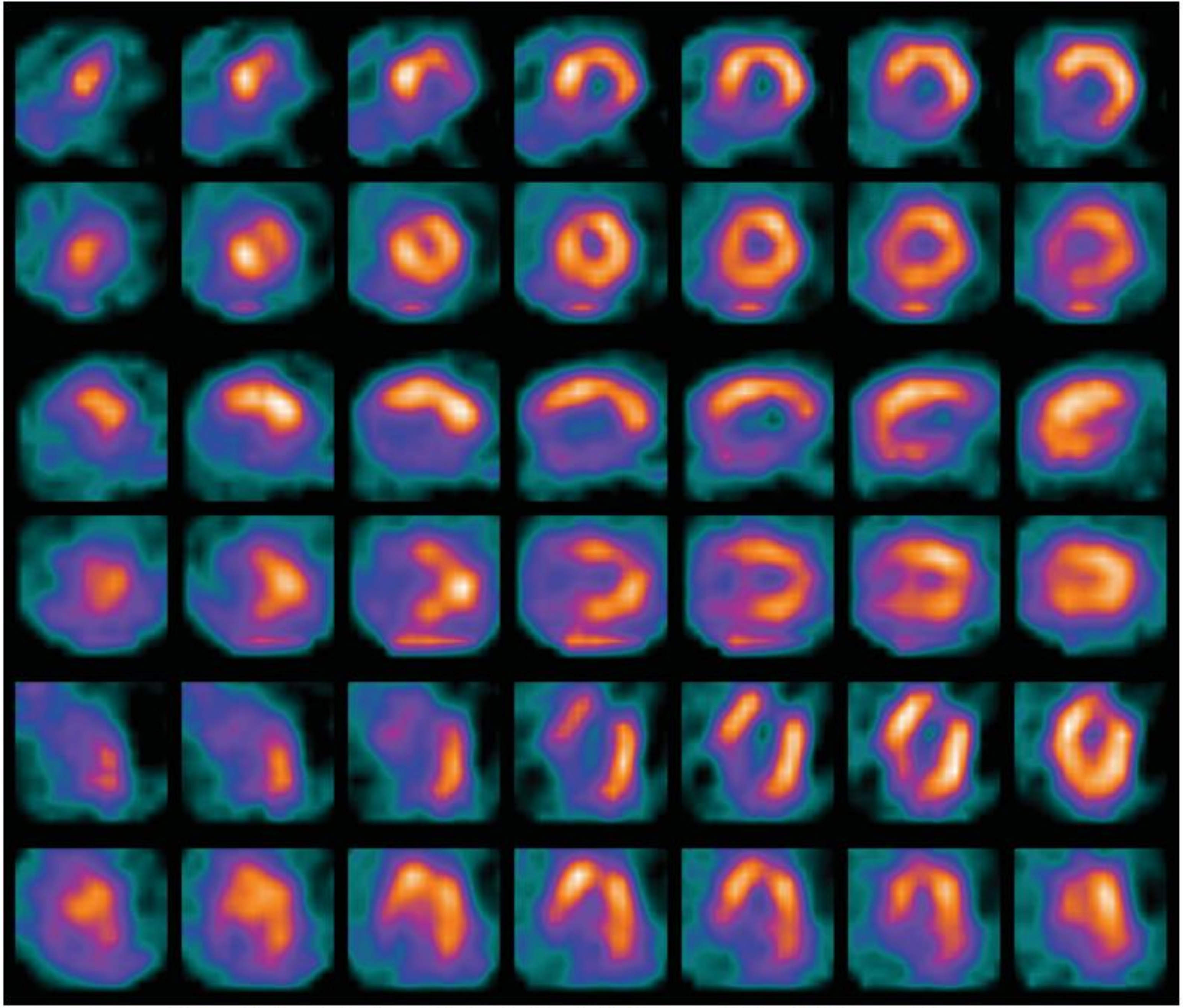

Figure 14-A 1, Inferior wall ischemia. Exercise Tc-99m sestamibi/rest Tl-201 myocardial perfusion. Marked hypoperfusion of the entire inferior wall and inferior apex post-stress, which normalizes on rest images consistent with a large region of severe ischemia.

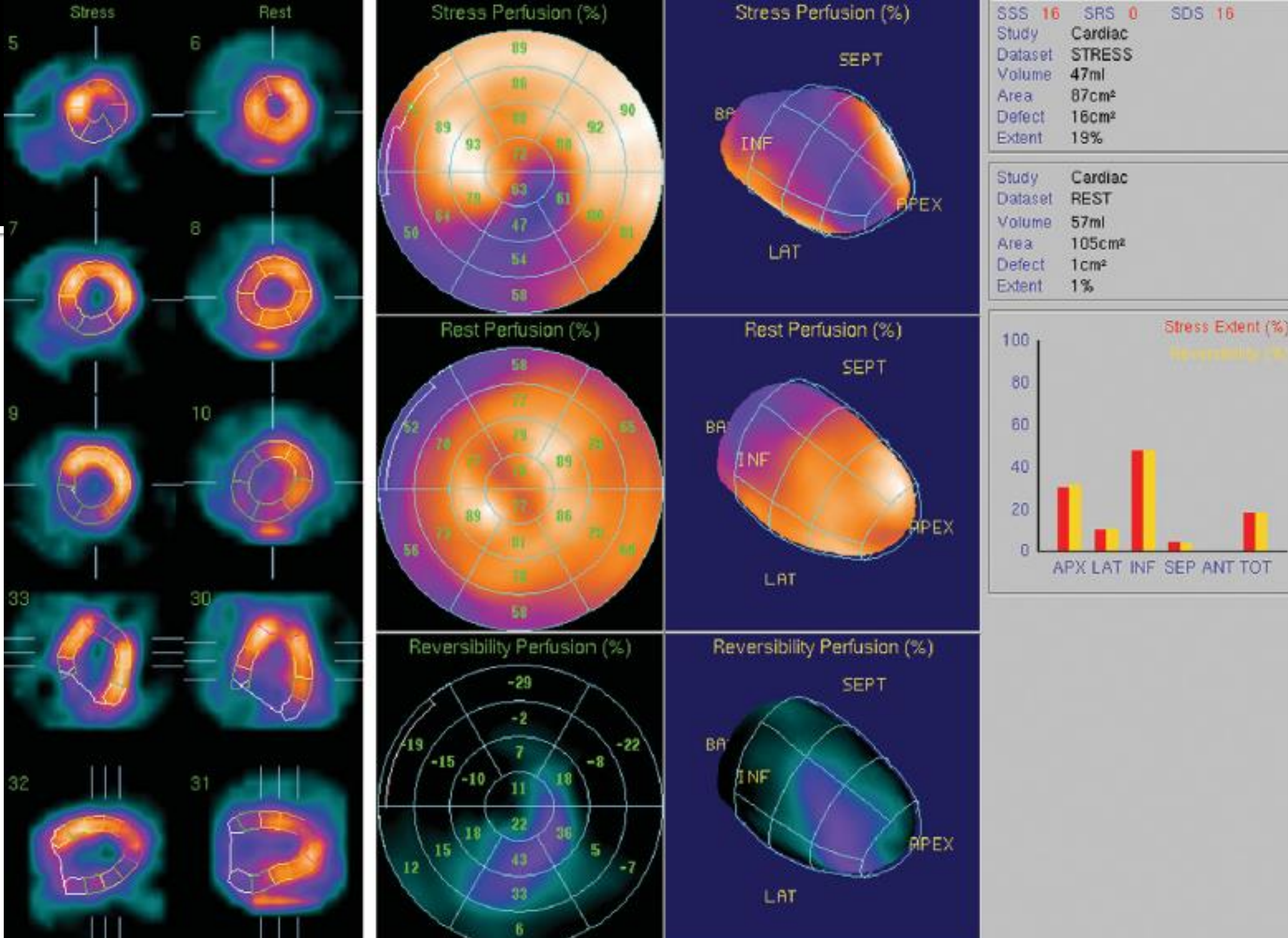

Figure 14-A 2, Inferior wall ischemia: polar map and volume quantitative display for **A1**. The reversibility perfusion (%) box shows the extent and severity of the reversible perfusion defect as a polar map and three-dimensional volume display. At the right, the stress extent (%) and reversibility (%) are shown in graph form.

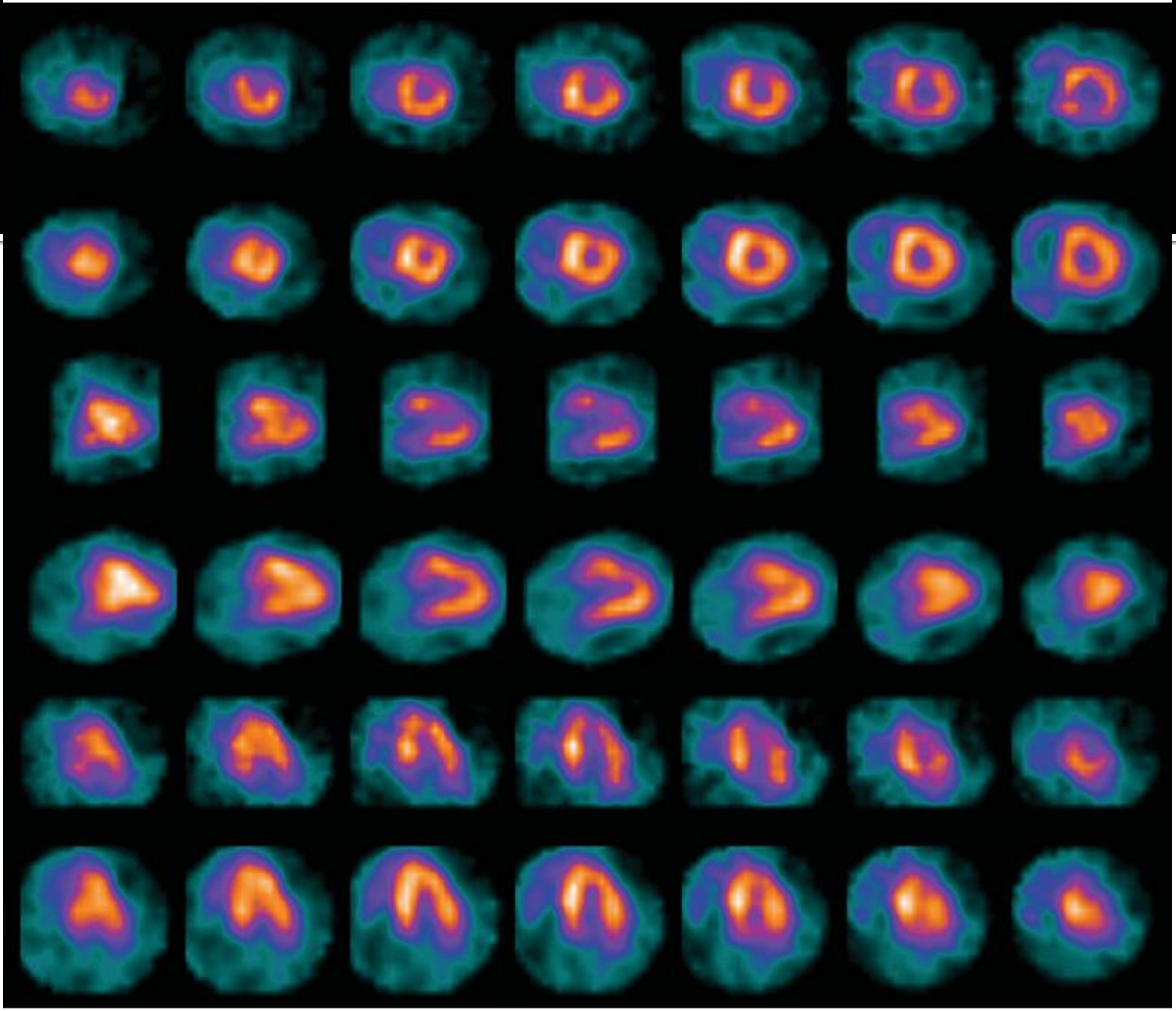

Figure 14-B 1, Anterior wall ischemia. Postexercise and 3-hour delayed Tl-201 myocardial perfusion. Stress induced hypoperfusion is seen in the anterior wall extending to the apex. At rest, there has been near complete redistribution consistent with moderate ischemia of a moderate sized region. This subjective evaluation can be compared to the quantitative display in **B2**.

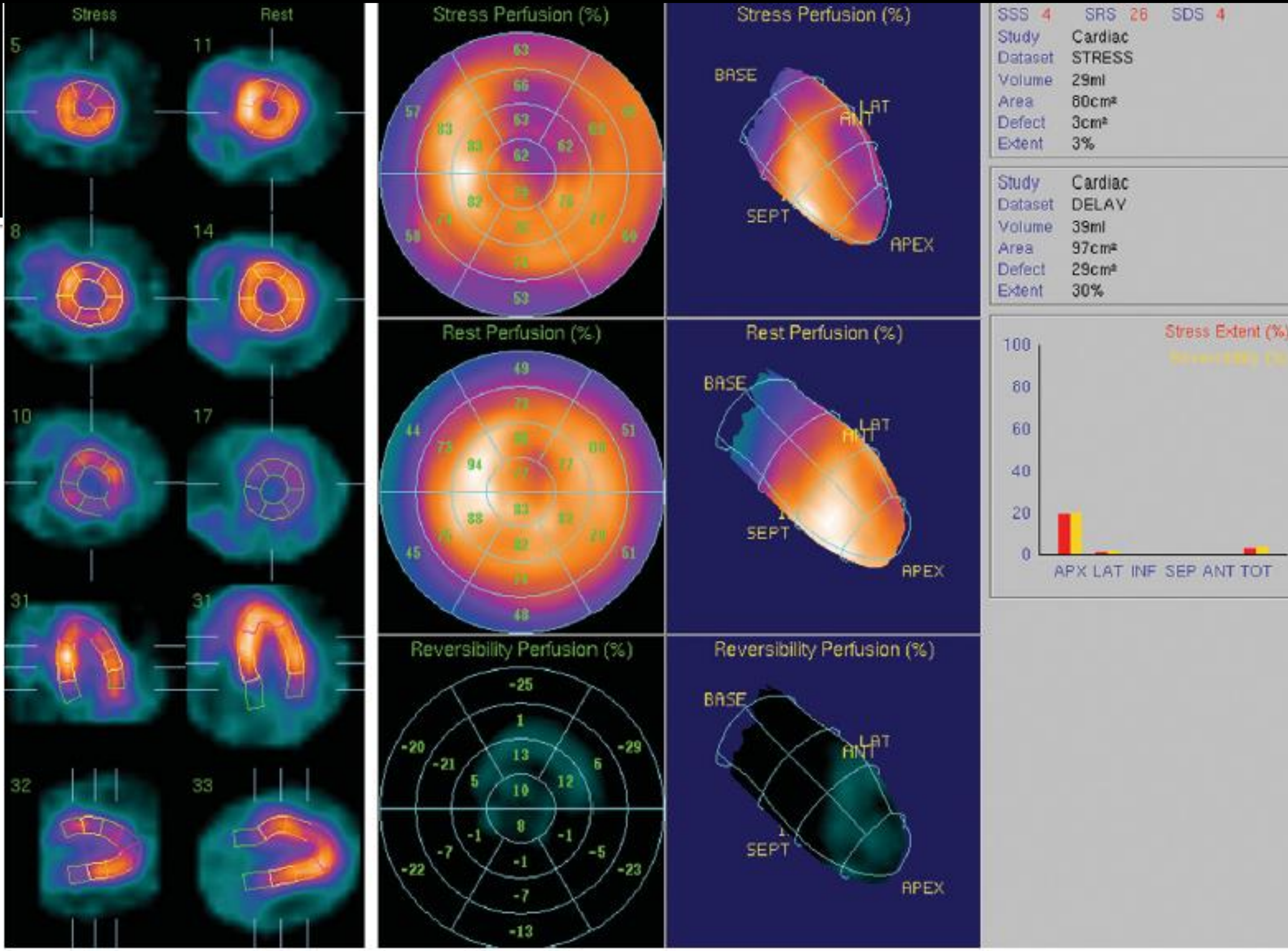

Figure 14-B 2, Anterior wall ischemia: polar map and volume quantitative display. Reversibility of 10–13% in individual regions of the anterior lateral apical region. The graph in the right hand column displays the stress extent and reversibility percentage. This suggests a somewhat lesser degree of ischemia than the interpretation of the splash display in B1.

Thanks from your attention

Good Luck

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