SUBMITTED 6 MAY 24
REVISION REQ. 10 JUL 24; REVISION RECD. 28 AUG 24
ACCEPTED 17 SEP 24
ONLINE-FIRST: OCTOBER 2024
DOI: https://doi.org/10.18295/squmj.10.2024.061

Unveiling the Marvels of 3D Echo

Illuminating prosthetic mitral valve dehiscence through 3D transillumination

Sheeraz Ahmad,[1] *Muhammad A. Sadiq,[2] Jai Parkash,[1] Ahmad Kamal,[1] Abdullah Al Ismaili,[2] Fahad Al Kindi[1]

[1]Department of Medicine, Sultan Qaboos University Hospital, University Medical City, Muscat, Oman; [2]Department of Medicine, College of Medicine & Health Sciences, Sultan Qaboos University, Muscat, Oman

**Corresponding Author's e-mail: mathar@squ.edu.om*

A 59-year-old man was admitted to a tertiary care center in Muscat, Oman, for mitral valve repair (with mitral ring annuloplasty) due to severe mitral regurgitation following coronary bypass surgery in 2022. His post-operative course was initially complicated by severe right ventricular failure and pulmonary hypertension, leading to cardiogenic shock. This necessitated Veno-Arterial Extracorporeal Membrane Oxygenation (VA ECMO) support, which was required for 2 days. Following the discontinuation of VA ECMO, the patient developed septic shock due to ventilator-associated pneumonia. Over the next few weeks, the patient gradually made a good recovery and was discharged after 1 month. However, shortly after discharge, he began to experience daily fevers, chills, and malaise, which led to his re-hospitalization. He was empirically treated with antibiotics for possible pneumonia or infective endocarditis, following multiple sets of negative blood and urine cultures. During this admission his transthoracic echocardiography (TTE) showed residual moderate mitral regurgitation and questionable mobile mass at posterior leaflet of MV. A more detailed assessment with transesophageal echocardiography (TEE) showed severe paravalvular leak causing severe MR, there was no

vegetation seen. The patient left the hospital against medical advice and was later readmitted due to persistent fevers and malaise. Blood cultures, taken in four sets, all tested positive for Candida albicans (susceptible to fluconazole). Transthoracic echocardiography revealed a vegetation (2.8 cm x 0.5 cm) on the mitral valve/ring, associated with moderate to severe mitral regurgitation and a paravalvular leak. The patient was diagnosed with prosthetic valve endocarditis and commenced on Anidulafungin to treat the Candida albicans infection. His course was further complicated by neurological complications, including a subarachnoid hemorrhage and intraparenchymal hemorrhage in the right posterior temporal and occipital lobes.

A more detailed follow-up assessment utilizing two-dimensional (2D) TEE revealed complete resolution of vegetation. In the four-chamber (4C) view, combined with color Doppler imaging, two regurgitant jets through the mitral valve were seen (Figure 1). The 2D TEE was unable to differentiate between the jet associated with valve dehiscence and the jet emanating directly from the valve itself. To acquire a clearer image, we first obtained a 2D TTE view of the heart structure, and subsequently captured a comprehensive 3D dataset using a multi-beat acquisition. Using 3D cropping tools, we optimized the visualization of the valve until its borders and morphology were well defined. The use of three-dimensional (3D) TEE then confirmed severe mitral regurgitation (MR) and identified a partially detached ring (Figure 2, Video 1).

For enhanced detail, a virtual light source was introduced into the 3D dataset, and its position was adjusted to highlight the pathology of interest, particularly the areas of dehiscence and MR jets. Lastly, the degree of tissue transparency was fine-tuned to achieve maximal border definition and to optimize the visualization of anatomy and pathology. Tissue imaging (TI) was instrumental in providing a clearer depiction of the separation points on the prosthetic ring and displaying two distinct MR jets: one emanating through the prosthetic valve itself and another through the area of dehiscence [Figure 3, Video 2]. The patient has made a good neurological recovery after eight weeks of treatment with Anidulafungin and is currently asymptomatic. He is now being considered for high-risk redo mitral valve surgery. Patients consent was obtained for publication purpose.

Comment

Traditional imaging techniques, such as standard 2D echocardiography, often struggle with depth perception and the clear visualization of complex cardiac structures, particularly in cases involving prosthetic valves. These limitations can hinder accurate diagnosis and assessment, especially in complex cases like prosthetic valve dehiscence.

The integration of Transillumination (TI) into 3D echocardiography introduces a cutting-edge tool designed to enhance specific image features that conventional 3D imaging struggles to optimally display.[1] TI incorporates a movable virtual light source within the dataset, allowing for strategic illumination of critical areas. This enhances image accuracy, improves depth perception, and provides a more detailed visualization, which was particularly beneficial in the presented case.[1,2] In this case, the regurgitant jets observed through TI were not only more clearly delineated but also provided essential insights into the severity and mechanism of the mitral regurgitation. The jets through the mitral valve, visualized in vivid detail, indicated the presence of both valve dehiscence and a failure at the coaptation site. This critical information guided the therapeutic strategy, underscoring the need for a potential high-risk redo surgery, aimed at addressing the identified mechanical failures.

While cardiologists possess various alternative imaging techniques to explore cardiovascular structure and function, the realm of 3D echo stands out amidst rapid technological advancements and enhanced data analysis. This area holds significant promise and is poised to gain growing clinical relevance. A systematic literature review and meta-analysis comparing different echocardiographic methods to CMR, which serves as the standard reference for assessing mitral valve regurgitation volume (MVR), shows that while CMR provides detailed tissue characterization and accurate volume measurements, it may not always be the most accessible or timely option in clinical settings.[4] 3D echocardiographic methods, particularly the 3D proximal isovelocity surface area (PISA) method, show high correlation and better agreement with CMR, with a correlation coefficient (R) of 0.84 and less underestimation of MVR severity.[4] This highlights the effectiveness of 3D echocardiography in quantifying MVR, which is further enhanced by TI's capability to improve visualization and depth perception in real-time assessments. Therefore, while CMR remains invaluable for its detailed and precise evaluations in

complex cardiac conditions, the use of 3D echo with TI in clinical settings offers distinct advantages due to its immediacy and the dynamic nature of the imaging it provides. This ability to deliver rapid and accurate assessments at the bedside is particularly critical in acute settings or when immediate surgical decisions are required.

Three DE application is deemed essential for conducting meticulous imaging during medical procedures.[5] Notably, transillumination proves its ultimate contribution to heightened diagnostic accuracy. In the presented panel, we are showcasing this case where the utilization of 3D echocardiogram with TI added substantial diagnostic value in assessing prosthetic valve dehiscence.

The allure of 3D echo as an imaging modality for planning cardiac interventions and evaluating procedures intraoperatively has surged due to the availability of high-quality 3D images and the portability of real-time 3D echocardiogram machines, eliminating the need for offline computation.[6] This capability eliminates the need for offline computation, facilitating immediate visualization and decision-making. For instance, real-time 3D echo is indispensable during emergency cardiac interventions where swift assessments are crucial for immediate surgical decisions. Additionally, real-time 3D echocardiography is crucial in catheter-based structural interventions, such as mitral and tricuspid clip procedures. It allows clinicians to assess the dynamic interactions between the catheter and cardiac structures, enabling precise placement of clips and immediate evaluation of their functional impact during the procedure.

This case highlights the importance of 3D echo in the evaluation of complex structural heart disease. Looking ahead, the integration of 3D echocardiography with Transillumination (TI) into clinical practice for the assessment of complex valve diseases offers promising enhancements in the visualization of cardiac structures. Future applications could include its extended use during minimally invasive procedures where precise imaging is crucial for successful outcomes. Further research might explore integrating TI technology with other imaging modalities, such as cardiac MRI, to enhance procedural guidance and post-operative assessments, broadening the implications of this technology in modern medicine.

Authors' Contribution

SA performed the TEE and drafted the manuscript with AK. MAS revised the manuscript to address the reviewer's comments. JP provided the images. AAI managed the case. FAK checked the final version of the manuscript. All authors approved the final version of the manuscript.

References

1. Silva MR, Azevedo AI, Sampaio F, Ribeiro J, Fontes-Carvalho R. "Lightning The Heart" with 3D Echo: Transillumination of a Prosthetic Mitral Valve Dehiscence. Arq Bras Cardiol 2022;119(2):358-60. https://doi: 10.36660/abc.20210655.
2. Faza NN, Little SH. Role of 3-dimensional transesophageal echocardiography in guiding transcatheter mitral valve replacement. Echocardiography 2020 Jun;37(6):945-53. https://doi.org/10.1111/echo.14712.
3. Sköldborg V, Madsen PL, Dalsgaard M, Abdulla J. Quantification of mitral valve regurgitation by 2D and 3D echocardiography compared with cardiac magnetic resonance a systematic review and meta-analysis. Int J Cardiovasc Imaging 2020;36(2):279-89. https://doi: 10.1007/s10554-019-01713-7.
4. Karagodin I, Shah AP, Lang RM. Guided by the Light—Transillumination of a Paravalvular Leak. JAMA Cardiol 2020;5(8):e203260. https://doi.org/10.1001/jamacardio.2020.3260.
5. Karagodin I, Addetia K, Singh A, Dow A, Rivera L, DeCara JM, Soulat-Dufour L, Yamat M, Kruse E, Shah AP, Mor-Avi V, Lang RM. Improved Delineation of Cardiac Pathology Using a Novel Three-Dimensional Echocardiographic Tissue Transparency Tool. J Am Soc Echocardiogr 2020;33(11):1316-23. https://doi.org/10.1016/j.echo.2020.08.005.
6. Volpato V, Mantegazza V, Tamborini G, Muratori M, Gripari P, Andreini D, Fusini L, Ghulam Alù S, Cefalù C, Italiano G, Pepi M. Diagnostic Accuracy of Transillumination in Mitral Valve Prolapse: Side-by-Side Comparison of Standard Transthoracic Three-Dimensional Echocardiography against Surgical Findings. J Am Soc Echocardiogr 2021;34(1):98-100. https://doi: 10.1016/j.echo.2020.08.017.

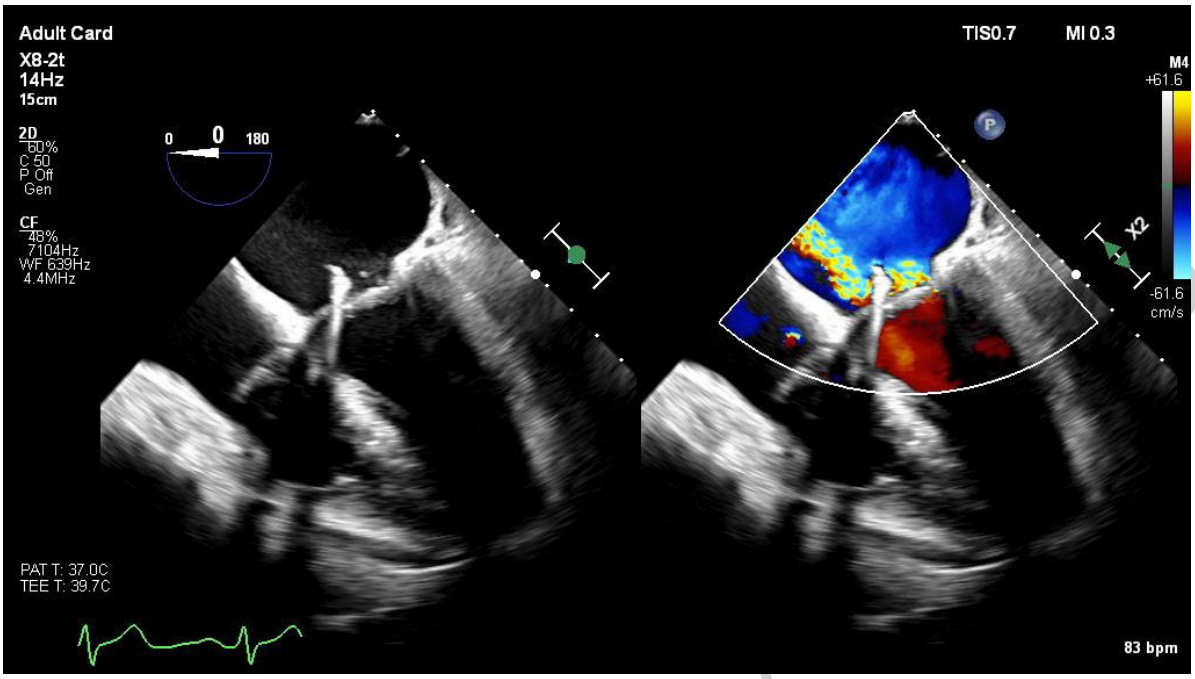

Figure 1: A two-dimensional Transesophageal Echocardiogram (TEE) in the 4-chamber (4C) view with color Doppler displays two regurgitant jets through the mitral valve; however, it cannot differentiate between the jet originating from the valve dehiscence and the jet passing through the valve itself.

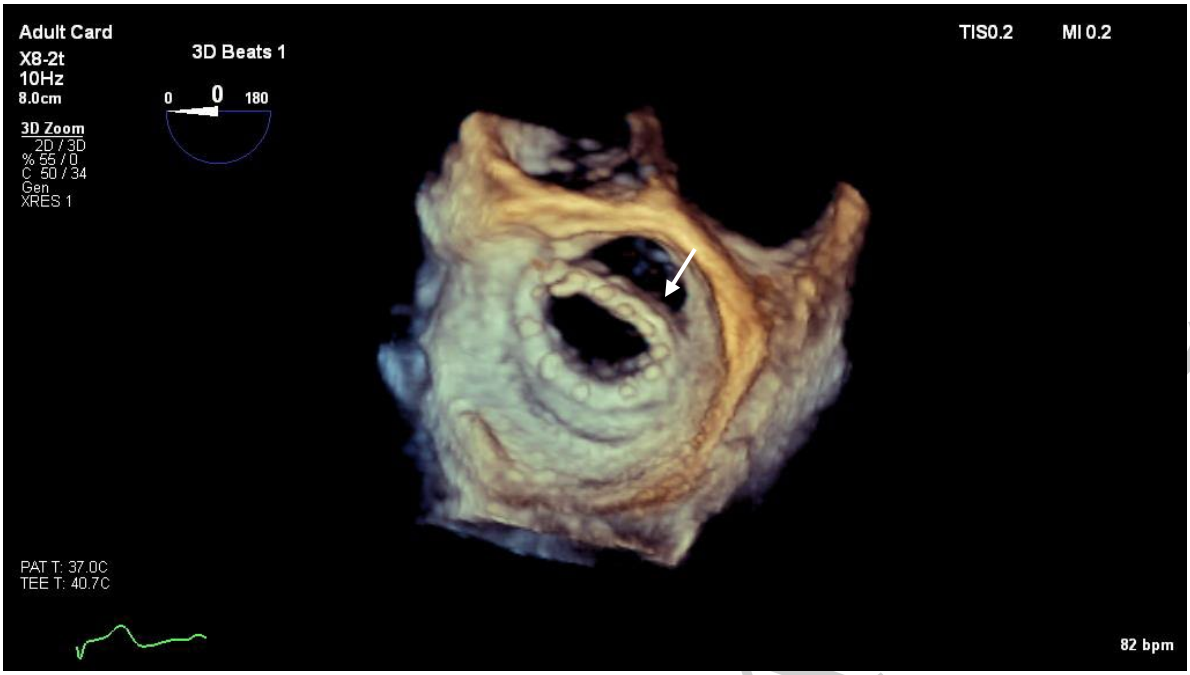

Figure 2: A three-dimensional echo image shows dehiscence of a bioprothetic mitral valve(arrow), visualized from the LA surgical view.

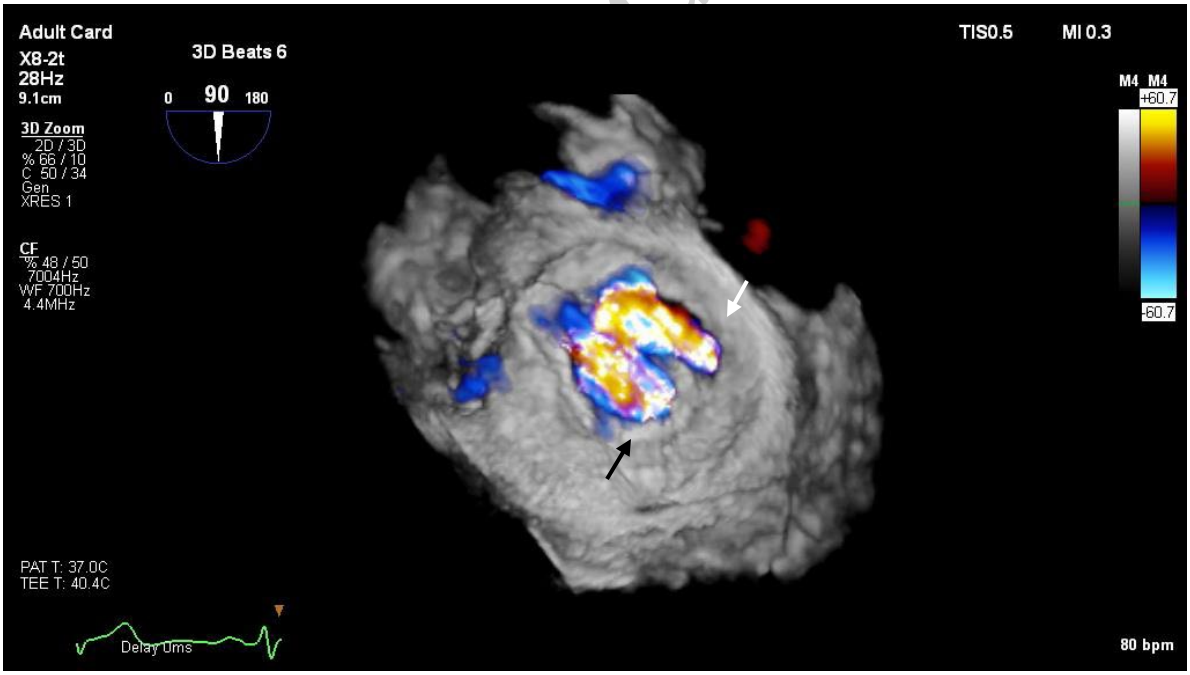

Figure 3: Three-dimensional echocardiogram displaying two distinct MR jets: one emanating through the prosthetic valve itself (black arrow) and another through the area of dehiscence (white arrow).

Supplementary videoclip 1: A three-dimensional echo image shows dehiscence of a mitral prosthesis, viewed from the left atrium and left atrial appendage, at the 9 o'clock position

Supplementary videoclip 2: Three-dimensional echocardiogram displaying two distinct MR jets: one emanating through the prosthetic valve itself and another through the area of dehiscence