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Diastolic Stress Testing
EAE Teaching Course
Sofia, Bulgaria 2012
Why would we want to assess diastolic function during stress?

1. Find a diagnosis for the breathless patient “to assess exertional breathlessness, you must exert the breathless!”
2. Assessing disease severity and prognosis
3. To define patients who may benefit from therapy
   - “patient targeted therapy”
Potential tools

- Volumetric assessments
- E/e’
- Torsion/ twist
- Lung comets
- Pulmonary artery pressure
- Biochemical
<table>
<thead>
<tr>
<th>Exercise vs. Pharmacological “stress”</th>
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</thead>
<tbody>
<tr>
<td><strong>Exercise</strong></td>
</tr>
<tr>
<td>• ↑SV and ↑afterload</td>
</tr>
<tr>
<td>• ↑preload</td>
</tr>
<tr>
<td>• Functional status</td>
</tr>
<tr>
<td>• Very safe</td>
</tr>
<tr>
<td>• Respiratory/ other movement</td>
</tr>
<tr>
<td>• Often in early recovery</td>
</tr>
<tr>
<td><strong>Dobutamine</strong></td>
</tr>
<tr>
<td>• ↑↑↑SV and ↓afterload</td>
</tr>
<tr>
<td>• ↓preload</td>
</tr>
<tr>
<td>• No functional status</td>
</tr>
<tr>
<td>• Arrhythmias (uncommon)</td>
</tr>
<tr>
<td>• Good quality images</td>
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<tr>
<td>• Real-time</td>
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</table>
Heart failure limits exercise in everyone
**Heart failure:** cardiac output insufficient to meet $O_2$ demands

- In health and disease exercise capacity is closely associated with maximal oxygen consumption
  - $O_2$ delivered $\times O_2$ metabolized
- Cardiac output explains $\sim 75\%$ of variability in oxygen utilisation
- HFPEF and a world-champ ion athlete:
  - the exercise limitations are similar
  - the workload differs
Atrial pressures during exercise in health

BNP as a surrogate of acute ventricular stretch

Change in BNP with exercise

<table>
<thead>
<tr>
<th></th>
<th>Athletes (n=40)</th>
<th>Non-athletes (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>7.5</td>
<td>7.5</td>
</tr>
<tr>
<td>Post MXT</td>
<td>28.4</td>
<td>12.9</td>
</tr>
</tbody>
</table>

* p<0.05 vs non-athlete
† p<0.001 vs Baseline
Flow and pressure with exercise

Increase pressure

Decrease pressure
The difference is in the workload.

![Graph showing comparison between trained and untrained conditions.](Image)

E/e’ as a measure of LA pressure
E/e’ as a measure of diastolic filling pressures

Burgess, Marwick JACC 2006

Talreja, Oh JASE 2007
Caveats I

Nagueh *JACC* 1997 vs. Mullens *Circulation* 2009
Caveats II

- Data is acquired during recovery and compared with pressures obtained at peak exercise
- Delay varies with pathology
- Measuring slow recovery rather than exercise pressures

Holland, Marwick *Am J Hypertension* 2008
Can we improve HFPEF diagnosis with exercise E/e’?

- Holland, Marwick *Heart* 2010
  - Resting criteria for HFPEF
  - Add E/e’ with exercise
  - Exclude ischemia testing with exercise
  - Add objective exercise intolerance

- 13/436 breathless patients met all criteria for HFPEF

- Relevant to patient selection for trials
Exercise E/e’ and prognosis

- 538 patients ‘clinically indicated stress test’.
- E/e’ >2SD from normal (14.5)
- Outcome CVS hospitalisation in 5 years

Holland, Marwick *Circ CVI* 2010
Summary of exercise E/e’

- ??? Measures LV filling pressures
- Probably does measure a sub-optimal cardiac response to exercise
- Need to wait for EA splitting maybe an advantage
- Moderately helpful in predicting prognosis
- Easy to add to standard exercise echo testing
Pulmonary Artery Pressures

- Invasive hemodynamic studies to diagnose HFPEF (defined as Ex PCWP > 25mmHg) in 55 breathless patients

Borlaug et al. *Circ Heart Failure* 2010
Failure to increase PAP with exercise is associated with a poor prognosis.

Lewis, Semigran et al. *Circ Heart Failure* 2011
Pulmonary vasodilators as therapy for HFNEF?

Guazzi et al. Circulation 2011
Echo estimates of PASP
Volumes, HFPEF and exercise

Haykowsky, Kitzman et al. JACC 2011
HFNEF and exercise

- Consistent finding of reduced contractile reserve rather than filling impairment
- However:
  
  ? chronotropic incompetence = filling impairment

<table>
<thead>
<tr>
<th></th>
<th>Kitzman et al. (8)</th>
<th>Borlau et al. (9)</th>
<th>Ennezat et al. (11)</th>
<th>Borlau et al. (10)</th>
<th>Maeder et al. (37)</th>
<th>Current Study</th>
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<tbody>
<tr>
<td>Peak VO₂</td>
<td>↓</td>
<td>↓</td>
<td>NR</td>
<td>↓</td>
<td>↓</td>
<td>↓</td>
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<tr>
<td>ΔCO</td>
<td>↓</td>
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<td>↓</td>
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<tr>
<td>ΔA⁻V₀₂ Diff</td>
<td>↓</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>↓</td>
</tr>
<tr>
<td>ΔHR</td>
<td>↓</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
<td>↓</td>
<td>↑ supine, ↓ upright</td>
</tr>
<tr>
<td>ΔEDV</td>
<td>↓</td>
<td>↔</td>
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<td>↔</td>
<td>NR</td>
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<tr>
<td>ΔESV</td>
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<td>ΔSVR</td>
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Haykowsky, Kitzman et al. JACC 2011
SYSTOLIC AND DIASTOLIC FUNCTION ARE INSEPARABLE
Flow and pressure with exercise

The best way of decreasing early diastolic suction is with effective systolic contraction.
Torsional reserve

Notomi et al. *Circ* 2006

Burns et al. *JASE* 2008
Direct assessment of exercise-induced heart failure
Conclusions

• Exercise intolerance (not resting symptoms) is the most frequent complaint of our patients

To assess exertional breathlessness we must exert the breathless
Conclusions

• ‘Diastolic stress testing’ is possibly an artificial premise
• Measures of systolic function at least as important
• Potential diagnostic and prognostic benefits in incorporating stress E/e’
• PASP estimates may be at least as instructive and should be attempted in all stress studies
a CMR approach

N = 18 healthy subjects
15 ♂, 3 ♀
Age: 32 ± 8 years

Rest: 65 ± 11 bpm
Moderate exercise: 114 ±16 bpm
Strenuous exercise: 153 ±11 bpm
CMR imaging @ 168 bpm (215W)

Short axis

Horizontal long axis
CMR imaging @ 168 bpm (215W)

Short axis

Horizontal long axis