How to evaluate diastolic function: general recommendations

Bogdan A. Popescu
University of Medicine and Pharmacy, Bucharest, Romania

My declaration of interest: I have nothing to declare
Echo assessment of diastolic function

Comprehensive 2D and Doppler echocardiography remains the most widely available non invasive clinical tool able to evaluate:

• abnormal LV relaxation
• changes in compliance
• level of LV filling pressure

providing a clinically relevant assessment of LV diastolic function
Relaxation

Compliance

E/A ratio, E deceleration time
Isovolumic relaxation time
Flow propagation velocity
Myocardial Ve, Se, SRe

Short duration A wave
Increased PV reversed flow
E/e’ ratio
Left atrial volume

Courtesy: A. Fraser
Assessment of LV diastolic function

- No single parameter can be used in a given pt
  - It requires a comprehensive echo study, incorporating all available 2D and Doppler data:
    - LA size (“Hb A1c of diastolic dysfunction”)
    - LV dimensions, function, wall thickness
    - Mitral inflow (baseline and with Valsalva)
    - Pulmonary vein flow profile
    - Tissue Doppler Imaging
    - Combined parameters
LA size and LV diastolic dysfunction

- In subjects without primary atrial pathology, arrhythmias, or mitral valve disease, increased LA volume usually reflects elevated ventricular filling pressures

- LA volume increases with severity of diastolic dysfunction

- The structural changes of the LA express the chronicity of exposure to abnormal filling pressures and provide predictive information beyond that of diastolic function grade

LV filling by transmitral PW Doppler

E/A ratio

- very good
- good
- bad

Relaxation
- restrictive filling
- pseudonormal
- impaired relaxation

Filling pressure
- very, very bad

Disease severity
Mitral inflow Doppler: normal values

The ageing effect:
• Peak E and E/A ratio decrease with age
• EDT, peak A, and IVRT increase with age

Other confounding factors:
• Heart rate, rhythm, loading conditions, PR, LA function

Table 1 Normal values for Doppler-derived diastolic measurements

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Age group (y)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16-20</td>
</tr>
<tr>
<td>IVRT (ms)</td>
<td>50 ± 9(32-68)</td>
</tr>
<tr>
<td>E/A ratio</td>
<td>1.88 ± 0.45(0.98-2.78)</td>
</tr>
<tr>
<td>DT (ms)</td>
<td>142 ± 19(104-180)</td>
</tr>
<tr>
<td>A duration (ms)</td>
<td>113 ± 17(79-147)</td>
</tr>
</tbody>
</table>
Mitral EDT is a strong predictor of PCWP

- 140 postinfarct pts in SR
- LV ejection fraction < 35%
- EDT < 120 ms best predictor of PCWP > 20 mm Hg

- 35 pts with HF and A Fib
- Mean LVEF 22 ± 5%
- EDT < 120 ms best predictor of PCWP > 20 mm Hg

Temporelli PL, et al. Am J Cardiol 1999
Persistence of Restrictive Filling Pattern in DCM: an ominous prognostic sign

EDT relation to filling pressures depends on LVEF

LVEF $\leq 50\%$

LVEF $> 50\%$

Assessing LV filling pressure by mitral flow parameters

Adequate interpretation often requires:

• Load manipulation (eg Valsalva, medication)
• Alternative load dependent parameters (PV flow)
• Newer, less load dependent techniques (eg TDI)
Unmasking of impaired relaxation in pseudonormalization by reducing transmitral filling pressure using the Valsalva maneuver.
A wave velocity change during Valsalva as a predictor of increased LVEDP

Unmasking elevated LVEDP in pts with impaired relaxation pattern

Normal LVEDP

Increased LVEDP

Practical advice

Standardize the Valsalva maneuver:
Keep a 40 mm Hg pressure for 10 sec
Pseudonormal pattern unmasked by Valsalva

Baseline

After Valsalva

- E/A ratio decreased from 1.3 to 0.6 (with >50%)
- A velocity increased from 60 to 75 cm/s (with 25%)
Mitral inflow - limitations

- **U-shaped relation with LV diastolic function**
  (normal vs pseudonormal)
- **Sinus tachycardia & first degree AV block**
  (fusion of the E and A waves)
- **Arrhythmias: atrial flutter**
  (LV filling influenced by rapid atrial contractions)
Pulmonary vein flow PW-Doppler

A systolic fraction <40% reliably predicts a PCWP >18 mm Hg (in pts with systolic dysfunction)

Pulmonary venous Flow Pattern and Filling Pressure

- $A_R$ dur >A predicts a LVEDP > 15 mm Hg with a sensitivity of 85% and a specificity of 79%
- Independent of LV ejection fraction
  - Rossvoll and Hatle, J Am Coll Cardiol 1993
- Age-independent

Courtesy of E. Schwammenthal
Problems with using PV flow for LV filling pressure assessment

- Parabolic distribution during progression to advanced diastolic dysfunction
- Rather low feasibility for TTE (especially for $A_r$)
- Less reliable in assessing LV filling pressures when LVEF is normal (for S, D, syst fraction)
- Atrial mechanical failure is often present in advanced diastolic dysfunction
Pulsed Doppler Tissue Imaging for measuring myocardial velocities

\[ E_m = E_a = E' \]
Tissue Doppler Imaging

E’ as an index of LV relaxation

- 38 pts, simultaneous Doppler-catheterization
- septal mitral annulus was used for E’ measurement

E’ is relatively preload-independent

Mitral PW Doppler

Mitral annulus TDI

Progression of diastolic indices

Amplitude

Time / severity of disease

Courtesy: A. Fraser
Assessment of LV filling pressures by combined Tissue Doppler and PW echocardiography

\[ E \approx \frac{p_w}{\tau} \]

\[ E' \approx \frac{1}{\tau} \]

\[ E/E' \approx p_w \]

Nagueh SF, et al.
Assessing LVFP by E/E’

- E/E’ <8 likely normal
- E/E’ >15 likely elevated
- E/E’ of 8-15 unclear

Figure 6. M-LVDP versus groups defined by values of septal E/E’. Indicates patients with EF <50%; , patients with EF >50%.
Age dependency of TDI-derived parameters


Table 2 Age-association of diastolic function parameters

<table>
<thead>
<tr>
<th>Age groups (y)</th>
<th>45-49</th>
<th>50-54</th>
<th>55-59</th>
<th>60-64</th>
<th>65-69</th>
<th>≥70</th>
<th>P value (CC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDI-mitral annulus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Septal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E’/m/s</td>
<td>0.10 (0.03)</td>
<td>0.09 (0.02)</td>
<td>0.09 (0.02)</td>
<td>0.09 (0.05)</td>
<td>0.08 (0.02)</td>
<td>0.08 (0.07)</td>
<td>&lt;.001 (-.35)</td>
</tr>
<tr>
<td>A’/m/s</td>
<td>0.10 (0.02)</td>
<td>0.11 (0.03)</td>
<td>0.11 (0.02)</td>
<td>0.11 (0.02)</td>
<td>0.11 (0.02)</td>
<td>0.11 (0.02)</td>
<td>&lt;.001 (.23)</td>
</tr>
<tr>
<td>E/E’/m/s</td>
<td>7.20 (2.14)</td>
<td>7.51 (2.31)</td>
<td>8.04 (2.63)</td>
<td>8.01 (2.27)</td>
<td>8.71 (2.40)</td>
<td>9.32 (3.32)</td>
<td>&lt;.001 (.27)</td>
</tr>
<tr>
<td>Lateral</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E’/m/s</td>
<td>0.13 (0.04)</td>
<td>0.12 (0.04)</td>
<td>0.11 (0.02)</td>
<td>0.11 (0.04)</td>
<td>0.09 (0.02)</td>
<td>0.09 (0.08)</td>
<td>&lt;.001 (-.5)</td>
</tr>
<tr>
<td>A’/m/s</td>
<td>0.11 (0.04)</td>
<td>0.11 (0.02)</td>
<td>0.12 (0.03)</td>
<td>0.12 (0.04)</td>
<td>0.12 (0.02)</td>
<td>0.12 (0.04)</td>
<td>&lt;.001 (.18)</td>
</tr>
<tr>
<td>E/E’/m/s</td>
<td>5.61 (1.38)</td>
<td>5.87 (1.70)</td>
<td>6.31 (1.87)</td>
<td>6.70 (1.69)</td>
<td>7.17 (2.05)</td>
<td>8.32 (2.81)</td>
<td>&lt;.001 (.39)</td>
</tr>
</tbody>
</table>

1012 subjects


Table 2 Doppler tissue imaging echocardiographic data obtained at the lateral annulus in 103 healthy participants

<table>
<thead>
<tr>
<th>Age (y)</th>
<th>20-29 (n = 11)</th>
<th>30-39 (n = 12)</th>
<th>40-49 (n = 24)</th>
<th>50-59 (n = 13)</th>
<th>60-69 (n = 17)</th>
<th>70-79 (n = 14)</th>
<th>≥80 (n = 12)</th>
<th>*P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>E’ (cm/s)</td>
<td>20 ± 3</td>
<td>18 ± 4</td>
<td>16 ± 4</td>
<td>14 ± 3</td>
<td>12 ± 3</td>
<td>11 ± 4</td>
<td>9 ± 2</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>A’ (cm/s)</td>
<td>11 ± 1</td>
<td>11 ± 3</td>
<td>12 ± 2</td>
<td>11 ± 3</td>
<td>14 ± 4</td>
<td>16 ± 5</td>
<td>13 ± 3</td>
<td>&lt;.0001</td>
</tr>
<tr>
<td>E/E’</td>
<td>4.0 ± 1.0</td>
<td>5.0 ± 1.0</td>
<td>5.2 ± 1.2</td>
<td>5.7 ± 1.4</td>
<td>6.2 ± 1.8</td>
<td>7.2 ± 3.2</td>
<td>8.0 ± 2.4</td>
<td>&lt;.0001</td>
</tr>
</tbody>
</table>

*Mean values by decade compared using analysis of variance.

Estimation of LVFP by the E/E’ ratio

E/E’ ratio has been shown to correlate with FP in:

- Sinus tachycardia (irrespective of LVEF)
- Atrial fibrillation
- Hypertrophic cardiomyopathy
- Patients after heart transplantation

E/E’ as a predictor of survival after AMI

Reported cut-off values for E’ and E/E’ ratio are based on PW TDI measurements.

PW TDI

Color TDI

Peak vel

Mean vel

About 25% lower than PW TDI
Adequately obtained measurements:

- E/E’ septal annulus, in 96% of pts
- E/E’ lateral annulus, in 90% of pts

ROC curves for prediction of M-LVDP >12 mm by E/E’

Impact of LVEF on estimation of LVFP by TDI

Patients with EF < 50%

Patients with EF ≥ 50%

Problems with using E/E’ for LV filling pressure assessment

• Uses a regional parameter (E’) to derive global information
• In patients with CAD and regional WMA may not be reliable (need to average several values)
• Cut-off values are different for different sites
• Relatively wide overlap when E/E’ between 8-15
Diastolic Stress Echocardiography: Hemodynamic Validation and Clinical Significance of Estimation of Ventricular Filling Pressure With Exercise

- 37 pts undergoing LH catheterization (invasive study)
- E/E’ at rest and during cycle ergometry (septal E’)
- 166 pts (noninvasive study)
- E/E’ before and after treadmill exercise (septal E’)

Diastolic Stress Echocardiography: Hemodynamic Validation and Clinical Significance of Estimation of Ventricular Filling Pressure With Exercise

ROC curve to predict exercise capacity <8 METs

Open bars = exercise $E/E' \leq 10$
Solid bars = exercise $E/E' > 10$

- Exercise $E/E'$ may confirm the cardiac etiology for exertional dyspnea and its measurement may explain functional impairment in patients with normal / mildly abnormal diastolic parameters at rest

Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography

Sherif F. Nagueh, MD, Chair†, Christopher P. Appleton, MD†, Thierry C. Gillebert, MD*, Paolo N. Marino, MD*, Jae K. Oh, MD†, Otto A. Smiseth, MD, PhD*, Alan D. Waggoner, MHS†, Frank A. Flachskampf, MD, Co-Chair†, Patricia A. Pellikka, MD†, and Arturo Evangelista, MD*
Estimation of Filling Pressures in Patients with Depressed EF

Mitral E/A

E/A < 1 and E ≤ 50 cm/s

- E/e' (average e') < 8
- E/Vp < 1.4
- S/D > 1
- Ar – A < 0 ms
- Valsalva Δ E/A < 0.5
- PAS < 30 mmHg
- IVRT/T_{E-e'} > 2

Normal LAP

E/A ≥ 1 - < 2, or E/A < 1 and E > 50 cm/s

- E/e' (average e') > 15
- E/Vp ≥ 2.5
- S/D < 1
- Ar – A ≥ 30 ms
- Valsalva Δ E/A ≥ 0.5
- PAS > 35 mmHg
- IVRT/T_{E-e'} < 2

Normal LAP

E/A ≥ 2, DT < 150 ms

- ↑ LAP
Estimation of Filling Pressures in Patients with Normal EF

- **E/e’ ≤ 8**
  - **LA volume < 34 ml/m²**
  - **Ar – A < 0 ms**
  - **Valsalva Δ E/A < 0.5**
  - **PAS < 30 mmHg**
  - **IVRT/T_{E-e’} > 2**
  - **Normal LAP**

- **E/e’ 9-14**
  - **LA volume ≥ 34 ml/m²**
  - **Ar – A ≥ 30 ms**
  - **Valsalva Δ E/A ≥ 0.5**
  - **PAS > 35 mmHg**
  - **IVRT/T_{E-e’} < 2**
  - **↑ LAP**

- **Sep. E/e’ ≥ 15**
  - or
  - **Lat. E/e’ ≥ 12**
  - or
  - **Av. E/e’ ≥ 13**
  - **↑ LAP**
Thank you!