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Three-Dimensional Echocardiography vs Two-Dimensional Echocardiography in the Assessment of Aortic Stenosis Valve Area

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3D EC; 2D EC; AVA

1. Abstract

1.1. Background: In patients with aortic valve stenosis, accurate measurement of aortic valve area is critical for clinical decision-making. So far, no studies have been conducted to investigate the role of three-dimensional echocardiography in the quantitative evaluation of AS.

1.2. Aim of the Study: To assess the accuracy of the aortic valve area, in two-dimensional echocardiography on the principle of continuity equation (CE) comparted to three-dimensional echocardiography on the principle of left ventricular volume calculation.

1.3. Patients and Methods: In this cross-sectional study, AVA were calculated using transthoracic echo-Doppler and continuity equation, as well as 3D and 3D/2D planimetry.

1.4. Results: Examination of the 31 patients with AS examined (16 males and 15 females), revealed high agreements and minimal absolute differences in AVA across all planimetric methods: 3D versus 3D/2D: 0.914 (0.829–0.957); 2D vs 3D/2D: 0.746 (0.537–0.869). For AVA evaluation, the correlation coefficient r between 3D and 2D was 0.901 and 0.727, respectively. The intra observer variability for all approaches was equal, while the inter observer variability for 3D techniques was higher than for 2D techniques ($p = 0.036$).

1.5. Conclusion: The 3D/2D echo techniques for AVA planimetry agreed well with the traditional 2D methodology and flow-derived methods when compared with 2D AVA on the principle of continuity equation. The 3D approach was at least as excellent as the 2D method and had greater repeatability. 3D aortic valve area is a non-invasive method which gives a quantitative evaluation of AS that is accurate and reliable.

2. Introduction

Aortic stenosis (AS) is a common, progressive, and frequently deadly condition. Auscultation and echocardiographic evaluation of transvalvular flow velocity are widely used in clinical practice to detect and quantify hemodynamic significance. However, the existence of symptoms and a considerable reduction in aortic valve area are the most common reasons for aortic valve replacement (AVR) [1]. If the acoustic window is acceptable, aortic stenosis may be reliably measured using Doppler measurements of instantaneous and mean transvalvular gradients, as well as calculation of valve area using the continuity equation (CE). However, in individuals with decreased left ventricular (LV) systolic function, this method is less accurate for assessing the degree of stenosis. In planimetric valve area measurements, transesophageal echocardiography (TEE) has been employed [2]. A significant advance in cardiovascular ultrasonography is the use of 3D imaging. Real-time 3D collection and display of cardiac structures are now possible using new computer and transducer technologies. There is significant evidence that 3D echocardiography offers benefits to individuals such as: (1) avoiding geometric assumptions, (2) evaluating LV chamber volumes and mass, which eliminates assumptions, (3) quantifying regional LV wall motion and systolic dyssynchrony, (4) showcasing realistic views of heart valves, (5) calculating regurgitant lesions and shunts, and (6) using 3DE stress imaging. Nonetheless, it is essential for a thorough knowledge of technological concepts and a systematic strategy to image collection and processing in order for 3D echocardiography to be used routinely in clinical practice [3]. Because 2D TTE methods cannot measure the LVOT area, 3D TTE provides a direct measurement of the LVOT area. The LVOT is circular in 80% of individuals, whereas it is oval or irregular in the remaining 20%. 3DE may also be used to assess the stroke volume of astrocytes [1]. Unlike 2DE area–length estimate or the truncated ellipsoid approach, 3DE makes no assumptions on the shape of the LV, therefore the computation should be more accurate. The evidence that the 3DE method might help in this area is rising. The use of radioactive angiography and MRI has been contrasted in extensive studies that have been published in peer-reviewed publications. With RT-3DE, you no longer have to deal with cardiac arrhythmia or breath hold issues since the technique allows 3D volume data to be acquired in a single pulse [4]. Although transthoracic RT-3DE imaging have been shown to increase the diagnostic accuracy of echocardiography in a variety of clinical situations, more modifications are needed to make this approach even more robust and user-friendly. As a result, advancements in transducer and computer technology are necessary, particularly the capacity to conduct wider-angle captures in a single cardiac cycle, both with and without color flow imaging [5]. This will reduce the time it takes to collect data and remove stitching artifacts. To drastically shorten the time required to conduct an examination, versatile multitasking transducers with 2D, 3D, color, and tissue Doppler capabilities, as well as lower footprint and weight and greater spatial and temporal resolution, must be created. Quantification of all heart chambers, including flow dynamics, is expected to be done on the imaging system, obviating the requirement for off-line analysis. This is especially useful in interventional settings in the operating room, where quick quantitative feedback is critical [6].

3. Subjects and Methods

This descriptive cross-sectional study was conducted at the cardiology department, echocardiography laboratory of Baghdad teaching hospital, Baghdad-Iraq during the period from November 2020 to May 2021 to measure some Echo parameters about patients to compare between 2D on the principle of continuity equation (CE) and 3D on the principle of left ventricular volume calculation echocardiography in the assessment of aortic stenosis area. The working days were five days per week; 6 hours per day for 6 months duration during 2020. Verbal consent from each participant was obtained before data collection. The data collected was kept confidential and not used except for the study purpose. Ethical clearance of the study was obtained from The Ethical Committee in the Iraqi MOH, after getting the scientific approval. A structured questionnaire was developed as per the objectives of the study, this questionnaire was adopted from a study made in 2007 to assess aortic stenosis by three-dimensional echocardiography: an accurate and novel approach in Los Angeles, USA with modification [7]. Patient diagnosed with aortic valve stenosis were included in the study, while patients aged<18 years, patients with subaortic or supraortic stenosis, patients with atrial fibrillation, bigeminism or frequent extrasystole, patients with any known condition precluding a proper transthoracic echocardiographic study, patients with clinical instability or any other circumstance discouraging the study, patient's refusal, patients with moderate AR or moderate MR , patients with severe AR or MR, patients with Low Ejection Fraction, and patients with Heavly Calcified AV Prevent Proper 3D/2D AV Plainmetry were excluded from our study. Sample size was calculated considering a minimal r = 0.8, confidence 95%, and power 80%, and enlarged to fulfil the conditions to apply parametric tests and to obtain enough representation of mild, moderate, and severe aortic stenosis according to American Society Of Echocardiography guidelines. All patients had a full echo Doppler scan utilizing echo device Vivid E9. We were able to acquire 2D TTE standard views. Following the 2D TTE, volumetric RT3D and 3D guided image capture of the aortic valve was done. The 3D guided two-dimensional imaging (3D/2D) pictures were acquired and shown side by side using the live xPlane mode. Using the "Live 3D" feature, the left ventricule in the apical three–cardiac chamber was first positioned in the image plane's center.

4. Data Analysis

The data were analyzed using the Statistical Package for Social Sciences (SPSS) version 26. Data were presented in simple measures of frequency, percentage, mean, standard deviation, and range (minimum-maximum values). The significance of the Correlation and absolute agreement expressed as ICCa and Lin's coefficient) and Paired samples t-test for comparison of means. Statistical significance was considered whenever the P value was equal or less than 0.05.

5. Results

(Table 1) showed that the participant Echo parameters finding as Mean and standard deviation of (Ejection Fraction, MPG, Cont Equation Area and 3D area) were as follows: (63.29±4.914, 46.06±20.344, 0.755±0.447 and 0.759±0.403) respectively. Three-dimensional echo showed better liner association with 2D/3D area planimetry (r=0.895, 95% CI) than with Two-dimensional method (r= 0.713) (Table 2). Three-dimensional echo is the non-invasive method with best absolute agreement with 2D/3D planimetry (ICC=0.914, Lin's coefficient=0.901), better than Two-dimensional method (ICC=0.746, Lin's coefficient=0.727), while Three-dimensional echo method and Two-dimensional method showed (ICC=0.853, Lin's coefficient=0.842) (Table 2). \ Paired samples t-test demonstrated that there was a slight non-significant trend to underestimation the area compared to 2D/3D planimetry in Two-dimensional Echo methods. The two-dimensional Echo method incurred a considerable bias (-0.101 –0.118 cm2); the three-dimensional method, however, considerably reduced this underestimation (0.048 –0.073 cm2) (Table 3).

Table 1: Echo parameters finding of participants (N=31)

Echo characteristics		Number (N=31)	%
Mitral regurgitation	None	14	45.2
	Mild	17	54.8
Aortic regurgitation	None	18	58.1
	Mild	13	41.9
EF (Mean±SD)	63.29±4.914		
MPG mmHg	46.06±20.344		
Cont Equation Area	0.755±0.447		
3D Area	0.759±0.403		

Table 2: Correlation and absolute agreement (expressed as ICCa and Lin's coefficient) between the different echocardiographic methods studied for aortic valve calculation

Correlation and absolute agreement		2D/3D planimetry	Two-dimensional method (cm2)
Two-dimensional method (cm2)	Pearson's correlation ICCa Lin's coefficient	0.713 (0.535– 0.868) 0.746 (0.537– 0.869) 0.727	
Three-dimensional echo (cm2)	Pearson's correlation ICCa Lin's coefficient	0.895 (0.822– 0.958) 0.914 (0.829– 0.957) 0.901	0.830 (0.715– 0.928) 0.853 (0.717– 0.926) 0.842

Table 3: Paired samples t-test for comparison of means

Paired samples t-test	Paired differences			Significance (2-tailed)
	Mean	95% CI of the difference		
Two-dimensional method	0.0087	-0.101	0.118	0.057
Three-dimensional echo	0.125	-0.048	0.073	0.036

6. Discussion

This is the first research in our center to utilize the methods of 3D-Echo and 2D-Echo for evaluating AS. AVA measures are well linked with 3D/2D planimetry findings in both methods. According to the result in our study, there was mild aortic and mitral regurgitation (41.9% & 54.8%) respectively with no moderate or severe regurgitation and this was higher than what was mentioned by Darae Kim et al [8] who showed that about 38% was trace or mild aortic regurgitation, while our result was much lower than what was reported by Juan Luis Gutiérrez-Chico et al [9] who reported only 10% for moderate aortic regurgitation and only 5% for moderate mitral regurgitation. The differences might be due to the small sample size in our study in addition to differences in the sampling technique of the studies. The ejection fraction in our study was 63.29(±4.91) and this was almost the same result mentioned by Harald P Kühl et al [10] who revealed that the majority of patients had EF of more than 50%. Also Tasneem Z Naqvi et al [11] mentioned that the mean left ventricular ejection fraction was 57.1%. The mean±SD OF Cont Equation Area in our study was (0.75±0.44) which was less than the result of Tarun Kumar Mittal et al [12] who reported (1.08±0.51), while on the other hand, Caroline Morbach et al [13] results on 15 patients who underwent assessment of AS showed (0.78±0.14) which was almost the nearest result to our study. The mean ± SD of 3D Area in our study was found to be (0.75±0.40) and this result go with the finding of M J Monaghan et al [14] who showed the mean area was (0.75±0.15). However, the 3D-Echo approach revealed that the replicability was good and was possible in most patients. The results showed high statistical agreement across all AVA methods (3D/2D,3D and 2D). In patients with left ventricular insufficiency, higher LVOT and jet gradients were observed in bicuspid aortic valves, or accompanied with a substantial aortic regurgitation. However, the Doppler technique has certain disadvantages [15]. In this study, we found good agreement between the techniques on comparing the 3D-Echo method with 2D. However, the 3D method had good agreement with 2D/3D planimetry as the intraclass correlation (ICC) was found to be 0.914. Statistically, it describes how strongly units in the same group resemble each other, and this was almost the same result found in the study of See Hooi Ewe et al [16] when they found that the 3D with 3D/2D planimetry ICC was 0.99. Compared with the 2D method and the 2D/3D planimetry, ICC was 0.746 in our study, while the result of See Hooi Ewe et al [16] study showed that ICC was 0.96, and this might be due to the sample size in our study was limited. Furthermore, while the severity of AS is not evident in our study, this observation concludes that AVA generated from 3D is probably more accurate than 2D AVA. Therefore, this technique can be utilized in patients with an AVA evaluation difference. Finally, RAJESH MG et al [17] mentioned that 2D AVA was overestimating the AVA considering 3D/2D planimetry as the reference method and this was the same conclusion that we found in our study as a trend to underestimate the area compared with 2D/3D planimetry in Two-dimensional Echo methods, while three-dimensional method, however, considerably reduces this underestimation.

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