Indications and Limitations of Cardiac Imaging Tests

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UTHSCSA and STVHCS

Cardiology is a very **visual** specialty, despite the importance of auscultation

Clinical Situation Dictates Choice of Imaging Test

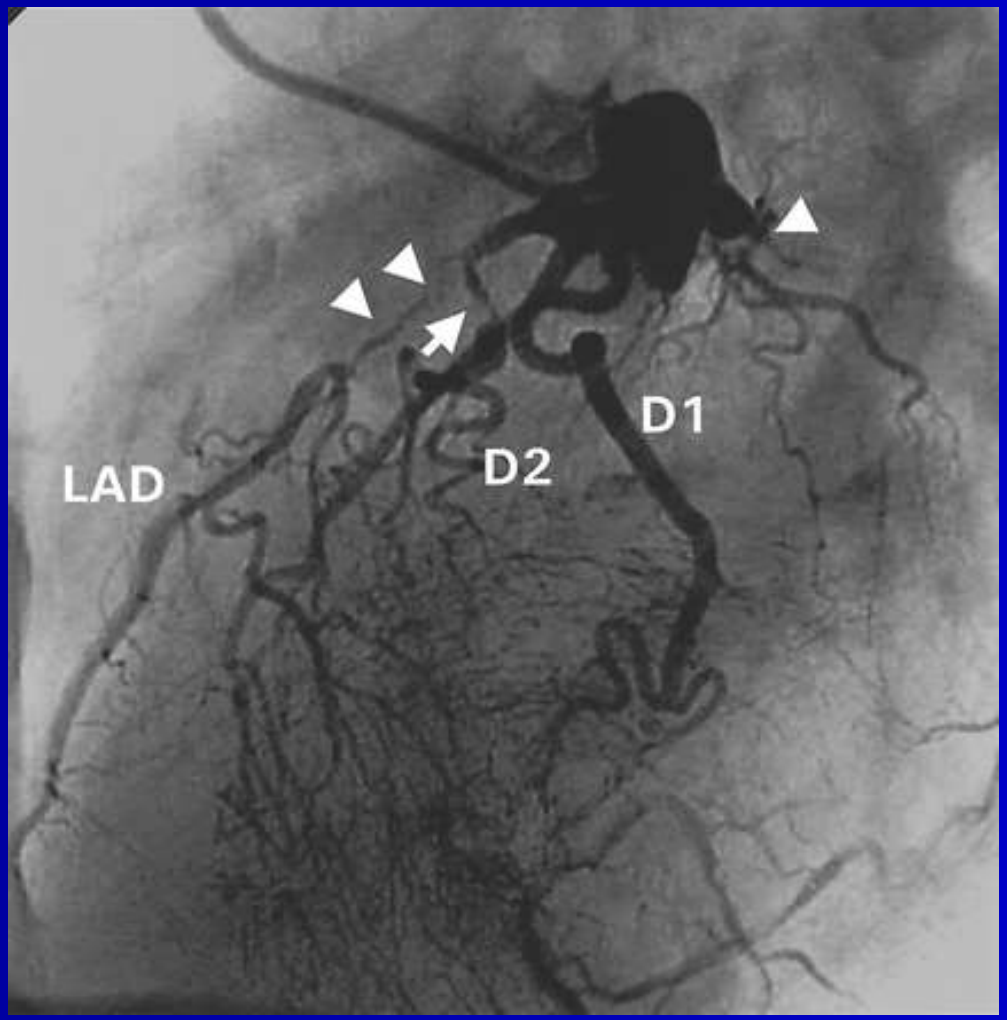
- Coronary heart disease
  - Screening and diagnosis (presence of ischemia)
  - Prognosis (severity of ischemia, LV function)
  - Acute coronary syndrome
  - Directing therapy (localization of ischemia, viability)
- Valvular or congenital heart disease
- Myocardial disease, heart failure, cardiopulmonary disease
- Pericardial disease
- Great vessel, arterial disease
- Arrhythmia (slow, fast, ventricular, atrial)

Rule: In **all** medicine, **all** tests are subservient to the clinical setting

Local Expertise Also Affects Choice of Imaging Test

- Availability of technical support
- Expertise and experience of technical personnel
- Availability of equipment
- Expertise and experience of interpreter

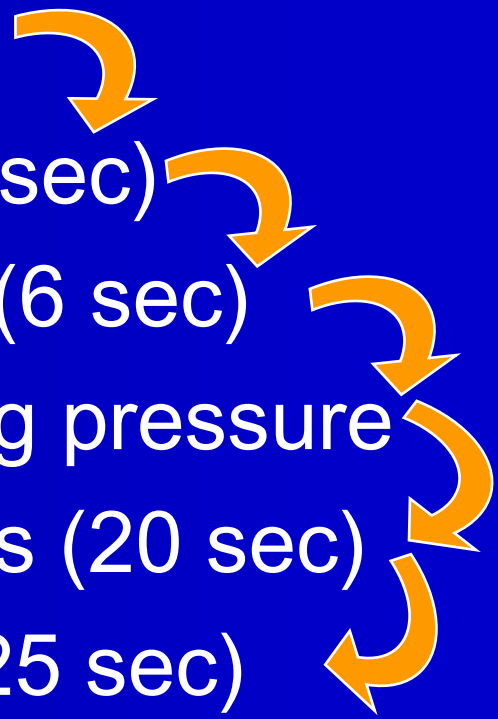
Coronary Heart Disease



Circulation. 2002

Physiology: Ischemic Cascade

1. Supply/demand imbalance
2. Diastolic dysfunction (4 sec)
3. Systolic dysfunction (6 sec)
4. Elevated LV filling pressure
5. ECG changes (20 sec)
6. Angina (25 sec)



From Sigwart U, et al, Silent Myocardial Ischemia 1984 and Armstrong WF, Prog Cardiov Dis 1997;39:499-522

Time Course of Ischemia

- Experimental Ischemia
  - Threshold of 10-20% reduction in blood flow impairs wall thickening and 80% reduction results in akinesis
  - Decreased wall thickening extends beyond reduced flow (“tethering”)
- Clinical Ischemia (complete balloon occlusion)
  - Regional endocardial dysfunction in 19 sec
  - ECG change in 30 sec
  - Chest pain 39 sec
- Clinical Ischemia (stress in region of coronary stenosis)
  - Wall motion abnormality in 30 sec
  - ECG change in 90 sec

Otto CM. 2nd Ed. 2002. p. 275, 307

Cardiac Imaging Tests in Coronary Disease

- **Invasive**: Cardiac catheterization (ventriculography, coronary angiography)

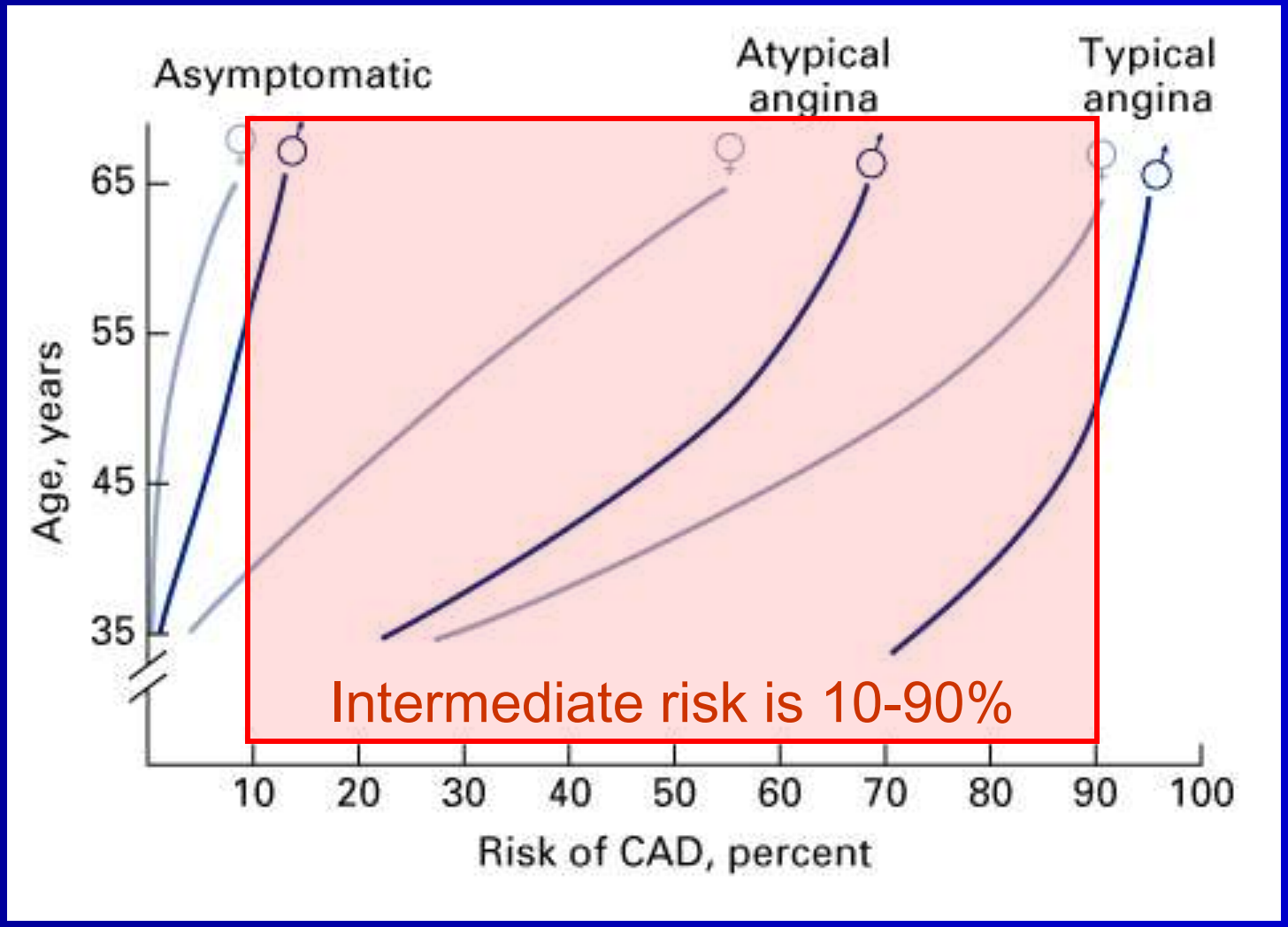
- **Noninvasive**:
  - Electric* "imaging" (ST segment – ischemia, arrhythmia)
  - Nuclear* (myocardial perfusion, pump function, viability)
  - Echocardiography* (wall motion, pump function, valve function)
  - Chest X-Ray*
  - CT Scan (coronary anatomy, coronary calcification)
  - MRI (coronary anatomy, ventricular function, myocardial perfusion, viability, valve function)

* = common, high volume use

Imaging is Used When Exercise ECG is not Adequate

- **Patients unable to exercise** (intermediate or high clinical likelihood of CAD based on age and symptoms)
- **ECG not interpretable** (LVH, WPW, Paced QRS, LBBB, digoxin therapy, >1mm ST depression)
- **Clinical situation demands** more information (angiographically intermediate lesions, intermediate Duke treadmill score, changing clinical situation with prior imaging study)

Effect of Symptoms on Risk of CAD



Hurst, 1998, Ch. 45

History of Noninvasive Testing

Master's 2 step

* Motorized treadmill ECG

* Myocardial perfusion imaging

Search for optimized sensitivity and specificity

Time

* Stress echocardiography

Balance of cost and benefit and risk

Coronary calcification

Magnetic resonance imaging

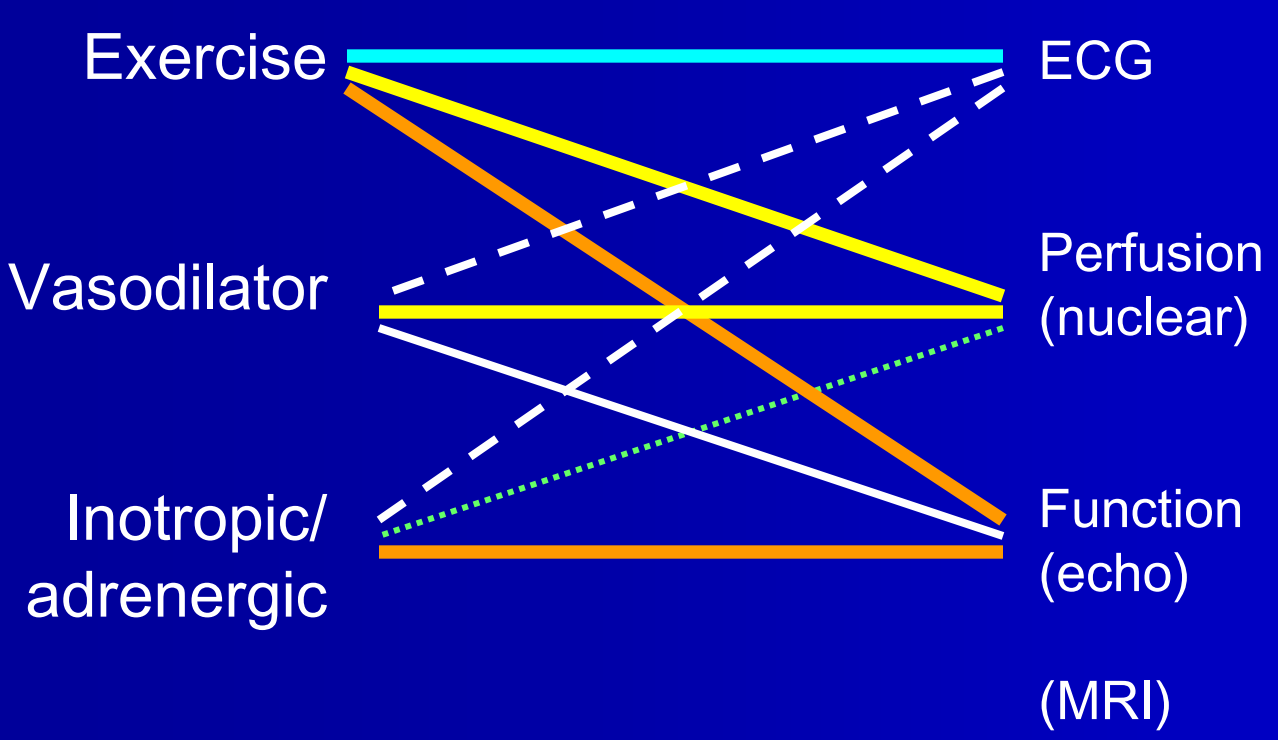
Choice depends on particular clinical question

Types of Stress

- Exercise is most desirable, treadmill in USA
  - Exercise tolerance has prognostic value, and clinical appearance and HR and BP response information are useful
- In patients who can't exercise:
  - Vasodilator for perfusion testing (dipyridamole, adenosine, regadenoson=Lexiscan)
  - Adrenergic for perfusion or wall motion (dobutamine)
- In other special circumstances
  - LBBB, Paced QRS (prefer vasodilator)

Simplified Summary of Noninvasive Assessment in CAD

Stress	Assessment
Exercise	ECG
Vasodilator	Perfusion (nuclear)
Inotropic/ adrenergic	Function (echo)
	(MRI)



- Exercise ECG
- Exercise perfusion scan
- Vasodilator perfusion scan
- Exercise echo
- Dobutamine stress echo

Exercise ECG in CAD

- Usefulness:
  - Widely available
  - Optimal type of stress
  - Least expensive procedure
  - Wealth of prognostic information
- Limitations:
  - Less sensitive than most imaging tests
  - False positive results
  - Many patients cannot exercise
  - Many patients have uninterpretable ECG

Exercise Nuclear Myocardial Perfusion Imaging (MPI) in CAD

- Usefulness
  - Widely available
  - Provides prognostic information from exercise
  - Useful in abnormal ECG with ST-T wave abnormalities
  - Very sensitive
  - Wealth of prognostic information
- Limitations
  - Expensive
  - False positive results
  - Many patients cannot exercise

Exercise Echocardiography in CAD

- Usefulness
  - Provides prognostic information from exercise
  - Useful in abnormal ECG with ST-T wave abnormalities
  - Very specific
  - Adequate prognostic information
- Limitations
  - Technically demanding, so less widely available
  - Expensive
  - Difficult to interpret in presence of resting wall motion abnormalities
  - Many patients cannot exercise
  - May be less sensitive than MPI

Vasodilator Nuclear Myocardial Perfusion Imaging in CAD

- Usefulness
  - Readily available
  - Useful in patients who cannot exercise
  - Useful in patients with LBBB and WPW
  - Very sensitive
  - Wealth of prognostic information
- Limitations
  - Expensive
  - False positive results
  - Adverse effects of vasodilating agents (dipyridamole, adenosine)

Vasodilator Echocardiography in CAD

- Infrequently used in USA, reported useful in Europe

Inotropic/Adrenergic Stress Echocardiography (Dobutamine)

- Usefulness
  - Useful in patients who cannot exercise and who have contraindication to vasodilator
  - Very specific, used for positive MPI
  - Adequate prognostic information
- Limitations
  - Expensive
  - Difficult to interpret in presence of resting wall motion abnormalities
  - May be less sensitive than MPI
  - May be less safe than MPI

Summary: Imaging Tests and Usefulness In CAD

Feature	Ex ECG	Ex Nuc	Ex Echo	Vaso Nuc	Ino Echo
Expense	++	++++	+++	++++	+++
Availability	++++	+++	++	+++	+++
Useful in LBBB	-	-	-	+++	-
Unable to exercise	-	-	-	+++	+++
Prognost info	+++	++++	+++	++++	+++
Use in ST-T	-	++++	++++	++++	++++
Specificity	+	++	++++	++	++++
Sensitivity	++	++++	+++	++++	+++
Wheezing	-	-	-	-	++++

Summary: Imaging Tests and Usefulness by Clinical Situation (Thin Ice)

Setting	ECG	Echo	Nuc	CXR	CT scan	MRI	Cath
Ischemia diagnosis	++++	+++S	++++	-	+	++	++
Ischemia severity	++++	+++S	++++	-	-	++	++
MI diagnosis	++++	+++	+++	-	-	-	+++
MI prognosis	++	+++	+++	+	-	-	++++
Viability	+	++++S	++++	-	-	+++	+++
Valve/cong. disease	+	++++	+	+	-	+++	+++
Arrhythmia	++++	+	+	-	+	+	+
CHF	+++	++++	++	++	-	++	++++

Interpreting Noninvasive Reports

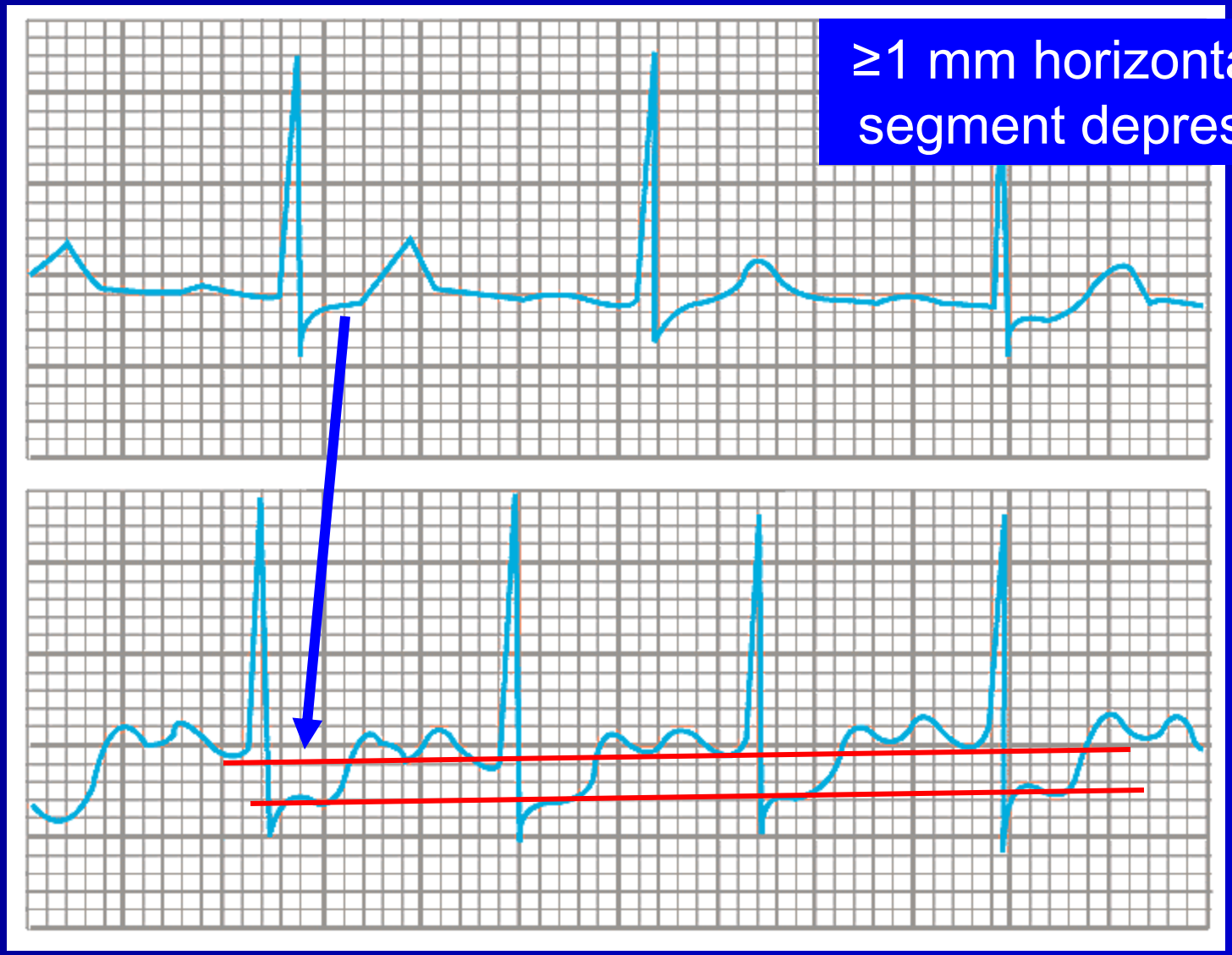
- Look at both the stress information and the imaging and electrical information
- Categorize as normal, abnormal with ischemia, abnormal without ischemia, and high risk
- Integrate into the clinical context

Choosing the Best Test

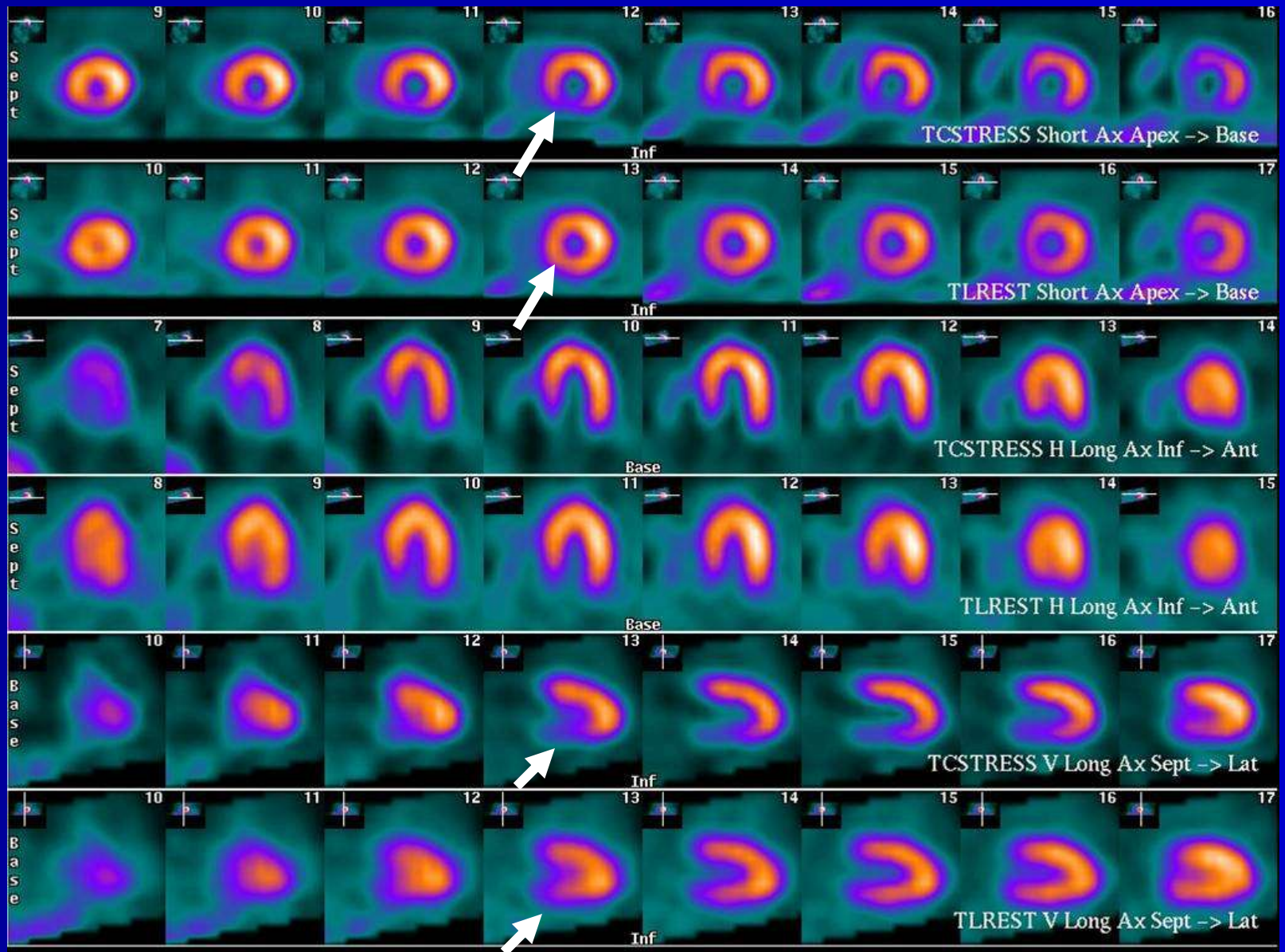
Depends on the institution

- Patient can exercise
  - and ECG is normal: Exercise ECG
  - and ECG is not interpretable: exercise perfusion study or exercise echocardiogram
  - and LBBB or LVH: vasodilator perfusion study
- Patient cannot exercise: vasodilator perfusion study or dobutamine stress echocardiogram
- Patient with asthma and wheezing: no vasodilator - dobutamine stress echo or perfusion study
- Patient with poor echo windows (COPD): may need echo contrast agent, or change to perfusion study
- Patient over 350 pounds: difficult - perfusion will be planar, echo also will likely be poor (also, can't do cardiac catheterization!)

Stress ECG Testing



Nuclear Perfusion Imaging



Heart Tests – Coronary Disease - 2

- Coronary Artery Calcium (CAC) score
  - Asymptomatic and intermediate risk of CAD (10-20% 10-yr risk)
  - Symptomatic and low risk of CAD (low score has high neg predict value)
- CT Coronary Angiography (Iodine +)
  - Anomalous coronary (also cardiac MR)
  - Acute chest pain, intermediate risk, neg Trop
  - Maybe Sx + (intermed prob – abn ECG – can't exercise – prior equivocal test)
- PET Scan, alternative to Nuc

Coronary Artery Calcium

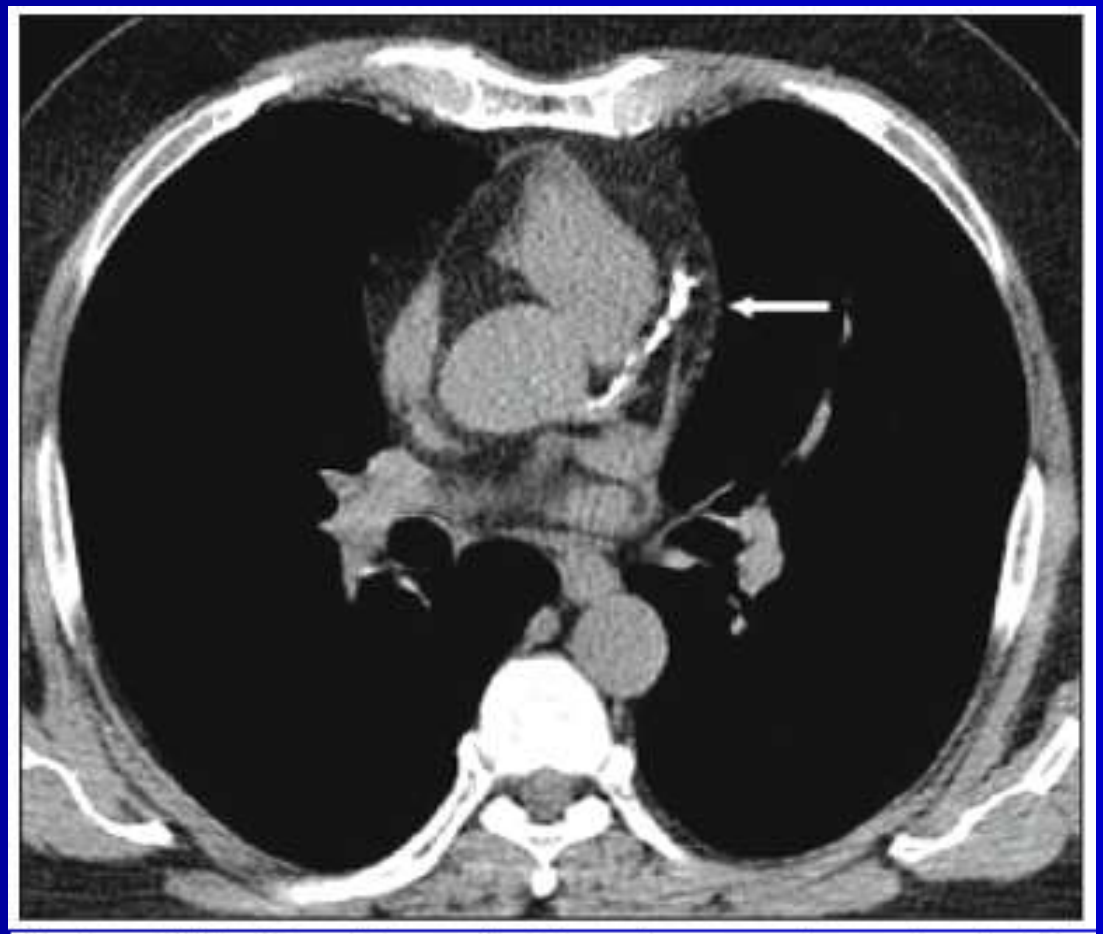
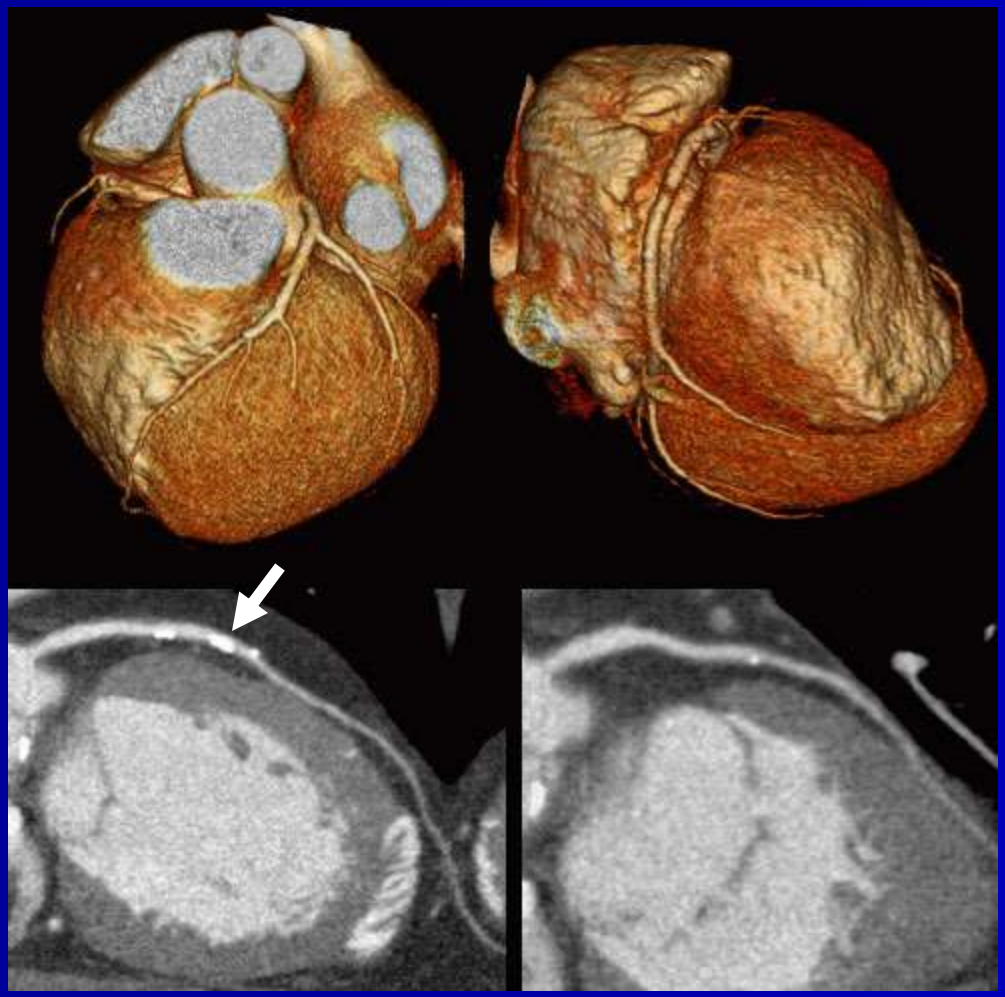
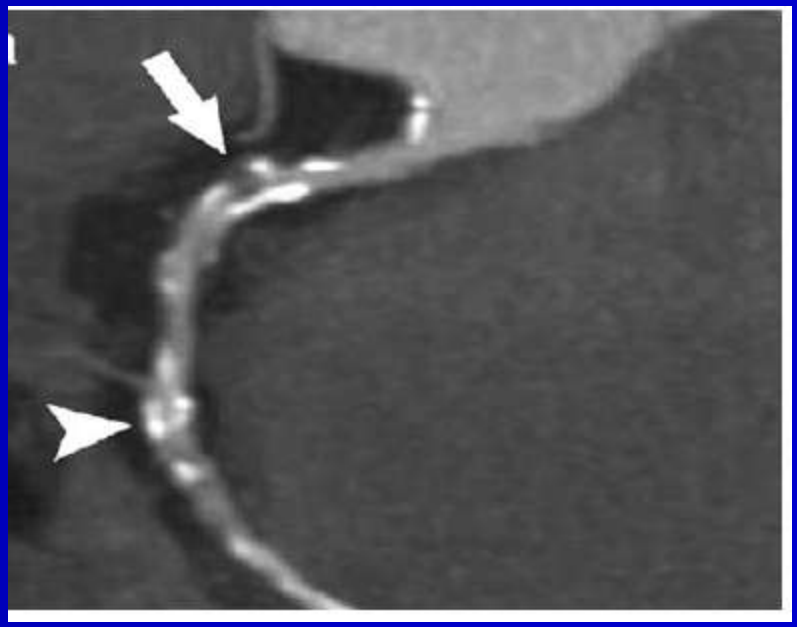


Fig. 1 - Calcification of the anterior descending artery detected on ultrafast tomography in an asymptomatic man (arrow).

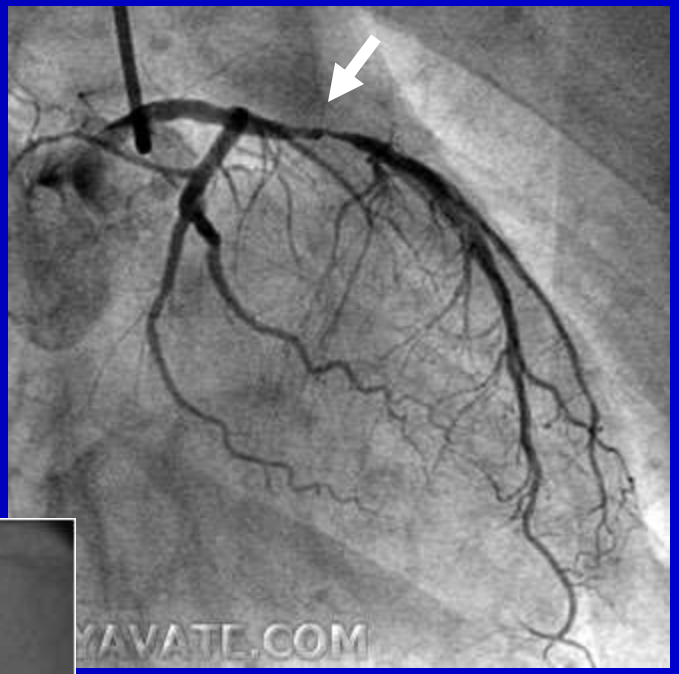
CT Coronary Angiography



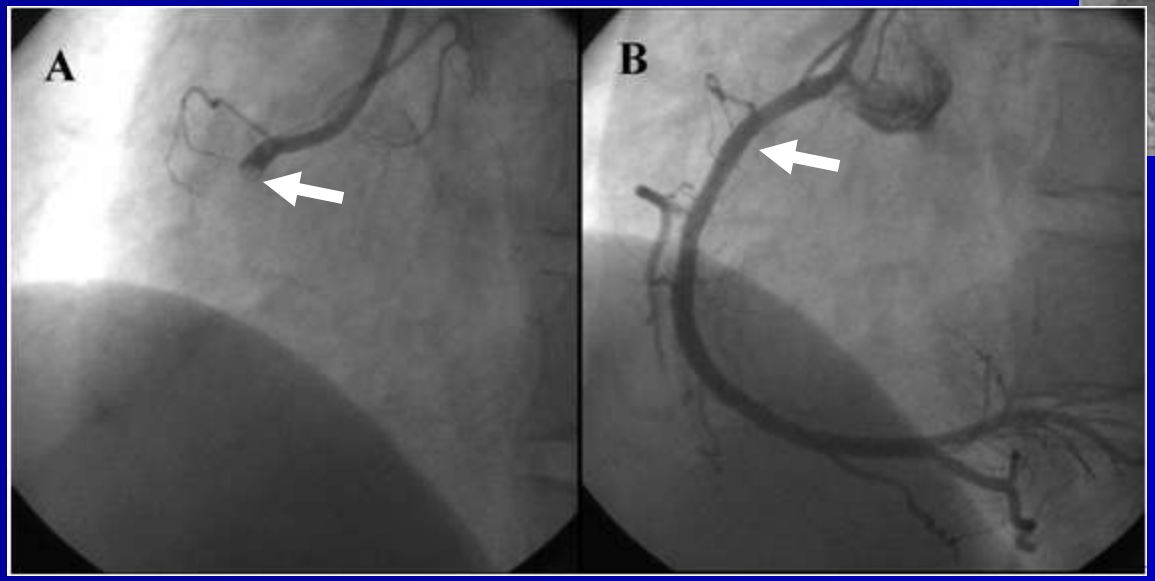


Coronary Angiography

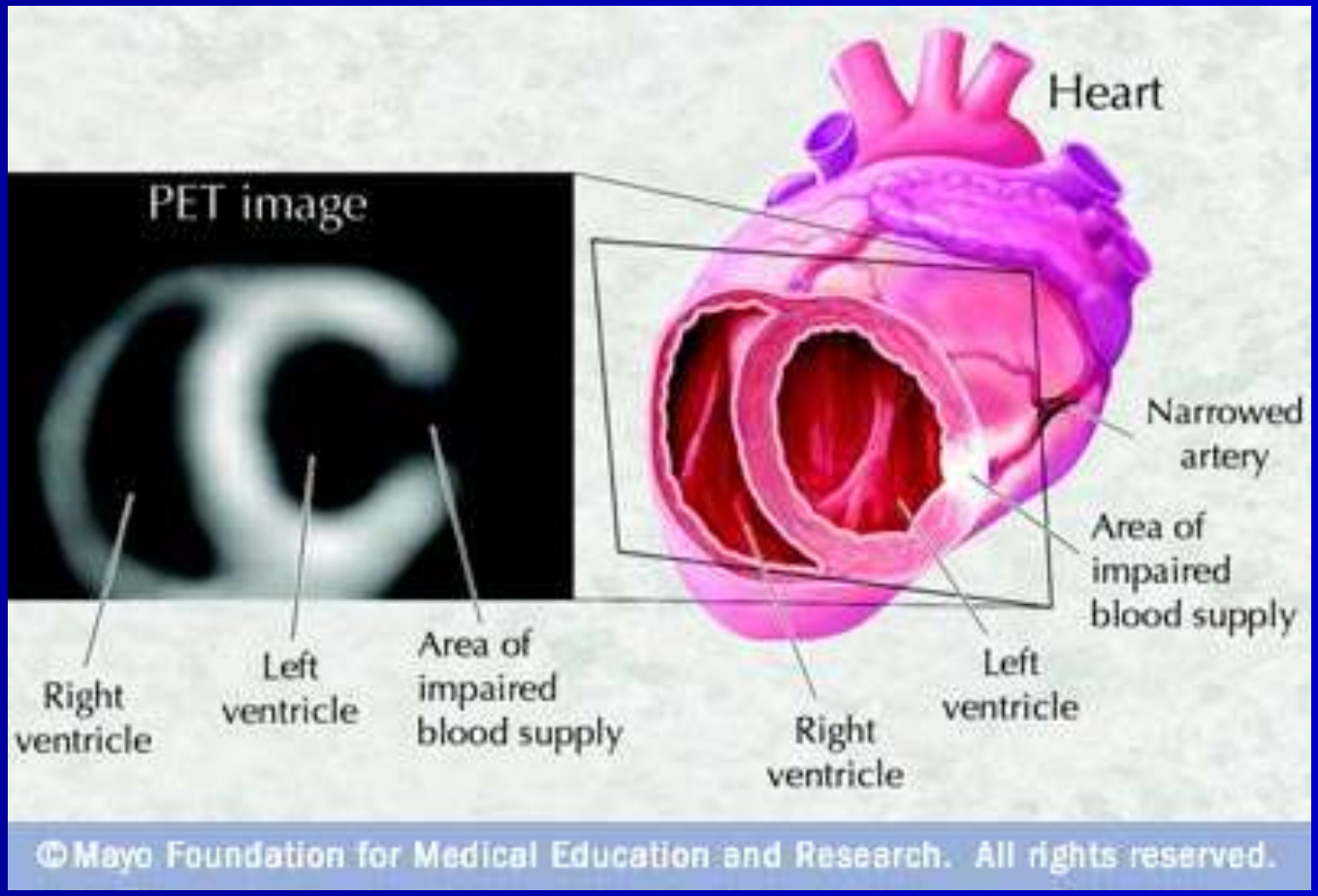
Tight LAD stenosis



Total RCA occlusion
and recanalization



Cardiac PET Scan



Heart Tests – Coronary Disease – Radiation Exposure

Procedure	# CXRs
Stress echocardiography	0
Cardiac MR Angiography	0
Coronary artery Calcium score	20-40
Coronary angiography (diagnostic)	200-500
Nuclear perfusion imaging	100-500
PET perfusion imaging	100-400
CT coronary angiography	700-2100

Definition of Angina

Table 5. Clinical Classification of Chest Pain

Typical angina (definite)

1) Substernal chest discomfort with a characteristic quality and duration that is 2) provoked by exertion or emotional stress and 3) relieved by rest or NTG.

Atypical angina (probable)

Meets 2 of the above characteristics.

Noncardiac chest pain

Meets one or none of the typical anginal characteristics.

Modified from Diamond, JACC, 1983 (45).

ACC/AHA Clinical Practice Guideline, Chronic Stable Angina, 2002.

Diagnosis: Pretest Probability of Obstructive Disease at Catheterization

Diagnostic testing is appropriate - **intermediate** pretest probability

Age (y)	Gender	Typical/Definite Angina Pectoris	Atypical/Probable Angina Pectoris	Nonanginal Chest Pain	Asymptomatic
30–39	Men	Intermediate	Intermediate	Low	Very low
	Women	Intermediate	Very low	Very low	Very low
40–49	Men	High	Intermediate	Intermediate	Low
	Women	Intermediate	Low	Very low	Very low
50–59	Men	High	Intermediate	Intermediate	Low
	Women	Intermediate	Intermediate	Low	Very low
60–69	Men	High	Intermediate	Intermediate	Low
	Women	High	Intermediate	Intermediate	Low

*No data exist for patients <30 or >69 years, but it can be assumed that prevalence of CAD increases with age. In a few cases, patients with ages at the extremes of the decades listed may have probabilities slightly outside the high or low range. High indicates >90%; intermediate, 10%–90%; low, <10%; and very low, <5%.

ACC/AHA Guideline Exercise Testing 2002, p. 7.

Stable CAD: Diagnostic Tests

- ECG normal and able to exercise = ETT
- ECG abnl and able to exercise = ETT with imaging (nuc-perfusion or echo-wall motion)
  - Exception: LBBB, use vasodilator
- Unable to exercise = vasodilator or dobutamine stress

Contraindications to Exercise Testing

- MI or UA <48 h
- Uncontrolled ventricular arrhythmia
- Symptomatic severe AS
- HCM (?)
- Decompensated HF
- Acute pulmonary embolism
- Acute aortic dissection
- Acute pericarditis

ACC/AHA Guideline Exercise Testing 2002, p. 5.

Stable CAD: Low Risk Test Results

- ECG result: Low risk Duke treadmill score (≥5)
  - Number of minutes of Bruce protocol
  - Minus 5 times number of mm ST depression
  - Minus 4 times angina score (0=none, 1=some, 2=limiting)
- Nuclear result: normal, or small perfusion defect at rest or stress
- Stress Echo result: Normal wall motion or no change in limited resting wall motion abnormalities with stress

ACC/AHA Guideline, Stable Angina, 2002

Stable CAD: Strongly Positive (High Risk) Test Results

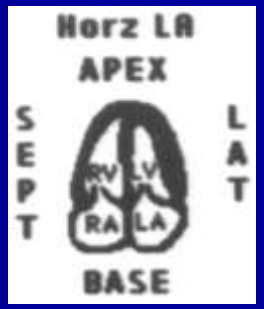
- Markedly positive result = coronary angio
- ECG result: Significant ST depression at low workload, ST elevation, low BP (Duke treadmill score ≤-11)
- Nuclear result: TID, lung uptake, multizone ischemia, EF<35%
- Stress Echo result: Fall in EF with stress, multizone hypokinesis, EF<35%

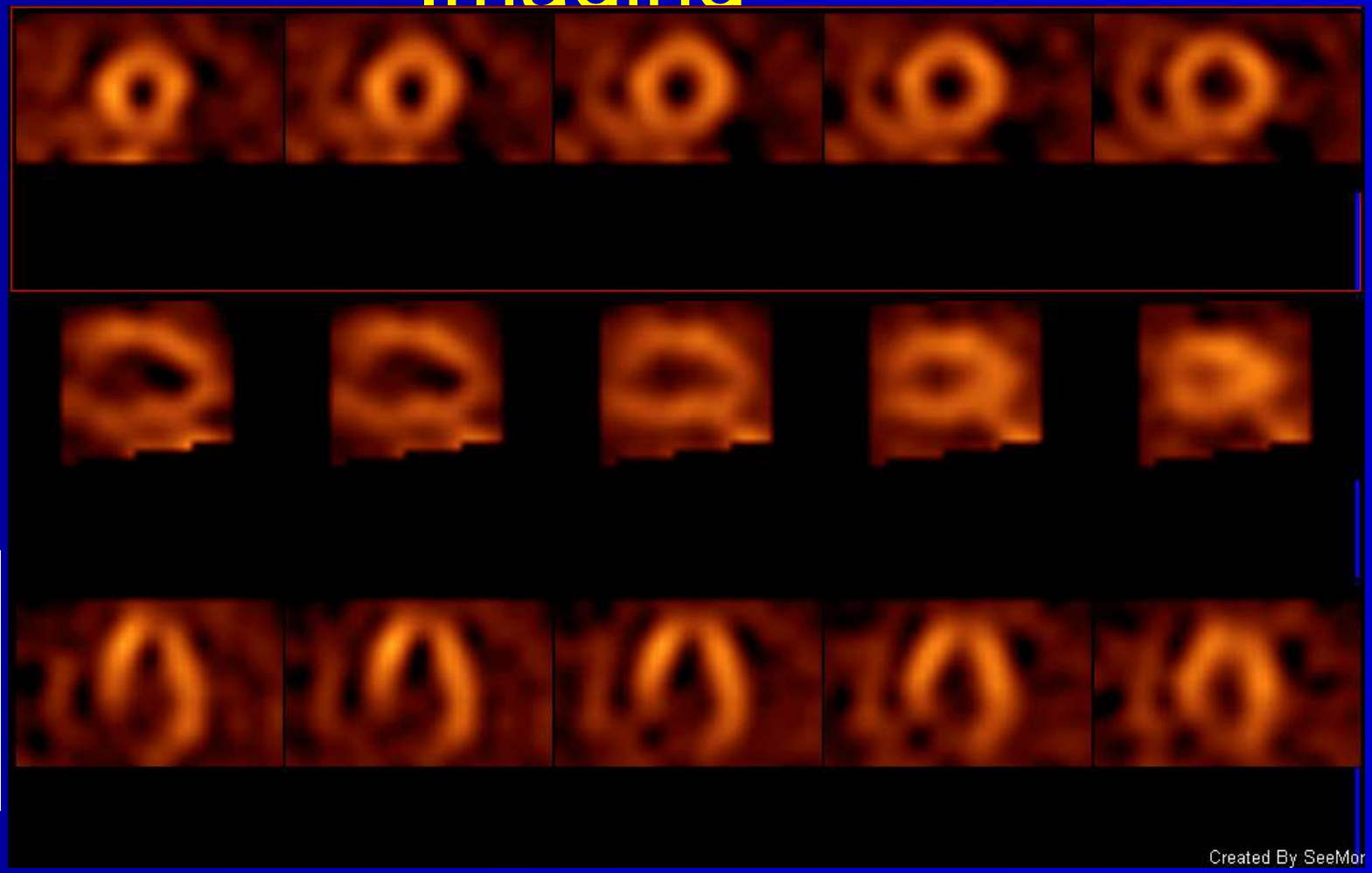
Coronary Angiography Indications

- Lifestyle-limiting angina despite medical therapy
- High-risk (markedly positive) stress testing
- Resuscitation from sudden cardiac death
- Documented VT
- Uncertain diagnosis with recurrent hospitalization for chest pain
- Angina and heart failure

ACC/AHA Clinical Practice Guideline, Chronic Stable Angina, 2002.

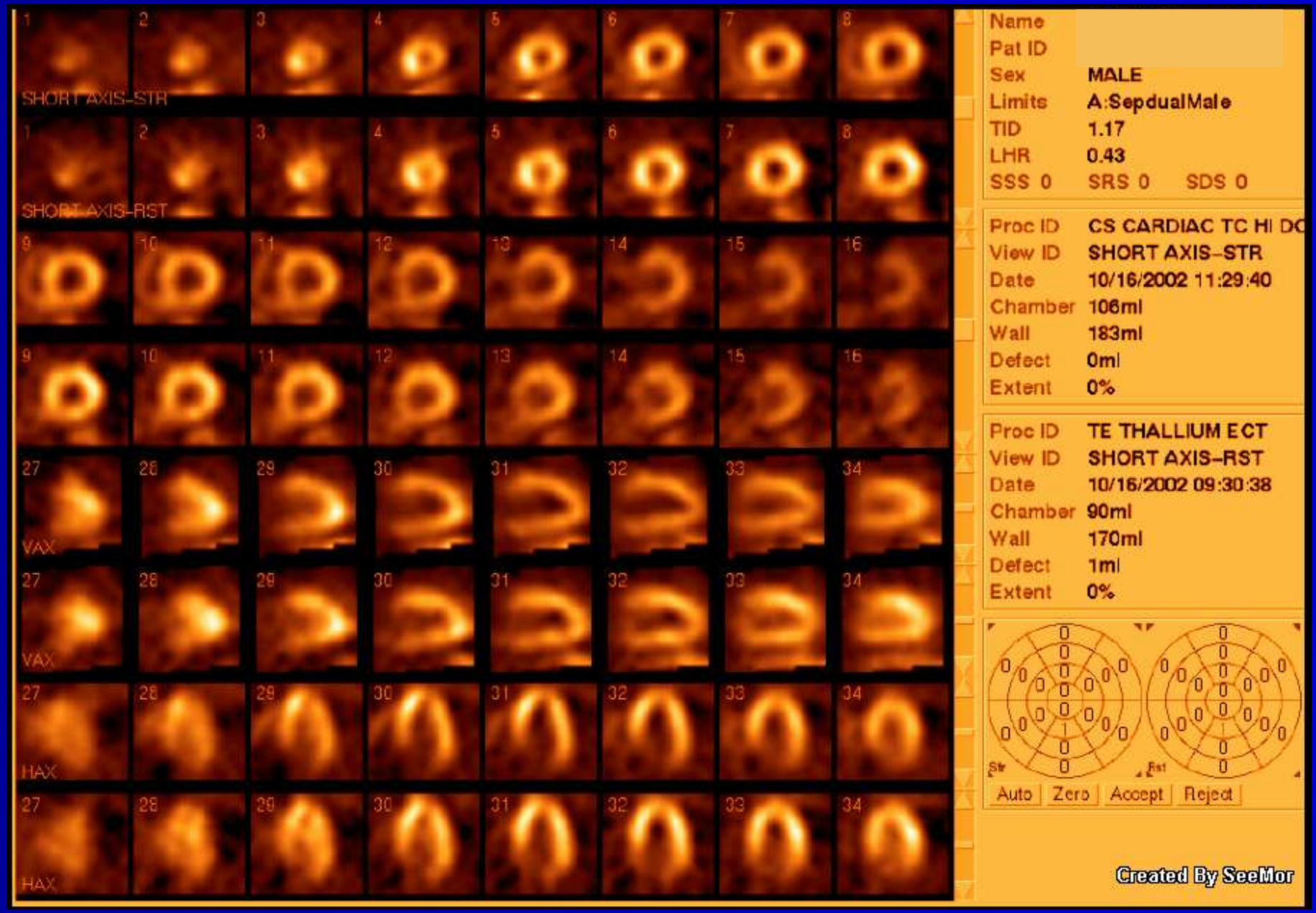
Stress Myocardial Perfusion Imaging





Normal

Courtesy of Dr. Janet Hays, UTHSCSA



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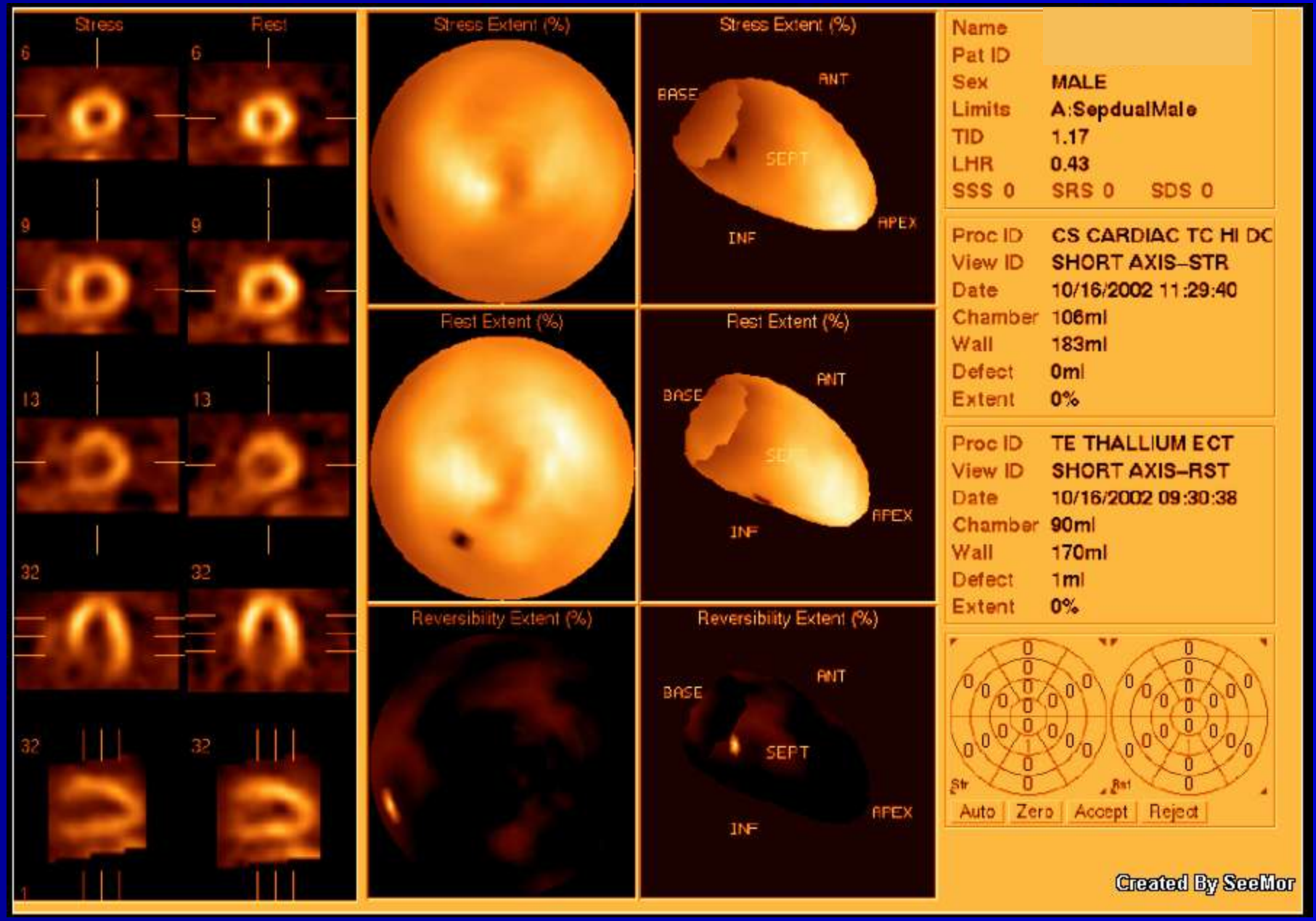

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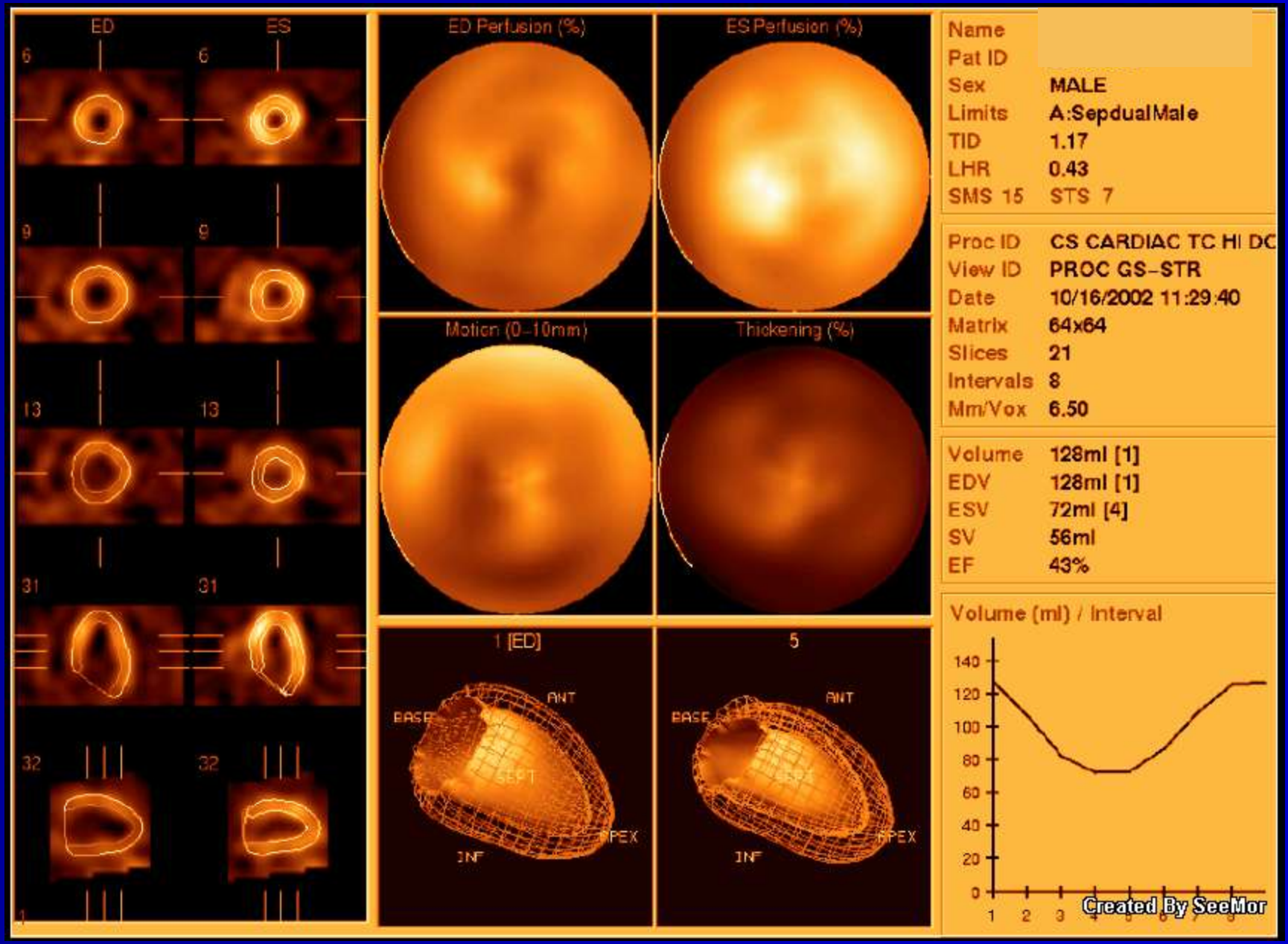

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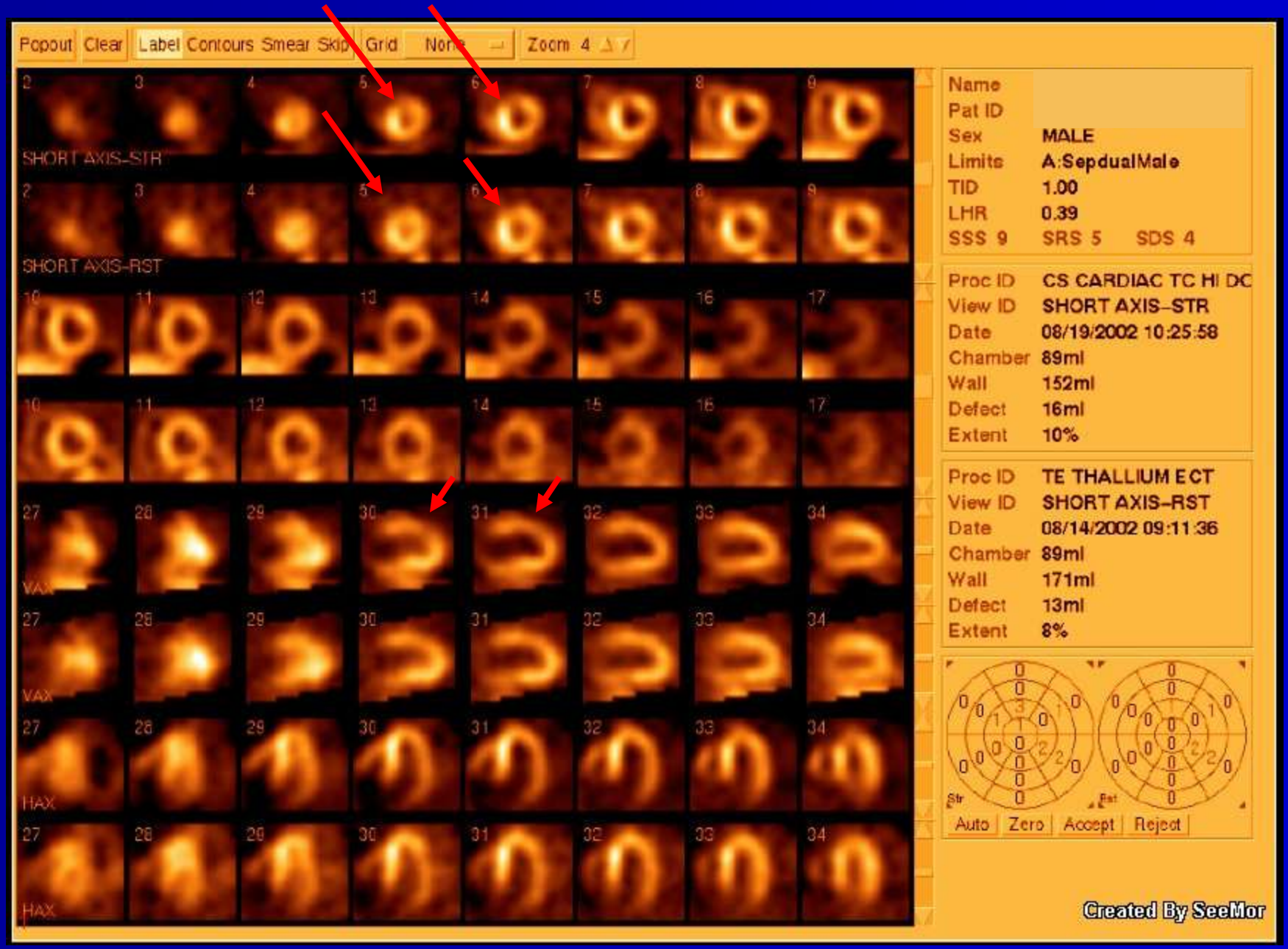

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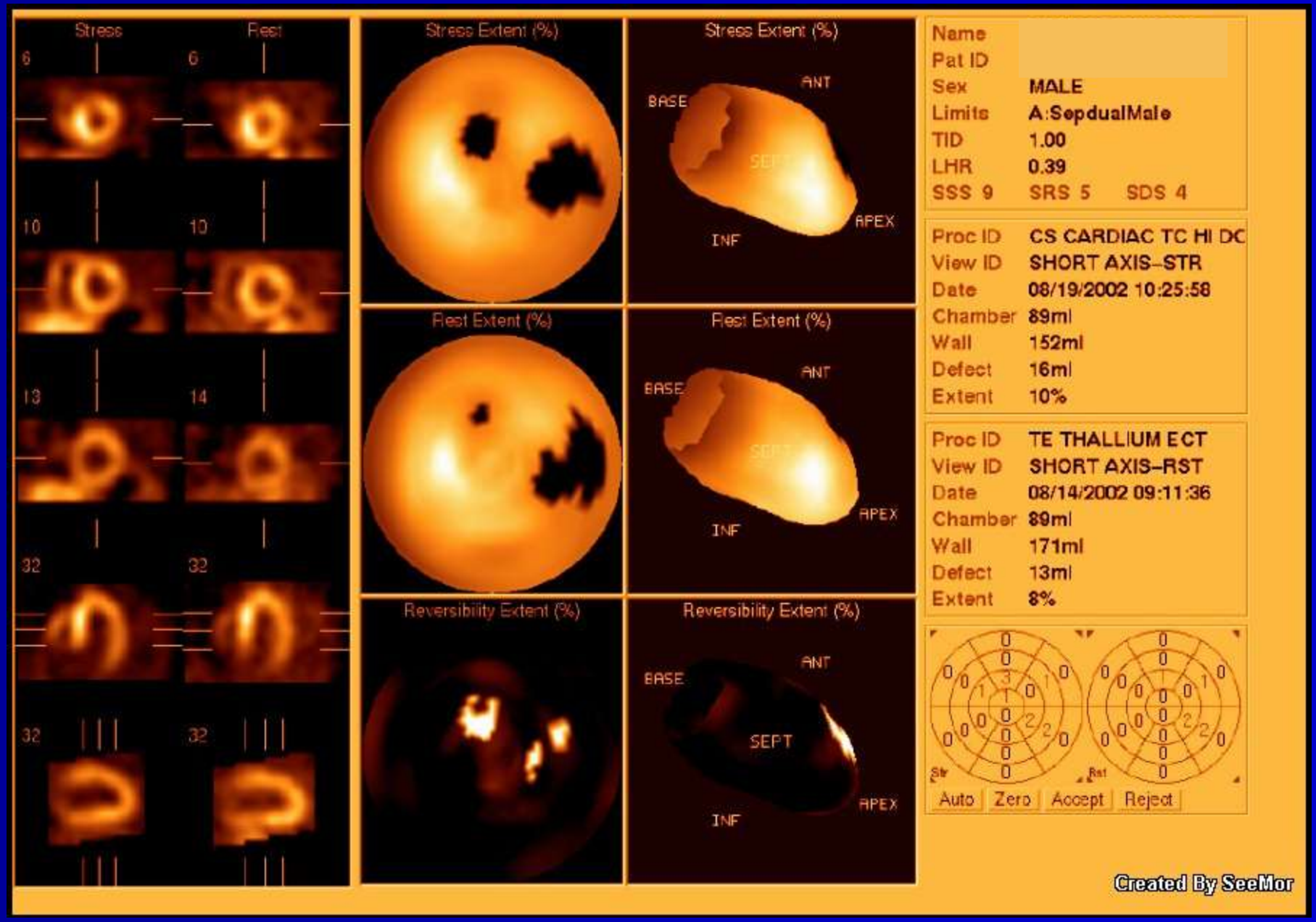
Abnormal



Abnormal

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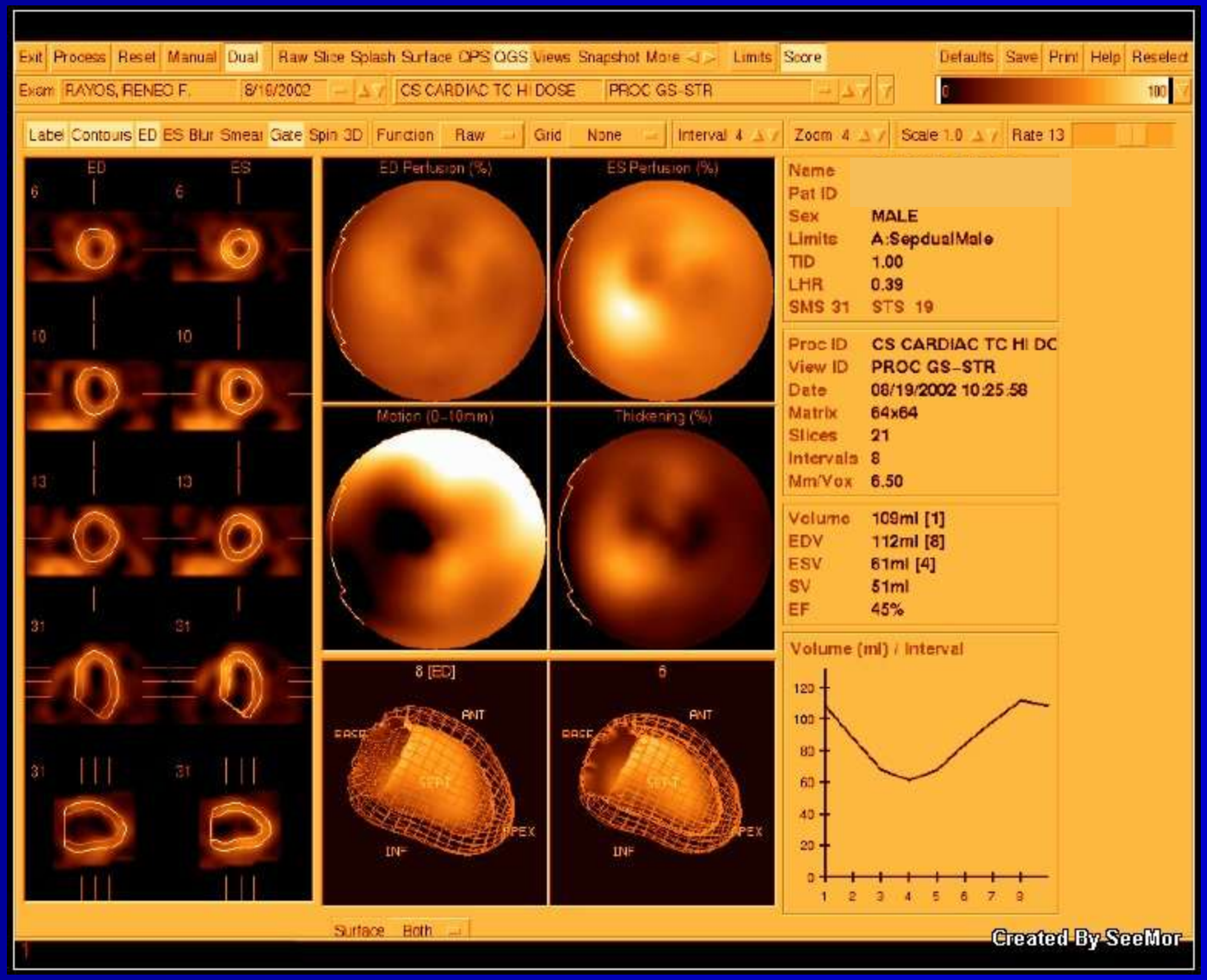


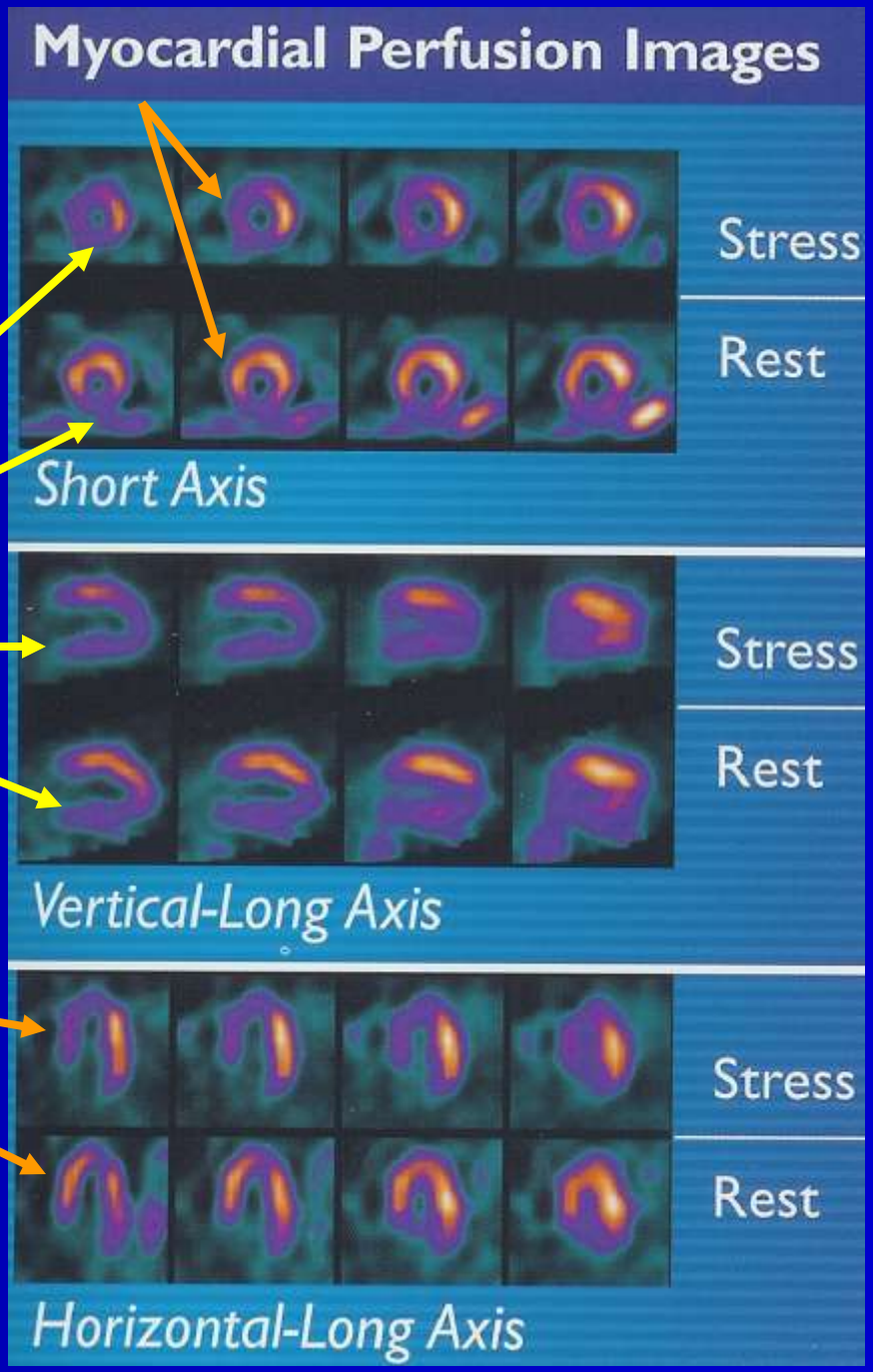
Courtesy of Dr. Janet Hays, UTHSCSA

Abnormal

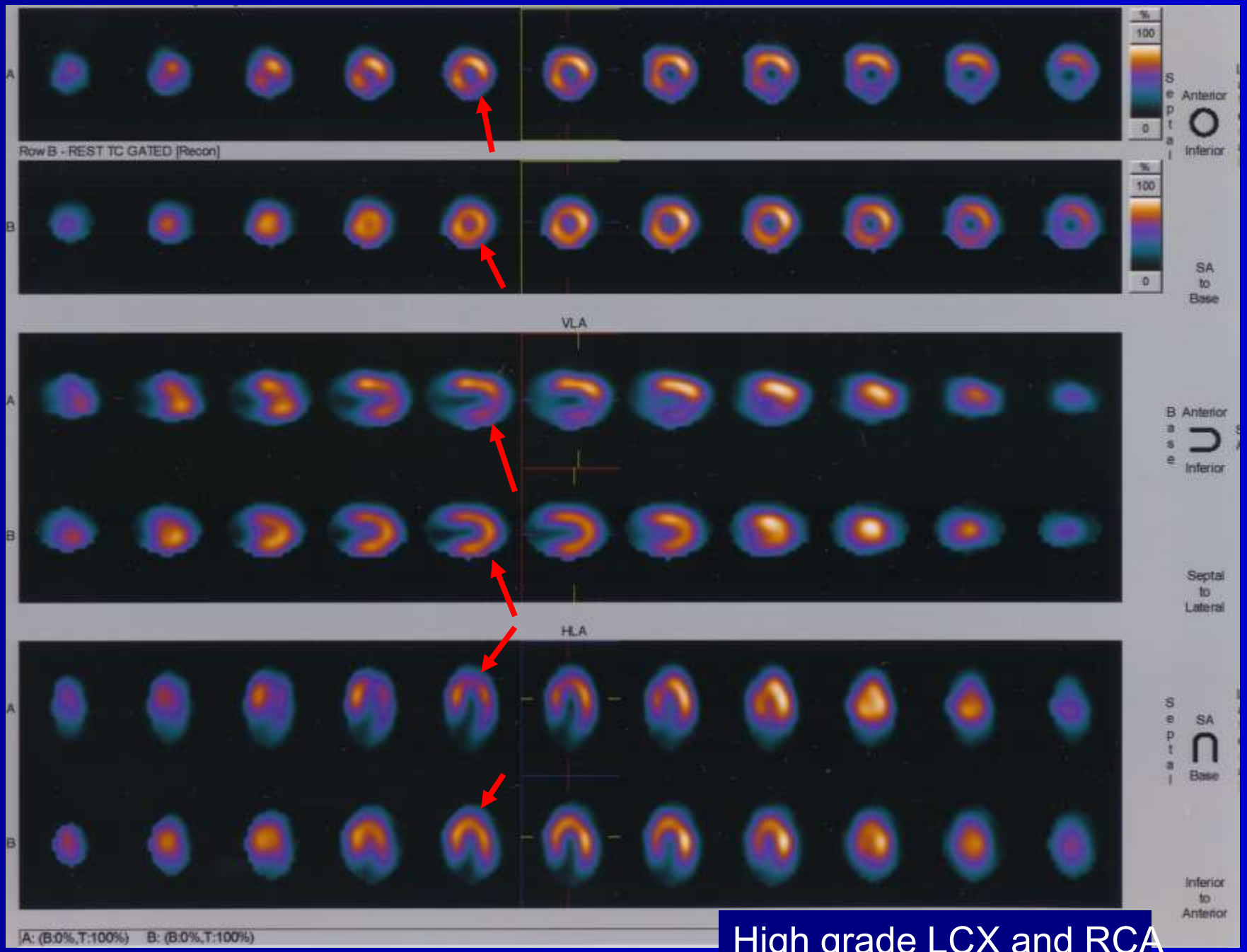
Abnormal Myocardial Perfusion Image

Inferior fixed defect

Small-moderate size, moderate severity reversible in apical septum



From Industry Advertisement for Technicium Sestamibi (Cardiolite)



High grade LCX and RCA

From South Texas Veterans' Health Care System


Thank You!

What is the Appropriate Test?

- Age: 67
- Gender: M
- Htn: +
- DM: +
- HLP: -
- Tob: +
- ECG: Normal

- Answer:

- Hx: Employed postal worker with no prior history of heart disease, with sharp left-sided pain lasting 2 seconds at rest

What is the Appropriate Test?

- Age: 67
- Gender: M
- Htn: +
- DM: +
- HLP: -
- Tob: +
- ECG: Normal

- Hx: Employed postal worker with no prior history of heart disease, with sharp left-sided pain lasting 2 seconds at rest

- Answer: Treadmill exercise ECG

What is the Appropriate Test?

- Age: 68
- Gender: M
- Htn: +
- DM: -
- HLP: +
- Tob: +
- ECG: T flattening

- Answer:

- Hx: thin patient with significant COPD on home O2, wheezing, with increasing dyspnea and mild chest tightness

What is the Appropriate Test?

- Age: 68
- Gender: M
- Htn: +
- DM: -
- HLP: +
- Tob: +
- ECG: T flattening

- Hx: thin patient with significant COPD on home O2, wheezing, with increasing dyspnea and mild chest tightness

- Answer: Adrenergic stress echo (Vasodilator- no)

What is the Appropriate Test?

- Age: 35
- Gender: F
- Htn: +
- DM: -
- HLP: -
- Tob: -
- ECG: minor T wave flattening
- Answer:

- Hx: asymptomatic secretary wishes permission to join an exercise program

What is the Appropriate Test?

- Age: 35
- Gender: F
- Htn: +
- DM: -
- HLP: -
- Tob: -
- ECG: minor T wave flattening
- Hx: asymptomatic secretary wishes permission to join an exercise program
- Answer: No test, reassure, treat hypertension

What is the Appropriate Test?

- Age: 72
- Gender: M
- Htn: +
- DM: -
- HLP: +
- Tob: 0 for 9 yr
- ECG: LBBB

- Answer:

- Hx: patient 9 years post CABG with return of his former chest pain, occurring about twice a week

What is the Appropriate Test?

- Age: 72
- Gender: M
- Htn: +
- DM: -
- HLP: +
- Tob: 0* 9 yr
- ECG: LBBB

- Hx: patient 9 years post CABG with return of his former chest pain, occurring about twice a week

- Answer: Vasodilator thallium (dobutamine not good)

What is the Appropriate Test?

- Age: 69
- Gender: F
- Htn: +
- DM: -
- HLP: +
- Tob: +
- ECG: T ↓ V1-3

- Answer:

- Hx: 3 days of pressure-like discomfort, with SOB and diaphoresis and a 20-minute episode this morning

What is the Appropriate Test?

- Age: 69
- Gender: F
- Htn: +
- DM: -
- HLP: +
- Tob: +
- ECG: T ↓ V1-3

- Hx: 3 days of pressure-like discomfort, with SOB and diaphoresis and a 20-minute episode this morning

- Answer: No test, too sick, Wellens', admit

What is the Appropriate Test?

- Age: 46
- Gender: M
- Htn: +
- DM: +
- HLP: +
- Tob: +
- ECG: T flattening

- Answer:

- Hx: computer programmer with dyspnea and edema and chest tightness with walking and sleeping, weight 450.

What is the Appropriate Test?

- Age: 46
- Gender: M
- Htn: +
- DM: +
- HLP: +
- Tob: +
- ECG: T flattening

- Answer: No good answer.

- Hx: computer programmer with dyspnea and edema and chest tightness with walking and sleeping, weight 450.

Vasodilator sestamibi?

Dobutamine echo?

Exercise stress test?

Medical therapy?

What is the Appropriate Test?

- Age: 71
- Gender: F
- Htn: +
- DM: -
- HLP: -
- Tob: +
- ECG: normal

- Answer:

- Hx: patient admitted with chest pain and ST depression and mild elevation of Tro-I, also weight loss, pulmonary nodules and cervical adenopathy, 5 years post mastectomy

What is the Appropriate Test?

- Age: 71
- Gender: F
- Htn: +
- DM: -
- HLP: -
- Tob: +
- ECG: normal

- Hx: patient admitted with chest pain and ST depression and mild elevation of Tro-I, also weight loss, pulmonary nodules and cervical adenopathy, 5 years post mastectomy

- Answer: Consult Oncology first

What is the Appropriate Test?

- Age: 42
- Gender: F
- Htn: +
- DM: +
- HLP: +
- Tob: -
- ECG: PPRWP

- Answer:

- Hx: patient with amputation left great toe for vascular disease, no chest pain, mild dyspnea when upset

What is the Appropriate Test?

- Age: 42
- Gender: F
- Htn: +
- DM: +
- HLP: +
- Tob: -
- ECG: PPRWP

- Hx: patient with amputation left great toe for vascular disease, no chest pain, mild dyspnea when upset

- Answer: Vasodilator thallium (DSE OK)

What is the Appropriate Test?

- Age: 72
- Gender: F
- Htn: +
- DM: -
- HLP: -
- Tob: -
- ECG: A Fib, LVH

- Answer:

- Hx: patient with chronic shortness of breath, slightly worsening

What is the Appropriate Test?

- Age: 72
- Gender: F
- Htn: +
- DM: -
- HLP: -
- Tob: -
- ECG: A Fib, LVH

- Hx: patient with chronic shortness of breath, slightly worsening

- Answer: Vasodilator thallium (DSE NOT OK)

What is the Appropriate Test?

- Age: 45
- Gender: M
- Htn: +
- DM: -
- HLP: +
- Tob: - * 2 yr
- ECG: normal

- Hx: patient with no symptoms, with abnormal cine CT result, worried

- Answer:

What is the Appropriate Test?

- Age: 45
- Gender: M
- Htn: +
- DM: -
- HLP: +
- Tob: none for 2 yr
- ECG: normal

- Hx: patient with no symptoms, with abnormal cine CT result, worried

- Answer: Exercise ECG, but difficult decision

What is the Appropriate Test?

- Age: 59
- Gender: M
- Htn: +
- DM: -
- HLP: +
- Tob: - * 2 yr
- ECG: Ant MI

- Hx: patient with refractory chest pain despite optimal medication, S/P CABG 1994, cath 1998 2 grafts down, native disease progression

- Answer:

What is the Appropriate Test?

- Age: 59
- Gender: M
- Htn: +
- DM: -
- HLP: +
- Tob: - * 2 yr
- ECG: Ant MI

- Hx: patient with refractory chest pain despite optimal medication, S/P CABG 1994, cath 1998 2 grafts down, native disease progression

- Answer: Review cath; if candidate, thallium

What is the Appropriate Test?

- Age: 63
- Gender: M
- Htn: +
- DM: +
- HLP: +
- Tob: - * 2 yr
- ECG: LVH, A Fib

- Hx: patient with no chest pain and no prior cardiac history admitted with new onset CHF

- Answer:

What is the Appropriate Test?

- Age: 63
- Gender: M
- Htn: +
- DM: +
- HLP: +
- Tob: - * 2 yr
- ECG: LVH, A Fib

- Hx: patient with no chest pain and no prior cardiac history admitted with new onset CHF

- Answer: Either Cath first, or viability first

What to do with the Answer?

- Age: 67
- Gender: M
- Htn: +
- DM: +
- HLP: -
- Tob: +
- ECG: Normal

- Hx: Employed postal worker with no prior history of heart disease, with sharp left-sided pain lasting 2 seconds at rest
- Treadmill ECG
  - Normal/normal →
  - Abnormal →

What to do with the Answer?

- Age: 67
- Gender: M
- Htn: +
- DM: +
- HLP: -
- Tob: +
- ECG: Normal

- Hx: Employed postal worker with no prior history of heart disease, with sharp left-sided pain lasting 2 seconds at rest
- Treadmill ECG
  - Normal/normal → reassure
  - Abnormal → imaging study or cath

What to do with the Answer?

- Age: 68
- Gender: M
- Htn: +
- DM: -
- HLP: +
- Tob: +
- ECG: T flattening

- Hx: thin patient with significant COPD on home O2, wheezing, with increasing dyspnea and mild chest tightness
- Stress echo
  - Normal →
  - Abnormal →

What to do with the Answer?

- Age: 68
- Gender: M
- Htn: +
- DM: -
- HLP: +
- Tob: +
- ECG: T flattening

- Hx: thin patient with significant COPD on home O2, wheezing, with increasing dyspnea and mild chest tightness
- Stress echo
  - Normal → reassure
  - Abnormal → medical management or cath

What to do with the Answer?

- Age: 35
- Gender: F
- Htn: +
- DM: -
- HLP: -
- Tob: -
- ECG: minor T wave flattening

- Hx: asymptomatic secretary wishes permission to join an exercise program
- Recall, no test needed
- Inappropriate test leads to
  - More inappropriate tests

What to do with the Answer?

- Age: 72
- Gender: M
- Htn: +
- DM: -
- HLP: +
- Tob: 0* 9 yr
- ECG: LBBB

- Hx: patient 9 years post CABG with return of his former chest pain, occurring about twice a week
- Vasodilator thallium
  - Normal $\rightarrow$
  - Abnormal $\rightarrow$
  - High-risk $\rightarrow$

What to do with the Answer?

- Age: 72
- Gender: M
- Htn: +
- DM: -
- HLP: +
- Tob: 0* 9 yr
- ECG: LBBB

- Hx: patient 9 years post CABG with return of his former chest pain, occurring about twice a week
- Vasodilator thallium
  - Normal → reassure, medical therapy
  - Abnormal → medical therapy
  - High-risk → cath

What to do with the Answer?

- Age: 69
- Gender: F
- Htn: +
- DM: -
- HLP: +
- Tob: +
- ECG: T ↓ V1-3

- Hx: 3 days of pressure-like discomfort, with SOB and diaphoresis and a 20-minute episode this morning
- Recall: no test – admit, probably LAD disease, likely cath

What to do with the Answer?

- Age: 46
- Gender: M
- Htn: +
- DM: +
- HLP: +
- Tob: +
- ECG: T flattening

- Hx: computer programmer with dyspnea and edema and chest tightness with walking and sleeping, weight 450.
- Treadmill stress test:
  - 3 min
  - HR 160, BP 180
  - Chest tight and SOB
  - Normal ST segment

What to do with the Answer?

- Age: 46
- Gender: M
- Htn: +
- DM: +
- HLP: +
- Tob: +
- ECG: T flattening

Answer: medical therapy, no real change in management

- Hx: computer programmer with dyspnea and edema and chest tightness with walking and sleeping, weight 450.
- Treadmill stress test:
  - 3 min
  - HR 160, BP 180
  - Chest tight and SOB
  - Normal ST segment

What to do with the Answer?

- Age: 42
- Gender: F
- Htn: +
- DM: +
- HLP: +
- Tob: -
- ECG: PPRWP

- Hx: patient with amputation left great toe for vascular disease, no chest pain, mild dyspnea when upset
- Pthall –
  - Normal →
  - Abnormal →
  - High risk →

What to do with the Answer?

- Age: 42
- Gender: F
- Htn: +
- DM: +
- HLP: +
- Tob: -
- ECG: PPRWP

- Hx: patient with amputation left great toe for vascular disease, no chest pain, mild dyspnea when upset
- Pthall –
  - Normal → reassure
  - Abnormal → cath or medical therapy
  - High risk → cath

Last Slide: Hurray!

- **Recall the physiology**
- **Means of assessing ischemia**
  - Electrical
  - Perfusion
  - Function (wall motion)
- **Means of producing stress**
  - Exercise
  - Adrenergic agent
  - Vasodilator
- **Integrate into clinical context**