Technique, Protocols and Instrumentation

Important concepts

- Spatial resolution
- Temporal resolution
- Contrast resolution
- Contrast to noise ratio

Cardiac MRI

- Gold Standard in evaluation:
  - Anatomy
    - » Heart and great vessels
  - Function (Regional and Global)
    - » Wall motion, myocardial mass and systolic wall thickening
    - » Valvular function
    - » Stroke volume and ejection fraction
    - » Myocardial Perfusion and viability
    - » Flow quantification

- Coronary artery anatomy
- Vessel wall imaging
- Spectroscopy

Advantages

- No radiation
- Multiplanar imaging capability
- Multi – functionality

Disadvantages

- Claustrophobia
- Traditional lengthy examinations – Now faster imaging with shorter scan times

1. Patient History

Why is the cardiac MRI being requested?

Have you ever had cardiac surgery? If the answer is 'yes' ask 'when' and 'why'.

Have you ever been diagnosed for ischemic or congenital heart disease.

Allergy

Claustrophobia

Metal implants

Cardiac Pacemaker

Cardiac Safety and Contra - Indications

Technique

Patient Positioning

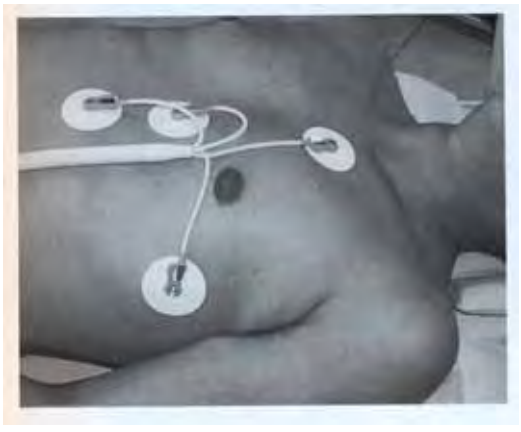
ECG-gating-Prospective and retrospective

Coils

IV-line

Coils

- Standard body
- Dedicated cardiac phase array coil preferred



Gating

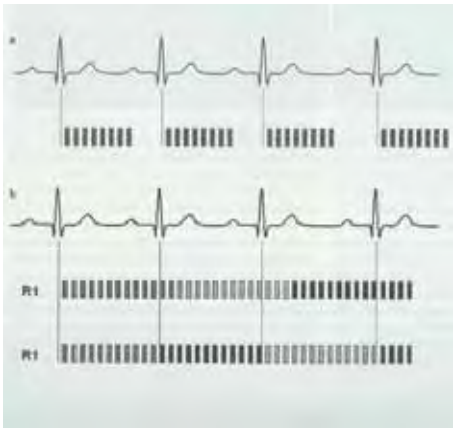
To reduce motion artifacts

Cardiac

- –R-wave identification
- –Prospective - only 80% of cardiac cycle
- –Retrospective – all data of cardiac cycle acquired
- –Magnet hydrodynamic effect – use vector ECG

Respiratory

- –Free breathing - navigator
- –Breath Hold

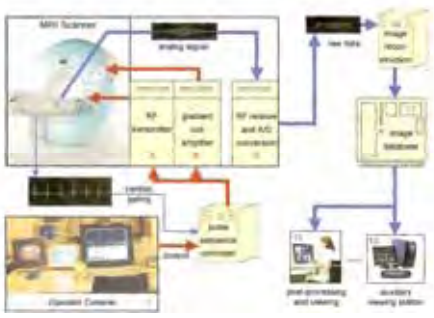


Magnetic Contrast

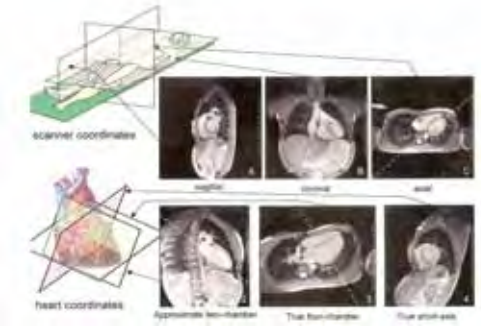
TABLE 7.2 Applications of Magnetic Resonance Contrast Media in Cardiac Imaging

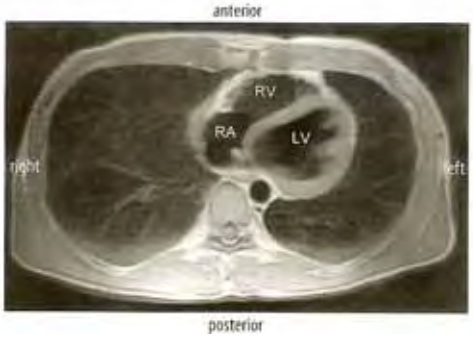
Assessing myocardial perfusion and perfusion reserve
Assessing myocardial viability
Measuring the spatial extent of myocardial stunning, acute and chronic (scar) infarctions
Discriminating acute infarctions from scar tissue
Demonstrating reperfusion at microvascular level and microvascular obstruction
Labeling of stem and progenitor cells
Enhancing plaque and vascular wall imaging
Guiding endovascular catheters during intervention
Anatomy of the coronary arteries

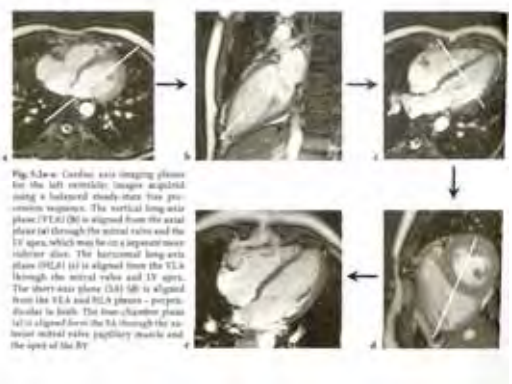
Scanner and Workstation

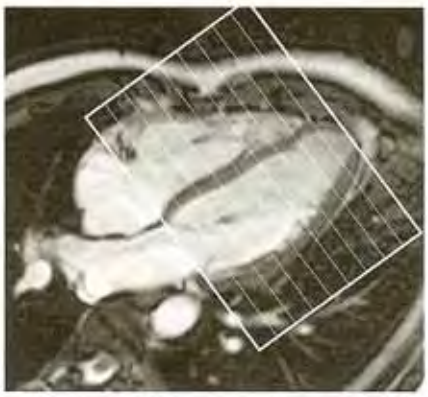


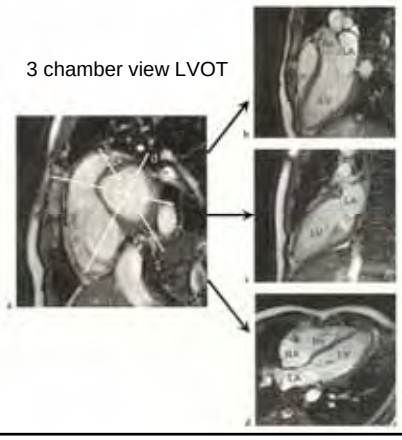
Protocols and pulse sequences

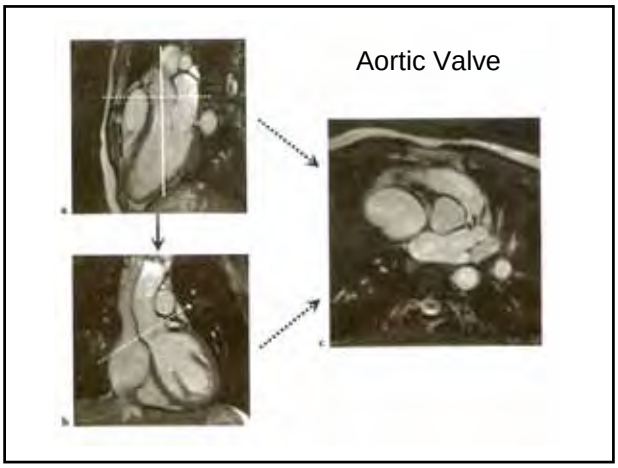


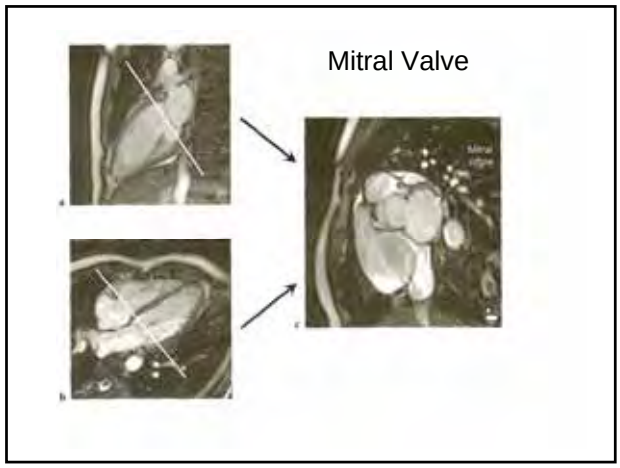


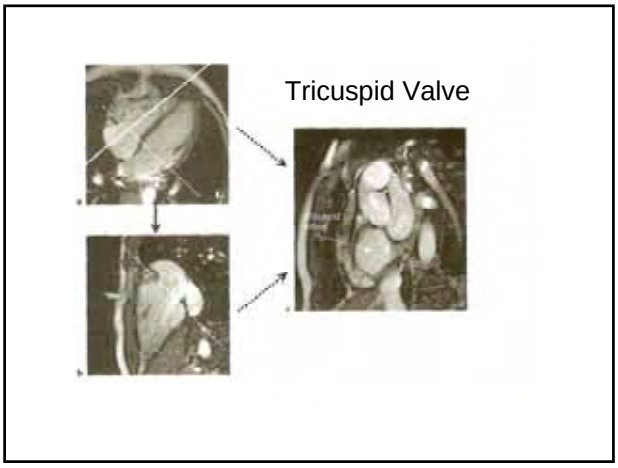


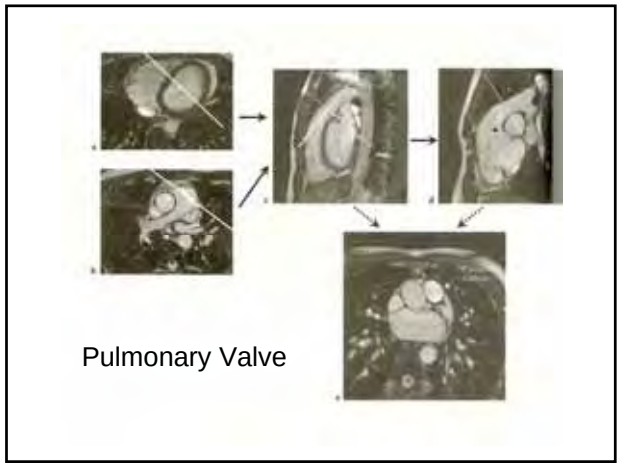


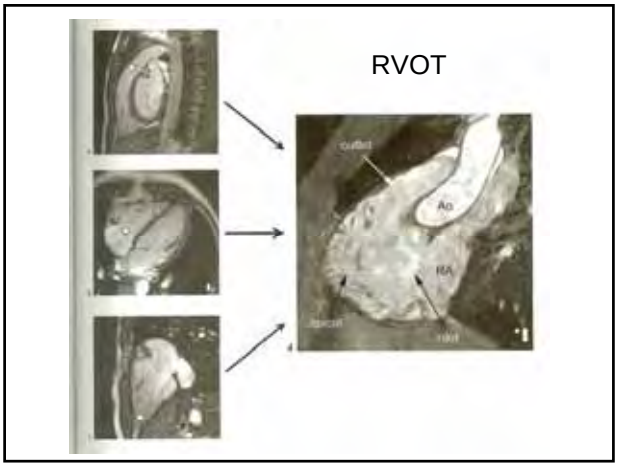


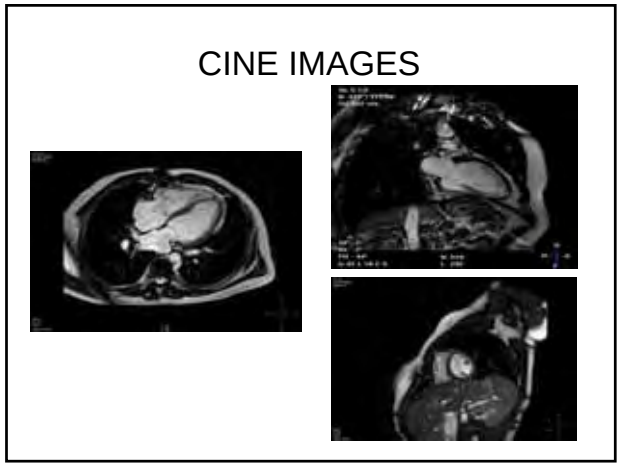

Aortic Valve


Mitral Valve


Tricuspid Valve

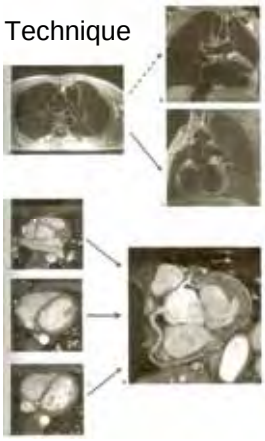

Pulmonary Valve

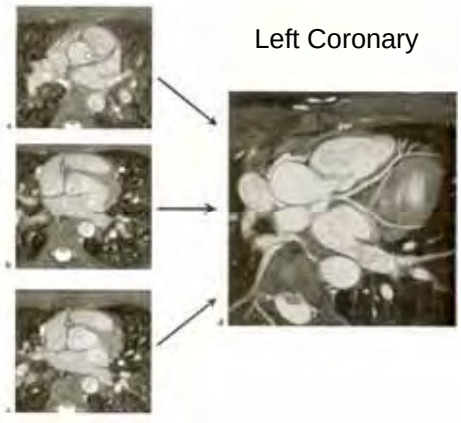

RVOT
Ao
RA

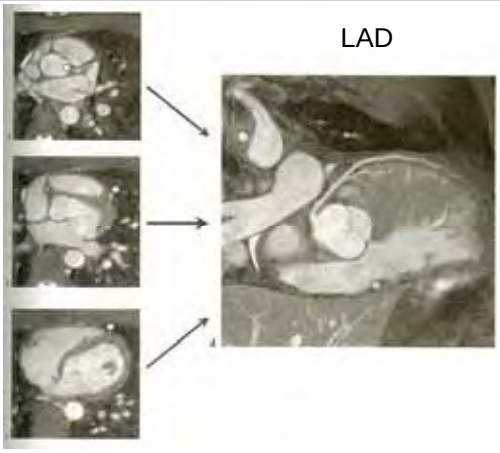

CINE IMAGES

3D Coronary artery plan imaging

Three Point Technique



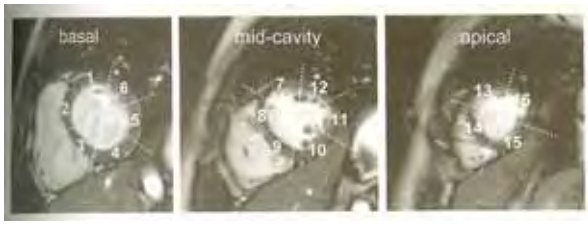




Protocols

- ECG gating
- Respiratory gating and navigator
- Pre-saturation pulse
- Fast imaging sequences
  - 2D and 3D segmented K-space GE recoil imaging
  - 3D b –SSFP-
  - Echoplanar imaging
- Arterial spin labeling
- Blood pool contrast agents

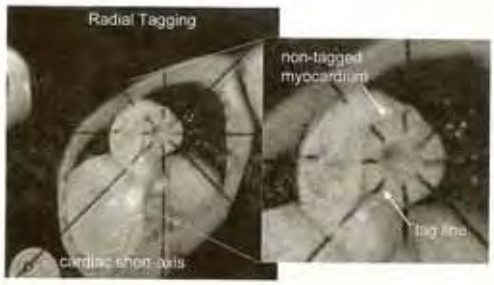
Segmentation

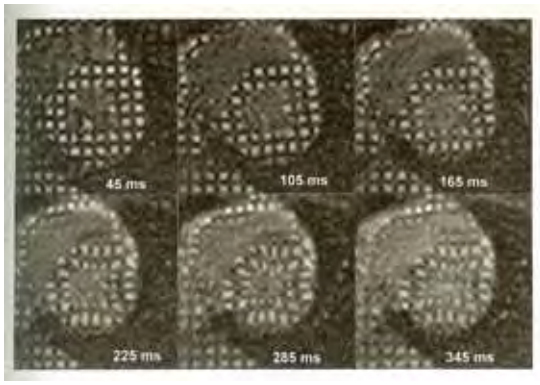


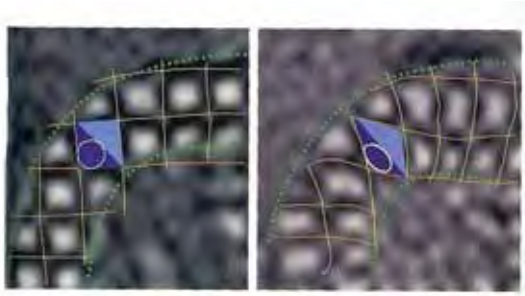
Regional and Global function

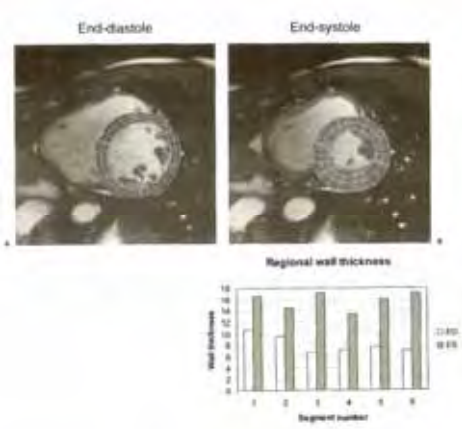
- Wall morphology and motion
- Strain analysis
- Systolic wall thickening
- Myocardial mass
- Volume quantification
  - End Diastolic
  - End Systolic
  - Stroke volume
  - Ejection fraction
  - Regurgitant fraction

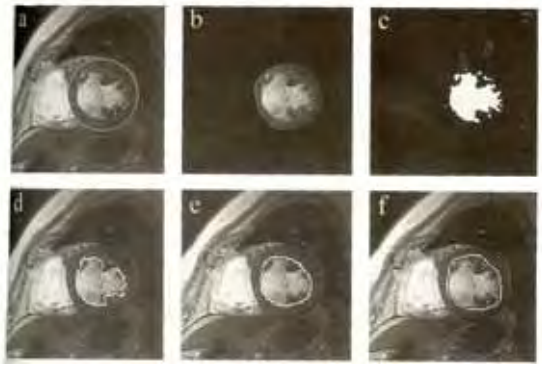
Myocardial Tagging

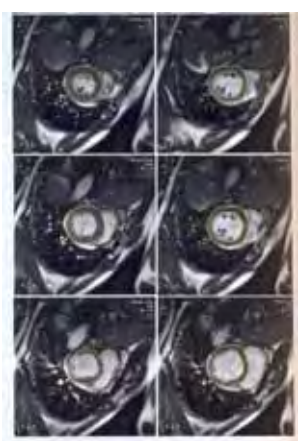


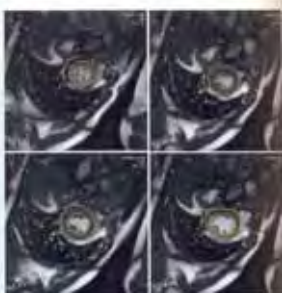










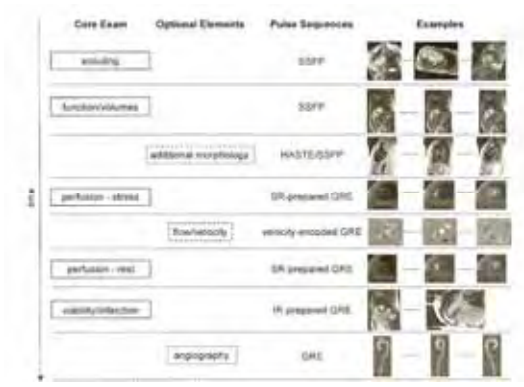


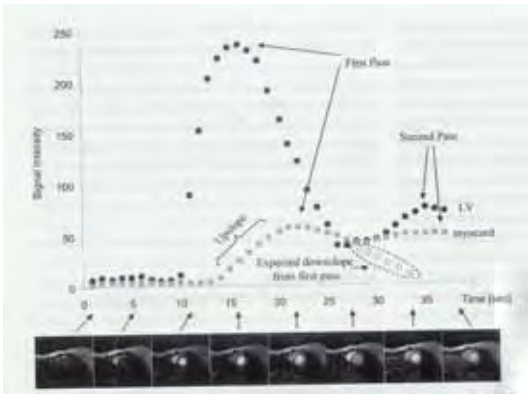
Endo- and epicardial contours

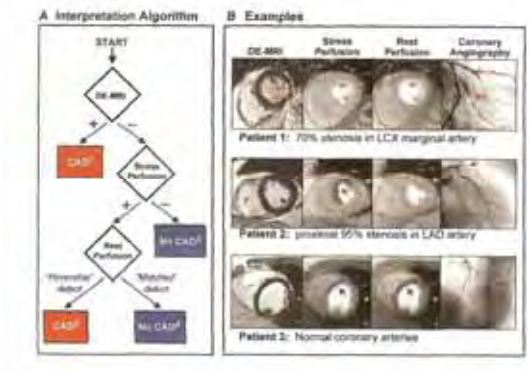
Myocardial perfusion and stress

First pass contrast imaging

Fast MR sequences imperative
Fast GE, echo-planar, EPI, Parallel imaging





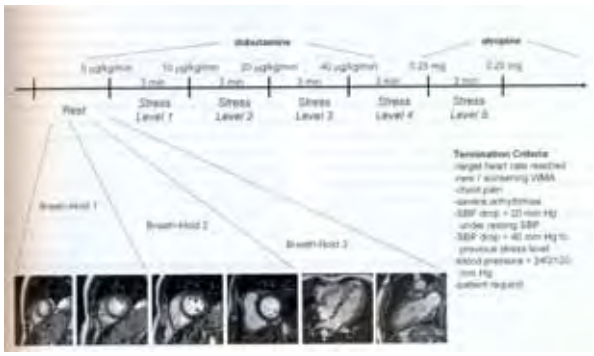


Dynamic Gadolinium contrast infusion

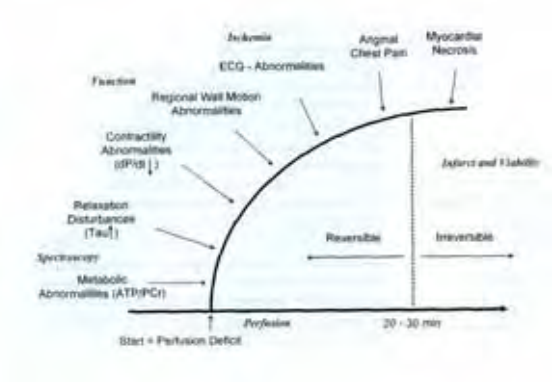
- 0.075 – 0.1 mml/kg
- Injection rate 3ml/sec
- Contrast during stress and rest with saline flush - 15min interval

Pharmocologic stress agents

- Adenosine –vasodilator
- Dobutamine- sympathomimetic a1,b1 and b2



Low dose – hibernating myocardium
High dose – induce ischaemia



Myocardial viability

Delayed contrast enhancement

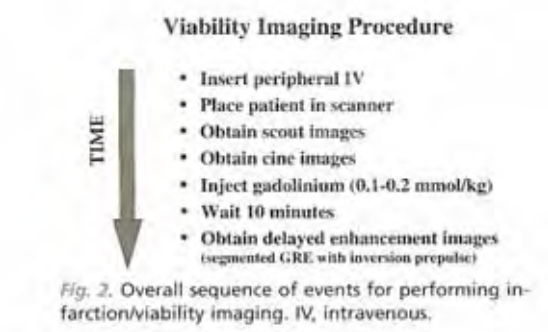
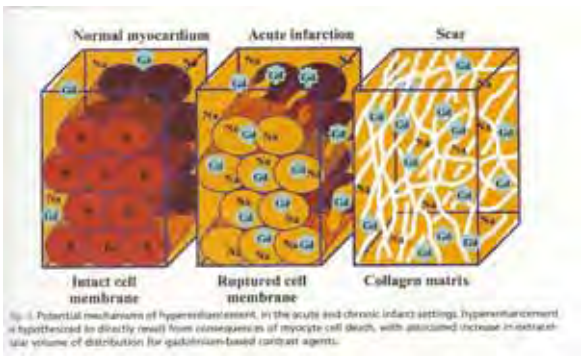
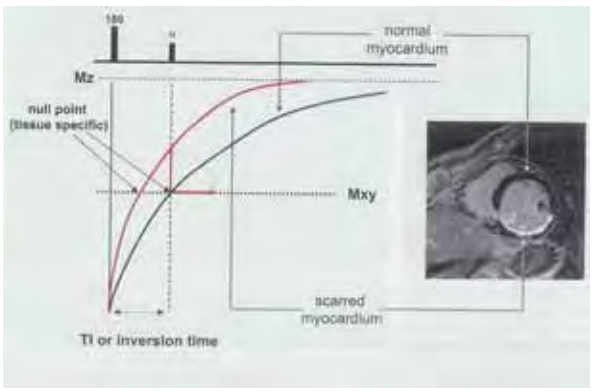
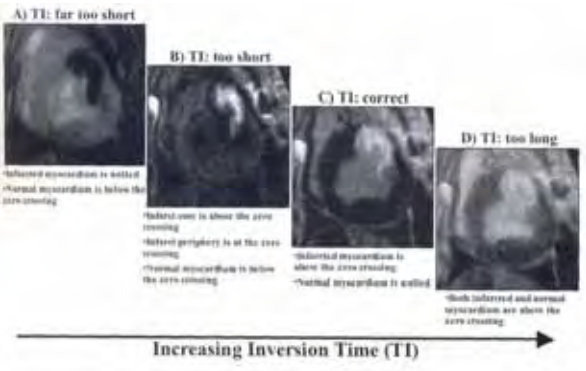
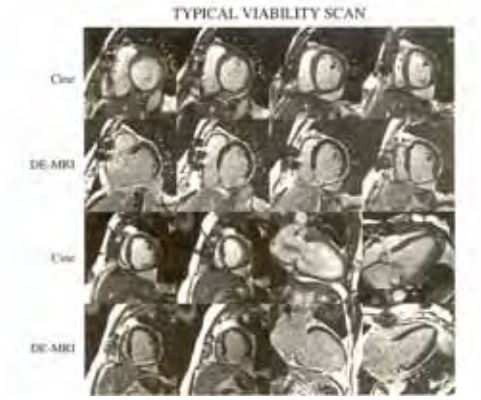


Fig. 2. Overall sequence of events for performing infarction/viability imaging. IV, intravenous.

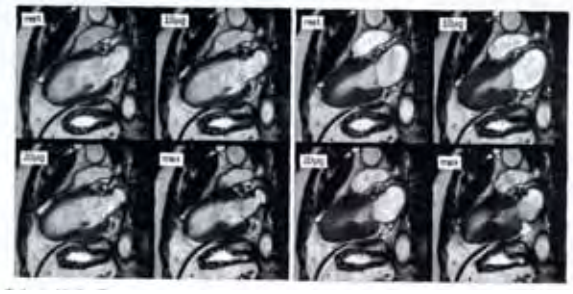


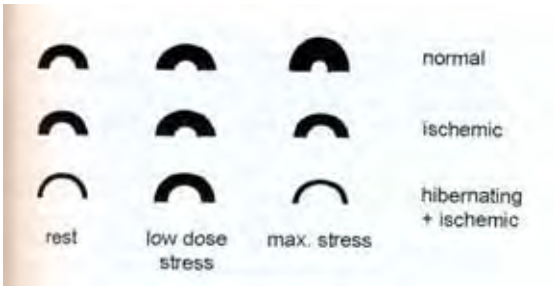




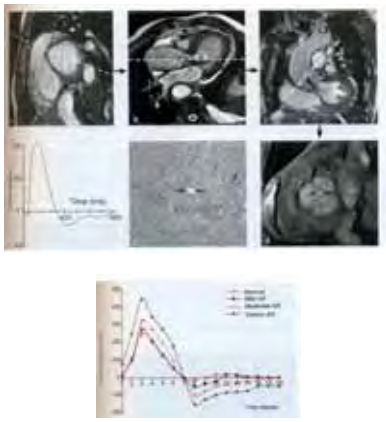


Wall motion during pharmacologic stress



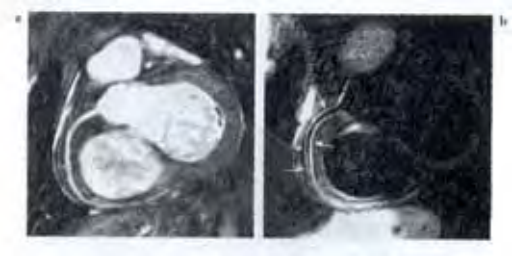


Flow quantification



Vessel Wall imaging

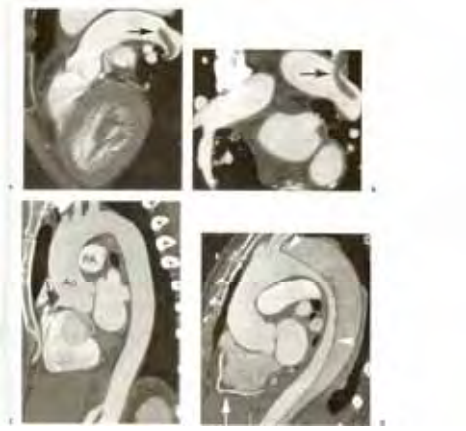
- Evaluation for plaque status
- Stable versus vulnerable



MDCT of the heart and great vessels

Clinical applications

- CAC – Calcified plaque burden
- Atypical chest pain and low to mid risk for CAD – normal coronary angiogram – high negative predictive value
- Indeterminate sress ECG
- Coronary angiography - for coronary artery anomalies
- Pre-op evaluation for CABG
- Post-op CABG evaluation
- Morphology and function
- Triple study



- **Advantages**
- Cross sectional capabilities
- Excellent spatial and temporal resolution
- Excellent tissue contrast differentiation – bone, muscle, fat,
- Contrast CT – evaluation of myocardium and coronary vessels
- **Disadvantages**
- Scanners stationary – patient transported to scanner
- Radiation exposure
- IV contrast necessary

- **Radiation dose**
- Primary valued measured value is known as CTDI (CT dose index) – represents integrated dose along the 2 axis, from one axial CT scan (one rotation)
- CTDI – [NXT/I] x CTDI w
- CTDI = CI/pitch x CTDI w
- CTDI – measures average radiation dose within the irradiated volume of a CT acquisition
- Effective dose for Common Imaging Exams Effective dose mSV
- Head CT 1-2 mSV
- Chest CT 5-7 mSV
- Abdomen and pelvis 8-11 mSV
- Selective coronory 3-5 mSV
- Chest xray (PA x lateral) 0,04-0,06mSV
- Average annual background 3-6mSV

- **Coronary Calcium screening**
- Presence of calcium confirms presence of coronary plaque
- The greater the amount of calcium, the greater the likelihood of occlusive coronary artery disease (no one-to-one risk relationship)
- Total amount of calcium correlates best with total amount of atherosclerotic plaque although true plaque burden underestimated
- A high calcium score of >400 may be consistent with moderate-high risk of CHD events in next 2-5 years.

Patient preparation

General

- Explain examination
- Refrain from stimulants e.g. caffeine on day of exam
- No solid foods four hours prior to test – emesis
- Liquid intake encouraged
- Patient history – previous cardiac events and the purpose of study – Asthma – pre treat steroids Medrol : 32 mg – 12h and 2 hours prior to procedure

IV – Access

- 18 gauge iv line
- Arm not above head – subclavian vein compression

Patient monitoring

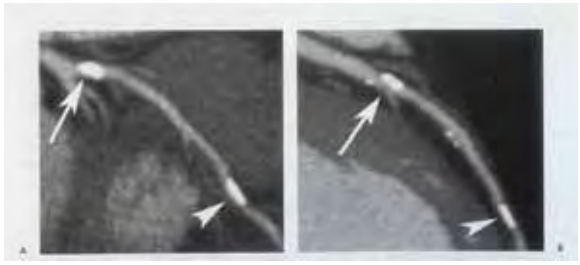
- ECG gating- 2 arm leads above level of heart. Lower lead in region of mid abdomen.
- Clean skin area – free of hair
- Clearly defined R waves
- Regular sinus rhythm optimal for test
- Base line BP

Heart rate

- ideal heart rate – regular sinus bradycardia – 50-60 bpm.
- Control heart rate
  - B-blockers – Metoprolol – 50 mgs
    - p-o 1 hour prior to test
    - rule out asthma
    - Metoprolol – 2.5mg IV if heart rate more than 65
    - Esmolol – ultra short acting drug – half life nine minutes
  - Ca-channel blockers
    - If contr-indication for beta blockers e.g. asthma
    - Diltiazem and Verapamil
    - Diltiazem less negative inotropic – 0.25 mgs per kgs
  - Treatment for bradicardia and hypotension
    - Antidote - beta blocker – glucagon
    - Ca – channel blocker – Ca gluconate/chloride
    -
    - ? Atropine

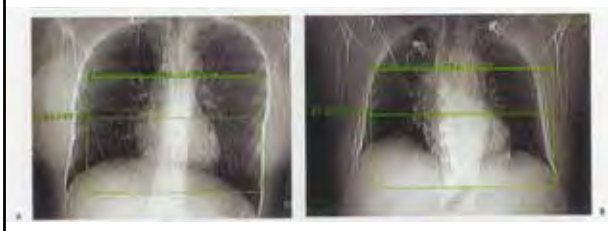
CAC

- Ca scoring test – low dose non contrast – Agaston 130 Ca – score above 1000 reduce image quality. Rather conventional coronary angiogram than CTA



Scan position

- Most scans FOV – 22 to 25 cm
- Topogram – carina to 2cm below inferior aspect of heart
- Tortuous ascending aorta – 2cm above carina
- CABG – thoracic inlet (internal mammary)
- Extend to abdomen – gastro epiploic bypass
- Triple study – from clavicle to inferior heart



Coronary Vasodilation

- Nitroglycerine – sub lingual – 800 mcg – 2 to 3 minutes prior. Also spray
- Two minutes before effect
- Average increase in vessel diameter – 12 to 21 %
- Non-distendable plaque more obvious
- Reflex tachycardia and hypotension with beta blockers

Contrast injection

- Steady high level of arterial enhancement (>300 HU)
- Biphasic injection (Saline) - to clear dense contrast SVC – streak artifacts
- Volume and rate of CI – depends on scan time
- General rule – contrast injection 3 seconds longer than scan time
- Triple study – no saline flush
- To increase level of arterial contrast increase injection rate(5,5 ml /sec max) or increase iodine concentration

Table 2–1 Contrast Injection Protocols—Biphasic Injection

CTA System	1st Phase	2nd Phase	2nd Phase
Basic coronary CTA (16 detector system)	100 cc @ 4 cc/s	40 cc @ 4 cc/s	Saline
Basic coronary CTA (40 detector system)	100 cc @ 5.5 cc/s	40 cc @ 5 cc/s	Saline
Basic coronary CTA (64 detector system)	75 cc @ 5.5 cc/s	40 cc @ 5 cc/s	Saline
Post-bypass CTA (64 detector system)	80 cc @ 5 cc/s	40 cc @ 5 cc/s	Saline
Triple rule-out study (64 detector system)	75 cc @ 5 cc/s	50 cc @ 5 cc/s	50:50 mixture of contrast and saline

Scan Timing

(i) Contrast Enhancement

-bolus tracking method of choice

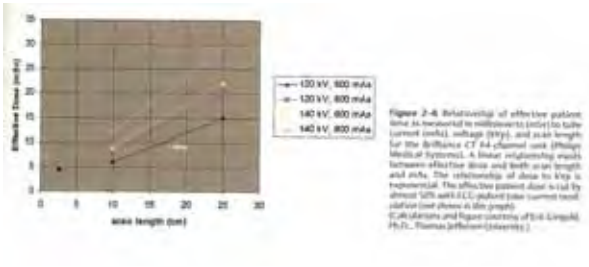
(ii) Breath hold

-patient practice

-not deep inspiration

Scan Parameters

- **Effective** mAs – mA (tube current) X rotation time (360 degrees) divided by the pitch
  Average patient 120 KVp requires 600 mAs for imaging the coronary arteries 0 – 5 – 0,6mm slice thickness
  Heavier patients – increase KVP or mAs to prevent a noise
- **Noise** = 1/√mAs
- **mAs** – controls number of x ray photons
- **KVp** – peak energy – effective energy ½ kVp – Higher energy enables more photons to reach x ray detector and reduces noise. May decrease contrast, Not important in cardiac imaging
- **Retrospective**
  120 KVP and 600 mAs – radiation dose 10 mSV
- **Prospective** ECG modulator in tube current may reduce radiation.
- **Pitch** – table travel distance per gantry rotation divided by total beam collimation.
  Generally 0.2 to 0.3 in cardiac.
  Automated algorithms adjust the pitch to optimize temporal resolution

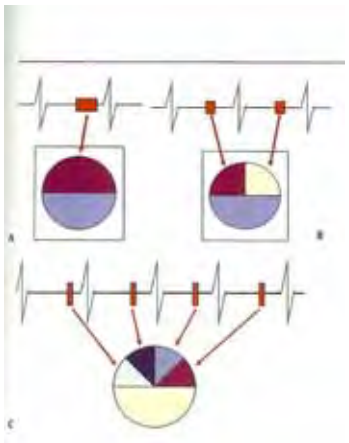


Temporal Resolution

- Temporal resolution – amount of time to acquire data for a single CT image
- ECG gating – based on detection of R waves
- Data – mid-diastole
- Increased heart rate - shortening of diastole- most quiescent period – data may alternatively acquired at end diastole or early systole.
- Empirically optimal time - 70 – 80% of R-R interval
- Retrospective – Data obtained from multiple phases of the cardiac cycle -data then selected from a particular phase of the cardiac cycle through retrospective ECG gating
- Prospective gating – lack of imaging data in other parts of the cycle not acquired.
- Ectopic beats- problem
- Regular sinus rhythm cause substantial reduction in radiation dose
- New intelligent algorithms – “step and shoot” may recognize ectopic beats

<u>Multi cycle reconstruction</u>

- Increased heart rate – diastole shortens – diagnostic data window period shorter than the temporal resolution – solution to acquire data from adjacent cycles (half of data) improves temporal resolution
- Regular heart rate essential – to prevent blurring



Improve Image quality

Increased temporal resolution

-multicycle reconstruction

-lower pitch

-gantry rotation speed optimized to pitch

-Dual CT source – two x-ray tubes simultaneously

-ectopic beads – less of a issue

-reduction in radiation dose

256 slice and flat panel CT

- Larger detector panels
- Acquire volumetric data of the whole heart in a single scan (120mm detector)
- Isotropic voxel resolution 0.25 mm
- Minimize blooming artifacts – calcifications and stents

ECG editing

- R-wave identification critical- improper modulation in prospective scan – error cannot be corrected
- ECG editing may correct retrospective gating and provide superior images

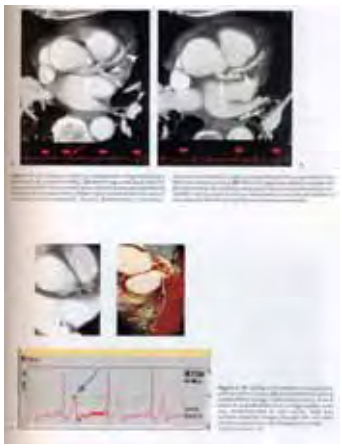


Image reconstruction

- Thin slices 0,5 -1.0 mm key
- Various reconstruction kernels provide a balance between edge enhancement and imaging noise (reduce blooming artifacts)
- Thicker slice reconstruction in obese patients or imaging other anatomySome images reconstructed with 50% overlap
- Thinner slices and sharper kernels may increase image noise – use filters

Summary

- Cardiac MDCT –established tool
- Atypical chest pain evaluation-Triple study
- Post-operative status - CABG

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