Echocardiographic Evaluation of Diastolic Function

Miguel A. Quiñones, MD, MACC, FASE
Houston Methodist
DeBakey Heart & Vascular Center

Disclosure: nothing to disclose
Practical Approach to Grade Diastolic Dysfunction

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,* Houston, TX; Phoenix, AZ; Ghent, Belgium; Novara, Italy; Rochester, MN; Oslo, Norway; St. Louis, MO; Erlangen, Germany; Barcelona, Spain

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Diastolic Function

Cardiac Dyspnea

SYSTOLIC HEART FAILURE

HIGH FILLING PRESSURES SECONDARY TO ABNORMAL DIASTOLIC FUNCTION

DIASTOLIC HEART FAILURE
Determinants of Diastolic Function

- Relaxation
- Stiffness
- Inflow Volume
- Atrial Contraction
- Filling Pressures
Diastolic Pressure-Volume Relations

![Graph showing diastolic pressure-volume relationship with normal and early diastolic dysfunction points labeled A and B.](image)
Diastolic Pressure-Volume Relations

- Severe diastolic dysfunction
- Early diastolic dysfunction
- Normal

LV Pressure (mmHg) vs. LV volume (ml)

Point A: Normal
Point B: Early diastolic dysfunction
Point C: Severe diastolic dysfunction

Rx: Treatment
Echocardiographic Evaluation of Diastolic Function

Assess

Relaxation

- Normal
- Impaired

Filling Pressures

- Normal
- Elevated
How To Assess Diastolic Function?

What do I use?

1. Clinical Sx’s and age
2. 2D echo findings
   a. LV size; EF; RMWA
   b. LVH
   c. LA size
3. Doppler findings
   a. transmitral velocity; IVRT; PV vel
   b. Lat and sep e’
   c. TR vel->PASP
Doppler Assessment of Diastolic Function
Transmitral and Pulmonary Vein Velocities

Sweep speed at 100mm/s
Myocardial (or annular) Velocity by Tissue Doppler

Septal

Lateral
Spectral Tissue Doppler
Technical Issues
Systolic Heart Failure

**RELAXATION**

**SYSTOLIC HF**

IVRT

IVRT
### Impaired LV Relaxation

<table>
<thead>
<tr>
<th></th>
<th>Type 1</th>
<th>Mild DD</th>
<th>Impaired relaxation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIF</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>MIF-Val</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DTI</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Increased LV Stiffness

- MIF: 0-+
- MIF-Val: +
- DTI: ++
- DTI: +++
- DTI: ++++

### Elevated Atrial Pressure

- MIF: 0
- MIF-Val: ++
- DTI: +++
- DTI: ++++

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#### When is Type 1 abnormal versus due to old age?

- When is $e'/10$?
- When is $e'/<8$?
- When is $E/A<1$?

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#### What about age > 80?

- Linear regression analysis shows:
  - $y = -0.22x + 23.92$
  - $r = 0.76$
  - $p = 0.0001$
Practical Approach to Grade Diastolic Dysfunction

- Septal or Lat e’
  - LA volume

  - Septal e’ ≥ 8
    - Lateral e’ ≥ 10
    - LA < 34 ml/m2
      - Normal function

  - Septal e’ ≥ 8
    - Lateral e’ ≥ 10
    - LA ≥ 34 ml/m2
      - Grade I
        - E/A < 0.8
        - DT > 200 ms
        - Av. E/e’ ≤ 8
        - Ar-A < 0 ms
        - Val ΔE/A < 0.5

  - Septal e’ < 8
    - Lateral e’ < 10
    - LA ≥ 34 ml/m2
      - Grade II
        - E/A 0.8-1.5
        - DT 160-200 ms
        - Av. E/e’ 9-12
        - Ar-A ≥ 30 ms
        - Val ΔE/A ≥ 0.5

      - Grade III
        - E/A ≥ 2
        - DT < 160 ms
        - Av. E/e’ ≥ 13
        - Ar-A ≥ 30 ms
        - Val ΔE/A ≥ 0.5

  - Normal function, Athlete’s heart, or constriction

- Grade I
- Grade II
- Grade III
Is LV relaxation normal or impaired?

Findings universally associated with normal LV relaxation*

- Normal LV structure and EF
- Normal regional wall motion
- Transmitral E ≥ A
- Normal e’ adjusted for age
- Normal LA volume

*All must be present to ensure normal LV relaxation

-Exception: LA may be enlarged in:
  - Primary MV disease (MR or MS)
  - Athletes
  - High CO states
  - Atrial fibrillation
Normal Heart
Is LV relaxation normal or impaired?

Findings universally associated with abnormal LV relaxation

- Low EF
- Abnormal Regional WM
- Concentric LVH
  - Exception: athletes
- Enlarged LA: found in >90% of patients with diastolic dysfunction
  - Sensitive but not specific
- Reduced e’
Myocardial (or annular) Velocity by Tissue Doppler

Normal Relaxation

Impaired Relaxation
64F; HTN and dyspnea
Assessment of Left Atrial Size

Normal LA vol: $\geq 34 \text{ml/m}^2$

Left Atrial Volume = 

$$\frac{8}{3\pi} \left[ \frac{(A_1)(A_2)}{(L)} \right]^*$$

JASE 2005;18:1440
Comparison of left and right atrial volume by echocardiography versus cardiac magnetic resonance imaging using the area-length method

55M with dyspnea: EF, 27%

100% likelihood of impaired relaxation
Systolic Heart Failure

**RELAXATION**

**IVRT**

**SYSTOLIC HF**
79M with HTN and dyspnea

100% likelihood of abnormal relaxation
Diastolic Dysfunction

When is Type 1 abnormal versus due to old age?

What about age > 80?
<table>
<thead>
<tr>
<th>Variable</th>
<th>All Participants</th>
<th>Women</th>
<th>Men</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA volume (ml)</td>
<td>64.6 ± 26</td>
<td>63 ± 23.7</td>
<td>66.2 ± 28.4</td>
</tr>
<tr>
<td>LV end-diastolic volume index (ml/m²)</td>
<td>68.4 ± 18.7</td>
<td>64 ± 17.8</td>
<td>73.1 ± 18.5</td>
</tr>
<tr>
<td>LV end-systolic volume index (ml/m²)</td>
<td>31.3 ± 14.2</td>
<td>28 ± 12.1</td>
<td>34.9 ± 15.4</td>
</tr>
<tr>
<td>LV mass index (g/m²)</td>
<td>122 ± 35.9</td>
<td>122.7 ± 40.3</td>
<td>121.4 ± 30.6</td>
</tr>
<tr>
<td>E/A ratio</td>
<td>1 ± 1.1</td>
<td>0.99 ± 0.57</td>
<td>1.1 ± 1.4</td>
</tr>
<tr>
<td>Deceleration time</td>
<td>205.9 ± 68.1</td>
<td>210.3 ± 72.2</td>
<td>201.6 ± 63.6</td>
</tr>
<tr>
<td>Tissue Doppler lateral E wave (cm/s)</td>
<td><strong>7.3 ± 2.2</strong></td>
<td>7 ± 2.2</td>
<td>7.7 ± 2.2</td>
</tr>
<tr>
<td>Tissue Doppler lateral A wave (cm/s)</td>
<td>9.8 ± 3.4</td>
<td>9.4 ± 3.5</td>
<td>10.2 ± 3.4</td>
</tr>
<tr>
<td>Tissue Doppler septal E wave (cm/s)</td>
<td><strong>6.2 ± 2</strong></td>
<td>5.9 ± 1.9</td>
<td>6.5 ± 2</td>
</tr>
<tr>
<td>Tissue Doppler septal A wave (cm/s)</td>
<td>8.3 ± 2.8</td>
<td>7.9 ± 2.8</td>
<td>8.8 ± 2.7</td>
</tr>
<tr>
<td>E/E’ ratio</td>
<td>12.2 ± 4.9</td>
<td>13.1 ± 5</td>
<td>11.3 ± 4.6</td>
</tr>
</tbody>
</table>

Is LV relaxation normal or impaired?

Findings universally associated with abnormal LV relaxation

- **Very advanced age**
- Low EF
- Abnormal Regional WM
- Concentric LVH
  - Exception: athletes
- Enlarged LA: found in >90% of patients with diastolic dysfunction
  - Sensitive but not specific
- Reduced e’
How To Assess Diastolic Function

1st question:

Is LV relaxation normal, reduced by age or abnormal?

2nd question:

Are resting LVFP’s normal or elevated?
Filling Pressures: What should we measure?

mean LAP/PCW

LV min P

LVEDP

LV pre-A wave

Relate better with Sx’s
Pulmonary Vein and Transmitral Velocity

PV-Ad = 170ms
MV-Ad = 120ms
Estimation of LVEDP

PV-Ad = 170ms
MV-Ad = 120ms

Rossvoll O, Hatle LK JACC 1993;21:1687
Systolic Heart Failure

RELAXATION

IVRT

SYSTOLIC HF
Abnormal LV relaxation

**MIF**

- **Normal DF**
- **Impaired DD**
- **Mild DD**
- **Moderate DD**
- **Severe DD**

**E/A**
- Type 1: E/A < 1
- Type 2: 1 ≤ E/A < 1.5
- Type 3: E/A ≥ 2

**PV**

- Impaired LV relaxation
- Increased LV stiffness
- Elevated atrial pressure

- Type 1: Yes
- Type 2: Yes
- Type 3: Yes

- Impaired LV relaxation
- Increased LV stiffness
- Elevated atrial pressure

- Type 1: Yes
- Type 2: Yes
- Type 3: Yes

<table>
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<th>Impaired LV relaxation</th>
<th>Increased LV stiffness</th>
<th>Elevated atrial pressure</th>
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<td>Yes</td>
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<td>Yes</td>
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<tr>
<td>Increased stiffness</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Elevated pressure</td>
<td>Increased stiffness</td>
<td>Increased pressure</td>
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<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Condition</td>
<td>Normal DF</td>
<td>Mild DD</td>
</tr>
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<td>---------------------------</td>
<td>-----------</td>
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<td>Impaired LV relaxation</td>
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<td>Yes</td>
</tr>
<tr>
<td>Increased LV stiffness</td>
<td></td>
<td>0-+</td>
</tr>
<tr>
<td>Elevated atrial pressure</td>
<td>0</td>
<td>++</td>
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Diagram showing different types of diastolic dysfunction (DD) with normalized diastolic filling (MIF) and pulmonary vein (PV) waveforms.
Doppler estimation of LV filling pressures in Patients With Depressed LVEF

mean PCWP = 17 + 5.3EA - 0.11IVRT

Naqueh et al, Am J Cardiol 75: 1256, 1995

Mean PCWP = [17 + (5 x E/A)] - (0.1 x IVRT)
= [17 + 17.5] - 4 = 31mmHg
mean PCWP = 17 + 5.3EA - 0.11IVRT

Prospective Group

All Patients

Doppler Estimate (mmHg)

Catheter Pressure (mmHg)

Naqueh et al, Am J Cardiol 75: 1256, 1995
<table>
<thead>
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<th>Normal DF</th>
<th>Type 1</th>
<th>Type 2</th>
<th>Type 3-4</th>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Increased LV stiffness</td>
<td>0+</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Elevated atrial pressure</td>
<td>0</td>
<td>++</td>
<td>+++</td>
</tr>
</tbody>
</table>

**MIF**

- Avg E/e’ < 9
- Avg E/e’ 9-12
- Avg E/e’ ≥13

**DTI**

- Avg E/e’ < 9
- Increased E/e’

**PV**

- Impaired LV relaxation
- Increased LV stiffness
- Elevated atrial pressure
56M with HTN and dyspnea
56M with HTN and dyspnea

Normal filling vs Pseudonormal?

Findings that favor pseudonormal

- HTN with LVH
- Large LA
- Apv duration > Amv duration
Severe LVH With E/A <1 and Elevated LAP

Nishimura et al, JACC 1996;28:1226
Conventional Doppler Estimation of LV Filling Pressures in HCM

NORMAL

RELAXATION

DIASTOLIC HF

IVRT

e'

[Graph and images showing cardiac function with IVRT measurements in different conditions: normal, relaxation, and diastolic heart failure.]
Estimation of mean LAP: Normal LVEF

**Normal DF**
- Avg E/e’ < 9

**Mild DD**
- Avg E/e’ 9-12

**Moderate DD**
- Avg E/e’ ≥ 13

**Severe DD**
- Estimation of mean LAP: Normal LVEF
  - Mean LAP < 15
- Mean LAP ≥ 15

- E > 50 cm/s
- E/A < 1
- Increased E/e’
The ratio of transmitral E-vel to e’ relates well with mean PCWP

\[ \text{Mean PCWP (mmHg)} \]

\[ E/e' \]

Nagueh et al, JACC 1997;30:1527-1533
Impact of LVEF on Estimation of Filling Pressures

LVEF > 50%

Rivas-Gotz et al Am J Cardiol 2003;91:780
65F diabetic; HTN with dyspnea

Filling pressures are:
A. normal
B. elevated
C. ???
65F diabetic; BP 214/104; Class 3 heart failure

Methodist DeBakey Heart Center

E/e’ = 20

E/e’ = 16
65F diabetic; HTN with dyspnea

Patient responded to therapy with diuretics and blood pressure reduction

TR = 3.3m/s

PASP = 44mmHg +RAP
Usefulness of PA systolic pressure to predict pulmonary arterial wedge pressure in patients with normal LV systolic function

*Bouchard JL, Aurigemma GP, et al. Am J Cardiol 2008;101:1673*
A practical approach

Dyspnea, enlarged LA, and high PASP = diastolic HF

E/e’ and TR vel are very helpful in validating Dx

Combining 2D LV and LA evaluation with Doppler was 85% sensitive and 95% specific for detecting heart failure and superior to BNP > 150pg/ml

(Dokainish Am J Cardiol 2004; 93:1130)
Limitations of Annular Velocity (e’)

• E/e’ cannot be used as an index of LV filling pressures in patients with mitral stenosis, prosthetic valve or even severe annular calcification
  – Short IVRT in the presence of reduced e’ is a marker of elevated LVFP
  • Particularly is LA is enlarged and PASP is elevated
Limitations of Annular Velocity (e’)

- E/e’ is unreliable in normal-healthy hearts
  - Ex: normal heart with severe MR
- E/e’ is unreliable in constrictive pericarditis.
  - Ea remains preserved despite increased LV diastolic pressure
- e’ is a regional index; thus, it can vary between sampling sites and in patients with abnormal regional wall motion
Patient with an anterior MI

Avg $e' = 7.5 \text{cm/s}$

Nagueh et al. JASE 2009
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
  - 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
  - ↑ LAP

- E/A ≥ 2, DT < 150 ms
  - ↑ LAP

Nagueh et al, JASE 2009
Estimation of mean LAP: Depressed LVEF

- Normal DF: Avg E/e’ < 9
  - Mean LAP < 15
  - E/A ≤ 1
- Mild DD: Avg E/e’ 9-12
  - Mean LAP < 15
- Moderate DD: Avg E/e’ ≥13
  - Mean LAP ≥15
  - Increased E/A and E/e’
  - Short DT

~ 85% accurate in patients with depressed LVEF
LA enlargement in > 95%
Estimation of Filling Pressures in Patients with Normal EF

E/e' ≤ 8 (Sep, Lat, or Av.)

E/e' 9-14

LA volume < 34 ml/m²
Ar – A < 0 ms
Valsalva ∆ E/A < 0.5
PAS <30 mmHg
IVRT >90

Normal LAP

LA volume ≥ 34 ml/m²
Ar – A ≥ 30 ms
Valsalva ∆ E/A ≥ 0.5
PAS >35 mmHg
IVRT <80

↑LAP

E/e' > 15 or
Lat. E/e' > 12 or
Av. E/e’ ≥ 13

↑LAP

Nagueh et al, JASE 2009
Estimation of LV Filling Pressures

- In pts with normal EF: look for LA enlargement
  - With type I pattern (E/A<1):
    - E ≤50cm/s: high PCWP is highly unlikely
    - E>50cm/s: use E/e’ or short IVRT

- With type II or III/IV pattern:
  - LVFP’s are most likely elevated (particularly if other 2D findings support it)
  - low e’ usually present

  Confirm with PASP by TR velocity
Estimation of mean LA Pressure

Normal LV Relaxation
- LAVI < 34 ml/m^2
- E/A < 1
- PV S/D ≥ 1
- E/e’ ≤ 8

Normal LAP
- PASP usually < 35 mmHg
  unless patient has PHT

Impaired LV Relaxation
- LAVI > 34 ml/m^2
- E/A < 1
- PV S/D ≥ 1
- E/e’ ≤ 8

Increased LAP
- PASP usually > 35 mmHg
  unless patient has low EF
  with poor CO

- E/A > 1
- PV S/D < 1
- E/e’ > 12
- E/e’ > 12
Estimation of LV Filling Pressures

Atrial Fibrillation

• Elderly pt with dyspnea and PASP ≥40mmHg has high LVFP until proven otherwise
• Exception
  – RV > LV with septal flattening
• DT <150ms predicts high LVFP in EF<40%
• E/e’ is problematic
Thanks