Learning Objectives
My presentation will help you to

• Appreciate the importance of myocardial relaxation for satisfactory diastolic function
• Assess and Grade diastolic function
• Estimate LV filling pressure noninvasively
• Incorporate Diastolic Function assessment into every Echo
• Apply Diastolic Function Assessment in
  • Diagnosis of HFpEF
  • Exercise Diastolic Test
  • Restrictive CM vs Constriction
Cardiac Function
Systole and Diastole (διαστολή)

Normal diastolic function allows adequate filling of the heart without excessive increase in diastolic filling pressure at rest and with stress.

Diastolic Filling with Relaxation
Diastolic Filling Patterns
Transmitral Gradient vs Mitral Inflow

LV Relaxation by Cath and Echo
τ (tau) vs e' (mitral annulus velocity)

Which of following patients has the most advanced diastolic dysfunction (or impaired relaxation)?

1

Myocardial Relaxation (e')

e' = 12 cm/sec  
e' = 7 cm/sec  
e' = 3 cm/sec
### Evaluation of Diastolic Function

#### Mitral Inflow and Annulus Velocity

<table>
<thead>
<tr>
<th>Normal</th>
<th>Ab Relax</th>
<th>Pseudo</th>
<th>Restrictive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grade 1</td>
<td>Grade 2</td>
<td>Grade 3</td>
</tr>
</tbody>
</table>

**Mitral Flow**
- Grade 1: Preload dependent
- Grade 2: Preload independent

**Mitral Annulus Velocity**
- Grade 1: Preload dependent
- Grade 2: Preload independent

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### Estimation of LV Filling Pressures

**E/e’ (Medial MV annulus)**

<table>
<thead>
<tr>
<th>EF &gt;50%</th>
<th>EF &lt;50%</th>
</tr>
</thead>
</table>

- **E/E’ <8**
- **E/E’ 8-15**
- **E/E’ >15**

**Evaluation of Diastolic Function**

Sohn et al: JACC, 1997

**Estimation of LV Filling Pressures**

Four Major Diagnostic Parameters
Normal Values
1. E’ velocity ≥ 7 (med), 10 (lat) cm/s
2. E/e’ ≤ 14 (Ave), 15 (Med)
3. TR velocity ≤ 2.8 m/sec
4. LAVI ≤ 34 mL/m²

New Criteria for Diastolic Function Assessment

In pts with normal LVEF≥ 50%

1 – Septal e’ velocity ≥ 7 cm/s or lateral e’ velocity ≥ 10 cm/s
2 – Average E/e’ ≤ 14, 15 (Med)
3 – TR velocity ≤ 2.8 m/s
4 – LA volume index ≤ 34 mL/m²

≥ 3 Normal
2 and 2
≥ 3 Abnormal

Normal diastolic function
Indeterminate
Diastolic dysfunction
71 year old woman with HR 45 BPM & LAVI = 39 mL/m²

LVOT TVI = 30 cm
Lateral e’ = 10 cm/sec Medial e’ = 9 cm/sec
E/e’ = 9
E/e’ = 10

E/e’ NL < 14
E’ NL > 7
LAVI Enlarged
TR NL < 2.8

67 year old man with HF

E = 100 A = 30 cm/sec
E/A = 3.3

e’ = 5 cm/sec
E/e’ = 20
In patients with depressed LVEF or normal EF with diastolic dysfunction:

- **Mitral inflow**
  - **E/A ≤ 0.8 + E < 50 cm/s**
  - **E/A ≤ 0.8 + E > 50 cm/s or E/A > 0.8 < 2**
  - **E/A ≥ 2**

3 criteria to be evaluated:

- 1. Average E/e′ > 14
- 2. TR velocity > 2.8 m/s
- 3. LA volume index > 34 mL/m²

When only 2 criteria are available:

- 2 negative
- 1 positive and 1 negative
- 2 positive

**Normal LAP**
- Grade I diastolic dysfunction
- If symptomatic consider CAD or proceed to diastolic stress test

**Cannot determine LAP and diastolic dysfunction grade**

**LAP**
- Grade II diastolic dysfunction
- Grade III diastolic dysfunction

**67 year old man with HF**

GR 3 Diastolic Dysfunction with Severe Increase in Filling Pressure

- **E = 100 cm/sec**
- **A = 30 cm/sec**
- **E/A = 3.3**
- **e′ = 5 cm/sec**
- **E/e′ = 20**
67 yo man with ischemic CM and HF
Gr. 1 dysfunction = normal filling pressure

E = 45 cm/s  A = 90 cm/s
E/A = 0.5

Grade 1 Dysfunction
E/A ≤ 0.8
E < 50 cm/sec

67 year old man with ischemic CM and HF

E = 120 cm/sec  E/A = 1.0
E/e' = 30
TR Vel = 3 m/sec

2 months before

E = 45 cm/s  Medial e' = 4 cm/s
E/A = 0.5  E/e' = 12
Ischemic Cardiomyopathy Echo Predictor
STICH Trial (N=1511)

Best survival with E/A 0.5-0.8

Case # 2 ARS
Grade the diastolic function of 23 YO male with HCM

1. Grade 1
2. Grade 2
3. Grade 3
4. Possibly normal

E = 70 cm/s  A = 30 cm/s  E/A = 2.3
23 yo with HCM

Medial e' = 8 cm/sec  E/e' = 9  Lateral e' = 10 cm/sec  E/e' = 7

Can he have a normal diastolic function?

23 yo man with HCM
LAVI  29 mL/m²

TR = 2 m/sec  IVRT = 120 msec
Valsalva in 23 yo HCM
Normal filling pressure

E/A = 2.3
E/A = 2.0

When LVEF is reduced or Diastolic Function is abnormal

Mitral inflow

E/A ≤ 0.8 + E < 50 cm/s

E/A ≤ 0.8 + E > 50 cm/s or E/A > 0.8 < 2

3 criteria to be evaluated*:

1. Average E/e’ > 14
2. TR velocity > 2.8 m/s
3. LA volume index > 34 mL/m²

2 of 3 negative

2 of 3 or 3 of 3 positive

When only 2 criteria are available

2 negative
1 positive and 1 negative
2 positive

Normal LAP
Grade I diastolic dysfunction

Cannot determine LAP and diastolic dysfunction grade*

↑ LAP
Grade II diastolic dysfunction

↑ LAP
Grade III diastolic dysfunction

If symptomatic consider CAD or proceed to diastolic stress test

When 2 criteria are negative:

2 negative

2 positive

When 2 criteria are positive:

2 positive

3 of 3 positive

When only 2 criteria are available:

2 positive

2 of 3 positive

If symptomatic consider CAD or proceed to diastolic stress test

↑ LAP
Grade III diastolic dysfunction

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Prognosis of a patient after AMI

E’ = 8 cm/s

TR = 2 m/sec

Anterior Wall Myocardial Infarction
An elderly man with exertional dyspnea

**HFpEF**

- **E** = 80  **A** = 80
- **E’** = 5 cm/sec
- **E/e’** = 16
- **TR** = 2.9 cm/s

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Diastolic function assessment in patients with mitral annulus calcification

- **E** = 100 cm/sec
- **E’** = 4 cm/s  **Med e’** = 3 cm/s
- **TR** = 2.4 m/sec
### Mitral annulus e’ velocity vs MAC

Mean age 73 years

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group 1 n=79 no MAC</th>
<th>Group 2 n=38 mild MAC</th>
<th>Group 3 n=38 mod-severe MAC</th>
<th>P for trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agatston Score</td>
<td>0</td>
<td>1-119</td>
<td>&gt;119</td>
<td></td>
</tr>
<tr>
<td>Septal e’</td>
<td>5.96±1.82</td>
<td>5.15±1.56</td>
<td>5.05±1.93</td>
<td>0.01</td>
</tr>
<tr>
<td>Lateral e’</td>
<td>7.37±2.44</td>
<td>6.89±2.71</td>
<td>6.28±1.81</td>
<td>0.01</td>
</tr>
<tr>
<td>Average e’</td>
<td>6.63±2</td>
<td>6.02±1.79</td>
<td>5.67±1.69</td>
<td>0.01</td>
</tr>
<tr>
<td>E/avg e’ ratio</td>
<td>13±4.93</td>
<td>15±8.95</td>
<td>18±8.26</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

LV diastolic parameters are altered in the presence of MAC. This could be due to direct effects of MAC or might reflect truly reduced diastolic function. Interpretation of diastolic parameters in patients with MAC should be performed with caution.

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### Proposed Clinical Algorithm for Estimation of Left Ventricular Filling Pressure in Subjects With Mitral Annular Calcification

**Initial Cohort (n=50):**
- Sensitivity: 81%
- Specificity: 100%

**Total Cohort (n=71):**
- Sensitivity: 85%
- Specificity: 95%

- **Mitral E/A**
  - **<0.8**
    - **Normal LVFP**
      - Initial: 8/9 (89%)
      - Total 12/13 (92%)
    - **IVRT**
      - ≥80 ms
        - **Normal LVFP**
          - 4/9 (44%)
          - 9/14 (64%)
        - **<80 ms**
          - **High LVFP**
            - 16/16 (100%)
            - 23/24 (96%)
  - **0.8-1.8**
    - **Normal LVFP**
      - 10/10 (100%)
      - 11/11 (100%)
  - **>1.8**
    - **High LVFP**
      - 10/10 (100%)
      - 11/11 (100%)
Atrial Fib. And Mitral Regurgitation

Medial e\(^{\prime}\) = 8 cm/s

E = 90 cm/s  E/e\(^{\prime}\) = 11

TR = 2.5 m/sec

Atrial Fib. And Mitral Regurgitation with exercise

E = 90 cm/s

E = 130 cm/s and DT 120 msec

Medial e\(^{\prime}\) = 8 cm/s

Medial e\(^{\prime}\) = 9 cm/s

TR = 2.5 m/sec

TR = 3.2 m/sec
Diastolic Function in A. Fib

- DT < 160 msec (with reduced EF)
- DT < 130 msec poor survival (Hurley, Oh)
- Other measurements
  - E acceleration > 1900 cm/sec²
  - IVRT ≤ 65 msec
  - E/e’ ≥ 11
  - IVRT/ T E-e’
  - TR velocity

Mitral Annulus Velocity in the Evaluation of Left Ventricular Diastolic Function in Atrial Fibrillation

Dae-Won Sohn, MD, Jong-Min Song, MD, Joo-Hee Zo, MD, In-Ho Chai, MD, Hyo-Soo Kim, MD, Hong-Gu Chun, MA, and Hee-Chan Kim, PhD, Seoul, Korea

JASE 1999
An elderly patient with worsening dyspnea

Take-home message Part 1

- Abnormal LV relaxation is one of the first manifestation of diastolic dysfunction
- Mitral annulus e’ velocity is a clinically reliable parameter for LV relaxation
- Diastolic function and filling pressure can be assessed by simple Echo-Doppler parameters at rest and with exercise
- $E/e' \geq 15$ is specific for increased filling pressure
Mitral Regurgitation and Diastolic Function

E = 80 cm/s
E' = 6 cm/s
E/e' = 13
Mitral Regurgitation and Diastolic Function

Assessment of Diastolic Filling
Before and after TAVR

Baseline Normal Filling Pressure
Post TAVR with PVAR
Increase in FP
89 year old with TAVR
4 year follow-up

Stages of Heart Failure
2013/14 HF Guideline

A
At high risk for HF W/O SHD or symptoms

B
Structural Heart Disease W/O symptoms or signs

C
Structural Heart Disease W/ symptoms or signs

D
Refractory Heart Failure
Distribution of Values of LV Morphofunctional Parameters for Stage B Heart Failure Categorization


Moderate-to-severe LVH
n=123

<table>
<thead>
<tr>
<th>E/e' &gt; 13</th>
<th>Strain &gt; -18% (n=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=40</td>
<td>Strain ≤ -18% (n=29)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>E/e' &lt; 13</th>
<th>Strain &gt; -18% (n=11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=83</td>
<td>Strain ≤ -18% (n=60)</td>
</tr>
</tbody>
</table>

No or mild LVH
n=387

<table>
<thead>
<tr>
<th>E/e' &gt; 13</th>
<th>Strain &gt; -18% (n=13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=71</td>
<td>Strain ≤ -18% (n=58)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>E/e' &lt; 13</th>
<th>Strain &gt; -49% (n=13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=316</td>
<td>Strain ≤ -18% (n=267)</td>
</tr>
</tbody>
</table>

Mitral A duration is shorter than PV AR
Increased LVEDP
LVEDP can be increased with normal mean LV diastolic pressure

LEVDP Elevation with normal filling pressure
“L” Wave
Delayed Relaxation + Increased Filling Pressure

Mid-diastolic mitral flow (L)
Delayed relaxation

95 year old woman
Normal “L” wave