Basic Concepts of Diastolic Function

Annemarie Thompson, MD
Professor of Anesthesiology
Duke University School of Medicine
Durham, North Carolina

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Objectives: At the conclusion of this session, the participant should be able to
1. Explain the importance of diastolic function assessment in the perioperative setting
2. Define diastolic physiology by 2D and Doppler echocardiography using surrogate measurements in the LA (pulmonary veins, mitral valve inflow)
3. Determine the degree of diastolic dysfunction using echocardiographic modalities

Introduction: Left ventricular (LV) diastolic function is an important component of the perioperative transesophageal echocardiographic examination. Diastolic dysfunction occurs when the left atrium (LA) is unable to fill the LV at normal LA pressures due to impaired relaxation, impaired compliance, or both. Epidemiologic studies suggest 50% of cases with heart failure have preserved systolic function, meaning that at least half of heart failure is isolated diastolic heart failure. LV diastolic dysfunction is an independent predictor of postoperative complications including CHF.

In spite of its clinical consequences, diastolic dysfunction receives little attention compared to systolic dysfunction. Normal LV diastolic function is an active, energy-consuming process, and not merely a ventricular rest period. Pathologic processes such as fibrosis and hypertrophy caused by hypertension, diabetes, and ischemia (to name a few) affect LV diastolic function and make diastolic function a “canary in the coal mine” for overall cardiovascular dysfunction.

The main reason for the scant attention paid to diastolic function is the inconvenience and impracticality of measuring it. Traditionally, catheter-based techniques utilize pressure-volume measurements and the rate of LV pressure fall during isovolumic relaxation to assess diastolic function, but are invasive and risky. However, echocardiographic evaluation can detect diastolic dysfunction with excellent sensitivity and minimal risk to the patient. By understanding the physiologic process of left ventricular relaxation and filling while performing a basic echocardiographic evaluation of diastolic function, even the novice echocardiographer can assess this important area of cardiovascular function.
**Diastole:** Diastole is classically divided into **four** phases: isovolumic relaxation, rapid filling, diastasis, and atrial contraction. The schematic below represents the phases of the cardiac cycle, with diastole highlighted in yellow in the above figure.

Isovolumic relaxation time (IVRT) is the period between closure of the aortic valve and opening of the mitral valve and represents LV relaxation. Although many variables can influence IVRT, typically it is 90-120 ms in duration.

The rapid filling phase begins with MV opening and extends to pressure equalization of the LA and LV. The rapid filling phase accounts for 80% of ventricular filling.

Diastasis is the period from pressure equalization to atrial contraction. It accounts for <5% of LV filling.

Atrial contraction normally contributes 20-25% of the LV end diastolic volume, but can be a larger percentage in patients with impaired diastolic function.

**Classification of diastolic function:** There are three terms used to describe the degree of diastolic dysfunction: Grade I (impaired relaxation pattern), Grade II (pseudonormal pattern), and Grade III (restrictive pattern). Restrictive pattern is further subdivided into Grade IIIa or Grade IIIb depending on whether or not the pattern is reversible to an impaired relaxation pattern with preload reduction via a Valsalva maneuver or other preload-reducing method.

**Echocardiographic measures of diastolic function:** Echocardiographic analysis of diastolic function has a high sensitivity for the detection of diastolic dysfunction when compared to the gold standard of invasive pressure-volume measurements over time. Four
methods of assessment will be discussed: transmitral inflow, pulmonary venous flow, mitral annulus tissue Doppler, and color M-mode Doppler (propagation velocity, Vp). No single test is an absolute determinant of diastolic function; therefore, multiple methods must be performed in order to accurately describe the diastolic function of any given patient.

**Transmitral inflow:** Flow occurs across the mitral valve when LA pressure exceeds LV pressure. Pulsed-wave Doppler echocardiography at the mitral valve leaflet tips in the midesophageal 4 chamber view creates a velocity vs. time spectral image representing the rapid filling phase, diastasis, and blood velocity during atrial contraction. Two sharp triangular-shaped waveforms appear below the baseline. The first wave, the E-wave, represents early diastolic filling and the second wave, the A-wave, represents atrial contraction. The period of relatively little flow between the two waves is diastasis. As with most of the diastolic interrogation methods, a non-stenotic mitral valve is essential for accurate assessment of LV diastolic function.

Deceleration time (DT) is measured from the peak of the E-wave along the downslope. As LV relaxation is prolonged, the DT is increased, indicating the presence of Grade I diastolic dysfunction. However, as diastolic dysfunction progresses, the equalization of pressures between the LA and the LV occurs earlier in diastole, resulting in shortened DTs seen with progressive diastolic dysfunction. The patterns of abnormality are summarized at the end of this section. Additionally, the peak E and A velocities should be recorded, as they can be compared with the E’ tissue Doppler wave and the A duration of pulmonary blood flow respectively (see JASE 2009 algorithm at the end of this syllabus) as a measure to help determine the presence or absence of diastolic dysfunction.

**Pulmonary vein flow:** A pulsed wave Doppler in the pulmonary veins in the presence of a non-stenotic mitral valve can help define the degree of diastolic dysfunction when used in conjunction with transmitral flow velocities. The major features of the spectral Doppler above the baseline are S1-wave (atrial relaxation), S2-wave (continued descent of the LV base), and D-wave (atrial emptying of the LV resulting in pulmonary blood flow into the LA). Below the baseline, and therefore away from the LA, is the A-wave, which represents atrial contraction and retrograde flow into the valveless pulmonary veins. Normally, S>D. The duration of the A wave should also be measured to aid in determining the degree of diastolic dysfunction according to the 2009 JASE guidelines.

**Tissue Doppler imaging (TDI):** TDI is considered a relatively preload-independent measure of LV diastolic function assuming there are no lateral or septal wall motion abnormalities or mitral valve replacement/annuloplasty. TDI assesses the low-velocity, high amplitude signals of tissue motion and is best measured in the midesophageal 4-chamber view where the axial motion of the LV is parallel to the pulsed wave Doppler beam. The spectral display demonstrates an S’ below the baseline representing descent of the base during ventricular systole. An E’ wave above the baseline represents enlargement of the LV chamber during relaxation and early filling while an A’ wave represents atrial contraction resulting in ventricular distension. E’ is always greater than A’ in patients with normal diastolic function. Unlike the mitral valve inflow measurement, the TDI does not
pseudo-normalize with progressive diastolic dysfunction – it remains abnormal \( E' < A' \).

**Color M-mode (Propagation velocity, \( V_p \)):** Another measure of diastolic dysfunction that is considered to be preload-independent (although there is some debate about this) is the propagation velocity. \( V_p \) essentially measures multiple pulsed wave Doppler signals simultaneously from the mitral valve orifice to the apex. The measurement occurs in the midesophageal 4 chamber view with color-flow Doppler across the LA, MV, and LV apex, being careful to minimize LV foreshortening. M-mode is placed along the aforementioned path and the color velocity is adjusted so the aliasing velocity is 75% for the peak E velocity. The sweep speed should be maximized. An E wave and an A wave similar to mitral inflow is seen in spectral display with color superimposed. \( V_p \) is measured by drawing the slope from the mitral valve to 4 centimeters into the LV toward the apex. A \( V_p \) of >55cm/s is associated with normal diastolic function.

**Putting it all together:** The two figures below can serve as quick references to help the clinician determine the presence and degree of diastolic dysfunction. The first figure represents the typical changes seen in the abovementioned waveforms as diastolic dysfunction worsens. The second figure is a modified table from the 2009 JASE recommendations for diastolic function assessment. The information from the table is easily obtained from the 4 Doppler assessments of diastolic function described above.
In 2011, the Duke simplified algorithm was developed from a validated intraoperative process to evaluate diastolic dysfunction by transesophageal echocardiography. The algorithm accurately predicts the incidence of major adverse cardiac events (MACE) based on the increasing degree of diastolic dysfunction and is an easy method for evaluating diastolic dysfunction in the intraoperative setting (adapted from Swaminathan et al):
References:


