Correlation between Assessment of Left Ventricular End Diastolic Pressure (LVEDP) by Doppler Echocardiography and Cardiac Catheterization in Patients of Coronary Artery Disease

Tungikar Sudhir[1*], Raul K. M.[2], R. Prasad Reddy[3]

[1]Associate Professor, Department of Medicine JIIU's Indian Institute of Medical Science and Research Warudi, Badnapur, Jalna, Maharashtra, INDIA.

[2]Professor, Department of Medicine, M.G.M. Medical College, Aurangabad, Maharashtra, INDIA.

[3]Professor and Head, Department of Cardiology, Mediciti Hospital, Hyderabad, Andhra Pradesh, INDIA.

Corresponding Address:

sudhirtungikar@rediffmail.com

Research Article

Abstract: Diastolic dysfunction is common in patients with coronary artery disease and contributes to the signs and symptoms of heart failure. Doppler echocardiography is widely used for the noninvasive assessment of diastolic filling of the left ventricle (LV). Combinations of the mitral flow velocity curves with other Doppler parameters like pulmonary venous velocity curves, color M-mode, Tissue Doppler imaging (TDI) of mitral annular motion has been shown to be excellent predictors of diastolic filling in subsets of patients with coronary artery disease. The present study compared these parameters against invasive assessment of left ventricular end diastolic pressure (LVEDP) by cardiac catheterization in 70 prospective cases of coronary artery disease and concluded that EF, E/A, EDT, and IVRT were the best predictors of left ventricular filling pressures in patients with coronary artery disease with either normal or impaired LV function.

Keywords: Diastolic dysfunction, Ejection Fraction (EF), Tissue Doppler Imaging (TDI), Left Ventricular End Diastolic Pressure (LVEDP)

Introduction

Coronary artery disease is assuming larger proportions in India and will be the leading cause of death by 2020. Diastolic dysfunction is common in patients with coronary artery disease and contributes to the signs and symptoms of heart failure. Doppler echocardiography is widely used for the noninvasive assessment of diastolic filling of the left ventricle (LV). Analysis of the mitral inflow velocity curve has provided useful information for determination of filling pressures and prediction of prognosis in selected patients. However, mitral flow is dependent on multiple interrelated factors, including the rate and extent of ventricular relaxation, suction, atrial and ventricular compliance, mitral valve inertance, and left atrial pressure. These factors may have confounding effects on the mitral inflow; thus, it has not been possible to determine diastolic function from the mitral flow velocity curves in many subsets of patients. To overcome these limitations of the mitral inflow parameters, combinations of the mitral flow velocity curves with other Doppler parameters have been used. These include the pulmonary venous velocity curves, color M-mode, and the response of the mitral inflow to altered loading conditions. Tissue Doppler imaging (TDI) of mitral annular motion has been proposed to correct for the influence of myocardial relaxation on transmitral flows. This has been shown to be an excellent predictor of diastolic filling in subsets of patients. The purpose of this study was to evaluate different Doppler methods of assessment of LV diastolic function in CAD patients by comparing against invasive assessment in catheterization laboratory. We also utilized the opportunity to determine which of those methods is accurately reflective of invasive pressures.

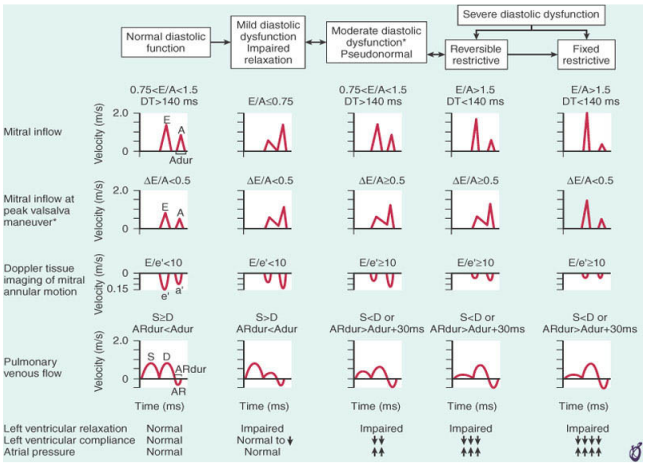
Review of literature

Stages in diastolic dysfunction

During evolution of diastolic dysfunction, a series of hemodynamic changes occur which is reflected in changing flow pattern in mitral and pulmonary velocities. Three stages are usually discernable (see the diagram)

1. Impaired / delayed relaxation
2. Pseudonormalization
3. Restriction

	Normal (young)	Normal (adult)	Delayed Relaxation	Pseudonormal Filling	Restrictive Filling
E/A(cm/s)	>1	>1	<1	1-2	>2
DT (ms)	<220	<220	>220	150-200	<150
IVRT (ms)	<100	<100	>100	60-100	<60
S/D	<1	≥1	≥1	<1	<1
AR (Cm/s)	<35	<35	<35	≥35	≥25
V_p(cm/s)	>55	>45	<45	<45	<45
E_m(cm/s)	>10	>8	<8	<8	<8



Diastolic dysfunction in Coronary Artery Disease

Myocardial ischemia alters diastolic function of the LV. The most prominent initial diastolic abnormality due to ischemia is prolonged and delayed myocardial relaxation. Relaxation becomes slower, resulting in prolongation of the isovolumic relaxation time (IVRT) as well as in lower transmitral pressure gradient at the time of mitral valve opening, which decreases early rapid filling (E) of the LV. The deceleration time (DT) of the E velocity is prolonged because of continued slow relaxation with an incompletely emptied LA, resulting in augmented LA contraction (increased A velocity), which augments LV filling.

The typical mitral flow pattern of a relaxation abnormality (reduced E, increased DT, increased A, decreased E/A) is seen during transient myocardial ischemia and in patients with CAD. When a patient has a MI, the mitral flow velocity pattern depends on interaction of various factors: relaxation abnormalities, ventricular compliance, LA pressure, loading conditions, heart rate, medications, and pericardial compliance in the setting of acute heart dilatation. Therefore, no particular mitral inflow pattern is seen consistently in patients with MI. Although numerous factors influence transmitral Doppler velocities, increased LA pressure is one of the most important determinants and produces a restrictive diastolic filling pattern (increased E, decreased DT, decreased A, increased E/A). Patients with AMI who demonstrate a restrictive filling pattern on transmitral Doppler echocardiography are more likely to experience heart failure from severe LV systolic dysfunction or severe underlying CAD (or both).

Aims and Objectives

The objective of the study was to correlate different methods of the assessment of left ventricular diastolic function by Doppler Echocardiography with invasive assessment in patients with coronary artery disease undergoing cardiac catheterization.

Material and methods

The study was conducted in Department of Cardiology, Mediciti Hospital, Hyderabad. The study protocol was approved by Institutional Ethical Committee. Written informed consent was obtained from patient prior to study participation. Study population consisted of patients in sinus rhythm scheduled for elective coronary angiography for evaluation of coronary artery disease. A total of 70 consecutive patients were enrolled into the study. Patients with valvular heart disease, atrial fibrillation and those with inadequate pulmonary venous signals were excluded from the study.

Detail medical history and findings of clinical examination as well as the values of the investigations were recorded. All the patients enrolled into the study underwent Doppler echocardiography and cardiac catheterization.

Transthoracic Echocardiography

A Philips Sonos 7500 ultrasound system with 2.5-MHz transducer was used to perform the Doppler echocardiographic studies. Transthoracic 2D echocardiography and Doppler echocardiographic studies were performed in the left lateral decubitus on the same day approximately 1.5 hrs (range 1-2 hr) after cardiac catheterization. Blood pressure and heart rate were recorded at the time of echocardiographic examination.

Ejection fraction was assessed by the area length method. From the apical 4-chamber view with the sample volume at the tips of the mitral leaflets, transmitral flow pattern was recorded by Pulsed Doppler echocardiography and 3-5 consecutive cycles were analyzed.

Transmitral Flow Velocity Curve Analysis

1. **E** - peak mitral early diastolic velocity.
2. **A** - peak mitral velocity with atrial contraction.

3. **DT (deceleration time)** – deceleration time between peak early diastolic velocity and the point where the steepest deceleration slope extrapolated to the baseline.
4. **IVRT (isovolumic relaxation time)** – time between the closing click of the aortic valve and the initiation of mitral flow or the interval from the end of aortic flow to onset of mitral inflow.
5. **MVa** – duration of mitral A wave.

Pulmonary venous flow velocities

From apical four-chamber view pulmonary venous flow velocity cures were recorded with the sample volume 0-1 cm into the right superior pulmonary view over 3-5 consecutive cycles.

1. PVs (Pulmonary venous systolic velocity) – peak systolic velocity. If biphasic, highest peak velocity considered.
2. PVd (Pulmonary venous diastolic velocity) – peak diastolic velocity
3. PVa (Pulmonary venous diastolic velocity) – The pulmonary venous reverse diastolic velocity with atrial contraction.
4. PVa dur – duration of pulmonary A wave
5. SF – systolic fraction of peak velocities PVs/(PVs + PVd)

Tissue Doppler Measurements

TDI of the mitral annulus was obtained from apical four-chamber view. A 1.5 mm sample was placed sequentially at the lateral and medial mitral annulus. Analysis was performed for early Ea and late diastolic velocity Aa, duration of velocity profile (Ea duration, Aa duration). These variables were analyzed individually as the average of the medial and lateral annulus.

Cardiac catheterization

Left heart catheterization was performed and catheter position in LV was verified by observing typical changes in pressure wave forms and by fluoroscopic observation of catheter tip. Transducers were balanced before acquisition of hemodynamic data with 0 level mid axillary line. Measurements were made at end expiration and the averages of 3 – 5 cardiac cycles were taken. LVEDP was measured as the pressure plateau immediately before the systolic increase of intraventricular pressure. Findings of coronary angiography were noted.

Statistical analysis

All the data was entered in excel spread sheet 2000. Continuous data was presented as mean and standard deviation, categorical data as percentages. Statistical analysis was performed with graph pad prism version-5. p value less than 0.05 was considered statistically significant.

Results

Out of 70 subjects participated in the study, 60 were males and 10 were females. The mean age of the patients was 55 $\pm$ 15 years. Mean ejection fraction was 48 $\pm$ 18 %. The mean differences between the systolic, diastolic pressures and heart rates at cardiac catheterization and echocardiography were 5$\pm$10, 1$\pm$8 mm Hg and 1$\pm$7 beats per minute respectively. The baseline characteristics are as represented in the table 1:

Table 1: Baseline Characteristics

Variable	LVEDP <=12mmHg (N=37)	LVEDP > 12 mmHg (N = 33)	P value
EF	52$\pm$ 14%	39$\pm$ 9%	<0.0001
Mitral inflow velocities			
E velocity (cm/sec)	74$\pm$ 22	88.5$\pm$ 25.5	
A velocity (cm/sec)	77.6$\pm$ 17.6	62$\pm$ 28	
E/A	1.0$\pm$ 0.5	1.7$\pm$ 0.5	<0.0001
MVa (duration	132$\pm$ 31	139$\pm$ 29	
DT (seconds)	182$\pm$ 47	144$\pm$ 50	= 0.0001
IVRT (seconds)	88.5$\pm$ 21.5	78$\pm$ 32	= 0.0009
Pulmonary vein flow velocities			
PVs	50$\pm$ 18	55$\pm$ 23	
Pvd	52$\pm$ 16	45$\pm$ 17	
SF	49$\pm$ 13	53.5$\pm$ 12.5	= 0.0289
PVa (duration)	140$\pm$ 35	151.5$\pm$ 30.5	
PVa – MVa	-1$\pm$ 28	5$\pm$ 25	= 0.3463
Tissue Doppler			
Ea	9.4$\pm$ 3.4	8.7$\pm$ 2.5	
Aa	8.8$\pm$ 4.3	8$\pm$ 2.5	

Relation of EF with LVEDP

It was found that 53% patients with LVEDP <= 12 mmHg had normal LV systolic function with EF of 52 +/- 14% and those with LVEDP >12 mmHg had either mild, moderate or severe LV systolic dysfunction with EF ranging between 39 +/- 9%. This relation between LVEDP and EF was found to be statistically highly significant ($p < 0.0001$).

Relation of Doppler Mitral Flow velocities (E & A) to LVEDP

Doppler mitral flow velocities E & A with their ratio E/A when correlated with LVEDP, it was found that patients with LVEDP < = 12 mmHg had E/A ratio of 1.0 +/- 0.5 and those with LVEDP > 12 mmHg had E/A ratio of 1.7 +/- 0.5. This relation between LVEDP and E/A was found to be statistically highly significant ($p < 0.0001$).

Relation of Doppler Mitral E deceleration time (EDT) to LVEDP

Doppler mitral EDT when correlated with LVEDP, it was found that patients with LVEDP < = 12 mmHg had EDT of 182 +/- 47 msec and those with LVEDP > 12 mmHg had EDT of 142 +/- 50 msec. This relation between LVEDP and EDT was found to be significant (p = 0.0001).

Relation of IVRT to LVEDP

Isovolumic relaxation time (IVRT) when correlated with LVEDP, it was found that patients with LVEDP < = 12 mmHg had IVRT of 88.5 +/- 21.5 msec and those with LVEDP > 12 mmHg had IVRT of 78 +/- 32 msec. This relation between LVEDP and IVRT was found to be significant (p = 0.0009).

Relation of Doppler Pulmonary Flow Variables to LVEDP

With pulmonary venous flow indices, systolic fraction of peak velocities correlated with LVEDP. Patients with LVEDP < =12 had SF of 49 +/- 13 and those with LVEDP > 12 mmHg were having SF of 53.5 +/- 12.5 with p value of 0.0289. So this correlation was not found to be statistically significant.

The difference in duration of PVa – MVa was also not found to be significant p= 0.3463).

Relation of Tissue Doppler Variables with Filling Pressures

DTI annular velocities: No significant relation was observed between LVEDP and E/Ea. With the use of this ratio patients were divided into 3 categories. Patients with E/Ea > 15 had elevated LVEDP. Majority with E/Ea 8-15 had normal LVEDP. 59 patients had indeterminate LVEDP when E/Ea is between 8-15. The number of patients in each category was shown in following table.

Table 2: number of patients in each category

	E/Ea≥ 15	**E/Ea≤ 8**	**E/Ea 8-15**
LVEDP ≤ 12	3	3	31
LVEDP > 12	3	2	28

Study Limitations

1) LVEDP was obtained with fluid-filled catheters, although micro manometer-tipped catheters would have been ideal.
2) Study group included only patients in sinus rhythm; the performance of this rhythm in the presence of non-sinus rhythms is currently unknown.

Doppler echocardiography and measurement of LVEDP were not done simultaneously. The interval between catheterization and Doppler study was minimized to about one and half hour but, still this could have affected the reliability as the loading conditions etc. might have changed.

Conclusions

We conclude that EF, E/A, EDT, and IVRT were the best predictors of left ventricular filling pressures in patients with coronary artery disease with either normal or impaired LV function. More importantly, a combination of these methods is more dependable in accurately predicting left ventricular filling pressures noninvasively.

Recommendations

Doppler Echocardiography with TDI can be very well utilized as non invasive tool in assessment of diastolic functions of LV and as an indirect measure of LVEDP in patients with CAD

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