Aortic-Mitral Valve Coupling in Mitral Valve Disease: A Study with Real-Time 3-Dimensional Transesophageal Echocardiography

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Declaration of Interest

• The speaker received unrestricted educational support from Philips Healthcare
• The aortic and mitral valves are coupled through fibrous aorto-mitral continuity and their proper function is integral in maintaining normal cardiac performance.

• Yet the valves have been studied in isolation, ignoring their anatomic and physiologic relationships.
It has been observed in the beating heart that mitral and aortic valves have synchronous dynamic physiology. Dynamic annular flexion may aid LV filling and ejection by maintaining proper orientation of the two valve planes.
Background (3)

- Previous studies evaluating this coupling mechanism were limited to experimental animals using invasive techniques, however
  - Collective mass of markers may alter normal annular motion
  - Cannot be used in human

Courtesy of Timek TA, et al.
Real-time 3D transesophageal echocardiography

- RT3D-TEE technology provides a new opportunity for in vivo assessment of the functional anatomy of mitral and aortic valve.

- Normal AMC in human heart has been described using RT3D-TEE\(^1\)

Study objectives

• To study the changes in aorto-mitral coupling in patients with mitral valve prolapse and ischemic mitral regurgitation using real-time 3D echocardiography.
Methods (1)

• RT3D-TEE (iE33) was performed in 95 patients:
  – 30 normal controls
  – 40 pts with moderate or severe MR due to mitral valve prolapse (MVP)
  – 25 pts with prior MI and moderate or severe ischemic mitral regurgitation (IMR)

• Exclusion criteria:
  – co-existing aortic valve diseases;
  – congenital or other structural heart diseases;
  – contraindication to TEE;
  – AF
Measurements were performed at 4 time points in a cardiac cycle:
- Early diastole
- End diastole
- Early systole
- End systole.

Statistical test used ANOVA of repeated measures.
Results
Clinical Characteristics of Controls, MVP and IMR groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>Normal controls (n=30)</th>
<th>MVP (n=40)</th>
<th>IMR (n=25)</th>
<th>ANOVA P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, year</td>
<td>51.6 ± 14.4</td>
<td>58.4 ± 10.0</td>
<td>67.7 ± 7.82*†</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Women, n (%)</td>
<td>14 (46.7)</td>
<td>13 (32.5 )</td>
<td>9 (30.0)</td>
<td>NS</td>
</tr>
<tr>
<td>BSA, m²</td>
<td>1.65 ± 0.15</td>
<td>1.68 ± 0.16</td>
<td>1.61 ± 0.16</td>
<td>NS</td>
</tr>
<tr>
<td>SBP, mmHg</td>
<td>133.3 ± 18</td>
<td>134.0 ± 18</td>
<td>125.7 ± 21</td>
<td>NS</td>
</tr>
<tr>
<td>DBP, mmHg</td>
<td>79.1 ± 10</td>
<td>80.1 ± 13</td>
<td>72.0 ± 15</td>
<td>NS</td>
</tr>
<tr>
<td>Heart rate, bpm</td>
<td>75.2 ± 12</td>
<td>79.7 ±13</td>
<td>74.3 ± 12</td>
<td>NS</td>
</tr>
</tbody>
</table>

BSA, body surface area; SBP, systolic blood pressure; DBP, diastolic blood pressure; NS = No statistically significant difference among groups
* P<0.05 vs controls
† P<0.05 vs MVP
### Echocardiographic Parameters of Controls, MVP and IMR Groups

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<tr>
<td><strong>LA volume/BSA (mL/m²)</strong></td>
<td>25.8 ± 7.5</td>
<td>75.0 ± 28.9*</td>
<td>52.0+17.2*†</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>LVEDV/BSA (mL/m²)</strong></td>
<td>53.2 ± 16.3</td>
<td>68.4 ± 16.7*</td>
<td>78.7 ± 24.7*</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>LVESV/BSA (mL/m²)</strong></td>
<td>20.1 ± 7.45</td>
<td>25.4 ± 8.85</td>
<td>48.1+23.6*†</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>LVEF (%)</strong></td>
<td>62.5 ± 5.0</td>
<td>63.4 ± 7.0</td>
<td>42.0 ± 15.9*†</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Forward stroke volume (mL)</strong></td>
<td>67.5 ± 18.7</td>
<td>61.7 ± 16.4</td>
<td>52.5 ± 16.0*</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>MR grade</strong></td>
<td>---</td>
<td>2.85 ± 0.36</td>
<td>2.72 ± 0.46</td>
<td>NS</td>
</tr>
<tr>
<td><strong>TDI</strong></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>s’ (cm/s)</td>
<td>7.9 ± 1.1</td>
<td>7.6 ± 1.3</td>
<td>5.2 ± 1.8*†</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>e’ (cm/s)</td>
<td>8.2 ± 3.4</td>
<td>8.6 ± 2.9</td>
<td>4.7 ± 1.9*†</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>a’(cm/s)</td>
<td>8.0 ± 2.2</td>
<td>6.7 ± 2.6</td>
<td>5.6 ± 2.5*</td>
<td>0.003</td>
</tr>
</tbody>
</table>

* P<0.05 vs controls
† P<0.05 vs MVP
Normal aortic-mitral coupling in control subjects

The aortic-mitral inter-annular angle was maximum at end-diastole and minimum at end-systole (systolic flexion).

Normal AMC shows reciprocal changes in mitral annulus and aortic annulus areas.

All p<0.0001 over time within subjects.
Comparison of Mitral Annular Dynamics in Normal Subjects and Mitral Valve Diseases

- **Mitral annulus area (cm²)**

**Time of cardiac cycle**

- Early diastole: 6.9, 9.3, 6.9
- End diastole: 6.5, 9.2, 9.5
- Early systole: 6.3, 9.1, 9.1
- End systole: 6.7, 11.7, 11.8

- *p<0.05 over time within subjects
- †p=NS over time within subjects
- p<0.0001 between groups
- p<0.0001 for time*group effect
Comparison of Aortic Annular Dynamics in Normal Subjects and Mitral Valve Diseases

Aortic annulus area (cm$^2$)

Time of cardiac cycle

- early diastole
- end diastole
- early systole
- end systole

p<0.0001 over time within subjects for all 3 groups
p<0.0001 between groups
p<0.0001 for time*group effect
Comparison of Aortic-Mitral Inter-annular Angle Dynamics in Normal Subjects and Mitral Valve Disease Diseases

Dynamicity of aortic-mitral angle is reduced in MVP and IMR.

Time of cardiac cycle:
- early diastole
- end diastole
- early systole
- end systole

**controls**
- early diastole: 124
- end diastole: 129
- early systole: 119
- end systole: 114

**MVP**
- early diastole: 118
- end diastole: 123
- early systole: 119
- end systole: 112

**IMR**
- early diastole: 116
- end diastole: 116
- early systole: 116
- end systole: 110

p<0.0001 over time within subjects for all 3 groups
p<0.0001 between groups
p<0.0001 for time*group effect
Correlation between left ventricular systolic function ($s'$) and annular angle excursion

$r=0.56, p<0.0001$
Summary of Findings and Interpretations

- Normal subjects
  - The mitral and aortic annuli contract and dilate in a reciprocal fashion
  - The aortic-mitral inter-annular angle is dynamic:
    - decreases during systole, bringing the LV base closer to the LVOT
    - increases during diastole, directing LV inflow towards the LV apex.
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- **Mitral valve prolapse**
  - Both mitral and aortic annuli are dilated
  - Reciprocal dynamics of annular areas is preserved
  - Dynamicity of aortic-mitral angle motion is reduced
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• Mitral valve prolapse
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  – Reciprocal dynamics of annular areas is preserved
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• Ischemic mitral regurgitation
  – Both mitral and aortic annuli are dilated
  – Mitral annulus becomes adynamic
  – Aortic annulus becomes less dynamic: reciprocal coupling is lost
  – Dynamicity of aortic-mitral angle is markedly diminished
Conclusions

• Aortic and mitral valves have closely coupled anatomy and their coupling physiology contributes as an integral part of normal cardiac performance.

• We demonstrated for the first time in human that pathologies of the mitral valve affect the structure and the coupling motion of the aortic annulus.

• The patterns of alteration in aorto-mitral coupling may be specific to the etiologies of mitral regurgitation.

• Aorto-mitral annular angle excursion may be related to LV long-axis systolic function.

• Our results lay down the framework for future studies to investigate the clinical significance of AMC in mitral valve diseases and may influence the development of new surgical techniques and prosthetic devices.
Think outside the box