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Evaluation of Left Ventricular Systolic and Diastolic Function Using Doppler Echocardiography: A Prospective Study

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Abstract: Background: Assessment of left ventricular (LV) function is essential in cardiovascular evaluation. While conventional Doppler echocardiography is widely used, Tissue Doppler Imaging (TDI) provides additional insights into myocardial relaxation and filling pressures. This study evaluated LV systolic and diastolic function using Doppler echocardiography, with emphasis on the role of TDI.**Material and Methods:** This prospective study included 120 adult patients undergoing transthoracic echocardiography. LV systolic function was assessed using left ventricular ejection fraction (LVEF). Diastolic function was evaluated using conventional Doppler parameters (E, A, E/A ratio, deceleration time, IVRT) and TDI-derived indices (septal and lateral e′, a′, s′ velocities, and E/e′ ratio).**Results:** The mean age was 52.8 ± 13.6 years, with 60.0% males. Normal systolic function (LVEF ≥50%) was observed in 68.3%, while 31.7% had systolic dysfunction. Diastolic dysfunction was present in 66.7% by conventional Doppler, predominantly Grade I (38.3%), followed by Grade II (20.0%) and Grade III (8.4%). Mean E/A ratio was 0.94 ± 0.32. TDI showed mean septal e′ of 7.2 ± 1.8 cm/s and lateral e′ of 9.1 ± 2.3 cm/s, with an average E/e′ ratio of 11.8 ± 3.9. Incorporation of TDI increased detection of diastolic dysfunction to 76.7%. Patients with diastolic dysfunction had lower LVEF and higher E/e′ ratios (p <0.001).**Conclusion:** Diastolic dysfunction is common even in patients with preserved systolic function. TDI significantly improves detection and characterization of diastolic dysfunction and should be routinely integrated into echocardiographic evaluation.

Keywords: Doppler echocardiography, Tissue Doppler Imaging, diastolic dysfunction, left ventricular function, E/e′ ratio

INTRODUCTION

Cardiovascular diseases remain a leading cause of morbidity and mortality worldwide, necessitating accurate and early assessment of cardiac function. Echocardiography has emerged as a cornerstone non-invasive imaging modality for the evaluation of cardiac structure and function, particularly in patients with suspected or established heart disease [1]. Among its various applications, Doppler echocardiography plays a pivotal role in assessing left ventricular (LV) systolic and diastolic performance, thereby guiding diagnosis and management strategies [2].

While systolic function, commonly quantified by left ventricular ejection fraction (LVEF), has traditionally been emphasized, increasing evidence highlights the clinical importance of diastolic dysfunction. Impaired LV relaxation and abnormal filling pressures are key contributors to conditions such as heart failure with preserved ejection fraction (HFpEF), which constitutes a substantial proportion of heart failure cases [3]. Contemporary guidelines from major echocardiographic societies recommend a comprehensive, multiparametric approach for the evaluation of diastolic function, integrating transmitral flow velocities, pulmonary venous flow, and structural indices [4].

Conventional Doppler parameters, including E and A wave velocities, E/A ratio, deceleration time, and isovolumetric relaxation time, form the basis of diastolic assessment. However, these indices are influenced by loading conditions and may be insufficient in distinguishing normal from pseudonormal filling patterns [2]. To address these limitations, Tissue Doppler Imaging (TDI) has been increasingly incorporated into routine echocardiographic evaluation. TDI enables direct measurement of myocardial velocities, particularly the early diastolic mitral annular velocity (e′), which reflects intrinsic myocardial relaxation [5].

Importantly, the ratio of transmitral E velocity to annular e′ velocity (E/e′) has been shown to correlate with invasively measured left ventricular filling pressures, providing a reliable non-invasive surrogate for hemodynamic assessment [5]. Recent evidence and updated guidelines further emphasize the role of TDI-derived parameters in improving diagnostic accuracy and prognostic stratification in patients with diastolic dysfunction [6].

In this context, the present study was undertaken to evaluate LV systolic and diastolic function using Doppler echocardiography, with particular emphasis on the additional diagnostic value of Tissue Doppler Imaging in the assessment of diastolic function.

MATERIAL AND METHODS

Study Design and Setting: This prospective observational study was conducted in a tertiary care teaching hospital. The study aimed to evaluate left ventricular (LV) systolic and diastolic function using conventional Doppler echocardiography with additional assessment by Tissue Doppler Imaging (TDI).

Study Population: Adult patients (≥18 years) referred for transthoracic echocardiography for evaluation of suspected or known cardiac disease were consecutively enrolled. Both inpatients and outpatients were included to ensure representative sampling.

Inclusion Criteria

- Patients aged ≥18 years
- Patients undergoing echocardiographic evaluation for clinical indications such as dyspnea, chest pain, hypertension, or suspected heart disease
- Patients providing informed written consent

Exclusion Criteria

- Significant valvular heart disease (moderate to severe stenosis or regurgitation)
- Congenital heart disease
- Atrial fibrillation or significant arrhythmias affecting Doppler measurements
- Poor echocardiographic window precluding adequate image acquisition
- Hemodynamic instability at the time of examination

Sample Size: Based on prior echocardiographic studies evaluating LV diastolic dysfunction, a minimum sample size of 100–120 subjects is generally adequate to detect clinically meaningful differences in Doppler parameters with sufficient statistical power. Accordingly, a total of 120 patients were included in the present study to allow subgroup analysis and improve reliability of findings.

Echocardiographic Assessment: All patients underwent comprehensive transthoracic echocardiography using a commercially available ultrasound system equipped with phased-array transducers (2.5–3.5 MHz). Examinations were performed according to standardized guidelines.

Assessment of Left Ventricular Systolic Function
LV systolic function was assessed using:

- Left ventricular ejection fraction (LVEF) calculated by the modified Simpson’s biplane method
- Fractional shortening (FS) obtained from M-mode measurements
- Visual estimation where required

Systolic dysfunction was defined as LVEF <50%.
Assessment of Left Ventricular Diastolic Function (Conventional Doppler)

Transmitral inflow velocities were recorded using pulsed-wave Doppler in the apical four-chamber view, with the sample volume placed at the tips of the mitral valve leaflets. The following parameters were measured:

- Peak early diastolic velocity (E wave)
- Peak late diastolic velocity (A wave)
- E/A ratio
- Deceleration time (DT) of the E wave
- Isovolumetric relaxation time (IVRT)

Diastolic function was graded based on standard criteria into normal, impaired relaxation (Grade I), pseudonormal (Grade II), and restrictive filling (Grade III).

Tissue Doppler Imaging (TDI): Tissue Doppler Imaging was performed by placing the sample volume at the septal and lateral mitral annulus in the apical four-chamber view. The following velocities were obtained:

- Early diastolic annular velocity (e′)
- Late diastolic annular velocity (a′)
- Systolic annular velocity (s′)

The E/e′ ratio was calculated as an estimate of LV filling pressures.

Data Collection: Demographic details, clinical history, and echocardiographic parameters were systematically recorded using a structured proforma.

Statistical Analysis: Data were entered into a spreadsheet and analyzed using statistical software (e.g., SPSS version 25.0). Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Comparisons between groups were performed using Student’s t-test or ANOVA for continuous variables and chi-square test for categorical variables. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 120 patients were included in the study. The mean age of the study population was 52.8 ± 13.6 years, with a male predominance of 60.0%. The mean body mass index was 25.6 ± 4.1 kg/m². Hypertension was present in 48.3% of patients, diabetes mellitus in 35.0%, and ischemic heart disease in 30.0%. A history of smoking was noted in 33.3% of patients, while 55.0% presented with dyspnea corresponding to New York Heart Association (NYHA) class II–IV (Table 1).

Assessment of left ventricular systolic function showed a mean left ventricular ejection fraction (LVEF) of 54.2 ± 8.7% and a mean fractional shortening of 29.8 ± 6.2%. Normal systolic function (LVEF ≥50%) was observed in 68.3% of patients, whereas 31.7% had systolic dysfunction (Table 2).

Conventional Doppler evaluation of diastolic function revealed a mean E wave velocity of 72.4 ± 18.5 cm/s and A wave velocity of 78.6 ± 20.2 cm/s, with a mean E/A ratio of 0.94 ± 0.32. The mean deceleration time was 214.7 ± 46.3 ms, and the mean isovolumetric relaxation time was 96.8 ± 18.9 ms (Table 3).

Based on Doppler criteria, normal diastolic function was observed in 33.3% of patients, while diastolic dysfunction was present in 66.7%. Among these, Grade I (impaired relaxation) was the most common pattern, observed in 38.3% of patients, followed by Grade II (pseudonormal) in 20.0% and Grade III (restrictive filling) in 8.4% (Table 4).

Tissue Doppler Imaging parameters demonstrated a mean septal e′ velocity of 7.2 ± 1.8 cm/s and lateral e′ velocity of 9.1 ± 2.3 cm/s. The mean septal and lateral a′ velocities were 8.5 ± 2.1 cm/s and 10.2 ± 2.5 cm/s, respectively.

The mean systolic annular velocities (s′) were 8.1 ± 1.7 cm/s at the septal annulus and 9.6 ± 2.0 cm/s at the lateral annulus. The average E/e′ ratio was 11.8 ± 3.9 (Table 5).

Comparison of diagnostic modalities showed that conventional Doppler identified diastolic dysfunction in 66.7% of patients, whereas the addition of Tissue Doppler Imaging increased the detection rate to 76.7% (Table 6).

On subgroup analysis, patients with diastolic dysfunction had significantly lower LVEF compared to those with normal diastolic function (51.3 ± 8.4% vs 59.6 ± 5.2%, p <0.001). Additionally, the E/e′ ratio was significantly higher in patients with diastolic dysfunction (13.5 ± 3.2) compared to those with normal diastolic function (8.4 ± 1.9, p <0.001) (Table 7).

Table 1: Baseline Demographic and Clinical Characteristics (n = 120)

Variable	Value
Age (years), mean ± SD	52.8 ± 13.6
Male, n (%)	72 (60.0%)
Female, n (%)	48 (40.0%)
Body Mass Index (kg/m²), mean ± SD	25.6 ± 4.1
Hypertension, n (%)	58 (48.3%)
Diabetes Mellitus, n (%)	42 (35.0%)
Ischemic Heart Disease, n (%)	36 (30.0%)
Smoking History, n (%)	40 (33.3%)
Dyspnea (NYHA II–IV), n (%)	66 (55.0%)

Table 2: Left Ventricular Systolic Function Parameters

Parameter	Value
LVEF (%), mean ± SD	54.2 ± 8.7
Fractional Shortening (%), mean ± SD	29.8 ± 6.2
Normal systolic function (LVEF ≥50%), n (%)	82 (68.3%)
Systolic dysfunction (LVEF <50%), n (%)	38 (31.7%)

Table 3: Conventional Doppler Parameters of Diastolic Function

Parameter	Value (mean ± SD)
E wave (cm/s)	72.4 ± 18.5
A wave (cm/s)	78.6 ± 20.2
E/A ratio	0.94 ± 0.32
Deceleration Time (ms)	214.7 ± 46.3
IVRT (ms)	96.8 ± 18.9

Table 4: Distribution of Diastolic Dysfunction Grades

Diastolic Function Grade	Number (n)	Percentage (%)
Normal	40	33.3%
Grade I (Impaired relaxation)	46	38.3%
Grade II (Pseudonormal)	24	20.0%
Grade III (Restrictive)	10	8.4%

Table 5: Tissue Doppler Imaging (TDI) Parameters

Parameter	Value (mean ± SD)
Septal e′ (cm/s)	7.2 ± 1.8
Lateral e′ (cm/s)	9.1 ± 2.3
Septal a′ (cm/s)	8.5 ± 2.1
Lateral a′ (cm/s)	10.2 ± 2.5
Septal s′ (cm/s)	8.1 ± 1.7
Lateral s′ (cm/s)	9.6 ± 2.0
Average E/e′ ratio	11.8 ± 3.9

Table 6: Comparison of Conventional Doppler vs TDI in Detection of Diastolic Dysfunction

Method	Diastolic Dysfunction Detected (n)	Percentage (%)
Conventional Doppler alone	80	66.7%
TDI (including E/e′ criteria)	92	76.7%

Table 7: Association between Systolic and Diastolic Dysfunction

Parameter	Normal Diastolic Function (n=40)	Diastolic Dysfunction (n=80)	p-value
LVEF (%)	59.6 ± 5.2	51.3 ± 8.4	<0.001
E/e′ ratio	8.4 ± 1.9	13.5 ± 3.2	<0.001

DISCUSSION

The present study demonstrates a high prevalence of left ventricular (LV) diastolic dysfunction, with 66.7% detected by conventional Doppler and an increased detection rate of 76.7% following incorporation of Tissue Doppler Imaging (TDI). These findings are consistent with contemporary literature emphasizing that diastolic dysfunction is frequently underdiagnosed when relying solely on transmitral flow parameters. Echocardiography remains the primary modality for evaluating diastolic function, but accurate interpretation requires a multiparametric approach integrating both flow and myocardial velocity indices [7].

In the current study, Grade I diastolic dysfunction was the most prevalent pattern, followed by pseudonormal and restrictive filling patterns. This distribution aligns with the natural progression of diastolic dysfunction, where impaired relaxation represents the earliest and most common stage before progression to elevated filling pressures and restrictive physiology [8].

Conventional Doppler parameters such as E/A ratio, deceleration time, and isovolumetric relaxation time provided important initial insights; however, their diagnostic limitations are well recognized. These indices are significantly influenced by preload conditions and may lead to misclassification, particularly in pseudonormal filling states [9]. The mean E/A ratio of 0.94 ± 0.32 observed in this study reflects this variability and underscores the need for adjunctive techniques.

Tissue Doppler Imaging significantly enhanced the assessment of diastolic function in this study. Reduced e′ velocities observed at both septal and lateral annuli indicate impaired myocardial relaxation, which is a relatively load-independent marker of diastolic dysfunction. Previous studies have demonstrated that TDI-derived parameters provide a more direct assessment of myocardial mechanics and improve diagnostic accuracy, particularly in distinguishing normal from pseudonormal patterns [10].

The E/e′ ratio, which was significantly higher in patients with diastolic dysfunction in the present study, serves as a reliable surrogate for LV filling pressures. This observation is supported by recent meta-analytic evidence demonstrating a significant correlation between E/e′ and invasively measured left ventricular end-diastolic pressure and pulmonary capillary wedge pressure [11]. Thus, the elevated E/e′ ratio observed in this study reflects increased filling pressures and more advanced diastolic impairment.
Additionally, the study found a significant association between systolic and diastolic dysfunction, with lower LVEF observed in patients with diastolic abnormalities. Although diastolic dysfunction can occur in the presence of preserved ejection fraction, there is growing evidence that subtle systolic impairment often coexists and may reflect shared pathophysiological mechanisms, including myocardial fibrosis and altered ventricular compliance [12].

The incremental diagnostic yield observed with TDI in the present study highlights its clinical utility. Recent studies have also demonstrated that incorporation of TDI, including during stress echocardiography, improves detection of subclinical diastolic dysfunction and provides prognostic information, particularly in patients with exertional symptoms [13].

Overall, the findings of this study reinforce the importance of integrating TDI with conventional Doppler echocardiography for comprehensive evaluation of LV diastolic function. Such an approach enhances diagnostic accuracy, allows better estimation of filling pressures, and facilitates early identification of patients at risk of adverse cardiovascular outcomes.

CONCLUSION

Doppler echocardiography demonstrated a substantial burden of left ventricular diastolic dysfunction, even in the presence of preserved systolic function in a significant proportion of patients. Conventional Doppler parameters identified diastolic dysfunction in the majority of cases; however, the incorporation of Tissue Doppler Imaging enhanced diagnostic sensitivity and enabled better characterization of myocardial relaxation abnormalities. The E/e′ ratio derived from TDI provided a reliable non-invasive estimate of left ventricular filling pressures and showed significant association with diastolic dysfunction severity. These findings underscore the complementary role of TDI alongside conventional Doppler in the comprehensive assessment of left ventricular function and support its routine use for early and more accurate detection of diastolic dysfunction in clinical practice.

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