Nuclear Cardiology: The basics and thoughts

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Disclosures

- None

Outline

- Nuclear cardiology – the basics

- Utilization of Nuclear cardiology in current practice

The Basics

General Approach

- IV administration of radiolabelled agents
- Scintillation or positron camera → computer processing
- Physiologic/functional data

SPECT

- "Single Photon Emission Computed Tomography"
  - IV radiotracer distributes to myocardium, proportional to blood flow
  - Gamma camera captures photons → digital data
  - Final result is multiple tomograms of radiotracer distribution

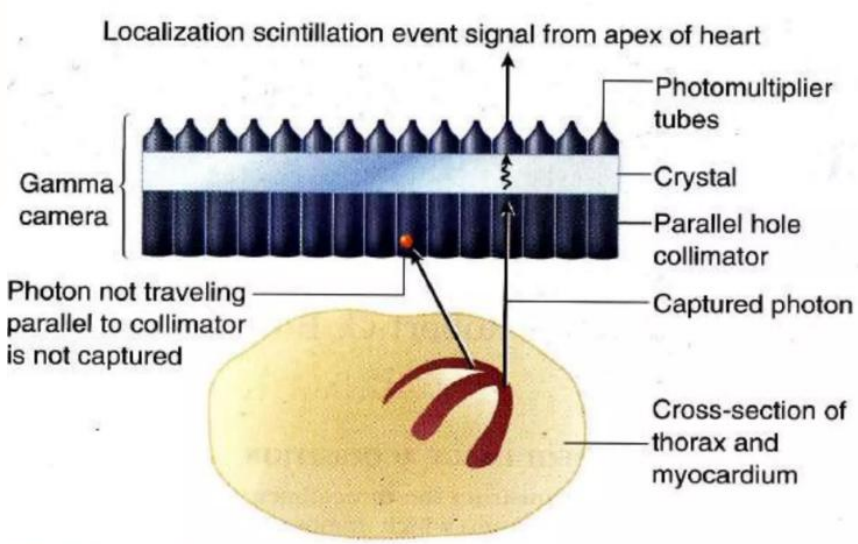


FIGURE 16–1 Capture of emitted photons by a gamma camera. Emissions are captured by a parallel hole collimator, allowing photons to interact with a detector crystal, and are recorded as scintillation events. The event is localized on the basis of where the photon interacts with the crystal.

SPECT image display

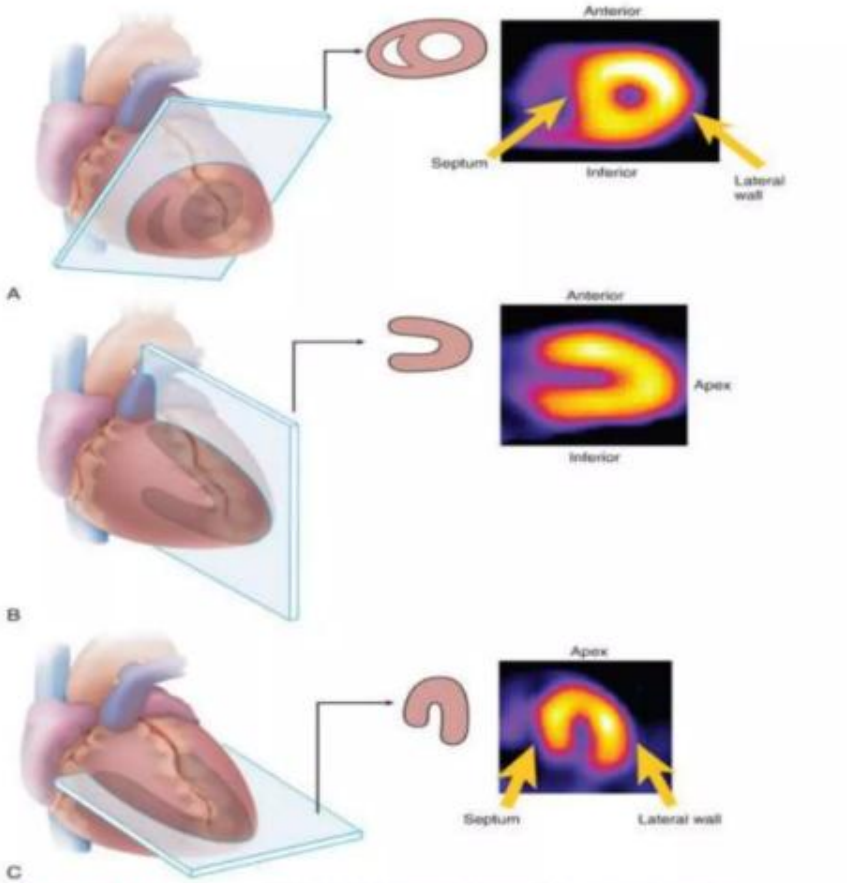


FIGURE 16.2 Standard SPECT imaging display. **A,** The short-axis images represent a portion of the anterior, lateral, inferior, and septal walls. **B,** Vertical long-axis images represent the anterior wall, apex, and inferior wall. **C,** Horizontal long-axis images represent the septum, apex, and lateral walls.

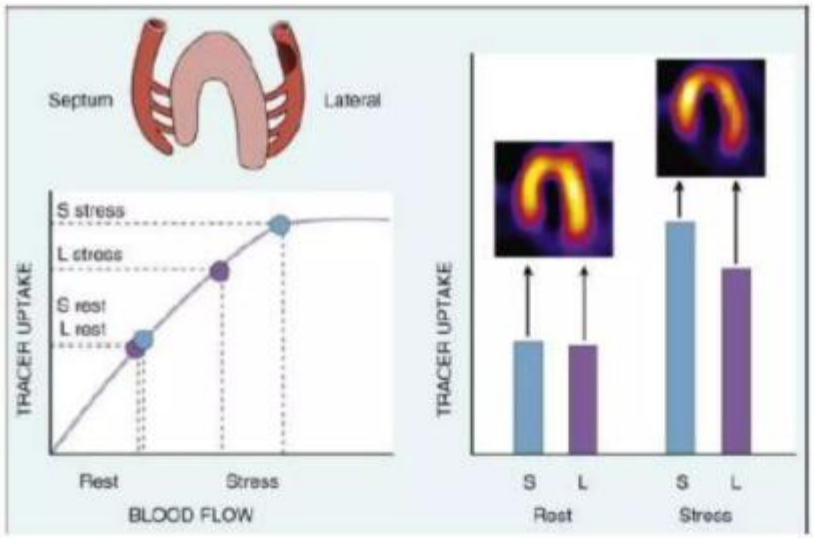


Illustration of coronary blood flow reserve abnormalities

SPECT Perfusion Tracers

- Thallium 201
- Technetium – 99m
  - Sestamibi (cardiolyte)
  - Tetrafosmin (myoview)
- Dual Isotope
  - Thallium at rest
  - Technetium-99m at stress

Stress protocols - Exercise

- ETT with Bruce protocol (bicycle also acceptable)
- Patient needs to exercise to acceptable workload (85% of maximum predicted HR
- Contraindications
  - ACS, unstable angina, known LM disease, severe HTN, LBBB, arrhythmias, pacemaker, clinical heart failure, PE/DVT
  - Unable to exercise

Stress protocol - pharmacologic

- Adenosine
  - Contraindications – ACS/UA, asthma, heart block more than 1st degree, SSS, hypotension, prior caffeine use
  - Can combine with exercise (may lessen symptoms)
  - Adenosine without treadmill is stress method of choice for LBBB or pacemaker
- Dobutamine
  - May use if unable to exercise and contraindication to adenosine
  - Contraindications – ACS/UA, LVOT obstruction, LM disease, severe HTN, LBBB, arrhythmias, pacemaker, CHF

Imaging Protocol

- Technetium
  - Most common-same day low dose rest/high dose stress
  - 2 day protocols for large body habitus (when higher doses required)

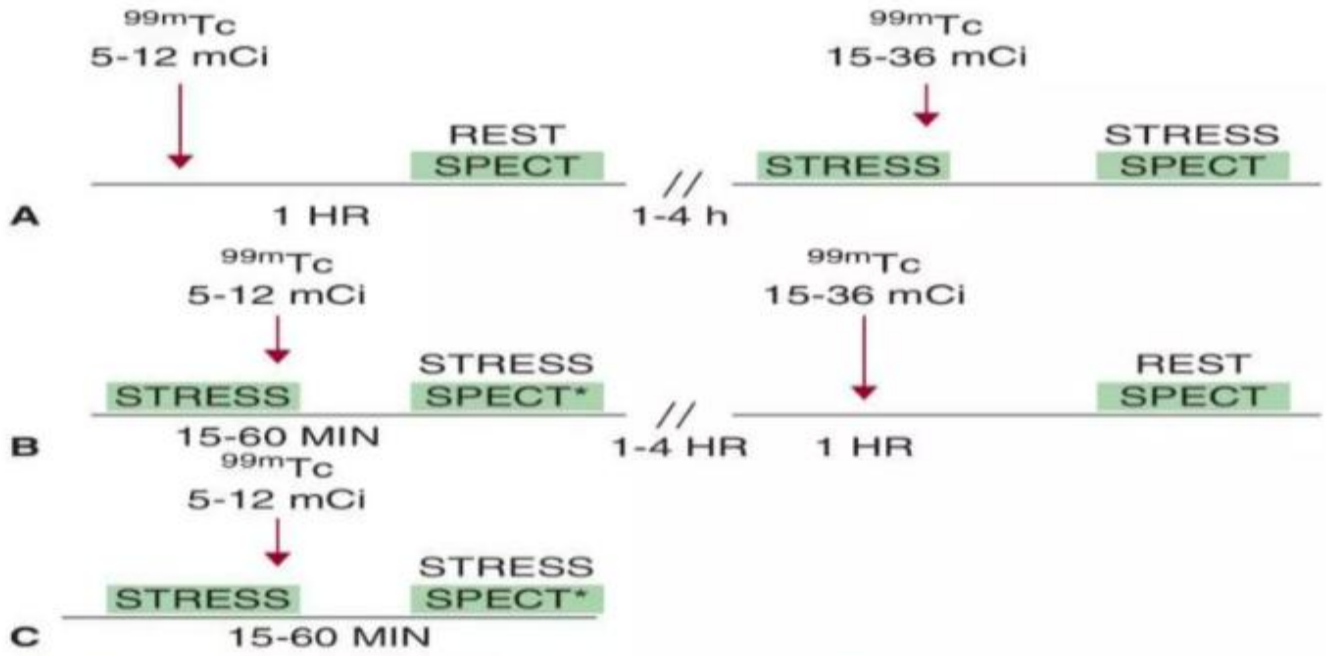
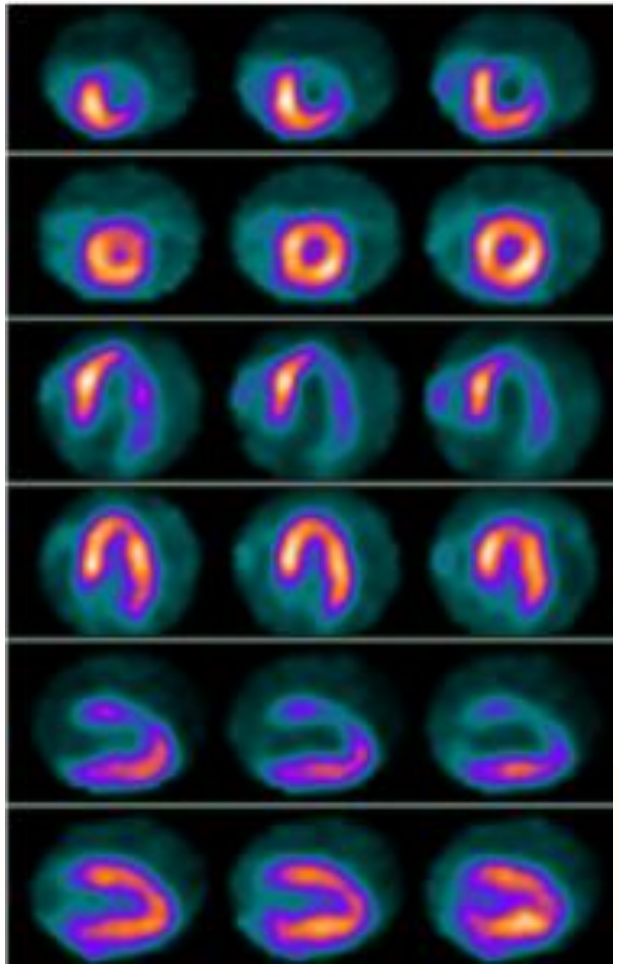


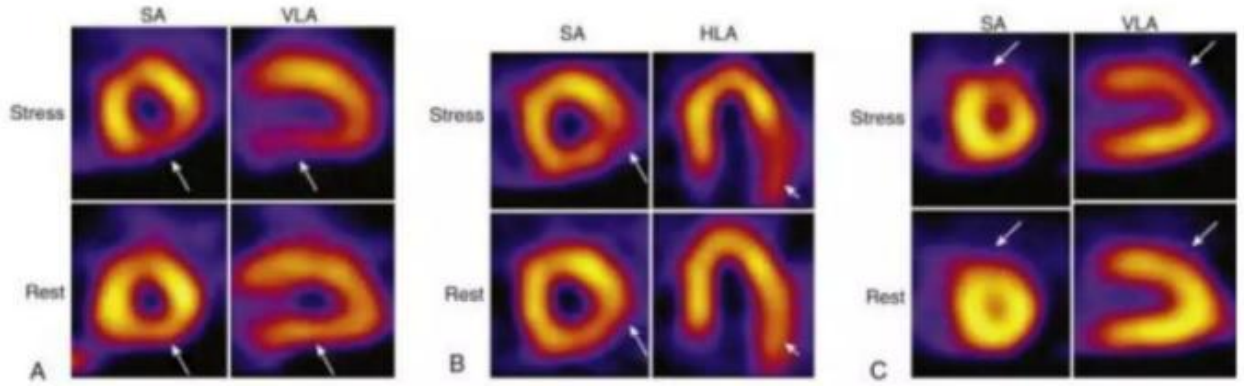
FIGURE 18–5. Same-day rest/stress (**A**), same-day stress/rest (**B**) and stress-only (**C**) technetium-99m (^{99m}Tc)-sestamibi or ^{99m}Tc-tetrofosmin protocols. An *asterisk* indicates where attenuation correction or imaging in multiple positions is recommended. SPECT, single-photon emission computed tomography.

SPECT Image Interpretation/reporting

- Perfusion defect
  - Presence/location
- Reversibility
  - Reversible = stress induced ischemia
  - Irreversible – infarction
- Extent of perfusion defect
- Severity
- Interpretation/recommendations

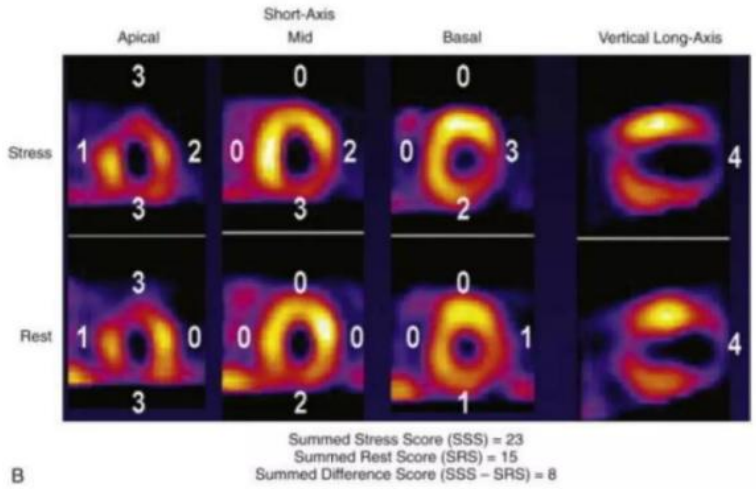


Visual Analysis



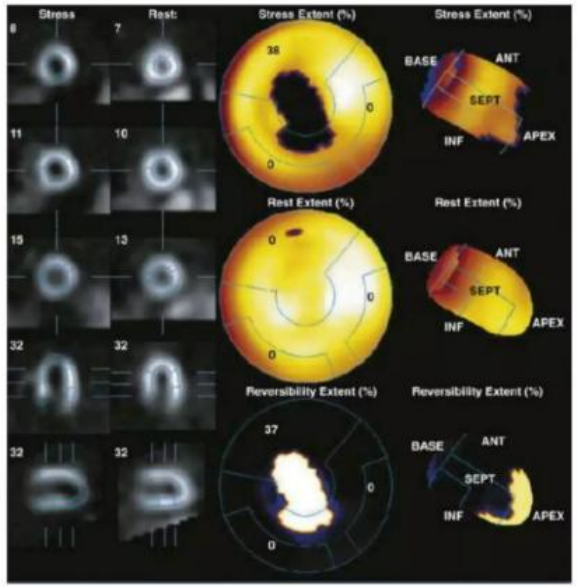
A, A reversible IW defect consistent with inducible ischemia in the RCA territory
B, A reversible lateral wall defect consistent with inducible ischemia in the LCX territory
C, A reversible anterior wall defect consistent with inducible ischemia in the LAD territory

Semi Quantitative vs Quantitative Analysis



Segmental scoring: severe apical fixed defect extending into the inferoapical and anteroapical walls with evidence of reversible defects in the inferior and lateral walls. SSS = 23; SRS = 15; SDS = SSS − SRS = 8 represents the extent of ischemia

Selected short- and long-axis tomograms from stress and rest studies are automatically segmented and scored



3D

Extent of ischemic myocardium (white area) measures 23% of the total myocardium

BULL's EYE PLOTS

* In practice: artefacts may not be accounted for in Quantitative analysis, final conclusion usually arrived by visual analysis incorporating the quantitative data

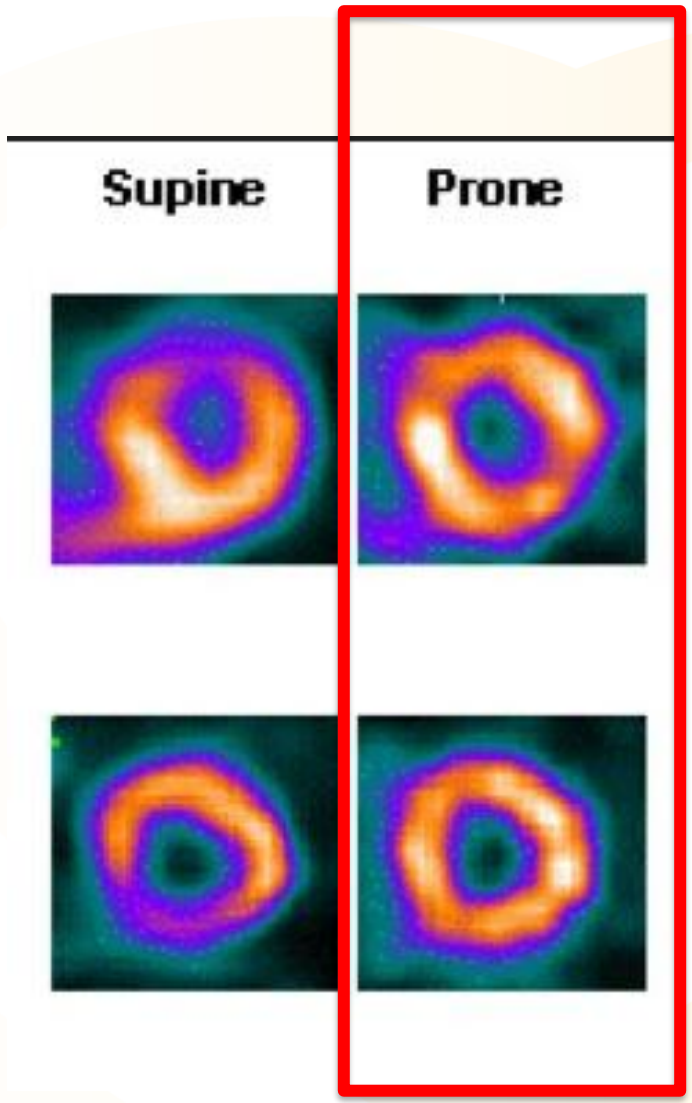
Transient Ischemic Dilation

- Stress induced cavity dilation
- May be present in severe/extensive CAD
  - With/without perfusion defect
- Derived ratio of size between rest/stress images
  - May be Significant if > 1.2 for exercise or pharmacologic testing

**Should be taken in context of patient

Major Artefacts in SPECT

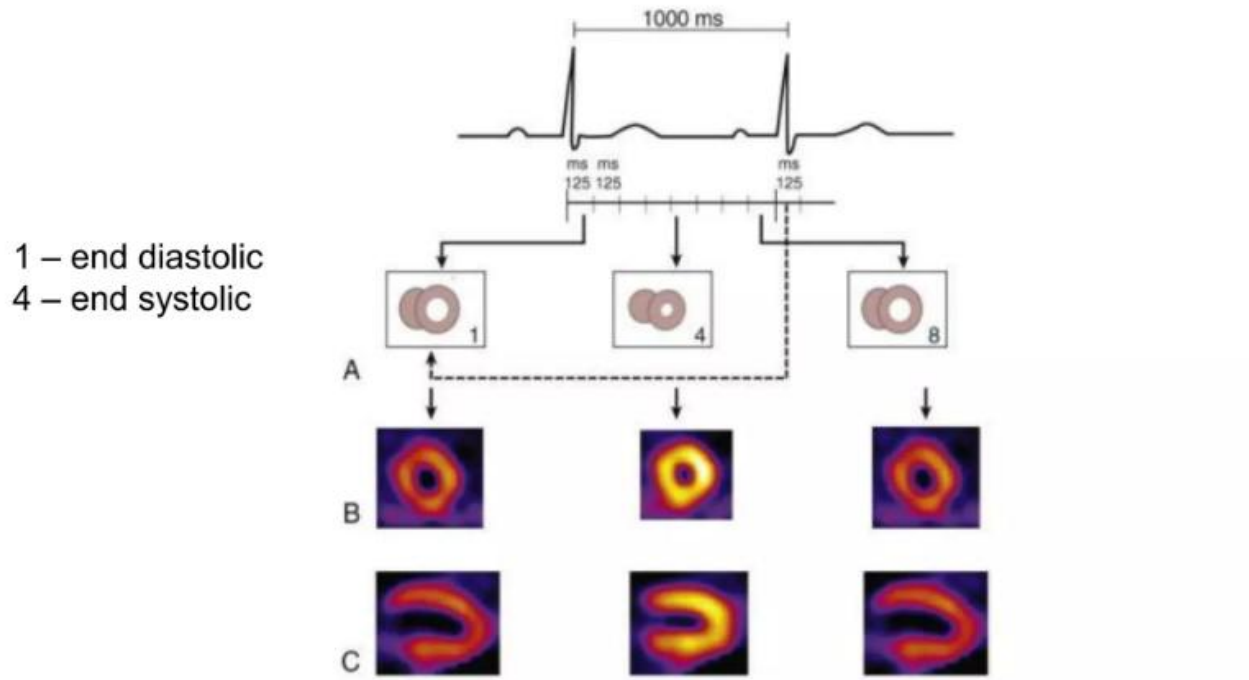
- Breast Attenuation
  - Anterior wall
- Diaphragmatic attenuation
  - Inferior wall
- LBBB
  - Isolated reversible perfusion defects of septum, due to delayed septal relaxation
- HCM
  - Appearance of lateral perfusion defect due to asymmetric septal hypertrophy



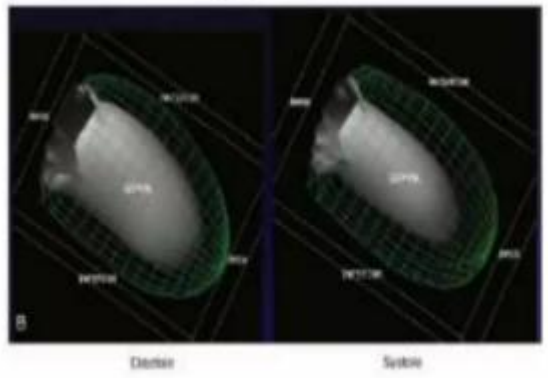
ECG Gated SPECT

- Simultaneous assessment of LV function and perfusion
- Creates one cardiac cycle for analysis that represents and average of several hundred beats
- Frames redisplayed in a cine/movie format

- Quantitative analysis calculates EF based on volume change

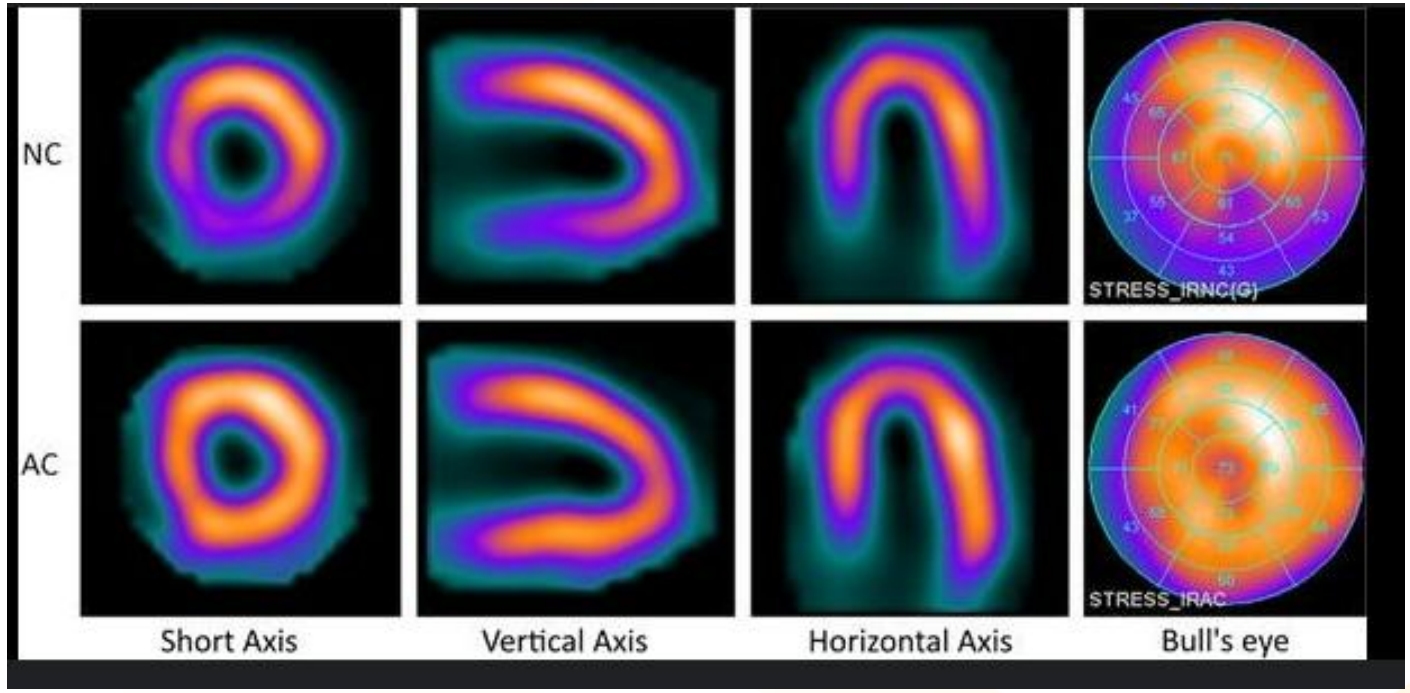


Wall thickening and brightening are seen across the course of systole



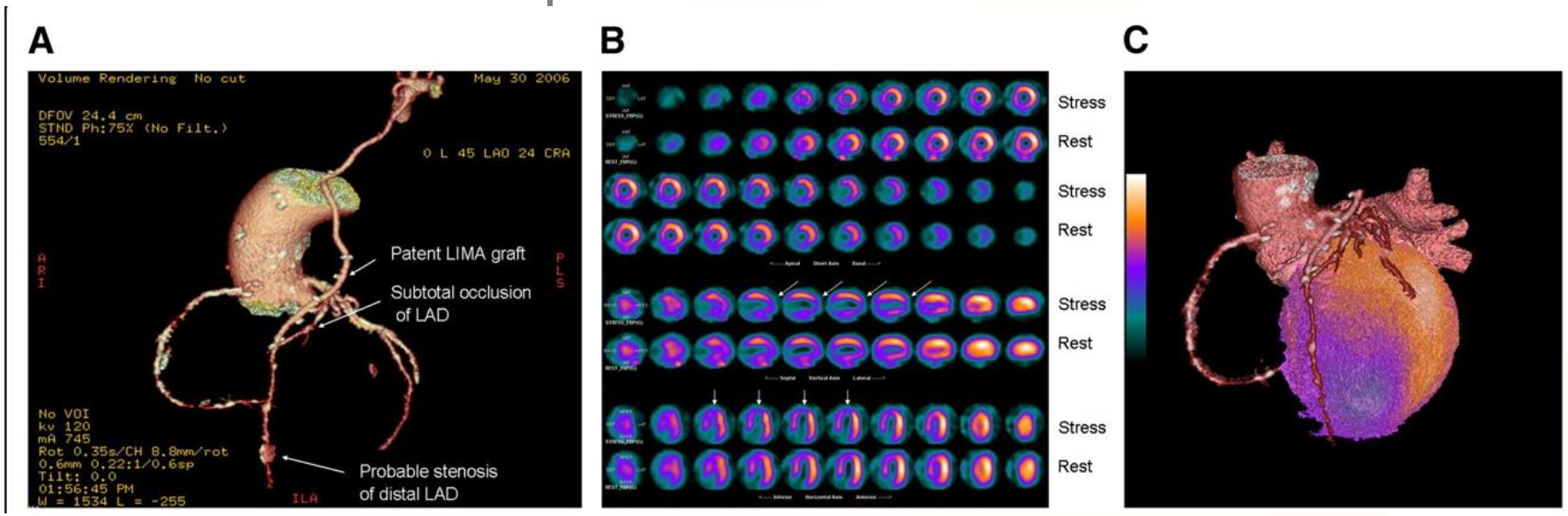
Combined SPECT/CT

- Attenuation correction
  - Computer based attenuation maps correct for tissue differences/artefacts
  - 20-30% improvement in specificity



Combined SPECT/CT

- Non-contrasted
  - Presence of coronary artery calcium can guide recommendations
  - ? Balanced ischemia
- Contrasted
  - Combined with CTCA provides anatomical and functional analysis



PET – Positron Emission Tomography

- Radiotracers labelled with positron emitting isotopes
  - perfusion tracer - Rb82 and N13 ammonia
  - metabolic tracer F18 FDG
- Beta decay positron emission
- Positron collides with electron to give off two gamma rays in opposite directions
- PET scanner detects opposing photons with spatial/temporal resolution
- FDG studies performed after glucose loading – increased glucose metabolism = FDG uptake

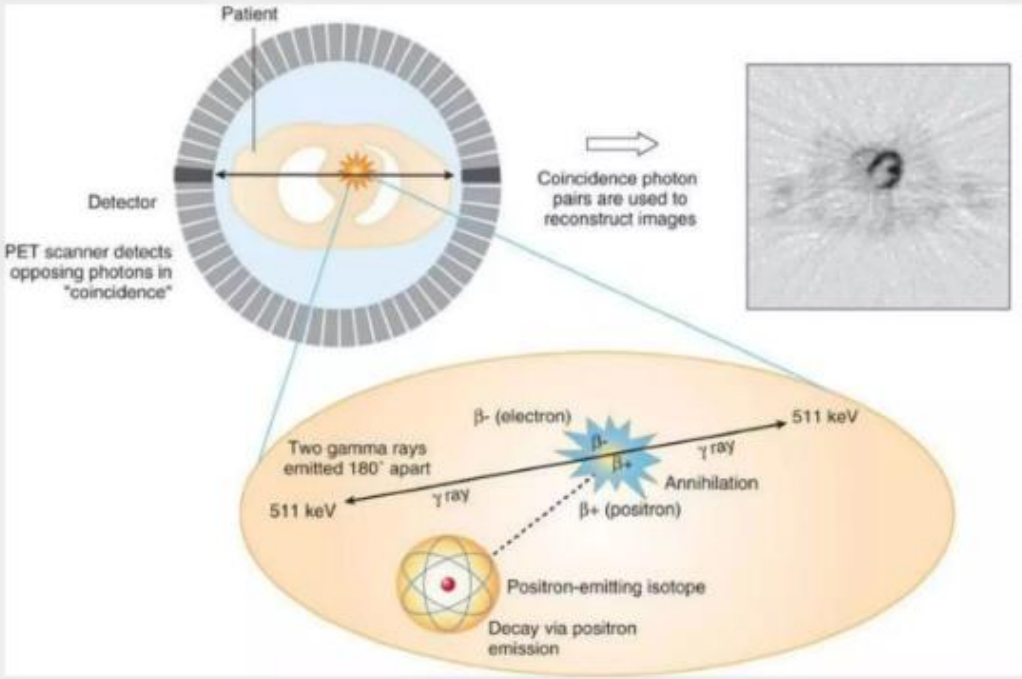
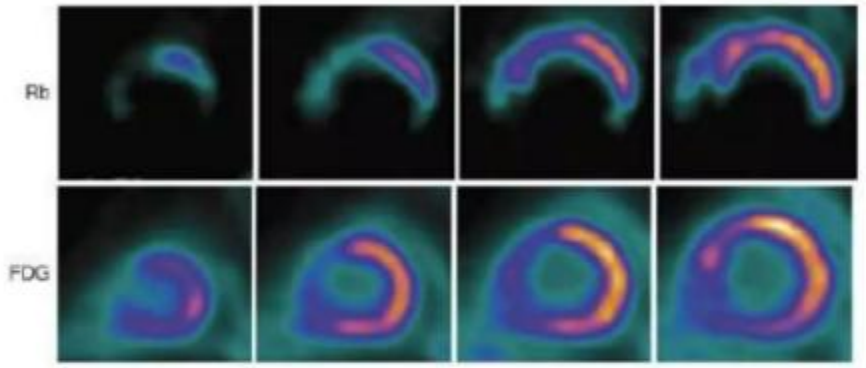


FIGURE 16.16 Schematic of positron and electron beta particle emission, with detection by a coincidence camera, as the basis of PET imaging.

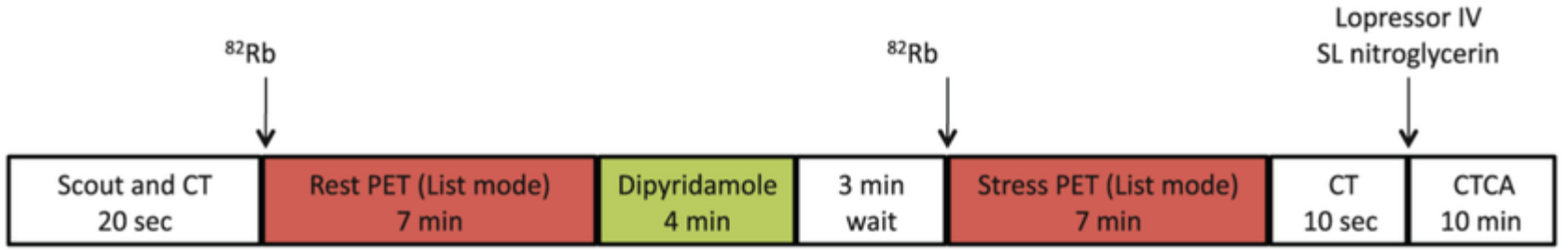
PET Image Analysis

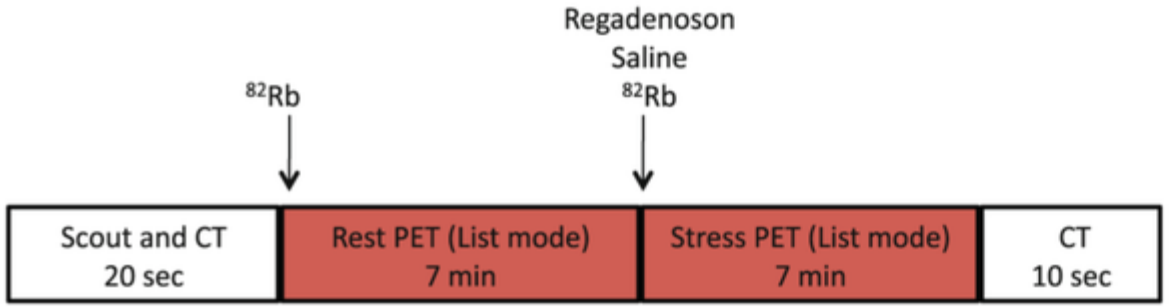
- Hibernating myocardium
  - Enhanced FDG uptake in regions of decreased blood flow
  - “PET mismatch”
  - 80-85% change of functional improvement following revascularization
- Necrotic myocardium
  - Concordant reduction in both metabolism and flow (“PET match”)
  - Only 20% change of functional improvement with revascularization
- Stunning
  - Regional dysfunction with normal perfusion



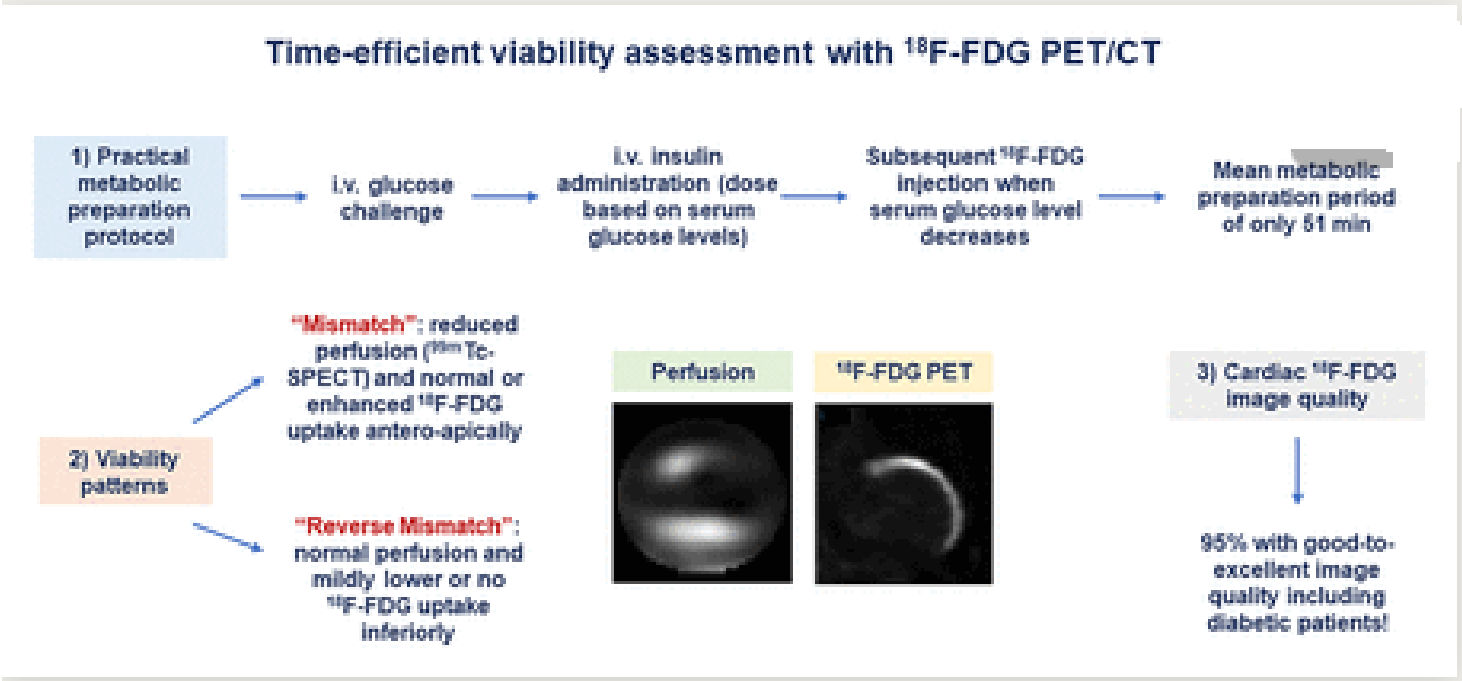
HIbernating myocardium
Scarred in anteroseptal region

PET STRESS PROTOCOL:



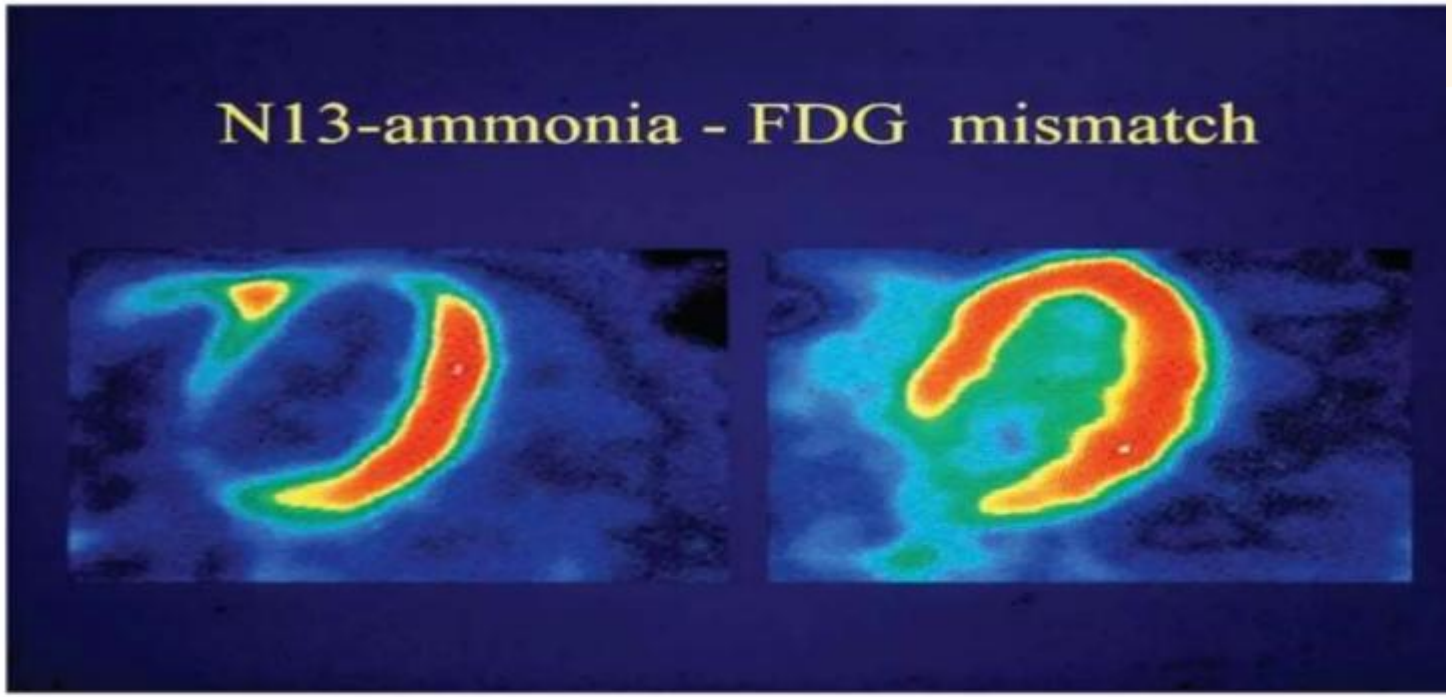


PET VABILITY PROTOCOL:



PET Pros/Cons

- Advantages:
  - Higher spatial resolution
  - Improved attenuation and scatter correction
  - Quantification of regional blood flow
    - SPECT can miss balanced ischemia
- Limitations:
  - Onsite cyclotron for 13N ammonia
  - Monthly generator replacement 82Rb
  - Short half lives of both – only pharm stress



PET with 13N-ammonia and 18F-FDG to assess myocardial viability . Regional myocardial 18F-FDG uptake is disproportionately enhanced compared with regional myocardial blood flow; this pattern is termed perfusion–metabolism mismatch and is indicative of hibernating myocardium

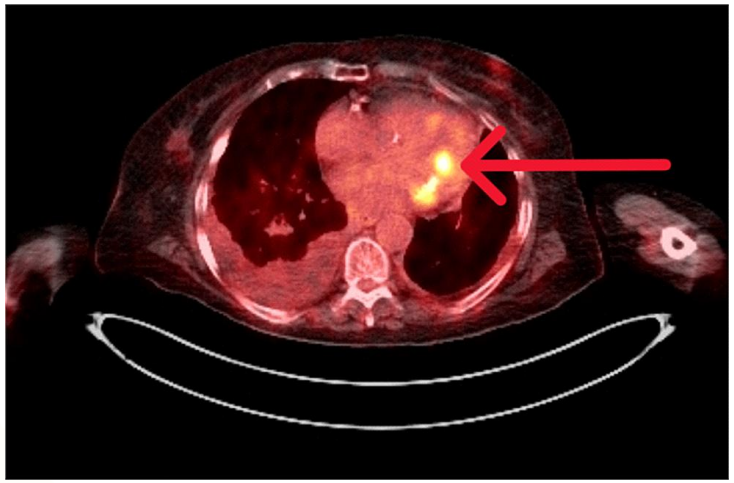
SPECT vs PET

Sensitivity and Specificity of PET versus SPECT in the Detection of Myocardial Ischemia

Protocol	Sensitivity (%)	Specificity (%)
SPECT	53–79	76–79
PET	84–97	82–100

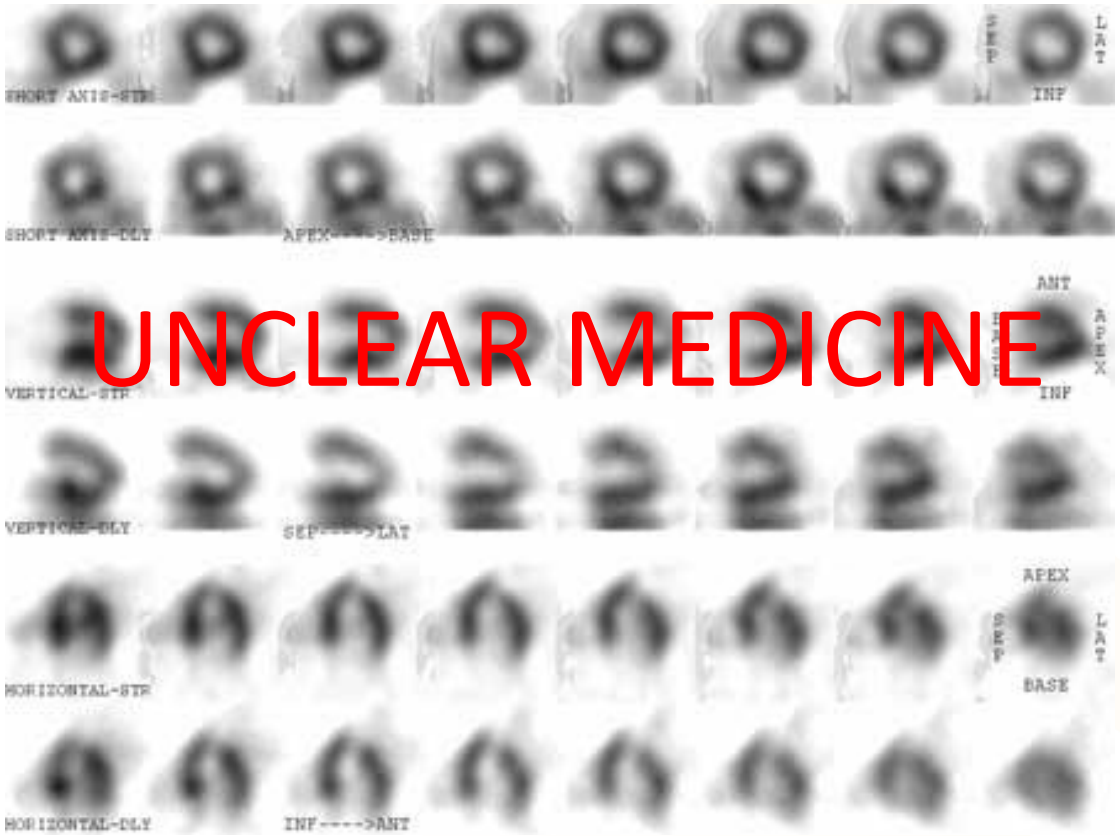
Other Cardiac SPECT/PET uses

- PET Absolute MBF (Myocardial blood flow)
  - Myocardial flow assessment
  - Coronary microvascular dysfunction
- Tc99m- PYP ATTR Cardiac amyloid Imaging
  - SPECT imaging for presence of ATTR amyloid
- FDG/Perfusion PET for Sarcoidosis
  - Specific patterns for inflammation/scar
- Radionuclide imaging for CV infection
  - FDG PET/CT
  - Radiolabelled leukocyte scintigraphy SPECT/CT



Nuclear Cardiology Thoughts

. . . But isn’t nuclear cardiology a little old fashioned?????



UNCLEAR MEDICINE

History of Cardiac Stress testing

- 1956 – ETT – Robert Bruce establishes “Bruce protocol”
- 1963 –myocardial scintigraphy using Thallium for myocardial perfusion
- 1973 – Thallium SPECT imaging - for perfusion and infarction
- Late 1970s – echo starts
- 1981 – Dobutamine stress echo introduced
- 1985 – Technetium-99m replaces thallium – better images
- Late 1980s – SPECT becomes routine - attenuation correction and gating
- 1990s –PET MPI expands – quantitative perfusion and viability
- 1990s – pharmacologic stress agents like adenosine developed/utilized

More History

- Early 2000s – fusion of PET/SPECT with CT
- 2004 – CTCA – anatomical assessment of coronary arteries
- Late 2000s – cardiac MRI stress testing
- 2010-2015 – Quantitative perfusion with PET and MRI improves accuracy, microvascular disease
- 2020-present – increasing integration of AI into interpretation of ECG, echoes, SPECT, PET
- 2022-2024 – novel PET agents like Flupiridaz for high resolution MPI
- Ongoing – broader use of CT FFR as non-invasive method for assessing hemodynamic significant of CAD

How does nuclear cardiology fit into cardiology practice today?

9 Million Nuclear Stress Tests Annually in the US

Why so much nuclear in the US???

NEWS

Shelton widow awarded $2.5 million in malpractice case

By **Daniel Tepfer**, *Reporter*
Updated June 27, 2015 1:31 a.m.

Listen Now: w awarded $2.5 million in malpractice
2:19
1x
Everlit

BRIDGEPORT— Two city cardiologists, accused of misdiagnosing a Shelton man who later died from a heart attack, were ordered Friday to pay his wife more than $2.4 million.

Test	US Medicare Reimbursement (USD)
ETT	$210-240
Stress Echo	$450-550
SPECT MPI	$1,100-1,400
Stress Cardiac MRI	$800-1,000
CT Coronary Angiogram	$300-450
Coronary angiogram	$900-1,200

Nuclear Cardiology Training - US

- COCATS Level 2
  - 6 months dedicated nuclear training
  - Formal didactic training
  - 80 hours Radiation training
  - Hands-on 30 patients
  - Minimum 300 cases read with supervision
  - Separate board certification (written test)

CBNC
Certification Board of Nuclear Cardiology

Nuclear Cardiology Board Exam PREP COURSE

ASNC
American Society of Nuclear Cardiology

What about New Zealand?


W·1094

Chest pain

Cardiomyopathy

Known CAD

Surgical Risk Assessment

ETT

CTCA

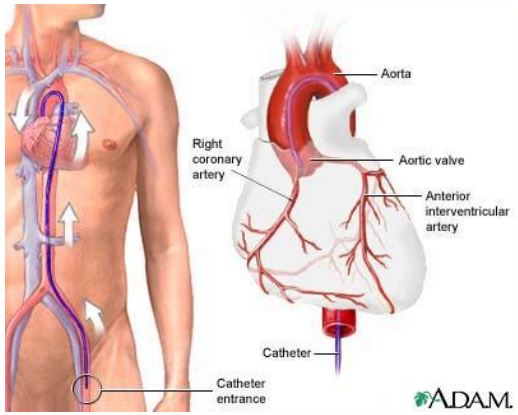
CT FFR

Stress Echo

SPECT MPI

Stress MRI

Cardiac PET/CT



Radiation Doses

Imaging Modality	Typical Radiation Dose (mSv)	Comments
SPECT MPI	4-12 mSv	Depends on protocol – one, two day or stress only
CTCA	1-12 mSv	Newer scanners and dose reduction protocols can decrease
Invasive Coronary Angiography	5-10 mSv	Dose depends on complexity/fluoroscopy time
PET-CT	Rubidium-82: 7-9 mSv N-13 ammonia : 2-4 mSv F-18 FDG: 5-7 mSv	PET 5-10, CT component variable 5-15 mSv
Mammogram	0.4 mSv	
Chest X-ray	0.1 mSv	
Annual background radiation	3mSv	

Ischemia Trial

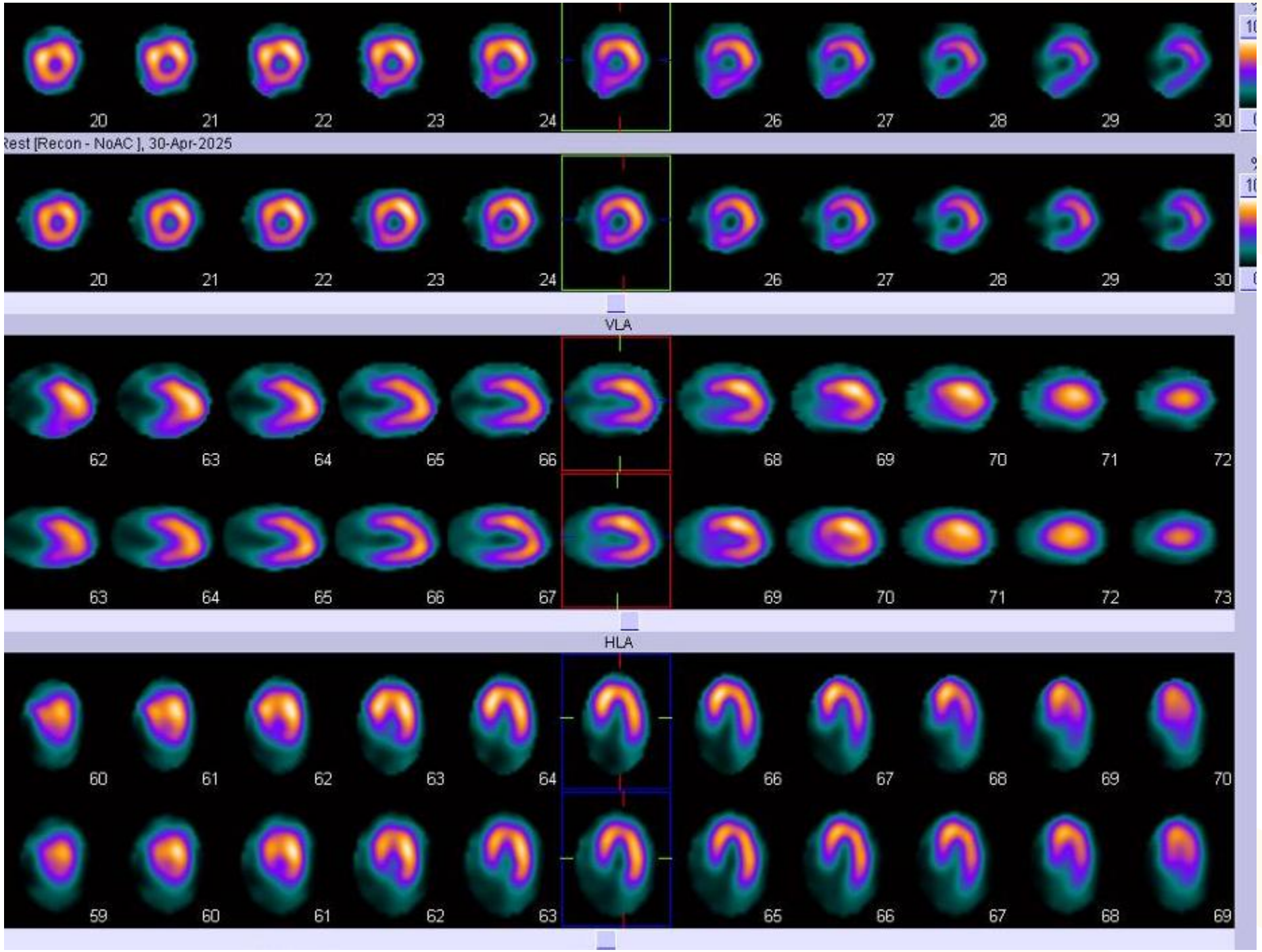
- NEJM April 2020
- Compared outcomes of initial angiogram/intervention with optimal medical therapy for stable angina
- 5,179 patients with stable CAD and mod/severe ischemia
  - LM disease ruled out by CTCA

- No significant difference of death, MI, cardiac arrest, hospitalization for UA/CHF
- Invasive strategy did improve symptoms
- Supports initial medical therapy as safe in stable ischemic heart disease

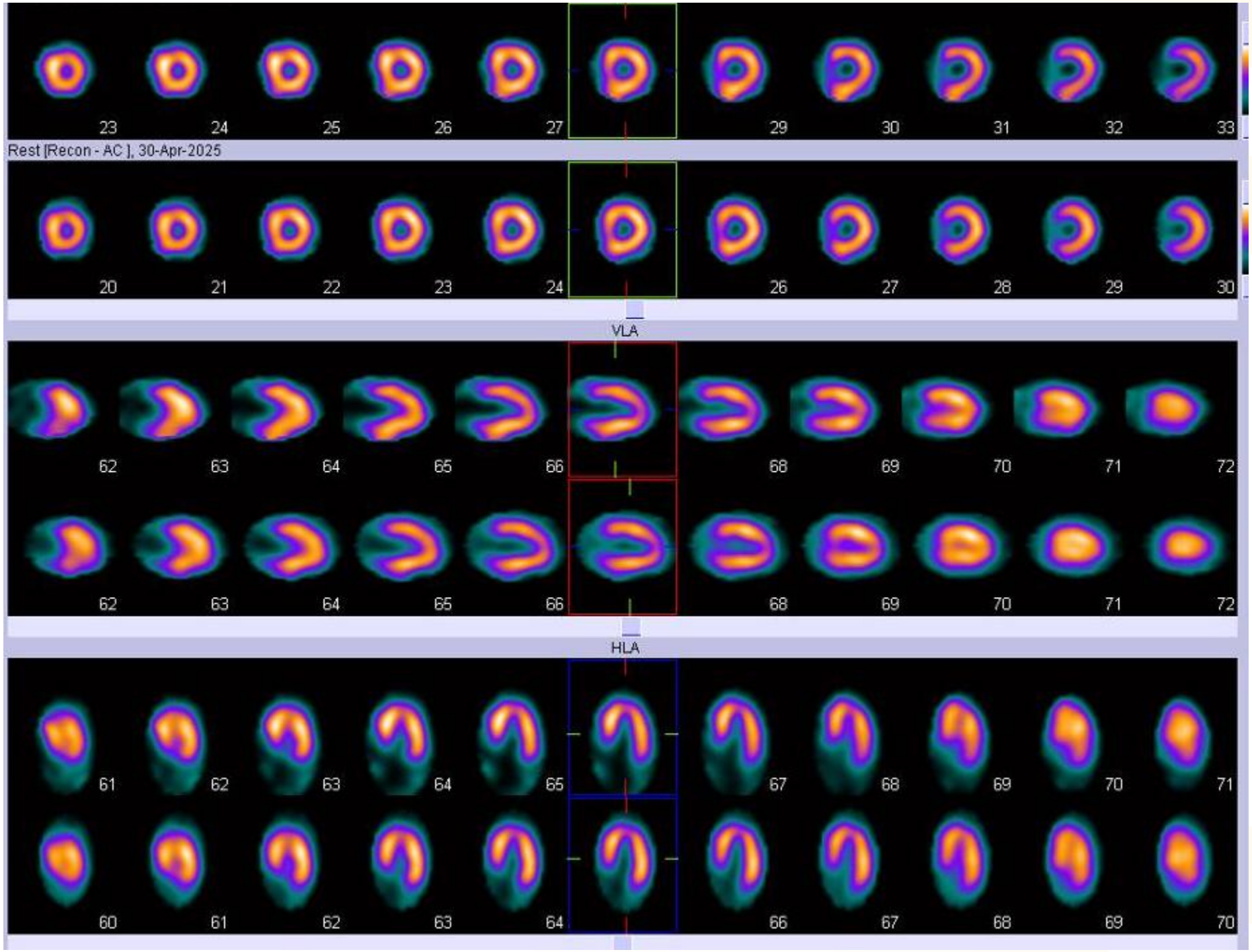
Case

- 74 yo M with dyspnoea on exertion mild CP on exertion
- Unable to walk on treadmill due to back pain

No CT Attenuation

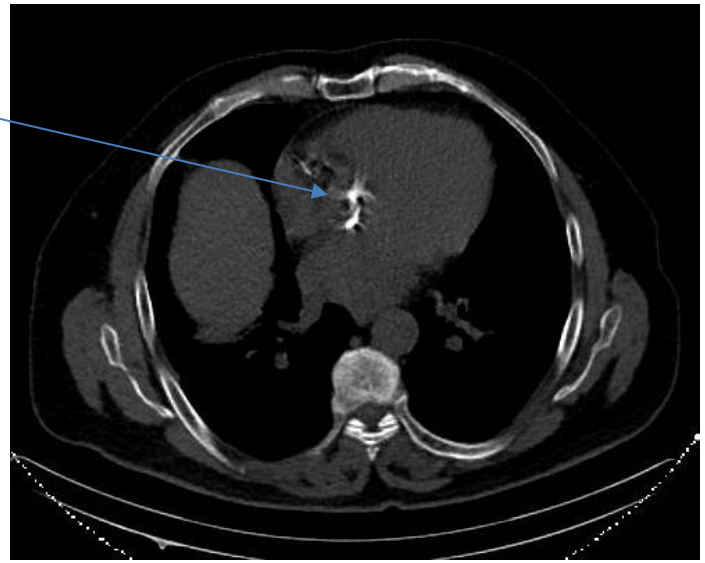


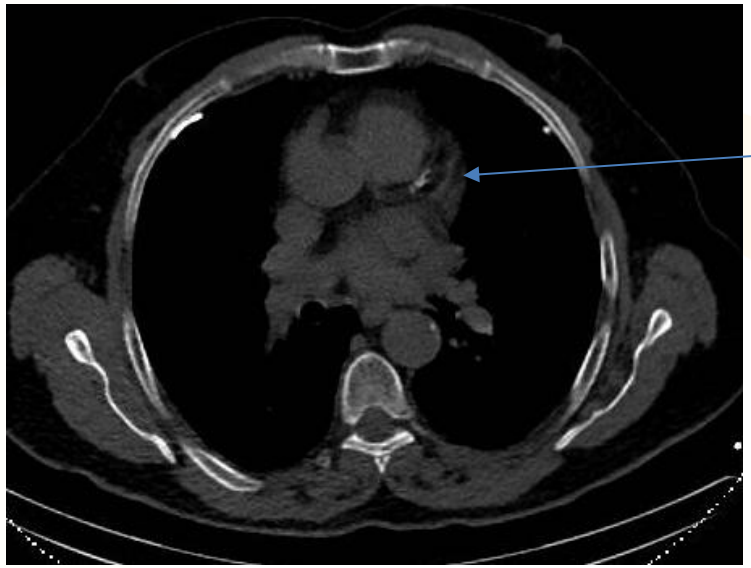
With CT Attenuation



EF 74%

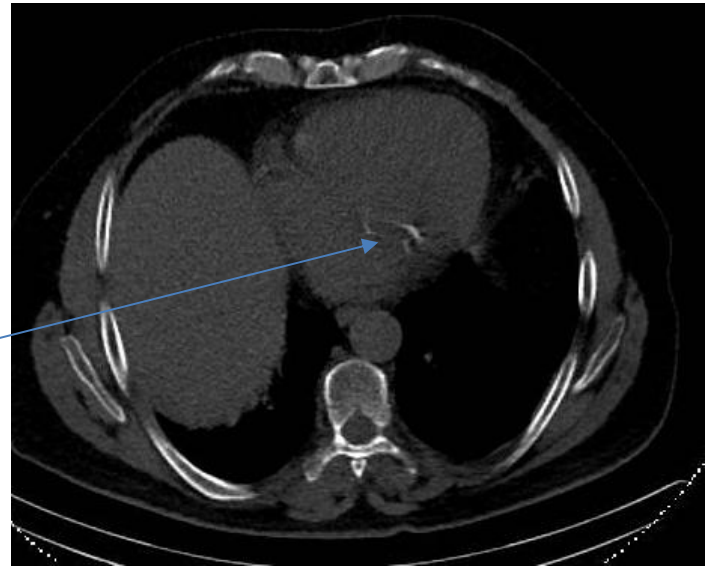
Aortic Valve

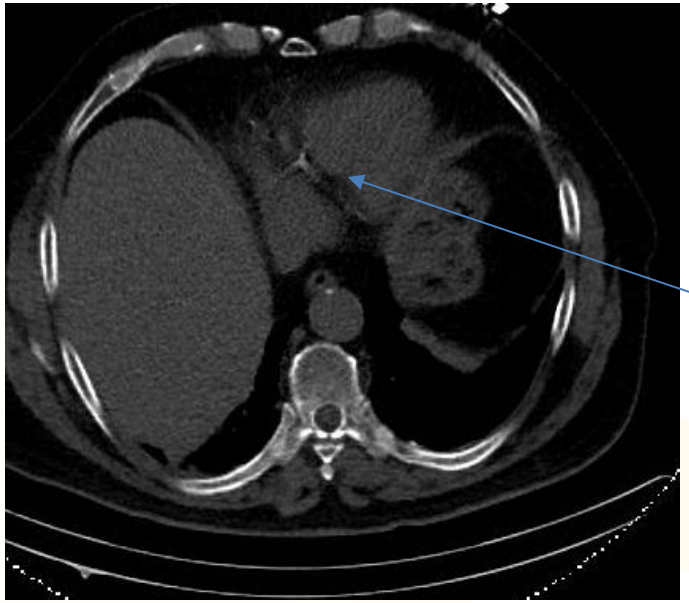




LAD

LCx





RCA

Conclusion:
1. Normal left ventricular size and systolic function.
2. No myocardial perfusion defects consistent with ischaemia or infarction.
3. Borderline dilation of the ascending aorta.
4. Severe aortic valve calcification on CT scan.
5. Coronary artery calcification visualised in all major coronary vessels on noncontrast CT.

Recommendation:
Although low risk myocardial perfusion imaging study with no identification of ischaemia or infarction and preserved EF, cannot definitively rule out balanced ischaemia. However, in light of severe aortic calcification, recommend echocardiogram for evaluation of aortic stenosis initially, as this could be aetiology of dyspnoea.

Conclusions

- Nuclear cardiology is not “old fashioned” or “unclear”
  - New developments increase sensitivity/sensitivity
- Has it’s place with all non-invasive imaging
- Development of robust nuclear imaging programs can support the entire department and population

Thoughts/Questions??

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