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Transesophageal Echocardiographic Evaluation of Pulmonary Vein Diastolic Wave Deceleration Time – As a Predictor of Left Atrial Pressure

Abstract

Background: The deceleration time of the pulmonary venous diastolic flow has been well-correlated with invasive pulmonary capillary wedge pressure in several studies regardless of left ventricular systolic function. This study was conducted to correlate deceleration time of pulmonary venous diastolic wave, $DT_{(D)}$, and left atrial pressure (LAP), obtained noninvasively from mitral early diastolic inflow velocity-to-early diastolic mitral annulus velocity ratio (E/e′), and to assess the ease of each method in patients with coronary artery disease undergoing off-pump coronary artery bypass grafting (OPCAB) by transesophageal echocardiography. **Methods:** Forty-five adult patients with coronary artery disease, with left ventricular ejection fraction of ≥50% posted for elective OPCAB were enrolled in the study. **Results:** Forty values of LAP and $DT_{(D)}$ were analyzed. A significant linear correlation ($r = -0.64$) was found between $DT_{(D)}$ and LAP. Area under the curve of $DT_{(D)}$ of ≤183 ms for predicting elevated LAP (>15) was 0.903 (95% confidence interval: 0.767 to 0.974, $P < 0.0001$). **Conclusion:** Deceleration time of pulmonary venous flow diastolic waveform, $DT_{(D)}$, feasible promising echocardiographic measure in determining elevated LAP and $DT_{(D)}$ ≤183 ms predicts elevated LAP.

Keywords: *Deceleration time, E/e′, left atrial pressure, pulmonary venous flow*

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Introduction

The left atrium serves as a contractile chamber for augmenting left ventricular filling. It also serves as a conduit for the passage of blood from the pulmonary veins to the left ventricle and as a reservoir for storing blood during left ventricular systole. Understanding each of these functions and the contribution of the left atrium to left ventricular function in normal and diseased cardiac patients is important.[1]

Left atrial pressure (LAP) is reported to be synonymous with left ventricular end-diastolic pressure (LVEDP) in the absence of mitral valve disease. Multiple echocardiographic parameters have been validated for the assessment of left ventricular filling pressures (LVFP).[2] The most commonly used Doppler parameter is the ratio of mitral early diastolic velocity to early diastolic mitral annular velocity (E/e′), which is found to be a better parameter among the available Doppler indices.[3-5]

The e′ velocity (mitral annular velocities) "corrects" E wave velocity for the impact of relaxation and lateral E/e′ ≥12 or septal E/e′ ≥15 is correlated with an elevated LAP.[6]

However, E/e′ is not reliable in conditions where the mitral annulus might be tethered by calcium or prosthetic ring[7] and also in LV disorders such as hypertrophic cardiomyopathy[8] and regional wall motion abnormality.[9] Thus, the authors sought for a parameter which can indirectly estimate LAP regardless of LV and mitral disorders.

Decelaration time of Pulmonary vein diastolic wave, DT(D) has been well-correlated with invasive pulmonary capillary pressure in several studies regardless of left ventricular systolic function and mitral annular disorders.[10-14] However, practice is limited by the difficulty to record the pulmonary venous flow (PVF) from apical windows in critically ill patients by transthoraccic echocardiography. Transesophageal echocardiography has provided an excellent window for imaging pulmonary veins as they are located posteriorly.

Hence, the present study was conducted to correlate TEE-derived $DT_{(D)}$ and calculated LAP obtained by E/e′ ratio, and to assess

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the ease of each method in patients with coronary artery disease undergoing off-pump coronary artery bypass grafting (OPCAB).

Methods

Forty-five adult patients with coronary artery disease with LV ejection fraction of ≥50% posted for elective OPCAB were enrolled in the study. Patients with any degree of valvular heart disease, critical left main coronary artery disease, intracardiac shunts, congenital heart disease, redo surgery, atrial fibrillation, regional wall motion abnormality, mitral annular disorders and with known contraindications for the insertion of TEE were excluded from the study.

After obtaining institutional ethical committee clearance and written informed consent from all the patients, the prospective observational clinical study was conducted at a tertiary care hospital.

All patients enrolled in the study were premedicated with injection midazolam 0.02 mg/kg. A 5-MHz, multiplane TEE probe (Philips EnVisor CHD, Bothell, WA, USA) was inserted following induction of anesthesia.

Measurements were recorded pre incision, in a stable hemodynamic patient at end expiration. Mitral early diastolic inflow velocity (E) and early diastolic mitral annular velocity (e') were obtained, and E/e′ ratio was calculated.

To obtain E wave velocity, pulsed wave (PW) cursor was aligned parallel to mitral valve inflow and the sample volume was placed at the mitral valve leaflet tips [Figure 1a]. e′ velocity was obtained in mid-esophageal four-chamber view, with activation of tissue Doppler imaging (TDI) function on TEE machine. PW TDI was used to measure peak myocardial velocities. Sample volume of PW Doppler was placed immediately adjacent to lateral mitral annulus [Figure 1b]. The first negative wave in mitral inflow velocity waveform was taken as ‘E’ and in TDI, the first positive diastolic wave was taken as e′ and the second positive diastolic wave was taken as a′.

PVF measurements were taken from left upper pulmonary vein obtained from two-chamber view (90° with slight rotation to left) by placing the PW Doppler sample volume approximately 1 cm beyond the orifice of left upper pulmonary vein. Color flow Doppler was used when necessary to assist with optimal sample volume placement [Figure 2].

Data collection and post-processing of the images was done by a single echocardiographer. For all measurements, five consecutive beats were traced and the results were averaged. LAP was then estimated by Nagueh’s formula LAP = 1.24 × (E/e′) + 1.9.[15] PVF was analyzed for the deceleration time of diastolic wave $DT_{(D)}$.

Statistical analysis

Data was expressed as mean ± standard deviation for normally distributed values. Pearson’s correlation coefficient was determined for the relationship between $DT_{(D)}$ and LAP. Receiver operating characteristic (ROC) analysis was constructed for evaluating $DT_{(D)}$ in predicting elevated left atrial pressure. P value of ≤0.05 was considered significant. MedCalc statistical software, version 12.2.1.0 (Ostend, Belgium), was used for statistical analysis.

Results

A total of 45 adult patients undergoing OPCAB were enrolled in the study. Pulmonary venous Doppler wave was obtained in 43 patients (96%), and E/e′ was obtained in 40 patients (89%). Forty values of LAP and $DT_{(D)}$ were analyzed.

The baseline clinical and hemodynamic characteristics are summarized in Table 1.

Correlation between $DT_{(D)}$ and LAP

A significant linear correlation (r = −0.64) was found between $DT_{(D)}$ and LAP [Table 2].

The ROC curve was constructed to evaluate the sensitivity and specificity of $DT_{(D)}$ to predict elevated LAP. Elevated LAP was defined as calculated LAP ≥15 mmHg. Area under the curve (AUC) of $DT_{(D)}$ of ≤183 ms for predicting elevated LAP (≥15 mmHg) was 0.903 [95% confidence interval (CI): 0.767–0.974, P < 0.001] with sensitivity of 95.7%, specificity of 70.6%, positive predictive value

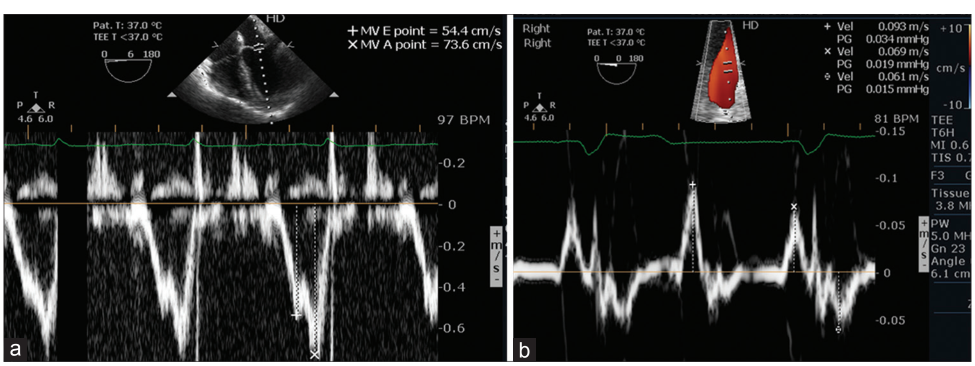

Figure 1: (a) Mitral inflow velocities (b) TDI of lateral mitral annulus

of 81.5%, negative predictive value of 92.3%, positive likelihood ratio of 3.25, and negative likelihood ratio of 0.062 [Figure 3].

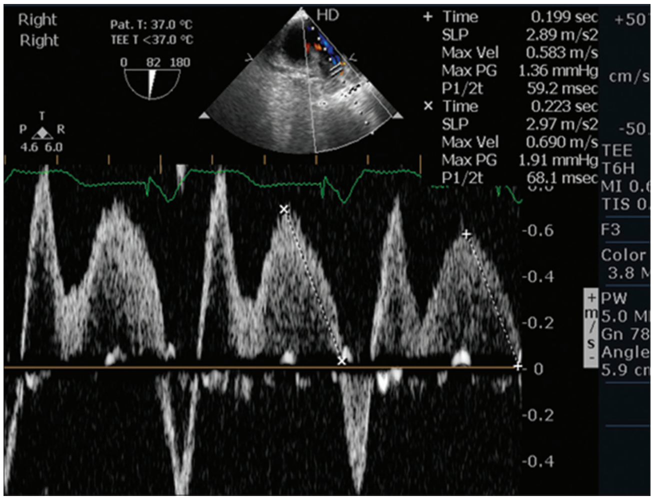

Figure 2: Pulmonary venous flow velocities

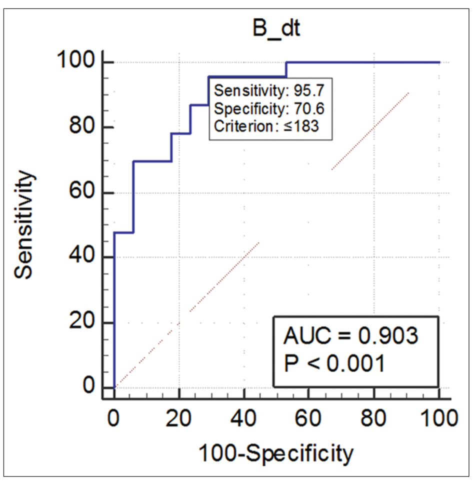

Figure 3: ROC curve for the sensitivity and specificity of DT(D) to predict elevated LAP (≥15 mmhg)

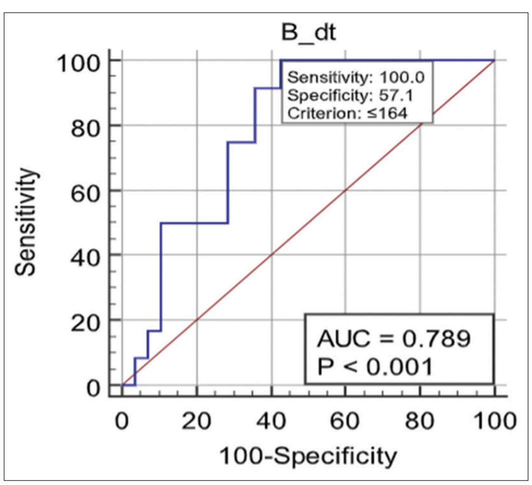

Figure 4: ROC curve for the sensitivity and specificity of DT(D) to predict severely elevated LAP (≥20 mmHg)

AUC of $DT_{(D)}$ of ≤164 ms for predicting severely elevated LAP (≥20 mmHg) was 0.789 (95% CI: 0.631–0.901, $P < 0.0001$) with sensitivity of 100%, specificity of 57.14%, positive predictive value of 50%, and negative predictive value of 100%, positive likelihood ratio of 2.33 and a negative likelihood ratio 0.00 [Figure 4].

Discussion

E/e′ is well validated with LV filling pressures and the prediction of normal and abnormal filling pressure being most reliable when the ratio is <8 or >15.[16,17]

Literature reports DT(D) to be more accurate than pulmonary artery occlusion pressure (PAOP) in estimating LAP in cardiac surgical patients.[16]

The results of the present study demonstrated significant linear correlation between DT(D) and calculated LAP measured noninvasively. AUC of DT(D) of ≤183 ms for predicting elevated LAP (≥15 mmHg) was 0.903 ($P < 0.001$) with sensitivity of 95.7% and specificity of 70.6%.

AUC of DT(D) of ≤164 ms for predicting severely elevated LAP (≥20 mmHg) was 0.789 with sensitivity of 100%, specificity of 57.14%.

Kinnaird *et al.*[18] compared a prediction of mean left atrial pressure (PLA) ascertained by Doppler echocardiography of PVF, with predicted LAP using the PAOP in 93 patients undergoing cardiac surgery. They concluded that $DT_{(D)}$ is more accurate than PAOP in estimating LAP in cardiac surgical patients ($r = -0.92$).

Table 1: Demographic profile

Variable	Mean±SD
Age (years)	57.5±13.5
Sex (m/f)	26/19
Height (cm)	163±6.3
Weight (kg)	66.3±8.3
BMI	24.3±2.5
Ejection fraction (%)	55.4±4.4
Mean arterial pressure (mmHg)	97.9±10.8
Heart rate (b/min)	68.4±5.5
Central venous pressure (mmHg)	6±1.9
Comorbidities	
Diabetes	22
Hypertension	29

SD: Standard deviation; m: male; f: female; BMI: body mass index; b/min: beats/minute

Table 2: Correlation between $DT_{(D)}$ and LAP

	Correlation coefficient	95% Confidence interval	*P*
$DT_{(D)}$ and LAP	-0.64 (*r*)	-0.7975-0.4196	0.0001

$DT_{(D)}$: deceleration time of pulmonary vein D wave; LAP: left atrial pressure

The authors of this study hypothesized a similar correlation between $DT_{(D)}$ and LAP, which is derived noninvasively by E/e′, unlike the invasive measurement of LAP in a previous study. The results of this study conclude a significant linear correlation between $DT_{(D)}$ and calculated LAP ($r = -0.64$). The authors opine that $DT_{(D)}$ can be a useful parameter in estimating elevated LAP.

Nishimura *et al*.[10] evaluated the relationship between changes in pulmonary venous and mitral flow velocities during different loading conditions as assessed by TEE in the operating room in 19 patients undergoing coronary artery bypass graft surgery. There was a direct correlation between the changes in the mitral E velocity and the early peak diastolic velocity in the pulmonary vein curves ($r = 0.61$) as well as a direct correlation between the deceleration time of the mitral and PVF velocities in early diastole ($r = 0.84$). The results indicated that diastolic flow velocity in the pulmonary vein is determined by the same factors that influence the mitral flow velocity curves. The findings of this study are in concordance with the present study, with a significant linear correlation between $DT_{(D)}$ with LAP ($r = -0.64$). AUC of $DT_{(D)}$ of ≤183 ms for predicting elevated LAP (>15 mmHg) was 0.903 ($P < 0.001$) with sensitivity of 95.7% and specificity of 70.6%.

Olariu *et al*.[19] assessed the potential value of PVF diastolic deceleration time to predict end-diastolic pressure and stratified patients with regard to elevation of left ventricular end-diastolic pressures. 174 patients were included in the study. Left ventricular end diastolic pressures (LVEDPs) were determined noninvasively by PVF diastolic deceleration time (obtained by transthoracic echo) and invasively by cardiac catheterization. The results of the study concluded that there is a fair correlation between left ventricular end-diastolic pressures with PVF diastolic deceleration time. A value of PVF diastolic deceleration time <220 ms suggested elevated left ventricular end-diastolic pressures; a value of PVF diastolic deceleration time <190 ms predicted elevated LV end-diastolic filling pressures. A value of PVF diastolic deceleration time <165 ms predicted severely elevated left ventricular end-diastolic pressures.

In the present study, LAP was indirectly calculated by Nagueh formula which is a surrogate of LVEDP in the absence of mitral valve disease. Deceleration time of pulmonary venous diastolic wave of ≤183 ms predicted elevated LAP (≥15 mmHg) and $DT_{(D)}$ of ≤164 ms predicted severely elevated LAP (≥20 mmHg).

From the results of the present study, the authors opine that deceleration time of pulmonary venous diastolic wave is a feasible method of imaging (96%), compared with E/e′ (89%). Also, as E wave and e′ images are obtained in two different cardiac cycles and as E/e’ is unreliable in patients with mitral annular calcification, regional wall motion abnormality and post mitral valve replacement, the authors are of the opinion that $DT_{(D)}$ can be an useful and easy to obtain parameter in determining elevated LAP, indirectly determining LV filling pressures in such patients.

Conclusion

The authors conclude that $DT_{(D)}$ deceleration time of PVF diastolic wave is a feasible promising echocardiographic measure in determining elevated LAP and $DT_{(D)}$ ≤183 ms predicts elevated LAP.

Limitations

Interobserver bias was not analyzed, and $DT_{(D)}$ was not evaluated in different loading conditions, in patients with valvular heart disease and regional wall motion abnormality and HOCM.

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Conflicts of interest

There are no conflicts of interest.

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