The ability to measure pressures within the heart has been one of the most important diagnostic and therapeutic tools within the cardiologist’s armamentarium over the past half century. Whereas this measurement initially required direct left ventricular puncture,1 transeptal catheterization,2 or retrograde placement of a catheter into the left ventricle, the advent of the Swan-Ganz catheter allowed for accurate estimation of left-sided filling pressures without requiring arterial or intraventricular access. These measurements have been useful to diagnose and treat hemodynamic compromise resulting from cardiac and pulmonary disease and other critical conditions associated with abnormal or unknown volume status.

Accurate assessment of left-sided intracardiac filling pressures is particularly crucial for the management of chronic heart failure, in which congestion causes most of the disabling symptoms and hospitalizations.3 High left-sided filling pressures predict rehospitalizations and death, and the degree to which pressures can be reduced predicts survival.4 Skilled estimation of jugular venous pressure, particularly in conjunction with orthopnea, provides the most reliable clinical evidence of elevated left-sided filling pressures.5 However, the accuracy of jugular venous pressure for the detection of elevated right atrial pressure is <75%. The concordance of right-sided and left-sided pressures is about 75% in chronic heart failure without known pulmonary disease,6 and lower when intrinsic lung or pulmonary vascular disease may uncouple ventricular filling pressures. Brain natriuretic peptide levels do not add to the clinical examination in assessing the elevation of filling pressures during admission with chronic heart failure6 and do not change rapidly enough to guide therapy in the inpatient setting7. A reliable noninvasive method to assess elevated filling pressures and their reduction during therapy would refine our current approach to therapy of decompensated heart failure.

Noninvasive approaches to measuring intracardiac pressures, particularly diastolic pressures, have been less successful than those utilizing the flow-guided pulmonary artery catheter. Pressure gradients between chambers or across valves can be estimated using echocardiography by combining knowledge of blood flow velocities (obtained through the use of Doppler echocardiography) with some mathematical assumptions (the Bernoulli equation). Estimation of the pressure within one of these chambers generally requires knowledge or estimation of the actual pressure within the other chamber, which must be added to the interchamber gradient. In practice, this approach is only routinely used for assessing right-sided pressures.

Left-sided pressure estimation has remained an elusive goal of noninvasive cardiac imaging. Although various methods have been proposed to translate standard Doppler assessments of left ventricular filling and pulmonary venous flow into measures of left ventricular filling pressure, these methods have not been accurate when applied to a wide range of patients.8,9 Thus, the observation from a number of laboratories over the past decade that newer Doppler tissue techniques could be used to estimate filling pressures was welcomed enthusiastically by the cardiovascular community. Doppler tissue imaging uses Doppler principles to assess the movement of myocardial tissue.10 The low-velocity, high-amplitude signals that emerge from moving tissues and are normally filtered when interrogating blood flow can be used to assess mitral annular movement during contraction and relaxation; the latter (referred to as E’, Ea, or Em) provides a measure of ventricular diastolic function that correlates inversely with the time constant of relaxation. Because mitral inflow velocity (the E wave on standard Doppler) is directly related to both left atrial pressure and ventricular relaxation, dividing this measure by annular relaxation velocity (E’), itself a measure of ventricular relaxation, can theoretically yield an estimate of left atrial pressure and, by extension, ventricular filling pressure.

A tight relationship between E/E’ and left ventricular filling pressures (Figure, A) has been demonstrated in a variety of conditions,11 including heart transplantation,12 tachycardia,13 and hypertrophic cardiomyopathy,14,15 suggesting that these measures could be used as surrogates of filling pressure. E/E’ is also a powerful predictor of outcome in patients with acute myocardial infarction,16 nonvalvular atrial fibrillation,17 left ventricular systolic dysfunction,18 and chronic heart failure.19 The current American Society of Echocardiography Recommendations for Quantification of Doppler Echocardiography20 and the European Consensus Statement on the Diagnosis of Heart Failure With Normal Left Ventricular Ejection Fraction21 include measurement of E/E’ prominently in the assessment of diastolic function and suggest that these...
measures can and should be used as a way to both diagnose and manage patients with a wide variety of heart diseases.

The utility of any medical test depends on its robustness and reproducibility in a wide range of patients. In this issue of Circulation, Mullens and colleagues assess the reliability of E/E' as a predictor of pulmonary capillary wedge pressure (PCWP) in patients with advanced decompensated heart failure. A total of 106 such patients underwent simultaneous assessment using invasive monitoring and Doppler echocardiography. In this patient population, E/E' correlated poorly with PCWP (r values all ≤0.27) with a sensitivity and specificity of an E/E' >15 detecting filling pressures >18 mm Hg a relatively low 66% and 55%, respectively. The authors assertion that the predictive value of E/E' in estimating PCWP in this population was “less robust than previously reported” is an understatement; the contrast between correlations observed in this study and those observed in prior published reports is striking (Figure 1). Another recent report in patients with hypertrophic cardiomyopathy showed a similar lack of relationship between left atrial pressure and E/E’, with an r value of 0.28 in patients with simultaneous assessments.

The authors acknowledge that a number of factors might have influenced their findings and account for the apparent discrepancies between this study and those published previously. First, patients enrolled in this study all had severe cardiac dysfunction and enlarged left ventricles, and had, by design, experienced worsening of their clinical status just before both evaluations. Greater left ventricular remodeling might alter the relationship between diastolic function and filling pressures, and the authors concede that the relationship between E/E' and PCWP might be considerably more robust in patients with less-severe heart disease. Second, a number of these patients had biventricular pacing devices for cardiac resynchronization therapy, although the relationship between E/E' and PCWP appeared similar regardless of cardiac resynchronization therapy.

Other factors that might account for differences between this and prior studies should also be considered. Patients with mitral regurgitation were excluded from the initial studies of this relationship. Mitral regurgitation will increase E wave velocity and may alter the relationship between E/E' and PCWP. Mitral regurgitation of at least moderate degree is present in almost all patients admitted with decompensated heart failure with low ejection fraction, and substantial reduction in quantified regurgitant flow occurs as left-sided filling pressures decrease. Moreover, although assessment of E' by Doppler tissue imaging is relatively straightforward, technical factors, including misplacement of the Doppler cursor on the mitral annulus or variation in Doppler filter settings, could also adversely affect the measure. Finally, whereas the relationship between E/E' and PCWP has been demonstrated by a number of different laboratories, studies demonstrating poor correlations might have been less likely to be submitted or accepted for publication.

In addition to casting doubt on the relationship between baseline E/E' and PCWP in advanced heart failure patients, Mullens et al have further shown that virtually no correlation exists between changes in PCWP and changes in E/E'. Whether these discrepancies were caused by low cardiac output, tachycardia, or hyperdynamic state, as the authors postulate, this finding will surely reduce our confidence in the utility of this measure for following a patient’s response to therapy and making further treatment decisions. Whether other approaches to assessment of volume status in both the inpatient and outpatient settings, including the use of a combination of echocardiographic features, would be of greater value remains unknown.

When seeking new indices to substitute for a key physiological parameter, initial study of a broad spectrum of disease may enhance an apparent correlation, which may be less robust within particular subgroups. Thus, after first validation, it is then necessary to reexamine the relationship in the narrower range within which the therapeutic implications may be important. Finally, if this parameter is likely to change spontaneously or with therapy, the stringent evaluation of the correlation of changes is crucial before therapy can be guided by the surrogate.
The current study examines both the absolute values and the changes in E/E’, and finds that this measurement may provide misleading information about left-sided filling pressures during diagnosis and therapy of patients with decompensated heart failure. Even if an altered E/E’–PCWP pressure relationship in patients with advanced heart failure accounts for differences between these findings and prior reports, as the authors suggest, these are precisely the kind of patients in whom a noninvasive estimate of filling pressures would be of value, particularly in the management of outpatients and those inpatients not requiring intensive care unit–level invasive monitoring. Although there may still be patient populations in whom the measure remains worthwhile, the results of this study are humbling and argue for exercising substantial caution when using this noninvasive measure to guide management in patients with advanced heart failure.

Moreover, these results reinforce the importance, before we adopt novel and potentially useful methodologies, of understanding more fully their utility and limitations across the full spectrum of patients in whom they might provide clinical value.

Disclosures

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References


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Recalibrating the Barometer: Is It Time to Take a Critical Look at Noninvasive Approaches to Measuring Filling Pressures?
Scott D. Solomon and Lynne W. Stevenson

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