Heart Failure

Two-Dimensional and Doppler Echocardiography

for the Assessment of Congestive Heart Failure

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Congestive heart failure is a major cause of morbidity and mortality in the United States. An estimated 2 million patients are treated annually and more than 400,000 new cases are diagnosed each year.[1] Fundamental to this diagnosis is accurate assessment of systolic and diastolic function.

Assessment of Systolic Function

A reliable and widely used method for the assessment of systolic function is 2-dimensional echocardiography. The parameter most often used to express global left ventricular (LV) systolic function is ejection fraction, which is a powerful predictor of outcome in almost all cardiac conditions. Several methodologies for the calculation of ejection fraction have been validated. These include the modified Simpson's method[2] using LV volumes, the simplified method of Quinones,[3] and the M-mode calculation of fractional shortening.[4] Visual methods of estimating ejection fraction have also been noted to be reliable by several authors.[5]

Other indices of systolic function have been validated by echocardiography, including dp/dt (ratio of change in ventricular pressure to change in time),[6,7] cardiac output (which correlates well with Fick cardiac output),[8] and systolic time intervals derived from Doppler echocardiography.[9]

Assessment of Diastolic Function

Doppler echocardiographic evaluation of diastolic function has become an important tool in the initial assessment of the patient with congestive heart failure, as well as an indicator of prognosis.

Normal Physiology. Mitral inflow represents the pressure differences between the left atrium and left ventricle throughout diastole (Fig. 1). The mitral valve opens when left atrial (LA) pressure exceeds LV pressure. The time from aortic valve closure to mitral valve opening is known as the isovolumic relaxation time (IVRT). The peak E wave of mitral inflow reflects the LA/LV pressure difference at the onset of diastole. The auscultatory equivalent is S_3.[10] The deceleration time is the time required for equilibration of LA/LV pressure (or the time to diastasis). The peak A wave reflects the LA/LV pressure difference at the onset of atrial systole (S_4).[10] With normal aging, the IVRT is progressively prolonged and the peak A wave velocity increases.[11]

As with mitral inflow, pulmonary and hepatic venous flows are also a reflection of atrial/ventricular pressure differences. During atrial diastole, there is venous inflow to the atria, which is inscribed as the dominant wave (*x* descent of the jugular venous pressure). During ventricular diastole, there is a lower-velocity inflow (*y* descent). A small reversal of flow occurs during atrial systole (Fig. 2).

Abnormal Filling Patterns in Congestive Heart Failure. As the LA pressure rises, the time to mitral valve opening shortens. This is reflected by a shortened IVRT, which is perhaps the most specific Doppler marker of high filling pressures in the presence of sinus rhythm. When filling pressures are high, the time to LA/LV equilibration shortens. Both of these shortened times are reflected in the mitral inflow as a high peak E wave, an increased E/A ratio, and a shortened deceleration time—the so-called "restrictive filling" pattern. Mitral inflow can be influenced by several variables, including the position of the patient,[12] loading conditions (i.e., preload and afterload),[13] heart rate, and PR interval. It should also be noted that in the presence of significant tachycardia, the E and A waves may

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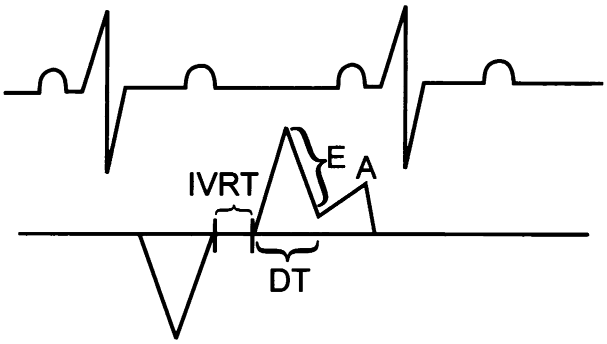

Fig. 1 Doppler echocardiography of the mitral inflow pattern.

A = A wave; DT = deceleration time; E = E wave; IVRT = isovolumic relaxation time

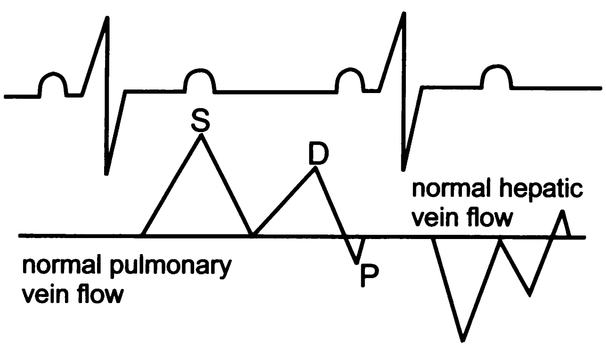

Fig. 2 Doppler echocardiography demonstrating normal pulmonary (left side) and hepatic venous (right side) profile.

D = diastole; P = P wave reversal; S = systole

be fused and the IVRT falsely shortened. Similarly, when LA pressure is high, there is a large LA "V" wave. This blunts systolic inflow from the pulmonary veins and thus results in the pattern of diastolic dominance (Fig. 2). This pattern, however, has also been demonstrated in young people with healthy, normal hearts.

Serial echocardiography before and after treatment has shown that mitral inflow is dynamic and a continuous reflection of LA/LV pressure differences;[10,11] therefore, it may "pseudo-normalize" when the patient has shown maximal response to medical therapy.

Use of Doppler Echocardiography to Predict Left Ventricular Filling Pressures. It has been well established that certain parameters of the mitral inflow correlate well with LA pressure.[14] In an elegant study that applied Doppler echocardiography and cardiac catheterization simultaneously, Nishimura and associates[15] demonstrated an inverse relationship between the deceleration time of the mitral inflow and LA pressure in patients with LV systolic dysfunction. In fact, the sensitivity and specificity of the deceleration time—less than 180 msec, which indicated LA pressures of 20 mmHg or higher—were both 100%. More complex regression equations for prediction of the pulmonary capillary wedge pressure have been derived using parameters of mitral and pulmonary venous inflow.[16]

Another simple method for the determination of pulmonary capillary wedge pressure was 1st described by Nishimura and Tajik[17] and further validated by Gorcsan and colleagues[18] This method makes use of the continuous Doppler wave signal of the mitral regurgitant jet, which is a reflection of the LA/LV pressure difference in systole. Subtracting the systolic blood pressure from this pressure difference yields the pulmonary capillary wedge pressure with an r value of 0.88.

Finally, Doppler echocardiography of the pulmonary veins provides insight into elevated LV filling pressures. This pattern is characterized by blunted or absent systolic forward flow,[14,19] which reflects the inability of blood to enter the left atrium in the presence of a large LA "V" wave. Diastolic dominance is also normal in the young and healthy heart. Caution must be used in the interpretation of pulmonary venous flow in the presence of atrial fibrillation, significant mitral regurgitation, ventricular pacing, and severe LV dysfunction.[20]

Therefore, the assessment of diastolic function should integrate the information derived from the mitral inflow, the IVRT, and the pulmonary venous flow profile.

With regard to the prognostic capabilities of Doppler echocardiography, several studies have indicated that Doppler-derived mitral deceleration time is a very powerful and independent predictor of mortality in patients with dilated cardiomyopathy.[21,22] In another study, Xie and coworkers[23] used Doppler-echocardiography-derived "restrictive" mitral inflow patterns in patients with congestive heart failure to predict a 4-fold increase in their mortality rate at 1 year.

Use of Dobutamine Echocardiography to Assess Myocardial Viability

The concepts of stunned and hibernating myocardium have expanded our understanding of the effects of ischemia on LV dysfunction. It has been suggested that LV dysfunction may be reversible in up to 40% of patients with coronary artery disease (CAD).[24] Stunned myocardium has been defined as myocardium that has sustained an acute injury but has adequate perfusion at rest. Hibernating myocardium, by contrast, involves chronic, severe ischemia that has caused severe systolic dysfunction; however, since the contractile mechanism of hibernating myocardium has been downregulated rather than damaged, revascularization may restore systolic function.[24,25] Positron emission tomography (PET) has been the gold standard for noninvasive assessment of myocardial viability in these cases.

Dobutamine echocardiography (DE) has accurately identified myocardial viability at low dobutamine doses (5, 7.5, and 10 µg/kg/min). Viability has been defined as an improvement in regional wall motion to the extent that an akinetic segment becomes hypokinetic or a hypokinetic segment becomes normal.

In one of the earliest reports on this topic, Pierard and associates[26] compared low-dose DE with PET for the noninvasive assessment of viable myocardium in 17 patients with acute myocardial infarction who had received thrombolytic therapy. There was a 79% concordance between the 2 techniques. A summary of currently available PET, thallium single-photon emission computed tomography (SPECT), and DE studies reviewed by Bonow[24] revealed positive predictive accuracies of 82% for PET, 69% for thallium SPECT, and 83% for DE. Smart and colleagues[27] performed DE on 63 patients after lytic therapy for myocardial infarction, with follow-up echocardiography at 1 month. In the hands of these very experienced investigators, the specificity of low-dose DE in predicting reversible ischemia was 90% and the sensitivity was 86%.

Several more recent reports compared thallium scintigraphy with DE for the assessment of myocardial viability. Table I summarizes the findings of these studies.[28-31]

In the study by Nagueh and coworkers,[28] the specificity of DE was enhanced by the demonstration of a biphasic response (improved wall motion at a low dose of dobutamine and deterioration at a peak dose), but DE sensitivity was increased by any improvement in wall motion. Furthermore, sensitivity for the prediction of functional recovery was higher in hypokinetic (100%) than in akinetic (70%) segments, although specificity was higher in akinetic (82%) than in hypokinetic (46%) segments. These authors demonstrated that myocardial contrast echocardiography (MCE) may be another good noninvasive method for the identification of hibernating myocardium. Myocardial contrast echocardiography had an 80% concordance with thallium-201 tomography and a negative predictive accuracy of 86% to 88%, but a poorer positive predictive accuracy (51% to 57%), depending upon the criteria used.

Finally, in a prospective study of 84 patients with chronic CAD and LV dysfunction who were undergoing aorto–coronary bypass, Scognamiglio and colleagues[32] demonstrated a 91.5% sensitivity, an 84% specificity, and an 88.1% accuracy for DE in predicting reversible wall motion abnormalities after aorto–coronary bypass.

Dobutamine echocardiography has also been found to be accurate in detecting CAD in patients with dilated cardiomyopathy. Sharp and associates[33] demonstrated DE to have an 83% sensitivity and a 71% specificity for diagnosing CAD in patients with LV dysfunction (defined as fractional shortening of less than 0.18). The sensitivity of DE increased as the number of diseased vessels increased (69% for single-vessel disease, 83% for double-vessel, and 100% for triple-vessel).

Table I. Selected Studies Comparing Thallium Scintigraphy with Doppler Echocardiography for the Assessment of Myocardial Viability

Study	Method	% Sensitivity	% Specificity
Nagueh[28]	DE	91	61
	Thallium	91	43
Vanovershelde[29]	SPECT	72	73
	DE	88	77
Marzullo[30]	Early thallium scintigraphy (10 minutes)	79	73
	Late thallium scintigraphy	86	92
	Sestamibi	75	84
	DE	82	92
*Perrone-Filardi[31]			

*In this study, concordance between thallium-201 tomography and dobutamine echocardiography was 82% in hypokinetic segments and 43% in akinetic segments.

DE = dobutamine echocardiography; SPECT = single-photon emission computed tomography

Conclusion

In conclusion, 2-dimensional and Doppler echocardiography are invaluable tools for the assessment and prognostication of systolic and diastolic heart failure. The development of new contrast agents may help to further delineate the role of ischemia during pharmacologic echocardiography. Further studies are needed to assess predictors of outcome for the newer methods of treating congestive heart failure, such as LV reduction surgery.

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