Cardiac MRI or Cardiac CT
Making the Right Choice

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Cardiac MR or Cardiac CT-
Making the Right Choice

- Congenital heart disease (CHD) most common congenital anomaly
- Survival after intervention expected
  - 3.5% mortality all CHD operations
- Average CHD patient age increasing
  - Mortality shifted toward adulthood
- Lifelong imaging surveillance
- Noninvasive imaging necessary
  - Echocardiography (echo) is mainstay
    - Limited by acoustical windows
    - Limited ability to assess distal vasculature
  - Catheterization reserved for hemodynamics/ intervention

Cardiac MR or Cardiac CT—Making the Right Choice

• Cardiac MR
  – Commonly used as adjunct to echo
  – Gold standard for functional analysis, valvular flow/regurgitation, tissue characterization

• Cardiac CT
  – Mainstay extracardiac vascular assessment
  – Advances in CT technology
  – Increasingly being used as adjunct to echo for extracardiac vascular and cardiac evaluation
Cardiac MR or Cardiac CT - Making the Right Choice Goals

• Cardiac MR
  – Pros and cons
• Cardiac CT
  – Pros and cons
• Recommendations for
  – “Making the Right Choice”
• Case examples
Ideal Cardiac Imaging Modality

- High detail cardiac/extracardiac vascular/airway/lung/MSK
- Characterize tissues
  - Edema, ischemia, viability, fibrosis
- Assess regional and global ventricular and valvular function
  - High temporal resolution
- Evaluate hemodynamics, blood flow, velocity
- Fetus to large adults
- Not susceptible to artifacts from implants
- Portable
- Inexpensive
- Quick
- No radiation, sedation, contrast
Cardiac MRI

• Complete anatomic assessment
  – 3D/4D anatomy visualization
• Gold standard for tissue characterization
  – Viability
  – Edema
  – Fibrosis/scar
• Gold standard for volumetric and systolic function analysis
  – Relatively high temporal resolution
• Blood flow, velocity evaluation
• Gold standard valvular regurgitation
• Radiation free
Cardiac MRI

- Gadolinium based contrast agents
  - Often required for complex anatomy
    - Non-contrast sequences available
    - Need further development
  - Stress imaging
- Risk of nephrogenic systemic fibrosis
  - Virtually no cases since 2008
    - Screening for kidney disease
  - No cases in children younger than 6 years
Cardiac MRI

- Gadolinium based contrast agents (GBCA)
- Brain deposition
  - Dentate nucleus and globus pallidus following linear GBCA administration
    - Adults and children
- FDA safety alert, 2015
  - “Prudent to consider the clinical benefit of the diagnostic information to treatment result that MRI may provide against the unknown potential risk of gadolinium deposition...”
- Pharmacovigilance Risk Assessment Committee – EU, March, 2017
  - Removal of 4 linear GBCAs from the European market due to deposition concerns

Ramalho. AJNR 2016. http://dx.doi.org/10.3174/ajnr.A4615
Cardiac MRI

- Recent data suggests no deposition in children with macrocyclics
  - Gadoterate meglumine
  - 5+ examinations
  - Dentate nucleus to pons and middle cerebellar peduncle SI ratios
  - No significant change, $p=0.665$ and 0.262

- No deposition in adults with macrocyclics
  - Gadoterate meglumine, gadobutrol
  - 20+ examinations
  - Dentate nucleus to pons and middle cerebellar peduncle SI ratios
  - No significant change, $p=0.961$ and 0.676

Cardiac MRI

• Metallic devices
  – Significant susceptibility artifact
  – Contraindications
Cardiac MRI

- 30-60 +/- min exam time
  - Sedation/GA children < 6-8 years
- FDA warning, December, 2016
  - "The U.S. Food and Drug Administration (FDA) is warning that repeated or lengthy use of general anesthetic and sedation drugs during surgeries or procedures in children younger than 3 years or in pregnant women during their third trimester may affect the development of children’s brains...Health care professionals should balance the benefits of appropriate anesthesia in young children and pregnant women against the potential risks, especially for procedures that may last longer than 3 hours or if multiple procedures are required in children under 3 years...”
  - All inhaled anesthetics, propofol, barbiturates, ketamine, benzodiazepines

https://www.fda.gov/Drugs/DrugSafety/ucm532356.htm
Cardiac MRI

- Texas Children’s
  - 43,000 cases
  - 13,000 under 3 years
  - 1300 more than 3 hours
    - 2/3 related to CHD
    - 2000 MRI sedation
- FDA warning discussed with parents before surgery children < 3 years
- Discussion among parents/caregivers
  - Anesthesia duration, multiple general anesthetics, delaying procedure until > 3 years

Cardiac CT

- Complete anatomic assessment
  - 3D/4D anatomy visualization
  - High spatial resolution
Cardiac CT

- Volumetric and functional analysis
  - Similar results for LV and RV function
  - No studies in children
  - Best temporal resolution 66 msec
- No quantitative flow imaging
  - Assess valvular regurgitation if one valve involved and careful echo correlation
- Volumetric differences


LV function
p=0.64 (SSCT); p=0.84 (DSCT)
BA analysis excellent agreement with no bias
Cardiac CT

**Iodinated contrast required**
- Allergic reaction
- Acute kidney injury (AKI)
  - Little data showing increased risk following contrast
  - No data in children
  - Two large recent studies show no increase in AKI following iodinated contrast compared to controls without contrast
  - Increased incidence of AKI as e-GFR decreases
  - Consider prehydration

<table>
<thead>
<tr>
<th>eGFR Subgroup (mL/min/1.73 m²)</th>
<th>AKI Following Contrast-enhanced Scanning*</th>
<th>AKI Following Unenhanced Scanning*</th>
<th>OR †</th>
<th>P Value‡</th>
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<tbody>
<tr>
<td>≥ 90</td>
<td>10/821 (1.2)</td>
<td>11/821 (1.3)</td>
<td>0.91</td>
<td>(0.38, 2.15)</td>
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<tr>
<td>60–89</td>
<td>40/1935 (2.1)</td>
<td>39/1935 (2.0)</td>
<td>1.03</td>
<td>(0.66, 1.60)</td>
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<td>30–59</td>
<td>161/2755 (5.8)</td>
<td>170/2755 (6.2)</td>
<td>0.94</td>
<td>(0.76, 1.18)</td>
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<tr>
<td>&lt; 30</td>
<td>102/743 (14)</td>
<td>105/743 (14)</td>
<td>0.97</td>
<td>(0.72, 1.30)</td>
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</tbody>
</table>

Cardiac CT

- Metallic devices
  - No contraindication
  - Less artifact than cardiac MR
Cardiac CT

- Radiation
- Children with complex diseases
  - May be exposed to relatively high cumulative burden of ionizing radiation from clinically indicated medical imaging procedures
- Appropriate study quality at the lowest achievable dose
  - Radiation dose reporting for CT not standardized
  - Variation by dose estimation method alone
  - Many reported pediatric cardiac CT effective doses
    - 0.2 to 28 mSv
      - Doses generally increase with age
      - Prospective < retrospective ECG synchronization

Cardiac CT

- Quick acquisition
- +/- sedation
  - No sedation in newborns/infants
  - No sedation in developmentally appropriate older children
Making the Right Choice
Cardiac MRI vs CT

Balance indications, risks, and benefits

Radiation
Temporally resolved imaging
Sedation
Spatial resolution
Contrast
Tissue characterization

MRI vs CT
Case 1.

- 15 year-old male with no past medical history following successful cardiopulmonary resuscitation for a syncopal and unresponsive episode that occurred while running in gym class. Transthoracic echocardiography was suspicious for an anomalous left coronary artery from the right sinus of Valsalva.

- Evaluate left coronary artery origin and course.
Making the Right Choice
Cardiac MRI vs CT

- Radiation
- Temporally resolved imaging
- Sedation
- MRI vs CT
- Spatial resolution
- Contrast
- Tissue characterization
Case 1. Anomalous aortic left coronary artery origin from the right sinus of Valsalva
High-pitch ECG-triggered cardiac CT
Case 1. Anomalous aortic left coronary artery origin from the left sinus of Valsalva
Case 2.

- 8-month old female with heterotaxy, double outlet right ventricle, mitral atresia, total anomalous pulmonary venous connection to the coronary sinus, and interrupted IVC with azygous continuation s/p pulmonary artery banding and Kawashima (bidirectional Glenn incorporating the azygous return)

- Failure to thrive and cyanosis with echo showing widely patent Glenn anastomosis with antegrade flow through the tight pulmonary artery band

- MRI ordered to evaluate for source of cyanosis
  - MRA, function, flow
Making the Right Choice
Cardiac MRI vs CT

- Radiation
- Temporally resolved imaging
- Sedation
- Spatial resolution
- Contrast
- Tissue characterization
Case 2. Kawashima with decompressing venovenous collateral causing desaturation. Cardiac MRI with GA
Case 3.

- 2-day-old girl with murmur heard on routine newborn check-up. Echo showed LV to aortic tunnel near the right sinus of Valsalva with the right coronary artery origin relative to the tunnel not well defined. Echo also showed pulmonary hypertension, dysplastic mitral valve, and moderately dilated left ventricle, and aorta.

- Evaluate right coronary artery origin relative to left ventricle to aortic tunnel.
Making the Right Choice
Cardiac MRI vs CT

- Radiation
- Temporally resolved imaging
- Sedation
- MRI vs CT
- Spatial resolution
- Contrast
- Tissue characterization
Case 3. Left ventricular to aortic tunnel
High-pitch ECG-triggered cardiac CT. No sedation
Case 3. Left ventricular to aortic tunnel
Cardiac MR or Cardiac CT—Making the Right Choice

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Making the Right Choice is case specific and depends on the exam indication and other relative procedural risks and benefits