Filling Velocities as Markers of Diastolic Function

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Introduction

Left ventricular (LV) filling velocities provide important insights into ventricular function and are useful clinical markers of diastolic dysfunction. Filling velocities can be measured at bedside by Doppler echocardiography and can be incorporated into everyday cardiology practice. Interpretation of filling velocities in a clinical context, however, requires insights into cardiac mechanics. The objective of this chapter is to review the essential physiology of filling and how changes in LV systolic and diastolic function can modify filling velocities as measured by Doppler echocardiography. This chapter addresses filling of the left ventricle only. Filling patterns for the right ventricle are of clinical importance for the diagnosis of restrictive cardiomyopathy and constrictive pericarditis and are addressed in Chapter 21.

The three hallmarks of diastolic dysfunction are (1) retarded LV relaxation, (2) reduced diastolic compliance, and (3) a compensatory elevation of LV diastolic pressure (Table 6.1). The latter is not a primary disturbance of cardiac function but is the result of regulatory mechanisms that seek to maintain stroke volume. Retarded relaxation and reduced compliance may occur in combination, or only one of the two may be disturbed. When one assesses diastolic function clinically, it is essential to interpret measurements with each of the three hallmarks in mind. Furthermore, one should understand that filling velocities are markers only and do not provide quantitative data regarding LV relaxation, chamber compliance, or end-diastolic pressure. Filling patterns, however, provide indices of diastolic dysfunction that are very useful clinically and can be recorded at bedside in virtually every patient. Filling velocities can be measured in the pulmonary veins, in the mitral orifice, and in the LV cavity, and this chapter deals with each of these measurement sites separately.

Pulmonary Venous Flow Velocities

Introduction

Assessment of pulmonary venous flow velocities by Doppler echocardiography represents an important “window” into the physiology of cardiac filling. Pulmonary flow velocities provide insights into left atrial as well as LV mechanical function. The pulmonary venous flow velocity typically has three phases: a systolic wave (S wave), a diastolic wave (D wave), and a reversed flow wave during atrial contraction (Figure 6.1). Furthermore, as illustrated in Figure 6.2, in many patients the systolic flow pulse has an early systolic wave and a late systolic wave. The latter is usually the larger of the two waves. Figure 6.2 also demonstrates that the pulmonary venous flow trace looks like an approximately inverted left atrial pressure tracing, which means that flow accelerates when atrial pressure decreases and vice versa. An exception to this is during mid/late systole, when flow accelerates while pressure is rising, and this is discussed later in more detail.
Table 6.1. Key points in assessment of diastolic filling.

Markers of impaired left ventricular (LV) relaxation
- Reduced transmitral early (E) velocity: confounded by elevated left atrial pressure, which may increase the transmitral pressure gradient and E velocity
- Reduced LV lengthening velocity (E') by tissue Doppler imaging
- Markers of reduced LV chamber compliance (increased stiffness)
- Abbreviated transmitral E deceleration time
- Reduced transmitral atrial (A) velocity

Markers of reduced LV chamber compliance (increased stiffness)
- Abbreviated transmitral E deceleration time
- Reduced transmitral atrial (A) velocity
- Markers of elevated LV end-diastolic pressure
- Duration of transmitral A much less than retrograde pulmonary venous A
- Elevated E/E' ratio
- Increased transmitral E/A ratio
- Enlarged left atrium

Markers of increased pericardial constraint
- Marked respiratory variation in mitral and tricuspid velocities
- Elevated jugular venous pressure indicates elevated pericardial pressure

Limitations of filling velocities
- Reduction of LV distensibility with no change in chamber compliance (parallel shift of pressure-volume curve) may not change E deceleration time or A velocity
- Filling velocities do not provide quantitative data on diastolic function

Figure 6.1. Intraoperative measurements of left atrial and left ventricular filling in a patient with coronary artery disease. Left ventricular ejection fraction was normal. Recordings were done prior to cardiopulmonary bypass. Left atrial and left ventricular pressures were measured with a single catheter with two pressure sensors 7 cm apart. Midway between the pressure sensors there was an electromagnetic velocity sensor that measured mitral blood flow velocity. Pressures were zero-referenced by comparison to pressure measured via a fluid-filled catheter in the left atrium.

Pulmonary venous flow was measured by ultrasound transit time from a flow probe on the right lower pulmonary vein, and flow velocity was derived by dividing with the cross-section of the vein by transesophageal echocardiography. A, transmitral atrial-induced velocity; Ar, atrial-induced reversed velocity; D, diastolic velocity; E, transmitral early velocity; L, transmitral L-wave, PLA, left atrial pressure; PLA-PLV, the atrioventricular pressure difference; PLV, left ventricular pressure; S, systolic velocity.

Figure 6.2. Representative recording of pulmonary vein flow and left atrial pressure, taken prior to cardiopulmonary bypass. Left ventricular pressure and electrocardiogram are included for timing. The letters indicate the atrial pressure waves and four pulmonary venous flow pulses, the Ar wave during atrial contraction, the S1 and S2 waves during ventricular systole, and the D wave in early diastole. (Modified from Smiseth OA, Thompson CR. Atrioventricular filling dynamics, diastolic function and dysfunction. Heart Fail Rev 2000;5:291–299.)