Comparative Value of Tissue Doppler Imaging and M-Mode Color Doppler Mitral Flow Propagation Velocity for the Evaluation of Left Ventricular Filling Pressure*

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Background: **Recently, two new indexes based on the ratio of transmitral early diastolic velocity (E) to tissue Doppler imaging (TDI), and early diastolic velocity of mitral annulus (E') and E to propagation velocity (Vp) have been proposed to predict left ventricular (LV) filling pressures. However, little is known about the comparative value of these two indexes.**

Methods: **We studied 71 consecutive patients referred for coronary angiography (mean age ± SD, 65 + 11 years; 21 patients with LV ejection fraction [EF] < 50%). Complete Doppler echocardiographic examination including TDI and Vp measurements and direct measurement of LV end-diastolic pressure (LVEDP) were performed simultaneously in the catheterization laboratory. LV filling pressures were considered elevated when LVEDP was ≥ 15 mm Hg.**

Results: **The correlation coefficients between E/E' and E/Vp and LVEDP were 0.68 (p = 0.01) and 0.54 (p = 0.01), respectively, in the overall population. The correlations were better in patients with low LV EF (< 50%) [0.8 (p = 0.01) and 0.77(p = 0.01)] and poor in patients with normal LV EF (0.57 [p = 0.05] and 0.41 [not significant]), respectively. Moreover, Vp measurements had higher interobserver variability compared to E' (14% vs 7%). The cutoff values for both indexes giving the best sensitivity and specificity in identifying LVEDP ≥ 15 mm Hg were 9 for (E/E') and 2 for (E/Vp)**

Conclusion: **Both E/E' and E/Vp can be used for the evaluation of LV filling pressures. However, the sensitivity of these indexes, especially E/Vp, is hampered by EF. E/E' has a lower variability than Vp and should be preferred for estimation of filling pressures especially in patients with EF > 50%.**

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Abbreviations: A = late diastolic velocity; A' = late diastolic velocity of the mitral annulus; E = early diastolic velocity; E' = early diastolic velocity of the mitral annulus; EF = ejection fraction; IVRT = isovolumic relaxation time; LV = left ventricular; LVEDP = left ventricular end-diastolic pressure; TDI = tissue Doppler imaging; Vp = propagation velocity

Noninvasive assessment of left ventricular (LV) filling pressures is a key issue in clinical practice. Pulsed Doppler echocardiographic measurements of transmitral flow velocities have been shown to be useful in this setting but only in selected patients with reduced LV ejection fraction (EF).[1–5] The early diastolic velocity (E) and deceleration are actually dependent on multiple interrelated factors, including mainly preload and relaxation. To overcome these limitations, it has been proposed to combine the transmitral flow velocities to other Doppler parameters, including pulmonary venous flow velocities or response of transmitral flow to decreased

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loading conditions.[6–11] Recently, tissue Doppler imaging (TDI) of the mitral annulus during diastole and color M-mode–derived flow propagation velocity (Vp) have been described as good indicators of ventricular relaxation, with a relative preload independency. Therefore, two new indexes based on the ratio of E to TDI early diastolic velocity of the mitral annulus (E'), and E to Vp have been proposed to predict LV filling pressure.[12–15] However, little is known about which index should be preferred for practical use. The aim of this study was to evaluate and compare accuracy and usefulness of E/Vp and E/E' in prediction of high LV filling pressures in patients with normal and low EFs.

Materials and Methods

Patients

We enrolled 88 consecutive patients in sinus rhythm referred for clinically coronary angiography. Patients with acute coronary syndrome, organic mitral or aortic valve disease, or heart transplant recipients were not included. The remaining 71 patients (mean age ± SD, 65 ± 11 years; 13 women) formed our study group. All the patients gave informed consent in agreement with ethics regulations.

Doppler Echocardiographic Studies

All patients were examined in the catheterization laboratory. Simultaneously with invasive pressure recordings, two-dimensional and Doppler echocardiographic examinations were performed with an ultrasonographic system (Sequoia 256; Acuson; Mountain View, CA) equipped with multifrequency transducer. LV EF was calculated from apical two- and four-chamber views using a modified Simpson rule. Transmitral flow patterns were recorded from apical four-chamber windows with 2- to 3-mm pulsed-sample Doppler volume placed between mitral valve tips in diastole during five consecutive cardiac cycles. Maximal velocities of E- and late diastolic velocity (A)-waves, deceleration time of E, A-wave duration time, and isovolumic relaxation time (IVRT) were measured. Pulmonary venous flow was assessed on right upper pulmonary vein, with sample volume positioned 5 to 10 mm proximal to its junction with the left atrium; velocities of the systolic reversal wave, diastolic reversal wave, atrial reversal wave, and pulmonary A-wave duration were measured.

The measurement of Vp was performed in apical four-chamber view by color Doppler echocardiography in M-mode. Then, adjustment of Doppler window and Nyquist velocity to two thirds of blood flow peak velocity was done to display the average velocity of mitral early wave from the mitral annulus to 4 cm toward the apex of the left ventricle. Vp of the early wave was measured as the slope of the line parallel to the recorded border between blue and red colors (which illustrates Nyquist velocity). M-mode color and pulsed Doppler signals were recorded at a horizontal sweep of 100 mm/s.

Tissue Doppler Measurements

The tissue Doppler program was set in pulsed-wave Doppler mode. Motion of mitral annulus was recorded in the apical four-chamber view. Sample volume was positioned sequentially at the lateral and septal corners of the mitral annulus. Two major negative velocities were recorded with the movement of the annulus toward the base of the heart during diastole, as follows: one during the early phase of diastolic myocardial velocity (E'), and another during the late phase of diastolic myocardial velocity (late diastolic velocity of the mitral annulus [A']). A major positive systolic velocity was recorded with the movement of the annulus toward the cardiac apex during systole. The peak myocardial systolic velocity was defined as the maximum velocity during systole, excluding the isovolumic contraction. All velocities were recorded for five consecutive cardiac cycles, and the results were averaged. TDI measurements of peak E' and A' were made for each cycle, and the mean was calculated. All tissue Doppler signals were recorded at horizontal time sweep set at 100 mm/s.

Pressure Measurements

Baseline LV end-diastolic pressure (LVEDP) recordings were acquired before coronary angiography and ventriculography. LV pressure measurements were done invasively with a 7F, fluid-filled pigtail catheter (Cordis Corporation; Miami, FL) with pressure transducers after calibration. The fourth intercostal space in the anterior axillary line was used as the zero level. We recorded LV diastolic pressures as follows: minimal pressure, catheterization-investigated pre-A-wave pressure and LVEDP. We defined LVEDP as maximal pressure drop after pressure increase due to atrial contraction and before the rise of systolic pressure. Pressure data were collected at end-expiration. Three consecutive heart cycles were evaluated, and the mean value of LVEDP was calculated. LV filling pressures were considered elevated in case of LVEDP $\geq$ 15 mm Hg.

Data Analysis

All data acquired during echocardiographic examinations were stored in digital imaging and communications in medicine format on magneto-optic disk. Analysis of obtained echocardiographic recordings and measurements was performed off-line on personal computer (Tomtec Imaging System, Image Arena Version 2.7; Tomtec; Munich, Germany) by two experienced echocardiographists with calculation of absolute differences and variability. Ratios of E/A, E/E', E/Vp, systolic/diastolic reversal waves, and difference between mitral A-wave duration and pulmonary atrial reversal duration (mitral − pulmonary A-wave duration) were calculated. For each result, the average taken from at least three recordings was used.

Statistical analysis was performed using software (Statistica 6.0; StatSoft; Tulsa, OK). All data are presented as mean and SD. Continuous variables were compared using Student *t* test for unpaired data when appropriate. Linear regression analysis was performed to evaluate the relationship between echocardiographic variables and invasive pressure measurements. A p value of 0.05 was considered statistically significant.

Results

Characteristics of the patient study group are presented in Table 1. Diagnosis of coronary artery disease was confirmed in 58 patients, while 6 patients had normal coronary arteries, 7 patients had low EF, and normal coronary arteries were diagnosed as dilated cardiomyopathy. Criteria of elevated LVEDP were fulfilled in group of 42 patients (mean