Cardiac MRI
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Objectives
• To understand cardiac MRI technology, its advantages and disadvantages versus other imaging techniques, and its applications for children with congenital and acquired heart disease
• To have a better appreciation for cardiovascular anatomy and physiology through understanding cardiac MR images
Road Map

- The power of Cardiac MRI
- What's in a name?
- What can we do with Cardiac MRI?
- Why isn't Cardiac MRI more common?
- Anesthesia and Cardiac MRI

Echo, circa 1980

“Limited” echo
Coarctation

Measure coarctation gradient

Coarctation
Road Map

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What’s in a name?
Magnetic Resonance Imaging

We become magnets!

Hydrogen atoms are little electromagnets
What’s in a name?

Magnetic Resonance Imaging

- Only the “a” tuning forks will resonate

Radiofrequency Pulse

- The energy is tuned to specific protons

Magnetic Resonance Imaging

- Fourier Transformation creates the image
**Cardiac MRI**

- Beating heart
- Moving blood
- Breathing motion
  - Breath hold
    - Patient holds his/her breath
    - Apnea on the ventilator
  - Track the diaphragm by imaging
  - Take the average over several breaths
    - Increase in scan time

What's in a name?

**ECG-gating:** compensates for heart motion

Still frames turn into movies

**Road Map**

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Transposition of the great arteries - atrial switch
Senning

Cardiac MRI Modalities: “Black Blood”
• Oldest type of cardiac imaging
• Still frames captured in diastole
• Good anatomic detail
• Longer acquisition times

Vascular Rings
Vascular Rings and Slings

Pulmonary artery sling

Cardiac MRI Modalities:
Movies- “Cine”

Ejection Fraction, LV mass

Cardiac MRI Modalities:
Flow

Regurgitant fraction = 35%
Cardiac MRI Modalities:
Magnetic Resonance Angiogram

Arterial switch operation

Cardiac MRI Modalities:
Myocardial damage
Myocarditis
Hypertrophic cardiomyopathy

Intermission
Road Map

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- Why isn’t Cardiac MRI more common?
- Cardiac MRI at UVA

Reasons to not do an MRI

- Implanted metal
  - Magnetism
  - Could pull an aneurysm clip off the blood vessel
- Radiofrequency energy
  - Can heat metal
  - Can affect electronic devices
  - Artifacts
- Need for anesthesia
- Renal failure
  - Gadolinium contraindicated
Artifacts:

- Metal
- Poor electrocardiogram gating
- Breathing motion
- Patient movement

Why isn’t Cardiac MRI more common?

So then we might think of doing a different study......
Echo/Ultrasound

**Pro**
- Portability
- Speed
- Don’t need sedation (usually)
- Better visual appearance of regurgitation
- Images are excellent for most children

**Con**
- Limited by body habitus, "window" quality
- Not as good for vasculature
- May need sedation

CT scans

**Pro**
- Excellent resolution
- Quick scans
- Pacemakers are safe
- Fewer artifact problems
- Better than MRI for coronaries

**Con**
- Limited modalities (i.e., just get anatomy)
- Radiation

Kawasaki Disease

Radiation Risk

<table>
<thead>
<tr>
<th>Study Type</th>
<th>Relevant Organ</th>
<th>Relevant Organ Dose $^*$ (mSv or mGy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dental radiography</td>
<td>Brain</td>
<td>0.005</td>
</tr>
<tr>
<td>Posterior-anterior chest radiography</td>
<td>Lung</td>
<td>0.81</td>
</tr>
<tr>
<td>Lateral chest radiography</td>
<td>Lung</td>
<td>0.13</td>
</tr>
<tr>
<td>Screening mammography</td>
<td>Breast</td>
<td>3</td>
</tr>
<tr>
<td>Adult abdominal CT</td>
<td>Stomach</td>
<td>10</td>
</tr>
<tr>
<td>Barium enema</td>
<td>Colon</td>
<td>15</td>
</tr>
<tr>
<td>Neonatal abdominal CT</td>
<td>Stomach</td>
<td>20</td>
</tr>
</tbody>
</table>

$^*$ The radiation dose, a measure of ionizing energy absorbed per unit of mass, is expressed in grays (Gy) or milligrays (mGy). 1 Gy = 1 joule per kilogram. The radiation dose is often expressed as an equivalent dose in sieverts (Sv) or millisieverts (mSv). For x-ray radiation, which is the type used in CT scans, 1 mSv = 1 mGy.
Cardiac Cath

**Pro**
- Opportunities for intervention
- Pressure, saturation measurements

**Con**
- Radiation
- Only 2 imaging planes
- Invasive

Indications for Cardiac MRI

- Complicated anatomy
  - Coarctation
  - Tetralogy of Fallot
  - Hypoplastic left heart syndrome
- Physiology
  - Regurgitant fraction
  - Right ventricular function
- Evaluation of symptoms
  - Chest pain
  - Cough
  - Wheezing

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The UVA experience: 2009-10 patients under 18 years

- Congenital cardiovascular disease: 115
  - Tetralogy of Fallot: 11
  - Coarctation: 7
  - Hypoplastic left heart: 6
  - Transposition of the great arteries: 5
  - Heterotaxy: 4
  - Aortic aneurysm: 4
  - Sinus venosus ASD: 4
  - Vascular ring: 4
- Acquired heart disease: 4
  - Myocarditis
- Evaluation of syncope, chest pain, etc: 14
  - Arrhythmogenic right ventricular dysplasia
  - Coronary artery abnormalities
Why anesthesia can be necessary

• Close monitoring of fragile patients
  – Then I can concentrate on imaging
• Keep the infant or child comfortable
  – 60-90 minute exams
  – Claustrophobia
  – Fear of the noise
• Secure airway while sedated
• Breath-hold imaging

Options

• No sedation
• MRI-compatible DVD player
• Papoose for neonates
• Anxiolysis
• General anesthesia
  – Free breathing
  – Mechanical ventilation

MRI-compatible DVD viewer

Hypoplastic Left Heart Syndrome

http://commons.wikimedia.org/wiki/Image:Hypoplastic_left_heart_syndrome.svg
Hypoplastic Left Heart

Angiograms: Hypoplastic left heart

Tetralogy of Fallot

Tetralogy of Fallot
Tetralogy of Fallot

2002-2004 at CHB

Risk Factors for Adverse Events During Cardiovascular Magnetic Resonance in Congenital Heart Disease

- 1334 CMR studies
  - 22 Adverse Events
- GA used in 274 studies
  - 12 Adverse Events
- Risk factors- multivariate analysis
  - General anesthesia (OR 3.91)
  - Inpatients (OR 3.56)
  - Under 1 year of age (OR 0.70)
  - Single ventricle physiology was not a risk
Future directions

• Hybrid lab
  – Combined MRI/Cath lab
• Non-invasive “cath”
  – Pre-Glenn
  – Post-transplant “biopsy”
  – Myocarditis
• Fetal cardiac MRI
• Using the 3 Tesla magnet
• MRI-safe pacemakers

In conclusion

• Cardiac MRI provides unrivaled cardiac imaging quality
• A complete non-invasive cardiac anatomic and physiologic evaluation can be accomplished
• Anesthesia is needed for infants and children but can be accomplished with rare adverse events

Thank you!

• Rajani Anand
• Chris Kramer, Klaus Hagspiel, and Patrick Norton
• Chris Clarke
• The adult cardiology fellows
• The MRI technologists
The Boston Children's Hospital Way

Anaesthesia considerations for cardiac MRI in infants and small children

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• General anesthesia, NM blockade, tracheal intubation in all children
• Apnea used for all imaging
• One anesthetist in the scanner, one outside

2002-2004 at CHB

Table 1
Summary of adult patients (n = 100) and infants (n = 30) from the cardiology ward

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Adult (%)</th>
<th>Infant (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI in room</td>
<td>10/15</td>
<td>2 (6%)</td>
</tr>
<tr>
<td>Age (mean, range)</td>
<td>3 (0-8)</td>
<td>6.5 (0.5-8.5)</td>
</tr>
<tr>
<td>Weight (mean, range)</td>
<td>62 (45-90)</td>
<td>67 (55-90)</td>
</tr>
<tr>
<td>Blood pressure (mm Hg)</td>
<td>100 (97)</td>
<td>110 (100)</td>
</tr>
<tr>
<td>ASA I</td>
<td>5 (20)</td>
<td></td>
</tr>
<tr>
<td>ASA II</td>
<td>64 (20)</td>
<td></td>
</tr>
<tr>
<td>ASA III</td>
<td>1 (0.3)</td>
<td></td>
</tr>
</tbody>
</table>

- LVOT defect
- PAP defect
- CP Anomalous
- Severe stenosis
- Vascular rings/tracheal compression
- Cardiac tumors/mass
- Methylene blue

LVOT, left ventricular outflow tract, PAP, right ventricular outflow tract, CP, anomalous coronary artery.
Results

• 250 CMR scans under GA
• 94% outpatients discharged same day
• No scans interrupted due to desaturation events or hemodynamic instability
• No one admitted due to GA complications
• 2 patients needed inotropes after induction
• 5 had hypotension that responded to brief interventions