Assessment of the American Society of Echocardiography-European Association of Echocardiography guidelines for diastolic function in patients with depressed ejection fraction: an echocardiographic and invasive haemodynamic study

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Aims
There is controversy surrounding the accuracy of echo-Doppler variables, including early mitral inflow/mitral annular velocity (E/e’), for estimating left ventricular filling pressure (LVFP) in patients with depressed ejection fraction (EF < 50%).

Methods and results
The American Society of Echocardiography-European Association of Echocardiography (ASE-EAE) algorithm for diastolic function in depressed LVEF was retrospectively applied to a database of patients who underwent echocardiography ≤ 20 min of cardiac catheterization. LV pre-atrial contraction pressure (pre-A) ≥ 15 mmHg was elevated. Of 62 patients studied, the mean age was 53.6 ± 10.6 years and the mean LVEF was 27.2 ± 11.8%. The correlations of E/e’ (R = 0.43, P = 0.0005) and E (R = 0.39, P = 0.002) with LV pre-A were modest, compared with pulmonary artery pressure (PAP, R = 0.69, P = 0.0006), E/late mitral (A) velocity (R = 0.52, P < 0.0001), and mitral deceleration time (DT, R = −0.51, P < 0.0001). Using the ASE-ESE algorithm starting with E/A, E, and DT, 54 of 62 patients were accurately classified to predict LV pre-A ≥ 15 or < 15 mmHg (sensitivity = 84%, specificity = 80%, area under the curve = 0.86, P < 0.001). The 6 of 6 patients with E/A < 1 and E < 50 and the 14 of 15 (93%) patients with E/A > 2 and DT < 150 were correctly classified as having normal and elevated LVFP, respectively, while 34 of 41 (83%) patients with E/A = 1–2 or E/A < 1 and E > 50 cm/s were correctly classified using the addition of E/e’ and PAP.

Conclusion
This retrospective study shows that in this population with depressed LVEF, no single echo-Doppler variable had high accuracy for predicting LV pre-A ≥ 15 mmHg. However, the ASE-EAE algorithm using multiple variables predicted LVFP with good accuracy, superior to any single echo-Doppler variable alone.

Keywords
Diastolic function • Heart failure • Haemodynamics

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Introduction

In patients with depressed left ventricular ejection fraction (LVEF < 50%), it is clinically important to determine whether the left ventricular filling pressure (LVFP) is normal (compensated) or elevated, in order to distinguish non-heart failure (HF) causes of dyspnoea from ones caused by decompensated HF, and to optimize volume status and titrate medications.1 2 While echocardiography is commonly performed as a first-line test for patients with suspected or known HF, it can be, at times, difficult to accurately estimate LVFP in a given patient.3–6 In particular, a recent publication has shed some doubt on the utility of early transmural velocity/tissue Doppler annular velocity (E/e′)—and echo-Doppler variables in general—for the assessment of LVFP in patients with acute decompensated HF with significantly depressed LV systolic function.5 Therefore, we sought to determine whether a stepwise approach that incorporated multiple echo-Doppler variables, as described in the American Society of Echocardiography-European Association of Echocardiography (ASE-EAE) guidelines for diastolic function,6 provided an accurate assessment of LVFP in patients with depressed LV systolic function.5 Therefore, we sought to determine whether a stepwise approach that incorporated multiple echo-Doppler variables, as described in the American Society of Echocardiography-European Association of Echocardiography (ASE-EAE) guidelines for diastolic function,6 provided an accurate assessment of LVFP in patients with depressed LV systolic function.5

Methods

This study protocol was approved by the Institutional Review Board of the Baylor College of Medicine. A retrospective analysis was performed on patients referred for coronary angiography for clinical reasons from January 2007 to July 2009 who underwent echocardiography with Doppler immediately after catheterization. This database was analysed and patients with depressed LVEF were identified.

All clinical catheterizations were performed after informed consent. Patients underwent left heart catheterization in the supine position via a retrograde approach from the femoral artery. The aortic valve was crossed to determine left ventricular diastolic pressures using fluid-filled catheters before selective injection of the coronary ostia for coronary angiography was performed. No patients in this study underwent percutaneous coronary intervention or LV angiography during cardiac catheterization, and therefore volumes of contrast used were minimized. The LV pre-atrial (pre-A) contraction pressure was measured as the pressure just prior to atrial contraction, and the LV end-diastolic pressure (LVEDP) was measured as the pressure at end-diastole, immediately following atrial contraction and just prior to mitral valve opening. These LV pressures were measured in millimetres of汞 (mmHg), and 10 consecutive cardiac cycles were measured during free respiration and then averaged. Standard diagnostic views of the left and right coronary anatomy were obtained, and lesions ≥70% by diameter in major epicardial arteries represented significant coronary artery disease (CAD). Readings of invasive cardiac haemodynamics and coronary anatomy were performed by an invasive cardiologist blinded to all clinical and echocardiographic data. A comprehensive transthoracic echo-Doppler examination was performed in the left lateral decubitus position immediately after catheterization. Patients were excluded if they had atrial fibrillation, paced rhythm, severe mitral regurgitation, any mitral stenosis, or prosthetic mitral valve, as these conditions render Doppler estimation of LVFPs less reliable.3 6 Patients were included in the analysis if echo-Doppler acquisition was commenced within 20 min after the catheterization was completed. Patients whose echocardiography commenced >20 min after catheterization were excluded from analysis.

Studies were performed on a General Electric Vivid 7 ultrasonographic machine (General Electric, Milwaukee, WI, USA). Two-dimensional measurements were performed according to the ASE guidelines7 and included: LVFP by the biplane method of discs (using an average of apical four- and two-chamber views), maximal left atrial volume (LAV) by the biplane method of discs (using an average of apical four- and two-chamber views), and LV mass by the area-length method; the latter two variables were indexed to the body surface area. Depressed LVFP was defined as <50%.6 Pulsed Doppler was used to record transmural inflow in the apical four-chamber view.4,8 Tissue Doppler velocities were then acquired at the septal and lateral annular sites and averaged as described previously.8–10

Studies were analysed by an echocardiologist blinded to all clinical and catheterization data. Mitral inflow measurements included peak early (E) and peak late (A) velocities, E/A ratio, and deceleration time (DT) of E.4,6 Pulmonary artery pressure (PAP) was estimated by adding the peak tricuspid regurgitation velocity, converted to peak pressure by the modified Bernoulli equation, to an estimate of right atrial pressure (RAP). Saline contrast was not used to enhance the tricuspid regurgitation signal. The RAP estimate was made using the following: RAP = 5 mmHg if the inferior vena cava (IVC) was <2 cm in diameter and had ≥50% inspiratory collapse, 10 mmHg if the IVC was ≥2 cm in diameter and had ≥50% inspiratory collapse, and 15 mmHg if the IVC was ≥2 cm in diameter and had <50% inspiratory collapse.11 All patients included in the analysis had IVC views. The early diastolic (e′) velocity by tissue Doppler at the septal and lateral annular sites was measured and the E/e′ ratio computed using the average of the septal and lateral e′ as described previously.6,8–10,12,13 Three cardiac cycles were measured and averaged for all Doppler measurements.

Continuous data are presented as mean ± standard deviation and categorical data as numbers (%). Student’s t-test was performed for continuous variables and the χ² test was used for dichotomous variables, to stratify patients according to LV pre-A pressure <15 or ≥15 mmHg. Linear regression was performed to determine the correlation between continuous variables and LV pre-A pressure. Sensitivity, specificity, and positive and negative predictive values were calculated by standard definitions, and receiver-operating characteristic (ROC) curves were constructed and area under the curve (AUC) was calculated for the prediction of LV pre-A pressure ≥15 mmHg. For incremental accuracy, as stated in the ASE-EAE guidelines,6 when E/A > 2 or DT < 150 ms, LVFP was determined elevated, and no further indices were needed. When E/A was >1 and E < 50 cm/s, LVFP was determined not elevated, and no further indices were needed. When E/A > 2, or E/e′ > 1 and E > 50 cm/s, either of the following variables had to be present in order to identify elevated LVFP by echo-Doppler: E/e′ > 15 or PAP > 35 mmHg.6 Therefore, using the ASE-EAE algorithm, patients either categorically fulfilled any of these three pathways, starting with mitral E/A, for the estimation of LVFPs of patients with depressed LVFP, or they did not. Using LV pre-A pressure as the continuous variable, and the ASE-EAE algorithm as the categorical variable, ROC curves were then calculated. In a subset of patients with LVEF < 30%, a stepwise multiple linear regression was performed for the echo-Doppler variables in the ASE-EAE algorithm, corrected for heart rate, to determine their independent relation to LV pre-A pressure. The Hanley–McNail test was used to assess for significant
diagnosed invasive stress test in 15 (24%), dyspnoea in 12 (19%), and 28 (45%), assessment of coronary disease with a positive non-
vascularization. The indications for catheterization were chest pain/angina in (40%) were diabetic, and 30 (48%) had significant CAD at catheter-
were hypertensive, 25 therefore, the data of 62 patients with LVEF < 50% were studied, of whom 26 (42%) were women, 46 (74%) were hypertensive, 25 (40%) were diabetic, and 30 (48%) had significant CAD at catheter-
resulting in an average of annuli 14.0
lateral annulus 13.2
septal annulus 14.9

Table 2 Echocardiographic and Doppler variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>LV pre-A &lt;15 mmHg (n = 18)</th>
<th>LV pre-A ≥15 mmHg (n = 44)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV diastolic dimension (cm)</td>
<td>5.3 ± 0.9</td>
<td>5.6 ± 0.6</td>
<td>0.17</td>
</tr>
<tr>
<td>Left ventricular mass index</td>
<td>112.1 ± 35.3</td>
<td>117.2 ± 41.2</td>
<td>0.70</td>
</tr>
<tr>
<td>Left atrial volume index (mL/m²)</td>
<td>36.2 ± 10.2</td>
<td>44.8 ± 14.8</td>
<td>0.04</td>
</tr>
<tr>
<td>Right ventricular diastolic dimension (cm)</td>
<td>3.6 ± 0.6</td>
<td>4.1 ± 0.5</td>
<td>0.04</td>
</tr>
<tr>
<td>Right atrial volume index (mL/m²)</td>
<td>21.9 ± 10.2</td>
<td>28.5 ± 7.8</td>
<td>0.08</td>
</tr>
<tr>
<td>Left ventricular ejection fraction (%)</td>
<td>33.3 ± 6.4</td>
<td>25.3 ± 6.2</td>
<td>0.009</td>
</tr>
<tr>
<td>Mitral E (cm/s)</td>
<td>70.9 ± 14.6</td>
<td>91.5 ± 15.30</td>
<td>0.002</td>
</tr>
<tr>
<td>Mitral A (cm/s)</td>
<td>72.5 ± 18.0</td>
<td>64.3 ± 17.1</td>
<td>0.30</td>
</tr>
<tr>
<td>Mitral E/A</td>
<td>0.9 ± 0.3</td>
<td>1.7 ± 0.3</td>
<td>0.006</td>
</tr>
<tr>
<td>Mitral deceleration time (cm/s)</td>
<td>224.6 ± 47.2</td>
<td>169.2 ± 44.9</td>
<td>0.001</td>
</tr>
<tr>
<td>Pulmonary artery systolic pressure (mmHg)</td>
<td>30.7 ± 7.2</td>
<td>45.0 ± 9.1</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mitral E/e ’ septal annulus</td>
<td>14.9 ± 3.1</td>
<td>23.5 ± 5.9</td>
<td>0.001</td>
</tr>
<tr>
<td>Mitral E/e ’ lateral annulus</td>
<td>13.2 ± 3.3</td>
<td>18.1 ± 5.2</td>
<td>0.01</td>
</tr>
<tr>
<td>Mitral E/e ’ average of annuli</td>
<td>14.0 ± 3.2</td>
<td>20.8 ± 5.5</td>
<td>0.004</td>
</tr>
</tbody>
</table>

A, mitral late diastolic velocity; E, peak early mitral inflow velocity; e’, tissue Doppler peak early mitral diastolic velocity.

Results

Of the 110 patients with depressed LVEF identified from the database, 20 were excluded for non-sinus rhythm, 12 for severe mitral regurgitation, 5 with prosthetic mitral valve, 2 with mitral stenosis, and 9 in whom the aortic valve was not crossed at catheterization. Therefore, the data of 62 patients with LVEF < 50% were studied, of whom 26 (42%) were women, 46 (74%) were hypertensive, 25 (40%) were diabetic, and 30 (48%) had significant CAD at catheterization. The indications for catheterization were chest pain/angina in 28 (45%), assessment of coronary disease with a positive non-invasive stress test in 15 (24%), dyspnoea in 12 (19%), and assessment of coronary disease in LV dysfunction in 7 (11%). The mean age of the population was 53.6 ± 10.6 years, and the mean LVEF was 27.2 ± 11.8%. When the population was divided into 18 patients with LV pre-A < 15 mmHg and 44 patients with pre-A ≥ 15 mmHg, there were no significant differences in age (P = 0.17), systolic blood pressure (P = 0.89), prevalence of diabetes (P = 0.98), prevalence of hypertension (P = 0.86), current smoking (P = 0.75), hypercholesterolaemia (P = 0.85), number of patients on β-blockers (P = 0.62), angiotensin-converting enzyme (ACE)-inhibitors/angiotensin receptor blockers (P = 0.98), or diuretics (P = 0.55) (Table 1). Among echocardiographic and Doppler variables, LAV index (LAVi) and right ventricular diastolic dimension were larger, LVEF was lower, and peak mitral E velocity, E/A, PAP, and E/e’ were higher in patients with LV pre-A ≥ 15 mmHg compared with patients with LV pre-A < 15 mmHg (Table 2). The data obtained at catheterization according to the categorization of LV pre-A < 15 or ≥ 15 mmHg are displayed in Table 3.
had quite modest correlations with LV pre-A pressure, compared with the correlations of PAP (R = 0.69, P = 0.0006), E/A (R = 0.52, P < 0.0001), mitral DT (R = −0.51, P < 0.0001), and LAVi (R = 0.50, P < 0.001) with LV pre-A pressure. By comparison, in the 24 of 62 (39%) patients in whom B-type natriuretic peptide (BNP) was clinically ordered, the correlation of BNP with LV pre-A pressure was R = 0.40 (P = 0.05). As individual echo-Doppler variables, E/e’ > 15 had a sensitivity of 77% and a specificity of 65% (AUC = 0.73, P = 0.004), compared with PAP > 35 mmHg (sensitivity = 79%, specificity = 75%, AUC = 0.79, P = 0.0005), DT < 150 ms (sensitivity = 81%, specificity = 64%, AUC = 0.77, P = 0.001), E/A > 0.99 (sensitivity = 76%, specificity = 62%, AUC = 0.73, P = 0.002), and LAVi > 35 mL/m² (sensitivity = 68%, specificity = 63%, AUC = 0.72, P = 0.008). There were no significant differences in AUCs between the individual echo-Doppler variables.

When applying the ASE-EAE algorithm for estimation of filling pressure in patients with depressed EF, 6 of 62 patients (10%) had E/A < 1 and E ≤ 50 cm/s (Group 1), 41 (66%) had E/A ≥ 1 and ≤ 2, or E/Ea < 1 and E > 50 cm/s (Group 2), and 15 (24%) had E/A ≥ 2 (Group 3). All 6 of 6 patients (100%) in Group 1 had LV pre-A <15 mmHg, while 14 of 15 patients (93%) in Group 3 had LV pre-A ≥15 mmHg. Of the 41 patients in Group 2, 34 of 41 (83%) had their LVFP correctly predicted using the presence of either of the additional variables: PAP ≥ 35 mmHg or E/e’ ≥ 15. Therefore, most patients (34 of 41, 83%) had indeterminate diastolic classification based on E/A and mitral DT alone (Group 2) and required further variables such as E/e’ and PAP; furthermore, despite addition of these additional variables, some patients remained unclassifiable. Overall, however, the ASE-EAE algorithm had higher diagnostic accuracy (sensitivity = 84%, specificity = 80%, AUC = 0.86, P < 0.001) for predicting LV pre-A pressure, compared with E/e’ alone (sensitivity = 77%, specificity = 65%, AUC = 0.73, P = 0.004) or any other individual echo-Doppler variable (P < 0.05 for comparisons; Figure 1). The optimal cut-off value for LV pre-A pressure was ≥15 mmHg using the ASE-EAE algorithm.

In the 13 of 62 (21%) patients with left bundle branch block (LBBB) and QRS complex >120 ms, the correlations of individual echo-Doppler variables with LV pre-A pressure were: LAVi (R = 0.53, P = 0.06), E/e’ (R = 0.46, P = 0.10), mitral E (R = 0.43, P = 0.13), mitral DT (R = 0.58, P = 0.03), and PAP (R = 0.62, P = 0.04). Using the ASE-EAE algorithm, 12 of 13 patients (92%) with LBBB and QRS duration >120 ms were correctly categorized according to pre-A pressure ≥15 or <15 mmHg.

On stepwise forward multiple linear regression analysis, adjusted for heart rate, E/e’ (P < 0.001), PAP (P = 0.001), DT (P = 0.002), and E/A (P = 0.013) were independent predictors of pre-A pressure. In the 36 (58%) patients with LVEF <30% (mean LVEF 19.3 ± 5.5%), E/A > 2 and DT < 150 ms were applied as a combined criterion to identify LV pre-A pressure ≥15 mmHg, as stated in the ASE-EAE guidelines (Group 3). Using this approach, E/A > 2 and DT < 150 ms correctly identified 22 of 36 (61%) patients as having LV pre-A pressure ≥15 mmHg, compared with 31 of 36 (86%) correctly classified using the ASE-EAE algorithm (P < 0.05 for comparison). Figures 2 and 3 show examples of patients in the database whose diastolic function was determined according to the stepwise ASE-EAE algorithm.

### Discussion

This retrospective study of patients with significantly depressed EF who underwent angiography with invasive LVFP measurement and echo-Doppler assessment of diastolic function demonstrates that a stepwise approach, as advocated in the ASE-EAE guidelines for LV diastolic assessment, is better than any single variable alone for the assessment of LVFP. Furthermore, while the ability of E/e’ in this study to predict LV pre-A pressure ≥15 mmHg appeared better than in other studies with patients with acute decompen-sated HF with severely depressed LVEF, the ability E/e’ alone to predict LVFP was somewhat modest. Overall, this study underscores the message that any single echo-Doppler variable alone is insufficient to accurately predict LVFP in patients with depressed LVEF; rather, a stepwise approach incorporating multiple variables is superior and will lead to a high accuracy. It is important to point out, however, that this study did not include pulmonary venous flow or mitral inflow during Valsalva manoeuvre, both of which are included in the ASE-EAE algorithm.

The use of transmural Doppler variables for the prediction of LVFPs has been well documented in patients with depressed LVEF. The Mayo Clinic group demonstrated that E/A was higher and DT was shorter in patients with as opposed to without HF by the Killip classification and that these indices predicted prognosis in patients with systolic HF. The Baylor group showed that DT and E/A, as well as isovolumic relaxation time...
and atrial filling fraction, significantly correlated with invasively measured LVEDP. The Mayo Clinic group also showed that DT < 180 ms and E/A > 1 significantly predicted elevated LVFP in patients with systolic HF and Pozzoli et al. demonstrated similar findings also using invasive measures of LVFP in patients with depressed LVEF. The latter group further demonstrated that these Doppler measures of diastolic function were reproducible. The Mayo group also demonstrated that LAV correlated (R = 0.70) with invasively measured LVFP, but LAVi index may better reflect chronic, rather than acute, changes in LVFP. The advent of tissue Doppler imaging and the derived ratio E/e’ has been shown in several studies to be a reasonable correlate of LVFP in patients with preserved as well as depressed LVEF. Yet, there is a general paucity of data regarding the prediction of LVFP using E/e’ in patients with significantly depressed LVEF and/or advanced systolic HF.

One recent study has cast some doubt on the reliability of E/e’, and echo-Doppler variables in general, for the accurate prediction of LVFP in patients admitted to the hospital with advanced systolic HF. While our study revealed modest correlations of individual echo-Doppler parameters, particularly E/e’, for the prediction of elevated LVFP, the correlation coefficients appeared better compared with the study of Mullens et al. The study by Mullens et al. had significant methodological differences compared with our study, including that it was performed in hospitalized, critical care unit patients with acute decompensated systolic HF (while ours is the study of patients with depressed LVEF undergoing cardiac catheterization), the use of pulmonary capillary wedge pressure (PCWP) by right heart catheterization to assess LVFP (while we used LV pre-A pressure by retrograde left heart catheterization), and the inclusion of patients with uni- or biventricular pacemakers, LBBB, significant mitral regurgitation, or atrial fibrillation, none of whom were included in our study. In addition, it was unclear from the Mullens’ study as to whether patients had already received medications to correct volume overload and ameliorate HF, or if changes in body position had occurred between invasive measurements of cardiac pressures and echo-Doppler acquisition. In addition, our study is one of few studies to employ a stepwise approach, as recommended by the ASE-EAE guidelines for diastolic function, using multiple echo-Doppler variables (E/A, peak E, DT, E/e’, and PAP), and apply this in a population with significantly depressed LVEF. Another recently published study has shown that in 270 patients with LV dysfunction and elevated LVFP defined as PCWP > 15 mmHg, combinations of E/e’, mitral DT,
Figure 2  The use of the ASE-EAE diastolic algorithm in a patient with depressed left ventricular ejection fraction: normal left ventricular filling pressure. In this patient with LVEF = 37%, (A) shows pulsed Doppler mitral inflow with $E = 0.73$ m/s, $A = 0.78$ m/s, $E/A = 0.94$, and DT = 247 ms. Therefore, the patient fits into Group 2 of the algorithm, for whom additional variables are required. (B) Lateral tissue Doppler early diastolic annular velocity ($e'$) = 10 cm/s and septal $e'$ = 9 cm/s (data not shown); therefore, average $E/e'$ = 7.9, consistent with normal left ventricular filling pressure. (C) Peak TR gradient = 20 + 10 mmHg based on IVC size resulted in PASP of 30 mmHg, again consistent with normal left ventricular filling pressure. (D) LAVi in the apical four-chamber view = 67 mL, with LAVi in the apical two-chamber view = 63 mL, (data not shown), resulting in a biplane LAVi of 31 mL/m² as the patient’s body surface area was 2.1 m², which is also consistent with normal left ventricular filling pressure (but not part of the ASE-EAE diastolic algorithm). Left ventricular pre-atrial contraction pressure at catheterization was not elevated at 11 mmHg; A, late transmitral pulsed Doppler velocity; DT, deceleration time; E, early transmitral pulsed Doppler velocity; IVC, inferior vena cava; LAVi, left atrial volume index; LVEF, left ventricular ejection fraction; PASP, pulmonary artery systolic pressure; TR, tricuspid regurgitation.

LAVi, colour flow propagation velocity, pulmonary venous flow, and PAP correctly allocated patients according to PCWP with an 87% sensitivity and a 90% sensitivity; in patients with LVEF > 50%, this model was 17% more accurate than the single best diastolic parameter. A very recently published study has shown that the ASE-EAE diastolic guidelines had high sensitivity and specificity for the prediction of PCWP > 15 mmHg in patients with new-onset, acute decompensated HF. In this study, 79 patients underwent simultaneous right heart catheterization and echo-Doppler interrogation while avoiding changes in the body position, with the following correlations with PCWP: mitral $E$ (R = 0.6), mitral $E/A$ (0.64) mitral DT (0.46), $E/e'$ (0.61), PAP (0.57), LAVi (0.25), and pulmonary venous systolic filling fraction (0.61) ($P < 0.001$ for all, except LAVi where $P = 0.03$). The ASE-EAE algorithm had a sensitivity of 98% and a sensitivity of 91% for the prediction of PCWP > 15 mmHg in this study. Therefore, the study of Nagueh et al. also showed that using multiple echo-Doppler variables, as per the ASE-EAE algorithm, had good accuracy for predicting elevated LVFPs. The differences between the studies include that it was performed in acute decompensated HF (while ours was in patients with chronic LV dysfunction), the use of right heart catheterization (while our study employed left heart catheterization), the simultaneous measurement of invasive pressures and echo variables (while ours were within 20 minutes of each other), and the measurement of pulmonary venous Doppler parameters (while ours did not).

In addition, this algorithmic approach likely more closely reflects that used by experienced echocardiologists in daily clinical practice. That is, it is uncommon, in our opinion, for an expert echocardiologist to depend on only one echo-Doppler variable in isolation (whether $E/e'$, $E/A$, or DT) to estimate diastolic function in a given patient with depressed (or preserved) LVEF. It is more likely for an expert echocardiologist to integrate multiple echo-Doppler variables, especially given that it is not infrequent for a patient to have conflicting variables. This stepwise, algorithmic approach, as advocated in the ASE-EAE guidelines, when applied to this retrospective database of patients with significantly depressed LVEF, showed reasonably good accuracy in predicting invasively measured LVFP. Another recently published study has shown that echo-Doppler variables are highly accurate in predicting simultaneously measured PCWP in patients with acute decompensated HF. In addition, more recent data have confirmed the robust prognostic power of a pseudonormal filling pattern in patients with HF and of $E/e'$ as an estimate of PCWP in patients with aortic stenosis. While these data on individual echo-Doppler variables are encouraging, we still feel that an approach integrating multiple echo-Doppler variables would be more reliable for the daily clinical scenario.
Limitations

This was a retrospective study of a database of patients with contemporary cardiac catheterization and echo-Doppler assessment; therefore, these data need to be prospectively validated in other populations or studies. While the invasive haemodynamics in this study were not simultaneous with echo-Doppler measurements, they were very close in proximity (≤20 min of catheterization). Fluid-filled, as opposed to solid, catheters were used to measure cardiac haemodynamics in this study. LV pre-A pressure (15 mmHg) was identified as elevated in this study, consistent with prior studies. As stated in the ASE-EAE diastolic guidelines, LVEDP, PCWP, mean LV pressure, and LV pre-A pressure are all reasonable estimates of mean LA pressure. Although LVEDP was also measured in this study, correlations were performed using LV pre-A pressure as it has been shown to better reflect the mean left atrial pressure. In addition, various cut-off values for these invasive indices have been used in prior studies as reflecting elevated LVFPs, ranging from 12 to 18 mmHg for PCWP, mean LV diastolic pressure, or LV pre-A pressure; however, the linear regressions of LV pre-A with echocardiographic variables performed in this study would obviate the need for an exact categorization of what is considered elevated. Although the patients in this study had significant depression of LVEF, patients with uni- or biventricular pacemakers or atrial fibrillation were not studied, thus precluding the assessment of diastolic function using echo-Doppler in this patient population. In addition, the patients in this study were not in advanced, decompensated HF. While pulmonary venous variables, flow propagation velocity, and response to Valsalva manoeuvre have been shown to be useful in patients with depressed LVEF, they were not routinely measured in this patient population and therefore cannot be commented upon. However, it may be argued that additional variables may further increase the accuracy in the estimation of diastolic function using echocardiography with Doppler.

Conclusions

In this retrospective study, while any single echo-Doppler variable— including E/e′—is an imperfect estimate of LVFP in patients with significant depression of LVEF, a stepwise approach incorporating multiple variables, as advocated in ASE-EAE guidelines for diastolic function, provides an accurate assessment of LVFP in this patient population, superior to any single variable alone.
Conflict of interest: none declared.

References