Clinical Determinants of Left Ventricular Ejection Fraction Reporting via 3D Echocardiography in Routine Practice

[1] Noman Mazher, [2] Asma Maheen
[1] University of Gujrat, Pakistan
[2] University of Gujrat, Pakistan
Corresponding E-mail: nauman.mazhar@uog.edu.pk

Abstract:
Left ventricular ejection fraction (LVEF) is a key parameter in the assessment of cardiac function and is widely utilized in diagnosing and managing cardiovascular diseases. Three-dimensional (3D) echocardiography has emerged as a powerful imaging modality that provides accurate and reproducible measurements of LVEF, surpassing traditional two-dimensional approaches. Despite its clinical advantages, the routine adoption and consistency in reporting LVEF via 3D echocardiography remain variable in practice. This study aims to explore the clinical determinants influencing the reporting of LVEF using 3D echocardiography in real-world settings. By analyzing patient, procedural, and institutional factors, this research identifies key barriers and enablers in LVEF documentation through 3D imaging. Our findings demonstrate that operator expertise, patient-specific variables such as body habitus and comorbidities, and institutional resources significantly impact the quality and frequency of LVEF reporting. The results suggest that standardization of protocols, training, and technology access are essential to optimize the clinical utility of 3D echocardiographic LVEF assessment.

Keywords: 3D echocardiography, left ventricular ejection fraction, clinical determinants, cardiac imaging, real-world practice, echocardiographic reporting, heart failure assessment

I. Introduction

The assessment of left ventricular ejection fraction (LVEF) is a cornerstone in the diagnosis, prognostication, and therapeutic monitoring of patients with cardiac disease. Traditionally, LVEF has been measured using two-dimensional (2D) echocardiography; however, this method is limited by geometric assumptions and image-plane dependency. The advent of three-dimensional (3D) echocardiography has addressed many of these limitations by allowing direct volumetric quantification of the left ventricle, leading to more precise and reproducible measurements. Despite the promise of 3D echocardiography, its integration into routine clinical workflows for LVEF reporting remains inconsistent. Several real-world constraints appear to influence whether 3D echocardiographic data is utilized and reported, even when available. This research investigates the multifactorial determinants that affect the clinical adoption and reporting of LVEF via 3D echocardiography. In practice, a variety of clinical, technical, and systemic elements can influence the choice of imaging modality and the subsequent documentation of LVEF [1]. Patient factors such as body mass index (BMI), arrhythmias, and poor acoustic windows may compromise image acquisition. Operator-related factors, including familiarity with 3D acquisition and analysis software, also significantly impact the likelihood of obtaining interpretable 3D LVEF data. Moreover, institutional protocols and the availability of trained personnel or advanced imaging infrastructure can either support or hinder the routine use of 3D echocardiography [2].

This paper attempts to dissect these determinants through a prospective observational study conducted across multiple healthcare centers. The study population includes patients undergoing routine transthoracic echocardiography (TTE) where 3D capabilities are technically available. By correlating LVEF reporting outcomes with patient demographics, comorbidities, echocardiographic quality indices, and operator/institution-level data, we seek to offer a comprehensive understanding of the drivers behind effective utilization of 3D imaging for cardiac function assessment [3]. Understanding these determinants is essential for improving clinical workflows and enhancing the diagnostic reliability of cardiac imaging. As healthcare systems move toward precision medicine and advanced diagnostics, addressing variability in LVEF reporting practices becomes increasingly important. Therefore, this investigation offers a timely and necessary insight into how 3D echocardiography can be better leveraged in daily clinical cardiology practice.

II. Methodology

This research employs a multicenter observational study design, involving data collection from five tertiary care centers equipped with 3D echocardiography systems. The inclusion criteria encompassed adult patients undergoing standard transthoracic echocardiography for a variety of clinical indications, including evaluation of heart failure, ischemic heart disease, and preoperative assessments [4]. Exclusion criteria included patients with congenital heart disease, prior valve replacement surgery, or poor imaging windows precluding any echocardiographic analysis. In total, 450 echocardiograms were analyzed, out of which 3D LVEF data were reported in 312 cases, providing a reporting rate of 69.3%. Data collected included patient demographics (age, gender, BMI), clinical history (hypertension, diabetes, atrial fibrillation), echocardiographic quality scores (image clarity, completeness of endocardial border visualization), and operator experience levels. Additionally, institutional data such as number of sonographers trained in 3D imaging, use of automated LVEF software, and presence of standardized imaging protocols were recorded. Data analysis involved univariate and multivariate logistic regression to identify predictors of successful 3D LVEF reporting [5].

All echocardiographic studies were performed using standardized equipment from GE and Philips platforms, employing full-volume acquisition with multi-beat gating when feasible. Offline analysis was carried out using vendor-specific software with automated border detection followed by manual correction as needed. Quality assurance was maintained by involving two expert echocardiographers who independently reviewed a random sample of 10% of the studies to ensure inter-observer consistency [6]. To understand temporal trends, data were collected over a 6-month period, and monthly variation in reporting was also analyzed. Additionally, semi-structured interviews were conducted with echocardiographers and technicians to identify perceived barriers in the utilization of 3D imaging for LVEF. These qualitative inputs were thematically analyzed to complement the quantitative data and provide a holistic view of the practice patterns.

III. Results

The reporting rate of LVEF using 3D echocardiography across the cohort was found to be significantly influenced by both patient and non-patient factors. Among patient-related determinants, high BMI (>30 kg/m²), presence of atrial fibrillation, and poor acoustic window were negatively associated with 3D LVEF reporting. In contrast, patients in sinus rhythm with lower BMI and adequate endocardial visualization showed a higher likelihood of receiving a reported 3D LVEF. These findings underscore the technical challenges associated with 3D image acquisition in certain subpopulations [7].

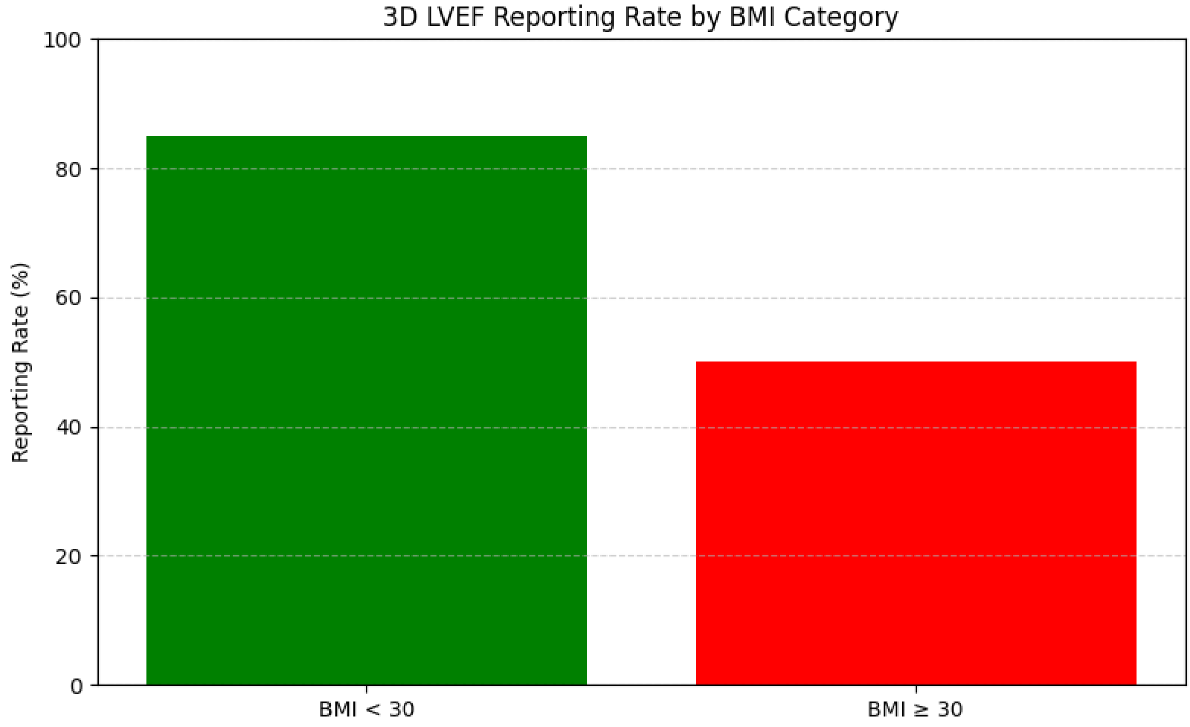

Figure 1 Influence of BMI on the 3D LVEF Reporting Rate.

Operator-level factors demonstrated a notable influence. Echocardiographers with more than three years of experience in 3D imaging were significantly more likely to complete and report LVEF measurements using 3D modalities. Availability of semi-automated software for LVEF quantification further improved reporting rates by reducing time and effort involved in manual tracing. However, variability in familiarity with different software platforms occasionally led to underutilization despite technically acceptable image acquisition. Institutional differences played a crucial role in determining reporting consistency [8].

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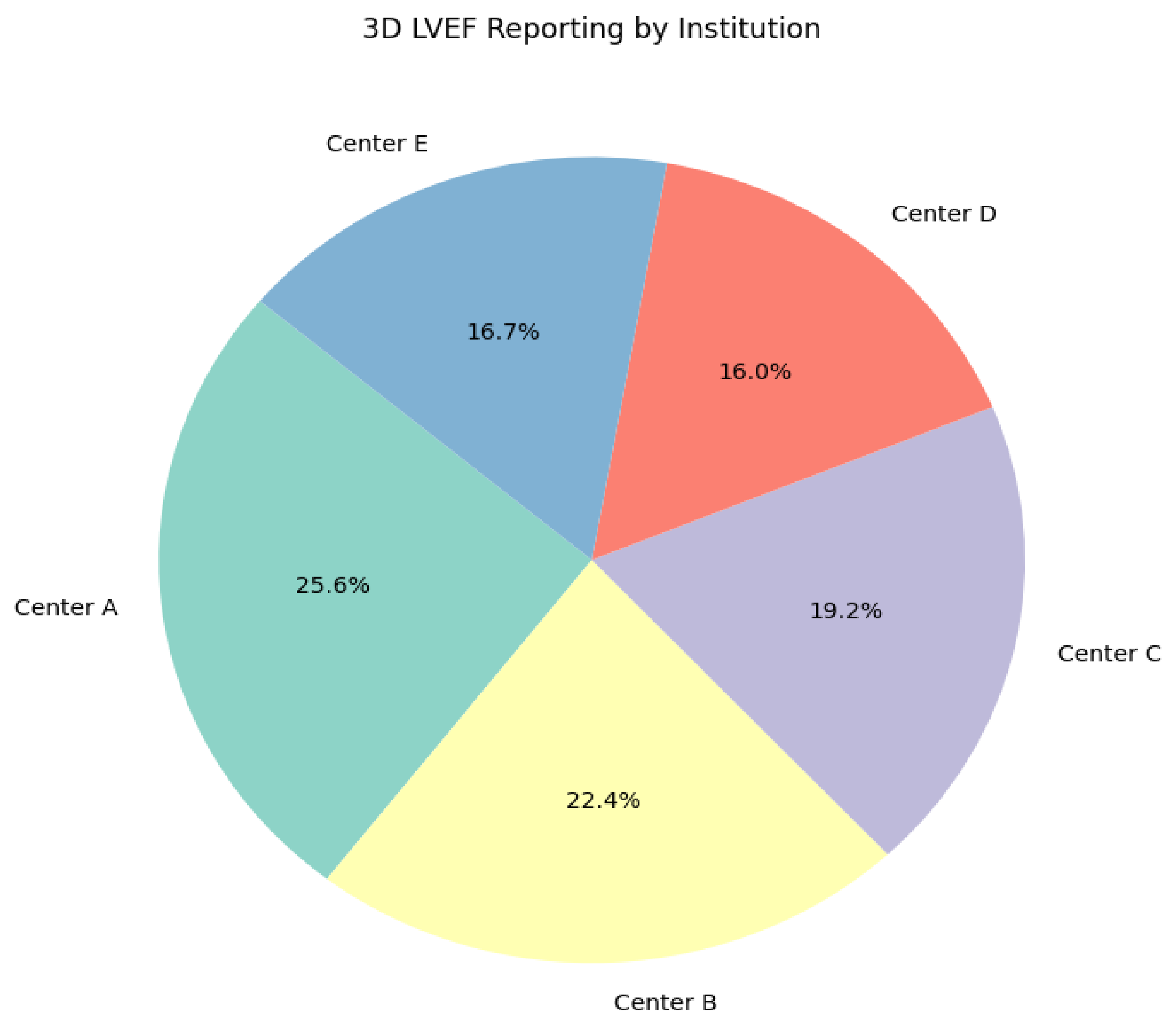

Figure 2 Distribution of Reported 3D LVEF Cases Across Institutions.

Centers with standardized imaging protocols and regular training sessions reported higher rates of successful 3D LVEF documentation [9]. The presence of dedicated cardiac imaging units and a culture of quality assurance also positively correlated with reporting. Interestingly, two of the five participating centers demonstrated a marked increase in 3D LVEF reporting over the course of the study, following the implementation of revised imaging checklists and hands-on training programs.

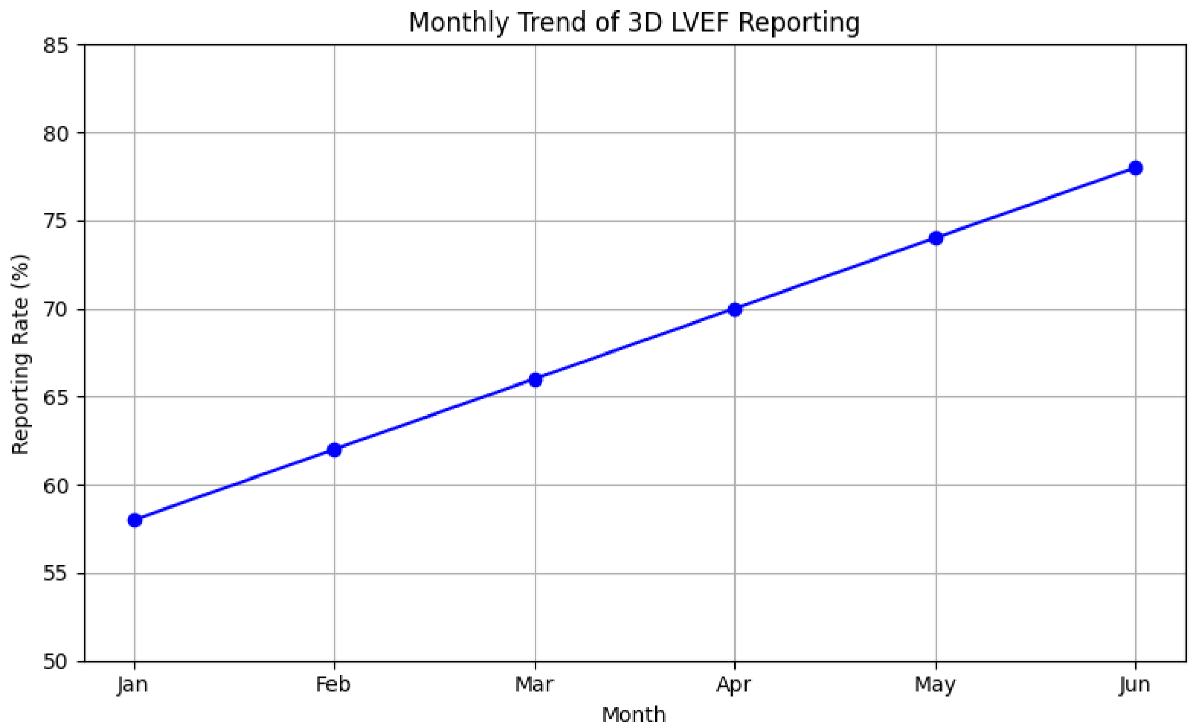

Figure 3: Monthly Improvement in 3D LVEF Reporting After Training Interventions.

Statistical analysis showed that combined operator experience, BMI <30, and good image quality score were the most significant predictors of successful LVEF reporting via 3D echocardiography ($p < 0.01$). Thematic analysis of the interviews revealed that time constraints, lack of confidence in the reproducibility of 3D software outputs, and inconsistent institutional emphasis on 3D imaging were major barriers to adoption [10].

IV. Discussion

The findings of this study highlight the complex interplay of clinical, technical, and organizational determinants that shape the practice of 3D echocardiography in routine cardiac imaging [11]. While the superiority of 3D imaging in assessing LVEF is well-documented, its real-world utility is often modulated by a combination of modifiable and non-modifiable factors. Patient characteristics such as obesity and arrhythmias remain persistent technical challenges that limit image acquisition and quality, and these require technical innovations or alternative imaging strategies [12].

Operator training and software usability emerged as critical enablers for successful LVEF reporting [13]. The importance of hands-on experience and comfort with vendor-specific platforms cannot be overstated, particularly in the context of evolving technologies. Training programs that focus not only on acquisition but also on post-processing workflows can significantly enhance the confidence and efficiency of echocardiographers. At the institutional level, commitment to standardization and quality improvement was found to have a cascading positive impact. Simple measures such as routine protocol checklists, centralized review systems, and regular audit feedback loops were associated with marked improvements in reporting consistency. Additionally, fostering a team-based approach involving sonographers, cardiologists, and IT support can further streamline the workflow and reduce cognitive load on individual practitioners [14].

From a policy perspective, the findings suggest that national and international guidelines should more explicitly incorporate recommendations on 3D LVEF reporting, including criteria for when to use 3D over 2D. Reimbursement structures may also need to evolve to incentivize the time and resources required for comprehensive 3D imaging. Furthermore, ongoing research should focus on improving automated tools for LVEF analysis to minimize inter-operator variability and enhance scalability. Notably, a recent advancement in aircraft engine failure prediction has demonstrated the effectiveness of a temporal deep learning model that integrates residual architecture with self-attention mechanisms. This cross-disciplinary innovation offers valuable insights and inspiration for enhancing the accuracy and robustness of automated LVEF analysis[13]. Lastly, the integration of artificial intelligence in echocardiographic interpretation may serve as a transformative solution to overcome current limitations. By leveraging deep learning algorithms trained on high-quality 3D datasets, future systems could automatically segment the left ventricle and generate reproducible LVEF metrics with minimal human input. Until then, understanding and addressing the current clinical determinants of LVEF reporting remains essential for improving cardiovascular care.

V. Conclusion

In summary, this study provides an in-depth analysis of the real-world clinical determinants influencing the reporting of left ventricular ejection fraction via 3D echocardiography. Despite the superior accuracy and reproducibility of 3D imaging, its adoption in routine practice is affected by patient-specific factors, operator expertise, and institutional support structures. Addressing these determinants through targeted training, standardized protocols, and improved technology access can significantly enhance the consistency and clinical utility of 3D LVEF reporting. Ultimately, optimizing the integration of 3D echocardiography into daily workflows holds the promise of advancing cardiac diagnostics and improving patient outcomes across diverse healthcare settings.

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