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EDITORIAL COMMENT

Artificial Intelligence in Echocardiographic Evaluation of Mitral Regurgitation

Envisioning the Future

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"The true sign of intelligence is not knowledge but imagination."

—Albert Einstein[1]

The journey of artificial intelligence (AI) in cardiovascular medicine began with pioneering efforts such as the development of self-learning neural networks for electrocardiography, using AI to locate atrioventricular accessory pathways in Wolff-Parkinson-White syndrome by analyzing delta wave polarities.[2] This laid the foundation for AI's integration into cardiovascular diagnostics. As AI techniques developed and computing power continued to improve, applications of AI in cardiology expanded to other fields, including cardiac imaging.

Echocardiography stands as the cornerstone of cardiovascular imaging and is integral to clinical care across the spectrum of valvular heart disease. Echocardiography is also witnessing a paradigm shift with AI integration, enhancing how cardiac imaging is performed, interpreted, and applied in patient care. AI in echocardiography focuses on automating measurements and refining data interpretation to address challenges, such as interoperator variability and the subjectivity of image assessment.[3] For example, AI algorithms have enhanced image acquisition, the quantification of left and right ventricular volumes, systolic and diastolic function, and global longitudinal strain, boosting diagnostic accuracy and enabling faster and reproducible assessments.[4]

Evaluation of mitral regurgitation (MR) by echocardiography presents inherent challenges due to the dynamic nature of the mitral valve apparatus, the complex regurgitant flow patterns affected by different factors, and the variability in quantitative parameters under different hemodynamic conditions. Traditional assessment relies on the echocardiographer's skill and expertise, and can result in subjective interpretation susceptible to diagnostic errors. AI helps standardize these evaluations, reducing dependency on individual operator skill and potentially decreasing the variability in MR assessment.[5] Recent studies have shown promising results in employing machine learning (ML) to refine risk assessment and treatment strategies for MR. In a study of 400 patients with primary MR, AI identified high-severity phenotypes, leading to better surgical outcomes, demonstrated by improved survival rates in French and Canadian cohorts ($P = 0.047$ and $P = 0.020$); this method outperformed traditional risk evaluations, evidenced by statistical improvements (Harrell C statistic; $P = 0.480$, net reclassification; $P = 0.002$).[6] The EuroSMR (European Registry of Transcatheter Repair for Secondary Mitral Regurgitation) study took this further, creating an AI-derived risk score from 18 parameters and data on 4,172 patients, predicting 1-year postoperative survival more accurately than existing models (AUC = 0.789); this score pinpointed a subset of patients with a 70% risk of 1-year mortality, thus refining patient selection for transcatheter edge-to-edge repair procedures.[7] In another cohort of 429 patients with mitral valve prolapse, ML identified 4 phenotypes related to cardiac remodeling, myocardial fibrosis, and cardiovascular event risk: 2 phenotypes with significant left ventricular (LV) and left atrial remodeling, and severe MR indicated higher

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fibrosis and cardiovascular event rate.[8] This algorithm using MR severity, LV systolic strain, and indexed left atrial volume improved diagnostic precision, suggesting that ML can refine mitral valve prolapse risk assessment and management.[8]

In this issue of *JACC Cardiovasc Imaging*, Sadeghpour et al[9] present a groundbreaking study that utilizes an automated, ML-based, multiparametric approach to grade MR severity. This method marks a significant advancement by incorporating a comprehensive array of echocardiographic parameters to achieve remarkable diagnostic accuracy. Phase 2 of the study employed a substantial data set from 438 patients, drawing from multicenter clinical studies, to validate the AI model against traditional assessment methods, achieving an impressive 80% accuracy for classifying the full spectrum of MR from none/trace to severe, and further refining this to 97% accuracy for distinguishing between significant and nonsignificant MR.[9] Their multiparametric model integrated 16 American Society of Echocardiography-recommended echocardiographic parameters,[10] categorized into MR-specific, chamber size, and hemodynamic parameters.[9] Notable among these were vena contracta measurements from multiple views, jet area ratio, continuous wave Doppler density, LV end-diastolic volume, LV outflow tract stroke volume, and pulmonary artery systolic pressure.[9] This comprehensive approach not only enhanced the diagnostic precision, but also demonstrated strong correlation with important clinical outcomes, such as 1-year mortality and heart failure hospitalizations.[9]

The strength of Sadeghpour et al's work[9] lies in its utilization of a multiparametric analysis, which aligns well with current trends in cardiovascular imaging that seek to leverage the breadth of data available from advanced imaging techniques. However, it is important to acknowledge the context of current American Society of Echocardiography guidelines for valvular regurgitation,[10] which emphasize the importance of multiple quantitative measurements to accurately assess MR severity. Although the study incorporates an impressive array of parameters, some key quantitative metrics of MR evaluation, such as effective regurgitant orifice area and regurgitant volume, were not included in their model. This may limit the model's applicability in clinical settings where comprehensive quantification incorporating these parameters is crucial for decision-making. Moreover, the study does not provide detailed data on the underlying etiologies of MR, categorizing MR jets only as central or eccentric. This limitation could affect the generalizability of the findings, as the pathophysiology of MR may vary significantly, which in turn could influence the effectiveness of the model across different patient populations.

Despite the potential transformative impact of AI on cardiovascular imaging, it is essential to acknowledge its limitations and challenges. Training deep learning models requires extensive data sets, which are often difficult to compile for rarer cardiac conditions without multicenter collaboration. Additionally, the computational resources needed are substantial, although advancements in high-performance computing may help mitigate this issue. The effectiveness of AI applications heavily depends on the quality of the data: poor quality data can render even the most advanced algorithms ineffective, a concept encapsulated by the phrase "garbage in, garbage out." Moreover, although results from studies like Sadeghpour et al[9] are promising, they require broader validation to ensure universal applicability. The integration of AI into routine echocardiographic practice faces hurdles, including a lack of randomized control trials and comprehensive validation studies, which limits widespread adoption. Future research should aim to demonstrate AI's diagnostic and prognostic utility across multicenter studies with diverse patient populations to ensure its generalizability and reliability. Ethically, the adoption of AI also raises questions about the future role of cardiologists in diagnostic imaging. It is crucial that cardiologists continue to lead clinical decision-making, utilizing AI as a supportive tool rather than a replacement for human clinical acumen. Adhering to rigorous standards for algorithm transparency and accuracy is vital, as outlined by initiatives such as the CONSORT-AI (Consolidated Standards of Reporting Trials-Artificial Intelligence).[11] AI's integration into echocardiography is not merely an enhancement of existing practices, but a transformation that promises more precise diagnostics and personalized care. Our commitment must be to leverage AI to its fullest potential, improving outcomes for patients while maintaining the essential human touch that defines quality care.

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