Introduction

Heart failure is defined as the pathologic state in which the heart is unable to pump blood at a rate required by the metabolizing tissues or can do so only with an elevated filling pressure. Inability of the heart to pump blood sufficiently to meet the needs of the body’s tissues is due to the inability of the left ventricle (LV) to fill (diastolic performance) and eject (systolic performance). Thus, consideration of the systolic and diastolic performance of the LV provides a conceptual basis to classify and understand the pathophysiology of heart failure.

Left Ventricular Systolic and Diastolic Performance

Systolic Performance

Left ventricular systolic performance is the ability of the LV to empty. The ability of the LV to empty can be quantified as the LV ejection fraction (EF; a ratio of stroke volume to end-diastolic volume). Thus, LV systolic dysfunction is defined as a decreased EF. The EF can be obtained by determining the LV volume by use of two-dimensional echocardiography or contrast or radionuclide ventriculography.

The EF has been used as an index of myocardial contractile performance. The EF, however, is influenced not only by myocardial contractility but also by LV afterload. Furthermore, in the presence of a left-sided valvular regurgitation (mitral or aortic regurgitation) or a left-to-right shunt (ventricular septal defect or patent ductus arteriosus), the LV stroke volume may be high, while the forward stroke volume (stroke volume minus regurgitant volume or shunt volume) is lower. Thus, the effective EF is defined as the forward stroke volume divided by end-diastolic volume. The effective EF is a useful means to quantify systolic function for two reasons. First, the effective EF represents the functional emptying of the LV that contributes to cardiac output. Second, the effective EF is relatively independent of LV end-diastolic volume over the clinically relevant range.

An operational definition of systolic dysfunction is an effective EF of <0.50. When defined in this manner, systolic dysfunction results from impaired myocardial function, increased LV afterload, and/or structural abnormalities of the LV.

Diastolic Performance

For the LV to function effectively as a pump, it must be able not only to eject but also to fill (diastolic function). Diastolic function has conventionally been assessed on the basis of the LV end-diastolic pressure volume relation. A shift of the curve upward and to the left has been considered to be the hallmark of diastolic dysfunction (Figure 8.1, curve A). In this situation, each LV end-diastolic volume is associated with a high end-diastolic pressure, and thus the LV is less distensible. Decreased LV distensibility is caused by...
aging, systemic hypertension, and hypertrophic or restrictive cardiomyopathy.\(^2\)

Diastolic function has also been assessed based on LV filling patterns by use of Doppler echocardiography.\(^3\) In the absence of mitral stenosis, three patterns of LV filling indicate progressive impairment of diastolic function: (1) reduced early diastolic filling with a compensatory increase in importance of atrial filling (impaired relaxation); (2) most filling early in diastole with normal deceleration of mitral flow (pseudonormalization); and (3) almost all filling of the LV occurring very early in diastole in association with very rapid deceleration of mitral flow (restricted filling) (Figure 8.2).

These LV filling patterns, however, are influenced not only by LV diastolic properties but also by left atrial pressure. In contrast, tissue Doppler measurement of mitral annular velocity and color M-mode measurement of the velocity of propagation of mitral inflow to the apex are much less load sensitive. The peak early diastolic mitral annular velocity provides a relatively load-insensitive measure of LV relaxation in heart failure.\(^4\) Peak early diastolic mitral annular velocity progressively decreases with increasing severity of diastolic dysfunction.\(^5,6\) The color M-mode imaging performed from the apex provides a temporal and

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**Figure 8.1.** A shift of the curve to A indicates that a higher left ventricular (LV) pressure will be required to distend the LV to a similar volume, indicating that the ventricle is less distensible. The slope of the LV end-diastolic pressure–volume relation indicates the passive chamber stiffness. Because the relation is exponential in shape, the slope ($\Delta P/\Delta V$) increases as the end-diastolic pressure increases. (From Little,\(^36\) with permission of the American Heart Association.)

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**Figure 8.2.** Transmitral Doppler left ventricular inflow velocity, Doppler tissue velocity, and color M-mode imaging during diastole. A, velocity of LV filling contributed by atrial contraction; Am, myocardial velocity during filling produced by atrial contraction; E, early LV filling velocity; Em, myocardial velocity during early filling; Sm, myocardial velocity during systole; V, velocity of propagation of mitral inflow to the apex.