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Comparative validity of left ventricular ejection fraction measured by M-mode versus three-dimensional echocardiography: A prospective observational study

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Abstract

Background: Accurate assessment of left ventricular ejection fraction (LVEF) is essential for the diagnosis, risk stratification, and management of cardiovascular disease. Although M-mode echocardiography remains widely used due to its simplicity and accessibility, it relies on geometric assumptions and one-dimensional measurements. Three-dimensional (3D) echocardiography enables direct volumetric assessment without geometric assumptions and is recommended by contemporary imaging guidelines. This study aimed to evaluate the validity and agreement of M-mode–derived LVEF compared with 3D echocardiographic LVEF.

Methods: In this prospective observational study, 200 consecutive adult patients undergoing transthoracic echocardiography were enrolled. LVEF was measured using M-mode (Teichholz method) and 3D echocardiography. Correlation between methods was assessed using Pearson correlation coefficient. Agreement was evaluated using Bland–Altman analysis. Diagnostic performance of M-mode LVEF for identifying reduced systolic function (LVEF <50%) was assessed using receiver operating characteristic (ROC) analysis.

Results: A total of 200 patients were included, of whom 198 had complete paired measurements (mean age 57.1 ± 10.9 years; 69.7% male). Mean LVEF measured by M-mode was 51.1 ± 11.8%, whereas mean LVEF measured by 3D echocardiography was 54.5 ± 10.9%. M-mode–derived LVEF demonstrated a strong positive correlation with 3D LVEF ($r = 0.911$, $p < 0.001$). However, Bland–Altman analysis revealed a mean bias of −3.37% with wide limits of agreement (−12.95% to +6.20%), indicating poor agreement between methods. M-mode LVEF demonstrated excellent diagnostic performance for identifying reduced systolic function, with an area under the curve of 0.973. An optimal cutoff of 48% yielded a sensitivity of 98.4% and specificity of 82.5%.

Conclusions: Although M-mode–derived LVEF demonstrates strong correlation with 3D echocardiography, it shows significant bias and wide limits of agreement, limiting its clinical interchangeability. Three-dimensional echocardiography provides a more accurate and reliable assessment of left ventricular systolic function and should be preferred in contemporary clinical practice.

Keywords: Left ventricular ejection fraction; M-mode echocardiography; Three-dimensional echocardiography; Bland–Altman analysis; Diagnostic accuracy; ROC analysis; Left ventricular systolic function

1. Introduction

Cardiovascular disease (CVD) remains the leading cause of morbidity and mortality worldwide, accounting for nearly one-third of all global deaths. In India, the burden of coronary artery disease (CAD) has increased substantially over

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recent decades, with earlier onset and higher prevalence compared with Western populations. The rising prevalence of traditional risk factors, including diabetes mellitus and hypertension, coupled with delayed diagnosis, contributes to significant clinical and economic burden. In this context, accurate assessment of left ventricular (LV) systolic function is essential for risk stratification, therapeutic decision-making, and prognostication.

Left ventricular ejection fraction (LVEF) is the most widely used parameter for evaluating systolic function in routine clinical practice. Among echocardiographic techniques, M-mode–derived LVEF remains commonly used due to its simplicity, rapid acquisition, and widespread availability. However, M-mode assessment is inherently limited by its reliance on one-dimensional linear measurements and geometric assumptions regarding LV shape. These limitations may result in inaccurate estimation of LVEF, particularly in the presence of regional wall motion abnormalities (RWMA), ventricular remodeling, or asymmetric contraction patterns—conditions frequently encountered in patients with CAD.

Advances in echocardiographic imaging have led to the development of three-dimensional (3D) echocardiography, which enables direct volumetric quantification of LV volumes and LVEF without geometric assumptions. Current recommendations from the American Society of Echocardiography and the European Association of Cardiovascular Imaging endorse 3D echocardiography as a more accurate and reproducible method for LVEF assessment compared with conventional techniques[1,2]. Despite these advantages, M-mode continues to be widely used in routine clinical practice, particularly in resource-limited settings, often without clear understanding of its limitations relative to contemporary imaging modalities[1,2].

Although previous studies have compared various echocardiographic techniques for LVEF estimation, data specifically evaluating the validity and agreement of M-mode–derived LVEF against 3D echocardiography in real-world clinical populations remain limited, particularly in regions with high CAD prevalence[3-5]. Furthermore, the extent to which discrepancies between these methods vary across clinical scenarios—such as preserved versus reduced LVEF and the presence of RWMA—has not been adequately characterized.

In this context, we hypothesized that M-mode–derived LVEF demonstrates limited agreement with 3D echocardiographic LVEF and is not clinically interchangeable, particularly in patients with altered ventricular geometry or regional dysfunction. Accordingly, the present study aimed to evaluate the correlation, agreement, and diagnostic performance of M-mode–derived LVEF compared with 3D echocardiography in a prospective cohort of patients undergoing transthoracic echocardiographic assessment.

2. Methods

2.1. Study Design

This prospective observational study was conducted at IMS & SUM Hospital over a period of **one year (2024-2025)**. The study protocol was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants prior to enrollment.

2.2. Study Population

Consecutive adult patients (≥18 years) undergoing clinically indicated transthoracic echocardiography were enrolled.

2.3. Inclusion Criteria

- Age ≥18 years
- Undergoing transthoracic echocardiography
- Adequate acoustic window for analysis

2.4. Exclusion Criteria

- Poor echocardiographic image quality
- Atrial fibrillation or significant arrhythmias affecting measurement accuracy
- Moderate or severe valvular heart disease
- Congenital heart disease
- Prior cardiac surgery or intracardiac device implantation

2.5. Data Collection

Baseline demographic and clinical data were recorded using a standardized case record form, including age, sex, cardiovascular risk factors (diabetes mellitus, hypertension, dyslipidemia, and smoking status), and clinical presentation (chronic stable angina, unstable angina, ST-elevation myocardial infarction, or non–ST-elevation myocardial infarction).

2.6. Echocardiographic Acquisition and Analysis

All echocardiographic examinations were performed using a commercially available ultrasound system (e.g., Philips EPIQ CVx) equipped with 2D, M-mode, and 3D capabilities. Image acquisition and analysis were performed in accordance with recommendations from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. All measurements were performed by experienced echocardiographers blinded to each other's results.

2.7. M-mode LVEF

M-mode recordings were obtained from the parasternal long-axis view. Left ventricular internal dimensions in end-diastole and end-systole were measured, and LVEF was calculated using the Teichholz formula.

2.8. Three-Dimensional (3D) LVEF

Full-volume 3D datasets were acquired from the apical window over multiple cardiac cycles during breath-hold. Datasets were analyzed offline using dedicated software (e.g., TOMTEC AutoStrain or vendor-specific software) with semi-automated endocardial border detection. Left ventricular volumes and LVEF were calculated without geometric assumptions.

2.9. Outcomes

2.9.1. Primary Outcome

- Agreement between M-mode–derived and 3D echocardiographic LVEF

2.9.2. Secondary Outcomes

- Correlation between M-mode and 3D LVEF
- Mean bias and limits of agreement (Bland–Altman analysis)
- Diagnostic performance of M-mode LVEF for identifying reduced systolic function (LVEF <50%)

2.10. Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics (version 26.0; IBM Corp., Armonk, NY, USA).

Continuous variables were expressed as mean ± standard deviation (SD), and categorical variables as frequencies and percentages. Normality was assessed using the Kolmogorov–Smirnov test.

Correlation between M-mode and 3D LVEF was evaluated using Pearson correlation coefficient (r). Agreement between the two methods was assessed using Bland–Altman analysis, including mean bias and 95% limits of agreement.

Receiver operating characteristic (ROC) curve analysis was performed to assess the diagnostic accuracy of M-mode LVEF for identifying reduced systolic function (LVEF <50%), with calculation of area under the curve (AUC), sensitivity, and specificity.

Logistic regression analysis was performed to evaluate the association between M-mode LVEF and reduced systolic function defined by 3D echocardiography.

A two-tailed p-value of <0.05 was considered statistically significant.

3. Results

A total of 200 patients were included in the study, of whom 198 had complete paired LVEF measurements and were included in the primary analysis.

Table 1 Baseline Demographic and Echocardiographic Characteristics of the Study Population

Variable	Value
Total patients enrolled, n	200
Patients with paired LVEF analysis, n	198
Age (years), mean ± SD	57.1 ± 10.9
Male sex, n (%)	138 (69.7%)
Female sex, n (%)	60 (30.3%)

Echocardiographic Parameters

Parameter	Value
M-mode LVEF (%), mean ± SD	51.1 ± 11.8
3D LVEF (%), mean ± SD	54.5 ± 10.9

Table 2 Correlation and Agreement Between M-mode and 3D Echocardiographic LVEF

Parameter	Value
Pearson correlation (r)	0.911
p-value	<0.001
Mean bias (M-mode − 3D)	−3.37%
Lower limit of agreement	−12.95%
Upper limit of agreement	+6.20%

Table 3 Diagnostic Accuracy of M-mode LVEF for Detection of Reduced Left Ventricular Systolic Function

Parameter	Value
AUC (ROC)	0.973
Optimal cutoff (M-mode EF)	48%
Sensitivity (%)	98.4
Specificity (%)	82.5

Table 4 Logistic Regression Analysis for Prediction of Reduced Left Ventricular Systolic Function

Variable	Odds Ratio (95% CI)	p-value
M-mode LVEF (per 1% decrease)	1.59 (1.34–1.88)	<0.001

Values are expressed as mean ± standard deviation or number (percentage).; LVEF = left ventricular ejection fraction; ROC = receiver operating characteristic; AUC = area under the curve.; Bland–Altman analysis was used to assess agreement between methods.; Reduced LVEF defined as <50% by 3D echocardiography.

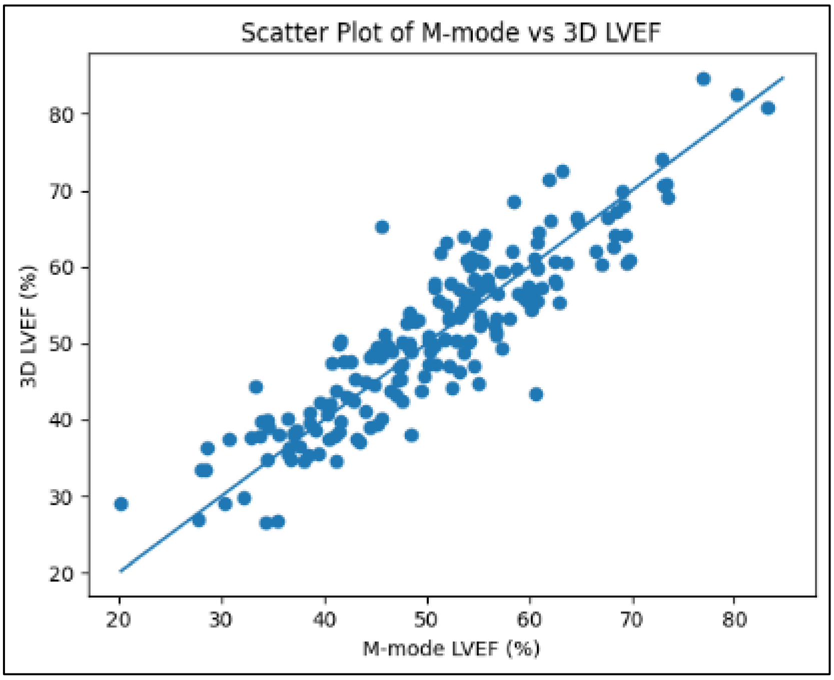

Figure 1 Scatter plot demonstrating the relationship between M-mode–derived and three-dimensional (3D) echocardiographic left ventricular ejection fraction (LVEF). The solid line represents the line of identity (y = x), indicating perfect agreement. Although a strong correlation was observed (r = 0.911, p < 0.001), substantial dispersion around the line of identity highlights variability between the two methods.

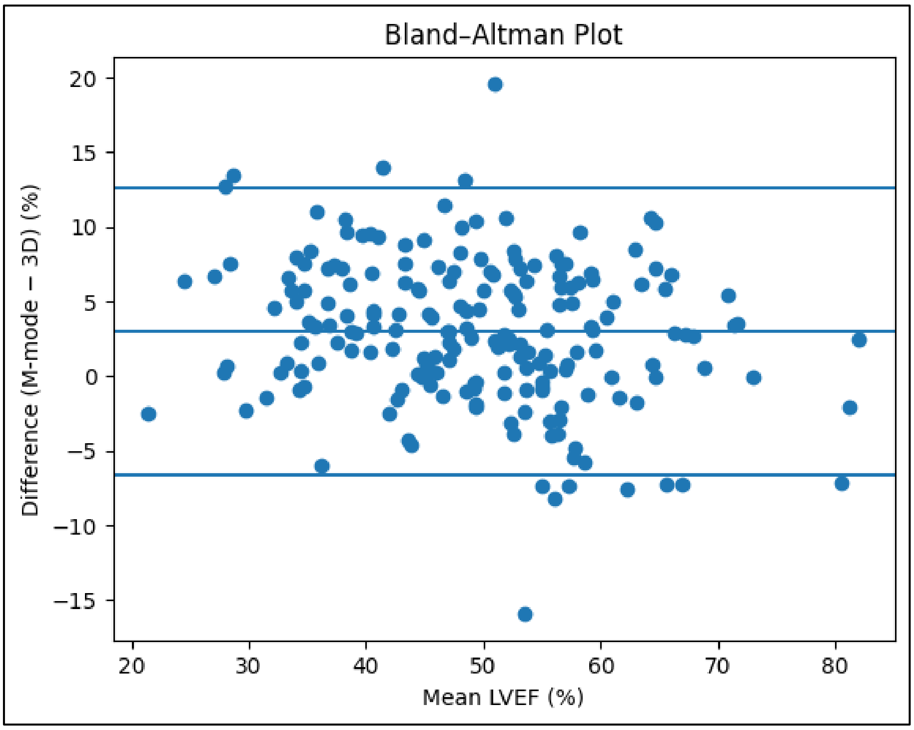

Figure 2 Bland–Altman Plot Showing Agreement Between M-mode and 3D Echocardiographic LVEF

Bland–Altman plot demonstrating agreement between M-mode–derived and three-dimensional (3D) echocardiographic left ventricular ejection fraction (LVEF). The solid central line represents the mean bias (−3.37%), while the upper and lower lines represent the 95% limits of agreement (−12.95% to +6.20%). The wide limits of agreement indicate significant variability between the two methods, suggesting limited clinical interchangeability.

4. Discussion

4.1. Principal Findings

In this prospective observational study of 200 patients, M-mode–derived LVEF demonstrated a strong correlation with 3D echocardiographic LVEF; however, this relationship did not translate into clinical interchangeability (Figure 2). Despite a high correlation coefficient (r = 0.911) (Table 2, Figure 1), M-mode systematically underestimated LVEF compared with 3D echocardiography, with a mean bias of −3.37% and wide limits of agreement (−12.95% to +6.20%) (Table 2, Figure 2). These findings highlight the critical distinction between correlation and agreement, underscoring that strong statistical association does not ensure clinical equivalence at the individual patient level.

Importantly, M-mode demonstrated excellent diagnostic performance in identifying reduced systolic function (AUC 0.973), with high sensitivity but comparatively lower specificity (Table 3). While this suggests potential utility as a screening tool, the observed variability limits its role in accurate quantification of LVEF, particularly in clinical scenarios where management decisions depend on narrow EF thresholds.

4.2. Comparison With Existing Literature

Our findings are consistent with prior studies demonstrating the limitations of M-mode–derived LVEF, primarily due to its reliance on one-dimensional measurements and geometric assumptions[3-5]. Previous investigations have reported moderate to strong correlations between M-mode and volumetric techniques, but consistently emphasize poor agreement, particularly in the presence of regional wall motion abnormalities or altered ventricular geometry.

Current recommendations from the American Society of Echocardiography and the European Association of Cardiovascular Imaging support the use of three-dimensional echocardiography as a more accurate and reproducible method for LVEF assessment. Our study reinforces these recommendations by demonstrating that even in a real-world cohort, M-mode measurements show clinically relevant deviations from 3D-derived values[1,2].

The magnitude of bias observed in our study (approximately 3%–5%) is comparable to previously reported differences between linear and volumetric techniques; however, the wide limits of agreement observed in our cohort further highlight the inherent variability of M-mode–based assessment.

4.3. Mechanistic Explanation of Findings

The discrepancies between M-mode and 3D echocardiographic LVEF can be explained by fundamental methodological differences. M-mode relies on linear measurements obtained from a single imaging plane and assumes a symmetric, ellipsoid LV geometry. In contrast, 3D echocardiography provides full volumetric assessment of the left ventricle, enabling accurate quantification irrespective of geometric distortion or regional dysfunction.

In patients with coronary artery disease—who constituted a substantial proportion of our cohort—regional wall motion abnormalities result in heterogeneous contraction patterns. Under such conditions, localized linear measurements may fail to represent global ventricular function, leading to systematic underestimation or overestimation of LVEF. This limitation becomes more pronounced with increasing severity of myocardial dysfunction, explaining the wider variability observed in patients with reduced LVEF.

4.4. Clinical Implications

The findings of this study have several important clinical implications. First, although M-mode–derived LVEF remains a rapid and widely available tool, it should not be relied upon for definitive assessment of LV systolic function, particularly in patients with suspected or established coronary artery disease.

Second, the observed limits of agreement indicate that M-mode and 3D LVEF are not interchangeable, especially in clinical contexts where management decisions depend on specific EF thresholds (e.g., ≤35% for device therapy or <50% for classification of systolic dysfunction). Even modest differences in LVEF estimation may lead to clinically meaningful misclassification and impact therapeutic decisions.

Third, our findings support the routine use of 3D echocardiography for LVEF assessment wherever feasible, particularly in tertiary care settings. In resource-limited environments, M-mode measurements should be interpreted with caution, and confirmatory evaluation using more robust imaging modalities should be considered when clinical decision-making is critical.

4.5. Strengths of the Study

This study has several important strengths. It includes a relatively large, real-world cohort encompassing a broad spectrum of clinical presentations, thereby enhancing the generalizability of the findings. Echocardiographic acquisition and analysis were performed using standardized protocols in accordance with recommendations from the American Society of Echocardiography and the European Association of Cardiovascular Imaging, ensuring methodological rigor and reproducibility.

In addition, the study incorporates a comprehensive statistical approach, including correlation analysis, Bland–Altman agreement assessment, receiver operating characteristic analysis, and logistic regression modeling. This integrated evaluation provides a robust and clinically relevant comparison between M-mode and 3D echocardiographic LVEF measurements.

4.6. Limitations

Several limitations should be acknowledged. First, this was a single-center study, which may limit the external generalizability of the findings. Second, although three-dimensional echocardiography is considered a reference standard in routine clinical practice, cardiac magnetic resonance imaging (CMR) was not used as an external gold standard for validation.

Third, interobserver and intraobserver variability were not formally assessed, which may influence the reproducibility of measurements. Finally, detailed subgroup analyses based on specific patterns and extent of regional wall motion abnormalities were not performed, which may further affect the degree of discrepancy between measurement techniques.

5. Conclusions

In conclusion, although M-mode–derived LVEF demonstrates strong correlation with 3D echocardiographic measurements, it exhibits systematic bias and wide limits of agreement, limiting its clinical interchangeability. These findings reinforce the principle that correlation alone is insufficient to establish equivalence between measurement techniques.

Three-dimensional echocardiography provides a more accurate and reliable assessment of left ventricular systolic function and should be preferred for clinical decision-making, particularly in patients with coronary artery disease or altered ventricular geometry. M-mode–derived LVEF may retain a role as a rapid screening tool; however, confirmatory assessment using volumetric techniques is recommended when precise quantification is required

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflict of interest.

Statement of informed consent

Written informed consent was obtained from all individual participants included in the study.

Study Note

This study was conducted during the author's DM (Cardiology) training at IMS & SUM Hospital, Bhubaneswar.

Statement of ethical approval

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Ethics Committee of IMS & SUM Hospital, Bhubaneswar.

References

[1] Lang RM, Badano LP, Mor-Avi V, Afilalo J, Armstrong A, Ernande L, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: An update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. *J Am Soc Echocardiogr.* 2015;28(1):1–39.

[2] Muraru D, Badano LP, Peluso D, Dal Bianco L, Casablanca S, Kocabay G, et al. Three-dimensional echocardiography: Benefits and limitations in clinical practice. *Eur Heart J Cardiovasc Imaging.* 2012;13(2):101–113.

[3] Thavendiranathan P, Popović ZB, Flamm SD, Dahiya A, Grimm RA, Marwick TH. Improved interobserver variability and accuracy of echocardiographic visual left ventricular ejection fraction assessment through a novel method. *J Am Coll Cardiol.* 2013;61(1):77–84.

[4] Jenkins C, Bricknell K, Hanekom L, Marwick TH. Reproducibility and accuracy of echocardiographic measurements of left ventricular parameters using real-time three-dimensional echocardiography. *J Am Coll Cardiol.* 2004;44(4):878–886.

[5] Sugeng L, Mor-Avi V, Weinert L, Niel J, Ebner C, Steringer-Mascherbauer R, et al. Quantitative assessment of left ventricular size and function: Side-by-side comparison of real-time three-dimensional echocardiography and computed tomography. *Circulation.* 2006;114(7):654–661.