Estimation of Left Ventricular End Diastolic Pressure by Tissue Doppler Imaging in Patients with Acute Myocardial Infarction

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Objective: To evaluate sensitivity and specificity of E / Ea > 10 for prediction of LVEDP > 15 mmHg in patients with coronary artery disease undergoing left heart catheterization.

Materials and Methods: Sixty patients of acute transmural myocardial infarction at Jinnah Hospital Lahore were enrolled in study from December 2008 to December 2009. Patients with sinus rhythm were included in the study. Patients with valvular heart disease, complete right/left bundle branch block, Pacemaker dependence, Atrial fibrillation and Post mitral valve replacement were excluded. All patients were examined by performing transthoracic Doppler echocardiography. The transmitral LV filling signal was traced manually and the following variables were obtained: peak early (E) and late (A) transmitral velocities, and E/A ratio. Tissue – Doppler derived indices were recorded at the lateral mitral annulus. These indices included systolic velocities (S'), early diastolic (Ea) velocities and late diastolic (Aa) velocities. Finally, the dimensionless index of E/Ea was calculated. All were averaged from at least three beats. Cardiac cathetrization was performed via transfemoral / trasradial route using six French (6F) sheaths. Left ventricular diastolic pressure was directly measured by fluid filled pigtail catheter attached to a pressure transducer.

Results: Mean age of the study population was 56.8 ± 12.7 years. There were 47 (78.3%) males and 13 (21.7%) females. Diabetes mellitus was present in 12(20%), hypertension in 32 (53.3%), smoking in 35 (58.3%), dyslipidemia in 24 (40%). Anterior wall myocardial infarction occurred in 44 (73.3%) and inferior wall MI in 16 (26.7%). Grade I diastolic dysfunction was present in 22 (36.7%), Grade II in 31 (51.7%) and Grade III in 7 (11.7%) patients. E/E < 10 was observed in 31 (51.7%), 11 – 15 in 20 (33.3%) and > 15 in 9 (15%). Overall 21 patients were true positive, 6 were false positive, 25 were true negative and 8 were false negative. By applying 2 × 2 table sensitivity was 77.7%, specificity was 80.6%, positive predictive value was 77.7% and negative predictive value was 75.7%.

Conclusion: Doppler echocardiography provided major insights into the pathophysiology of diastolic LV dysfunction. E/Ea ratio is a reasonably good index for predicting elevated left ventricular filling pressure. E/Ea significantly correlated with LVEDP in the population with high prevalence of coronary artery disease. This method is the standard in measuring pressures in most clinical settings.

Key Words: Acute myocardial infarction; Coronary artery disease; Doppler echocardiography; Tissue Doppler imaging; Diastolic dysfunction.

Introduction

Heart failure is a condition of high morbidity and mortality, and its incidence is increasing.[1] In the era of constantly advancing medical therapies and devices, early identification of high – risk subjects with left ventricular dysfunction remains mandatory to prevent heart failure and to improve prognosis. In the United States, approximately 5 million patients have heart failure, and over 550,000 individuals are newly diagnosed with heart failure each year.[2]

Diastolic dysfunction is common in cardiac 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).[3] Analysis of the mitral inflow velocity curve has provided useful information for determination of filling pressures and prediction of prognosis in selected patients.[3]

Doppler echocardiography has become the non-invasive and reproducible method for the assessment of systolic and diastolic function of the left ventricle and also of the left ventricular filling pressure.[4] Mitral inflow velocities [Early mitral inflow velocity (E wave) and late mitral inflow velocity (A wave)], measured by pulsed Doppler echocardiography, are used to evaluate left ventricular diastolic performance.[5]

However, mitral flow is dependent on multiple interrelated factors, including the rate and extent of ventricular relaxation, suction, atrial and ventricular compliance, and left atrial pressure.[6] 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.[7]

Tissue Doppler imaging (TDI) of mitral annular motion has been proposed to evaluate diastolic filling function and detect pseudonormalization of mitral valve inflow.[3,8,9] There are several reports about using TDI parameters such as peak early diastolic velocity of mitral annulus (Ea), peak late diastolic velocity of mitral annulus (Aa), and E/Ea, to predict left ventricular filling pressure. However, there was not correlation between TDI interval (duration, acceleration time and DT) and LVEDP.[3] Combining transmitral flow velocity with annular velocity (E/Ea) has been proposed as the best single Doppler predictor for evaluating left ventricular filling pressure.[3,8,10]

The cut off point of E/Ea to predict high LV filling pressure was still uncertain, varying between 8-15.[3,8-11] The purpose of this study is to evaluate sensitivity and specificity of E/Ea > 10 for prediction of LVEDP > 15 mmHg in patients with acute transmural myocardial infarction undergoing left heart catheterization.

Materials and Methods

Sixty patients of acute transmural myocardial infarction admitted via emergency at Jinnah Hospital Lahore were enrolled in study from December 2008 to December 2009. The study was reviewed and approved by the ethical committee Jinnah Hospital Lahore. Informed consent was taken from all patients undergoing the study. Patients with sinus rhythm were included in the study on the basis of these criteria. a) Patients presenting with first acute myocardial infarction were included in the study on the basis of any two of the following criteria: 1) Chest pain consistent with acute myocardial infarction. 2) i. Electrocardiographic changes; ST segment elevation > 0.2 mv in at least two contiguous chest leads or > 0.1 mv in at least two contiguous limb leads or ii. New or presumably new left bundle branch block.

Major exclusion criteria were: Valvular heart disease, Complete right/left bundle branch block, Pacemaker dependence, Atrial fibrillation and Post mitral valve replacement.

All patients were examined by performing transthoracic Doppler echocardiography before cardiac catheterization by the operators who were blinded to patients' history and hemodynamic data. Parasternal and apical views were obtained using the GE Vivid 7 (GE Medical Systems, Milwaukee, WI) standard echocardiographic system and multifrequency transducer with tissue Doppler capability. Standard two dimensional images, M-mode, spectral and color Doppler, and TDI were performed. All echocardiographic procedures were performed within 6 hours of the patient's initial admission to hospital.

Left ventricular (LV) inter – ventricular septal thickness (IVS), posterior wall thickness (PWT), and LV ejection fraction (EF) were determined from 2 – dimensional images according to established criteria. Left ventricular diastolic function was assessed using both conventional and novel diastolic parameters. Transmitral LV filling velocities at the tips of the mitral valve leaflets were obtained from the apical 4 – chamber view using pulsed wave Doppler echocardiography. The transmitral LV filling signal was traced manually and the following variables were obtained: peak early (E) and late (A) transmitral velocities, and E/A ratio. Tissue - Doppler derived indices were recorded at the lateral mitral annulus. A sample volume of 6 × 6 mm was positioned along the basal lateral wall of the apical 4 chamber view. These indices included systolic velocities (S'), early diastolic (Ea) velocities and late diastolic (Aa) velocities. Finally, the dimensionless index of E/Ea was calculated. All were averaged from at least three beats.

Cardiac cathetrization was performed via trasfemoral / trasradial route using six (6F) French sheaths. Left ventricular diastolic pressure was directly measured by fluid filled pigtail catheter attached to a pressure transducer.

The fourth intercostals spaces between the anterior-posterior diameter of the chest wall measured at zero level. All hemodynamic data was recorded before the left ventriculogram was performed. The left ventricular end diastolic pressure (LVEDP) was obtained by computer recording. Results from at least five beats were averaged. After that, standard technique coronary angiogram was performed.

Study Design

It is an observational study.

Statistical Analysis

All the data were analyzed by SPSS (Statistical Package for Social Sciences release 14.0; SPSS, Inc; Chicago, IL) system for Windows. Categorical variables were expressed as frequencies and percentages and continuous variables as means ± Standard deviations (SD). Risk factors for coronary artery disease like smoking, hypertension, family history of Ischemic heart disease, site of myocardial infarction were reported as frequencies and percentages. True positive, true negative, false positive and false negative were calculated. By applying 2 × 2 tables measures of diagnostic accuracy like sensitivity, specificity, positive and negative predictive values were computed.

Results

Mean age of the study population was 56.8 ± 12.7 years. There were 47 (78.3%) males and 13 (21.7%) females. Diabetes mellitus was present in 12 (20%), hypertension in 32 (53.3%), smoking in 35 (58.3%), dyslipidemia in 24 (40%). Anterior wall myocardial infarction occurred in 44 (73.3%) and inferior wall MI in 16 (26.7%).

Grade I diastolic dysfunction was present in 22(36.7%), Grade II in 31 (51.7%) and Grade III in 7 (11.7%) patients. E/Ea < 10 was observed in 31 (51.7%), 11 – 15 in 20 (33.3%) and > 15 in 9 (15%). Overall 21 patients were true positive, 6 were false positive, 25 were true negative and 8 were false negative. By applying 2 × 2 table sensitivity was 77.7%, specificity was 80.6%, positive predictive value was 77.7% and negative predictive value was 75.7%.

Discussion

Heart failure is a condition of high morbidity and mortality, and its incidence is increasing.[1] In the era of constantly advancing medical therapies and devices, early identification of high – risk subjects with left ventricular dysfunction remains mandatory to prevent heart failure and to improve prognosis. Diastolic dysfunction is common in cardiac 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).[3] Analysis of the mitral inflow velocity curve has provided useful information for determination of filling pressures and prediction of prognosis in selected patients.[3] Tissue Doppler imaging of mitral annular motion has been proposed to evaluate diastolic filling function and detect pseudonormalization of mitral valve inflow.[3,8,9]

The current study has revealed high sensitivity and specificity for tissue Doppler imaging in estimation of LV end diastolic pressure. Our results are in accordance with previous studies.[3,5,12]

Ommen et al[3] reported that the noninvasive assessment of LV filling pressures can be an important clinical tool. In diseased ventricles, progressive shortening of the transmitral DT and increasing E/A ratio can be seen with decreasing ventricular compliance and increasing left atrial pressure. Ommen et al[3] studied 100 consecutive patients referred for cardiac catheterization who underwent simultaneous Doppler interrogation. Invasive measurements of LV pressures were obtained with micromanometertipped catheters, and the mean LV diastolic pressure (M-LVDP) was used as a surrogate for mean left atrial pressure. Doppler signals from the mitral inflow, pulmonary venous inflow, and TDI of the mitral annulus were obtained. Isolated parameters of transmitral flow correlated with M-LVDP only when ejection fraction < 50%. The ratio of mitral velocity to early diastolic velocity of the mitral annulus showed a better correlation with M-LVDP than did other Doppler variables for all levels of systolic function. E/Ea < 8 accurately predicted normal M-LVDP, and E/Ea > 15 identified increased M-LVDP. Wide variability was present in those with E/Ea of 8 to 15.

Table 1: *Demographics of the study population.*

Characteristics	Numbers (Percentages) n = 60
Age mean years	56.8 ± 12.7
Gender	
Male	47 (78.3%)
Female	13 (21.7%)
Diabetes mellitus	12 (20%)
Hypertension	32 (53.3%)
Smoking	35 (58.3%)
Dyslipidemia	24 (40%)
MI territory	
AWMI	44 (73.3%)
IWMI	16 (26.7%)

Table 2: *Diastolic dysfunction.*

Characteristics	Numbers (Percentages) n = 60
Standard	
Grade I	22 (36.7%)
Grade II	31 (51.7%)
Grade III	7 (11.7%)
E/Ea	
< 10	31 (51.7%)
11 – 15	20 (33.3%)
➢ 15	9 (15%)

Table 3: *Parameters of diagnostic accuracy.*

Parameter	2 × 2 table	Results		Percentages
Sensitivity	a / a + c	21 / 21 + 8	21 / 27 × 100	77.7%
Specificity	d / d + b	25 / 25 + 6	25 / 41 × 100	80.6%
PPV	a / a + b	21 / 21 + 6	21 / 27 × 100	77.7%
NPV	d / c + d	25 / 25 + 8	25 / 33 × 100	75.75

PPV = Positive predictive value; NPP = Negative predictive value

Tongyoo et al[5] studied patients scheduled for cardiac catheterization studied with Doppler echocardiography immediately before the procedure. Early and late mitral inflow velocity (E, A wave respectively) and peak diastolic velocity from medial and lateral mitral annulus (Ea medial, Ea lateral) were obtained. Invasive measurement of LVEDP was obtained with a fluid filled pigtail catheter. The results were blinded to the interpreter. Tongyoo et al[5] studied 138 patients, significant coronary lesions were found in 75.4%. The correlation between LVEDP and E, Ea medial or Ea lateral were significant. E/Ea medial > 10 accurately predicted LVEDP > 15 mmHg with 82% sensitivity and 84% specificity. In patients with EF > 50%, the correlation between E / Eamedial and LVEDP was still significant. Tongoo et al[5] concluded that E / Ea medial correlates well with LVEDP and can be used to estimate LVEDP in coronary artery disease patients even in patients with normal LVEF.

Kim et al[12] performed a study to validate the clinical usefulness of E/Ea ratio in a large number of patients. Simultaneous left ventricular pressure measurements and Doppler examinations were performed in 200 consecutive patients at the cardiac catheterization laboratory. The E/Ea ratio correlated well with pre – Awave pressure, and the correlation was not dependent on the left ventricular systolic function. The E/Ea ratio of ≥ 9 best discriminated elevated (> 12 mm Hg) from normal left ventricular pre-A pressure with a sensitivity of 81% and a specificity of 80%.

Lam et al[13] found that Ea was reduced and E/Ea was increased in patients with heart failure and a normal EF compared with both normal subjects and patients with hypertension without heart failure. Similarly, Kasner et al[14] observed that an elevated E/Ea ratio was the best non-invasive measure of diastolic dysfunction for distinguishing patients with heart failure and a preserved EF with invasively proven diastolic dysfunction from normal subjects. Consistent with these observations, the European Society of Cardiology consensus statement on how to diagnose diastolic heart failure suggests that an E/Ea ratio >15 alone or an E/Ea > 8 in combination with an elevated B–type natriuretic peptide > 200 pg / mL can be used as the simplest noninvasive objective indication of diastolic dysfunction to confirm the presence of diastolic heart failure.[15]

All of the measures discussed above are useful in identifying patients with or without elevations of LA pressure. However, the most commonly used and easiest-to-interpret parameter to estimate LA pressure is the E/Ea ratio. As discussed, the mitral E wave is augmented when there is an increased LA – to – LV pressure gradient. The Ea is reduced and delayed in the presence of slow relaxation. Thus, a high E and a low Ea (ie, increased E/Ea ratio) indicates that the increased E was due to an elevation of LA pressure, not a fall in LV diastolic pressure. E/Ea has been found to correlate with pulmonary capillary wedge pressures in a wide range of patients studied in multiple laboratories.[16] It has a stronger correlation with pulmonary capillary wedge pressure than B – type natriuretic peptide.[17] An E / Ea > 15 has been found to clearly indicate elevated pulmonary capillary wedge pressure, whereas an E/Ea < 8 is associated with normal LA pressure.[3] In the intermediate range, an assessment of LA pressure should include the evaluation of other echo Doppler parameters associated with increased LA pressure.[16]

The cutoff value of E/Ea of 15 to recognize elevated LA pressure was obtained using Ea velocity from the medial mitral annulus. Because Ea velocity from the lateral annulus is usually higher than the medial Ea velocity, the cutoff should be adjusted to 12 if the lateral annular velocity is used. An average of the medial and lateral annular velocities has been recommended,[16] but as long as there is no basal regional LV wall motion abnormalities, the consistent use of 1 annular velocity should be adequate in clinical practice. We prefer using the medial annular velocity because it is helpful in differentiating myocardial disease from constrictive pericarditis.

There are several situations when E/Ea may not provide an accurate assessment of pulmonary capillary wedge pressure. First, in a normal heart, Ea occurs coincidentally with E and responds to changes in LA pressure. For example, E/Ea was not increased but actually decreased in response to massive fluid loading in normal experimental animals.[18] However, because LA pressure is rarely elevated in patients with a normal heart,[19] the failure of E/Ea to recognize elevated LA pressures in normal subjects is of little clinical importance. Furthermore, E/Ea can distinguish an overfilled normal LV (decreased E/Ea) from elevated LA pressure associated with cardiac dysfunction (elevated E/Ea).[18] Second, E/Ea does not increase in patients with constrictive pericarditis despite elevated pulmonary capillary wedge pressures.[20] In fact, the medial e′ increases as constriction becomes worse, which results in a decrease in E/Ea as constriction gets more severe and diastolic filling pressure increases (annulus paradoxus). The lateral annular velocity may be decreased and often is lower than the medial annular velocity in constriction. If a patient has clinical signs of heart failure, especially with increased jugular venous pressure, a normal or increased medial Ea velocity strongly suggests constrictive pericarditis. Third, E/Ea may not provide an estimate of LA pressure in patients with mitral stenosis or mitral regurgitation, especially without a reduction in EF.[16,21]

Conclusion

Doppler echocardiography provided major insights into the pathophysiology of diastolic LV dysfunction. E/Ea ratio is a reasonably good index for predicting elevated left ventricular filling pressure. E/Ea significantly correlated with LV-EDP in the population with high prevalence of coronary artery disease. This method is the standard in measuring pressures in most clinical settings.

References

1. Mogelvang R, Sogaard P, Pedersen SA, Olsen NT, Marott JL, Schnohr P, et al. Cardiac Dysfunction Assessed by Echocardiographic Tissue Doppler Imaging Is an Independent Predictor of Mortality in the General Population. Circulation 2009; 119: 2679-2685.
2. American Heart Association. Heart disease and stroke statistics: 2005 update. Dallas, Texas : American Heart Association; 2005.
3. Ommen SR, Nishimura RA, Appleton CP, Miller FA, Oh JK, Redfield MM, Tajik AJ. Clinical Utility of Doppler Echocardiography and Tissue Doppler Imaging in the Estimation of Left Ventricular Filling Pressures. A Comparative Simultaneous Doppler – Catheterization Study. Circulation 2000; 102: 1788-1794.
4. Hurrel DG, Nishimura RA, Ilstrup DM, Appleton CP. Utility of preload alteration in assessment of left ventricular filling pressure by Doppler cardiography : a simultaneous catheterization and Doppler cardiographic study. J Am Coll Cardiol 1997; 30: 1644-50.
5. Tongyoo S, Jakrapanichakul D, Chaowalit N. Estimation of Left Ventricular End-diastolic Pressure by Tissue Doppler Imaging in Patients with Coronary Artery Disease. Thai heart J 2006; 19: 105-113.
6. Nishimura RA, Tajik AJ. Evaluation of diastolic filling of left ventricle in health and disease: Doppler echocardiography is the clinician's Rosetta Stone. J Am Coll Cardiol. 1997; 30: 8–18.
7. Yamamoto K, Nishimura RA, Chaliki HP, et al. Determination of left ventricular filling pressure by Doppler

echocardiography in patients with coronary artery disease: critical role of left ventricular systolic function. J Am Coll Cardiol. 1997; 30: 1819 –1826.

8. Bruch C, Schmermund, Bartel T, Schaar J, Erbel R. Tissue Doppler Imging : a new technique for assessment of pseudonormalization of the mitral inflow pattern. Echocardiography 2000; 17: 539-46.
9. Dagdelen S, Eren N, Karabulut H, Akdemir I, Ergelen M, Saglam M, Yuce M, Alhan C, Caglar N. Estimation of left ventricular end-diastolic pressure by color – M – mode Doppler echocardiography and tissue Doppler imaging. J Am Soc Echocardiogr 2001; 14: 951-8.
10. Poerner TC, Goebel B, Unglaub P, Suedebeck T, Strotmann JM, Pklegur S, Borggrefe M, Hasse KK. Detection of a pseudonormal mitral inflow pattern : an echocardiographic and tissue Doppler study. Echocardiography 2003; 20: 345-56.
11. Rivas – Gotz C, Manolios M, Thohan V, Nagueh SF. Impact of left ventricular ejection fraction on estimation of left ventricular filling pressures using tissue Doppler and flow propagation velocity. Am J Cardiol 2003; 91: 780-4.
12. Kim Y, Sohn D. Mitral Annulus Velocity in the Estimation of Left Ventricular Filling Pressure: Prospective Study in 200 Patients. J Am Soc Echocardiogr 2000; 13: 980-5.
13. Lam CSP, Roger VL, Rodeheffer RJ, Bursi F, Borlaug BA, Ommen SR. Cardiac structure and ventricular – vascular function in persons with heart failure and preserved ejection fraction: from Olmstead County, Minnesota. *Circulation*. 2007; 115: 1982–1990.
14. Kasner M, Westermann D, Steendijk P, Gaub R, Wilkenshoff U, Weitmann K, Hoffmann W, Poller W, Schultheiss HP, Pauschinter M, Tschope C. Utility of Doppler echocardiography and tissue Doppler imaging in the estimation of diastolic function in heart failure with normal ejection fraction : a comparative Doppler – conductance catheterization study. *Circulation*. 2007; 116: 637– 647.
15. Paulus WJ, Tschope C, Sanderson JE, Rusconi C, Flachskampf FA, Rademakers FE, et al. How to diagnose diastolic heart failure: a consensus statement on the diagnosis of heart failure with normal left ventricular ejection fraction by the Heart Failure and Echocardiography Associations of the European Society of Cardiology. *Eur Heart J*. 2007; 28: 2539 –2550.
16. Nagueh SF, Appleton CP, Gillebert TC, Marino PN, Oh JK, Smiseth OA, et al. Recommendations for the evaluation of left ventricular diastolic function by echocardiography. *J Am Soc Echocardiogr*. 2009; 22: 107–133.
17. Dokainish H, Zoghbi WA, Lakkis NM, Al – Bakshy F, Dhir M, Quinones MA, et al. Optimal noninvasive assessment of left ventricular filling pressures : a comparison of tissue Doppler echocardiography and B – type natriuretic peptide in patients with pulmonary artery catheters. *Circulation*. 2004; 109: 2432–2439.
18. Oki T, Tabata T, Yamada H, Wakatsuki T, Shinohara H, Nishikado A, et al. Clinical application of pulsed tissue Doppler imaging for assessing abnormal left ventricular relaxation. *Am J Cardiol*. 1997; 79: 921–928.
19. Oh JK. Echocardiography as a noninvasive Swan – Ganz catheter. *Circulation*. 2005; 111: 3192–3194.
20. Ha J – W, Oh JK, Ling LH, Nishimura RA, Seward JB, Tajik AJ. Annulus paradoxus: transmitral flow velocity to mitral annular ratio is inversely proportional to pulmonary capillary wedge pressure in patients with constrictive pericarditis. *Circulation*. 2001; 104: 976–978.
21. Diwan A, McCulloch M, Lawrie GM, Reardon MJ, Nagueh SF. Doppler estimation of left ventricular filling pressures in patients with mitral valve disease. *Circulation*. 2005; 111: 3281–3289.