Quantifying Valvular Regurgitation

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Valvular Regurgitation

General Considerations

Importance of:

• Valvular structure/Mechanism
• Cardiac adaptation to the volume overload
• Hemodynamics: affect severity & regurgitation parameters—irrespective of the modality
• Acute vs. chronic regurgitation
Mitral Regurgitation
Mitral Regurgitation

**Indicators of Severity**

- Mitral valve pathology
- LV/LA size
- **Color Doppler:** Vena contracta
  - Jet Area, Flow convergence
- Mitral E; Pulmonary vein pattern
- Regurgitant flow/fraction
- **CW** density and contour
## Evaluating MR Severity

*An Integrative Approach*

<table>
<thead>
<tr>
<th>Structural parameters</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA size</td>
<td>Normal*</td>
<td>Normal or dilated</td>
<td>Usually dilated**</td>
</tr>
<tr>
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### Doppler parameters

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<tr>
<th>Color flow jet area*</th>
<th>Small, central jet (usually &lt; 4 cm² or &lt; 20% of LA area)</th>
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<th>Large central jet (usually &gt; 10 cm² or &gt; 40% of LA area) or variable size wall-impinging jet swirling in LA E wave dominant* (E usually 1.2 m/s) Dense</th>
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<tr>
<td>Mitral inflow – PW</td>
<td>A wave dominant*</td>
<td>Variable</td>
<td>Dense</td>
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<td>Jet density – CW</td>
<td>Incomplete or faint</td>
<td>Dense</td>
<td>Early peaking–triangular Systolic flow reversal†</td>
</tr>
<tr>
<td>Jet contour – CW</td>
<td>Parabolic</td>
<td>Usually parabolic</td>
<td></td>
</tr>
<tr>
<td>Pulmonary vein flow</td>
<td>Systolic dominance§</td>
<td>Systolic blunting§</td>
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### Quantitative parameters

| VC width (cm) | < 0.3 | 0.3-0.69 | ≥ 0.7 |
| R Vol (ml/beat) | < 30 | 30-44 | 45-59 | ≥ 60 |
| RF (%) | < 30 | 30-39 | 40-49 | ≥ 50 |
| EROA (cm²) | < 0.20 | 0.20-0.29 | 0.30-0.39 | ≥ 0.40 |

Mitral Regurgitation

Color Flow Doppler Evaluation
Vena Contracta
Proximal Jet Width

VC width (cm)

- Mild: < 0.3
- Moderate: 0.3 - 0.7
- Severe: > 0.7
Flow Convergence Method
Proximal Isovelocity Surface Area (PISA)

PISA radius (r)

Reg Flow = $2\pi r^2 \times Va$
EORA = $\frac{\text{Reg Flow}}{\text{Vel}_{MR}}$
## Effective Orifice Regurgitant Area & Regurgitant Volume

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<tr>
<td><strong>EROA (cm²)</strong></td>
<td>&lt; 0.2</td>
<td>0.20-0.29</td>
<td>≥ 0.4</td>
</tr>
<tr>
<td><strong>RVo1 (mL/beat)</strong></td>
<td>&lt; 30</td>
<td>30-44</td>
<td>45-59</td>
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<td></td>
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<td>≥ 60</td>
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Flow Convergence

- Can be used semiquantitatively
- Variability during the cardiac cycle
- Less accurate in eccentric jets
- Assumptions of hemispheric geometry, less accurate in functional MR
Mitral Regurgitation

Indicators of Severity

- Mitral valve pathology
- LV/ LA size
- Color Doppler: PISA-EROA, Vena Contracta, Jet Area...Beware of eccentric jets!
- Regurgitant flow/fraction (Pulsed Doppler)
- CW density and contour
- Mitral E; Pulmonary vein flow pattern
Regurgitant Fraction/Flow

**Pulsed Doppler**

\[
RF = \frac{\text{Regurgitant Volume}}{\text{total LV stroke volume}}
\]

\[
RF = \frac{\text{Mitral SV} - \text{Systemic SV}}{\text{Mitral SV}}
\]

In MR, Systemic SV = aortic SV or pulmonic SV
\[
\begin{align*}
SV_{\text{LVOT}} &= CSA_{\text{LVOT}} \times VTI_{\text{LVOT}} \\
&= 0.785 \times d_{\text{LVOT}}^2 \times VTI_{\text{LVOT}} \\
SV_{\text{MV}} &= CSA_{\text{MV}} \times VTI_{\text{MV}} \\
&= 0.785 \times d_{\text{MV}}^2 \times VTI_{\text{MV}}
\end{align*}
\]
Assessment of MR Severity

Regurgitant Volume & Fraction

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<td>Reg Volume</td>
<td>&lt; 30 ml</td>
<td>30-44 ml</td>
<td>45-59 ml</td>
</tr>
<tr>
<td>Reg Fraction</td>
<td>&lt; 30%</td>
<td>30-49%</td>
<td>45-59</td>
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In low flow Functional, more emphasis on Reg Fraction
Regurgitant Volume & Fraction

**Advantages**
- Quantitative, valid in multiple jets and eccentric jets
- Provides both lesion severity and volume overload

**Limitations**
- Needs training; Cumbersome; wide (20%) confidence limits
- Measurement of flow at MV annulus is less reliable in calcific MV and/or annulus
Mitral Regurgitation

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- CW density and contour
- Pulmonary vein flow pattern
Assessment of MR Severity

Density & Contour of MR jet by CW

Mild  Moderate  Severe
Pulmonary Vein Flow in Severe MR
## Evaluating MR Severity

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<td>Systolic dominance$^g$</td>
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### Quantitative parameters$^*$

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**$^*$ Quantitative parameters: VC width, R Vol, RF, EROA.

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Mitral Valvular Regurgitation

Why an Integrative Approach

- Addresses difficulty and variability in quantitation
- Internal check & evaluation of hemodynamic impact (*heart remodeling, inflow dynamics, Pulmonary vein, and pressure*).
- Inherent cardiac remodeling with chronic significant MR
CMR Quantification of MR Severity

Mitral Reg Vol = LV stroke volume – Aortic stroke volume

Assessment of MR Severity dependent on volume comparisons only
Mitral Regurgitation

CMR vs Echo (mostly flow convergence)

<table>
<thead>
<tr>
<th>MRI</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>Moderate</td>
<td>19</td>
<td>10</td>
<td>2</td>
<td>31</td>
</tr>
<tr>
<td>Severe</td>
<td>20</td>
<td>25</td>
<td>13</td>
<td>58</td>
</tr>
<tr>
<td>Total</td>
<td>53</td>
<td>35</td>
<td>15</td>
<td>103</td>
</tr>
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*Uretsky S et al JACC 65:1078, 2015*
Regurgitant Volume

PISA vs. CMR

Uretsky S et al JACC 65:1078, 2015
? Why

- The only study to show an Overestimation of MR severity by Echo & PISA
- Time between Echo & CMR studies: Median 15 days
- Use of PISA alone, particularly that 57% had eccentric MR
- 47% were Degenerative MR (? some with late systolic MR, an Issue with PISA)
Mitral Regurgitation Severity Grades
Agreement between Echo & CMR

<table>
<thead>
<tr>
<th></th>
<th>Mild MR CMR</th>
<th>Moderate MR CMR</th>
<th>Moderately Severe MR CMR</th>
<th>Severe MR CMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild MR Echo</td>
<td>20</td>
<td>7</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Moderate MR Echo</td>
<td>7</td>
<td>7</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Moderately Severe MR Echo</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Severe MR Echo</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
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</table>

Agreement within 1 grade= 91%
Significant discrepancy= 9%

Lopez Mattei et al. AJC Dec 2015
Relation of Regurgitant Fraction by TTE & CMR

15% Significant Discrepancy by quantitation:
½ of outliers accounted for equally by Echo and CMR!
All in secondary MR
Yes, Variability in Quantitating Regurgitation is less for CMR, but... *It is not Nil!*

- In Pts without Regurgitation:
  - “pseudo regurgitation” for CMR is: 10 ± 9 % (Gelfand, 2006), 3 ± 12 % (Lopez-Mattei, 2013)
  - “Pseudo regurgitation” for Echo is 5 ± 14 % (Lopez-Mattei, 2013)
Aortic Regurgitation
Assessment of AR Severity

Echo/Doppler Indicators of Severity

- Aortic Valve/ Root/Mechanism
- LV enlargement
- Color Doppler: jet width; vena Contracta
- Pressure half-time
- Regurgitant Volume/Fraction
- Diastolic retrograde flow in aorta

Vena Contracta

- Different from Jet height/LVOT
- Valid in eccentric jets

Mild < 0.3 cm
Moderate 0.3-0.6 cm
Severe >0.6 cm
Assessment of AR Severity

Indicators of Severity

- Aortic Valve/ LV enlargement
- Color Doppler: Proximal jet width/CSA; Vena Contracta > PISA
- Intensity of jet by CW
- Pressure half-time
- Diastolic retrograde flow in aorta
- Regurgitant Volume/Fraction
Mild AR

Severe AR

- Color Doppler
- CW Doppler
- Desc Aorta - PW
Regurgitant Fraction

\[ RF = \frac{\text{Aortic SV} - \text{Systemic SV}}{\text{Aortic SV}} \]

*Systemic SV = mitral, pulmonic or average*
## Grading of AR Severity

### Quantitative Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mild</th>
<th>Moderate</th>
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<tbody>
<tr>
<td>RVOL (mL/beat)</td>
<td>&lt;30</td>
<td>30-44</td>
<td>45-59</td>
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<tr>
<td>RF (%)</td>
<td>&lt;30</td>
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<td>EROA (cm²)</td>
<td>&lt;0.10</td>
<td>0.10-0.19</td>
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CMR in Aortic Regurgitation

- Forward volume = 160 ml
- Regurgitant vol = 80 ml

Flow vs Time

Legend:
- Data
- Spline (+/- 1)
Valvular Regurgitation
Towards a More Accurate Assessment of Severity...

• Have a methodical approach....

• Know advantages and limitations of various Echo/Doppler methods and which ones are reliable in a particular patient

• Learn quantitation

• Look for internal consistency of flow findings (LV size/function/Doppler)

• The more you quantitate, the more accurate you are at estimation of regurgitation severity and integration of findings

• CMR quantitation of regurgitant volume/fraction is easier and more reproducible, but lacks hemodynamic assessment