Imaging Assessment of Aortic Stenosis/Aortic Regurgitation

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SCAI Fall Fellows Course 2014 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:


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”
Virtual basal ring

Courtesy Dr. Robert Anderson
Left Ventricular Outflow Tract Obstruction

- Subvalvar: 33%
- Supravalvar: 17%
- Valvar: 50%
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
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
  - Dec Doppler grad
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
Aortic Valve Stenosis - Doppler

Pre-balloon

Post-balloon
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
- \( SV_{AV} = SV_{LVOT} \)
- \( AVA \times VTI_{LVOT} \)

Baumgartner et al. JASE 2009,
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
Aortic Valve Imaging - MSCT

RC: right coronary
LC: left coronary
NC: non-coronary

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

\[
\text{SCORE} = 10.98 \times \text{BSA} + 0.56 \times \text{aortic annulus z-score} + 5.89 \times \text{LAR} - 0.79 \times \text{(grade 2 or 3 EFE)} - 6.78
\]

\(< -0.65 \text{ predicts death with biventricular repair}\)

*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

JTCVS 2001;121:10-27

Assumes that survival with single ventricle is equivalent to survival with biventricular circulation
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></th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specific signs for AR severity</strong></td>
<td>● Central Jet, width &lt; 25% of LVOTᵣ</td>
<td>Signs of AR=mild present but no criteria for severe AR</td>
<td>● Central Jet, width ≥ 65% of LVOTᵣ</td>
</tr>
<tr>
<td></td>
<td>● Vena contracta &lt; 0.3 cm²</td>
<td></td>
<td>● Vena contracta &gt; 0.6cm¹</td>
</tr>
<tr>
<td></td>
<td>● No or brief early diastolic flow reversal in descending aorta</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Supportive signs</strong></td>
<td>● Pressure half-time &gt; 500 ms</td>
<td>Intermediate values</td>
<td>● Pressure half-time &lt; 200 ms</td>
</tr>
<tr>
<td></td>
<td>● Normal LV size*</td>
<td></td>
<td>● Holodiastolic aortic flow reversal in descending aorta</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>● Moderate or greater LV enlargement*</td>
</tr>
<tr>
<td><strong>Quantitative parameters</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R Vol, ml/beat</td>
<td>&lt; 30</td>
<td>30-44</td>
<td>≥ 60</td>
</tr>
<tr>
<td>RF, %</td>
<td>&lt; 30</td>
<td>30-39</td>
<td>≥ 50</td>
</tr>
<tr>
<td>EROA, cm²</td>
<td>&lt; 0.10</td>
<td>0.10-0.19</td>
<td>≥ 0.30</td>
</tr>
</tbody>
</table>

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

- Cardiac MRI
- Cardiac CT
Case Example - Newborn
Case Example - Newborn
Case Example – After Balloon Dilation

Good News!  

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