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Original Article

A Comparison of the Strain and Tissue Doppler-Based Indices as Echocardiographic Correlates of the Left Ventricular Filling Pressures

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Objectives: Diastolic strain and strain rate, combined with E (peak transmitral velocity), have been proposed as novel noninvasive predictors of left ventricle (LV) filling pressures, avoiding angulation errors inherent to tissue Doppler indices (TDI). The primary objective was to study the correlation of strain-based indices (SBI) and TDI with pulmonary artery catheter–derived LV end-diastolic pressures (LVEDP). The secondary aim was to determine appropriate cut-off of indices to predict LVEDP ≥ 15 mmHg.
Design: A prospective observational clinical study.
Setting: Single university hospital.
Participants: One hundred twenty adults with preserved ejection fraction (EF) undergoing coronary artery bypass grafting.
Interventions: None.
Measurements and Main Results: Two-dimensional speckle-tracking echocardiography estimated global longitudinal diastolic strain (Ds) and strain rate (DSr) at peak mitral filling to compute E/Ds and E/10DSr. TDI was measured as the ratio of E and e' (mitral annular diastolic velocity). E/e', E/Ds, and E/10DSr were significantly higher ($p < 0.001$) in patients with LVEDP ≥ 15 mm Hg (31/120). Correlation of E/Ds, E/10DSr with LVEDP was $R = 0.86$ and 0.88 ($p < 0.001$), respectively, compared with a correlation of $R = 0.63$ ($p < 0.001$) for E/e'. SBI correlated well with LVEDP ≥ 15 mm Hg compared with TDI. E/Ds ≥ 11 and E/10DSr ≥ 12 had higher sensitivity and specificity (96.77%, 93.26%; 100%, 96.63%, respectively; area under the curve [AUC] = 0.99) than E/e' ≥ 13 (74%,75%; AUC = 0.84) for prediction of LVEDP ≥ 15 mmHg. SBI accurately predicted elevated LVEDP in the indeterminate zone of $8 < E/e' < 13$.
Conclusions: SBI were better predictors of LVEDP, compared with TDI, in patients with preserved EF and indeterminate E/e' values.

Key Words: diastolic strain; diastolic strain rate; diastolic function; left ventricular filling pressures; speckle tracking echocardiography

ACCURATE NONINVASIVE MEASUREMENT of left ventricle (LV) filling pressures is an important tool to evaluate, stratify, and guide the overall management of cardiac surgical patients.[1] The quantification of diastolic dysfunction is an indispensable assessment tool independent of systolic

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function, because it contributes significantly to adverse postoperative outcomes.[2] Various transesophageal echocardiography (TEE)-derived parameters serve as noninvasive surrogates of LV filling pressures, avoiding the inherent complications associated with right-heart catheterization.

Tissue Doppler mitral annular early diastolic velocity (e'), when combined with peak transmitral early diastolic velocity (E), computes a dimensionless index E/e'. E/e' provides an echocardiographic estimate of LV filling pressure.[3–5] However, tissue Doppler index (TDI: E/e') is less reliable in patients with preserved LV ejection fraction (EF $>50\%$)[6,7] and has a considerable gray zone of indeterminate values for the prediction of LV end-diastolic pressures (LVEDP).[3–5]

Two-dimensional (2D) speckle-tracking echocardiography (STE) measures global longitudinal diastolic strain and strain rate, avoiding Doppler-associated angulation errors and tethering artifacts.[8] Using such a system, the authors proposed to measure global diastolic strain (Ds) and strain rate (DSr) at peak mitral filling to produce novel strain-based indices (SBI: E/Ds and E/10DSr) with the aim of studying the correlation of SBI with pulmonary artery catheter (PAC)-derived LVEDP, in comparison with the TDI.

Methods

This was a prospective observational study. After receiving institutional ethics committee approval and obtaining written informed consent, 120 adult patients with coronary artery disease with preserved EF ($>50\%$) who were scheduled for elective coronary artery bypass grafting on cardiopulmonary bypass were included in the study. Patients were excluded if they had non-sinus rhythm, recent myocardial infarction, severe mitral regurgitation, any mitral stenosis, prosthetic mitral valve, or known significant respiratory disease, because these conditions would render PAC and echocardiogaraphic estimation of LVEDP unreliable.

Anesthesia was induced and maintained as per standard institutional protocols. All patients underwent volume-controlled mechanical ventilation with oxygen in the air (fraction of inspired oxygen = 0.6) and a positive end-expiratory pressure of 5 cm H_2O targeted to an end-tidal carbon dioxide level of 35 mmHg. A Swan-Ganz catheter (Edwards Lifesciences, Irvine, CA) was positioned in the pulmonary artery through the 7 Fr sheath inserted in the right internal jugular vein. The echocardiographic analysis was accompanied by simultaneous estimation of pulmonary capillary wedge pressure by appropriate wedging of the PAC, confirmed by the presence of characteristic variations in pressure waveforms. The mean pulmonary capillary wedge pressure was measured at end expiration 6 times, and the averaged values estimated the mean LVEDP. An assistant anesthesiologist who was blinded to the echocardiographic results estimated the LVEDP, with both the echocardiographic and LVEDP measurements performed prior to sternotomy.

The TEE examination was performed with a matrix array probe and Philips Healthcare IE 33 ultrasound machine (Bothell, WA). The echocardiographic information was analyzed using dedicated QLAB cardiovascular ultrasound quantification and cardiac motion quantification software (Philips Medical Systems, Andover, MA). An investigator with 10 years of experience conducted a comprehensive 2D echocardiographic examination. The echocardiographer who

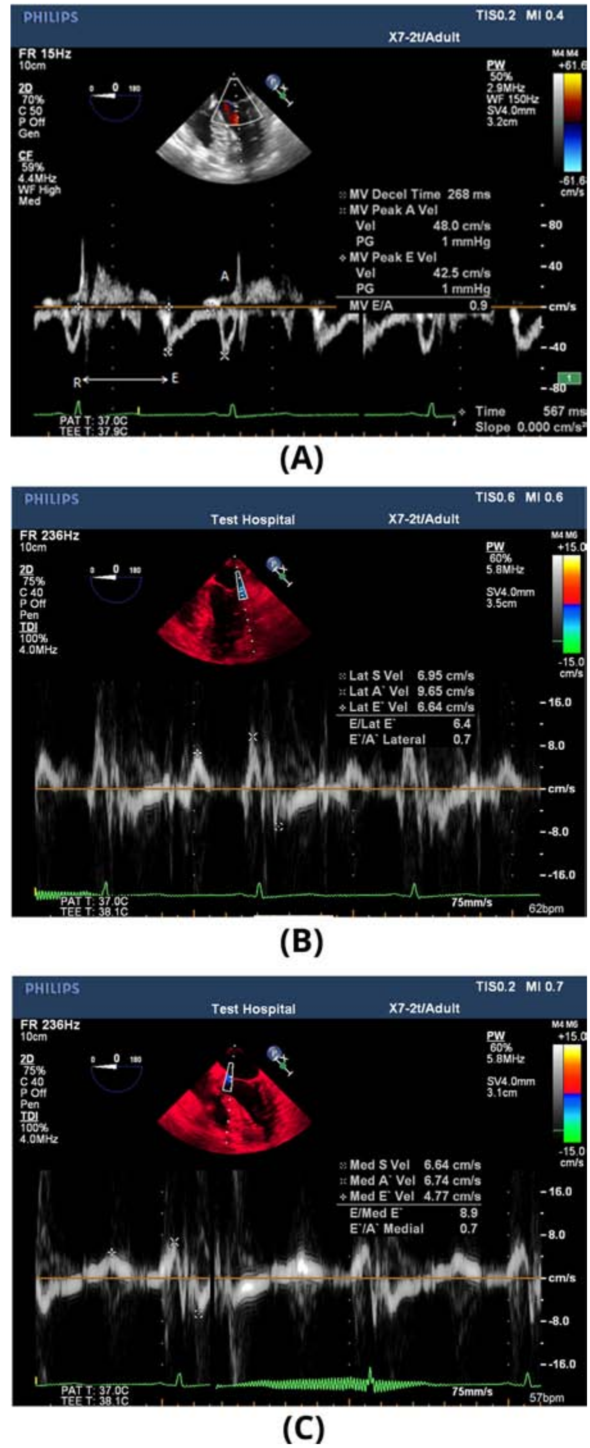

Fig 1. The echocardiographic image panel showing (A) pulse wave Doppler across the mitral valve showing the peak transmitral early diastolic velocity (E = 42.5 cm/s) and the duration from R wave to E wave (567 ms); (B) tissue Doppler estimation of the E/e' at the lateral annulus (6.4); (C) tissue Doppler estimation of the E/e' at the septal (medial) annulus (8.9). Thus, the resultant E/e' (7.51) is computed as the average of the E/e' across the 2 annuli.