Nuclear Stress Test and Imaging

Presented by

Tamra Rocsko BS, CNMT, CMRT, ARRT(N)

Program outline

- What is a Nuclear Stress Test
  - What does it detect
  - Blood Flow
- Examination
  - Basic Test Flow
- Clinical Indications
  - What patient is a candidate for a nuclear stress test

Program outline

- Patient Prep
  - How should the patient prepare for the test
    - **Clothing**
    - **Medications**
    - **Food and drink**
- Study Time Frame
  - How long does a study take

Program outline

- Radioactive Tracers (Radiopharmaceutical)
  - **Sestamibi**
  - **Tetrofosmin**
  - **Thallium**
- Methods of Stress Testing
  - **Exercise**
  - **Chemical**
- Images

Blood Flow Through the Heart

Myocardial Perfusion Imaging (Nuclear Stress Test)

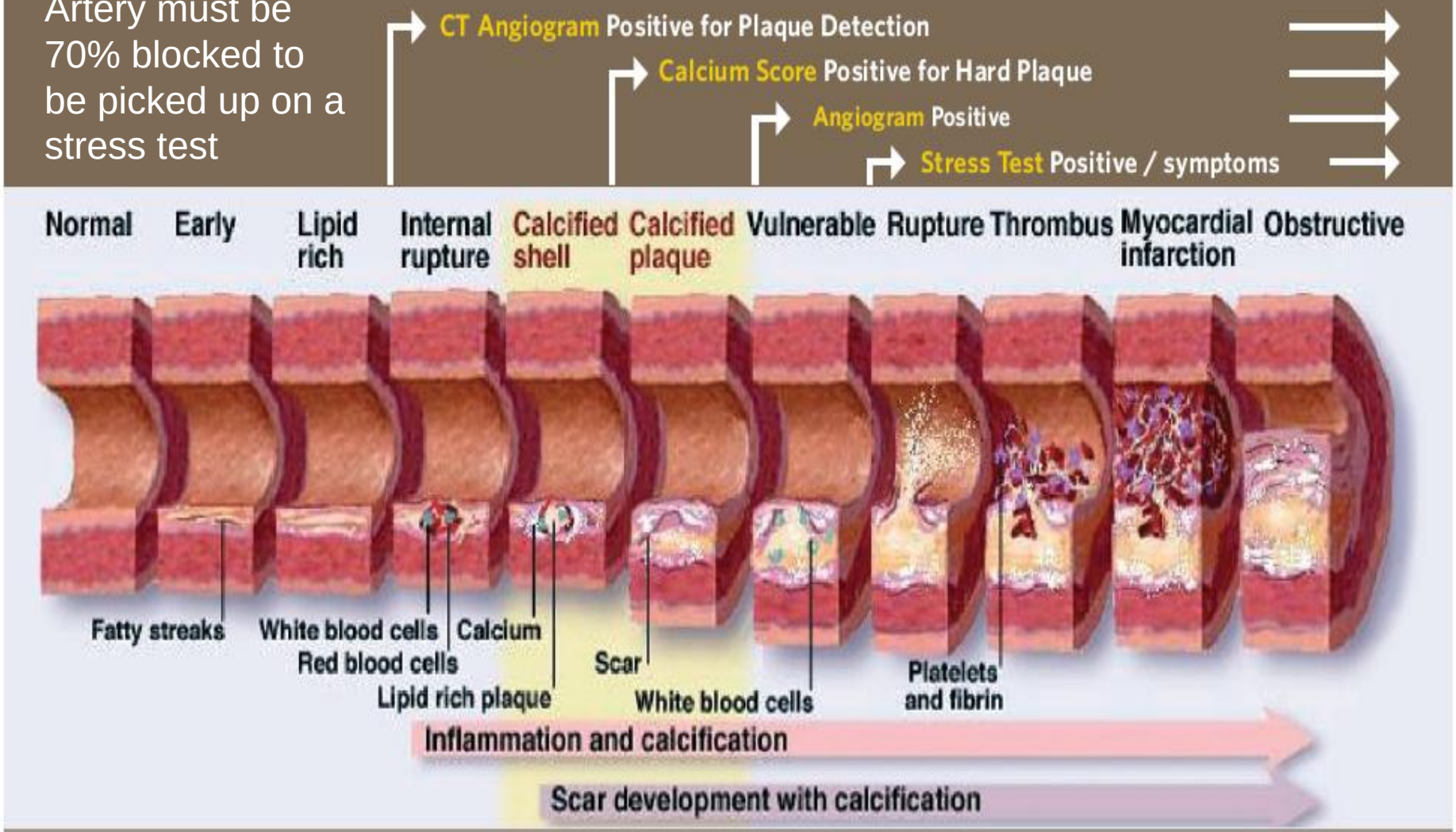
- Uses a radioactive compound that is taken up and retained in viable cardiac muscle
- Produces an objective, quantifiable 3-D map of myocardial perfusion
- One of the most widely used nuclear studies and most used diagnostic/prognostic tests in Cardiology

Myocardial Perfusion Imaging (MPI) or a Nuclear Stress Test

- The heart receives blood from the coronary arteries. If these arteries become blocked or narrowed by the accumulation of plaque like materials, the heart may not receive the amount of blood it needs to function properly. This blockage or narrowing of the coronary arteries is called coronary artery disease or CAD.
- Progression of CAD may cause the heart muscle to receive a lack of blood when under stress (for example, in a stressful anxiety producing situation such as fear or anger, or when exercising) and the increase myocardial oxygen demand goes up. This can result in chest pain called angina. In many cases however, there are no outward physical signs of the CAD. If CAD is limiting blood flow to a portion of the heart, the nuclear stress exam would be useful in detecting the presence and significance of the disease.

Progression of Disease as Detected by These Testing Methods

Artery must be 70% blocked to be picked up on a stress test



ATHEROSCLEROTIC PLAQUE DEVELOPMENT

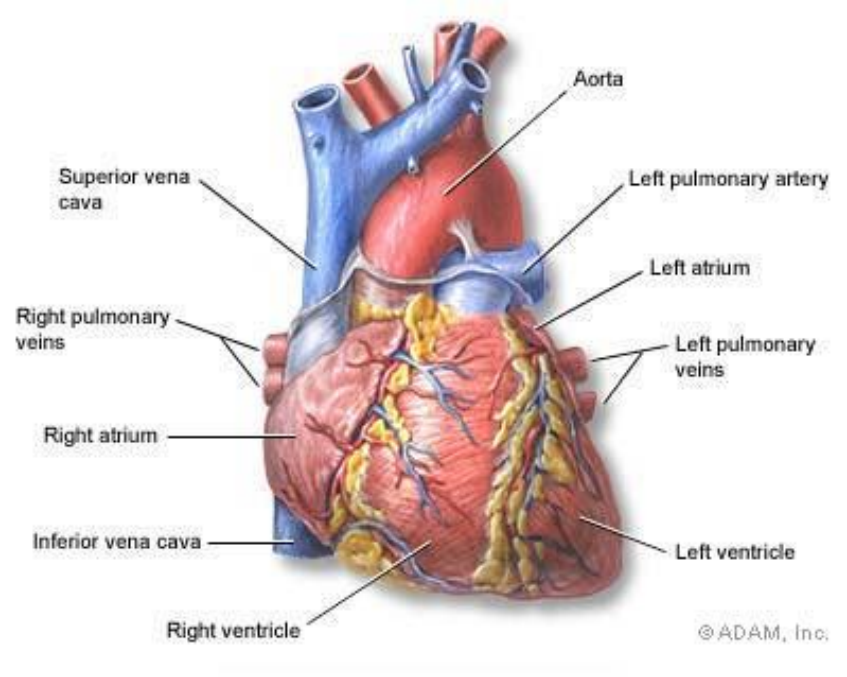
How a Fatal Heart Attack Happens

Examination

- Verify the Patient Identity
- Verify Order
- Obtain Patient History
- Verify Patient is Prepped
- Explanation of Exam *
- Answer Questions
- Consent
- Start IV
- Inject Resting Radiopharmaceutical (Sestamibi, Tetrofosmin, or Thallium)
- Image the patient for rest images
- Stress (either Treadmill or Lexiscan/Adenosine)
- Radiopharmaceutical injection again (Sestamibi or Tetrofosmin)
- Have your Patient Drink a Glass of Cold Water
- Image the patient for stress images
- Remove IV
- CUT PATIENT LOOSE!!

Indications

- Asses risk of cardiovascular event
- Determine long-term prognosis
- Localize region of ischemia
- Assist in therapeutic decision making
- Evaluate efficacy of therapy
- Assess exercise capacity
- Detect exercise-related arrhythmias



Clinical Indications

Treadmill Stress Test

- Detection of obstructive coronary artery disease (CAD) in the following:
  - Patients with an **intermediate** probability of CAD based on age, gender, Abn. Lipids, Hx Tobacco use, HTN, Overweight, Sedentary Lifestyle, Family Hx of premature heart disease, Metabolic Syndrome, Pre-diabetes, and symptoms.
  - Patients with **high-risk** factors for CAD (eg. diabetes mellitus, peripheral or cerebral vascular disease, CCS ≥100, Abn. CTA, Abn. EKG).
- Patients 2-6 weeks post-myocardial infarction.
- Patients with chronic stable CAD that can be managed medically or high-risk category that should be considered for coronary revascularization via angioplasty/Stent or Bypass.
- Assessment of patients with acute coronary syndrome (chest pain due to insufficient blood supply to the heart muscle that results from coronary artery disease. These patients may or may not have an abn. EKG)
- Patients with known CAD or those with high risk factors for CAD that need pre-op clearance before a noncardiac surgery .
- To evaluate whether therapeutic interventions (anti-ischemic **drug** therapy or coronary revascularization via angioplasty/stent or bypass) are successful.
- To track subsequent risk based on serial changes in a nuclear stress test in patients with known CAD.

Clinical Indications
Lexiscan

- Inability to perform adequate exercise due to non-cardiac physical limitations (pulmonary, peripheral vascular, musculoskeletal, or mental conditions) or due to lack of motivation. Of note, as with exercise testing, anti-ischemic cardiac medications (Beta blockers) should be discontinued for at least 24 hours prior to performing a diagnostic imaging test.
- Treatment with medications which blunt the heart rate response (beta blockers). Unable to increase heart rate due to medications or patient "gives out" before reaching target heart rate
- Evaluation of patients very early after acute myocardial infarction (<3 days) or very early after angioplasty/stenting (<2 weeks).
- ECG: LBBB, ventricular preexcitation (Wolff-Parkinson-White syndrome), and permanent ventricular pacing.

Clinical Indications
Adenosine

- Inability to perform adequate exercise due to non-cardiac physical limitations (pulmonary, peripheral vascular, musculoskeletal, or mental conditions) or due to lack of motivation. Of note, as with exercise testing, anti-ischemic cardiac medications (including Beta-blockers) should be discontinued for at least 24 hours prior to performing a diagnostic imaging test.
- Treatment with medications which blunt the heart rate response (beta blockers). Unable to increase heart rate due to medications or patient "gives out" before reaching target heart rate.
- Evaluation of patients very early after acute myocardial infarction (<3 days) or very early after angioplasty/stenting (<2 weeks).
- ECG: LBBB, ventricular preexcitation (Wolff-Parkinson-White syndrome), and permanent ventricular pacing.

Patient Preparation

NO:

- Food (2-4 hrs)
- Alcohol (4-6 hrs)
- Caffeine (12-24 hrs)

Medications:

- Insulin- Take ½ of dose
- Beta Blockers- off 48 hours
- Caffeine- off 12-24 hours
- Nitro- off 4-6 hours

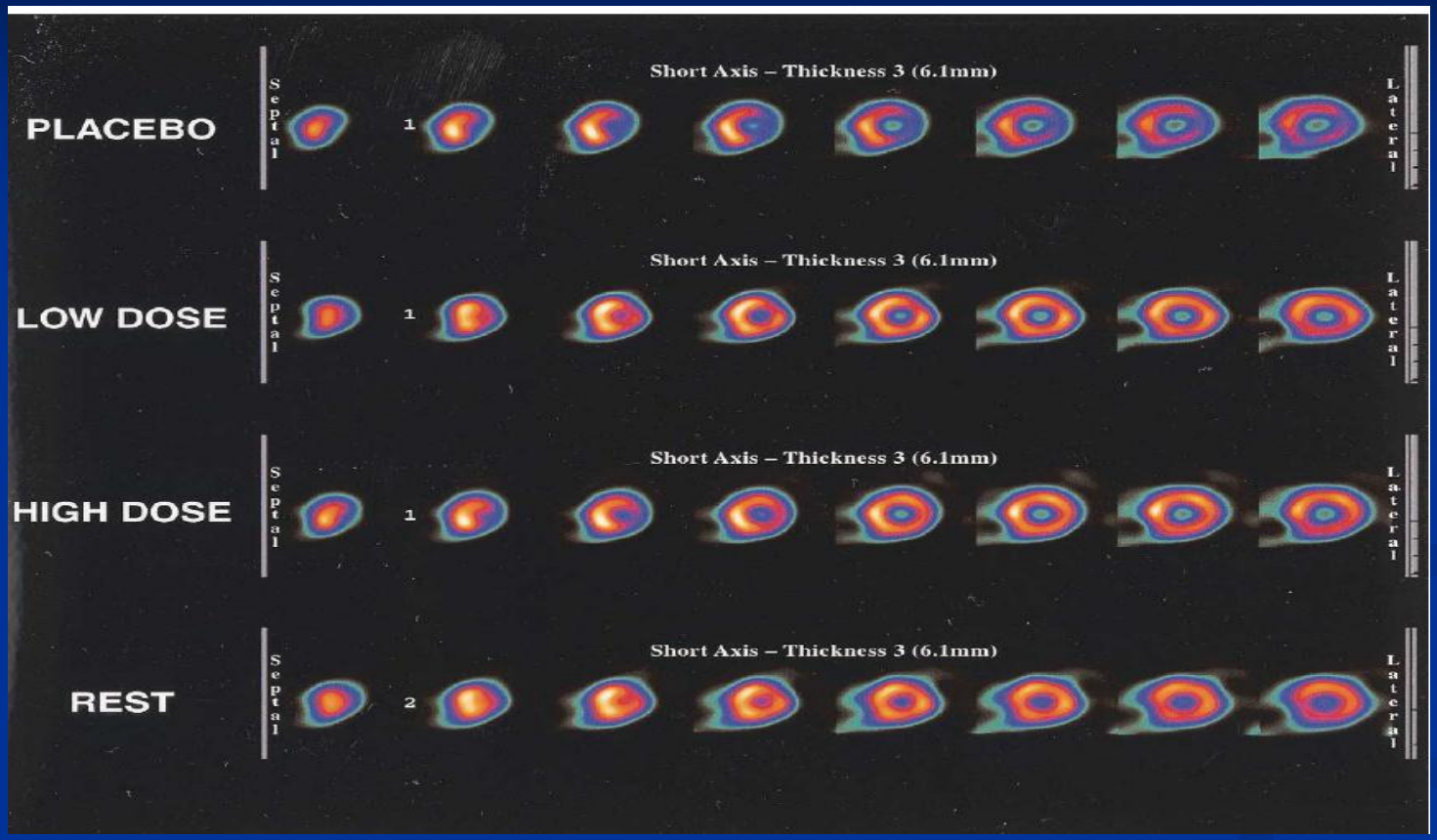
- 2. Comfortable clothes and shoes
- 3. Bring Medications
- 4. **Discontinue Medications**

Diagnostic vs. Functional Scan

- Meds Containing Caffeine- 24 hrs
- Anacin
- Carredrine
- Cardiotea
- Excedrin
- Fioricet
- Fiorinal
- Hycomine
- Norgesic
- Repan
- Vivarin

The Unprepped Patient/Beta Blocker

Effect of Beta-Blockade and Dipyridamole



Taillefer R, et al. Acute Beta-Blockade Reduces the Extent and Severity of Myocardial Perfusion Defects with Dipyridamole Tc99m sestamibi SPECT Imaging. J Am Coll Cardiol 2003;42:1475-83.

Taillefer et al tested 21 patients at baseline, after low-dose intravenous metoprolol tartrate and after high-dose intravenous metoprolol tartrate. They found that the stress defect extent and severity were reduced by 25% to 30% even at the low dose of the B-Blocker, with no change in the rest defect appearance. As such, B-blockers “masked” the ischemic burden.

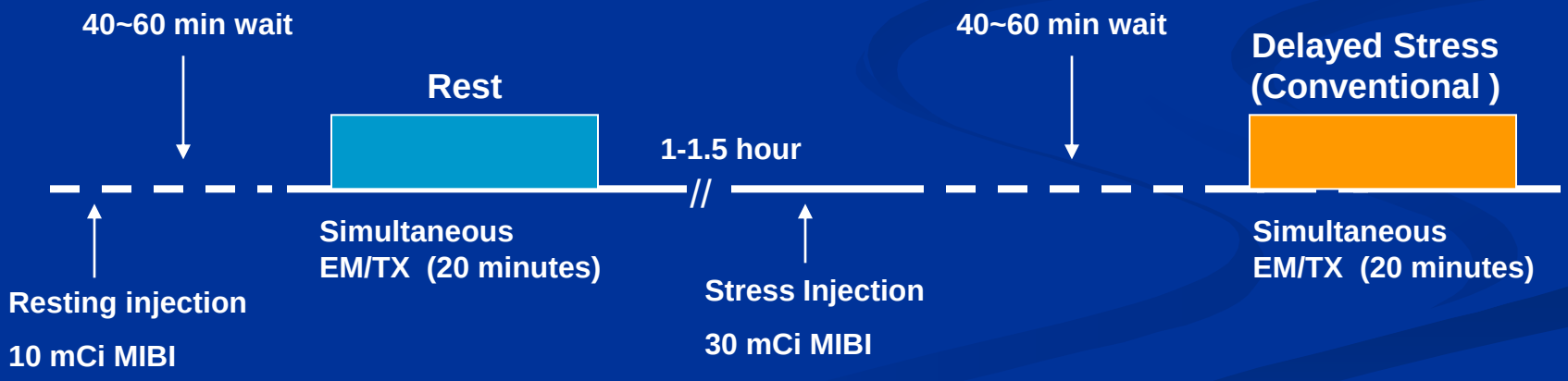
Study Time Frame

Study time frame varies by selected protocols and Radiopharmaceutical; however a typical One Day Protocol with low dose rest Sestamibi and high dose stress Sestamibi is normally completed in approximately 2 to 3 hours.

Imaging Protocols

Conventional Same-day ECG-gated Tc99m-MIBI SPECT

- Image patient 40~60 minutes after resting injection
- Stress patient
- Image patient 45-60 minutes after stress injection
- Imaging x2 for 11-20 minutes



>2.5 hours

The Tracer

Cyclotron means a particle accelerator in which the charged particles travel in an outward spiral or circular path. A cyclotron accelerates charged particles at energies usually in excess of 10 megaelectron volts and is commonly used for production of short half-life radionuclides for medical use

The Tracer

One of most important radio-nuclides produced by a *cyclotron*, is Tl-201. This radioisotope is generated by bombarding the tick copper substrate electroplated with enriched 203Tl, with 28.5MeV protons, at ~145μA beam current via 203Tl (p, 3n) 201Pb reaction, which decays to 201Tl with a half life of 72 h. The target bombardment results in the production of intense fields of high-energy neutrons and gamma rays

The Tracer

A *nuclear reactor* is a system that contains and controls sustained nuclear chain reactions

The Tracer

Technetium-99m is a metastable nuclear isomer of technetium-99, symbolized as ^{99m}Tc. The "m" indicates that this is a metastable nuclear isomer, i.e., that its half-life of 6 hours. The life-time of technetium-99m is very long in terms of average gamma-decay half-lives, though short in comparison with half-lives for other kinds of radioactive decay, and in comparison with radionuclides used in many kinds of nuclear medicine tests.

Technetium-99m is used as a radioactive tracer that medical equipment can detect in the body. It is well suited to the role because it emits readily detectable 140 keV gamma rays (these are about the same wavelength emitted by conventional X-ray diagnostic equipment), and its half-life for gamma emission is 6.0058 hours (meaning that 93.7% of it decays to ^{99}Tc in 24 hours). The "short" half-life of the isotope (in terms of human-activity and metabolism) allows for scanning procedures which collect data rapidly, but keep total patient radiation exposure low.

The Tracer

As in all gamma decay reactions, a metastable nuclear isomer does not change into another element (transmute) upon its isomeric transition or "decay"; thus ^{99m}Tc decays to technetium-99 (Tc-99, the ground state of the same isotope) and remains technetium. The decay of technetium-99m is accomplished by rearrangement of nucleons in its nucleus, a process that allows energy to be emitted as a gamma ray.

The resulting technetium-99 then decays to stable ruthenium-99 with a half-life of 211,000 years. It emits soft beta particles (electrons) in this process, but no gamma rays (photons). All of these characteristics ensure that the technetium-99 produced from technetium-99m produces very little extra radiation burden on the body.

The Tracer

Due to its short half-life, technetium-99m for nuclear medicine purposes is usually extracted from technetium-99m generators which contain molybdenum-99 (Mo-99, half-life 2.75 days), which is the usual parent nuclide for this isotope. The majority of Mo-99 produced for Tc-99m medical use comes from fission of HEU (highly enriched uranium) from only five reactors around the world: NRU, Canada; BR2, Belgium; SAFARI-1, South Africa; HFR (Petten), the Netherlands; and the OSIRIS reactor in Saclay, France. Production from LEU (low-enriched uranium) is possible, and is produced at the new OPAL reactor, Australia, as well as other sites. Activation of Mo-98 is another, currently smaller, route of production.

Demand for medical use of Mo-99 to make Tc-99m began to overtake a dwindling supply, in the late 2000s. Global shortages of technetium-99m emerged in the late 2000s because two aging nuclear reactors (NRU and HFR) that provided about two-thirds of the world's supply of molybdenum-99, which itself has a half-life of only 66 hours, were shut down repeatedly for extended maintenance periods. Two replacement Canadian reactors constructed in the 1990s were closed before beginning operation, for safety reasons

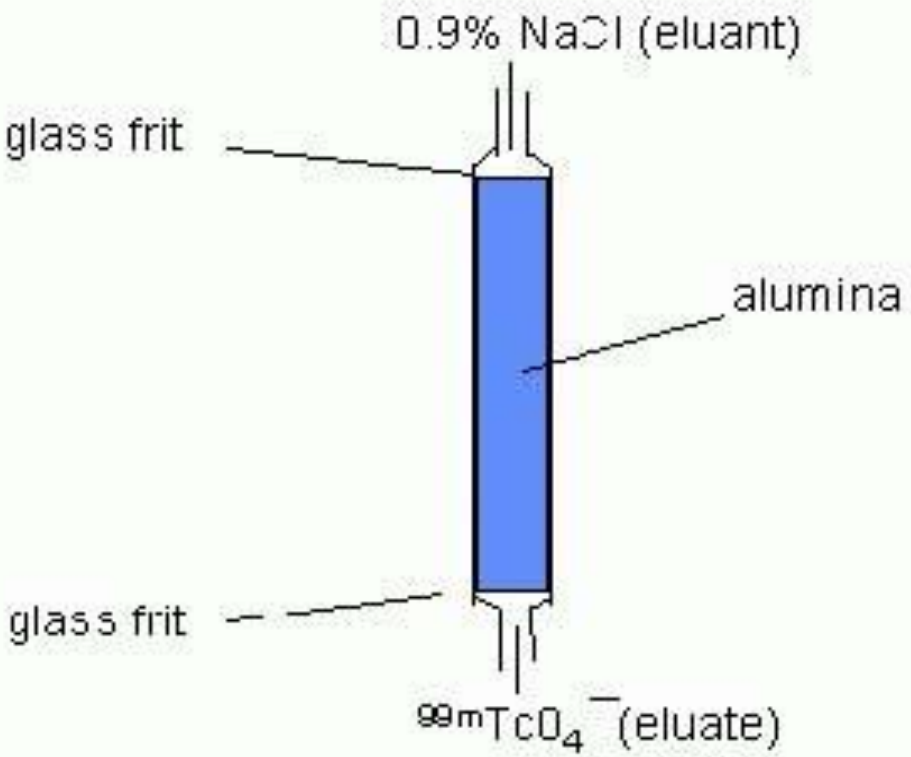
How is the Tracer Produced

You might wonder how the lab gets the tracers. The typical fashion is delivered in what is called unit doses. Thallium is usually flown in to the Radiopharmacy in bulk and the pharmacy divvies out what each lab orders by drawing it up in a syringe and delivering per order to the lab. The Tc99 Sestamibi or Tetrofosmin is derived from a generator that the Radiopharmacy receives and draws unit doses from bulk right there in the pharmacy.

How is the Tracer Produced
Principles of operation of a Mo/Tc generator

Prior to shipping the generator to the Nuclear Medicine Department, Mo-99 sodium molybdate is immobilized on a column of alumina (Al_2O_3; aluminum oxide) due to its very high affinity for alumina

How is the Tracer Produced
Principles of operation of a Mo/Tc generator

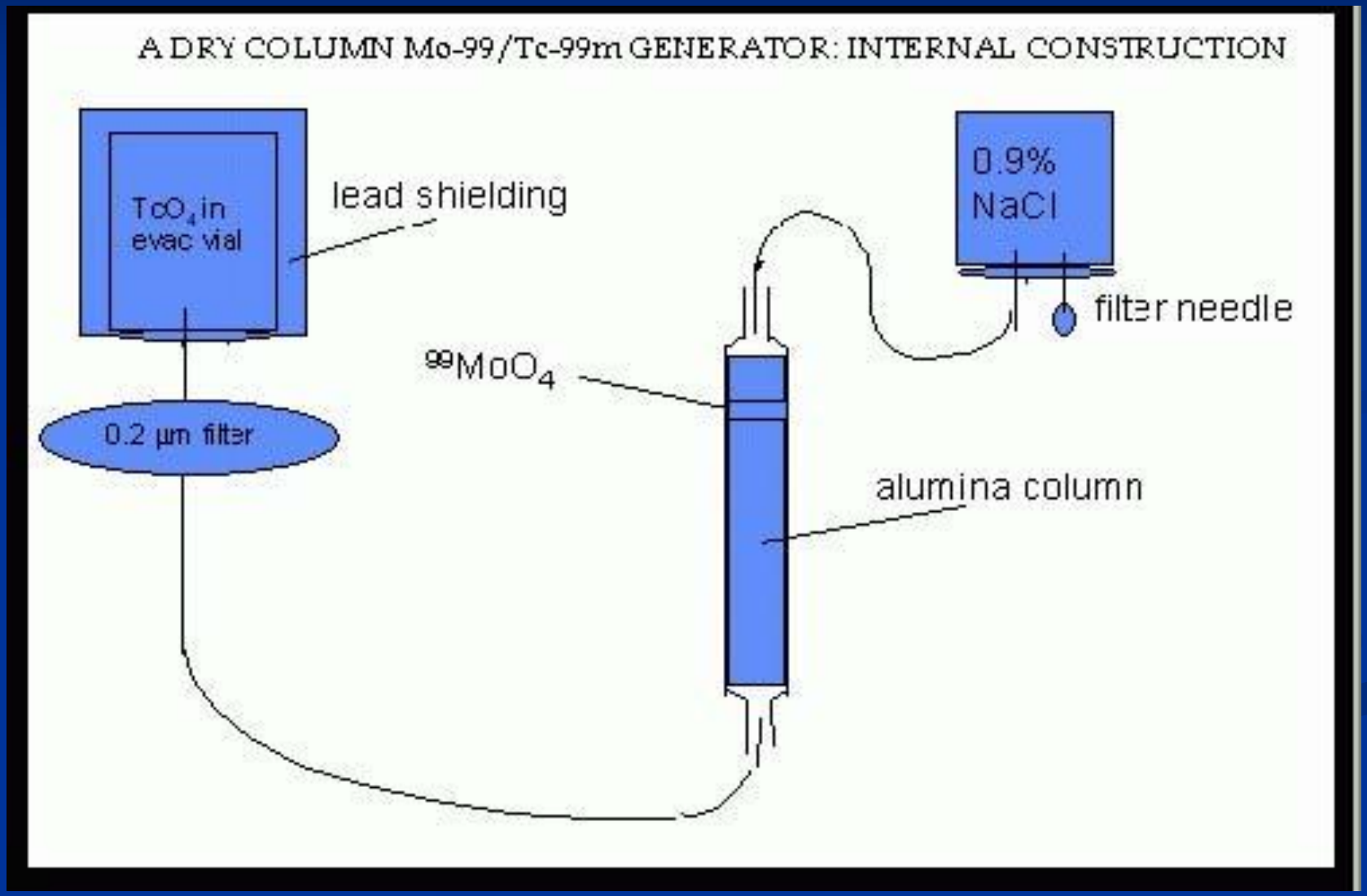


How is the Tracer Produced
Principles of operation of a Mo/Tc generator

0.9% saline solution (the eluant) is passed through the column and sodium pertechnetate, the daughter of Mo-99 decay, is eluted from the column due to its almost total lack of affinity for alumina

The pertechnetate is collected in a shielded, evacuated sterile vial and calibrated prior to use. It is referred to as the eluate

How is the Tracer Produced
Principles of operation of a Mo/Tc generator



How is the Tracer Produced
Principles of operation of a Mo/Tc generator

Quantitative removal of pertechnetate is attributed to the lack of affinity of pertechnetate for alumina, whereas molybdate is essentially completely and irreversibly bound to the alumina.

When eluting the generator, the elution volume should be carefully controlled so a relatively constant radioconcentration is obtained every day.

The Tracer

- Isotopes
  - Thallium-201 or Technetium-99m sestamibi/tetrofosmin
  - Both assess LV function and ischemia
  - Sestamibi/tetrofosmin has superior imaging quality
    - Good for obese or female patients
- Isotopes taken up by viable myocardial cells in quantities proportional to perfusion
- Well perfused regions appear brighter

Radiopharmaceutical Tracers

- Thallium(or Tl201)
  - Dual Isotope (Rest Thallium 4 mCi and Stress Sestamibi/Tetrofosmin 30 mCi)
  - Thallium only (***no*** Sestamibi/Tetrofosmin injection, one injection of Thallium at stress (4 mCi or units)

- Sestamibi/Tetrofosmin
  - Sestamibi Tc99m (9-11 mCi rest dose/ 27-33 mCi stress dose)
  - Totals 41-44 mCi of the two combined injections

RADIOACVTIVE TRACES ARE NOT MEDICATIONS, THEY ARE NOT STRESSING AGENTS, THEY ARE STRICKTLY USED FOR IMAGING ONLY. THIS IS INJECTED INTO THE PATIENTS VEIN FOR IMAGING.

Alternate Protocols if there is a Tc99m Shortage

- Dual Isotope
  - Patient receives 4 mCi of Thallium at rest and 30 mCi of Sestamibi/Tetrofosmin at stress.
- Thallium only
  - Patient receives 4 mCi of Thallium at stress, there is no second injection (no resting injection).

Patient Radiation Dosimetry

Isotope	Effective Dose Equivalent	Per study	Total
Tc-99m mibi	51 mrem/mCi	30 mCi	1500 mrem
Th-201	850 mrem/mCi	4 mCi	3200 mrem

The Stress:
Exercise vs. pharmacologic

- Exercise
  - Pt walks on treadmill with increasing speed/incline (BRUCE protocol)
  - Goal = increase myocardial oxygen demand (MVO_2)
    - CAD: the increased demand exceeds supply = ischemia
  - Advantages: flexible protocols
  - Disadvantages: pt must be able to achieve 85% of maximal HR

The Stress:
Exercise vs. pharmacologic

- Pharmacologic
  - Dobutamine = increases HR, BP, contractility; mimics exercise (rarely used)
  - Coronary vasodilators – Dipyridamole (Perstanine), Adenosine(Adenoscan), and Regadenoson (Lexiscan)
    - Flow mismatch; diseased dilated arteries get less flow
  - Sensitivities and specificities comparable to exercise stress
  - Advantages: useful in pts with ambulation limitations
  - Risks: ventricular arrhythmias (Dobutamine), bronchospasm (Adenosine/Dipyridamole)

Methods of Stress Testing

- Treadmill
  - Patient walks on treadmill until they reach 85% of their maximum predicated heart rate at which point the tracers injected

Bruce Protocol GXT

Stage	Speed	Grade	Dur.
I	1.7 mph	10 %	3 min
II	2.5 mph	12 %	3 min
III	3.4 mph	14 %	3 min
IV	4.2 mph	16 %	3 min
V	5.0 mph	18 %	3 min
VI	5.5 mph	20 %	3 min

Modified Bruce Protocol GXT

Stage	Speed	Grade	Dur.
I	1.7 mph	0 %	3 min
II	1.7 mph	5 %	3 min
III	1.7 mph	10 %	3 min
IV	2.5 mph	12 %	3 min
V	3.4 mph	14 %	3 min
VI	4.2 mph	16 %	3 min
VII	5.0 mph	18 %	3 min

Methods of Stress Testing

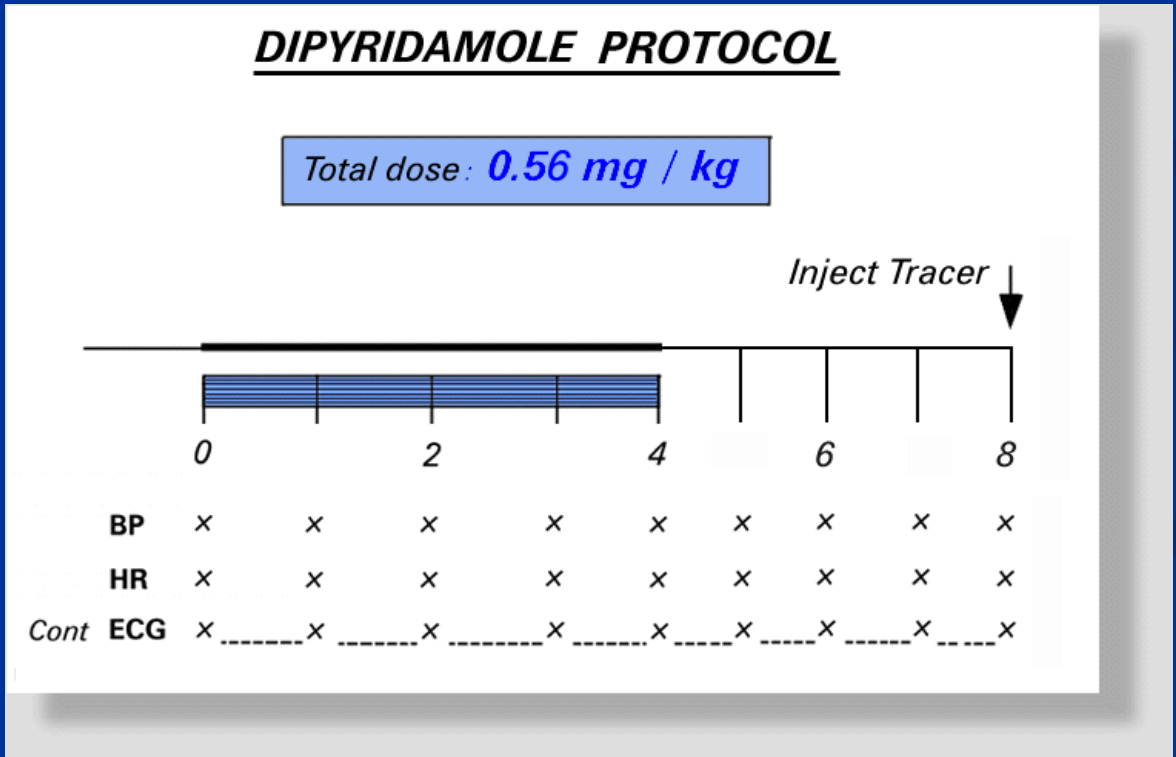
- Lexiscan (is a vasodilator and is not designed to increase the heart rate. With the vessel dilation, the blood flow is increased to the heart.)
  - Patient is unable to exercise (or has LBBB) or increase heart rate and receives Lexiscan over 10 seconds, at 30 seconds the tracer is injected

Methods of Stress Testing

- Adenosine (is a vasodilator and is not designed to increase the heart rate. With the vessel dilation, the blood flow is increased to the heart.)
  - Patient is unable to exercise (may have LBBB) or increase heart rate and receives Adenosine over a 4 minute infusion, at 2 minutes into the infusion the tracer is injected OR over a 6 minute infusion, at 3 minutes into the infusion the tracer is injected

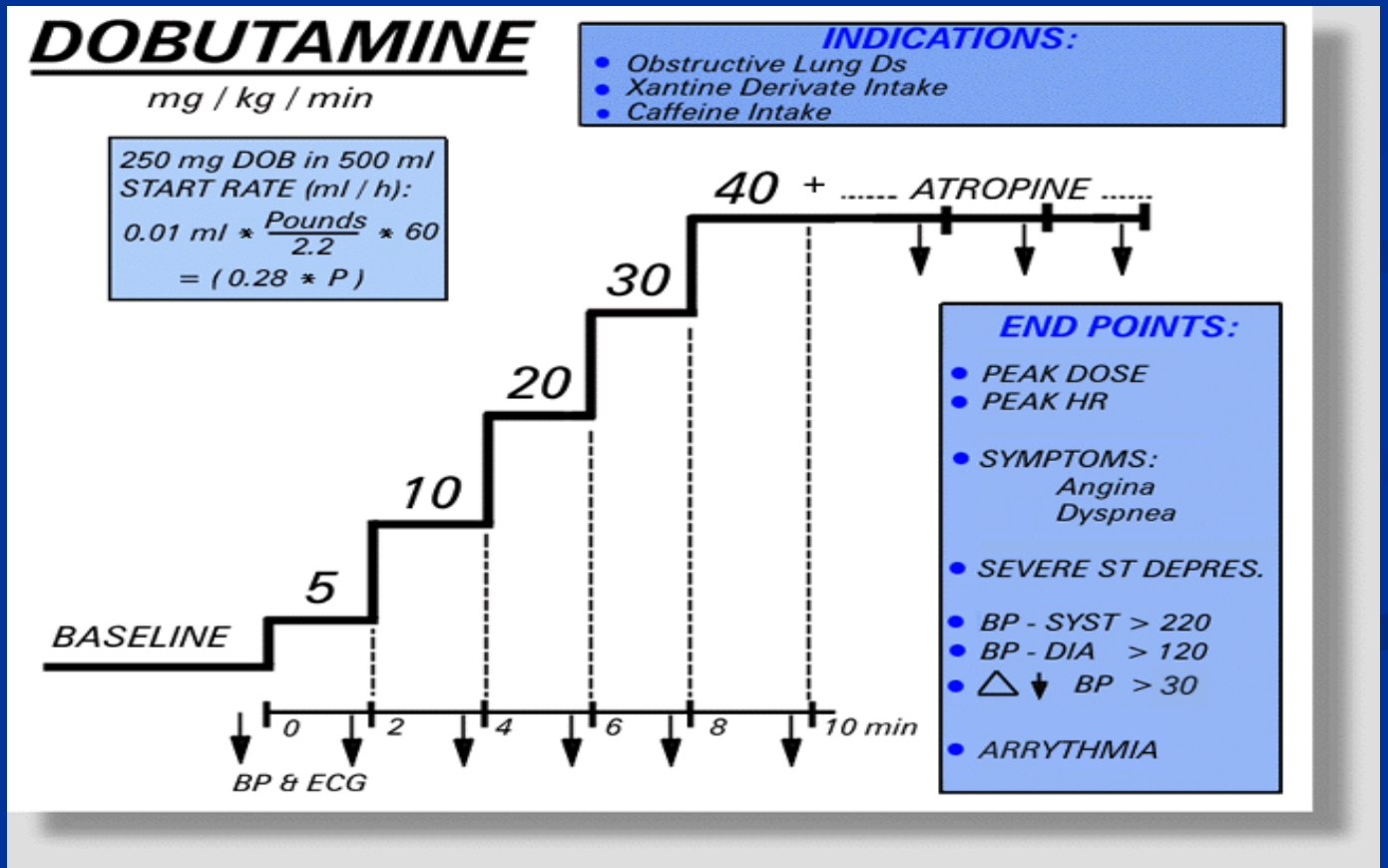
Methods of Stress Testing

- Dipyridamole (is a vasodilator and is not designed to increase the heart rate. With the vessel dilation, the blood flow is increased to the heart.)
  - Patient is unable to exercise (may have LBBB) or increase heart rate and receives Dipyridamole over a 4 minute infusion, at 3-4 minutes post infusion the tracer is injected



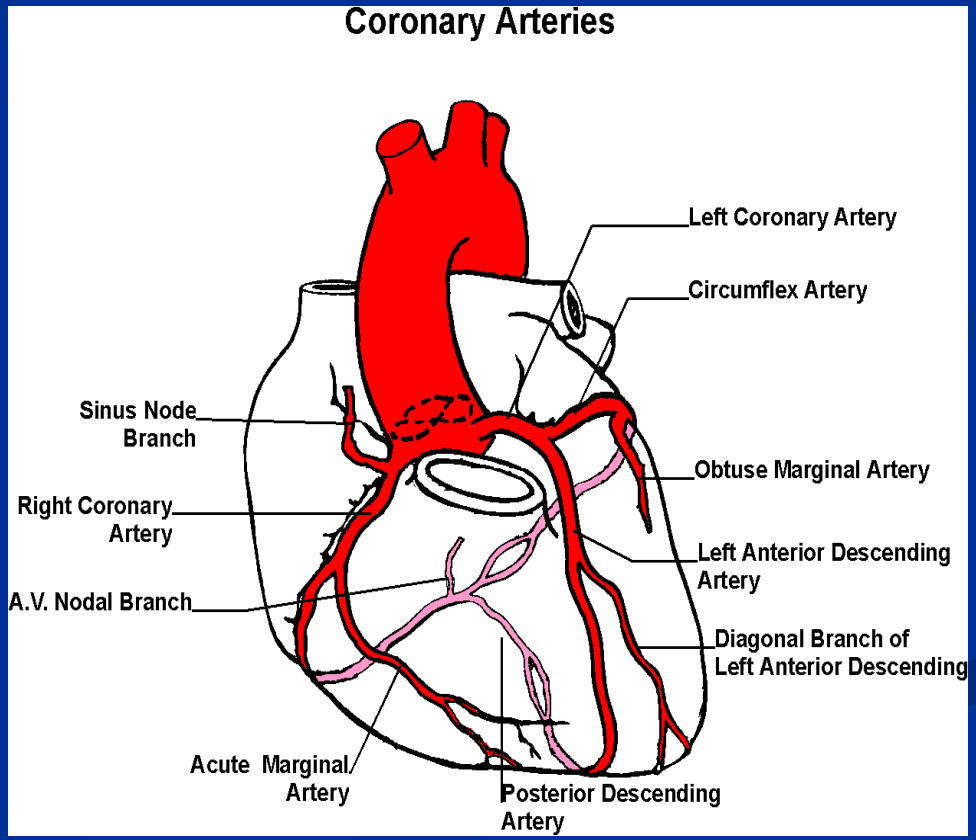
Methods of Stress Testing

- Dobutamine (increases heart rate)
  - Patient is unable to exercise or increase heart rate and has uncontrolled reactive airway disease. Infused in 3 minute increments until 85% of MPH is achieved, tracer in then injected. (This is a rarely used protocol)

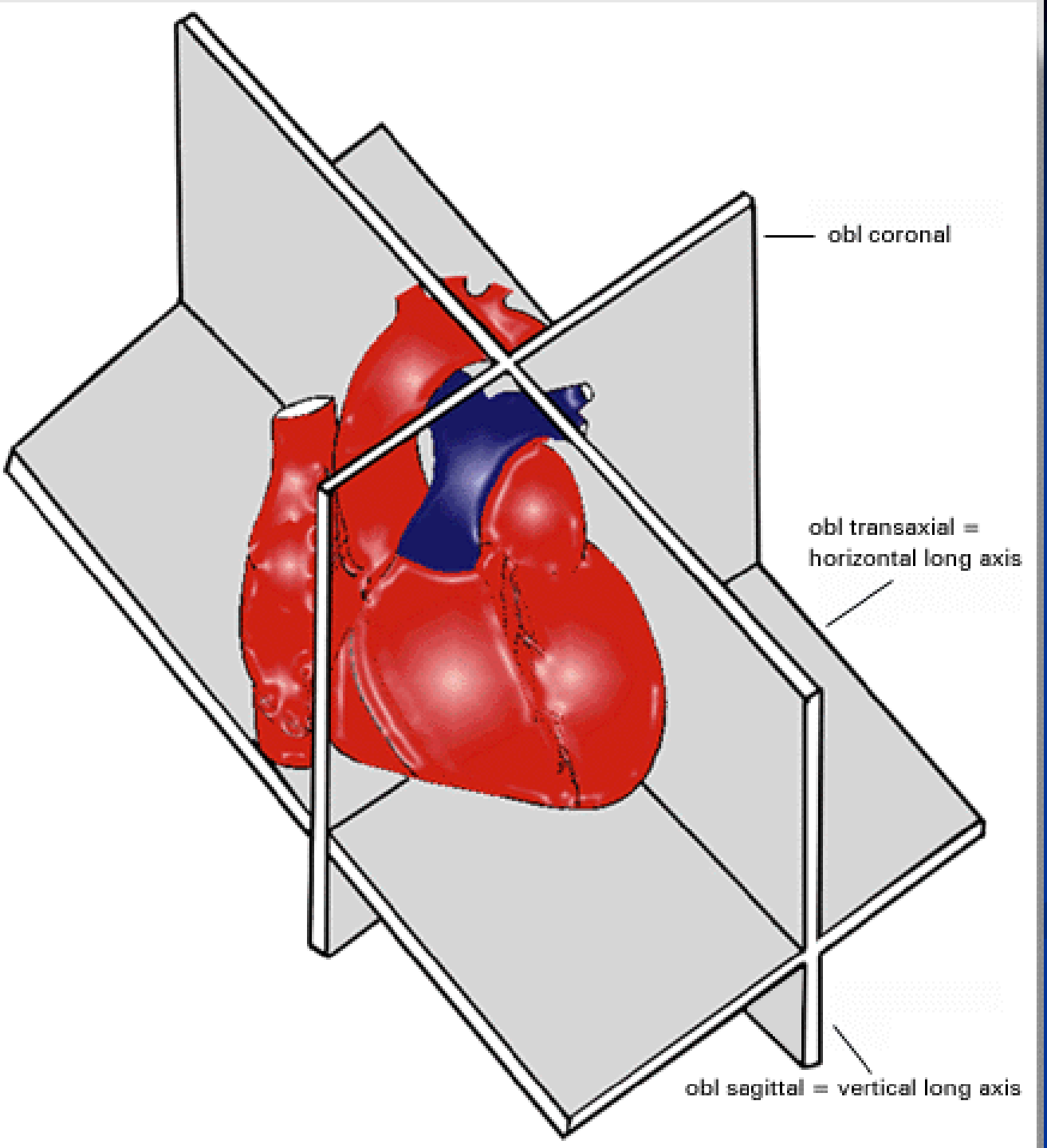


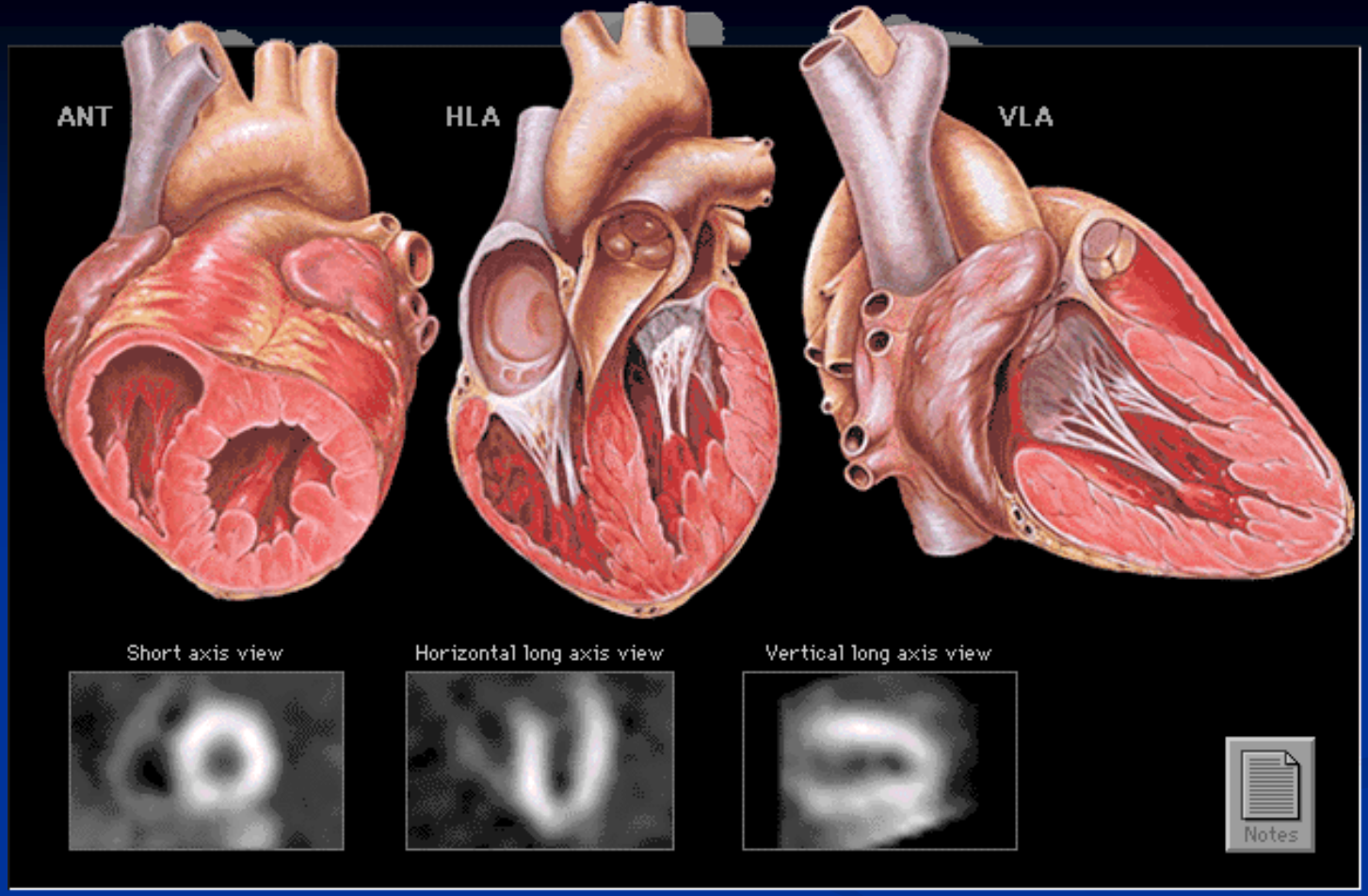
Coronary Artery Review

- Left Coronary
  - LAD
    - Anterior wall
    - apex
  - LCX
    - Left lateral wall
- Right Coronary
  - Right ventricle
  - Posterior wall



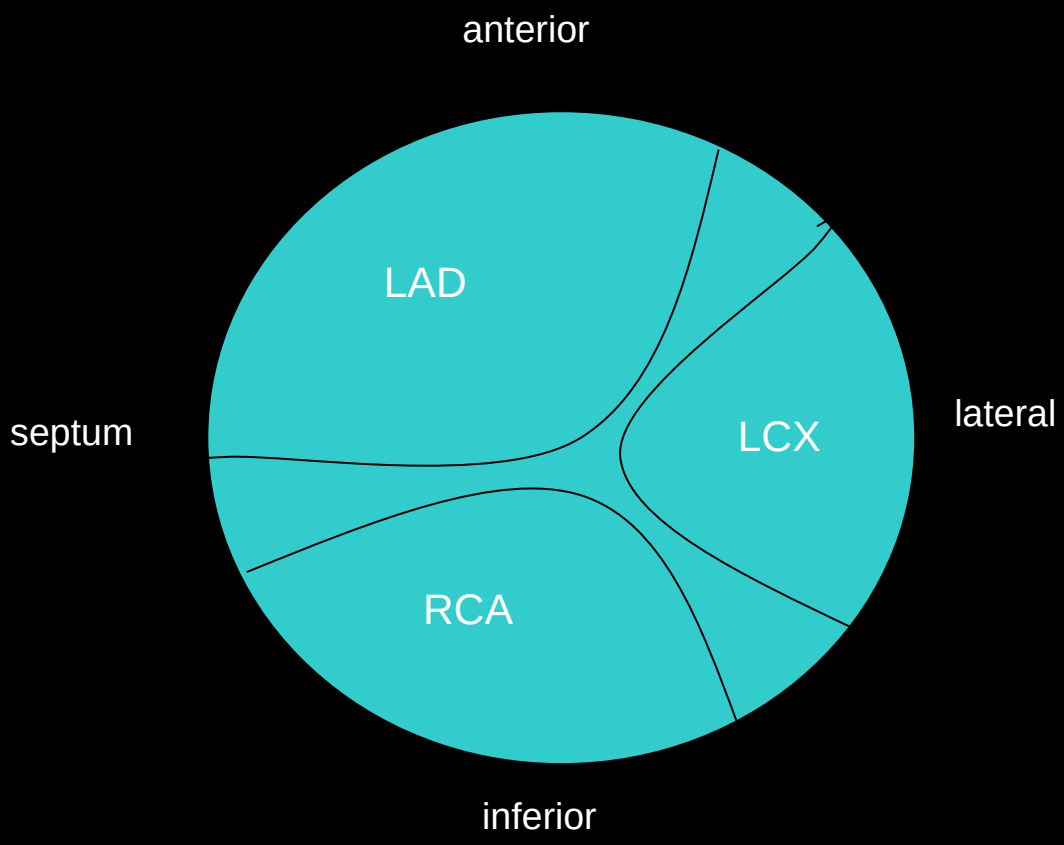
3 Views


obl coronal
obl transaxial =
horizontal long axis
obl sagittal = vertical long axis



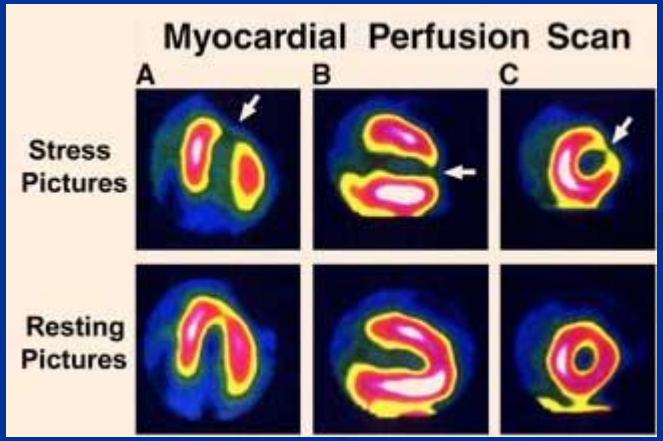
- Short axis = coronal cut (donut)
- Vertical long axis = sagittal cut (sideways "U")
- Horizontal long axis = transaxial cut ("U")

Coronary Artery Territories



What are we looking for?

- Compare resting images to stress images
- Both sets look the same in a normal patient
- Defects in the stressed imagines suggest ischemia



Short Axis

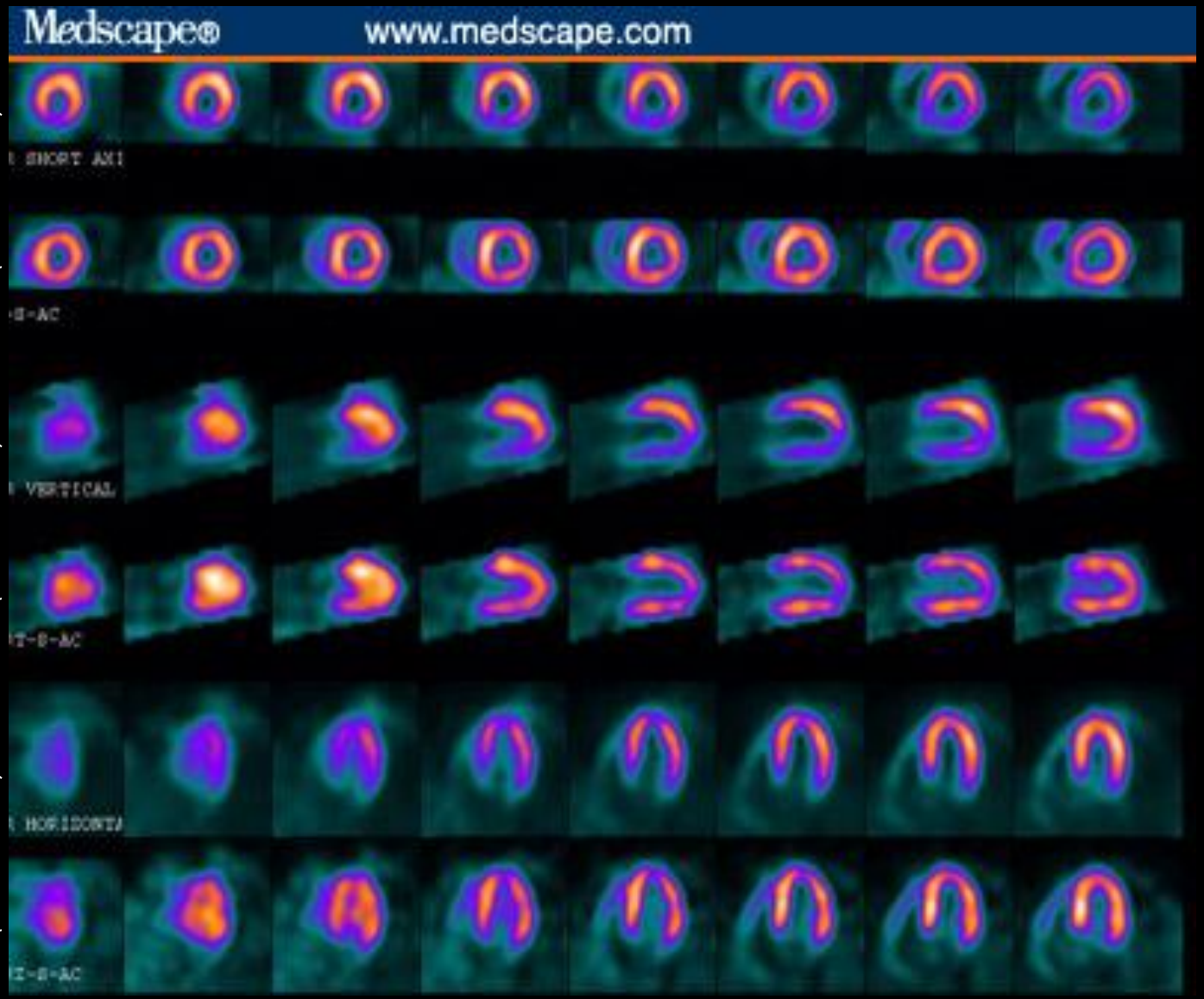
(apex to base)

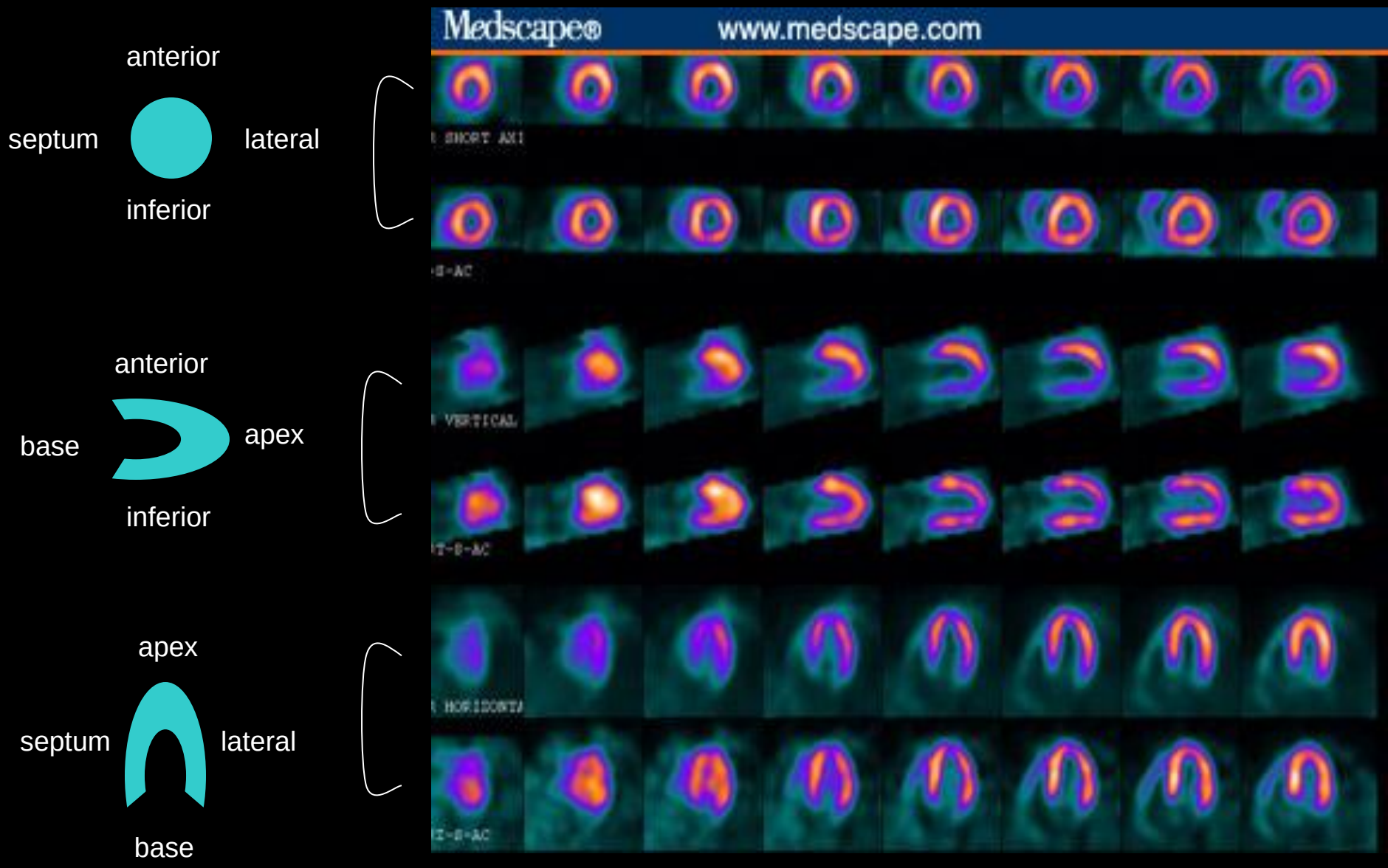
Vertical Long Axis

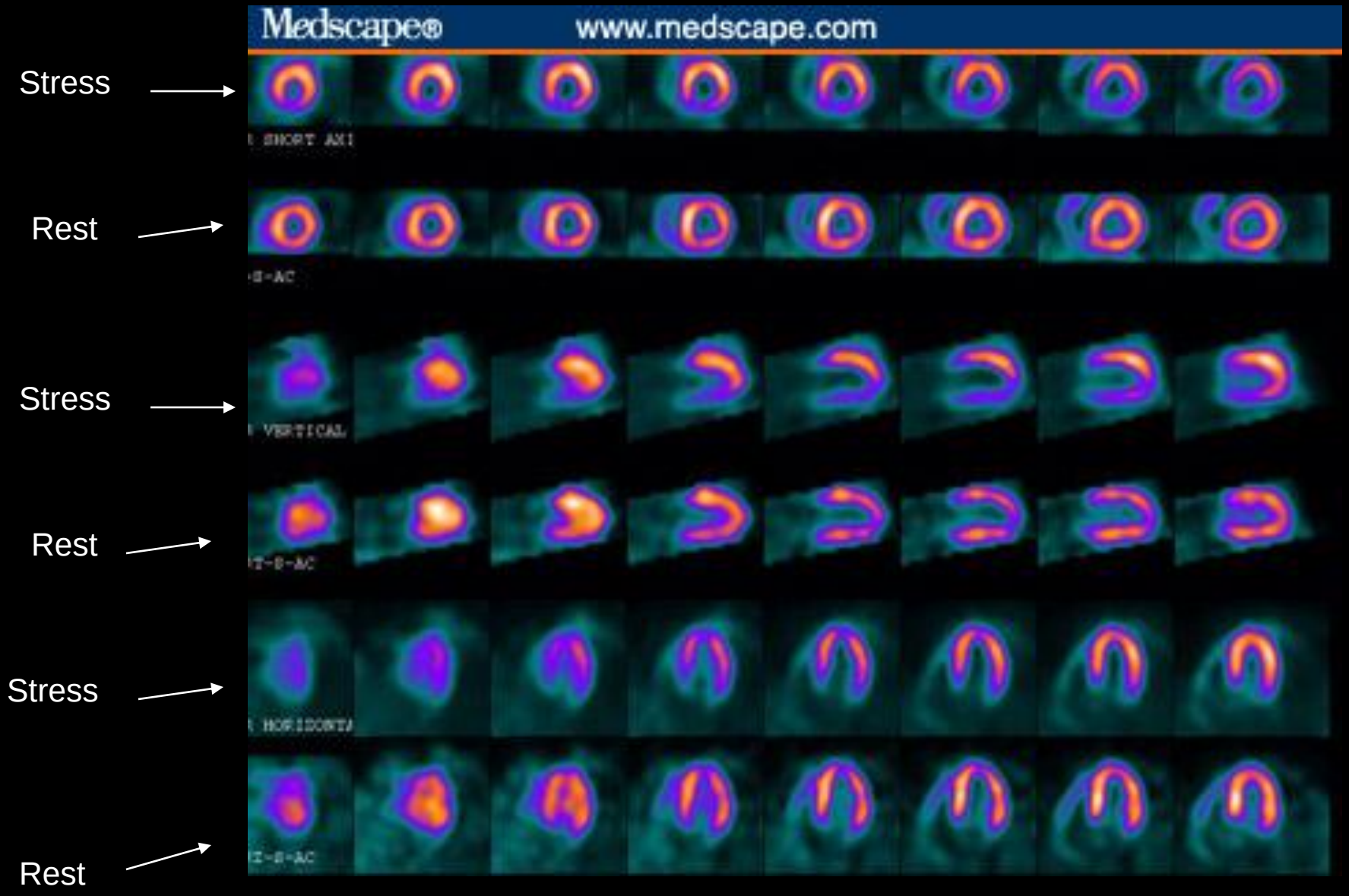
(septum to lateral)

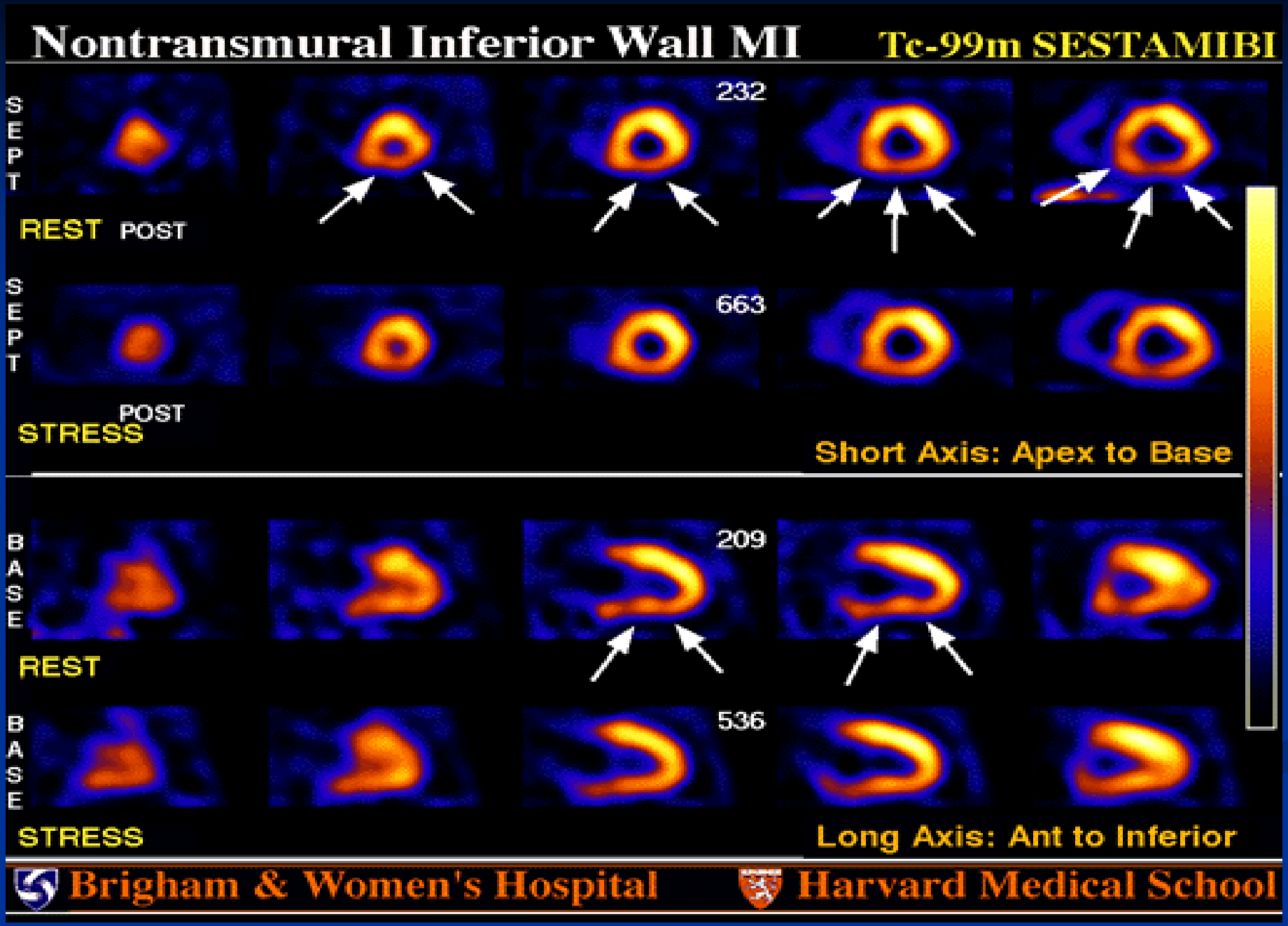
Horizontal Long Axis

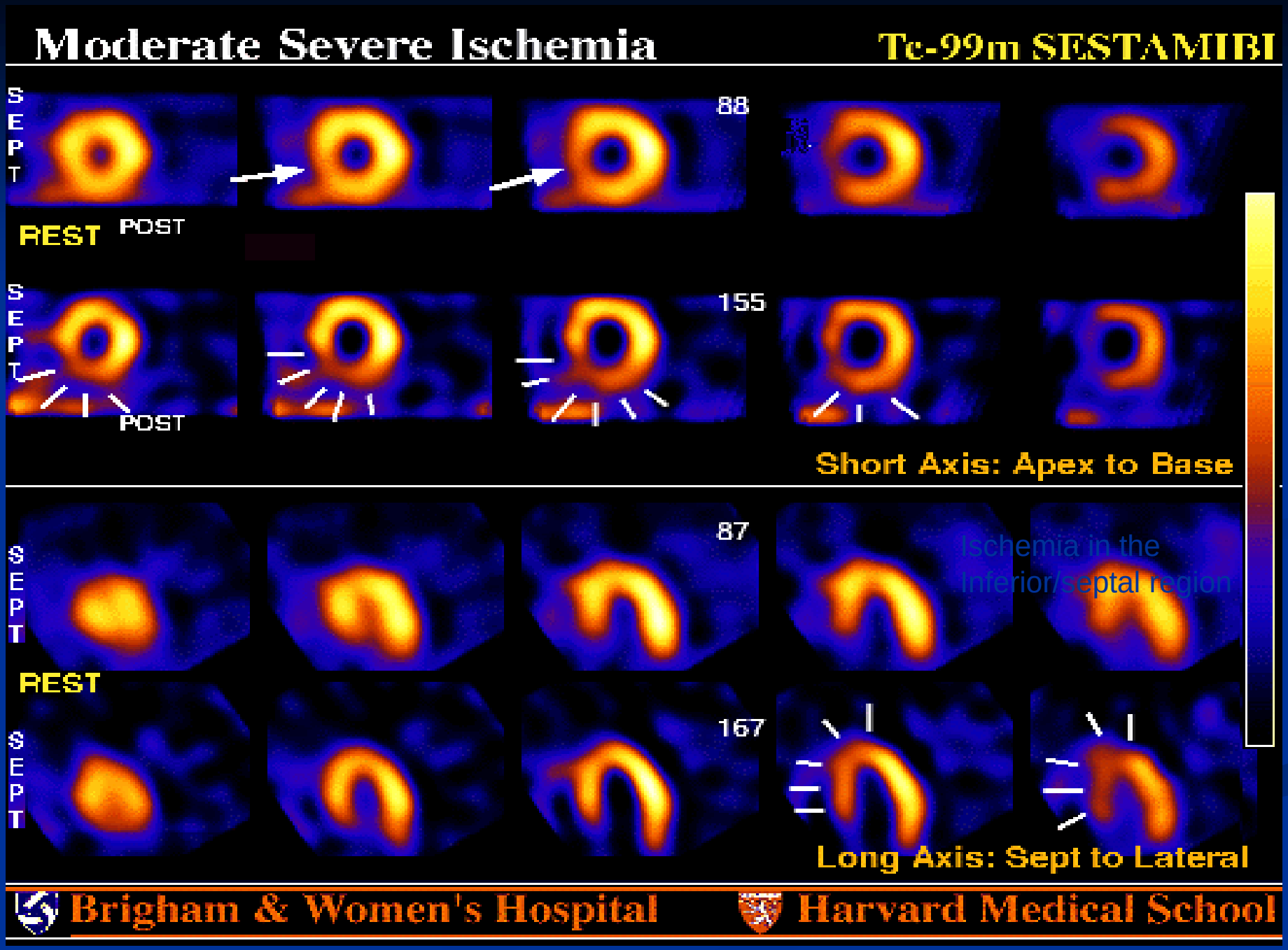
(inferior to anterior)

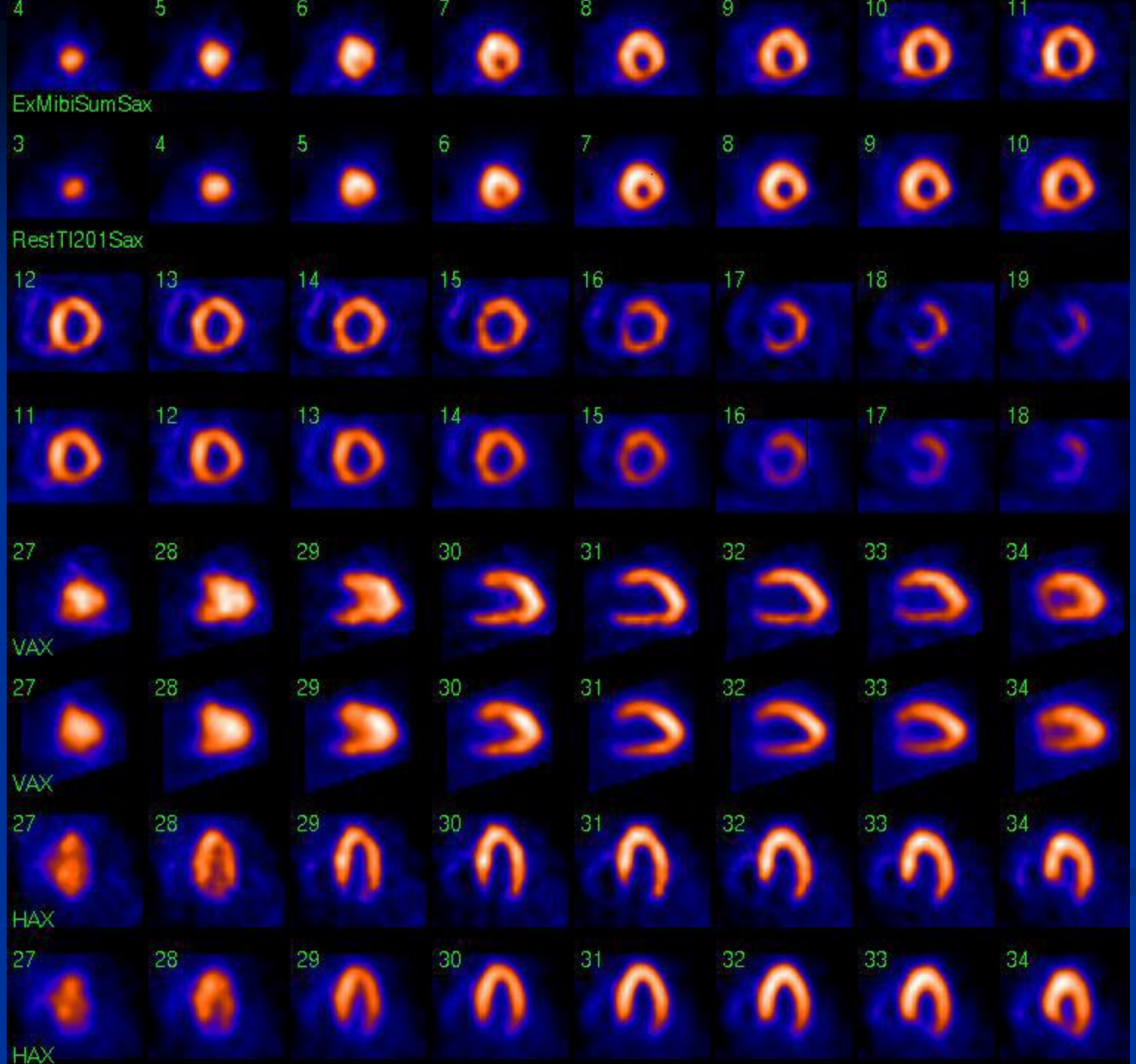



anterior
septum
lateral
inferior
anterior
base
apex
inferior
apex
septum
lateral
base
Medscape®
www.medscape.com

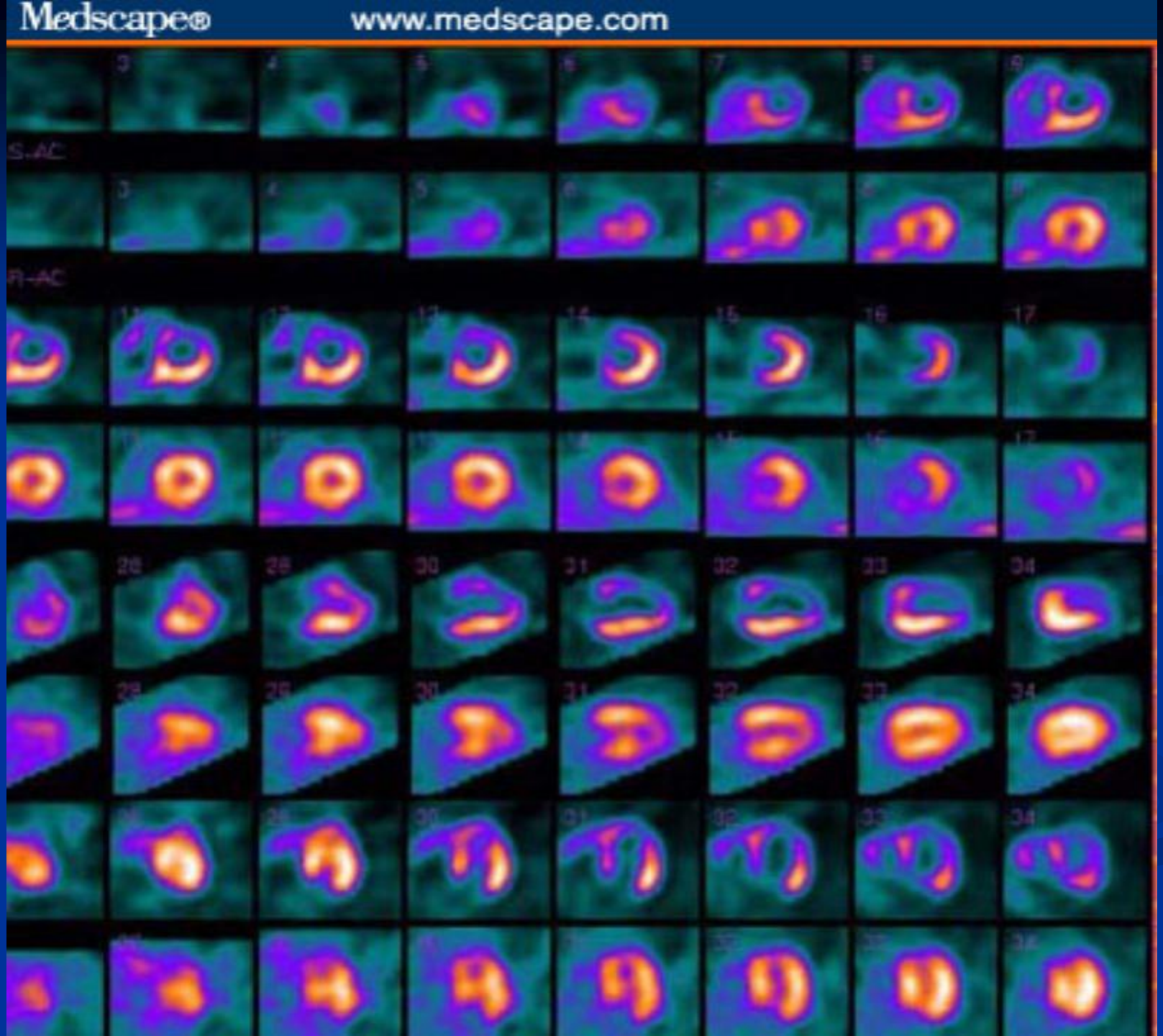

Stress
Rest
Stress
Rest
Stress
Rest
Medscape®
www.medscape.com


Nontransmural Inferior Wall MI
Tc-99m SESTAMIBI
SEPT
232
REST
POST
SEPT
663
POST
STRESS
Short Axis: Apex to Base
BASE
209
REST
BASE
536
STRESS
Long Axis: Ant to Inferior
Brigham & Women's Hospital
Harvard Medical School


Moderate Severe Ischemia
Tc-99m SESTAMIBI
SEPT
REST
POST
88
155
Short Axis: Apex to Base
87
167
Ischemia in the
Inferior/septal region
Long Axis: Sept to Lateral
Brigham & Women's Hospital
Harvard Medical School


4 5 6 7 8 9 10 11
ExMibiSumSax
3 4 5 6 7 8 9 10
RestTl201Sax
12 13 14 15 16 17 18 19
11 12 13 14 15 16 17 18
27 28 29 30 31 32 33 34
VAX
27 28 29 30 31 32 33 34
VAX
27 28 29 30 31 32 33 34
HAX
27 28 29 30 31 32 33 34
HAX

NORMAL



ABNORMAL

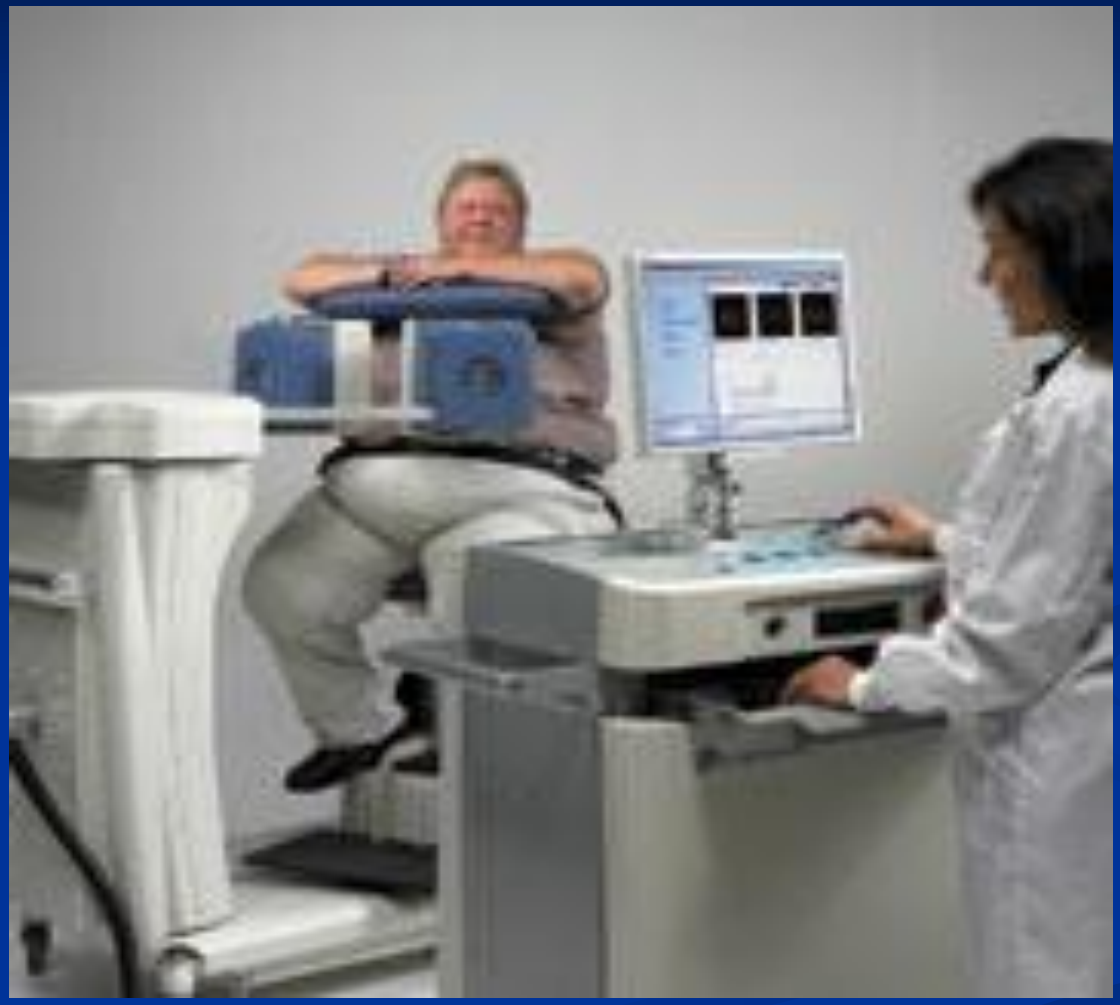
Summary of "Chemicals"

- A nuclear stress test does not indicate that the patient will not walk on the treadmill. It only indicates that the patient will have a stress test (treadmill or chemical) and an injection of a radioactive tracer along with imaging
- Lexiscan and Adenosine ***ARE NOT radioactive***, they are stressing agents used in a chemical stress test to stress the heart
- Sestamibi Tc99m/Tetrofosmin Tc99m and Thallium ***ARE RADIOACTIVE*** tracers, they are not medications of any kind and are not used for stressing the heart they are only used for imaging

Pictures of Camera


PHILIPS


PHILIPS



NUCLEAR STRESS TEST

NIK NIKAM, MD, MHA

SUGAR LAND HEART CENTER

WAKE UP, It's Time For Lunch!!

References

- Pitman A. 2006. Myocardial perfusion imaging: a validated and mature cardiac imaging modality. Australian Family Physician 35:288-292.
- Bulow H and Schwaiger M. 2005. Nuclear cardiology in acute coronary syndromes. The Quarterly Journal of Nuclear Medicine and Molecular Imaging. 49: 59-71.
- Atlas of Myocardial Perfusion website. Brigham and Women's Hospital. Harvard Medical School, Boston MA.
- Up-to-Date: Advantages and limitations of different stress testing modalities. Author Donald A Weiner, MD.
- Awtry EH, Jeon C, and Ware MG. Blueprints Cardiology. Second Edition. Copyright 2006. pages 21-25.