Diastolic Dysfunction

Gary W. Lewis, M.D.
Diastolic heart failure (DHF) is a clinical syndrome in which patients have symptoms and signs of HF, normal or near normal left ventricular ejection fraction (LVEF), and evidence of diastolic dysfunction (eg, abnormal left ventricular filling and elevated filling pressures).
Diastolic dysfunction and diastolic heart failure (DHF) are not synonymous. The term diastolic HF is reserved for patients with clinical HF, in the setting of a normal or near-normal EF, and abnormalities in diastolic function
HFPEF
HFPEF
Heart Failure with Preserved Ejection Fraction
Types of heart failure

Chronic heart failure

- EF <35 percent: HF-REF, SHF
- EF 35-50 percent: HF-PEF
- EF >50 percent: DHF

Clinical trials
- DIG Ancillary Study EF: EF >45 percent
- CHARM-Preserved: EF >40 percent
- PEP-CHF: EF >45 percent
- I-Preserve: EF >45 percent
- SENIORS: EF >35 percent

Courtesy of Dr. Michael Zile.
## Left ventricular structure and function in chronic heart failure

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<th>Systolic heart failure</th>
<th>Diastolic heart failure</th>
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<td>End-diastolic volume</td>
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<td>End-systolic volume</td>
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<td>Geometry</td>
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<td>Cardiomyocyte</td>
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<td>Extracellular matrix</td>
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<td><strong>LV systolic properties</strong></td>
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<td><strong>Performance</strong></td>
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<td>Stroke volume</td>
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<td><strong>Function</strong></td>
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<td>Stress shortening</td>
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<td>Preload reserve</td>
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<td><strong>LV diastolic properties</strong></td>
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<td>End diastolic pressure</td>
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<td>Chamber stiffness</td>
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<tr>
<td>Myocardial stiffness</td>
<td>Normal (or ↑)</td>
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Courtesy of Dr. Michael Zile.

[UpToDate]
A model of the sliding filament theory of muscular contraction. Panel A shows myosin in the relaxed state having just been bound by ATP. Panel B shows the first step by which myosin is energized via hydrolysis of an ATP high energy phosphate bond, resulting in the formation of ADP and inorganic phosphate (Pi). The myosin head then binds actin at the myosin binding site, forming the actin-myosin crossbridge as shown in Panel C. Panel D shows release of ADP and inorganic phosphate, plus flexion of the myosin molecule at its hinge point, causing the filaments to slide past each other. The crossbridge remains until myosin is again bound by ATP which allows dissociation of the myosin and actin and relaxation of the myosin molecule. The actin-myosin complex returns to the state in Panel A except that the filaments have now moved relative to each other.

*Courtesy of Timothy W Smith, MD, PhD.*
DHF is associated with remodeling that affects left ventricular and left atrial chambers, the cardiomyocytes, and extracellular matrix with impact on diastolic as well as systolic function. Nearly all patients with diastolic HF have a normal LV end diastolic volume; most have increased LV wall thicknesses, mass and relative wall thickness
The prevalence of DHF increases with age. DHF is more common in women than in men.

Asymptomatic diastolic dysfunction is much more common than symptomatic disease.
The major causes of DHF are chronic hypertension with left ventricular hypertrophy, hypertrophic cardiomyopathy, coronary heart disease, and restrictive cardiomyopathy. Diastolic function is determined by two factors: the process of myocardial relaxation (which is an active process that requires metabolic energy) and the elasticity or distensibility of the left ventricle (which is a passive process).
Diastolic and systolic HF have similar symptoms. Exercise intolerance seen in DHF may be caused by elevation in left atrial and pulmonary venous pressures and/or impaired stroke volume leading to dyspnea and fatigue.
In clinical practice, the diagnosis of DHF is typically based upon finding signs and symptoms of HF, normal or mildly abnormal LVEF (LVEF >50 percent), and evidence of diastolic dysfunction on Doppler echocardiography.
DHF is one of several causes of cardiogenic pulmonary edema in patients with a normal LVEF.

Occult coronary heart disease is a potentially reversible cause of DHF.
Plasma BNP and N-terminal pro-BNP are elevated in patients with DHF but cannot effectively distinguish DHF from SHF
The key distinguishing feature between systolic and diastolic HF is whether the ejection fraction is reduced (indicating systolic HF) or preserved, meaning normal or near-normal (indicating diastolic HF). Diastolic dysfunction is not the only cause of HF in patients with preserved LVEF.
### Differential diagnosis of heart failure with preserved left ventricular ejection fraction

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<td>Restrictive cardiomyopathy</td>
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<td>Infiltrative cardiomyopathies</td>
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<td>Hypertrophic cardiomyopathy</td>
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<td>Noncompaction cardiomyopathy</td>
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<td>Coronary heart disease</td>
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<td>Miscellaneous factors: diabetes mellitus, chronic kidney disease, aging</td>
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<td>Valvular stenosis</td>
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<td>Valvular regurgitation</td>
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<th>Right heart failure</th>
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<td>Pulmonary hypertension</td>
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<td>Right ventricular infarction</td>
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<td>Arrhythmogenic right ventricular cardiomyopathy</td>
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<th>Pericardial disease</th>
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<td>Cardiac tamponade</td>
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<td>Constrictive pericarditis</td>
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<td>Effusive-constrictive pericardial disease</td>
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<th>Intracardiac mass</th>
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<td>Atrial myxoma</td>
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<th>Episodic or reversible LV systolic dysfunction</th>
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<th>Pulmonary vein stenosis</th>
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During exercise, physiologic mechanisms normally ensure that cardiac input keeps pace with cardiac output with preservation of a low pulmonary venous pressure.
Since both afterload (systolic pressure) and diastolic load (left atrial diastolic pressure) can affect measurement of diastolic function, these factors must be considered in assessing the intrinsic relaxation rate.
The two most common pathways to DHF are left ventricular hypertrophy and ischemia.
In patients with diastolic heart failure (DHF), certain types of hemodynamic stress including atrial fibrillation; tachycardia; abrupt, severe, or refractory elevations in systemic blood pressure, and myocardial ischemia are associated with worsening of diastolic dysfunction.
Echocardiography is the recommended imaging modality for the assessment of left ventricular (LV) diastolic function.
Doppler measurements provide incremental prognostic information to clinical and anatomic findings
Phases of diastole

- Aorta
- Left ventricle
- Left atrium
- LV volume

Systole: MVC to AVC
Diastole: AVO to MVO

Isovolumic pressure decline
Isovolumic relaxation
Auxotonic relaxation
Rapid filling
Slow filling
Atrial filling
Diastole begins with isovolumic relaxation followed by auxotonic relaxation and continues until atrial contraction is complete. During the later phases of diastolic HF, the LV is readily distensible. Atrial contraction normally contributes 20 to 30 percent to total LV filling volume but usually increases diastolic pressures by less than 5 mmHg.
Diastole
Isovolumic Relaxation Time (IVRT)
Normal IVRT 70-90ms. IVRT lengthens w/ impaired LV relaxation and shortens when LV compliance is decreased and LV filling pressures increase. IVRT varies with HR, preload and ventricular function.
Calculation of PA systolic pressure using the TR jet.

\[ 4 (V)^2 \text{ of peak TR velocity} = \text{PAS} - \text{RAP} \]
\[ 4 (3.6)^2 \text{ or } 52 = \text{PAS} - 20 \]
\[ \text{PAS} = 52 + 20 = 72 \text{ mmHg} \]

Calculation of PA diastolic pressure using the PR jet (left) and hepatic venous by PW Doppler (right).

\[
4 \cdot (V)^2 \text{ of end diastolic PR velocity} = \text{PAD} - \text{RAP}
\]
\[
4 \cdot (2)^2 \text{ or } 16 = \text{PAD} - (15 \text{ or } 20)
\]
\[
\text{PAD} = 16 + (15-20) = 31-36 \text{ mmHg}
\]

In patients with normal LV EF, the initial step is calculating the E/e' ratio.
Tissue Doppler Imaging (e’)

- E/e’ ratio (combo of transmitral flow velocity and annular velocity) is best parameter for predicting mean LVEDP
  - <8 is normal,
  - >15 abnormal
Tissue Doppler Imaging (e’)

http://www.echobasics.de/diastole-en.html
Septal and lateral velocities should be acquired by PW Doppler
Sample volume should be placed at or 1 cm within septal and lateral insertion sites of mitral leaflets
Identify e’ from
Isovolumic Relaxation velocities

Avoid angulation
E/e’ not accurate in mitral valve disease, heavy annular calcification, constrictive pericarditis, and abnormal septal motion
Average E/e’ ratio in patients with regional dysfunction
Example of tissue Doppler recordings

- Frequency: 1.7 MHz/3.4 MHz
- Depth: 20.0 cm
- Gain: 3.0 dB

- e' 3-5 cm/s
- Septal e'

- e' 6.5-8 cm/s
- Lateral e'

Courtesy of Dr. Sherif F Nagueh.
A ratio <8 is often associated with normal LV filling pressures and a ratio >15 is indicative of elevated LV filling pressures. In patients with a ratio >8 but <15, other parameters are needed, which include pulmonary venous flow velocities, LA maximum volume index, and PA systolic pressure using the tricuspid regurgitation jet using continuous wave Doppler.
Tissue Doppler (TD) recording from the lateral mitral annulus from a normal subject aged 35 years (left) (é = 14 cm/s) and a 58-year-old patient with hypertension, LV hypertrophy, and impaired LV relaxation (right) (é = 8 cm/s).


Septal (left) and lateral (right) tissue Doppler recordings from a patient with an anteroseptal myocardial infarction.

Lateral (left) and septal (right) TD velocities from a patient with constrictive pericarditis.
Two-dimensional (2D) imaging is important to determine LV volumes, mass, and systolic function and left atrial (LA) volume. Patients with diastolic heart failure frequently have left ventricular hypertrophy, LA enlargement and increased PA pressures.
LA Volume

• Barometer (HgA1C) of the chronicity of diastolic dysfunction.
• Should be measured in comparison to body surface area (ml/m2)
• LA volume index
  > 34 ml/m2 is an independent predictor of death, heart failure, atrial fibrillation and ischemic stroke

(Left) End-systolic (maximum) LA volume from an elite athlete with a volume index of 33 mL/m².


Practical Approach to Grade Diastolic Dysfunction

Scheme for grading diastolic dysfunction.


Primary measurements include peak E and A velocities, E/A ratio, DT, and IVRT.
Mitral flow inflow velocities

Courtesy of Dr. Sherif F Nagueh.
The 4 phases of diastole are marked in relation to high-fidelity pressure recordings from the left atrium (LA) and left ventricle (LV) in anesthetized dogs.

<table>
<thead>
<tr>
<th>IR</th>
<th>rapid filling</th>
<th>slow filling</th>
<th>atrial contr.</th>
<th>systole</th>
</tr>
</thead>
</table>

Schematic diagram of the changes in mitral inflow in response to the transmitral pressure gradient.

Figure Legend:
The Natural History of Diastolic Function and LV Filling
DD = diastolic function; e' = early diastolic mitral annular velocity; LAP = left atrial pressure; LV = left ventricular.
Pulsed Wave Doppler is performed in the apical 4 chamber view to obtain mitral inflow velocities to assess left ventricular filling.
1-3 mm sample volume between tips of the leaflets of the mitral valve during diastole
Transmitral Doppler Inflow

http://www.echobasics.de/diastole-en.html
Valsalva maneuver can be performed to identify pseudonormal filling
The Valsalva maneuver is performed by forceful expiration (about 40 mm Hg) against a closed nose and mouth.

The patient must generate a sufficient increase in intrathoracic pressure, and the sonographer needs to maintain the correct sample volume location between the mitral leaflet tips during the maneuver. A decrease of 20 cm/s in mitral peak E velocity is usually considered an adequate effort in patients without restrictive filling.
In cardiac patients, ≥ 50% decrease in E/A ratio has high specificity for increased filling pressures, but smaller changes do not always indicate normal diastolic function.
In Systolic Heart Failure, mitral velocities and time intervals correlate better with filling pressures, and prognosis than Ejection Fraction.
In patients with depressed left ventricular systolic function, mitral inflow velocities can be used as the first step in an algorithm to estimate LV filling pressure.
When the E/A ratio is <1 and pulmonary venous flow shows predominant systolic filling, LV filling pressures are usually normal.

On the other hand, a restrictive LV filling pattern (transmitral E/A ratio (≥2), IVRT (<70 ms) and DT (<150 ms)) indicates elevated LA pressure. LA pressure elevation can be confirmed with a systolic filling fraction <40 percent.
While most patients with pseudonormal filling have elevated filling pressures, it is preferable to confirm that conclusion by additional Doppler findings. These include the following: change in E/A ratio with Valsalva, E/e' ratio (average >15), E/Vp ratio (≥2.5), and PA systolic pressures (>35 mmHg).
In Diastolic Heart Failure, mitral inflow velocities do not relate well with LV filling pressures.
Tissue Doppler echocardiography (TDE) can be used to assess the motion of the mitral annulus during diastole as a method of detecting diastolic dysfunction. The mitral valve ring moves toward the left ventricular apex (upward on the image) during systole. During diastole, there are two phases of motion. An early phase of movement away from the cardiac apex (downward on the image) corresponds to early diastolic filling and is analogous to the E wave on the Doppler profile of mitral inflow; it is marked E'. A late phase of movement in the same direction corresponds to atrial contraction and is analogous to the A wave; it is marked A'. The E' wave is blunted in the presence of either impaired relaxation or diminished compliance (restrictive physiology).

Mitral Inflow Propagation Velocity (Vp)

http://www.echobasics.de/diastole-en.html
M-mode scan line should be placed in centre of LV inflow column
Baseline shift so central highest velocity jet is blue
Color M-mode Vp from a patient with depressed EF and impaired LV relaxation.

In Systolic Heart Failure, an 
E/Vp ≥ 2.5 
has good accuracy 
in predicting 
PCWP >15 mmHg
In normal Ejection Fraction, caution should be exercised as 
Vp >50 cm/s 
despite impaired LV relaxation
Left ventricular diastolic dysfunction is a predictor of outcome after a myocardial infarction

Pulsed Doppler recordings of transmitral filling (panel A) and color M-mode Doppler echocardiography (panel B) are methods for evaluating left ventricular (LV) diastolic function. In a normal filling pattern, the mitral E-wave deceleration time (DT) is 140 to 240 ms and the M-mode flow propagation velocity (Vp) is \( \geq 45 \) cm/s. In diastolic dysfunction with impaired relaxation the DT is prolonged \( \geq 240 \) ms and Vp is normal or reduced \( (<45 \) cm/s). In a pseudonormal filling pattern the DT may be normal or prolonged, but the Vp is \(<45 \) cm/s. In diastolic dysfunction with a restrictive filling, the DT is \(<140 \) ms and the Vp is normal or \(<45 \) cm/s. Patients with a myocardial infarction who have a restrictive or pseudonormal pattern have an increased incidence of left ventricular dilation and cardiac death.

Data from Moller JE, Sondergaard E, Poulsen SH, Egstrup K. J Am Coll Cardiol 2000; 36:1841. Reprinted with permission from the American College of Cardiology.
Recording of mitral inflow at the level of the annulus (left) and pulmonary venous flow (right) from a patient with increased LVEDP. Notice the markedly increased pulmonary venous Ar velocity at 50 cm/s and its prolonged duration at >200 ms in comparison with mitral A (late diastolic).
Pulmonary vein velocities

Courtesy of Dr. Sherif F Nagueh.
Pulmonary Venous Doppler Flow

http://www.echobasics.de/diastole-en.html
PW Doppler of pulmonary venous flow is performed in the apical 4-chamber View. A 2-mm to 3-mm sample volume is placed 0.5 cm into the pulmonary vein for optimal recording of the spectral waveforms.
Measurements include peak S and D velocities, the S/D ratio, systolic filling fraction, and peak Ar velocity in late diastole. Another measurement is the time difference between Ar duration and mitral A-wave duration (Ar -A).
With increased LVEDP, Ar velocity and duration increase, as well as Ar-A duration
In Systolic Heart Failure, a SFF <40% is associated with increased LA Pressure
In Diastolic Heart Failure, systolic and diastolic velocities are not reliable predictors of LV filling pressures, but Ar and Ar-A duration can still be applied
Sinus tachycardia and AV block are major limitations to the clinical application of pulmonary venous flow to assess LV diastolic function.
Doppler echocardiographic criteria for classification of diastolic function

<table>
<thead>
<tr>
<th>Normal diastolic function</th>
<th>Mild diastolic dysfunction*</th>
<th>Moderate diastolic dysfunction*</th>
<th>Severe diastolic dysfunction</th>
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<tbody>
<tr>
<td>0.75 ≤ E/A ≤ 1.5 DT &gt; 140 ms</td>
<td>E/A ≥ 0.75 DT &gt; 140 ms</td>
<td>E/A &gt; 1.5 DT &lt; 140 ms</td>
<td>E/A &gt; 1.5 DT &lt; 140 ms</td>
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Mitral inflow

- Velocity: m/s
- Adur: A duration
- E: peak early filling velocity
- A: velocity at atrial contraction

Mitral inflow at peak Valsalva Maneuver

- ΔE/A < 0.5
- ΔE/A ≥ 0.5

Doppler tissue imaging of mitral annular motion

- E/A' < 10
- E/A' ≥ 10

Pulmonary venous flow

- S < D
- A > D
- S ≥ D or A > D + 30 ms

Left ventricular relaxation

- Normal
- Impaired

Atrial pressure

- Normal

Participants with atrial fibrillation with DT > 140 ms, other arrhythmia, fusion of E and A, or in whom diastolic parameters were not obtained, who had only one criterion suggesting moderate or severe diastolic dysfunction, or in whom diastolic parameters were borderline and suggestive of but not diagnostic of abnormality were classified as having indeterminate diastolic function.

Grade I (mild) diastolic dysfunction is characterized by the impaired relaxation pattern.

Grade II (moderate) diastolic dysfunction is characterized by a pseudonormal pattern.

Grades III and IV (severe) diastolic dysfunction is characterized by a (irreversible and fixed) restrictive pattern.

E: peak early filling velocity; A: velocity at atrial contraction; DT: deceleration time; Adur: A duration; E/A: peak A velocity; ΔE/A: systolic annular motion; ΔD: diastolic forward flow; AR: pulmonary venous atrial reversal flow; e': velocity of mitral annulus early diastolic motion; a': velocity of mitral annulus motion with atrial systole; DT: diastolic E velocity deceleration time.

Mitral inflow (top), septal (bottom left), and lateral (bottom right) tissue Doppler signals from a 60-year-old patient with heart failure and normal EF. The E/é ratio was markedly increased, using é from either side of the annulus.


Septal E/e’ = 80/4 = 20

Lateral E/e’ = 80/5 = 16


Exercise Doppler recordings from a patient with reduced diastolic reserve.

Baseline

Supine Bike at 50 Watts

E = 50 cm/s, DT = 250 ms

\( e' = 7 \), \( E/e' = 7 \)

\( TR = 2.4 \text{ m/s} \)

E = 85 cm/s, DT = 140 ms

\( e' = 8 \), \( E/e' = 11 \)

\( TR = 3.8 \text{ m/s} \)


(Top left) Recording of TR jet by CW Doppler (peak velocity marked by yellow arrow) from a patient with primary pulmonary hypertension.


Special Populations

- Atrial fibrillation
- Sinus tachycardia
- Hypertrophic cardiomyopathy
- Constrictive pericarditis
- Restrictive cardiomyopathy
- Noncardiac pulmonary hypertension
- Mitral Stenosis
- Mitral Regurgitation
Figure Legend:

VVI Illustrating the Rotation Motion of the LV Apex
(Left) Systole where the apical rotation is predominantly anticlockwise; (right) systole where the apical rotation (now untwisting) is predominantly in the clockwise direction. LV = left ventricular; VVI = Velocity Vector Image.
Diagnostic algorithm for the estimation of LV filling pressures in patients with depressed EFs.

Estimation of Filling Pressures in Patients with Depressed EF

Mitral E/A

E/A <1 and E ≤ 50 cm/s

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

E/A ≥2, DT <150 ms

E/e’ (average e’) < 8
E/Vp <1.4
S/D >1
Ar – A < 0 ms
Valsalva ∆ E/A < 0.5
PAS <30 mmHg
IVRT/T\_{E-e’} >2

Normal LAP

E/e’ (average e’) > 15
E/Vp ≥ 2.5
S/D < 1
Ar – A ≥ 30 ms
Valsalva ∆ E/A ≥ 0.5
PAS >35 mmHg
IVRT/T\_{E-e’} <2

↑ LAP

↑ LAP


Diagnostic algorithm for the estimation of LV filling pressures in patients with normal EFs.

Estimation of Filling Pressures in Patients with Normal EF

E/e’

E/e’ ≤ 8
(Sep, Lat, or Av.)

E/e’ 9-14

LA volume < 34 ml/m²
Ar – A < 0 ms
Valsalva Δ E/A < 0.5
PAS <30 mmHg
IVRT/TE-e’ >2

Normal LAP

LA volume ≥ 34 ml/m²
Ar – A ≥ 30 ms
Valsalva Δ E/A ≥ 0.5
PAS >35 mmHg
IVRT/TE-e’ <2

↑ LAP

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

↑ LAP

Scheme for grading diastolic dysfunction.

Practical Approach to Grade Diastolic Dysfunction

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

- **Septal e’ ≥ 8**
  - **Lateral e’ ≥ 10**
  - **LA ≥ 34 ml/m²**
  - Normal function, Athlete’s heart, or constriction

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

- **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 II

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

Treatment

Medications proven to be effective in the treatment of HFPEF
The RELAX (Phosphodiesterase-5 Inhibition to Improve Clinical Status and Exercise Capacity in Heart Failure with Preserved Ejection Fraction) trial compared the effects of the PDE-5 inhibitor sildenafil with placebo in patients with HFPEF.

Conclusions:
The use of the phosphodiesterase-5 inhibitor sildenafil in patients with HFPEF did not result in significant improvement in exercise capacity or clinical status when compared to placebo.

Asymptomatic LV diastolic dysfunction is a predictor of future cardiovascular morbidity. Symptomatic patients with DHF experience morbidities (eg, hospitalization for heart failure) at a rate that is virtually the same as that seen in patients with SHF. Mortality rates in both DHF and SHF are high; published data on differences in mortality rates are conflicting.
The treatment of DHF remains empiric since trial data are limited. The general principles for treatment of DHF are control of systolic and diastolic hypertension, control of ventricular rate, particularly in patients with atrial fibrillation, control of pulmonary congestion and peripheral edema with diuretics, and coronary revascularization in patients with coronary heart disease with ischemia judged to impair diastolic function.
An important caveat is that the patient who has LV diastolic dysfunction with a small, stiff left ventricular chamber is particularly susceptible to excessive preload reduction, which can lead sequentially to underfilling of the LV, a fall in cardiac output, and hypotension. In patients with severe left ventricular hypertrophy (LVH) due to hypertension or hypertrophic cardiomyopathy, excessive preload reduction can also create subaortic outflow obstruction.
For these reasons, the administration of diuretics or venodilators such as nitrates and dihydropyridine calcium channel blockers must be performed with caution.
Restoration and maintenance of sinus rhythm is preferred when AF occurs in patients with DHF. When this cannot be achieved, rate control becomes important.
### Class I - There is evidence and/or general agreement that the following approaches are effective in the management of HF and preserved left ventricular systolic function

- Control of hypertension, both systolic and diastolic, according to current guidelines.
- Control of ventricular rate in atrial fibrillation.
- Control of pulmonary congestion and peripheral edema with diuretics.

### Class IIa – The weight of evidence or opinion is in favor of the usefulness of the following approach in the management of HF and preserved left ventricular systolic function

- Coronary revascularization for symptomatic or asymptomatic myocardial ischemia that is thought to have an adverse effect of cardiac function.

### Class IIb - The weight of evidence or opinion is less well established for the usefulness of the following approaches in the management of HF and preserved left ventricular systolic function

- Restoration of sinus rhythm to improve diagnosis in patients with atrial fibrillation.
- Among patients controlled hypertension, use of beta blockers, angiotensin converting enzyme inhibitors, angiotensin II receptor blockers, and calcium channel blockers in an attempt to reduce symptoms of HF.
- Digitalis to reduce symptoms of HF.

Management of patients with diastolic heart failure

### Control edema
- Low salt diet (e.g., <2 g sodium per day)
- Diuretic (e.g., furosemide or hydrochlorothiazide)
- ACE inhibitor* (e.g., enalapril or lisinopril)
- Angiotensin II receptor blocker* (e.g., candesartan, valsartan, or losartan)
- Aldosterone antagonist* (e.g., spironolactone)

### Rate control
- Calcium channel blocker (e.g., diltiazem or verapamil)
- Beta blocker (e.g., atenolol, metoprolol)
- Radiofrequency modification of atrioventricular node and pacing

### Maintain and restore atrial contraction
- Cardioversion
- Radiofrequency ablation
- Antarrhythmic therapy

### Manage myocardial ischemia
- Medical management
  - Nitrates (e.g., isosorbide dinitrate or isosorbide mononitrate)
  - Beta blocker (e.g., atenolol or metoprolol)
  - Calcium channel blocker (e.g., diltiazem or verapamil)
- Percutaneous coronary intervention
- Coronary artery bypass surgery

### Control arterial hypertension *
- Diuretic (e.g., chlorothalidone or hydrochlorothiazide)
- Beta blocker (e.g., atenolol or metoprolol)
- Calcium channel blocker (e.g.,amlodipine or felodipine)
- Angiotensin converting enzyme inhibitor (e.g., enalapril or lisinopril)
- Angiotensin II receptor blocker (e.g., candesartan, valsartan, or losartan)

*The renin-angiotensin-aldosterone system is inhibited by angiotensin converting enzyme inhibitor, angiotensin II receptor blocker, and aldosterone antagonist and thus these agents have a theoretical benefit in promoting regression of left ventricular hypertrophy and preventing myocardial fibrosis. However more data are required to demonstrate whether they improve outcomes in patients with diastolic heart failure. Two of these three agents may be combined in some patients with proper monitoring but use of all three is generally not recommended.

- The list of medications is not comprehensive but rather includes examples that are in common clinical use or have been included in studies of patients with diastolic dysfunction or heart failure. A more exhaustive list of antihypertensive agents can be found in the guidelines of the Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure.

*Courtesy of Dr. William H. Gaasch.*