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Evaluation of Left Ventricular Diastolic Dysfunction in Patients with Coronary Artery Disease: Correlation between Echocardiographic and Hemodynamic Parameters

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Abstract
In patients with coronary heart disease, evaluation of the left ventricular end diastolic pressure (LVEDP) provides assessment of the hemodynamic severity and aids in assessing the prognosis, and in deciding the proper management and therapeutic interventions. It also helps to distinguish this syndrome from other diseases such as pulmonary disease that can result in dyspnoea.
The early diastolic doppler indexes derived from transmitral flow velocity curves correlated significantly with LV filling pressures in patients with systolic dysfunction, but the correlation was weak in patients with preserved systolic function. The difference between the pulmonary venous and mitral A durations correlated well with LVEDP in patients with CAD, irrespective of the systolic function.
In this study we found echocardiographic doppler derived transmitral and pulmonary venous flow indices can be used as a safe and noninvasive means of predicting the LV filling pressures in patients with coronary artery disease, especially in patients with LV systolic dysfunction, as an alternative to the invasive measurements obtained during cardiac catheterization.
Keywords: *Coronary artery Disease (CAD), Left ventricular Ejection Fraction (LVEF), Left ventricular end diastolic pressure (LVEDP), Echo Doppler parameter.*

Introduction

Coronary artery disease (CAD) is considered as the most common cause of morbidity and mortality worldwide, which results as the consequence of many complications such as ventricular dysfunction or hemodynamic problems [(1,2,3)]. Pulmonary congestion after infarction reflects raised LV filling pressures, but it is frequently seen after what appears to be only minor myocardial damage. The pathophysio-logical mechanism for this is incompletely understood but may involve impaired active

relaxation of the myocardium and increased LV chamber stiffness and hence abnormalities in diastolic function.

LV filling pressures as measured invasively include mean pulmonary wedge pressure or mean left atrial (LA) pressure (both in the absence of mitral stenosis), Left ventricular end-diastolic pressure (LVEDP, which is the pressure at the onset of the QRS complex or after A-wave pressure), and pre-A LV diastolic pressure. Although these pressures are different in absolute terms, they are closely related, and they change in a predictable progression with myocardial disease, such that LVEDP increases prior to the rise in mean LA pressure.

In patients with ischemic heart disease, evaluation of the LVEDP provides the assessment of hemodynamic severity and aids in the proper management and therapeutic interventions[4,5]. LVEDP is evaluated by using different techniques, including both invasive (cardiac catheterization) and noninvasive (echocardio-graphy) approaches [6,7].

Although there are studies that have indicated the utility of non-invasive methods such as echocardiography in evaluating left ventricular diastolic dysfunction, invasive techniques are predominantly used in this regard, the use of which is not without risks[8,9]. Hence, it is possible that echocardiography, which is a simple, noninvasive and safe technique for measurement of left ventricular diastolic dysfunction, could prove to be a valuable tool for evaluating the clinical status of coronary artery disease (CAD) patients with diastolic dysfunction[10,11,12].

The aim of the present research was to estimate the LVEDP in patients with ischemic heart disease by cardiac catheterization, and to compare the same with the various echocardiographic indices that indicate diastolic dysfunction.

Materials and Methods

This was a single centre hospital based study carried out on patients who were admitted with a diagnosis of coronary artery disease (CAD), in the Department of Cardiology at ICVS, R.G. Kar Medical College, Kolkata from march 2015 to march2016. Patients with CAD as defined on Coronary angiogram (CAG), by the presence of at least one lesion measuring greater than or equal to 70% in any of the three major epicardial coronary arteries or in any vessel measuring at least 1.5mm in diameter, were included in the study. Patients with valvular heart diseases, cardiomyopathies (non ischemic etiologies), congenital heart diseases, significant arrhythmias and on pacemaker or implantable cardiac defibrillators (ICD), and with severe systemic disease were excluded from the study.

Prior to the injection of the contrast dye into the coronary system, the measurement of the left ventricular end diastolic pressure (LVEDP) was done. The LVEDP measurement was done by placing a fluid filled 6F catheter into the left ventricle via either the right femoral or right radial percutaneous approach [13,14].

Transthoracic two-dimensional and Doppler echocardiographic studies were done within 24 hours after the patients had undergone the cardiac catheterization. The transmitral flow velocity curves were recorded with the sample volume at the mitral tips, and the pulmonary venous flow velocity curves were recorded with the sample volume 0-1 cm into the right superior pulmonary vein. [15,16,17].

The information obtained from this study were statistically analyzed using SPSS software version 22.0.

Results and Observations

The study population comprising 100 patients, was divided further into two groups, based on the presence or absence of left ventricular systolic dysfunction, i.e. those patients with systolic dysfunction (EF < 50%) i.e Group A and those patients without systolic dysfunction (EF >= 50%) i.e Group B. A comparison of the clinical characteristics between the two groups and the overall study population is given in Table 1.

Table 1: Comparison of the Baseline Characteristics of the Groups

VARIABLE	OVERALL POPULATION (n=100)	EJECTION FRACTION >= 50% (n=45)	EJECTION FRACTION < 50% (n=55)	P VALUE
E VELOCITY	68.08 ± 17.43	66.48 ± 14.95	69.38 ± 19.26	0.41
A VELOCITY	82.05 ± 9.05	83.87 ± 8.63	80.56 ± 9.19	0.07
E/A RATIO	0.84 ± 0.29	0.80 ± 0.21	0.88 ± 0.37	0.16
E' VELOCITY	7.00 ± 0.77	7.04 ± 0.80	6.96 ± 0.74	0.60
A' VELOCITY	9.53 ± 1.32	9.6 ± 1.32	9.48 ± 1.33	0.63
E/E' Ratio	9.99 ± 3.45	9.69 ± 3.06	10.24 ± 3.76	0.44
DECELERATION TIME	202.96 ± 30.31	201.6 ± 30.78	204.07 ± 30.17	0.69
ISOVOLUMIC RELAXATION TIME	83.6 ± 18.28	82.49 ± 17.79	84.51 ± 18.77	0.59
PEAK PULMONARY VENOUS A WAVE VELOCITY (Ar)	34.25 ± 11.25	37.15 ± 10.72	31.66 ± 11.25	0.07
Ar_{dur} - A_{dur}	27.89 ± 11.17	30.15 ± 10.48	25.79 ± 11.56	0.15
LVEDP	15.54 ± 3.23	13.73 ± 1.89	17.02 ± 3.35	<0.001

The Peak E velocity values correlated significantly with LVEDP in the overall study population (r = 0.331, p = 0.001). The correlation was statistically significant in Group A (r = 0.358, p = 0.007) and not statistically significant in Group B (r = 0.288, p = 0.055).

The E/A ratio correlated significantly with LVEDP in the overall study population (r = 0.381, p < 0.001), and this correlation was statistically significant in both, Group A (r = 0.379, p = 0.004) and Group B (r = 0.314, p = 0.036).

The E/E' ratio and Deceleration Time (DT) both, correlated significantly with the LVEDP in the overall study population: E/E' (r = 0.314, p = 0.001) and DT (r = -0.235, p = 0.018), and the correlation was statistically significant in Group A : E/E'(r = 0.356 , p = 0.008) and DT(r = -0.426 , p = 0.001). The correlation was not statistically significant in Group B: E/E' (r = 0.237, p = 0.117) and DT (r = -0.061, p = 0.689).

The correlation of IVRT with LVEDP was statistically significant only in Group A (r = -0.338 , p = 0.012). The Peak pulmonary venous A wave velocity (Ar) correlated significantly with the LVEDP in the overall population group (r = 0.637, p < 0.001) and in Group A (r = 0.59 , p = 0.001).

The difference between the pulmonary venous and mitral A wave durations ($Ar_{dur} - A_{dur}$) correlated significantly with the LVEDP in the overall population group. (r= 0.675, p < 0.001) and in both the subsets i.e Group A (r= 0.489 , p = 0.007) and Group B (r= 0.74 , p < 0.001).

Discussion

Our study group had a mean age of 56 years, which for a disease CAD, indicates a relatively young population. Hence, our study generated an opportunity to examine the diastolic dysfunction in CAD patients, without any other confounding age related comorbidities. The mean age among the two subsets was similar (57.11 ± 9.41 vs 56.2 ± 10.02).

Sex predilection was uniform across the two subgroups. The risk factors profile (Hypertension and Diabetes) when compared between the two groups, found no significant statistical difference.

In the present study, the early diastolic Doppler indexes derived from transmitral velocity curves i.e. Peak mitral E wave velocity, E/A ratio, E/E' and Deceleration time (DT), correlated significantly with LV filling pressures in patients with systolic dysfunction (EF < 50%), but the correlation was weak in patients with preserved systolic function. (EF >= 50%). In contrast, the difference in pulmonary venous and transmitral flow during atrial contraction, correlated well with LV filling pressure, regardless of the systolic function.

Recent studies have shown an excellent correlation between LV filling pressures and the early diastolic doppler indexes in a large number

of patients [18]. All the subjects had systolic dysfunction due to either myocardial infarction or Ischemic cardiomyopathy, and the results are similar to those for our patients with a reduced EF [18,19].

In the present study, the estimated LV filling pressures showed poor correlation with the Doppler measured variables, if patients with preserved systolic function were selected, despite a good correlation in the study group as a whole. The early diastolic doppler indexes of both, transmitral and pulmonary venous flow velocity curves, respond in a certain manner to changes in preload [20,21,22,23]. However, they are dependent on many other interrelated factors. The peak mitral E wave velocity, the deceleration time (DT) and the isovolumic relaxation time (IVRT) are affected by LV relaxation, compliance and systolic function and left atrial compliance [24,25,26,27,28].

In the early stages of diastolic dysfunction, when LV relaxation is impaired with little increase in filling pressures, the deceleration time is prolonged, the E/A ratio is decreased, the isovolumic relaxation time is prolonged and the pulmonary venous systolic fraction is increased. Further progression of ventricular diastolic dysfunction is associated with altered compliance and increased LV filling pressures, which induces "normalization" of transmitral indexes. In end-stage disease, increased LV filling pressures produce a "restrictive" transmitral pattern, with shortened deceleration and isovolumic relaxation times, an increased E/A ratio and a decreased pulmonary venous systolic fraction.

Patients with impaired ventricular relaxation are the least symptomatic, whereas a restrictive filling pattern is associated with a poor prognosis, especially if it persists after preload reduction. Likewise, a pseudonormal or restrictive filling pattern associated with acute myocardial infarction indicates an increased risk for heart failure, unfavourable LV remodelling, and increased cardiovascular mortality, irrespective of the ejection fraction.

In patients with coronary artery disease, in whom LVEF is >50%, mitral variables correlate poorly with hemodynamics. This may be related to the marked variation in the extent of delayed LV relaxation seen in these patients, which may produce variable transmitral pressure gradients for similar LA pressures. In contrast to the patients with normal systolic function, all patients with LV systolic dysfunction have some amount of diastolic dysfunction[29,30,31]. In these patients, who have abnormal systolic and diastolic function, there is a relation between the early diastolic doppler indexes and LV filling pressures. Using the ratio of peak mitral E wave velocity to early mitral annulus velocity (E/E'), numerous studies have demonstrated a good approximation of LV filling pressures. This relationship has been validated in the presence of atrial fibrillation, sinus tachycardia, preserved or depressed LV systolic function, secondary mitral regurgitation, and LV hypertrophy [32,33,34,35]. Ommen et al demonstrated that E/E' > 15 accurately detects elevated filling pressures, and E/E' <8 accurately detects normal LV filling pressures [32]. In our study however, we found that this relation between E/E' and the LV filling pressures, is better correlated in patients with depressed systolic function.

The difference between pulmonary venous and mitral A durations can detect increased LVEDP in patients with systolic dysfunction and in those with preserved systolic function, in contrast to the poor ability of the other doppler indexes in patients with preserved systolic function. Rossvoll and Hatle proposed that the difference in the durations is a reliable index for assessing LV end-diastolic pressure on the basis of the previous finding that left atrial A wave pressure is widened in association with an increase in LV diastolic pressure [36,37,38].

Our present study confirms and extends the findings of these previous studies by demonstrating that this index is reliable in assessing LV end-diastolic pressure, irrespective of the systolic function.

In the current study, the peak pulmonary venous A wave velocity did not correlate with the LVEDP in patients with preserved systolic function, possibly because of the presence of patients with a normal filling pressure and high peak pulmonary venous A wave velocity. The absolute value of the peak velocity is affected by left atrial contractility [39,40]. In contrast, the pulmonary venous and mitral A durations may be affected equally by left atrial contractility, thus, effects of left atrial contractility on each index may be canceled by the difference in their durations.

Conclusions

The echocardiographic transmitral early doppler indexes, such as Peak E velocity, E/A ratio, E/E' ratio and Deceleration Time (DT), is a safe and non invasive means of predicting increased LV filling pressures in patients with coronary artery disease, especially in patients with LV systolic dysfunction.

Although technically more demanding, the determination of the difference between the pulmonary venous and mitral A durations ($Ar_{dur} - A_{dur}$) is useful in detecting increased LV filling pressures in patients with coronary artery disease , irrespective of the systolic function.

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