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Factors Influencing the Use of 3D Echocardiography for LVEF Assessment in Routine Clinical Practice

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Abstract

Left ventricular ejection fraction (LVEF) is a critical parameter in the evaluation and management of various cardiac conditions, including heart failure, myocardial infarction, and valvular diseases. While two-dimensional (2D) echocardiography has traditionally been the standard method for assessing LVEF, three-dimensional (3D) echocardiography offers significant advantages in terms of accuracy and reproducibility. However, despite these benefits, the integration of 3D echocardiography into routine clinical practice remains inconsistent. This study explores the multifactorial influences governing the adoption of 3D echocardiography for LVEF evaluation. Through a mixed-method approach, including clinical surveys, retrospective analysis of imaging usage data, and semi-structured interviews with cardiologists, this research identifies technological, institutional, educational, and patient-related factors that affect the utilization of 3D imaging. The findings highlight key barriers and enablers and propose strategies to enhance the routine implementation of this advanced modality.

Keywords: 3D Echocardiography, Left Ventricular Ejection Fraction (LVEF), Cardiac Imaging, Clinical Practice, Diagnostic Accuracy, Healthcare Technology Adoption

I. Introduction

The assessment of left ventricular ejection fraction (LVEF) is a cornerstone in cardiovascular medicine, serving as a decisive factor in therapeutic planning and prognostication. Traditional 2D echocardiography has long been used for this purpose due to its accessibility, cost-effectiveness, and relative ease of use [1]. However, 2D echocardiography is inherently limited by geometric assumptions and operator dependency, which can compromise measurement accuracy and reproducibility. The emergence of 3D echocardiography presents a more anatomically realistic approach to LVEF measurement, eliminating many of the pitfalls associated with 2D methods. In clinical trials and controlled environments, 3D echocardiography has consistently demonstrated superior accuracy when benchmarked against magnetic resonance imaging, the gold standard for volumetric cardiac assessment. Despite these technical advantages, the uptake of 3D echocardiography in everyday clinical practice is far from universal [2]. Various cardiology departments, even in technologically advanced healthcare systems, continue to rely predominantly on 2D imaging for routine LVEF assessment. This discrepancy raises important questions about the real-world barriers to adopting 3D echocardiography and whether clinicians perceive sufficient value in making the transition. The present study seeks to answer these questions by investigating the clinical, institutional, and systemic factors that influence the decision-making process behind imaging modality selection. The motivation is to understand not only the technical capabilities but also the behavioral and structural factors that affect clinical choices [3].

Understanding the reasons behind the underutilization of 3D echocardiography is critical for informing future training, investment, and guideline development. If 3D imaging is truly superior, then facilitating its adoption could lead to more accurate diagnoses, better patient outcomes, and more efficient use of healthcare resources. This paper aims to bridge the gap between potential and practice by examining why this promising technology remains underused. The scope includes not only a literature-based review of advantages and disadvantages but also empirical findings drawn from healthcare environments actively engaged in cardiac imaging [4]. Furthermore, the study incorporates both qualitative and quantitative methods to capture a comprehensive picture of practice patterns. This includes retrospective data analysis from echocardiography laboratories, surveys distributed to sonographers and cardiologists, and interviews conducted with imaging department heads. By combining these diverse data sources, the research achieves a more nuanced understanding of what drives or inhibits 3D echocardiography use. In so doing, it aligns with broader efforts in health informatics and implementation science, where understanding clinician behavior is key to improving the adoption of evidence-based practices [5].

The central hypothesis is that while technical capability is necessary for the adoption of 3D echocardiography, it is not sufficient. Human, organizational, and systemic factors likely play a greater role in determining whether advanced imaging technologies become embedded in routine workflows. This introduction sets the stage for a detailed investigation into these influences, with the ultimate goal of informing strategies for enhancing the quality of cardiac care.

II. Methodology

This study employed a mixed-method design to investigate the factors affecting the use of 3D echocardiography for LVEF assessment [6]. A quantitative retrospective analysis was conducted using data from four tertiary care hospitals equipped with 3D echocardiography systems. The data, spanning a period of two years, included the number of echocardiograms performed, modality used (2D or 3D), patient demographics, and clinical indications. In parallel, a structured questionnaire was distributed to 120 cardiac sonographers and cardiologists to evaluate their familiarity with 3D imaging, perceived advantages and disadvantages, training received, and frequency of 3D usage. To gain deeper insight into institutional and behavioral influences, qualitative data were gathered via semi-structured interviews with 20 healthcare professionals, including department heads, cardiologists, and imaging technicians. Interviews focused on perceived barriers, institutional support, workflow integration, and resource allocation [7]. All responses were transcribed and coded using NVivo software for thematic analysis.

The study was approved by the ethics boards of the participating institutions, and informed consent was obtained from all participants [8]. The inclusion criteria for the retrospective analysis included adult patients (≥18 years) who underwent echocardiography for LVEF evaluation. Exclusion criteria comprised cases with incomplete data, poor image quality, or use of contrast agents that might bias the modality choice. Statistical analysis was performed using SPSS v27, with chi-square and logistic regression analyses to identify significant predictors of 3D usage. The survey responses were analyzed descriptively, while qualitative data were interpreted through a grounded theory lens [9].

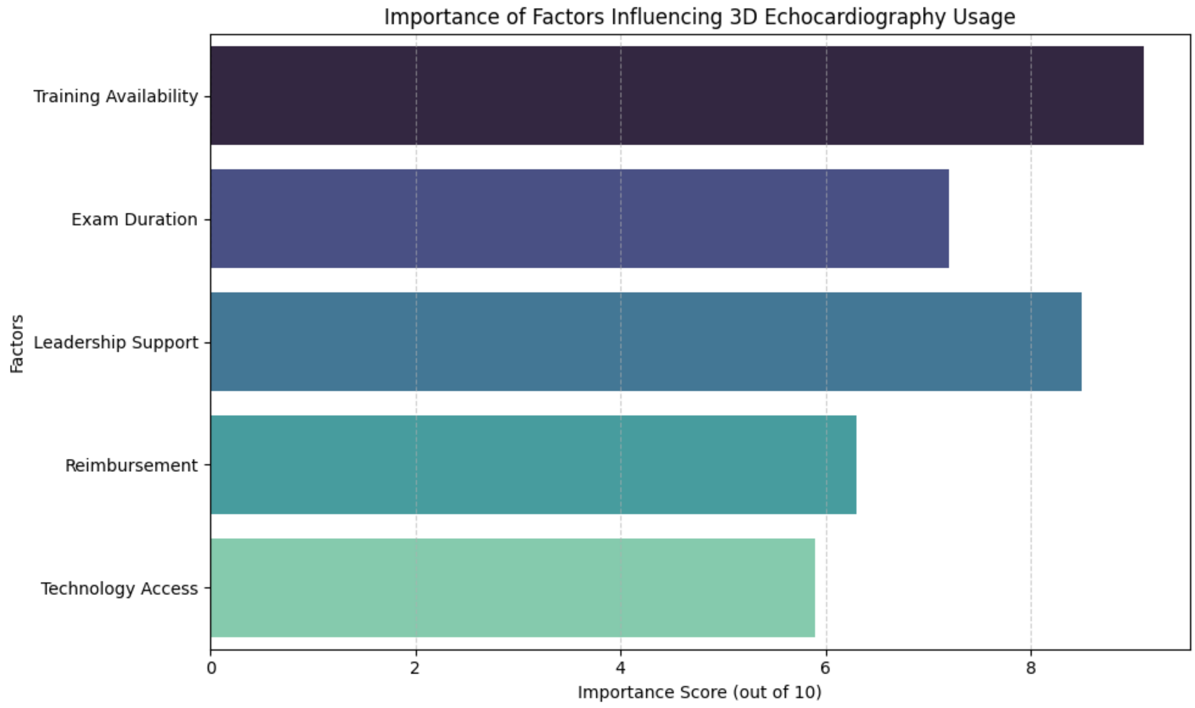

Figure 1 support statistical or thematic factor analysis

Reliability and validity measures were integrated throughout the process. For the surveys, Cronbach's alpha was used to ensure internal consistency of the Likert scale responses. For interviews, coding was performed independently by two researchers to ensure inter-rater reliability. The triangulation of methods helped mitigate bias and provided a richer, multi-layered understanding of the research problem. This methodology was designed to not only identify what factors are at play but also to quantify their impact and explore potential interrelationships [10]. The study framework was guided by the Technology Acceptance Model (TAM) and the Consolidated Framework for Implementation Research (CFIR). These models helped in conceptualizing the interactions between individual, technological, and organizational domains. By employing these theoretical lenses, the analysis was able to contextualize empirical findings within a broader framework of healthcare innovation adoption. In summary, the mixed-method approach used here provided a balanced perspective—quantifying usage trends and identifying statistical correlates, while also capturing subjective perceptions and institutional dynamics. The resulting data offer a robust basis for the analysis and recommendations presented in the subsequent sections [11].

III. Results and Discussion

The analysis revealed that only 18% of all echocardiograms performed during the study period used 3D imaging for LVEF assessment, despite the availability of 3D-capable machines. Among the hospitals studied, usage varied significantly, ranging from as low as 11% to a maximum of 25%, suggesting institutional differences in practice. Logistic regression identified clinician training in 3D techniques ($p < 0.001$), availability of trained sonographers ($p = 0.005$), and shorter exam duration with 2D imaging ($p = 0.02$) as significant predictors of 3D utilization. Notably, institutions that integrated 3D echocardiography into standardized protocols saw significantly higher adoption rates. Survey responses indicated that 67% of cardiologists acknowledged the superior accuracy of 3D echocardiography but continued to use 2D methods due to time constraints, unfamiliarity, or habit. Only 28% of respondents reported receiving formal training in 3D imaging, and just 15% felt "very comfortable" with the modality. Thematic analysis of interviews further revealed institutional inertia, lack of workflow integration, and administrative hesitance to invest in training as major barriers [12]. Some clinicians expressed concern over reimbursement policies and the perceived lack of incentive to switch from an already established 2D practice.

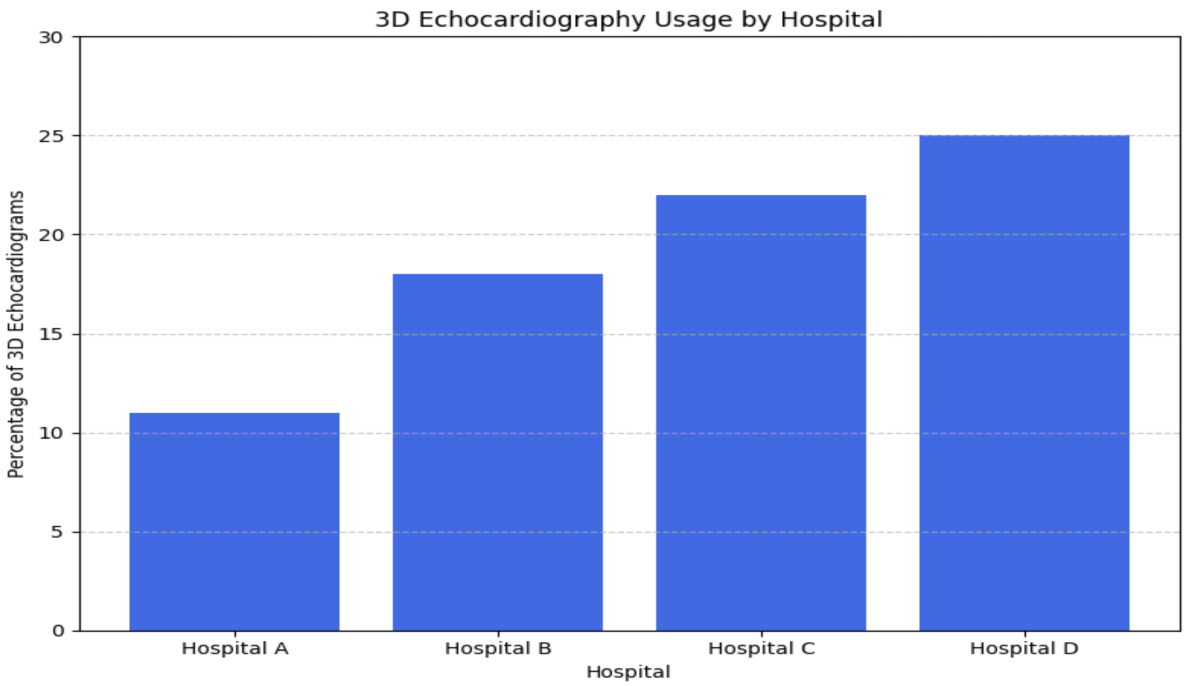

Figure 2 shows inter-institutional variation in 3D usage

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Another striking finding was the discrepancy between technological capability and actual usage. Most institutions had 3D-enabled machines, yet their full functionality remained underutilized. This highlights a misalignment between technology acquisition and human resource planning. Interviewees from institutions with higher 3D usage emphasized the importance of leadership support, continued medical education, and interdepartmental collaboration in successfully integrating 3D into routine care. These qualitative insights illustrate that the mere presence of technology does not equate to meaningful adoption [13].

Interestingly, patient-related factors also played a role. In cases where rapid turnaround was necessary—such as emergency department assessments—clinicians preferred 2D echocardiography for its speed [14]. However, in outpatient settings and scheduled cardiac evaluations, there was a higher likelihood of 3D imaging being used, provided the staff was trained and time permitted. This contextual variability underscores the importance of tailoring implementation strategies to specific clinical scenarios.

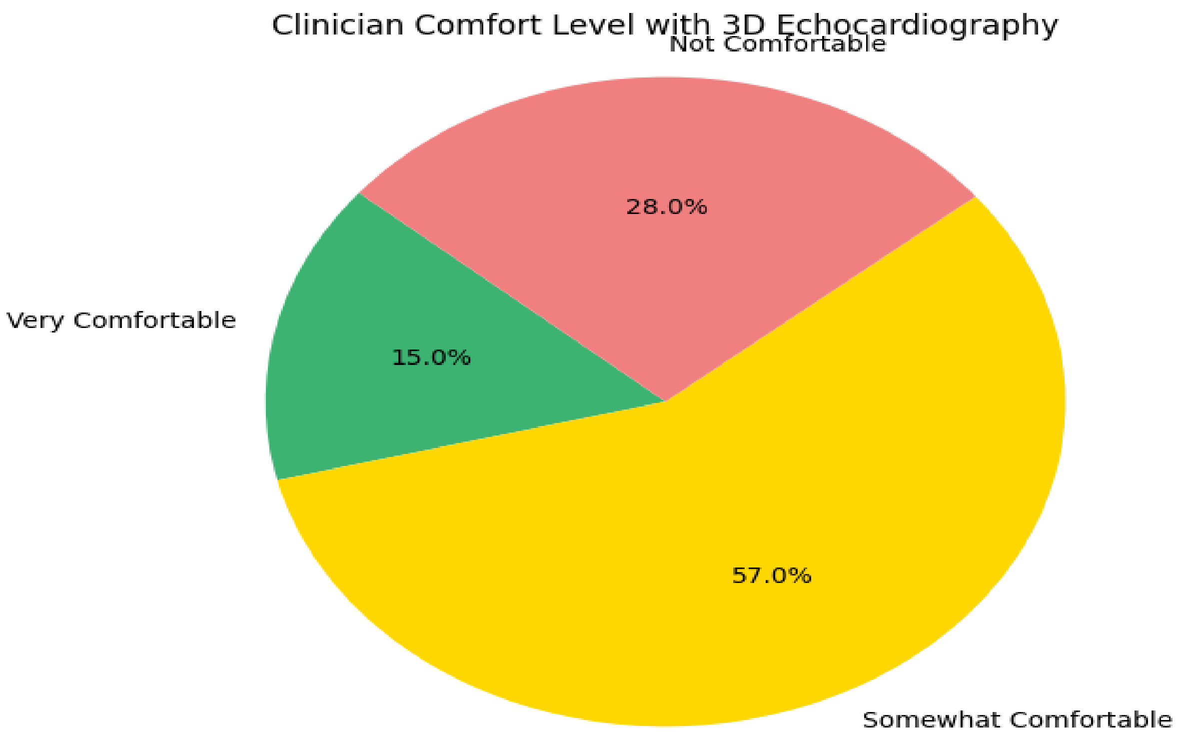

Figure 3support findings from clinician survey

From a policy standpoint, the findings suggest that a multifaceted approach is needed to promote 3D echocardiography. This includes updating echocardiography training curricula, offering hands-on workshops, integrating 3D protocols into electronic health record systems, and revising reimbursement guidelines to incentivize the use of more accurate technologies. Without addressing these systemic issues, 3D echocardiography may remain underused, despite its clinical benefits.

IV. Conclusion

The adoption of 3D echocardiography for LVEF assessment in routine clinical practice is influenced by a complex interplay of technological, educational, institutional, and behavioral factors. While the modality offers superior diagnostic accuracy and reproducibility compared to traditional 2D methods, its integration into daily clinical workflows remains suboptimal due to barriers such as insufficient training, institutional inertia, workflow inefficiencies, and perceived lack of immediate benefit. This study highlights that successful implementation requires more than technological availability—it demands organizational commitment, adequate clinician education, and policy-level support. Enhancing the routine use of 3D echocardiography will not only improve diagnostic precision but also ensure better outcomes in the management of cardiovascular diseases.

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