Overview

- Safety Issues
- Imaging Planes
- Clinical Protocols: A How To ...
  - Cardiac Morphology and Masses
  - Valvular Disease
  - LV Function
  - Ischemic Heart Disease

MR Safety Issues

- Contraindications
  - Pacemaker/Defibrillator/Pumps
  - Recent (< 6 wks) coronary stenting

- Not Contraindications
  - Prosthetic valves
  - Vascular stents (> 6 wks)
  - Sternotomy wires
  - IVC filters
  - Arrhythmias (use special sequences)

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Commonly Used Imaging Planes

- Short Axis
- RV
- LV
Commonly Used Imaging Planes

Vertical Long Axis (2 Chamber)

Commonly Used Imaging Planes

Horizontal Long Axis (4 Chamber)

Commonly Used Imaging Planes

Three-chamber view

Imaging Planes

A Step-by-Step Guide ...

Imaging Planes

Coronal Scout

Imaging Planes

2 chamber scout
Imaging Planes: Short Axis

- 2 chamber scout
- Axial HASTE

Imaging Planes: 4 chamber

- 2 ch scout
- Short axis

Imaging Planes: 2 chamber

- 4 chamber scout
- Short axis

Imaging Planes: LVOT

- Axial HASTE

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    - Cardiac Masses
    - Pericardial Disease
    - ARVD
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Cardiac Masses/Pericardium

- Set-up
  - ECG leads
  - IV/Gd optional
- Axial/Coronal SS TSE/HASTE
- Multiplanar T1 TSE (limited coverage)
- Selected multiplanar cine GRE
- Optional
  - Gd-DTPA, Post-contrast T1 TSE
  - Single slice BH STIR or FS-TSE
Cardiac Masses

- **Benign**
  - Myxoma: left atrium most common
  - Lipoma
  - Rhabdomyoma
  - Fibroma
  - Thrombus
- **Malignant**
  - Metastases
  - Angiosarcoma
  - Rhabdomyosarcoma

**Characterization of masses**
- Lipoma—fatty mass
- Myxoma—classic septal attachment
- Thrombus
  - Gd-enhancement/ Viability imaging
- Location and extent
- Effect on hemodynamics

**Location and extent**

**Effect on hemodynamics**

- **Lipomatous hypertrophy of the interatrial septum**

- **Thrombus (LV infarct)**

- **LV Thrombus**
  - Non-enhancing
  - Well seen on delayed CE-MRI

- **Lymphoma**
Constrictive Pericarditis

- Pericardial thickening > 3 – 4 mm
- Small RV and LV
- Enlarged RA and LA
- Paradoxical Septal Motion

Cardiac Mass?

Right Atrial Pseudomass

- Nodular thickening, linear strands
- Between IVC and coronary sinus
- 59-90% of cardiac MR studies
- Normal anatomic structures:
  - Crista terminalis
  - Eustachian valve
  - Thebesian valve
  - Chiari network

ARVD

Arrhythmogenic right ventricular dysplasia

- Ventricular tachycardia
- 30% familial
- Diagnosis difficult
  - Biopsy
  - Echocardiography
  - Electrophysiology
  - MRI
    - Fibrofatty replacement of right ventricular myocardium
    - Right ventricular aneurysmal dilatation
    - Dyskinesis

ARVD Protocol

- Set-up
  - ECG leads
  - No iv, no Gd
- Axial SS TSE/HASTE
- Axial TSE
  - High resolution
- Axial cine GRE

ARVD FSE: Imaging Tricks

Saturation band over LV
**ARVD FSE: Imaging Tricks**

- Turn Posterior coil elements off
- Decrease FOV

**ARVD FSE**

- Fibrofatty replacement of RV wall

**ARVD**

- **RV Dyskinesis**

**Cine GRE**

**ARVD Diagnostic Criteria**

- Two major criteria
- One major and two minor criteria
- Four minor criteria


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**Not Right Ventricular Dysplasia**

- Potential Pitfalls
  - Moderator band
  - Apical thinning

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Valvular Disease

- Set-up
  - ECG leads
  - No IV
- Axial SS TSE/HASTE
- Double oblique scouts
- LV function cine GRE
- Cine GRE biplane through valve
- Phase contrast flow quantification
- Optional:
  - High resolution black blood TSE

Phase Contrast Applications

- Peak velocity tracings
  - Doppler-like waveforms
  - Pressure gradient estimates

Modified Bernoulli Equation

\[ \Delta P = 4 \times v_{max}^2 \]

- Volume flow rates
  - Total blood flow (Aorta, PA)
  - Regurgitant volume

Aortic Stenosis

- PC through Jet
  - Venc = 500

Aortic Valvular Disease

By planimetry: 1.2 cm² (Mild stenosis)

Peak = 223 cm/sec
Aortic Valvular Disease

- Peak systolic velocity
  - 223 cm/sec
  - 2.23 m/s
- Peak pressure gradient
  - 4 \times v^2
  - 20 mmHg

Volume Flow Measurements

Clinical History: Status post pulmonic valvulotomy
Clinical question: Is there pulmonic insufficiency?

Pulmonic Artery Phase Contrast

Phase-Contrast

Pulmonic Insufficiency

120 cc forward flow
50 cc reverse flow
Effective forward flow = 70 ml
Regurgitant fraction = 0.42

Tricks for Quantifying Regurgitation

- Regurgitant Fraction = Regurgitant flow/Forward flow
- Mitral Regurgitant Fraction = (SV – Aortic Forward Flow)/SV or (SV – Pulmonary Forward Flow)/SV

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LV Function

- Set-up
  - ECG leads
  - No i.v.
- Axial SS FSE/HASTE
- Double Oblique Scouts
- Cine GRE
  - Short axis from base to apex (6-8mm/2mm)
  - Long axes views
- Phase contrast flow quantification
  - Aortic outflow (SV)

LV Functional Parameters

- LV End Diastolic Volume (EDV) (ml)
- LV End Systolic Volume (ESV)
- Stroke Volume (SV) = EDV – ESV
- Ejection Fraction = SV/EDV (%)
- Cardiac Output = SV x HR (L/min)
- Cardiac Index = Cardiac Output/BMI
  - (BMI based on height and weight)
- LV Mass = LV myocardial vol x 1.04 g/ml

Calculating LV Volumes

- Cine GRE Short Axis
- Modified Simpson’s rule
  - LV = A1 + A2 + … + An
  - Assuming t = 1 cm (8/2 gap)

Short axis - Base

End diastole
EDV A2 = 19 cm²

End systole
ESV A2 = 9 cm²

Short axis - Apex

End diastole
EDV A5 = 12 cm²

End systole
ESV A5 = 6 cm²

Stroke Volume = EDV - ESV
EF = SV / EDV x 100%
Tip #1: Choosing the slices
- LV covers larger number of slices at EDV and ESV
- Avoid including LA
- Tip:
  - Include only slices that have circumferential muscle ring

Tip #2: Papillary muscles?
- Bottom line: Be consistent

Wall Motion/Contractility

Ischemic Heart Disease
- Exercise impractical
- Dobutamine for increased contractility and oxygen consumption
  - Target HR 0.85 x (220-age)
- Adenosine/persantin for differential hyperemia

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    - Stress testing
    - Viability

Stress Protocol Option #1
- Dobutamine Cine GRE
  - Careful monitoring
    - BP, Pulse ox, ECG (rate/rhythm)
    - Beta blocker to reverse
  - Cine GRE following incremental doses
    - Rest
    - 10 ug/min/kg 3 min
    - 20 ug/min/kg 3 min
    - 30 ug/min/kg 3 min
    - 40 ug/min/kg 3 min
    - Optional Atropine 0.25 mg x 4 to achieve HR
  - Real-time image reconstruction/display
Dobutamine Example

Stress Protocol Option #2
- Adenosine/Persantine Perfusion
  - Careful monitoring
    - BP, Pulse ox, ECG (rate/rhythm)
    - Aminophylline to reverse
  - Stress perfusion
    - Adenosine 140 ug/min/kg 6 min (image at 3 min)
    - Dipyridamole 0.56 mg/kg over 4 min
  - 20 min delay
  - Rest perfusion

Myocardial Perfusion
- Sequences
  - Gated single-shot SR or IR turboFLASH or true FISP
  - Notched interleaved SR spoiled GRE
- Typically 3 – 6 short axis slices every HB or every other HB
- First pass Gd (0.02 – 0.1 mmol/kg)
  - 5 – 20 ml

Perfusion Example

Myocardial Infarct Imaging
- Enhancement on delayed imaging = infarct
- Viability Images
  - Cine GRE
Myocardial Infarct Imaging

- 52-year-old diabetic woman
  - History of prior MI
  - 4 day history of nausea/GI symptoms

- Interpretation:
  - Old anterior wall infarct
  - New inferior infarct (RCA disease)

Myocardial Viability

- Contrast-enhanced magnetic resonance imaging (MRI) to identify reversible myocardial damage

Set-up
- ECG leads
  - 20 – 30 ml Gd
- Axial HASTE
- Scans for double oblique
- Inject Gd
  - Optional: Perfusion (+ stress)
- Cine GRE
  - Short and long axes
- Viability (scar)

Viability Protocol: 30 min

- Conventional Viability sequences
  - CHOOSE TI (Inversion Time)
  - IR turboFLASH
  - IR true FISP (1 – 3 slices/BH)
  - New sequences
    - Single shot IR true FISP
    - 3D IR turboFLASH
    - 3D IR true FISP
  - Phase-Sensitive IR Viability

Delayed Hyperenhancement

- Causes
  - Subacute/Chronic myocardial infarct
  - Acute myocardial infarct
  - Hypertrophic cardiomyopathy*
  - Sarcoidosis*
  - Acute myocarditis*

*Patchy distribution differentiates these from coronary causes which arise from subendocardial surface and extend to subepicardial region

TTC MRI


Gd-DTPA for cardiac MRI is off-label application
Cine IR True FISP to select TI

Optimal TI

Infarct

Normal

TI = 170 ms

TI = 203 ms

TI = 238 ms

TI = 275 ms

12 sec BH

Viability: 5 breath holds

2D IR True FISP (9 sl/3 BH)

3 sl/BH

Viability: 1 breath hold

2D IR True FISP (9 sl/3 BH)

3D IR True FISP (24 x 4mm BH)

Viability Case: Interpretation

- Subendocardial infarct extends along entire anterior wall/apex, septum, lateral wall (LAD)
- Additional foci in inferolateral base (LCx)

- Impression:
  Salvageable myocardium LAD and circumflex territory

Real-time True FISP

Viability

CAD: Interpretation

- 17 segment interpretation

Cerqueira MD et al., Circulation 2002; 105:539
Clinical applications
- Hypokinesis: Nonviable vs. Hibernating?
  - Is revascularization indicated?
- Equivocal scintigraphy or echocardiography
  - Attenuation artifacts/inadequate window
  - Abnormality too subtle/subendocardial infarct
- Acute chest pain, r/o MI

Case: 76-year-old man with DOE
- Stress-rest Sestamibi
  - Normal wall motion
  - EF 67%
  - Fixed defect anterior wall
  - Infarct vs. Attenuation?

Interpretation:
- Normal wall motion
- EF 70%
- Subendocardial infarct
- LAD territory
- Coronary Cath
  - 3 vessel disease
  - Severe stenosis of 1st diagonal (off LAD)

Lee VS et al, Radiology, 2004

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