Review Article

Stress Echocardiography Using Real-Time 3D Imaging

Ecocardiografia sob Estresse Usando Imagem Tridimensional em Tempo Real

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Abstract

The need to examine the heart using a three-dimensional (3D) tool is not new. This complex and dynamic organ has always required 3D and real-time understanding. Without this feature, the examiner has to transform two-dimensional images to understand its volume, which requires complex knowledge and approximation interactions. Echocardiography was invented three decades ago, and its improvements resulted in commercial products at the beginning of the century. Some studies demonstrate 3D equivalence with gains in handling the necessary time. We use triplane modalities in our routine, with time gain and less stress on the examiner's upper limb. Thus, 3D examinations can answer more complex questions and provide a more geometric approach to contraction, with thickening being analyzed in the background.

Three-dimensional imaging needs

The first machine capable of presenting three-dimensional (3D) ultrasound images was described[1] in the 1990s. With the technology available at that time, it produced low-definition images, but it was able to provide valuable volumetric information. A long path has been traced toward image enhancement, evolving with transducers with numerous crystals and a high processing capacity. However, the greatest difficulty remained, the need to penetrate between the ribs and reduce the possibility of transducer lens expansion. According to specialists,[2] after nearly 20 years of development, the technology was ready for use. However, the high cost of 3D cardiac examination machines remains an obstacle to the expansion of their use in small- and medium-sized services. A complete device with a 3D heart probe can cost up to four times that of a machine without 3D capabilities but with all current technologies embedded.

A relevant aspect in Brazil is the lack of reimbursement for 3D echocardiography, making the acquisition of the machine a complex step to justifying the investment. In our opinion, the use of 3D stress echocardiography may justify the higher outlay with increased productivity.

Keywords

Echocardiography, Three-Dimensional; Echocardiography, Stress; Imaging, Three-Dimensional.

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Stress echocardiography: A proven and widespread methodology

The most recent stress echocardiography guidelines show a safe and sensitive method of diagnosing several pathologies that can be observed in addition to the rest test.[3] The main mode indicated for investigating induced myocardial ischemia is the one with an exercise bicycle or treadmill, which is justified for use in valve and structural pathologies as well as in diastolic dysfunction analyses. The use of stress medication is limited to patients who cannot exercise and specific aortic stenosis and feasibility research cases despite the possibility of also evaluating exercise feasibility.[4]

We recommend a complete rest test first. However, the stress test should focus on changes in parameters relevant to its completion.

In our services, we use a horizontal exercise bicycle to produce effort with access to all exercise images and phases, following the Balke protocol for increasing loads (Table 1).

We have used the above mode to examine a wide range of pathologies[5] far beyond coronary artery disease[6] and based on extensive literature, mostly on the use of two-dimensional (2D) images and Doppler.

3D echocardiography in stress echocardiography

The use of real-time 3D images in stress echocardiography seems natural and can greatly expand our understanding of ischemic phenomena and ventricular geometry changes.

Peteiro was one of the first echocardiographers to compare 3D and 2D imaging for exercise-induced ischemia[7], as was Yang[8], who used the dobutamine protocol. Sensitivity and specificity were comparable during effort, with 3D being slightly worse for ease of execution. Dobutamine had a significantly reduced image acquisition time with comparable sensitivity and specificity.

The advantages of 3D imaging include a sequence of better ventricular apex visualization, rapid peak image acquisition before heart rate decline, and evaluation of multiple segments from a single position in the apical view.[9]

Table 1 - Exercise images and phases.

Rest	4-chamber	2-chamber	Apical long
Low load	4-chamber	2 chambers	Apical long
Peak	4-chamber	2-chamber	Apical long
Recovery	4-chamber	2-chamber	Apical long

These advantages are more evident when using new devices with higher frame rates and quick access buttons for programmable functions.[10] Learning and understanding 3D imaging requires targeted training and is unnatural for echocardiographers trained only in 2D imaging.

Badano et al.[11] analyzed 44 patients undergoing angiography and reported that 3D had sensitivity and specificity comparable to 2D in devices with higher frame rates and was better to analyze apical changes in the anterior descending territory. The group considers 3D echocardiography equivalent to 2D with advantages in some relevant aspects, making 3D echocardiography appropriate for different applications.

Routine use

We have been using 3D devices in stress echocardiography for just over 2 years, initially in a public university hospital and later in a supplementary medicine laboratory. The first advantage of this is the triplane method with three simultaneous planes, which provides apical long-axis and apical four- and two-chamber views. When we obtain a good four-chamber window, this setting automatically shows the other windows with a good frame rate, normally above 30 frames per second and commonly reaching 60 frames per second. Acquiring just one window to look at all windows reduces the time to acquire the clip by one-third. Performing the tests during the Balke protocol allows image capture at any time during exercise or after interruption, with repeated effort for the left upper limb, which is spared by performing only the four-chamber sections without rotation to obtain the two following sections (Figure 1).

A test routine that could involve up to 12 tests per period uses limb tension equivalent to four tests with 2D and the necessary transducer rotations.

The high frame rate and speed to obtain the complete frame have made this approach the favorite in our stress echocardiography service, where we have already performed more than 3,000 tests since arrival of the 3D machine. All tests start with the triplane mode and all images used in the analysis were in triplane format.

This mode is also easier for beginners, as rotating the transducer to obtain the three necessary planes can be challenging. We noticed the superior performance of the residents when using the triplane method, especially for obtaining the long-axis view, which requires greater transducer rotation and loss of the ideal spot for fast imaging that the test requires.

Real-time 3D use

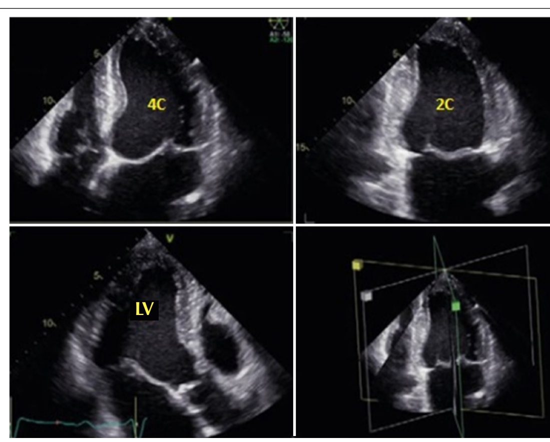
The triplane mode has some advantages, but it remains a 2D demonstration of the cardiac chambers and does not replace the volumetric view. After decades of technological evolution, 3D images offer a reasonable frame rate with good image resolution. This frame rate can be significantly improved using device settings, ranging from 12 to 24 volumes per second with common settings such as depth and width but also decreasing or removing multi-beat analysis and gaining control and volume (Figure 2).

Adaptation to 3D analysis was facilitated in our stress echocardiography service, which maintains a geometric assessment of contraction and placing geometry variation as the first stress analysis. Thickening is in the second plane and mostly used when geometric variations are found. Using this protocol, the dependence on a high frame rate is much lower, being similar to other imaging methods that also work with low frame rates such as cardiac resonance.

The analysis of the entire heart is facilitated with 3D and provides, even for professionals non-initiated in the method, the understanding that ventricular deformation occurred in the stress condition. The disadvantage is the need to acquire apical long-axis and four- and two-chamber images as each slice presents a volume range.

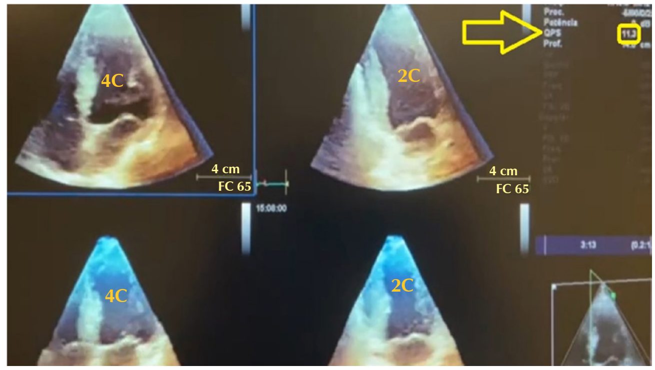
We performed a volume analysis faithful to the ventricle's geometry that ignored the fast frame rate of the triplane mode.

We should make choices during the test, always starting with the triplane mode. Normal ventricles at rest are completely evaluated using this method. Abnormal ventricles may require 3D technology to ensure more accurate diagnosis.



4C: four chambers; 2C: two chambers; LV: apical long axis view.

Figure 1 – *Three simultaneous planes obtained only in the apical four-chamber view.*



4C: four chambers; 2C: two chambers.

Figure 2 – *Comparable ventricular volumes in the dynamic examination.*

The analysis alternates between the two modalities, takes only seconds, and can be performed during exercise without difficulty. We also capture 3D for training purposes and to enable more complete interpretation of the images, but we use the triplane mode for the indispensable test basis.

Conclusion

Our extensive experience recommends the use of a 3D device to perform stress echocardiography using the triplane mode and real-time 3D.

Reimbursement difficulties are overcome by greater productivity and examiner comfort. However, this scenario is favorable for high-volume services performing above 200 tests monthly.

We believe that technological improvements will still reduce the cost of the machine to the point of being accessible to stress echocardiography services of any size.

Authors' contributions

Research conception and design: Souza JRM, Rossi G; data collection: Souza JRM, Rossi G; data analysis and interpretation: Souza JRM, Rossi G; statistical analysis: Souza JRM, Rossi G; funding: Souza JRM, Rossi G; manuscript writing: Souza JRM, Rossi G; critical review of the manuscript for important intellectual content: Souza JRM, Rossi G.

Conflict of interest

The authors have declared that they have no conflict of interest.

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