Quantification of Aortic Regurgitation

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Boston

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And thanks to Dr. Roberto Lang

Disclosure

None related to this presentation
Objectives

• Anatomy
• Acute vs chronic
• Etiology
• Grading severity
  – Qualitative
  – Semiquantitative
  – Quantitative

• The cusps
• The aorta including
  – Sinuses of Valsalva
  – Sinotubular junction
• The aortomitral continuity
• The membranous septum
Valve cusps are not planar
Abnormal Leaflets

- LEAFLET
  - CONGENITAL
  - ACQUIRED

- Bicuspid, unicuspid, quadracusp, VSD
- Endocarditis, rheumatic disease, calcification, radiation, anorectic drugs
Abnormal aorta

- CONGENITAL
  - Bicuspid aortic valve, annuloaortic ectasia, CT disease

- ACQUIRED
  - HTN, SLE, Ankylosing spondylitis, dissection, syphilis
  - trauma

Acute severe
- LV not dilated
- Jet may appear small or not be visible
- EF likely to be reduced
- Early MV closure

Chronic severe
- LV dilated and globular
- Jet visible in all views
- EF may fall as late finding
Cause of Acute Severe Aortic Dissection

- Dissection with disruption of the valve commissures
- Endocarditis
- Chest trauma

Acute Aortic Regurgitation

69-year-old man admitted for sudden onset of severe shortness of breath with production of pink, frothy sputum
Acute Aortic Regurgitation

Early Diastolic Closure of the Mitral Valve
Diastolic Opening of the Aortic Valve

Severe Acute Aortic Regurgitation

Early DCMV
Diastolic Opening of the Aortic Valve

Meyer T et al., Am J Cardiol 1987;59:1144-1148

LV AO LA AR
AR assessment

- What is the etiology
- What are the hemodynamic consequences
- How severe is the regurgitation
HTN most common cause of mild AR
Etiology of Chronic AR is key to surgical plan

Grading the Severity of Chronic AR

- Structural parameters
- Qualitative Doppler parameters
- Semi-quantitative Doppler parameters
- Quantitative Echo-Doppler parameters
Natural History of Asymptomatic Patients with Severe AI and Normal LV Function

From Bonow et al. Circulation 1991;94:1625-1635

Asymptomatic Severe AR with Normal LV Function
Rate of Progression to death, symptoms and LV Dysfunction

Chronic AR generally evolves slowly with a long asymptomatic compensated phase...
Grading the Severity of Chronic AR

- **Structural parameters**
  - Aortic leaflets
  - LV size

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic leaflets</td>
<td>Normal or abnormal</td>
<td>Normal or abnormal</td>
<td>Abnormal/flail, or wide coaptation defect</td>
</tr>
<tr>
<td>LV size</td>
<td>Normal²</td>
<td>Normal or dilated</td>
<td>Usually dilated³</td>
</tr>
</tbody>
</table>

- **Qualitative Doppler parameters**
  - Jet width in LVOT
  - Flow convergence
  - Jet density, CW
  - Jet deceleration rate, CW (PHT,msec)
  - Diastolic flow reversal in descending AO, PW
Qualitative Doppler parameter

Jet Width/LVOT Diameter
1. Long-axis, zoomed view
2. Align jet to optimize VC imaging (may be different from PISA)
3. Measure jet (red arrows) in LVOT within semi-oval of VC
4. Measure LVOT (white arrow)

Advantages:
- Simple sensitive screen for AR
- Rapid qualitative assessment

Disadvantages:
- Underestimates AR in eccentric jets
- May overestimate AR in central jets as AR jet may expand unpredictably below the orifice
- Affected by the size of the LVOT

Proximal Flow Convergence
1. Align direction of flow with insonation beam
2. Zoomed view
3. Variance off
4. Change baseline of Nyquist limit (in direction of jet)
5. Measure radius (white arrow in image) from point of color aliasing to vena contracta

Advantage:
- Rapid qualitative assessment

Disadvantages:
- Multiple jets
- Constrained jet (aortic wall)
- Non-hemispheric shape
- Timing in early diastole
Qualitative Doppler parameter

Density of Regurgitant Jet
1. Align insonation beam with the flow
2. Adjust overall gain

Advantages:
• Simple
• Faint or incomplete jet is compatible with mild or trace AR

Disadvantages:
• Qualitative
• Perfectly central jets may appear denser than eccentric jets of higher severity
• Overlap between moderate and severe AR

Jet Deceleration Rate (Pressure Half-time)
1. Align insonation beam with the flow
2. Usually best from apical windows
3. In eccentric jets, may be best from parasternal window, helped by color Doppler

Advantage:
• Simple
• Specific sign of pressure relation between Ao and LV

Disadvantage:
• Qualitative
• Poor alignment of Doppler beam may result in lower PHT
• Affected by changes that modify LV-Ao pressure gradient (if short, implies significant AR or high LV filling pressure)
Decel slope vs PHT

- **PHT** - msec
  - Mild - > 500
  - Moderate – 500-200
  - Severe < 200
- **Decel slope** – cm/sec
  - Mild - < 200
  - Moderate – 200 - 300
  - Severe >300

- PHT here is 130 msec
- Peal velocity ?
- Disadvantage of PHT method is that detecting peak velocity is key
- Easy in Mitral inflow
- Tougher in AR
Qualitative Doppler parameter

Holodiastolic Flow Reversal in Proximal Descending Aorta

1. Align insonation beam with the flow
2. Pulsed sample volume in the proximal descending or abdominal aorta

Advantages:
- Simple supportive sign of severe AR
- More specific sign if seen in abdominal aorta

Disadvantages:
- Depends on compliance of the aorta; less reliable in older patients
- Brief velocity reversal is normal
- May be seen in other conditions
- May not be holosystolic in acute AR

Severe Aortic Regurgitation
Grading the Severity of Chronic AR

Qualitative Parameters

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<tr>
<th>Parameters</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet width in LVOT, color flow</td>
<td>Small in central jets</td>
<td>Intermediate</td>
<td>Large in central jets; variable in eccentric jets</td>
</tr>
<tr>
<td>Flow convergence, color flow</td>
<td>None or very small</td>
<td>Intermediate</td>
<td>Large</td>
</tr>
<tr>
<td>Jet density, CW</td>
<td>Incomplete or faint</td>
<td>Dense</td>
<td>Dense</td>
</tr>
<tr>
<td>Jet deceleration rate, CW (PHT, m/s)</td>
<td>Incomplete or faint, Slow &gt;500</td>
<td>Medium</td>
<td>Steep &lt;200</td>
</tr>
<tr>
<td>Diastolic flow reversal in descending aorta, PW</td>
<td>Brief, early diastolic reversal</td>
<td>Intermediate</td>
<td>Prominent holodiastolic reversal</td>
</tr>
</tbody>
</table>

- **Semiquantitative parameters**
  - VCW (cm)
  - Jet width/LVOT width, central jets (%)
  - Jet CSA/LVOT CSA, central jets (%)
**Vena Contracta**

1. Long-axis, zoomed view
2. Align jet to optimize VC imaging (may be different from PISA)
3. Measure the narrowest jet diameter at or just apical to the valve

**Advantages:**
- Surrogate for regurgitant orifice size
- May be used in eccentric jets
- Independent of flow rate and driving pressure
- Less dependent on technical factors
- Good at identifying mild or severe AR

**Disadvantages:**
- Presence of multiple jets or bicuspid valves
- Convergence zone needs to be visualized
- The direction of the jet will influence its appearance

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**3D Vena Contracta**

1. Color flow sector should be narrow
2. Align orthogonal cropping planes along the axis of the jet
3. Choose a mid-diastolic cycle
4. Non-coaxial jets or aliased flow may appear “taminar” but still represent regurgitant flow

**Advantage:**
- Multiple jets of differing directions may be measured

**Disadvantage:**
- Dynamic jets may be over- or underestimated
How severe is this AR?

How about now?
Explanaiton
**Semi-quantitative parameter**

**Jet Area/LVOT Area**
1. Short-axis, zoom view
2. Measure in LVOT within 1 cm of the VC

**Advantage:**
- Estimate of regurgitant orifice area

**Disadvantages:**
- Direction and shape of jet may overestimate or underestimate jet area

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**Grading the Severity of Chronic AR**

**Semi-Quantitative Parameters**

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<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>VCW (cm)</td>
<td>&lt;0.3</td>
<td>0.3-0.6</td>
<td>&gt;0.6</td>
</tr>
<tr>
<td>Jet width/LVOT width, central jets (%)</td>
<td>&lt;25</td>
<td>25-45</td>
<td>≥55</td>
</tr>
<tr>
<td>Jet CSA/LVOT CSA, central jets (%)</td>
<td>&lt;5</td>
<td>5-20</td>
<td>21-59</td>
</tr>
</tbody>
</table>
Grading the Severity of Chronic AR

- Quantitative parameters
  - RVol (ml/beat)
  - RF
  - EROA (cm²)
Q_{prox} = Q_{distal}

A_1 V_1 = A_2 V_2

(2\pi r^2) \times V_a = EROA \times V_{jet}

Peak AI velocity (cm/s) = 525 cm/s

Flow Convergence Calculation

(2\pi r^2) \times V_{alias} = EROA \times V_{AI}

6.28 \times (0.86)^2 \times 25.1 = EROA \times 525

116.6 = EROA \times 525

116.6/525 = 0.22 cm^2 = EROA
**Quantitative parameter**

**Flow Convergence Method (PISA)**

1. Align insonation beam with the flow
2. Lower the color Doppler baseline in the direction of the jet
3. Look for the hemispheric shape to guide the best lower Nyquist limit
4. CW Doppler of regurgitant jet for peak velocity and VTI

**Advantages:**
- Rapid quantitative assessment of lesion severity (EROA) and volume overload (RVOL)

**Disadvantages:**
- Feasibility is limited by aortic valve calcifications
- Not valid for multiple jets, less accurate in eccentric jets
- Small errors in radius measurement can lead to substantial errors in EROA

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**Regurgitant Volume**

\[ \text{EROA} \times \text{VTI} = \text{AI} \]

\[ \text{RVOL} = 0.22 \times 294 = 65 \text{cc} \]

\[ \text{EROA} = 0.22 \text{ cm}^2 \]

\[ \text{VTI} = 294 \text{ cm} \]
Regurgitant Volume

Mild <30 cc
Mild-moderate 30-44 cc
Moderate 45-59 cc
Severe ≥ 60 cc

Quantitative parameter

Advantages:
- Quantitative, valid with multiple jets, eccentric jets
- Provides both lesion severity (EROA, RF) and volume overload (RVol)

Disadvantages:
- Difficulties measuring mitral annulus diameter
- In setting of MR, pulmonic stroke volume used for forward stroke volume
- Cumbersome, needs training
- Small errors in diameter measurement can lead to substantial errors in EROA

1. LVOT systolic diameter and pulsed Doppler sample volume from different views but at same anatomic level (represents total stroke volume)
2. Mitral mid-diastolic annulus and pulsed Doppler of the same annulus from apical view (represents forward stroke volume)
3. Total SV stroke volume can also be measured by the difference between LV end-diastolic volume and end-systolic volume traced by 3D
Regurgitant Volume = SV Ao – SV MV

\[ RF \% = \frac{AR \text{ regurg. volume (cc)}}{Ao \text{ stroke volume}} \times 100 \]

\[ = \frac{65 \text{ cc}}{89 \text{ cc}} \times 100 \]

RF = %

- <30
- 30 - 39
- 40 - 49
- >50
Effective Regurgitant Orifice Area

Reg Vol = ERO x REG TVI
ERO = REG Vol / Reg TVI

Grading the Severity of Chronic AR
Quantitative Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mid</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVol (mL/best)</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>≥40%</td>
</tr>
<tr>
<td>EROA (cm²)</td>
<td>&lt;0.10</td>
<td>0.10-0.19</td>
<td>0.29-0.29</td>
</tr>
</tbody>
</table>
When to Perform CMR or TEE

- Poor TTE quality or low confidence in measured Doppler parameters
- Discordant quantitative and qualitative parameters and/or clinical data

Indeterminate AR
Consider further testing: TEE or CMR for quantitation

*Beware of limitations of color flow assessment in eccentric AR jets; volumetric quantitation and integration of other parameters is advised

Forward: 138 mL
Reverse: 70 mL
RF:
Conclusions

• Establishing the size of the ventricle and aorta of key importance
• Serial echoes in asymptomatic severe (or suspected severe) AR meet appropriate use criteria for echo
• Be prepared for discrepant indices

Thank you for your attention