New 3D Quantification of Mitral Regurgitation Severity

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No Financial Disclosures

• No off label discussion of devices or drugs
Quantification of MR

"I think you should be more explicit here in step two."
Color Doppler Methods to Quantitate MR

- Jet area/left area ratio: semi quantitative
- Vena contracta: semi quantitative
- PISA method: quantitative; calculates an effective regurgitant orifice area and regurgitant volume
Color Doppler Assessment of Mitral Regurgitant Jet

Adapted from M. Enriquez-Sarano et al. JACC 2000
Components of MR Jet

- PISA ZONE
- VENA CONTRACTA
- DISTAL JET
Vena Contracta

- Parasternal Long Axis
- Narrowest level of Jet
Limitations: Vena Contracta

- Semi-quantitative

- Can be technically challenging (maximize image size, perform a sweep across the entire orifice or may miss)

- Narrow range for quantitation given resolution of technique—small differences can make a big difference in “degree” category

- Using a single dimension to assess regurgitant orifice
Distal Jet: Jet area/left atrial area

- Frame of maximal jet area
- Performed in same frame
Limitations: Distal Jet

- Subject to machine settings (gain, Nyquist level)
- Sensitive to load conditions
- Eccentric jets underestimated or missed
- Entrainment of blood pool from left atrium
PISA: Conservation of Mass

Flow 2 = Flow 1

\[ A_2 \cdot V_2 = A_1 \cdot V_1 \]

\[ A_2 = A_1 \cdot \frac{V_1}{V_2} \]

Slide Courtesy of Dr. Maurice Sarano
Proximal Flow Convergence Method
For Measuring Mitral Valve Function

\[ \text{EROA} = \frac{2\pi R^2 \times \text{Aliasing Velocity}}{\text{Peak Velocity of MR}} \]
Shifting of the Color Baseline

Regular

Nyquist Velocity: 58 cm/s
Aliasing Velocity: 58 cm/s

Baseline-shifted

Nyquist Velocity: 58 cm/s
Aliasing Velocity: 19 cm/s

58

19

Courtesy of Robert A. Levine, MD
Flat PISA Zone: Underestimation of flow rate
Oval PISA Zone: Overestimation of flow rate
Flow Direction nonparallel
Optimal PISA zone measurement
Leaflets
Regurgitant Flow
PISA-aliasing velocity

• Should be set at using the Goldilocks Principle: Not to high, not to low, “just right”

Low enough to give you a radius that can be reasonable measured after optimizing velocity resolution and zoom but high enough so that blood flow adjacent to the PISA region do not become entrained
Would you take this PISA?
Proximal Isovelocity Surface Area (PISA) Baseline Shift to typically 30 to 40 cm/s

Aliasing velocity (30-40 cm/sec)
Geometric Assumptions for PISA Zone

Hemispherical

Hemielliptical

Yosefy C. et al. JASE 2008
Color Doppler is important for MR quantification but use all data available.

Integrative Assessment
# ASE Recommendations for Evaluation of the Severity of MR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EROA(cm²)</strong></td>
<td>&lt;0.2</td>
<td>0.2-0.39</td>
<td>≥0.4</td>
</tr>
<tr>
<td><strong>VC width (cm)</strong></td>
<td>&lt; 0.3</td>
<td>0.3-0.69</td>
<td>≥0.7</td>
</tr>
<tr>
<td><strong>Jet/LA area</strong></td>
<td>&lt;20%</td>
<td>20-40%</td>
<td>&gt;40%</td>
</tr>
<tr>
<td><strong>Mitral inflow</strong></td>
<td>A wave dominant</td>
<td>Variable</td>
<td>E wave dominant</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(E usually&gt;1.2m/s)</td>
</tr>
<tr>
<td><strong>Pulmonary vein flow</strong></td>
<td>Systolic dominance</td>
<td>Systolic blunting</td>
<td>Systolic reversal</td>
</tr>
<tr>
<td><strong>Jet density/contour (CW)</strong></td>
<td>faint, parabolic</td>
<td>Dense</td>
<td>Dense, triangular</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>with early peaking</td>
</tr>
<tr>
<td><strong>LA size</strong></td>
<td>normal</td>
<td>Normal or dilated</td>
<td>Usually dilated</td>
</tr>
<tr>
<td><strong>LV size</strong></td>
<td>normal</td>
<td>Normal or dilated</td>
<td>Usually dilated</td>
</tr>
</tbody>
</table>

Table adapted from Zoghbi et al. JASE 2003
Real-time 3D echocardiography
Matrix array transducer
In Vitro Validation of Real-Time Three-Dimensional Color Doppler Echocardiography for Direct Measurement of Proximal Isovelocity Surface Area in Mitral Regurgitation

Stephen H. Little, MD\textsuperscript{a}, Stephen R. Igo\textsuperscript{b}, Bahar Pirat, MD\textsuperscript{a}, Marti McCulloch\textsuperscript{a}, Craig J. Hartley, PhD\textsuperscript{b}, Yukihiro Nosé, MD, PhD\textsuperscript{b}, and William A. Zoghbi, MD\textsuperscript{a,*}
Proximal Flow Convergence Region as Assessed by Real-time 3-Dimensional Echocardiography: Challenging the Hemispheric Assumption

Chaim Yosef, MD, Robert A. Levine, MD, Jorge Solis, MD, Mordehay Vaturi, MD, Mark D. Handschumacher, BA, and Judy Hung, MD,
Boston, Massachusetts

3D measurement of PISA Surface Area
3D surface area of an ellipsoid is not so simple.
3D VCA Excellent Correlation with Cardiac MR

Figure 3. Comparison between mitral Rvol assessed with RT3DE (Rvol-3D) and by 3-Directional Velocity-Encoded CMR (Rvol-CMR)

(A) Correlation between mitral regurgitant volume (Rvol) assessed with real-time 3-dimensional echocardiography (RT3DE) (Rvol-3D) and by 3-directional velocity-encoded cardiac magnetic resonance (CMR) (Rvol-CMR).
(B) Bland-Altman scatter plot of differences in Rvol between RT3DE and CMR and the average Rvol between the 2 techniques: Rvol-3D is 0.08 ml/beat lower than Rvol-CMR (p = 0.87), limits of agreement from −7.7 to 7.6 ml/beat.

Ajmone Marsan et al.
Mitril Regurgitation Quantification by RT3DE

JACC: CARDIOVASCULAR IMAGING, VOL. 2, NO. 11, 2009
### Table 1. Mean Values and Range of EROA

<table>
<thead>
<tr>
<th></th>
<th>Total Population (n = 64)</th>
<th>L/S &gt; 1.5 (n = 18)</th>
<th>L/S ≤ 1.5 (n = 46)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2D: EROA-4CH, cm&lt;sup&gt;2&lt;/sup&gt;</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>0.11 ± 0.12&lt;sup&gt;*&lt;/sup&gt;</td>
<td>0.06 ± 0.06&lt;sup&gt;†&lt;/sup&gt;</td>
<td>0.14 ± 0.13</td>
</tr>
<tr>
<td>Range, min–max</td>
<td>0.008–0.64</td>
<td>0.008–0.27</td>
<td>0.008–0.64</td>
</tr>
<tr>
<td><strong>2D: EROA-elliptical, cm&lt;sup&gt;2&lt;/sup&gt;</strong></td>
<td></td>
<td></td>
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<tr>
<td>Mean ± SD</td>
<td>0.14 ± 0.15&lt;sup&gt;†&lt;/sup&gt;</td>
<td>0.15 ± 0.14</td>
<td>0.14 ± 0.16</td>
</tr>
<tr>
<td>Range, max–min</td>
<td>0.008–0.75</td>
<td>0.02–0.55</td>
<td>0.008–0.75</td>
</tr>
<tr>
<td><strong>RT3DE: EROA-3D, cm&lt;sup&gt;2&lt;/sup&gt;</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Mean ± SD</td>
<td>0.22 ± 0.14</td>
<td>0.23 ± 0.14</td>
<td>0.20 ± 0.16</td>
</tr>
<tr>
<td>Range, max–min</td>
<td>0.04–0.78</td>
<td>0.07–0.41</td>
<td>0.04–0.78</td>
</tr>
</tbody>
</table>

Measured by 2 different 2-dimensional (2D) echocardiographic approaches (from the 4-chamber [4CH] view, and with the elliptical formula [elliptical]) and measured by real-time 3-dimensional echocardiography (RT3DE), in the total population and among patients with (ratio of the longest and shortest diameter of effective regurgitant orifice area [EROA]-3D [L/S] > 1.5) and without (L/S ≤ 1.5) an asymmetrical regurgitant orifice. *p < 0.001 between 2D echocardiography and RT3DE. †p < 0.05 between patients with L/S > 15 and with L/S ≤ 1.5.

max = maximum; min = minimum.
3D Guided Measurement of vena contracta area in MR
Measuring the vena contracta area
3D Guided Vena Contracta Area
3D vena contracta method (from apical 4 window)
3D VCA vs. 2D ROA
Central vs. Eccentric MR Jets

A. Central MR jet

B. Eccentric MR jet

Zeng X. et al. Circulation CVImaging 2011; Vol. 4
3D VCA vs. 2D ROA

Etiology of MR

Degenerative

Functional

Zeng X. et al. Circulation CVImaging 2011; Vol. 4
Summary

- Increasing Validation of 3D color Doppler for MR Quantification
- Useful adjunct to 2D Integrative Method; especially in cases with mixed criteria
- 3D guided measurement of vena contracta area (effective regurgitant orifice area) is most validated
  - Eccentric Jets
  - Do not need Geometric Assumptions
The Good
EROA by 3D VCA vs 2D EROA PISA

Zeng X. et al; Circ CVIM; October, 2011
How much MR?

EROA = $2\pi R^2 \times$ Aliasing Velocity $\div$ Velocity of MR