Learning Objectives for Diastology
After this talk, you will be able to

• Understand physiology and hemodynamics of diastole
• Know correlation between Echo diastolic parameters and underlying hemodynamics
• Appreciate how 2016 Guideline was created
• Understand pitfalls of Echo diastolic function assessment
• Classify and grade diastolic function
• Estimate filling pressure reliably in most patients at rest and with exercise
Do you believe Diastolic Function Assessment is Essential in Echocardiography and Patient management?

1. YES
2. NO
3. I Am Not Sure
4. Only Important for Board Examination
Transmitral Blood Flow Reflecting Diastolic Behavior of the Left Ventricle in Health and Disease—A Study by Pulsed Doppler Technique—

Healthy Normal

Hypertension

Hypertrophic CM

Myocardial Infarction

Diastolic Filling with Relaxation

διαστολή: Greek word for dilation
Myocardial relaxation is one of the earliest manifestations of mechanical dysfunction of the human LV. The time constant tau (T) is higher in the elderly and patients with HCM, CAD, and cardiomyopathies.
Relation of Transmital Flow Velocity Patterns to Left Ventricular Diastolic Function: New Insights From a Combined Hemodynamic and Doppler Echocardiographic Study

CHRISTOPHER P. APPLETON, MD, LIV K. HATLE, MD, RICHARD L. POPP, FACC
Stanford, California and Tucson, Arizona

Pseudo-normalization

LV relaxation

LA pressure

All combinations = 7
(ie, same mitral inflow velocity pattern)
Mitral Inflow and Pulmonary Vein Flow
Diastolic Function Assessment

Diastolic Function Grading
Mitral Inflow (U curve)

Normal
Abnormal relaxation
Pseudo-normalization
Restrictive

LAP
NL (< 15)
Normal
↑ ↑
↑ ↑

TAU
NL (< 45)
↑
↑

Grade
1
2
3

Concept from Appleton and Hatle, 1985
Assessment of LV Relaxation by Echo

*e’* velocity reflects LV relaxation

Myocardial Relaxation is the Key for Diastole

Myocardial Relaxation (*e’*)

- *e’* = 12 cm/s
- *e’* = 7 cm/s
- *e’* = 4 cm/s
Evaluation of Diastolic Function

Mitral Inflow and Annulus Velocity

Normal
Ab Relax
Grade 1

Pseudo
Grade 2

Restrictive
Grade 3

Mitral flow
Mitral annulus velocity

Preload dependent
Preload independent

DW Sohn et al: JACC, 1997

As LV filling pressure ↑

Mitral E ↑
Annulus E ’ ↓
E/E ’ ↑

Nagueh et al: JACC, 1997
Ommen et al: Circ, 2000

y=1.9 + 1.24x
r=0.87
n=60

PCWP (mm Hg)
Estimation of LV Filling Pressures
E/e’ (Medial MV annulus)


Serial Doppler Echocardiography and Tissue Doppler Imaging in the Detection of Elevated Directly Measured Left Atrial Pressure in Ambulant Subjects With Chronic Heart Failure

Ritzema et al JACC Imaging 2011
What are normal values for e’ and E/e’? Who has normal diastolic function?

LA Volume Index vs Diastolic Dysfunction

Indexed LA volume

Diastolic function grade

Normal I II III

r=0.78
n=147 pt
Hypertensive Heart Disease vs HFpEF
Importance of PASP and E/e’

- PASP*
- E/e’ ratio†
- Left atrial volume index*†
- Relative wall thickness*†
- Left ventricular mass index†
- Line of no information

1-Specificity

Sensitivity

p<0.01 *vs line of no information; †vs PASP

Four Major Parameters in Diastology

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

ASE/EACVI GUIDELINES AND STANDARDS

Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging

Sherif F. Naghieh, Chair, MD, FASE,1 Otto A. Smaith, Co-Chair, MD, PhD,2 Christopher P. Appleton, MD,1 Benjamin F. Byrd, III, MD, FASE,1 Hisham Dokainish, MD, FASE,1 Thor Edvardsen, MD, PhD,2 Frank A. Flachskampf, MD, PhD, FESC,2 Thierry C. Gillebert, MD, PhD, FESC,2 Allan L. Klein, MD, FASE,1 Patrizio Lancellotti, MD, PhD, FESC,2 Paolo Marino, MD, FESC,2 Jae K. Oh, MD,1 Bogdan Alexandru Popescu, MD, PhD, FESC, FASE,2 and Alan D. Waggner, MHS, RDMS1, Houston, Texas

Four Major Diagnostic Parameters

Normal Values

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

JASE and EJ CV Imaging April 2016
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

Criteria for diagnosis of LV diastolic dysfunction in patients with normal LVEF in JASE 2016

Echocardiographic reference ranges for normal cardiac Doppler data: results from the NORRE Study

Luis Caballero et al: EHJ, 2015
Normal Diastolic Function According to 2016 Guideline
Both have LAVI < 34 mL/m² and TR < 2.8 m/sec

E = 80 A = 40  E/A = 2.0
Septal e’ = 12 cm/sec  E/e’ = 7
True Normal

E = 50 A = 100  E/A = 0.5
Septal e’ = 6 cm/sec  E/e’ = 8
Age-Related Normal

Burden of Systolic and Diastolic Ventricular Dysfunction in the Community

- Majority was asymptomatic
- Mean age 62.8 year old
- 4.5% Diabetes
- 12.2% CAD
- 25% Hypertension

Asymptomatic patients with Grade 1 have > 40% Mortality at 4 year

Redfield et al. JAMA 2003
59 year old male with multiple myeloma
No cardiac symptoms

LAVI = 28 mL/m²

59 year old male with multiple myeloma
No cardiac symptoms

TR = 2.3 m/s
E = 50 cm/s E/A = 0.8
Septal e’ = 5 cm/s E/e’ = 10

3 are Normal → Normal DF
Impact of the 2016 ASE/EACVI recommendations on the prevalence of diastolic dysfunction in the general population

Almeida et al EJCVI 2018


Prabhakaran Gopalakrishnan MD et al AHA 2018
72 year old male with dyspnea
LAVI and TR Velocity are Normal

\[ E = 40 \text{ cm/s} \quad E/A = 0.5 \]

\[ \text{Medial } e' = 5 \text{ cm/s} \quad E/e' = 8 \]

What if he has hypertension,?

Abnormal Diastolic Dysfunction by History and 2-D 2016 Diastolic Function Guideline (Algorithm #2)

- Reduced LVEF (< 50%)
- Hypertension
- Coronary artery diseases
- Diabetes Mellitus
- LVH
- LA enlargement

We are assuming abnormal relaxation, hence reduced e’ velocity. The best diastolic function in this population is grade 1 based on mitral inflow velocity.
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
    - 3 criteria to be evaluated
      - Average E/e’ >14
      - TR velocity >2.8 m/s
      - LA volume index >34 mL/m²
  - 2 of 3 or 3 of 3 positive

- Cannot determine LAP and diastolic dysfunction grade:
  - 2 negative
  - 1 positive and 1 negative
  - 2 positive

- LAP
  - Grade II diastolic dysfunction
    - 2 of 3 or 3 of 3 positive
  - Grade III diastolic dysfunction
    - 3 of 3 positive

If symptomatic consider CAD or proceed to diastolic stress test.

71 year old woman with TR = 2.6 m/sec & LAVI = 39 mL/m²

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

1= Grade 1
2= Grade 2
3= Grade 3
4= Normal

Lateral e’ = 10 cm/sec
Medial e’ = 9 cm/sec
71 year old woman with TR = 2.6 m & LAVI = 39 mL/m²

- Lateral e' = 10 cm/sec
- E/e' = 9
- LVOT TVI = 26 cm

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

Reasons for LA enlargement

- Diastolic dysfunction
- Increased filling pressure
- Increased volume
- Athlete’s heart
- Measurement error
Definition of Diastolic Function and Dysfunction

- Normal Diastolic Function
  - Normal Myocardial Relaxation
  - Normal Mitral Annulus e’ velocity

- Abnormal Diastolic Function
  - Abnormal Myocardial Relaxation
  - Reduced Mitral annulus e’ velocity

- Increased Filling Pressure
  - Abnormal Relaxation, E/e’, TR and (LA Volume)

Diastolic Function Assessment by E and e’
82 year old male with dyspnea

LAVI = 38 mL/m²

E/A = 1  E= 95 cm/s

TR = 2.83 m/s

Medial e′= 5  E/e′=17

Lateral e′= 7  E/e′=13

The 2016 Algorithm #1

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

Criteria for diagnosis of LV diastolic dysfunction in patients with normal LVEF in JASE 2016
Suggested Algorithm #1 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

E/e’, TR, and LAVI indicate increased filling pressure

≥ 3 Normal

≥ 3 Abnormal

Normal diastolic function

Diastolic dysfunction

Normal Filling Pressure

Indeterminate

Increased Filling Pressure

The 2016 Algorithm for Reduced EF (<50%) or Known (or Suspected) Diastolic Dysfunction/EF ≥ 50%

(Hypertension, CAD, Diabetes, MI, History of HF, LVH, LAE)

Mitral inflow

E/A ≤ 0.8 + E > 50 cm/s

3 criteria to be evaluated

2 of 1 negative

2 of 3 negative

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

T LAP

Grade II diastolic dysfunction

Grade III diastolic dysfunction

E/A = 2.3

E = 70 cm/s  A = 30 cm/s

Grade 3

23 yo with LVH
23 yo with LVH

E = 70 cm/s

Medial $e\prime = 8$ cm/sec

Lateral $e\prime = 10$ cm/sec

E/e’ = 9

E/e’ = 7

Can he have a normal diastolic function?

23 yo man with HCM

LAVI 29 mL/m$^2$

TR = 2 m/sec

IVRT = 120 msec
Valsalva in 23 yo HCM
Normal filling pressure

Normal Valsalva: Both E and A decrease with E/A change < 0.5

Valsalva Maneuver: E/A reduced > 0.5
Grade 2 Dysfunction

E = 90 A = 40 E/A = 2.3
E = 60 A = 60 E/A = 1.0
Individuals with HPT, CAD, LVH, DM, or MI Can Have Normal Diastolic Function

Especially in Young Individuals

The 2016 Algorithm for Reduced EF (<50%) or Known (or Suspected) Diastolic Dysfunction/EF≥50%
(Hypertension, CAD, Diabetes, MI, History of HF, LVH, LAE)

- 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

- When only 2 criteria are available
  - 2 negative
  - 1 positive and 1 negative
  - 2 positive

- E' < 7 cm/s

- If symptomatic consider CAD or proceed to diastolic stress test

- Normal LAP
  - Grade I diastolic dysfunction

- Cannot determine LAP and diastolic dysfunction grade

- ↑LAP
  - Grade II diastolic dysfunction

- ↑LAP
  - Grade III diastolic dysfunction
What about combining 2 algorithms together?

**Revised Algorithm for Diastolic Function Assessment**

*In Most Patients*

1. Septal e’ velocity ≥7 cm/s
2. E/e’ ≤ 15 (Med)
3. TR velocity ≤2.8 m/s
4. LA volume index ≤34 mL/m²

*Except for*
- MAC
- MR
- LBBB/PM
- HCM
- Constriction
- Unusual Cases

≥ 3 Normal
- Normal filling pressure
- Normal DF

2 and 2
- Need more data
- PV, IVRT, Valsalva, Strain
- Grade 1 DF

≥ 3 Abnormal
- Increased filling pressure
- Grade 2 DF
- Grade 3 DF

**Diastolic Exercise**
Difficult Situations

- Assessment of diastolic function or filling pressure in
  - 2 normal and 2 abnormal
  - HCM
  - LBBB
  - MAC
  - Atrial Fibrillation
- Additional supportive parameters
  - Pulmonary vein
  - Valsalva
  - IVRT and timing intervals

How is filling pressure in a 80 yo woman with Mitral annulus calcification and TAVR?

1 = Normal  2 = Increased  3 = Indeterminate

- E = 100 cm/s
- S 50 cm/s
- D 30 cm/s
- TR = 2.4 m/sec
Correlation of Selected Doppler Variables With Left Ventricular Filling Pressure

Abudiab et al: J Am Coll Cardiol Img, 2017

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

Initial Cohort (n=50):
- Sensitivity: 81%
- Specificity: 100%
- PPV: 100%
- NPV: 67%

Total Cohort (n=71):
- Sensitivity: 85%
- Specificity: 95%
- PPV: 97%
- NPV: 78%

Initial: 8/9 (89%)
Total 12/13 (92%)

Abudiab et al: J Am Coll Cardiol Img, 2017
Diastolic Function in A. Fib

- DT < 160 msec (with reduced EF)
- DT < 130 msec poor survival
- Other measurements
  - IVRT ≤ 65 msec
  - E/e’ ≥ 11
  - 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

L wave

E/e’ = 20

JASE 1999
Atrial Fibrillation
Variation in E velocities: NL Pressure

Variation in E velocities and E/e’ <11

E/e’ = 9
E/e’ Predicts Survival in Nonvalvular Atrial Fibrillation


23 YO with LVH on ECG
What does the white arrow indicate?

1. J wave
2. K wave
3. O wave
4. L wave

E = 70 cm/s  A= 30 cm/s  E/A = 2.3
**L wave**

• Usually > 40 cm/sec
• Related to delayed myocardial relaxation
• Indicates increased filling pressure
  - Grade 2 or 3 dysfunction
• Can be present in normal heart with bradycardia
  - Usually < 40 cm/sec

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**Diastolic Function?**

1. Grade 1
2. Grade 2
3. Grade 3
4. Normal
5. Indeterminate

- e’ ABNL < 7
- E/e’ ABNL > 14
- LAVI ??
- TR ABNL > 2.8
Diastolic Function?

- $e' = 4$ cm/sec
- $E/e' = 30$
- $E = 120$ cm/s
- $E/A = 6$
- $e' ABNL < 7$
- $E/e' ABNL > 14$
- LAVI ??
- TR NL > 2.8

Mid-diastolic mitral flow (L)

**Delayed relaxation**

Mitral annulus e’ velocity

- ASE/EACVI recommends average value
- E’ from one location is acceptable
- We need a caution in using e’
  - Primary pulmonary hypertension
  - Pacemaker
  - LBBB
  - Wall motion abnormality
  - Mitral annulus calcification
  - Hypertrophic CM
67 yo woman with LBBB

E = 60 A = 80 E/A = 0.7

Medial e' = 3 cm/s E/e' = 23

Lat e' = 9 cm/s E/e' = 8

67 yo with LBBB

TR = 2.4 m/sec
Conclusion: In decompensated patients with advanced systolic heart failure, tissue Doppler-derived mitral E/e' ratio may not be as reliable in predicting intracardiac filling pressures, particularly in those with larger LV volume, more impaired cardiac indices, and the presence of cardiac resynchronization therapy.
Discordance between PCWP and E/e’
Reduced LVEF and LBBB


E/A >2
E/e’ 18 Medial
E/e’ 7 Lateral
PCWP 23

Echocardiographic Evaluation of Hemodynamics in Patients with Decompensated Systolic Heart Failure
Sherif F. Naghieh, Rajat Bhatt, Rey P. Vico, Selim R. Kran, Sebastian Imre Savari, Kristoffer Russell, Thor Edvardsen, Otto A. Smaleseth and Jerry D. Estep
Circ Cardiovasc Imaging published online March 11, 2011.
DOI: 10.1161/CIRCIMAGING.111.963496
Diastolic Function Evaluation in HCM

• E' velocity is reduced in almost all patients
• E/e' predicts clinical outcome
• Use following parameters (ASE 2016 Guideline)
  • E/e' >15
  • LAVI >34 mL/m²
  • TR velocity > 2.8 m/sec
  • PV Ar-A duration ≥ 30 msec
• The majority rules

Evaluation of Left Ventricular Filling Pressures by Doppler Echocardiography in Patients With Hypertrophic Cardiomyopathy
Correlation With Direct Left Atrial Pressure Measurement at Cardiac Catheterization

Jeffrey B. Geske, MD; Paul Sorajja, MD; Rick A. Nishimura, MD; Steve R. Ommen, MD

Conclusions—In 100 symptomatic patients with HCM, Doppler echo estimates of LV filling pressure correlate modestly with direct measurement of LAP. Given the complex nature of diastolic dysfunction in HCM, precise characterization of LV filling pressure in an individual patient cannot be determined with the use of these noninvasive parameters. (Circulation. 2007;116:2702-2708.)
Medial E/e’ Ratio Versus Mean LAP in HCM


Mean LAP vs Medial E-e’ ratio
Hypertrophic CM

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

Cannot determine LAP and diastolic dysfunction grade*

 ↑ LAP
Grade II diastolic dysfunction

If symptomatic consider CAD or proceed to diastolic stress test

Grade III diastolic dysfunction

Diastolic Stress Echocardiography
First Published in Jan 2005

Diastolic Stress Echocardiography: A Novel Noninvasive Diagnostic Test for Diastolic Dysfunction Using Supine Bicycle Exercise Doppler Echocardiography

Jong-Won Ha, MD, PhD, Jae E. Oh, MD, Patricia A. Petikis, MD, Steve R. Ommen, MD, Vicky L. Sunyer, RN, RD, DNS, Kent R. Bailey, PhD, James B. Seward, MD, and A. Jamil Tajik, MD, Rochester, Minnesota

Left ventricular filling pressures can be estimated reliably by combining mitral inflow early diastolic velocity (E) and annulus velocity (E′). An increased E/E′ ratio reflects elevated filling pressures and may be useful in assessing an abnormal increase in filling pressures for patients with diastolic dysfunction. Although the percentage of dyspnoeic patients with depressed E/E′ during exercise (group 1A) and 9 in E/E′ during exercise (group 1B). For group 2, E/E′ did not increase. Despite different responses in left ventricular filling pressures, no significant difference in diastolic function between the different groups although the percentage of dyspnoeic patients with depressed E/E′ during exercise (group 1A) and 9

If symptomatic consider CAD or proceed to diastolic stress test

Diastolic Stress Echocardiography: The Time Has Come for Its Integration into Clinical Practice

Jae K. Oh, MD and gastroenterology JASE 2014

Ha et al JASE 2005 and Oh et al JASE 2014

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73 yo woman with Hypertension and Exertional Dyspnea
No ischemia

"This patient has delayed myocardial relaxation, but filling pressure is not increased at rest"

Change in CI and PCWP with Exercise
Normal and Abnormal Diastolic Function

Cardiac index (L/min/m²)

PCWP (mm Hg)
Dynamic Diastology
Filling Pressure (E/e’) with Exercise

Normal

Abnormal

LV filling pressure (E/e’) does not increase much with exercise in normal heart, but increases in symptomatic patients with diastolic dysfunction.

Diastolic Stress Test

Baseline and Peak (or Post) Exercise

• Supine bike or Treadmill
• 25 watts (3 min) increments
• Assess LVEF, size, and wall motion
• Mitral inflow (E, A, and DT)
• Mitral annulus velocity
• E/e’ ratio
• TR velocity
### Effects of Treadmill Exercise on Mitral Inflow and Annular Velocities in Healthy Adults

Jong-Won Ha, MD, PhD, Fabijan Lukic, MD, Kent R. Bailey, PhD, Patricia A. Pellikka, MD, James B. Seward, MD, A. Jamil Tajik, MD, and Jae K. Oh, MD

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>E (cm/s)</td>
<td>73±19</td>
<td>90±25</td>
</tr>
<tr>
<td>A (cm/s)</td>
<td>69±17</td>
<td>87±22</td>
</tr>
<tr>
<td>DT (ms)</td>
<td>192±40</td>
<td>176±42</td>
</tr>
<tr>
<td>e' (cm/s)</td>
<td>12±4</td>
<td>15±5</td>
</tr>
<tr>
<td>E/e'</td>
<td>6.7±2.2</td>
<td>6.6±2.5</td>
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Mean age 59±14 yrs

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### LV Diastolic Function at Rest and With Stress

Diastolic Stress Echocardiography in the Young: Nonathletic (NA) and Endurance-Trained (ET) Healthy Subjects

Bruengger et al: JASE, 2014

- **E** (cm/s)
  - Rest: ET, NA
  - Exercise: ET, NA

- **e' septal** (cm/s)
  - Rest: ET, NA
  - Exercise: ET, NA

Mean age 29 yrs
Exertional Dyspnea

Baseline

- E = 50
- DT = 250
- e' = 7
- E/e' = 7
- TR = 2.4

Supine Bike

- E = 85
- DT = 140
- e' = 7
- E/e' = 12
- TR = 3.8

Echo Hemodynamics During Exercise
E/e' at Sub- and Maximal Exercise
HFpEF = PCWP > 25 mmHg

Submaximal (20W)
- P<0.0001
- 11% Not measurable

Peak
- P<0.0001
- 20% Non measurable

The 2016 Guideline can be improved!

- Cut-off values are based on the asymptomatic elderly
- Confusion between diastolic dysfunction and increased filling pressure
- Early or compensated diastolic dysfunction (Grade 1) can be classified as normal diastolic function
- Adjudication of diastolic dysfunction by clinical and 2-D imaging data may not be reliable or available
- There are 2 separate algorithms
- Additional promising parameters (LA Strain)
Left atrial volume index (LAVI) and LA strain

- Overlap of LAVI among normal and abnormal diastolic function (26% abnormal in Almeida study; EHJ Imaging 2018)

- LA volume measurement can be technically challenging

- LAVI does not regress much as LVFP gets normalized, but LA strain does. (Huynh et al JASE 2015)

Singh et al: JACC Imaging 10:735, 2017
Diastolic Function Assessment
Take Home Point #1

- LV myocardial relaxation is reduced in all stages of diastolic dysfunction
- Mitral annulus e’ velocity reflects myocardial relaxation
- Normal e’ = Normal diastolic function
- Algorithm #1 separates normal filling from elevated filling pressure
- Initial assessment of diastolic function is based on
  - E’, E/e’, TR velocity, and LAVI
Diastolic Function Assessment
Take Home Message #2

- Grade 1 diastolic dysfunction is the best pattern for the patients with Heart Failure
- Evidence for diastolic dysfunction needs an objective evidence
  - Hypertension
  - Cardiac amyotrophy
  - Old age
  - DM

The best evidence is reduced relaxation
- Reduced e’
- L wave
- Prolonged IVRT

Clinical Applications of Diastolic Function Assessment

- Estimation of Filling Pressure at Rest and with Exercise
  - Diagnosis of Heart Failure (with Preserved LVEF)
  - Evaluation of Dyspnea

- Identification of Myocardial Disease
  - Amyloid vs HCM vs Athlete’s Heart vs Hypertension
  - Distinction between Restrictive CM and Constriction

- Prognosis
  - Myocardial Infarction
  - Myocardial Diseases
  - Aortic Stenosis
Echocardiography as a Noninvasive Swan-Ganz Catheter

Jae K. Oh, MD

E/e' = PAWP

RAP

PAP

PCWP

Hepatic Vein

IVC

TR

Mitral Inflow E

Mitral Annulus e'

Oh Circulation June 2005

Questions & Discussion