Imaging Assessment of Aortic Stenosis/Aortic Regurgitation

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SCAI Fall Fellows Course 2013
Las Vegas
Echocardiographic assessment of Aortic Stenosis/Aortic Regurgitation

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As a faculty member for this program, I disclose the following relationships with industry:

- (GRS): Grant/Research Support
- (C): Consultant
- (SB): Speaker's Bureau
- (MSH): Major Stock Holder
- (AB): Advisory Board
- (E): Employment
- (O): Other Financial or Material Support

None
Goals

• Aortic Valve
• Aortic Stenosis
• Aortic Regurgitation
• Example
Aortic Valve

- Valve extends from ventricle to sinotubular junction
- Leaflets attached in semilunar fashion
- Interdigitation of sinus and ventricle
- No ring-like “annulus”
Sinutubular junction

Ventricular attachment

Courtesy Dr. Robert Anderson
Virtual basal ring

Courtesy Dr. Robert Anderson
Left Ventricular Outflow Tract Obstruction

- Valvar: 50%
- Subvalvar: 33%
- Supravalvar: 17%
Aortic Valve Morphology
Aortic Valve Morphology

- Congenital bicommissural valve (2% incidence)
  - Most common congenital lesion
- Unicommissural
- Tricommissural dysplastic
- Doming – Thickened leaflets with restricted mobility
Dysplastic Aortic Valves
Aortic Valve Stenosis
Aortic Valve Stenosis

Distance cal = 2.0 cm

Distance = 6.6 mm
3-D Echo after balloon aortic valvuloplasty
## Aortic Valve Stenosis - Doppler

<table>
<thead>
<tr>
<th>Severity</th>
<th>Peak Doppler (mmHg)</th>
<th>Mean Doppler (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>&lt;36 (3 m/s)</td>
<td>&lt;25</td>
</tr>
<tr>
<td>Moderate</td>
<td>36-64</td>
<td>25-40</td>
</tr>
<tr>
<td>Severe</td>
<td>&gt;64 (4 m/s)</td>
<td>&gt;40</td>
</tr>
<tr>
<td>Extremely Severe</td>
<td>&gt;100</td>
<td>&gt;60</td>
</tr>
<tr>
<td>Critical</td>
<td>Left ventricular dysfunction</td>
<td>Ductal dependent</td>
</tr>
</tbody>
</table>
Critical Aortic Stenosis

- Thickened and domed aortic leaflets
  - Nearly immobile
- Post stenotic dilatation
- LVH
- Echogenicity from EFE
- Decreased LV function
- Decreased cardiac output  →  Decreased Doppler gradient
Echocardiographic Assessment of Severity

• Indirect signs
  – LV mass
  – LV mass/volume
  – LA hypertension

• Doppler
  – Peak Instant. Gradient
  – Mean Systolic Gradient
  – Tissue Doppler, Strain

• Aortic Valve area
  – Planimetry
  – Continuity
Echocardiographic Assessment of AS/AR SCAI 2013

Aortic Valve Stenosis - Doppler

Pre-balloon

Post-balloon

[Diagrams showing ultrasound images before and after balloon procedure]
Advantages of Doppler Mean vs Peak Instantaneous

- Mean grad directly comparable to cath
- Mean grad not dependent on a single velocity measurement
  - Greater accuracy and reproducibility
- Mean grad less affected by transvalvular flow
- More direct relationship to valve area
Cath: Peak to Peak

Echo: Peak Instantaneous

Beekman et al AJC 1992;69:813
Aortic Valve Area

- Continuity equation
  \[ S_{AV} = S_{LVOT} \]
  \[ AVA \times VTI_{AV} = AVA \times VTI_{LVOT} \]

Baumgartner et al. JASE 2009, 22:1-23
Aortic Valve Area – Continuity Equation Potential Error

- Inaccurate measurement LVOT diameter
  - Error is squared
- Error in proximal velocity
- Doppler Area = Effective Orifice Area
- Planimetry Area = Anatomic Orifice Area
Effective Aortic Valve Area – 3D Echo

- Direct measurement
- Can align with eccentric orifice
- Change in 3D EOA correlated with acute change in aortic gradient

Bharucha Tet al Echocardiography 2011;29:484-91
Pressure Differences (Gradients)

Depends on flow of blood through a restricted orifice

- Interpretation:
  - Effect of cardiac output
    - anesthesia / sedation / agitation
  - Effect of time
  - Sensitive to changes in contractility
    - anesthesia, contrast, etc
  - Effect of intervention
Pressure and Flow

- Pressure is determined by flow and resistance
- Remember that both are variable and can change between echo and catheterization
  - Vascular resistance
  - Stenosis and Regurgitation
  - Myocardial Contractility
  - Volume status
  - Hematology
Univentricular versus Biventricular

• “Rhodes’ Score” for Critical Aortic Stenosis
  • LV to apex of heart long axis < 0.8
  • Indexed aortic root < 3.5 cm/m²
  • Mitral valve area < 4.75 cm/m²
  • LV mass < 35 g/m²

BiV Mortality 100% if 2 or more risk factors

SCORE = 14.0 (BSA) + 0.943(indexed Ao root) + 4.78(LAR) + 0.157 (MVA indexed) – 12.03

<-0.35 predicts death with biventricular repair
Univentricular versus Biventricular

• 2006 “Rhodes’ Score” revisited/re-evaluated
• Revised discriminant score
  – Ao root replaced with Ao annulus z-score
  – MVA and LV mass removed
  – EFE added

SCORE = 10.98 (BSA) + 0.56 (aortic annulus z-score) + 5.89 (LAR) - 0.79 (gr 2 or 3 EFE) - 6.78

<-0.65 predicts death with biventricular repair

Colan SD et al. JACC; 47: 1858-65
Univentricular versus Biventricular

CHSS data:
1. ascending aorta
2. Valve (at level of sinuses)
3. Length (apex to MV) in long axis.
4. Echo grade of EFE: 0-none, 1-papillary, 2-pap muscles and some of the myocardium. 3- extensive EFE.
5. Length and wt of child
6. Amount of TR
7. Prediction of management pathway that provided survival benefit

Assumes that survival with single ventricle is equivalent to survival with biventricular circulation

JTCVS 2001;121:10-27
Aortic Regurgiation – Anatomic Variants

- **Primary Congenital Valve**
  - Structural Ao valve abnormalities
  - Aortico-left ventricular tunnel
  - Absence of Ao valve cusps
- **Associated Congenital Heart Disease**
  - VSD
  - Subvalvar AS
  - Truncus arteriosus
- **Aortic Root dilation**
  - Connective Tissue disorder
  - Genetic disorder
- **Infection**
  - Infective Endocarditis
  - Rheumatic Fever
  - Ruptured aneurysm of sinus of Valsalva
Aortic Regurgitation – Echo Severity

- LV Size and Function
  - LVEDD or LVEDV, LVESD or LVESV, LV mass, EF
  - ↑ LVESD/LVESV occurs with LV failure
- Indirect Doppler indicators
  - Diastolic flow reversal in aorta
  - AR Deceleration rate, pressure half-time

In pediatric patients, few absolute echo predictors for intervention have been identified
Aortic Regurgitation – Integrative Approach

- LV Size
- Aortic leaflet changes
- Jet width in LVOT
- Vena Contracta width
- Flow quantitation
  - Regurg volume and fraction
  - Effective ROA
- AR Jet Pressure half-time, slope
- Diastolic flow reversal in descending aorta
Aortic Regurgitation
## Aortic Regurgitation - Guidelines

<table>
<thead>
<tr>
<th>Specific signs for AR severity</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
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<tbody>
<tr>
<td>• Central Jet, width &lt; 25% of LVOT&lt;sup&gt;5&lt;/sup&gt;</td>
<td>Signs of AR&gt; mild present but no criteria for severe AR</td>
<td>• Central Jet, width ≥ 65% of LVOT&lt;sup&gt;5&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>• Vena contracta &lt; 0.3 cm&lt;sup&gt;5&lt;/sup&gt;</td>
<td></td>
<td>• Vena contracta &gt; 0.6 cm&lt;sup&gt;5&lt;/sup&gt;</td>
<td></td>
</tr>
<tr>
<td>• No or brief early diastolic flow reversal in descending aorta</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Supportive signs | | Intermediate values | |
|------------------|-------------------|---------------------|
| • Pressure half-time > 500 ms | | |
| • Normal LV size<sup>*</sup> | | |

<table>
<thead>
<tr>
<th>Quantitative parameters&lt;sup&gt;6&lt;/sup&gt;</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>R Vol, ml/beat</td>
<td>&lt; 30</td>
<td>30-44</td>
<td>45-59</td>
</tr>
<tr>
<td>RF, %</td>
<td>&lt; 30</td>
<td>30-39</td>
<td>40-49</td>
</tr>
<tr>
<td>EROA, cm&lt;sup&gt;2&lt;/sup&gt;</td>
<td>&lt; 0.10</td>
<td>0.10-0.19</td>
<td>0.20-0.29</td>
</tr>
</tbody>
</table>

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*Zoghbi et al. JASE 2003; 16: 777-802*
Aortic Regurgitation – Multi-modality

- Cardiac MRI
- Cardiac CT
Case Example - Newborn
Case Example - Newborn

Echocardiographic Assessment of AS/AR SCAI 2013
Case Example – After Balloon Dilation

Good News!  Bad News
Case Example – After Balloon Dilation
Case Example – After Balloon Dilation
Thanks !