

Diastolic Functions: Evaluation & Clinical Applications

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Diastology i.e. diastolic dysfunction of the heart has assumed significant importance in last several years. This is because it can lead to isolated heart failure. Traditionally, poor left ventricular (LV) systolic function was thought to be responsible in most heart failure patients. However, it has now been recognized that almost 40% of all patients with clinically diagnosed heart failure have a normal ejection fraction. This clinical entity, which occurs without significant valvular lesion or pericardial disease, is now referred as Heart Failure with Normal Ejection Fraction (HFNEF), which in the past was labeled as Diastolic Heart Failure (DHF). Clinical conditions usually responsible for it are hypertension, cardiomyopathies, coronary artery disease, diabetes mellitus, obesity, sleep apnoea, constrictive pericarditis etc. HFNEF might be having a better short-term prognosis as compared to systolic heart failure (SHF), however the long term mortality and incidence of recurrent hospitalizations are almost the same. Echocardiography, combined with Doppler and Tissue Doppler Imaging, are the most practical methods for evaluation of diastolic dysfunction of the heart.

This paper will discuss the hemodynamic concepts of various phases of diastole, types of diastolic dysfunction and clinical applications.

Hemodynamic concepts of diastole

Basically diastole starts with closure of aortic valve and ends with closure of mitral valve. As such the main phases of diastole are as follows:

- Isovolumic relaxation phase (IVRT)
- Rapid ventricular filling
- Late diastolic filling due to atrial contraction.

The IVRT starts with aortic valve closure and ends with mitral valve opening. During this phase the left ventricle (LV) pressure falls. At the same time the left atrial (LA) pressure is increasing as it is being filled up by the pulmonary veins. Due to this phenomenon, an atrio-ventricular gradient occurs. As a result of this gradient, at the opening of mitral valve, the second phase of diastole starts with a rapid ventricular filling. Approximately 80% of LV filling occurs during this phase. As a result of this filling, the LV pressure increases and momentarily may exceed LA pressure and this results in deceleration of mitral inflow known as deceleration time (DT). As such a phase of equalization of pressures occurs and LA acts as a conduit. During the late diastolic phase the LA acts as a 'booster pump' with a late diastolic filling of LV and contributes to almost 20% of LV filling in normal subjects. For each person, the proportion of LV filling during the early and late phases of diastole depends upon elastic recoil (suction), the rate of myocardial relaxation, chamber compliance and LA pressure. Changes in transmitral pressure gradient are demonstrated accurately by mitral inflow Doppler velocities, which reflect the relation between LV and LA pressures during diastole.

The relaxation and rapid LV filling are active, energy requiring processes. Molecular events like removal of calcium from the myofilaments and the uncoupling of actin-myosin cross-bridge bonds are responsible for rate of relaxation and thus the rate of ventricular pressure decline.

After LV relaxation and rapid filling has reached its peak, the mechanical properties of the LV will be determined by passive factors like LV wall thickness, extracellular matrix and chamber geometry which indirectly define the LV compliance, stiffness and thus end- diastolic

pressure – volume relationship. In simplest terms they reflect the ease of filling. Compliance is the ratio of change in volume to pressure (dV/dP) while stiffness is the reverse of compliance (dP/dV). The changes in compliance and stiffness are frequently responsible for elevated LA pressure and symptoms of heart failure, which will be discussed later.

What is diastolic dysfunction: A normal ventricle fills without an abnormal increase in end diastolic pressure (LVEDP). Diastolic dysfunction is an abnormal increase in LVEDP for a given end diastolic volume. As such diastolic dysfunction may be the result of active (relaxation) or passive (compliance or stiffness) abnormalities or both. Usually there is increased filling pressure of LV, which is practically synonymous with LA pressure and pulmonary capillary wedge pressure.

Consequences of diastolic dysfunction

Increased filling pressure for a given volume

Increased LA volume and LA remodeling

Pulmonary venous hypertension

Heart failure with normal EF

Echocardiographic techniques to evaluate diastolic dysfunction

Echocardiography, being a simple non – invasive technique, has gained wide acceptance in the evaluation of diastolic properties of LV. The following parameters are being widely employed:

- 2-D echo
- Mitral inflow Doppler
- Valsalva maneuver, which is an additional source to evaluate validity of mitral Doppler
- Pulmonary vein Doppler, more as a complementary method
- Tissue Doppler imaging
- Mitral inflow color propagation velocity
- LA volume and function
- Strain imaging for regional diastolic dysfunction only

To understand better the parameters of diastolic dysfunction it would be worthwhile to know the normal pattern of various techniques mentioned above. In 2-D echo, presence of left ventricular hypertrophy and LA enlargement can give indirect suggestion of diastolic dysfunction.

Normal Transmitral Inflow Velocity Pattern

For assessment of mitral inflow a pulsed Doppler is used and the sample volume is placed at the tips of mitral leaflet in the apical views. As mentioned earlier, this flow velocity depends upon the early diastolic pressure gradient between LA and LV across the mitral valve. As such the LV inflow shows an early diastolic E wave (Fig.1). With a higher pressure gradient, the E wave would be of a higher velocity. At end diastole, when the atrium contracts, the rise in LA pressure results in an end diastolic gradient between LA and LV. This is responsible for A wave seen on Doppler tracing. Since most of the LV filling and hence LA emptying occurs in early diastole, the atrium is relatively empty at end diastole. Therefore there is only a small end-diastolic LA – LV gradient which results in a low velocity A wave. As such normally the E / A ratio is > 1.0 . The mitral deceleration time (DT) is the interval from the peak of the E velocity to its extrapolation to baseline and reflects the rapidity with which LV and LA pressure tend to equalize. The normal value is about 190 ± 30 msec.

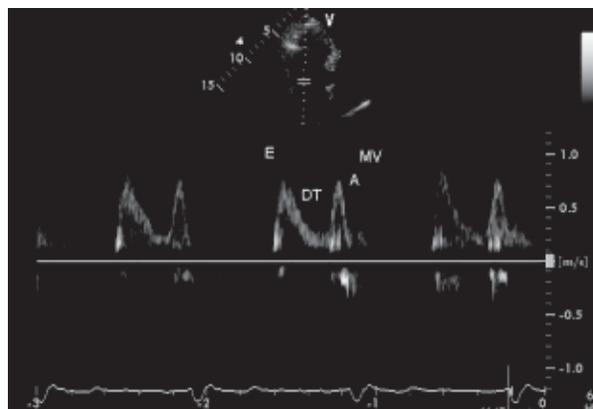


Fig.1: A normal mitral spectral Doppler. See text for details

Valsalva maneuver: This maneuver has earlier been used to assess cardiac murmurs, but it has been found to be useful in assessment of diastolic function. It involves forceful expiration against a closed nose and mouth. It can be more scientifically

performed by blowing in the tube of sphygmomanometer and keeping a pressure of 40 mmHg. During the strain phase, there is a reduction of preload and hence a fall in LA pressure. In normal patients (normal filling pressures) there is reduction of both mitral E and A velocities and lengthening of DT. As would be discussed subsequently, valsalva can be helpful in differentiating various grades of diastolic dysfunction.

Normal Pulmonary Venous Flow Pattern

The pulmonary veins are interrogated from apical 4 Ch. view utilizing colors flow mapping. The sample volume is placed about 1 cm within its orifice. The sample volume should not be in LA. The Doppler tracing (Fig.2) comprises of the following waves: Systolic wave (S), diastolic wave (D) and a small end diastolic atrial reversal wave (Ar). These waves are timed with the ECG. Sometimes, especially in patients with bradycardia, two systolic waves can be recorded. The first antegrade systolic wave is related to decline in LA pressure during atrial relaxation. This leads to a higher pressure gradient between PV and LA, and therefore to an antegrade systolic velocity. The second antegrade systolic wave is due to descent of mitral annulus during LV systole, which again produces a decline in LA pressure associated with late systolic increase in pulmonary venous pressure. With early diastolic LA emptying, the LA pressure declines leading to an early diastolic D wave. During end diastolic LA contraction, its pressure rises above PV pressure, resulting in a small retrograde flow wave (Ar). The duration of Ar wave is normally shorter than the duration of transmitral A flow velocity wave by about 30 msec. Some of the normal PV velocities are shown in Fig. 2a.

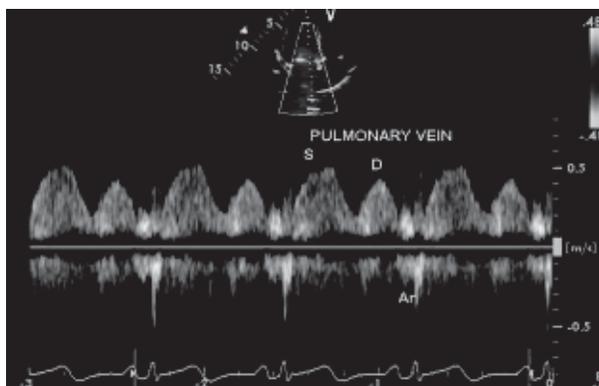
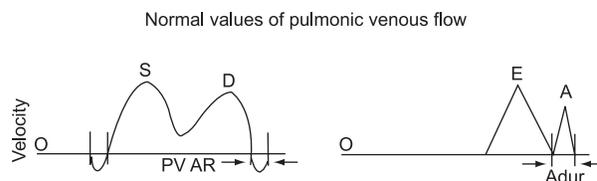


Fig 2: Pulmonary vein Doppler showing systolic (S) and diastolic waves (D). Atrial reversal wave (Ar) is seen coinciding with P wave of ECG.



'S' wave: 40-60 cm/sec, - Reduced in : AF, LV systolic dysfunction, Raised LA pressure, Severe MR
 'D' wave: 35-45 cm/sec. S:D ratio = 1.3-1.5
 Systolic fraction: S/S+d x 100 = 68 ± 10%
 AR duration: 125 ± 31 msec. AR velocity: <35 cm/sec.
 Mitral 'A' wave duration: 137 ± 12 msec.

Fig 2a: Normal values for pulmonary vein Doppler

Tissue Doppler Imaging (TDI)

This is a novel ultrasound modality that records the motion of myocardial tissues with Doppler echo. The conventional Doppler records high velocity flows with erythrocytes as a target. The velocities of myocardial tissues are much lower (1-20 cms/ sec). Therefore the Doppler ultrasound systems have been modified to record the low velocities of myocardial tissues and reject the high velocities generated by blood flow. TDI is not dependent on imaging quality and tracings are easily obtainable. A normal TDI velocity has five components/waves (Fig.3) (a) isovolumic contraction (ICT), (b) systolic wave (S), (c) isovolumic relaxation (IVRW), (d) early diastolic wave (E'i.e.E prime or Em wave) (e) late diastolic wave (A at the time of atrial contraction). The E' is good indicator of LV myocardial relaxation and hence gets reduced in all grades of diastolic dysfunction. Its normal value is approximately or more than 10 cms /sec. from the medial annulus while it is approximately 15 cms / sec. from the lateral annulus The ratio of mitral E velocity to

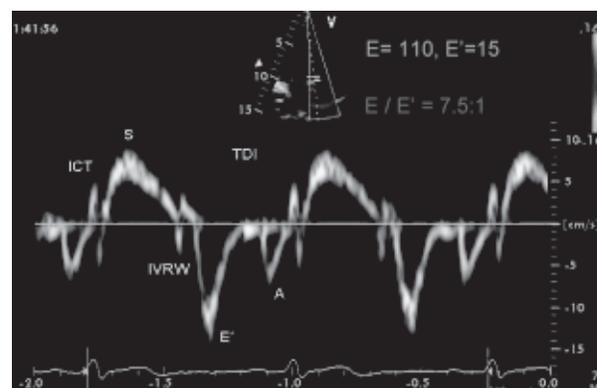


Fig. 3: A normal Tissue Doppler tracing (see text for details).

TDI E' is an important parameter to assess LV filling pressure and normal ratio is < 8-10:1. From the apical views, the TDI parameters indicate longitudinal muscle fiber function. In many diseased states, including diabetes mellitus, the subendocardial fibers are involved earliest which is apparent from TDI study. As such TDI helps in the diagnosis of early LV dysfunction even if ejection fraction is normal.

Mitral inflow color propagation velocity: Active relaxation in early diastole defines the velocity at which blood is propagated from the mitral valve orifice to the apex. As such it displays color-coded mean velocities from base to apex over time. It is an index of active relaxation of LV. This velocity can be obtained from apical views using M-Mode color flow imaging. The slope is measured from the mitral annulus along the first aliased velocity, red – blue, slope (Fig 4) to 4 cm distal in LV. Normal propagation velocity is 45 - 50 cm/sec or higher.

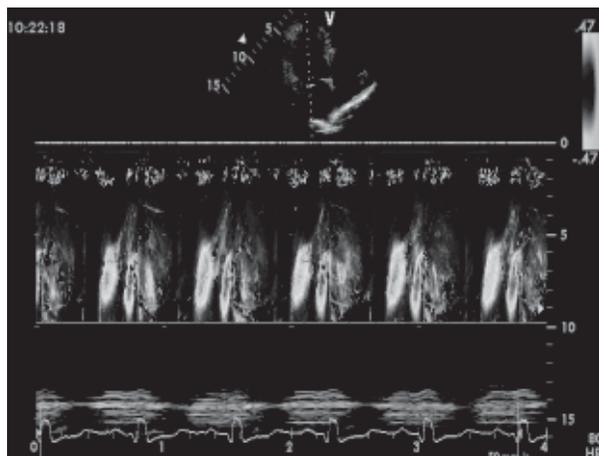
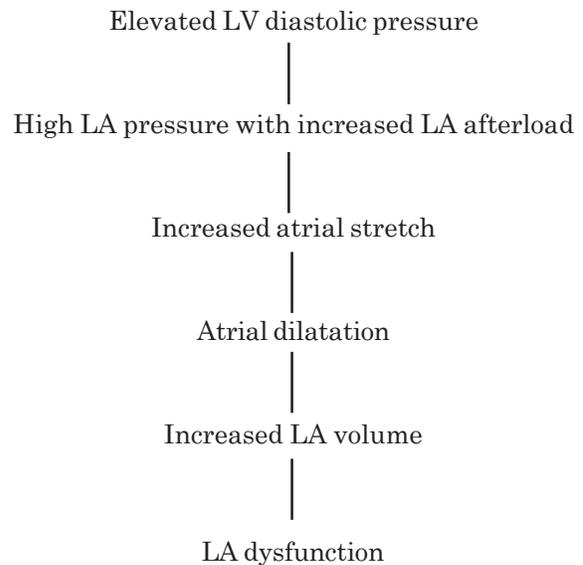


Fig. 4: Mitral inflow color propagation velocity

Left Atrial volume: In the last few years there has been growing evidence that the LA size and volume has robust clinical and prognostic implications in a variety of conditions. Its role in diastology is significant because during diastole, the thin wall LA is directly exposed to LV pressure load through the mitral valve. It has been shown that the size and volume of LA increases as diastolic dysfunction progresses. As such LA volume is an expression of LV filling pressure as shown in the following flow chart:



Hence LA volume reflects cumulative effect of filling pressure over time and is a measure of chronicity, while Doppler and TDI reflect filling pressure at one point of time. In view of this Jim Seward from Mayo Clinic designates LA volume as HbA1C of diastology.

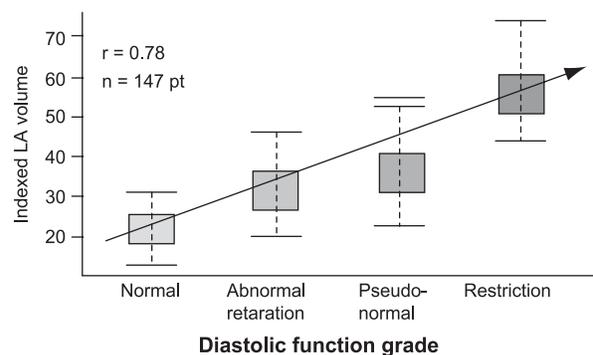


Fig. 5: A direct correlation between LA volume and degree of diastolic dysfunction.

The LA volume is more critical than anteroposterior dimension because (a) LA is not a symmetrical shaped 3-D structure (b) LA enlargement may occur eccentrically, more so when it is enlarged (c) LA size varies with body surface area (d) patients with normal LA dimension can have LA volumes varying between 27.5 ml – 106 ml. As such simple LA size has low accuracy and limited reproducibility. The LA volume can be readily evaluated by echo and hence should be a part of routine echocardiography and evaluation of diastolic dysfunction, because an increased LA volume increases the risk of atrial

fibrillation, transient ischemic attacks / stroke, heart failure and cardiovascular death. The 5-year mortality in those with LA volume of $> 32 \text{ ml} / \text{m}^2$ is about 34.5% as compared to 14.2% in those with LA volume of less than $32 \text{ ml} / \text{m}^2$. As shown in Fig 5, as the diastolic dysfunction increases there is increase in indexed LA volume.

Criteria for dilated LA and increased LA volume

LA Antero-posterior diameter	: $> 1.2 - 2 \text{ cm} /$ meter sq.
LA area	: $> 20 \text{ cm sq.}$
LA volume	: Normal $22 \pm$ $0.6 \text{ ml} / \text{msq.}$ Mildly increased $29-33 \text{ ml} / \text{msq.}$ Moderately $34 - 39 \text{ ml} / \text{msq}$ Severe $> 40 \text{ ml}$ $/\text{msq.}$

Patients with LA volume index $> 40 \text{ ml} / \text{m}^2$ suggests an LA pressure of $> 12 \text{ mmHg}$.

Types of Diastolic Dysfunction

- Grade 1 : Abnormal relaxation
- Grade 2 : Pseudo-normal or mixed pattern
- Grade 3 : Reversible restrictive pattern
- Grade 4 : Irreversible restrictive pattern

Each stage is characterized by a progressive rise in LA pressure and hence carries a worsening prognosis.

Basic rule of diastolic dysfunction

The basic rule is that relaxation abnormality is present in all grades of diastolic dysfunction. As mentioned above, with every increasing grade the LA pressure increases leading to an increased LA – LV gradient. As such there is pronounced increase in flow across mitral valve in early diastole leading to a tall E wave. As most of the filling has occurred in early diastole and less blood volume is available in late diastole, hence A velocity decreases leading to increased E / A ratio. As the mitral E velocity increases and TDI E' velocity decreases because it is an index of diastole, hence E / E' ratio increases. Pulmonary vein Doppler changes occur in various grades which will be highlighted subsequently.

Diagnosis of various grades of diastolic dysfunction

The various types of diastolic dysfunction are mainly evaluated by transmitral Doppler and TDI, while other echo techniques are complimentary. The hemodynamic explanations of various grades will also be discussed for a better understanding.

Isolated LV relaxation abnormality

This is a relatively benign abnormality as it can be seen during normal ageing process.

In this abnormality, the decline of early diastolic LV pressure is slow due to impaired relaxation. As LV is at a slightly higher pressure, the LA-LV gradient is reduced. As such due to restricted LV filling in early diastole, the mitral E velocity is small. The smaller LA-LV gradient does not permit complete emptying of LA; therefore LA remains relatively full at end diastole with an increased LA-LV gradient leading to higher velocity A wave. As such the E/A ratio is < 1.0 . Because of higher LV pressure, it takes a longer time for LV-LA pressure to equalize; hence deceleration time is prolonged (Fig. 6). The TDI also shows similar abnormality of E' and A velocity waves with a reduced velocity of E' wave.

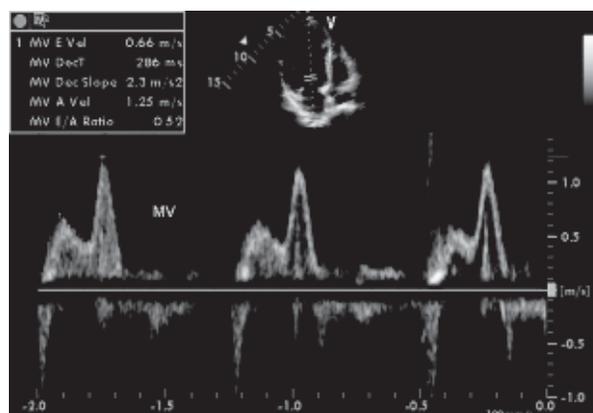


Fig 6: Mitral Doppler showing small early diastolic mitral wave with prominent late diastolic atrial wave with an E/A ratio of only 0.52. The mitral deceleration time is prolonged to 286 msec.

Pseudonormal diastolic dysfunction

This pattern is due to a combined effect of abnormal relaxation + increased LA pressure. The abnormal relaxation, as mentioned above, tends to lead to a small E wave while an increased LA pressure tends to increase E wave velocity. These mechanisms counterbalance each other and tend to produce a

normal looking transmitral Doppler, despite an increased LA pressure. It is therefore called “Pseudonormal”, despite the fact that it is an intermediate stage between impaired relaxation and restriction. To diagnose this pseudonormal pattern, the 2-D echo is carefully evaluated. Finding of LV hypertrophy and / or LA dilatation or increased volume suggest the possibility of pseudonormal with normal looking transmitral Doppler spectrum. Other echocardiographic tools for the differentiation between normal and pseudonormal transmitral patterns include: pulmonary vein Doppler, mitral inflow color propagation velocity and TDI.

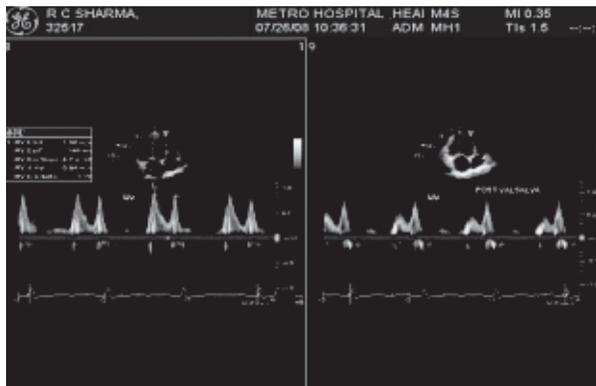


Fig.7: Mitral Doppler with a pseudonormal pattern changing to impaired relaxation following Valsalva (right panel)

In pulmonary vein Doppler some of the findings are: (a) decrease in ‘S’ wave and prominent ‘D’ wave with reduction of S/D ratio (b) due to increased LA pressure the atrial reversal vein (Ar) velocity is increased (c) the duration of Ar wave may exceed the transmitral ‘A’ wave by more than 30 msec. The color propagation velocity may be increased.

The E' velocity of TDI will be decreased as it is a marker of abnormal relaxation. As such the E/E' ratio may be increased beyond 10:1.

Pre – load reduction: A decrease in pre-load may result from certain maneuvers like Valsalva or from pharmacological venodilation i.e. Nitroglycerine or rarely in sitting up position. Valsalva is comparable to other methods. This is based on the principle that during any of these methods there is a reduction of pre-load and a fall of LA pressure. As such the counterbalancing forces of abnormal relaxation and increased LA pressure are disturbed. So with a fall of LA pressure, the abnormal relaxation pattern becomes dominant and the pseudonormal pattern is

converted to abnormal relaxation with a small E wave and large A wave (Fig. 7). A standardized valsalva can be obtained by asking the patient to blow in a hollow tube that is attached to a mercury sphygmomanometer. Patient should be instructed to blow sufficiently hard to keep the mercury at a level of 40 mmHg. (Gillian Whalley et al). As mentioned earlier, due to increased LA pressure the pulmonary vein to LA gradient is increased, thereby blunting the systolic wave. The pulmonary atrial wave velocity and duration is increased as compared to mitral A wave due to increased LA pressure (Fig. 8)

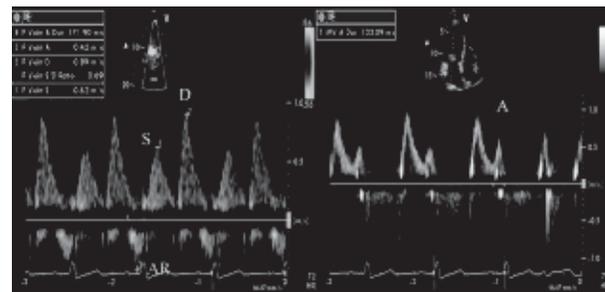


Fig. 8: Pulmonary vein Doppler, in a pseudonormal pattern, showing blunting of pulmonary systolic wave (S) as compared to diastolic wave (D) thereby reversing the S/D ratio. The pulmonary atrial wave (AR) duration is more than the atrial A wave duration by 38 msec.

Restrictive LV Pattern

Restrictive pattern is considered the worst and most advanced form of diastolic dysfunction. It is commonly associated with major myocardial pathology such as myocardial ischemia, scar, infiltrative – restrictive abnormalities, heart failure etc. The basic pathophysiology is significantly elevated LA pressure + all the echo parameters of abnormal relaxation. Because of high LA pressure the isovolumic relaxation time is decreased. Due to increased LA pressure there is significantly increased LA-LV gradient. As such, in early diastole, the mitral E wave is very tall even more than pseudonormal pattern. Because of most of the LV filling and LA emptying is in early diastole, less blood remains in late diastole, hence E/A ratio is significantly increased – usually more than 2:1. These patients mostly have a poor LV compliance which leads to rapid elevation of LV diastolic pressure. This restrictive pattern is responsible for “square root sign” on invasive studies. This also leads to rapid deceleration of E wave and the deceleration time is usually < 150 msec. (Fig. 9). The associated relaxation abnormalities lead to E/E' ratio which is more than 15:1.

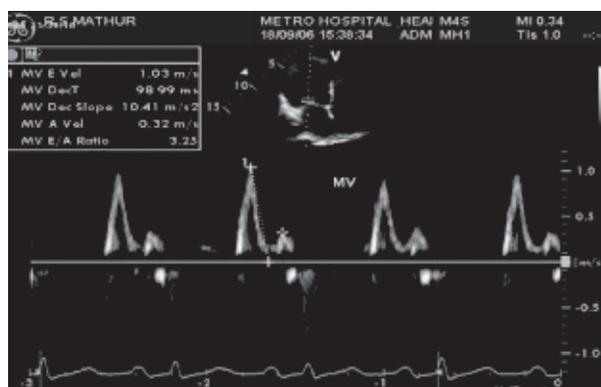


Fig 9: Mitral Doppler in a restrictive pattern showing tall E wave and very small A wave leading to a significantly increased E/A ratio of 3.25. The mitral deceleration time is reduced to 98 msec.

To summarise restrictive pattern is characterized by: tall mitral E wave, small A wave, increased E/A ratio, decreased deceleration time, E/Em ratio of more than 15:1, decreased mitral inflow color propagation velocity, pulmonary vein Doppler findings as noted with pseudonormal. A word of caution is that young, healthy individuals who have excellent active relaxation can show similar mitral E and A wave pattern. However these individuals are usually asymptomatic with normal 2-D echo and TDI is normal. In grade 4 or irreversible restrictive pattern there is no significant change with preload reduction.

The summary of various types of diastolic dysfunction is shown in table 1.

Table-I

Summary of various types of diastolic dysfunction.

Finding	Normal	Grade I .Relax.	Grade II .Relax./ LVEDP	Grade III .Relax. .Comp. LVEDP	Grade IV .Relax. .Comp. LVEDP
E/A ratio	0.75-1.50	<1	1.0-1.5	1.5-2.0	>2.0
IVRT(msec.)	70-100	>100	N		
DT(msec.)	160-220	>220	>140	<140	<140
PVs/PVD	>1.0	N- <1	<1	<1	<<1
PVA(m/sec)	<0.35	<0.35	>0.35	>0.35	>0.35
Adur- Adur(msec)	<30	<30	>30	>30	>30
E/Em	<8	<8	8-15	>15	>20
E/wp	<1.4	<1.4	1.4-1.9	>2.0	>2.0
Ep/AP	>2.0	<1	<1	<1	<1

Clinical applications of diastolic dysfunction

Estimation of filling pressure

This is the most clinically useful application of Doppler echocardiographic evaluation of diastolic

variables, especially in critically ill patients from therapeutic point of view. In patients with LV dysfunction, the mitral inflow pattern is useful in assessing the filling pressures. A high velocity mitral E wave and a low velocity A wave leading to an increased E/A ratio coupled with a deceleration time of < 140 msec. indicates increased filling pressure. However the ratio of mitral E wave and TDI Em wave (E/Em) is the best parameter to assess filling pressure. This has been well validated in large number of studies including cardiac catheterization co-relation. Different authors have taken either medial mitral annulus for recording TDI while some recommend lateral annulus. Current trend is to record from both annulus and take an average. An E/Em ratio of 15 or more indicates a PCWP of more than 20 mmHg. (Fig.10). A ratio less than 10 indicates a normal PCWP. If the ratio is 10 – 15 obtained from septal annulus, then this ratio may be less reliable for estimation of LAP. Under these circumstances one can ascertain other echo variables like pulmonary vein Doppler, valsalva maneuver and mitral A- wave duration/ pulmonary vein A- duration ratio to demonstrate elevated filling pressures, if present. In one of the latest studies by Kasner et al a simultaneous Doppler and conductance catheterization studies were performed on patients with pure diastolic heart failure. They concluded that of all the echocardiographic methods studied, the LV filling index E/E' was identified as the best index to assess diastolic dysfunction in DHF. They recommended it as the most useful index for evaluation of filling pressure. However this index is not well validated in patients with abnormal interventricular motion like post operative state, patients with LBBB, RV pacing or RV volume overload (D'Souza et al). It is because the TDI diastolic velocity is underestimated because of either postoperative cardiac translation or asynchronous motion due to LBBB etc, the angle of interrogation is increased. E/E' index is also affected by severe mitral regurgitation which artifactually increases the mitral E velocity. Olson et al determined LV filling pressure, both invasively and by echo. They

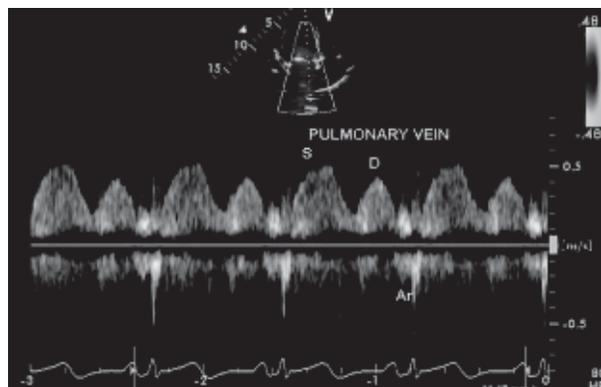


Fig 10: The left hand panel shows a mitral Doppler tracing. The right hand panel is the TDI. Note a markedly increased E/Em (also E') ratio of 30:1 suggesting significantly increased filling pressure.

concluded that E/Em ratio was not reliable in predicting LV filling pressure in the setting of severe mitral regurgitation. In these cases mitral deceleration time and pulmonary vein S/D ratio may be better indicators of LVEDP.

Diastolic Stress Echocardiography

There are patients, especially with diabetes and/or hypertension with no significant coronary artery disease, who have exertional dyspnoea and resting echo studies are normal, including ejection fraction. Many of these patients thus remain undiagnosed. It is also recognized that symptoms of primary diastolic dysfunction may occur only during exertion because diastolic filling pressure is normal at rest and increases strikingly only with exertion (Kitzman et al). Therefore to evaluate diastolic dysfunction, diastolic filling pressures must be measured during rest and exercise.

The rationale for this test is that in patients with diastolic dysfunction (DD), the abnormal relaxation prevents augmentation of relaxation as heart rate increases during exercise. Therefore a way to assess diastolic functional reserve (defined as the capacity of the ventricle to accommodate diastolic filling necessary for increased cardiac demand without resulting in abnormal filling pressure) in patients considered at risk for DD would be to quantify the response of diastolic functional indices to dynamic exercise. In this test patient undergoes a symptom-limited exercise. The peak early mitral velocity (E wave) and early diastolic TDI velocity (Em) are measured at rest and immediately after exercise. In normal individuals there is a

proportionate increase in both velocities so E/Em ratio is almost unchanged. The increase in E velocity is due to normal physiological response with a faster myocardial relaxation causing an exaggerated suction effect of LV. In patients with DD, the mitral E velocity increases due to raised LA pressure while Em is almost unchanged or decreases due to relaxation abnormality, so the E/Em ratio increases which indicates increased filling pressure. However the response can be variable (Jong – Won Ha, Jae K. Oh et al).

Talreja et al performed simultaneous echo and invasive studies from the internal jugular access, both at rest and following exercise. They reported that following exercise, an E/Em ratio greater than 15 was associated with a significantly elevated PAWP of greater than 20 mmHg.

The clinical implications of this test are that those who have exercise induced DD and symptoms of exertional dyspnoea may have clinical improvement after proper treatment. This will also contribute to better management of congestive heart failure caused by primary DD. Also this test can be an excellent way to distinguish between cardiac and non-cardiac dyspnoea for patients with multiple coexisting conditions that can cause exertional dyspnoea (Fig 11 A, B).

Management of Heart Failure

The diagnosis of HFNEF is based on mainly three criteria (a) presence of clinical syndrome of heart failure (b) preserved LV systolic function or $EF > 45\%$ (c) demonstration of diastolic dysfunction. A noninvasive estimate of PCWP allows a better and scientific management of heart failure. The mitral

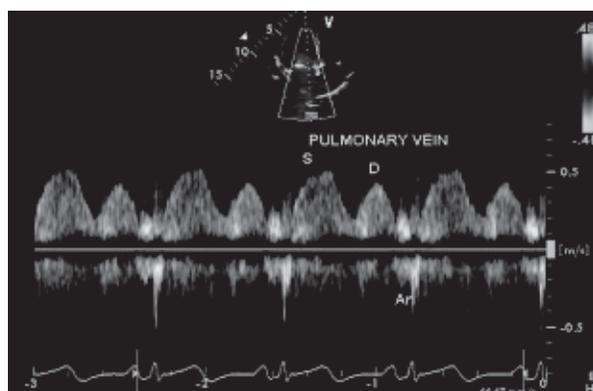


Fig 11 A: A pre-exercise study showing an E/Em ratio of 13:1 and deceleration time of 211 msec.

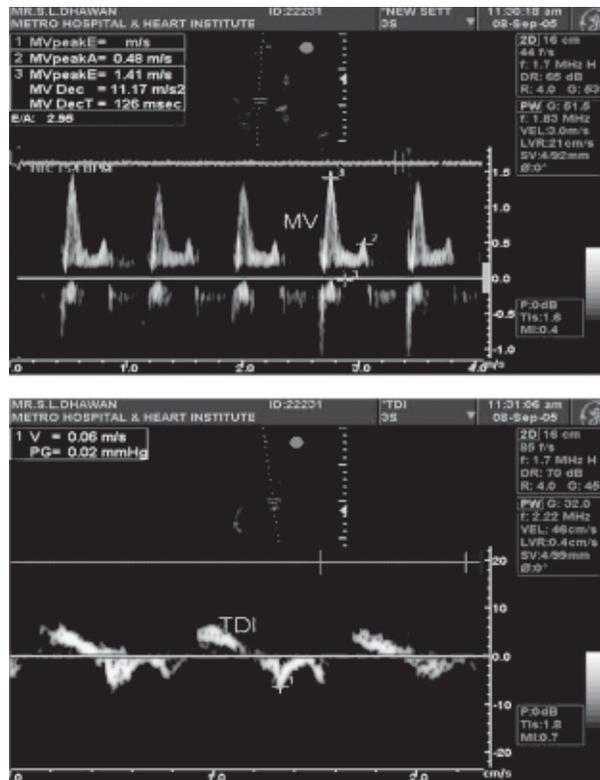


Fig. 11B: Following exercise, in the same patient, there is significant deterioration of diastolic function with increase in filling pressure as evident by an increase of E/E' ratio of 23:1 and the deceleration time dropping to 126 msec. Post exercise there is also significant increase in mitral E/A ratio.

diastolic filling pattern and filling period can provide a guide to a more selective management of heart failure as discussed below:

Grade 1 diastolic dysfunction: Patients in this group are asymptomatic as long as the diastolic filling period is sufficiently long to accommodate the delay in myocardial relaxation. As such the key to management is the prevention of exercise-induced tachycardia or the development of atrial fibrillation. Beta – blocker therapy is helpful in minimizing the tachycardia.

Grade 2 diastolic dysfunction: As mentioned earlier patients in this group have a moderate increase in filling pressure in addition to impaired relaxation. Hence, a decrease in preload or venous congestion is required as well as neurohormonal modulation with an angiotensin converting enzyme (ACE) inhibitor or angiotensin receptor blocker (ARB).

Grades 3 and 4 diastolic dysfunction: Patients in these groups have a markedly increased filling pressure, and diastolic filling occurs mostly during diastole, with a relatively fixed stroke volume. Diuresis is the initial treatment of choice and also titrated with ACE inhibitor or ARB. However in the CHARMES Study, it was reported that the combined use of ACE inhibitors and ARB's improved the outcome as compared to ACE inhibitors alone. However, further studies are warranted to confirm or negate these findings.

Assessment of Prognosis

Various Doppler variables of mitral inflow, TDI and LA volume are powerful prognostic indicators for various diseases. Even in asymptomatic individuals with a restrictive filling pattern, which is uncommon, indicates a poor prognosis. Hurrell et al followed up patients both with normal sinus rhythm (NSR) and AF for 5 years with a deceleration time of less than 130 msec. In the normal population the expected survival rate for those with NSR and AF was 86% and 82%. However those with a DT of < 130 msec. the survival rate, over a period of 5 years was found to be 42% and 39% respectively.

Persson et al in a study on 312 patients, with a median follow-up of 18.7 months reported that moderate and severe DD had a poor outcome as compared with normal and mild DD (18% vs 5%). The moderate and severe DD had significantly higher event rates of CV death or hospitalization (16% and 29%) as compared to normal individuals or those with relaxation abnormality (6%).

LA volume (LAV): As mentioned earlier LAV is a barometer of increased filling pressure because of increased after load secondary to increased LV diastolic pressure. An increased LAV is a predictor of adverse prognosis in various cardiovascular disorders. Moreover it predisposes to the development of atrial fibrillation (AF) which predisposes an individual to various embolic episodes. As per Framingham study a 5 mm incremental increase in LA diameter has a 39% increased risk of developing AF. LAV has been shown as a powerful independent predictor of mortality in myocardial infarction. Beinart et al studied 395 consecutive patients of acute myocardial infarction within 48 hours of admission. 5 years mortality was determined. The 5 years

mortality in those patients with LAV > 32 ml / m² was 34.5% as compared to 14.2% in those with LAV less than 32 ml / m². Those with a higher LAV had more incidences of cardiac failure, mitral regurgitation and LV dysfunction (Fig 12). Moller et al studied 55 patients of acute myocardial infarction and followed them from 0-33 months. 15% patients died during this period of follow up. There were 27 patients (EF < 40) and had LAV less than 32ml/msq. Out of these only one died. On the other hand 22/55, with similar EF, died whose LAV was more than 32ml/msq. All these studies confirm the prognostic significance of LAV.

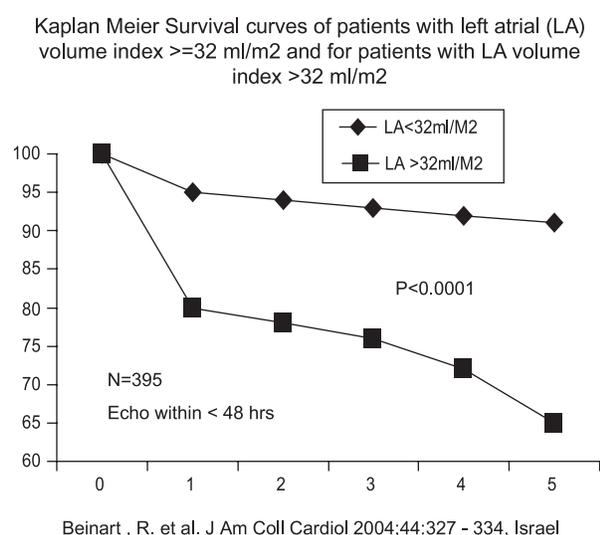


Fig. 12: showing outcome in cases of acute myocardial infarction in patients with normal and increased indexed LA volume.

Tissue Doppler 'Am' Velocity. A recent study demonstrated that mitral annular 'A' velocity less than 5 cms/sec. was the most powerful predictor of cardiac death or hospitalization for worsening heart failure compared with clinical, hemodynamic and other echo variables. Importantly, this study demonstrated a significant negative correlation ($r = -0.94$) between the peak mitral annular 'A' velocity and mean PCWP in patients with different grades of mitral filling pattern and LV systolic function.

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