Quantification of Mitral and Tricuspid Regurgitation

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And Muhamed Saric, MD, PhD
who gave kind permission to use some of their slides

Valvular Insufficiency

1. Pressure Gradient
2. Regurgitant Flow Volume
3. Regurgitant Area

Normal Intracardiac Pressures
3-D Reconstruction of TEE: FLAIL P-2

Note regurgitant area

Flail posterior leaflet

Flail P2
Mitral Regurgitation

Early Indications for Surgery in MR

• **Severe MR**
  - no symptoms
  - No signs of LV dysfunction
  - **Provided that:**
    - Valve is repairable
    - Operative risk is low (< 1%)

Thompson HL et al. Cardiology in Review. Volume 9, Number 3, 2001
ACC-AHA Guidelines: Principles

1. QUALITATIVE
2. QUANTITATIVE
3. SUPPORTIVE

2006 ACC/AHA Guidelines

Regurgitation The 3 Elements

1. Regurgitant Jet
2. Vena contracta
3. PISA
Color Jet Area = 11cm.sq
% of LA area = 63%

Vena Contracta

- What is vena contracta?
  - Narrowest portion of regurgitant flow
  - Occurs at or just distal to regurgitant orifice
  - Diameter of vena contracta is:
    - Independent of driving pressure for fixed orifice size
    - Less sensitive to color Doppler settings compared to jet area

V. contracta Robust to Change in Color Settings

VC = 0.47 cm
VC = 0.46 cm
MR: Vena Contracta


MR Guidelines: Qualitative Criteria

2006 ACC/AHA Guidelines

Quantitation of MR by PISA

Area hemisphere = \(2 \pi r^2\)

Mitral Regurgitation

LV

LA

500 cm/sec

30 cm/sec

50 cm/sec

20 cm/sec

Area hemisphere = \(2 \pi r^2\)
PISA Flow Rate = \[ 2 \times \pi \times r^2 \times Va \]

Fluid Mechanics Equation

Orifice Area (cm²) = Flow (cm³/sec) / Velocity (cm/sec)

PISA Flow Rate

EQA_{max} = \[ 2 \times \pi \times r^2 \times Va \]

PISA

MR flow rate

ERO

MR velocity

Courtesy Dr Jae Oh
LV
LA
PISA Radius 1.0 cm
Aliasing V = 40 cm/sec
Flow rate = 2\times3.14\times1\times40 = 251 cc/sec
ERO = \frac{251}{400} = 0.625 \text{ cm}^2/\text{sec}

Simplified PISA

If aliasing velocity is 40 cm/sec, and peak MR jet velocity is 500 cm/sec
(or set aliasing velocity at approx. 1/12 of MR peak velocity)

ERO = \frac{2 \times 3.14 \times R^2 \times 40}{500} = \frac{R^2}{2}

Or even more simple, Just measure the PISA Radius

<table>
<thead>
<tr>
<th>R(mm)</th>
<th>MR</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;4</td>
<td>1+</td>
</tr>
<tr>
<td>4-6</td>
<td>2+</td>
</tr>
<tr>
<td>7-9</td>
<td>3+</td>
</tr>
</tbody>
</table>

Mitral Regurgitation

Color Doppler baseline scale adjustments

TTE
TEE

Direction of flow
Mitral Regurgitation

Tips and Tricks

PISA calculation of regurgitant volume

\[ \text{Flow volume} = \text{Area} \times \text{VTI} \]

\[ (\pi \times r^2) \]

\[ \text{ERO} \times \text{VTI} = \text{Regurg. Volume} \]
Mitral Regurgitation

**Regurgitant Volume (RV)**

\[ RV_{MV} = \text{Flow}_{MV} - \text{Flow}_{AV} \]

Severe > 60 ml

**Regurgitant Fraction (RF)**

\[ RF_{MV} = \frac{\text{Flow}_{MV} - \text{Flow}_{AV}}{\text{Flow}_{MV}} \times 100 \]

Severe > 50 %

**MR Guidelines: Quantitative Criteria**

<table>
<thead>
<tr>
<th>Severe</th>
<th>Moderate</th>
<th>Mild</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regurgitant orifice area (cm²):</td>
<td>Less than 0.25</td>
<td>0.25-0.5</td>
</tr>
<tr>
<td>Regurgitant volume (ml/beat):</td>
<td>Less than 30</td>
<td>31-50</td>
</tr>
<tr>
<td>Regurgitant Fraction (%):</td>
<td>Less than 30</td>
<td>31-49</td>
</tr>
</tbody>
</table>

2006 ACC/AHA Guidelines
Severe MR

Regurgitant orifice (cm²) > 0.4
Regurgitant fraction > 50%
Regurgitant volume (mL) > 60
Vena contracta (cm) > 0.7

The “4,5,6,7” rule.

Mitral Regurgitation
Mitral Valve Inflow

Mitral Inflow:
E wave > 1.2 m/s

Mitral Regurgitation
MR Jet

Intensity of Doppler signal
Doppler tracing of a MR jet

PW-Doppler tracing from the left upper pulmonary vein during TEE

- Severe MR

MR Guidelines: Additional Criteria

<table>
<thead>
<tr>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left atrial size</td>
<td>Enlarged</td>
<td></td>
</tr>
<tr>
<td>Left ventricular size</td>
<td>Enlarged</td>
<td></td>
</tr>
</tbody>
</table>

2006 ACC/AHA Guidelines
**TR Severity**

- Poor leaflet coaptation
- RV dilatation
- Jet area >10 cm²
- Vena contracta >0.7 cm
- Pisa radius >0.9 cm
- Hepatic vein flow systolic reversal
- Dense, triangular and early peaking

**Primary Means of Quantifying TR**

<table>
<thead>
<tr>
<th>Method</th>
<th>SEVERE TR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet Area</td>
<td>&gt; 10 cm²</td>
</tr>
<tr>
<td>Vena Contracta</td>
<td>&gt; 0.7 cm</td>
</tr>
<tr>
<td>PISA Radius</td>
<td>&gt; 0.9 cm</td>
</tr>
</tbody>
</table>

Semiquantitative assessment of TR severity using regurgitant jet area in the right atrium.

**Ancillary Methods for Assessing TR**

- Right Heart Size
  - Big RA & RV in chronic TR
  - Normal RA & RV in acute TR
- E Wave Velocity
  - Native tricuspid valve $E_{max} > 1.0 \text{ m/s}$
- Hepatic Veins
  - S wave reversal
  - TO-AND-FRO FLOW
  - Also seen in very acute TR resembles systolic flow void and late diastolic flow
Shapes of Spectral TR Jet

- **PARABOLIC SHAPE**
  - Seen e.g. in severe TR or in severe TR when RA pressure is not very high.
  - Early peaking, rapidly decelerating TR jet.
  - Such jets are often turbulent on color Doppler.

- **TRIANGULAR SHAPE**
  - Seen in less than severe TR or in severe TR when RA pressure is not very high.
  - Such jets are often laminar on color Doppler.

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**Grading TR Severity**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tricuspid valve</td>
<td>Usually normal</td>
<td>Normal or abnormal</td>
<td>Abnormal/Patient leaflet/Poor coaptation</td>
</tr>
<tr>
<td>IVRBA/VVC size (cm²)</td>
<td>Normal²</td>
<td>Normal or dilated</td>
<td>Normal or dilated</td>
</tr>
<tr>
<td>Jet area - central jet</td>
<td>&lt; 5</td>
<td>5-10</td>
<td>&gt; 10</td>
</tr>
<tr>
<td>VC width (cm)</td>
<td>Not defined</td>
<td>Not defined, but &gt; 0.7</td>
<td>&gt; 0.7</td>
</tr>
<tr>
<td>PISA ratio</td>
<td>0.5</td>
<td>0.5-0.9</td>
<td>&gt; 0.9</td>
</tr>
<tr>
<td>Jet density and contour</td>
<td>Soft and parabolic</td>
<td>Dense, variable contour</td>
<td>Dense, triangular with early peaking</td>
</tr>
<tr>
<td>Hepatic vein flow</td>
<td>Systolic dominance</td>
<td>Systolic blunting</td>
<td>Systolic reversal</td>
</tr>
</tbody>
</table>

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**Pulmonic Regurgitation**

Pulmonary regurgitation seen on the echocardiogram at the level of the pulmonic valve.
Primary Means of Quantifying TR

<table>
<thead>
<tr>
<th>Method</th>
<th>Validation for PR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jet Area</td>
<td>Not validated</td>
</tr>
<tr>
<td>Vena Contracta</td>
<td>Not validated</td>
</tr>
<tr>
<td>PISA Radius</td>
<td>Not validated</td>
</tr>
</tbody>
</table>

Significantly, severe pulmonic regurgitation is uncommon.

Severe pulmonic regurgitation may be a long-term complication of congenital heart surgeries (such as tetralogy of Fallot repair).

Significant pulmonic regurgitation can be seen, e.g. in endocarditis or carcinoid disease.

Shapes of Spectral PR Jet

**TRAPEZOIDAL SHAPE**
- Suggests tricuspid prolapse
- Seen in severer pulmonic regurgitation

**TRIANGULAR SHAPE**
- Suggests pliable valve leaflets
- Seen in mild to moderate PR

Ancillary Methods for Assessing PR

1. **Right Heart Size**
   - Big RA & RV in severe PR
   - Normal RA & RV in acute PR

2. **Antegrade Velocity**
   - Increased velocity across the PV
   - Antegrade flow across the PV

3. **Flow Reversal in PA**
   - Severe PR → Holodiastolic flow reversal
   - Peak systolic velocity 2.3 m/s (Normal ~ 1.0 m/s)
Other Doppler Signs of Severe PR

Majority of PR occurs in early diastole.

TTE - COLOR DOPPLER
Note the laminar (non-turbulent) flow of severe PR.