Review Article

My Approach to 3D Echocardiography in Mitral Valve Insufficiency: How and When

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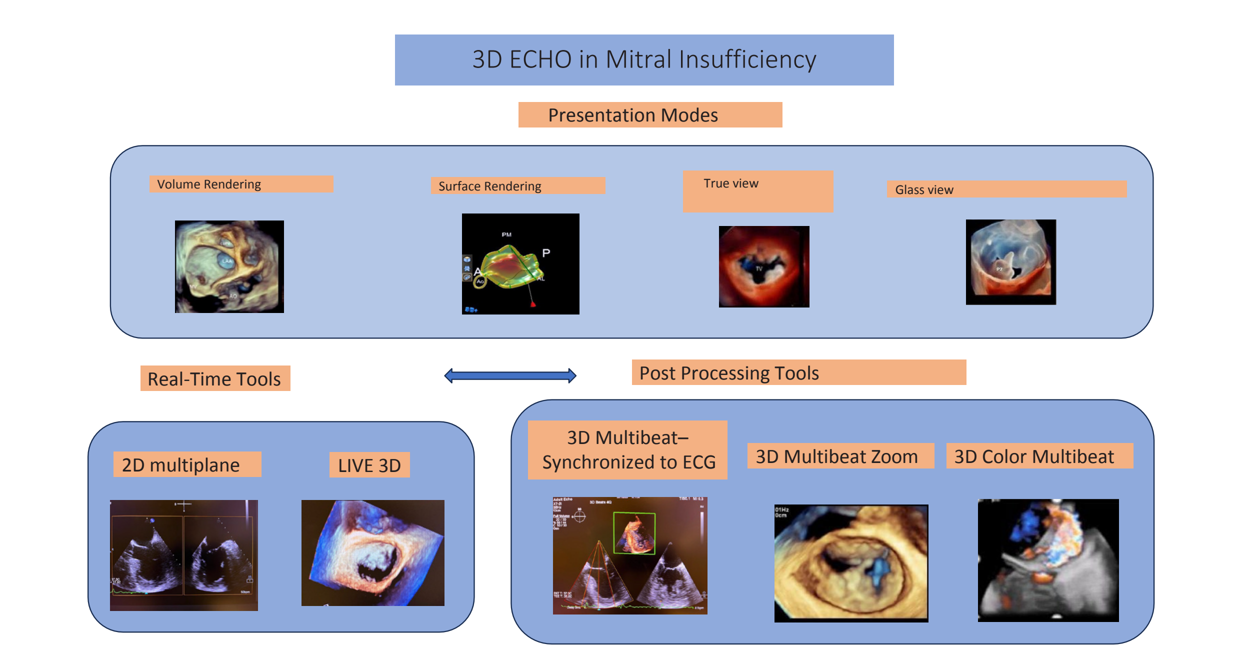
Central Illustration: **My Approach to 3D Echocardiography in Mitral Valve Insufficiency: How and When**



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Abstract

3D Echocardiogram is an indispensable tool in all stages of mitral valve disease, from its diagnosis to the moment of treatment, playing a fundamental role mainly in the decision for surgical plasty or percutaneous correction. In this article, we sought to present very important basic concepts in the use of the technique, from obtaining a 2D image, through the main tools for obtaining 3D images, to new solutions brought by manufacturers for presenting images and for post-processing software. This knowledge is fundamental and contributes to the demystification of 3D Echo, often labeled as difficult to perform and still little incorporated into our clinical practice.

Keywords

Three-Dimensional Echocardiography; Mitral Valve Insufficiency Diagnosis

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Introduction

Mitral regurgitation is the most common valvulopathy in developed countries, accounting for 2 to 3% of the population.[1] When it comes to correcting mitral insufficiency, whether surgical or percutaneous, 3D Echocardiography is the method of choice, whether to confirm the degree of reflux, or to confirm the possibility of preferential plasty treatment or, in cases where the procedure Percutaneous surgery is recommended to assess the feasibility of the procedure and assist the team during surgery.

This occurs because the 3D transesophageal method allows a perpendicular angulation between the emitted pyramidal beam and the mitral leaflets, an ideal proximity, allowing the use of high frequency, better temporal and spatial resolution, in addition to allowing visualization of the entire valve apparatus of various angles and perspectives.

However, 3D echocardiography is no magic trick. Simply pressing a button to capture an image is not enough. The secret of 3D imaging is in an excellent capture of the two-dimensional (2D) image. There is no quality 3D exam without a good 2D echocardiographic window. Furthermore, adjustments made on a case-by-case basis are very important for obtaining excellent images and 3D data sets that can be properly manipulated offline, such as computed tomography (CT) and magnetic resonance imaging (MRI) images.

My approach to

Knowing the basic principles of 3D that influence image acquisition is essential, especially in valvular heart diseases whose regurgitant flow velocities are quite high.

Fortunately, electronic advances and miniaturization have allowed modern transesophageal probes to have approximately 2,500 piezoelectric crystals that can be activated simultaneously for imaging. This significant number of crystals allows the transducer to emit a wide beam and receive multiple smaller beams that will form the received volumes.[2] Obviously, the greater the number of beams received, the greater the chance of deterioration in image quality (signal to noise), or of a drop in temporal resolution with the appearance of stitches.

Therefore, the 2D image must always be optimized primarily. Poor 2D images result in even worse 3D images. I usually set an intermediate gain, up to 60, with intermediate compression.

As a rule, we try to optimize the 2D image and then activate the 2D multiplane mode, where the system receives the command to activate two or three lines of orthogonal crystals, which despite not presenting a 3D image, generate the simultaneous visualization of two orthogonal planes. Initially, we use the image at 0 degrees, positioning the rotation line, under which we will make the other orthogonal cuts at the level of the anterior mitral leaflet (Figure 1) (Video 1). One can then activate color Doppler, which can give us a perspective on the extent of a possible regurgitant jet.

The wide and rapid mobility of the mitral valve leaflets, often associated with the presence of structures with even greater mobility, such as vegetation, require the use of a 3D technique of high spatial and temporal resolution.

Initially, we activate, through a dedicated button (normally identified on the display as a 3D key), the analysis modality in real time, beat by beat — Real Time Single Beat or Live 3D —, capturing a volume that encompasses the entire mitral apparatus, the atrial appendage and the aortic valve, normally from a 2D section of 120°.[3] Once 3D is activated, the "in face" view is obtained, similar to the surgeon's view, with the aortic valve at 12 o'clock on the display, the appendix

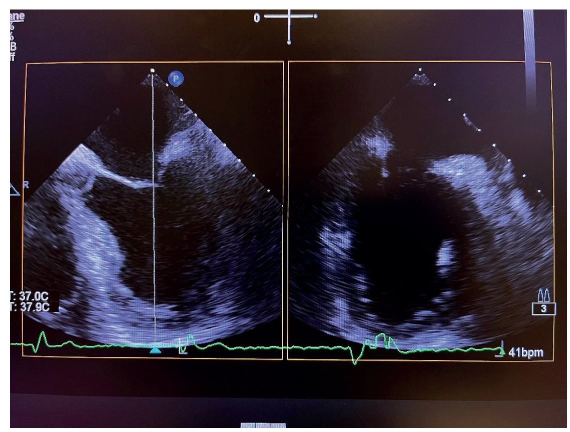
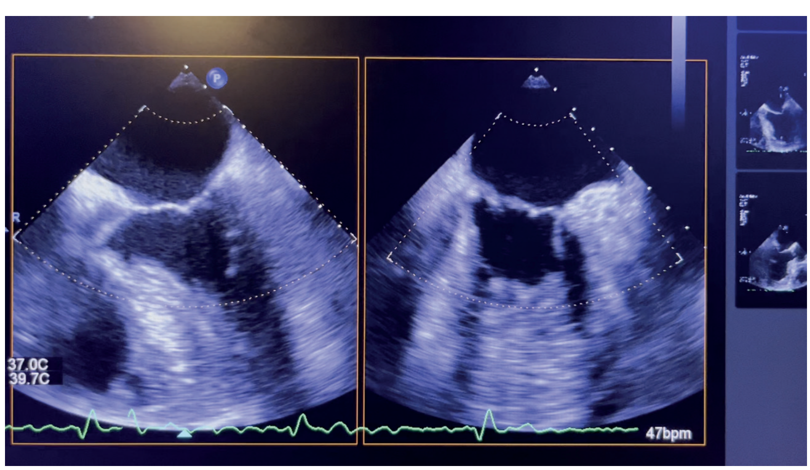


Figure 1 – *Activation of 2D Multiplane mode, with the display showing, simultaneously, 2 orthogonal planes of four and two chambers. The image can be rotated at the cursor line axis.*



Video 1 – *2D multiplane mode activated, showing two orthogonal planes simultaneously. Link: http://abcimaging.org/supplementary-material/2024/3701/2023-0105_AR_video1_1.mp4* at 9 o'clock and the interatrial septum at 15 o'clock (Video 2A). With this module activated, it is possible to move the 3D pyramidal block containing the mitral valve in several directions, allowing accurate anatomical visualization. You can also change the dimensions of the volumetric pyramid obtained, improving spatial and temporal resolution. Normally the acquired volume appears as a pyramidal block of 30 x 60°, which can be adjusted up to 90 x 90° (Figure 2). At this point, tangential and angled cuts allow us to accurately identify prolapses and flails, mainly.

This modality enables excellent spatial resolution, being the preferred method of analysis in patients with rhythm disturbances, mainly atrial fibrillation, very common in mitral insufficiency. It is also the method used to monitor structural procedures, as it does not present the Stitching artifact (image fragmentation).

We then use acquisition synchronized to the electrocardiogram (ECG-gated), with multi-beat acquisition, essential for offline analyses and measurements.[4,5]

This mode of acquisition requires a regular rhythm and collaboration from the patient, with breath holding. If the heart rate is too high, an IV B-blocker can be used to maintain it at approximately 80 bpm, optimizing the volume rate achieved.

The acquired pyramid is built from the fusion of up to six subvolumes obtained, which allows the final image to have the same volume rate and smaller density of lines, with the same high temporal and spatial resolution, allowing an excellent image for later analysis (post-processing). However, the disadvantage of this method is that it does not happen in real time, which makes it difficult to use during structural procedures (Figure 3).

Alternatively, one can choose to directly use the ECG-gated 3D Zoom multi-beat modality, which presents the highest temporal resolution, with more than 100 volumes/s and excellent spatial resolution, since the zoom will be used to capture a smaller block focused only on the mitral valve (Vídeo 2B).

After using the above modalities for morphological analysis of the valve, we normally begin to evaluate the mitral regurgitant jet and its relationship with the leaflets. This is carried out by means of the 3D color Doppler modality, both multi-beat and single-beat. Obviously, if the regurgitation jet has a wide base, along the corners, the multi-beat method is preferred, providing us with better temporal resolution. In narrow base jets, most of the time the single-beat is sufficient to evaluate reflux and quantitative measurements (PISA), even with lower volume rates (Figure 4) (Video 2C).

Post processing of obtained volumes

Every echocardiographer debuting in the 3D world searches for literature and guidelines on ideal gain adjustments, smoothing, and compression to optimize 3D images, but this data is scarce.[6]

As a rule, we must remember that when compression is reduced, one is actually producing more contrasted images, which facilitate the evaluation of fine or delicate structures.

When Smoothing is increased, one can falsely make a surface less irregular (for example, in AAE assessment).

By increasing the Gain, one is actually increasing or amplifying the echoes that return to the transducer, which can create artifacts and static echoes within the cavity that are mistaken for spontaneous contrast (Figures 5A and 5B).

By reducing the gain too much, there is a risk of producing Dropout artifacts, which are the absence of echoes mainly in the mitral leaflets, which in turn can be confused with leaks or perforations.

Therefore, optimal gain must be sought on a case-by-case basis, depending on the depth, thickness, location, and orientation of the structure of interest in relation to the ultrasound beam. In most cases, optimal gain is achieved by reducing echoes (static echoes) from inside the atrial cavity (Figures 5A and B).

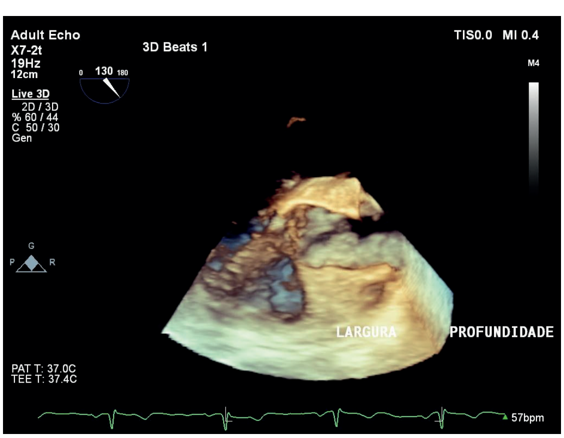
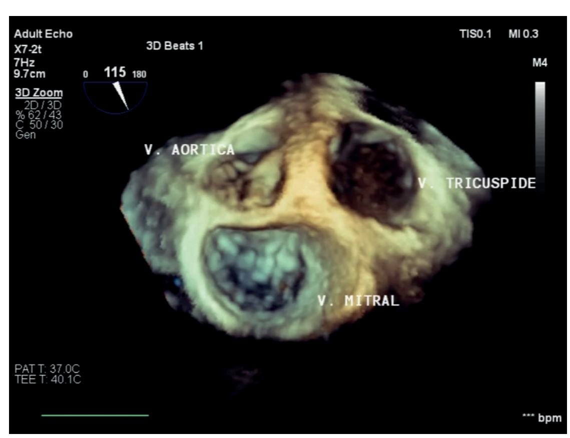


Figure 2 – *Live 3D zoom mode, preferably obtained from a 2D slice at 120 degrees, encompassing the aortic valve, the left ventricle outflow tract (LVOT), and the mitral valve. One can adjust both the width (A) and the height of the pyramidal volume.*



Video 2A – *In-face view of the mitral valve obtained from a 2D section at 120°. When obtaining this volume, the Left Atrial Appendage (LAA) must always be included with the volume, in addition to the LVOT and the aortic valve. Link: http://abcimaging.org/supplementary-material/2024/3701/2023-0105_AR_video2A_1.mp4*

Using the tools for cropping the obtained volumes

Once the appropriate volumes have been captured, we move on to using the tools that will allow us to evaluate the valve in three dimensions.[7-9]

One can use the cropping tool, initially on the fixed axes (x,y,z).

Obviously, fixed cuts do not always offer us ideal images and in some situations, such as flails and prolapses, the free cropping plane tool must be used, which allows us adjustable and angled cuts, revealing images not possible with fixed cuts and in 2D (Figures 6A and B) (Videos 3A and 3B).

Another important tool is focused cropping, which allows to evaluate smaller volumes in real time, resulting in better image definition, often eliminating structures that are not of interest (Video 4).

Finally, in cases of doubt regarding the severity of the reflux, we can use color Doppler associated with 3D to calculate the area of the *vena contracta* and the regurgitant volume. The method was validated against 2D and MRI methods, with a value greater than 0.41 cm^2 presenting a sensitivity of 97% and a specificity of 82% to differentiate moderate and severe MI. The color box must be as small as possible to allow the highest possible frame rate, due to the high speed of the regurgitant jet. Cropping must be done orthogonally to the plane of the jet and planimetry must be done at the point of its greatest speed (Video 4) (Figure 7).

The 3D image presentation/display process

In recent years, the process of demonstrating and presenting images on the 3D ultrasound screen has undergone profound transformations.

Today, depending on the manufacturer, there are different ways of presenting the 3D image on the equipment's display/screen. Each of them has its own characteristics that

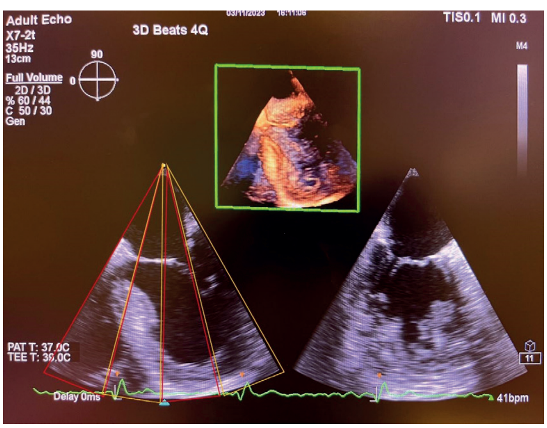
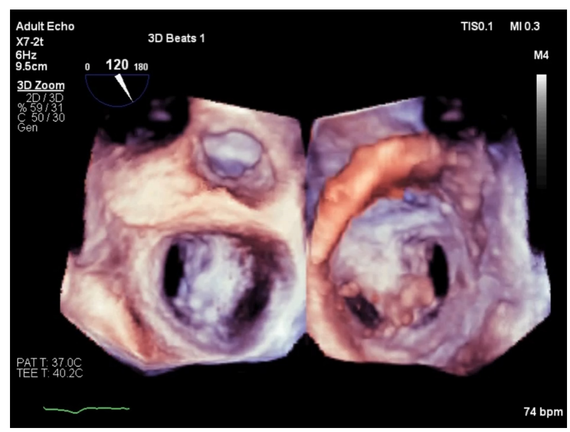


Figure 3 – *Full volume section at 0°, mid-esophageal, with 3D image formation from subvolumes obtained by synchronized electro capture, obtaining the same spatial and temporal resolution of the subvolumes.*



Video 2B – *The result of a miter-clip can be seen, a procedure in which the 3D modality is fundamental. Link: http://abcimaging.org/supplementary-material/2024/3701/2023-0105_AR_video2B_1.mp4*

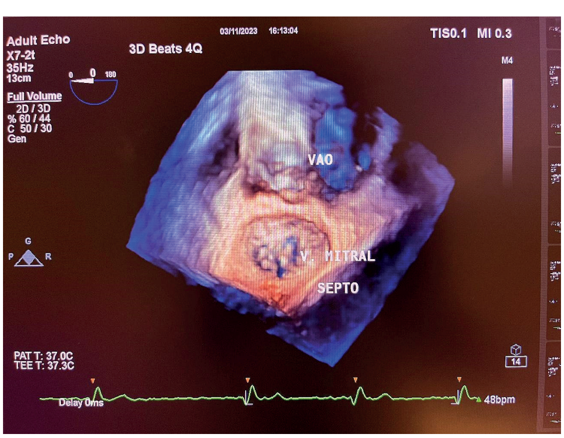
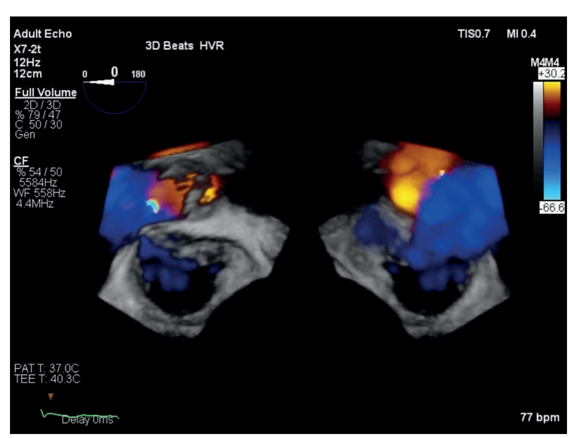


Figure 4 – *3D zoom color multi-beat, a modality that presents excellent temporal resolution of the mitral regurgitation jet along the entire edge of the leaflets.* VAO: aortic valve.



Video 2C – *The use of 3D color is essential to study the relationship and extent of the reflux jet along the edges of the leaflets. Link: http://abcimaging.org/supplementary-material/2024/3701/2023-0105_AR_video2C_1.mp4*

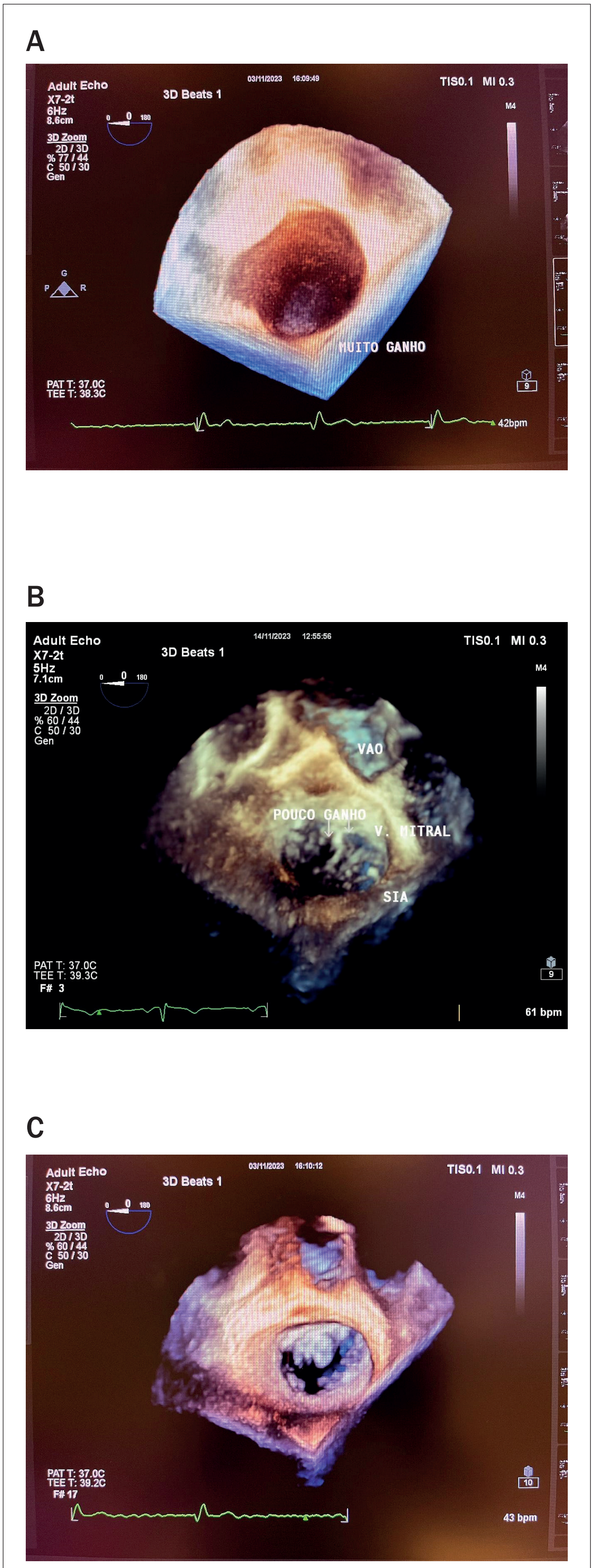


Figure 5 – *(A) excess gain in the 2D image preventing visualization of the mitral V. in the in face section; (B) little gain from the appearance of artifacts that simulate perforations or leaks in the leaflets and base of the LA; (C) ideal gain.*

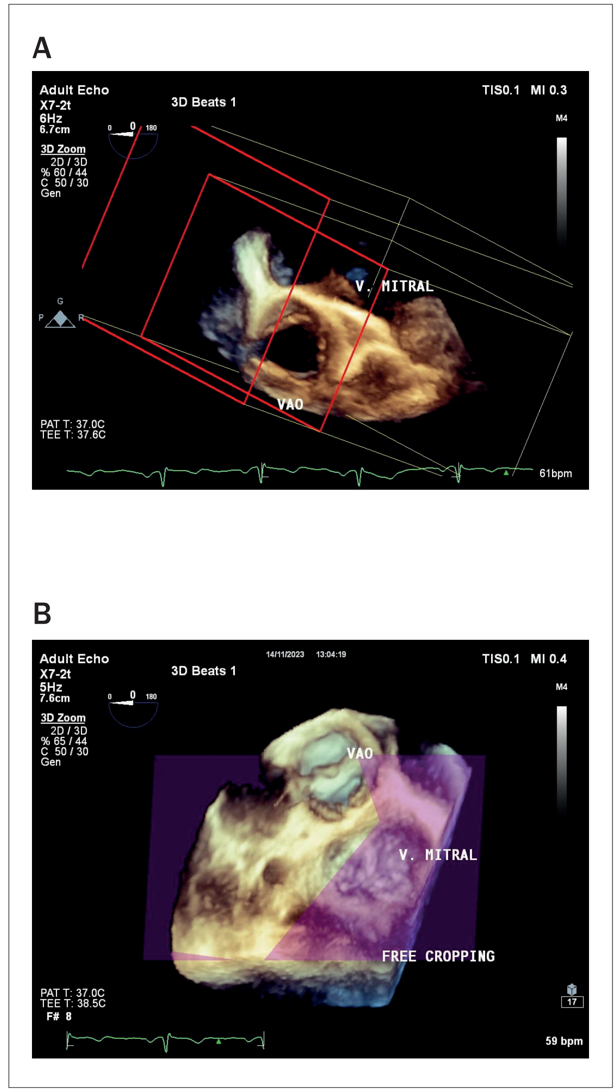
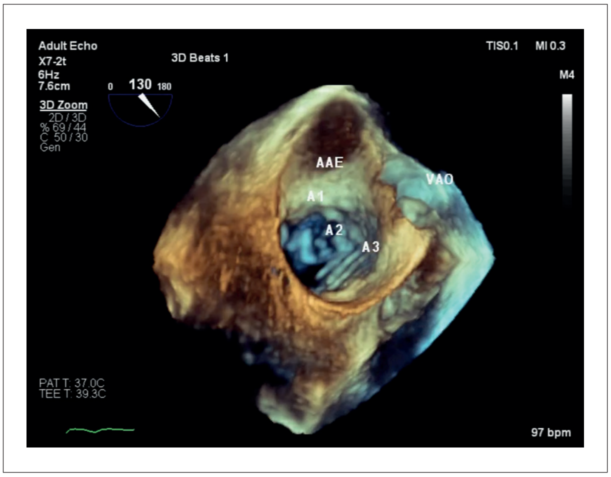


Figure 6 – *(A) activation of the cropping tool in depth for better visualization of the aortic valve; (B) free cropping tool, very useful for evaluating valve prolapses and flails.*

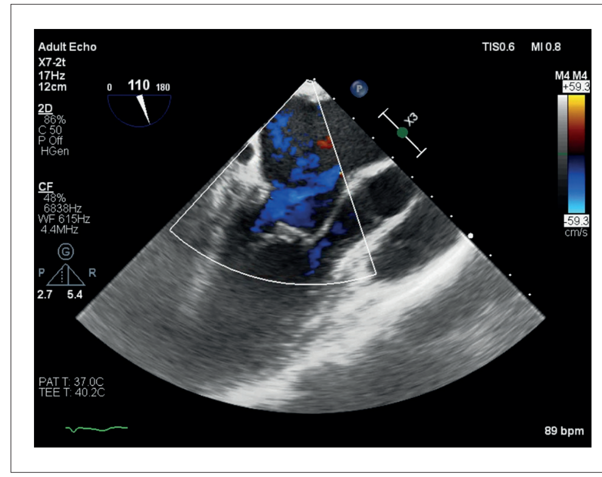
can contribute to better image definition and diagnostic accuracy. This is done through computerized texturing or shading of the image, creating the visual perception of a three-dimensional image.

In mitral valve disease, the first mode of presentation of the 3D image was volume rendering, and to this day it is the most used in most machines, where the software uses different modalities of blue and bronze in combination, to give us the perception of the third dimension. Typically, softwares use lighter colors like yellow and bronze to define superficial structures and darker colors like blue and brown to define deep structures (Figure 8A).

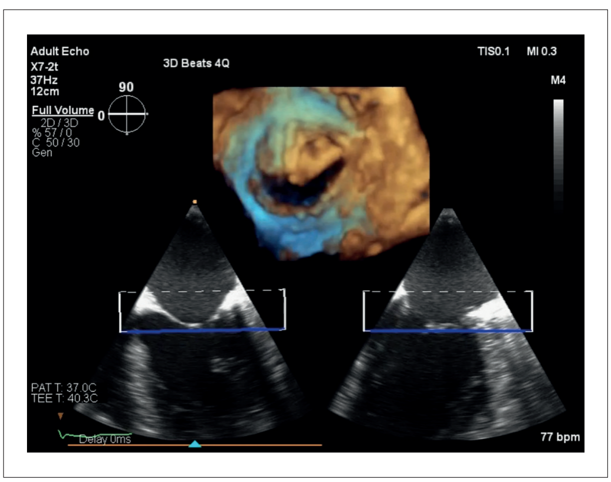
Some devices also have surface rendering for the mitral valve, where the machine uses automatic algorithms or artificial intelligence (AI) to identify pre-defined anatomical points or not (in the case of AI), allowing the creation of



Video 3A – *Isolated prolapse of A3 identified mainly in an angled section, cutting out the interatrial septum using the cropping tool. Link: http://abcimaging.org/supplementary-material/2024/3701/2023-0105_AR_video3A_1.mp4*



Video 3B – *2D image where the identification of the bocellation responsible for the prolapse is quite imprecise. Em: http://abcimaging.org/supplementary-material/2024/3701/2023-0105_AR_video3B_1.mp4*



Vídeo 4 – *Focused cropping tool allowing an impressive improvement in temporal resolution. Link: http://abcimaging.org/supplementary-material/2024/3701/2023-0105_AR_video4_1.mp4*

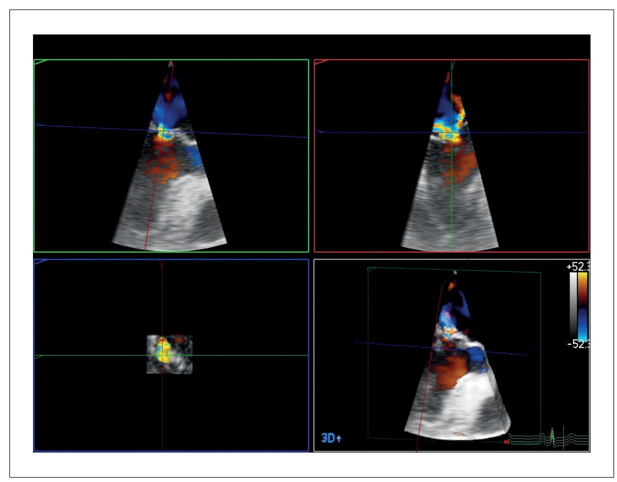


Figure 7 – *Moving the planes perpendicularly to the edges of the mitral valve, the area of the regurgitant orifice is identified.*

anatomical models of the valve and its apparatus, very useful for taking measurements on the ring and leaflets (Figure 8B).

More recently, new and creative ways of presenting and texturing images have emerged.

In the case of the photorealistic vision software, it is possible to use a virtual light focus, as if it were a flashlight, which creates shading of the structure and the sensation of depth. The operator manipulates the focus in any direction, generating a transillumination effect that, in the case of the mitral valve, delimits the valve orifice. Furthermore, this technique can define areas of greater valve thickening and calcification, as the light does not cross these structures (Figure 8C).

Another software available is Glass View, which allows to adjust degrees of transparency of the valve and neighboring structures, but honestly I do not fathom additional advantages in terms of diagnostics and accuracy in relation to its use. However, associated with color Doppler, it often favors the exact location of the regurgitant jet.

So... What about 3D transesophageal echo in mitral insufficiency?

In cases of mitral prolapse where plasty is planned, 3D certainly plays a fundamental role, as even the most common P2 prolapses have different anatomies. In some cases of P3 or anterior leaflet prolapse, 2D diagnosis is quite limited.

Other situations in which the use of 3D is essential are cases of suspected congenital clefts and in the study of posterior leaflet indentations, especially those that can be confused with clefts.

There is no doubt that 3D echocardiography, especially transesophageal echocardiography, will be increasingly

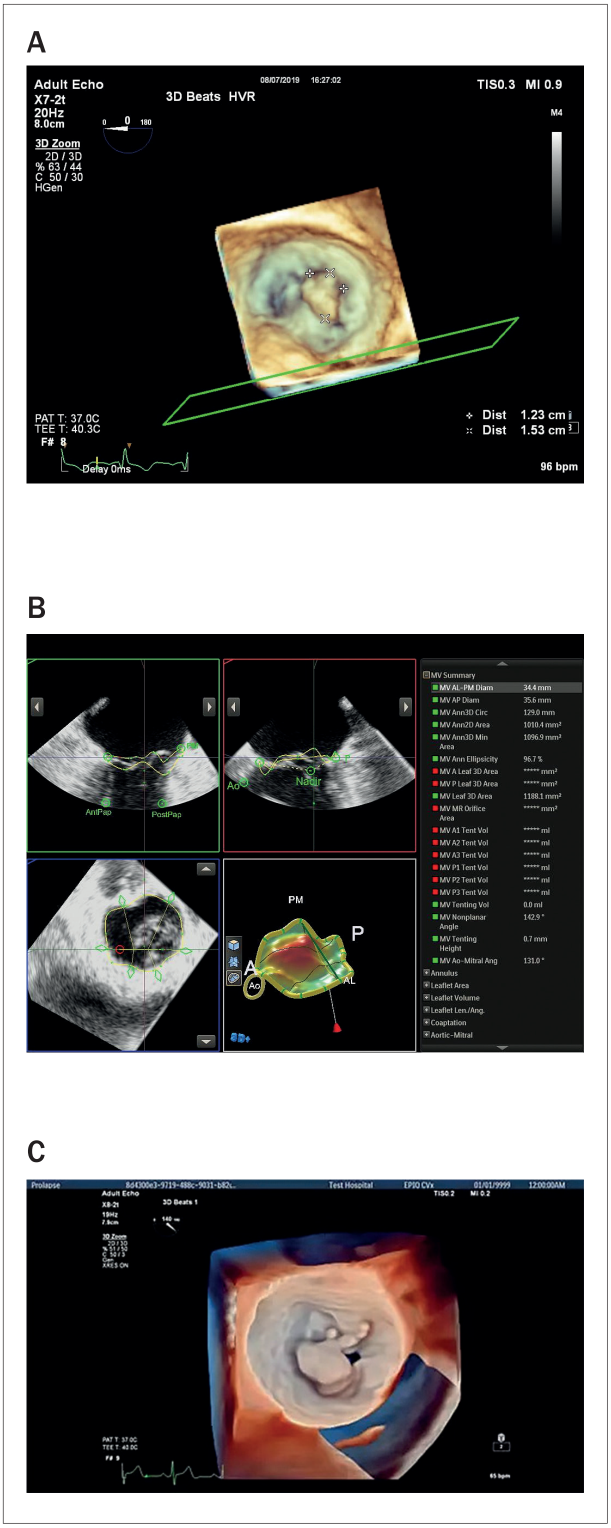


Figura 8 – *3D image presentation modes. (A) volume rendering; (B) used to measure mitral valve structures, such as annulus area, diameters, angles between the mitral and aortic valves, leaflet volumes, prolapse height, etc.; (C): photorealistic view.*

used in mitral anatomical assessment, morphological quantification, through reconstruction and surface rendering softwares, which are increasingly automated, as well as in reflux quantification. 2D assessment remains a mainstay in diagnosing the severity of mitral insufficiency. But once we enter the scenario of searching for the best treatment and during percutaneous procedures, 3D is essential.

Author Contributions

Conception and design of the research and writing of the manuscript: Cañellas F.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

This study is not associated with any thesis or dissertation work.

Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

References

1. Iung B, Vahanian A. Epidemiology of Valvular Heart Disease in the Adult. Nat Rev Cardiol. 2011;8(3):162-72. doi: 10.1038/nrcardio.2010.202.

2. Yang HS, Bansal RC, Mookadam F, Khandheria BK, Tajik AJ, Chandrasekaran K. Practical Guide for Three-Dimensional Transthoracic Echocardiography using a Fully Sampled Matrix Array Transducer. J Am Soc Echocardiogr. 2008;21(9):979-89. doi: 10.1016/j.echo.2008.06.011.

3. Scali MC, Basso M, Gandolfo A, Bombardini T, Bellotti P, Sicari R. Real Time 3D Echocardiography (RT3D) for Assessment of Ventricular and Vascular Function in Hypertensive and Heart Failure Patients. Cardiovasc Ultrasound. 2012;10:27. doi: 10.1186/1476-7120-10-27.

4. Lang RM, Badano LP, Tsang W, Adams DH, Agricola E, Buck T, et al. EAE/ASE Recommendations for Image Acquisition and Display using Three-Dimensional Echocardiography. Eur Heart J Cardiovasc Imaging. 2012;13(1):1-46. doi: 10.1093/ehjci/jer316.

5. Faletra FF, Agricola E, Flachskampf FA, Hahn R, Pepi M, Marsan NA, et al. Three-Dimensional Transoesophageal Echocardiography: How to use and When to use-a Clinical Consensus Statement from the European Association of Cardiovascular Imaging of the European Society of Cardiology. Eur Heart J Cardiovasc Imaging. 2023;24(8):e119-97. doi: 10.1093/ehjci/jead090.

6. Pino PG, Madeo A, Lucà F, Ceravolo R, di Fusco SA, Benedetto FA, et al. Clinical Utility of Three-Dimensional Echocardiography in the Evaluation of Mitral Valve Disease: Tips and Tricks. J Clin Med. 2023;12(7):2522. doi: 10.3390/jcm12072522.

7. Mantegazza V, Gripari P, Tamborini G, Muratori M, Fusini L, Ali SG, et al. 3D Echocardiography in Mitral Valve Prolapse. Front Cardiovasc Med. 2023;9:1050476. doi: 10.3389/fcvm.2022.1050476.

8. Yosefy C, Hung J, Chua S, Vaturi M, Ton-Nu TT, Handschumacher MD, et al. Direct Measurement of Vena Contracta Area by Real-Time 3-Dimensional Echocardiography for Assessing Severity of Mitral Regurgitation. Am J Cardiol. 2009;104(7):978-83. doi: 10.1016/j.amjcard.2009.05.043.

9. Pastore MC, Mandoli GE, Sannino A, Dokollari A, Bisleri G, D'Ascenzi F, et al. Two and Three-Dimensional Echocardiography in Primary Mitral Regurgitation: Practical Hints to Optimize the Surgical Planning. Front Cardiovasc Med. 2021;8:706165. doi: 10.3389/fcvm.2021.706165.