Pediatric Cardiac Imaging

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Learning Objectives

- Identify specifics associated with cardiac MRI imaging of pediatric population
- Understand the anatomy of common congenital heart diseases and post surgical hearts
- Understand utility of different sequences
- How to perform MR Angiography in pediatric patients
- Introduction to volume CT scanning for cardiac imaging
Unique challenges in pediatric patients

- Patient size
- Higher heart rate and breathing rate
- Need for faster exam
- Sedation
- Equipment
- Complex congenital pathologies
Unique challenges in pediatric patients

- Slice thickness
- Field-of-view (FOV)
- Gating
  - EKG
  - Respiratory
- NEX
- Parallel Imaging
SENSE (Sensitivity encoding)

- Sensitivity encoding (SENSE) is a technique that enables to reduce scan time
- Permits the acquisition of more slices and the use of longer TR without reduction in scanning time compared with the usual sequences
- Decreased signal-to-noise ratio (SNR)
- Compensate by increasing NEX
Common Pediatric Heart Conditions

- Tetrology of Fallot (TOF)
- Transposition of Great Vessels (TGV)
- Single Ventricle Physiology [Hypoplastic left heart syndrome (HLHS), Tricuspid atresia (TA), Double outlet right ventricle (DORV)]
- Valvular stenosis (Aortic or Pulmonary)
- Vascular Lesions (Coarctation of Aorta, Vascular Rings)
Normal Cardiac Anatomy

Coronal View
Normal Cardiac Anatomy

Sagittal View
Normal Cardiac Anatomy

Short Axis view
Tetrology of Fallot

- Right ventricular outflow tract obstruction
- Right ventricular hypertrophy
- Ventricular Septal Defect (VSD)
- Over-riding aorta
Tetrology of Fallot

Source: National Heart Lung and Blood Institute
Tetrology of Fallot

Mild narrowing at RVOT with aneurysmal dilatation of Left Pulmonary Artery
Tetrology of Fallot

Right heart enlargement

VSD
Transposition of Great Vessels
Transposition of Great Vessels

Pulmonary artery after the arterial switch procedure (SI view)
Transposition of Great Vessels
Transposition of Great Vessels

Senning Procedure
Hypoplastic Left Heart Syndrome

- Hypoplastic left heart occurs when one or all parts of the left heart do not develop (mitral valve, left ventricle, aortic valve and aorta)
Hypoplastic Left Heart Syndrome

Small Left ventricle with dilated Right Ventricle
Hypoplastic Left Heart Syndrome

Hypoplastic left ventricle and ascending aorta

Fontan Conduit
Aortic Stenosis
Coarctation of Aorta

- Narrowing of the Aorta
  - pre-ductal
  - ductal
  - post-ductal

- If severe enough, it is called Interrupted Aortic Arch (IAA)
Coarctation of Aorta
Coarctation of Aorta and Collaterals
Planning the basic cardiac views

Axial

RAO view
Planning the basic cardiac views

Semi-4 chamber

Short axis
Planning the basic cardiac views

- Short Axis
  - 4 chamber
    - Right 2 chamber
    - Left 2 chamber
  - Basal short axis
    - LVOT
Planning the basic cardiac views

True 4 chamber

Red line- Basal short axis
Yellow line- Left 2 chamber
Blue line- Right 2 chamber
Planning the basic cardiac views

Axial

Right ventricular Outflow Tract
Protocols- “The Works”

- TOF, TGV, Pulmonary stenosis, Truncus etc.
- Axial T1 Inversion recovery (Black blood technique)
- Cine (bright blood imaging)
  1. 4 chamber
  2. RV outflow
  3. Short axis
- Contrast enhanced MRA
Protocols- “The Works”

- Flow Analysis Aorta, Pulmonary artery, AV valves
- Optional
  - a. Flow analysis of each branch pulmonary artery
  - b. Delayed Myocardial enhancement
Protocols-Single ventricle physiology

- Axial black blood
- Cine bright blood
- 3D SSFP (non-contrast) MRA
  - RV outflow
  - Short axis
Protocols - Single ventricle physiology

- Contrast enhanced MRA
- Flow Analysis
  - Aorta
  - SVC
  - IVC
  - Shunts (e.g. Sano, central, BT)
Protocols-Coarctation and Vascular Rings

- Axial black blood
- Contrast enhanced MRA
- Flow Analysis pre-coarctation, at coarctation and at diaphragm level
MR Angiography

- Non-Contrast 3-D MRA of heart and great vessels
- Contrast enhanced MRA (CE-MRA)
Non-contrast MRA

- non-contrast, non breath-hold 3D-SSFP sequence
- Used with parallel imaging
- Useful for coronary arteries and intra-cardiac evaluation
- Gated
  - EKG
  - Respiratory
Non-contrast MRA
CE- MRA

- Dynamic flow imaging provides temporal resolution
- “Triple dose technique”
- Visual trigger to start scanning once the contrast is injected
- Scanning in sagittal plane with 3 dynamic runs obtained
CE- MRA: Contrast Dose

- Adult dose of gadolinium-DTPA
  - 0.1-0.2 mmol/kg
  - 20-40 ml
- Pediatric Dose (Arkansas Children’s Hospital)
  - 1 ml minimum dose
  - 0.3 mmol/kg up to 20 ml (1 bottle)
  - 0.2 mmol/kg up to 40 ml (2 bottles)

0.1 mmol = 0.2 ml
CE MRA: Contrast Rate

- Double headed power injector
- Injection rate ranging from 0.2-3 ml/sec
- Followed by normal saline flush of 5-20 ml at the same rate
  - to clear the tubing
  - to push the contrast bolus forward
CE MRA Technique

- 3D, fast radiofrequency spoiled gradient echo
- FOV Variable
- TR/TE: 4.8/1.1, flip angle 45°, slice thickness 3-5 mm
CE-MRA

1st dynamic run

2nd run

3rd run
CE-MRA
CE-MRA

Aortic Annulus

Aortic arch
CE-MRA

Main Pulmonary artery

Left Pulmonary artery
Wide Detector CT in Children

Early Experience
Ideal Pediatric MDCT

- Fast
  - ↓ Sedation
  - ↓ motion Artifacts
- Image Quality
  - ↑ Spatial Resolution
- Radiation
  - ↓ Dose Techniques

Airway CT in a 4 yr old
Effective dose 1.5 mSv
Evolution of MDCT

- ↑ Coverage
- ↑ Speed
- Detector row ➔ Volume

2 ➔ 320
Helical or Volume acquisition

- Entire z-axis of data set acquired simultaneously
  - Motion Artifact
    - Breathing
    - Cardiac
  - Contrast
    - Volume
Step-Stair Artifacts

Helical

Wide Detector
Heterogeneous contrast enhancement

↓ contrast in renal upper poles using helical MDCT
Radiation Dose

- Inherent wasted dose in Helical scanning
  - Z-over scanning
  - Over beaming

Effective dose 0.9 mSv, 54% less than helical scan
Challenges for Volume scanning

- Complex reconstruction algorithms
- Scatter
- Truncation
Cone Beam scatter reconstruction
Truncation
CTA for coronary artery evaluation

Left pulmonary artery stenosis
Truncation limits field of view
Cardiac

- Reduced Dose
  - Inherent wasted dose in helical
  - Claims of 75-80% reduced dose
- More complicated
  - Effect of heart rate
  - Gating at higher heart rates
Cardiac Dose Reduction: Volume vs. Helical

<table>
<thead>
<tr>
<th>Heart Rate (bpm)</th>
<th>Dose Reduction (%)</th>
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<tbody>
<tr>
<td>60</td>
<td>80</td>
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<tr>
<td>80</td>
<td>↓</td>
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<tr>
<td>120</td>
<td>↓</td>
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<tr>
<td>150</td>
<td>↓</td>
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Non-gated chest CTA in children <3 yrs old

- **Helical Scan**
  - Effective dose: 2.64 mSv
  - Standard Deviation: 0.62 mSv

- **Volume scan**
  - Effective Dose: 0.80 mSv
  - Standard Deviation: 0.36 mSv

- 70% dose reduction using volume scan
  - p value < 0.0001
Gated CTA

- Age and heart rate matched gated studies in 7 children
- All children <9 years old
- Heart rate range: 98-147 bpm
- Results
  - Volume CTA dose reduced by 49%
  - p value = 0.004
Infant with vascular anomalies

Patent Ductus Arteriosus  
Pulmonary Sling

Effective Dose = 0.6 mSv
1 year old with Williams Syndrome

Thorax and Abdomen Cardiac Gated
Effective Dose 5.2 mSv
1 year old with Williams Syndrome

Supra Valvar Aortic and branch pulmonary artery stenosis

Effective Dose 5.2 mSv, Free Breathing
Normal Renal Arteries
Summary

- Volume imaging ideal for Pediatric population
  - Fast
  - Low Dose
  - Higher Resolution
- Potential new applications