# Comparison between Tissue Doppler Imaging and Color M-Mode Doppler Indices in LV Systolic Dysfunction Patients with Different Filling Pressures

Mervat M. Khalaf

Critical Care Medicine Department, Cairo University Hospitals
samasalma@yahoo.com

**Abstract:** Indices derived from tissue Doppler imaging (TDI), including transmitral to early diastolic velocity ratio (E/E') strongly correlate with left ventricular filling pressures LVFP, however its application with other diastolic Doppler techniques on patients with systolic dysfunction need more clarifications. **Purpose:** to estimate the chacteristics of both systolic and diastolic functions indices in LV systolic dysfunction patients by the use of TDI and color M-mode (CMM) Doppler techniques. **Methodology**: fifty two patients with systolic dysfunction by echocardiography (mean age were 62±*9.3* yrs, 62% males) were divided into 3 groups according to their LVFP using E/Ems ratio as follow: group 1: with normal NFP as E/Ems < 10, group 2: with moderate LVFP as E/Ems between 10:15 and group 3: with high LVFP as E/Ems ≥15. Comparisons between the 3 groups were made in relation to all demographic and echocardiographic data. **Results:** patients of HFP group showed significantly the highest values regarding LVEDV, LVESV and significantly lower values regarding FS% and EF% by M-mode (*P-value= 0.028, 0.015, 0.032 and 0.025 respectively)* when compared to other 2 groups, as well E, DT and E/Vp were significantly different between the 3 groups (*P-value=0.00001),* while Vp was statistically non significant in the three groups (*P-value=0.138).* **Conclusions:** The measurement of LVFP in patients with LV systolic dysfunction by TDI and CMM Doppler is very important in prediction of patients with HFP who need prompt management by preload reduction therapy; the more LVFP is, the more LV volume load and low EF% will be. The measurement of E/Vp is more predictive of LVFP than Vp alone in patients with LV systolic dysfunction.
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**Key words:** TDI, CMM, LVFP, propagation velocity and systolic dysfunction.

## 1. Introduction

Tissue Doppler imaging (TDI) is a sensitive, noninvasive echocardiographic method that records velocity of tissue motion within the myocardium. TDI has been evaluated in both in vitro and in vivo studies, allowing for the quantitative assessment of both global and regional function of the myocardium **(1).**

Indices derived from TDI, including systolic velocity (S'), early (E') and late (A') diastolic velocities of the lateral mitral annulus, are reduced in heart failure patients (EF < 30%) and portend a poor prognosis. Transmitral to early diastolic velocity ratio (E/E') obtained via TDI correlates strongly with LV filling pressures **(2).** An E/E' ratio > 10 identified a pulmonary capillary wedge pressure (PCWP) > 15 mm Hg with a sensitivity of 92% and a specificity of 80% **(3).**

Simultaneous cardiac catheterization and echocardiographic studies have shown that LV filling pressures are correlated with the ratio of the mitral inflow E wave to the tissue Doppler Ea wave (E/Ea) **(2, 4).** This relation is based on Ea velocities that "correct" E-wave velocities for the impact of relaxation. The E/Ea ratio can be used to estimate LV filling pressures as follows: E/lateral Ea>10 or E/septal Ea>15 are correlated with an elevated LV end-diastolic pressure and E/Ea<8 are correlated with a normal LV end-diastolic pressure.

Color M-mode Doppler and estimation of flow propagation velocity (Vp) is another method that is used to evaluate diastolic dysfunction and prove a superiority over other conventional pulsed wave PW Doppler indices for being a relatively preload independent technique **(5, 6).** Measurement of MV peak E velocity to rate of flow propagation, E/ Vp > 2.0 predicts LVED pressure >15mmHg (sensitivity 100%, specificity 77%). **(7)**

This study aimed to compare the systolic and diastolic indices in LV systolic dysfunction patients with different LV filling pressures by the use of TDI and CMM techniques.

## 2. Methodology:

Fifty two patients with systolic dysfunction by echocardiography (EF% < 55%) were included in the study from the period of October 2010 to December 2011, twenty three (44%) of them were ambulatory compensated patients coming for routine assessment of cardiac function at the echo-lab and twenty nine (56%) of the patients were admitted to the ICU with heart failure.

All patients were subjected to full history taking, cardiologic and transthoracic echocardiographic TTE examinations.

**Transthoracic echocardiography TTE:**

Images were obtained using Toshiba machine with TDI software is enabled inside it, the transducer was phased array sector 2.5-3.5 MHZ, and were done in the supine and left lateral decubitus to determine:

**Left ventricular systolic function using:**

I- M-mode echocardiography: Ejection fraction (EF %) and fractional shortening (FS %) were obtained by measuring left ventricular end diastolic diameter (LVEDD) and left ventricular end systolic diameter (LVESD).

II- 2 D echocardiography the end-systolic (ESV) and end-diastolic (EDV) volumes were recorded by the method of disc summation based on Simpson's rule. This method treats the ventricle as a stack of discs; the endocardial border was traced in each phase of the cardiac cycle and the system computer partitioned the ventricle into 20 discs of equal thickness. The computer then summed the individual disc volumes to give the total volume of the cavity.

**Left ventricular diastolic function using:**

**I-Standard trans-mitral Doppler indices of diastolic function:**

These indices were derived from PW Doppler examination with the sample volume placed at the tip of opened mitral leaflet in the apical 4-chamber view.

Measured and calculated Doppler parameters included: 1. Peak early diastolic filling velocity in cm/sec (E) measured as 'the height of the early peak flow velocity. 2. Peak late diastolic filling velocity in cm/sec (A) measured as the height of the atrial peak. 3. The ratio between the E velocity and A velocity (E/A) ratio. 4. Deceleration time of peak early filling velocity (DT) in m.sec. This is the time measured by extrapolation of the slope of E velocity to the zero base line.

**II-Color M-mode Doppler (CMM):**

M-mode cursor was placed through the center of the mitral inflow region in the apical four chamber view. The imaging transducer cursor line in some cases was displaced towards the lateral wall if needed to position the M-mode scan line in parallel with the direction of flow observed by 2D-color Doppler.

The measured and calculated Doppler parameters included: the velocity at which flow propagates within the ventricle (Vp) in cm/sec is given by the slope of color wave-front from mitral tips to the apex **(8),** to measure both Vp and peak E velocity to rate of flow propagation; E/ Vp **fig (1).**

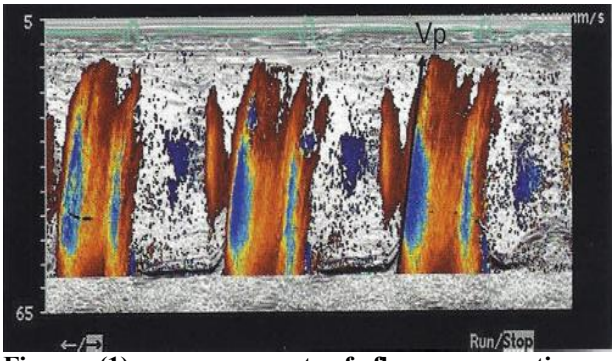


**Figure (1): measurement of flow propagation velocity Vp by CMM:**

**III-Tissue Doppler imaging (TDI):**

PW TDI was performed by activating TDI function in the same machine with the sample volume placed at the septal corner of the mitral annulus in the apical four chamber view. The following measures were obtained from the mitral annular TDI: 1. Systolic mitral annulus velocity (Sm) in cm/sec, 2. Early mitral annulus diastolic velocity (Ems) in cm/sec and 3. Late mitral annulus diastolic velocity (Ams) in cm/ sec.

The patients were divide into 3 groups according to E/Ems by TDI on the septal part of the mitral leaflet as follow: **group 1 NFP**: 17 patients with E/Ems < 10 and they were considered as having normal left ventricular filling pressure LVFP, **group 2 MFP**: 16 patients with E/Ems ranging from 10: 15 and they were considered as having moderate LVFP and **group 3 HFP**: 19 patients with E/Ems > 15 and they were considered as having high LVFP.

Comparisons between the 3 groups were made in relation to all demographic and echocardiographic data.

**Statistical analysis:**

Patients' data were tabulated and processed using SPSS (15.0) statistical package for Windows XP.

Quantitative variables were expressed by means and standard deviation and were analyzed using student's unpaired t-test.

One-way ANOVA test was used to compare more than two groups as regard a quantitative variable (SD<50% mean).

Mann Whitney Willcoxon U test was used instead of unpaired t-test in non-parametric data (SD>50% mean).

Qualitative data was expressed by frequency and percent and were analyzed using Chi-square.

P value >0.05 → insignificant, P value <0.05 → significant, P value <0.01 → highly significant.

**3. Results:**

The study included 52 patients with mean age were 62±*9.3* yrs, 65.4% were males, 61.5% of them were diabetics and 58% were hypertensive.

As regards the demographic data and the risk factors there were no statistically significant differences between the 3 groups (**Table 1).**

**Table (1): comparison of demographic data of the 3 groups:**

| | G1 NFP (n=17) | G2 MFP (n=16) | G3 HFP (n=19) | Total (n=52) | *P*- value |
|---|---|---|---|---|---|
| **Age (yrs)** | 59.8±7.5 | 64.18±9.3 | 63.3±10.4 | 62.4±*9.3* | 0.28 |
| **Sex /male** | 56.2% | 84.2% | 52.9% | 65.4% | 0.094 |
| **DM** | 56.2% | 68.4% | 58.8% | 61.5% | 0.73 |
| **HTN** | 43.8% | 57.9% | 70.6% | 57.7% | 0.29 |

**Echocardiographic data:**

Data collected for the **diastolic function** of the 3 groups by the different Doppler studies are shown in **table 2**; it was found that there were statistically significant differences between 3 groups in relation to E, DT, Ems and E/Ems, E/Vp (P-value=0.0001), while Vp was the only parameter for measuring the diastolic function that show insignificant relation (*P*-value=0.138) among the three groups.

**Table (2): comparison of diastolic function indices of the 3 groups by TTE:**

| | G1 NFP (n=17) | G2 MFP (n=16) | G3 HFP (n=19) | *P*- value |
|---|---|---|---|---|
| E cm/sec | 61.1±12.5 | 78.4 ± 19.6 | 83± 13.8 | **0.0001** |
| Ems cm/sec | 7.6 ± 2 | 5.9 ±1.3 | 3.6 ± 0.93 | **0.0001** |
| DT m.sec | 210.3 ±75 | 141.24 ± 30 | 134.5 ± 25 | **0.0001** |
| Vp cm/sec | 37.1±5.7 | 32.8±7.9 | 32.5±7.3 | 0.138 |
| E/Ems | 8.2 ± 2.3 | 13.2 ± 1.1 | 24.3 ±5.8 | **0.0001** |
| E/Vp | 1.64± 0.5 | 2.4± 0.9 | 2.8±1.1 | **0.0001** |

Data of the dimensions and systolic function of the left ventricle are shown in **table 3:**

It was found that there were statistically significant relation between the 3 groups as regards LVESD, FS%, EF%, LVEDV and EF%.

Patients of group 3 with HFP were found to have significantly more dilated LV at end of systole and more volume at end of diastole and systole when compared to the other 2 groups (*P- value=0.05, 0.028 and 0.015 respectively),* patients of this group were also found to have low EF% by M-mode when compared to the other 2 groups (*P- value=0.025).* **(Table 3)**

Table (3): comparison of systolic function indices of the 3 groups by TTE:

| | G1 NFP (n=17) | G2 MFP (n=16) | G3 HFP (n=19) | P- value |
|---|---|---|---|---|
| LVEDD | 5.7±0.7 | 5.9±0.2 | 6.3±0.7 | 0.07 |
| LVESD | 4.3±0.6 | 4.6±0.3 | 5±0.7 | **0.05** |
| FS% | 24.4±2.9 | 21.6±3.6 | 21.2±3.9 | **0.032** |
| EF% | 47.7±3.9 | 43.3±6.1 | 42.2±7 | **0.025** |
| LVEDV | 149.4±46.6 | 166.4±65.3 | 235.5±137.7 | **0.028** |
| LVESV | 89.2±29.3 | 96.1±46.6 | 139.3±88.3 | **0.015** |
| EF% | 46.4±5.6 | 43±9.9 | 40.6±7.2 | 0.08 |

**4. Discussion:**

Diastolic heart failure can occur alone or in combination with systolic heart failure. In patients with isolated diastolic heart failure, the only abnormality in the pressure-volume relationship occurs during diastole, when there are increased diastolic pressures with normal diastolic volumes. When diastolic pressure is markedly elevated, patients are symptomatic at rest or with minimal exertion (NYHA class III to IV). With treatment, diastolic volume and pressure can be reduced, and the patient becomes less symptomatic (NYHA class II),

but the diastolic pressure-volume relationship remains abnormal **(9).**

In patients with systolic heart failure, there are abnormalities in the pressure-volume relationship during systole that includes decreased EF, stroke volume, and stroke work. In addition, there are changes in the diastolic portion of the pressure-volume relationship. These changes result in increased diastolic pressures in symptomatic patients, which indicate the presence of combined systolic and diastolic heart failure. Whereas the diastolic pressure-volume relationship may reflect a more compliant chamber, increased diastolic pressure and abnormal relaxation reflect the presence of abnormal diastolic function. Thus, all patients with systolic heart failure and elevated diastolic pressures in fact have combined systolic and diastolic heart failure. Another form of combined systolic and diastolic heart failure is also possible, Patients may have only a modest decrease in EF and a modest increase in end-diastolic volume but a marked increase in end-diastolic pressure and a diastolic pressure-volume relationship that reflects decreased chamber compliance. Therefore, virtually all patients with symptomatic heart failure have abnormalities in diastolic function, those with a normal EF have isolated diastolic heart failure, and those with a decreased EF have combined systolic and diastolic heart failure (**9).**

Tissue Doppler imaging (TDI) has evolved to become a useful noninvasive method that can complement other echocardiographic techniques in assessment of left ventricular myocardial velocities in a variety of clinical conditions **(2, 10, 11).**

The study done by (Kasner M, et al) concluded that of all echocardiographic parameters investigated, the LV filling index $E/E'_{lateral}$ was identified as the best index to detect diastolic dysfunction in heart failure with normal ejection fraction (HFNEF) in which the diagnosis of diastolic dysfunction was confirmed by conductance catheter analysis. **(12)**

As concluded by (Ozer N, et al) that combination of left atrial volume index (LAVI) and septal E/e' is useful to detect diastolic dysfunction. They found that septal E/e' (≥15) and LAVI (≥ 34 ml/m2) were the better predictors of the increased LVEDP than the other chocardiographic parameters. There were statistically significant moderate positive correlations of LVEDP with septal E/ e' and LAVI in 54 studied patients **(13)**. A similar conclusion was found also by (Liang HY et al ) regarding E/Ems ratio **(14).**

It was found that DT and Ems were significantly higher in group 1 (NFP) when compared to other 2 groups of high LV filling pressure (*p*-value=0.0001). E and E/Vp ratio were significantly lower in group 1 (NFP) in comparison to other 2 groups of high filling pressure (*p*-value=0.0001), only Vp that was found to be non significantly higher in group of normal filling pattern than the other 2 groups (*p*-value=0.138). The previous results means that Vp is more preload dependant when compared to TDI indices used for measuring diastolic dysfunction as mentioned by previous studies **(15- 17).**

Many studies support that Vp measurement in patient with LV systolic dysfunction is not accurate in predicting LV filling pressure even may be misleadingly normal in its value when used in that group of patients (**18, 21),** contrary to the ratio E/Vp which found to be accurate in predicting LV filling pressure in patients with LV systolic dysfunction but not in patients with normal EF% (**19),** these previous study conclusions were found actually typical to the results of the present study on patients with LV systolic dysfunction as E/Vp was found to be highly statistically significant in the 3 groups if compared to Vp alone as mentioned before.

The use of this parameter (E/Ems) to classify the groups in the present study and to compare all systolic and diastolic function indices between the groups proved that patients with normal filling pattern (E/Ems less than 10) was associated with significantly less LV dilatation and volume at end systole and diastole (*p*-value=0.028, 0.015, respectively) and higher EF% (p-value=0.025) as regards the systolic function of the LV. These results are similar to those conducted by (Rovner A, et al) who grouped the patients according to their LVFP by E/Ems ratio and found significant relations regarding all the systolic and diastolic parameters **(22).**

**Conclusions:**

The measurement of LV filling pressures in patients with LV systolic dysfunction by TDI and color M –mode Doppler is very important in prediction of patients with HFP who need prompt management by preload reduction therapy; the more LVFP is the more LV volume load and low EF% will be. The measurement of E/Vp is more predictive of LVFP than Vp alone in patients with LV systolic dysfunction.

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