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Echocardiographic Assessment of the Aortic Stenosis Valve Area: Parameters and Outcome

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ABSTRACT

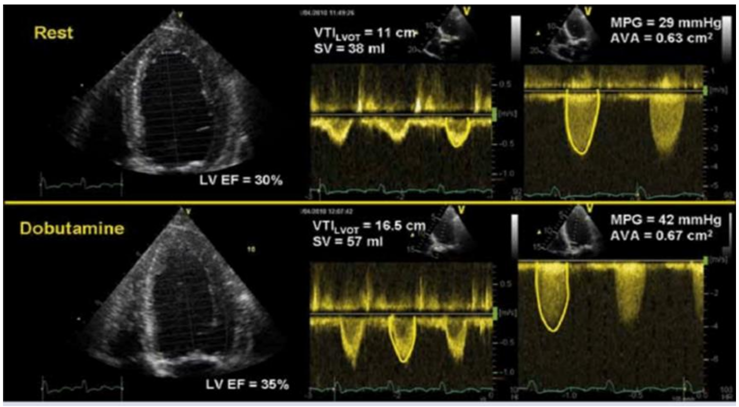
Background: Among individuals who have a stenotic aortic valve, a precise assessment of aortic valve area is essential for clinical judgment. So far, no studies have been conducted to investigate and assess the role of the three dimensional echo-cardiography in the assessment of the valve stenosis. This study aims to compare and assess the precision of the measurement of the stenosis area of the aortic valve by 2D versus 3D echo-cardiography.

Method: This was a cross-sectional study conducted in Baghdad Medical City, Ministry of Health in Iraq from the 1st December 2021 to the 1st June 2022. Aortic valve area was calculated in a cross-sectional study by using transthoracic echo-Doppler, continuity equation, and 3D and 3D/2D planimetr.

Results: 33 patients with aortic stenosis were examined. AVA analysis of correlation and absolute agreement revealed the agreement was high and the absolute differences were minimal across all planimetric methods: 3D vs. 3D/2D: 0.913 (0.829–0.957); 2D vs. 3D/2D: 0.747 (0.537–0.869). For AVA evaluation, the correlation coefficient r between 3D and 2D was (0.902) and (0.729), respectively. The observer variability was equal for all approaches, while the 3D inter-observer variability was higher than for 2D techniques ($p = 0.036$).

Conclusion: The 3D/2D echo techniques for AVA planimetry agreed 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 a greater repeatability. Using 3D Echo in the evaluation of aortic valve area is a not-invasive procedure leading to the AS quantitative assessment that is accurate and reliable.

GRAPHICAL ABSTRACT



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Introduction

Aortic valve stenosis (AS) is progressive, common, and frequent. Echocardiographic evaluation of transvalvular flow velocity is widely used in clinical practice to detect and quantify hemodynamic significance. However, the presence of symptoms and a considerable decrease in the 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 by using Doppler measurements of instantaneous, mean transvalvular gradients, and calculation of valve area by using the Continuity Equation (CE). However, in individuals with decreased left ventricular (LV) systolic function [2], this method is less accurate for assessing the stenosis degree. Transesophageal echocardiography (TEE) can be used to measure the planimetricvalve area [2,3].

Because the 2D TTE methods cannot measure the left ventricular outflow and the 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%. The three-dimensional echo may also be used to assess the stroke volume of astrocytes [1,2]. Unlike the two dimensional echo area–length estimate or the truncated ellipsoid approach, 3DE makes no assumptions on the LV shape. Therefore, the computation should be more accurate.

As a result, employing a flow-independent method like planimetry is critical for AVA estimation. AVA is commonly recognized as the benchmark for determining the AS severity [3.4].

The Real-time three-dimensional echocardiography (RT3DE) offers a peculiar "in-face" image of the aortic valve, potentially improving AVA planimetry accuracy. 2D echocardiography can also provide this picture, although it is likely to be less accurate. Several cut planes may now be acquired for better alignment with AVA based on the introduction of a new three-dimensional transthoracic matrix array probe (Philips, Andover, MA, USA) [2,3].

The SV at LVOT is calculated by using standard two-dimensional echocardiography (2DE) to measure the diameter across LVOT and stroke distance (the time of velocity integral by pulse-wave Doppler) [1]. The continuous wave Doppler measurement unlike the comparatively easy utilized the SV measurement at the valve level, the LVOT accurate validity of SV which calculates the area of aortic valve (AVA), that utilizing the continuity equation, is most sensitive to assumptions on geometry and uniform velocity [3,4].

Most investigations directly evaluated the three dimensional measurements of left ventricle volumes and EF percentage to 2D technique. This fact led to routinely underestimate the ventricle volumes and indicated the superiority of three-dimensional approach over two-dimensional methodology [2]. There is now enough data in the medical literature to suggest that RT-3DE measurement of LV volumes [5], EF, and mass should be regarded as the selecting technique in normal practice. Because many clinical choices that impact patient care, include the device implantation, left ventricular assessment in body builder and athletics heart, precise measurement of left ventricular function, and ejection fraction, this method becomes a part of clinical main practice.

Method

This was a cross-sectional study, conducted in Baghdad Medical City, Ministry of Health in Iraq from the 1st December 2021 to the 1st June 2022.

The Ethical Committee Code was obtained after getting the scientific approval. A questionnaire was adopted from a study made in 2007 to evaluate aortic stenosis by 3D echo-cardiography as a precise and novel approach in Los Angeles, USA with modification [7].

Thirty-three patients were included in this study according to inclusion criteria that all patients diagnosed with aortic valve stenosis. While exclusion criteria involved all patients with age < 18 years old, subaortic stenosis, arrhythmia, mitral and aortic regurgitation, and patients with heart failure and calcified valve.

All patients had a full echo Doppler scan by using echo device Vivid E9. We were able to acquire 2D TTE standard views. In the apical three-chamber or five-chamber view, the data of Doppler flow was collected from the LVOT area in mode of pulsed wave (velocity time $integral_{LVOT}$) and from apical, right para- sternal, and suprasternal windows, and also the maximal measurement was employed for aortic formula calculations in continuous wave mode (velocity time $integral_{valve}$). In the parasternal long axis (LAX) view, the LVOT diameter was measured at the site of pulse wave Doppler data ($LVOT_{area}$). The continuity equation method was used to calculate AVA (AVA = $LVOT_{area}$(velocity time $integral_{LVOT}$/velocity time $integral_{valve}$)).

We took three Doppler measurements, and the estimation was carried out based on the heart beat which is the best representative and was selected separately.

Following the 2D TTE, volumetric RT3D and 3D guided image capture of the aortic valve was done. These pictures were captured with a Vivid E9 Active Matrix 4D Volume Phased Array transducer (frequency range: 1.5–4.0 MHz), which used parallel processing to gather a pyramidal volume dataset in real time from a single window, 2D, Live xPlane, and Live 3D performance. The 3D guided pictures were acquired and indicated by using the live xPlane mode.

The three dimensional guided two dimensional imaging (3D/2D) pictures were acquired and illustrated side by side use of the live xPlane mode. This approach was utilized for mitral valve planimetry and offered precise alignment of the limiting orifice [8]. For the AVA evaluation, we used the same method. The LAX view was utilized to direct the placement of a manually placed cursor at cusp edges of the aortic valve. Simultaneously, the valve orifice area was measured in the short axis plane and drawn on the fly, while the cusps were maximum open in mid-systole.

Using the "Live 3D" feature, the left ventricle in the apical three-cardiac chamber was first positioned in the center of the image plane. To improve the quality of the 3D pictures, gain and compression parameters, as well as time gaining compensation settings were employed. The full volume RT3D with semi-automated border detection recordings were then obtained from a single acoustic window (LAX), with four wedge shaped sub-volumes triggered to the ECG R-wave) recorded from two successive cardiac cycles during exhul hold breathing to create the "pyramid" (60°60°). For improved resolution, a high-density setting was employed that was capable of fitting the whole left ventricle. All volumetric pictures were digitally saved on a compact drive and analyzed online or offline. For accurate alignment and measurement of LVV, the multi-planar reconstruction method was utilized. The pyramidal volume data was presented in three distinct cross-sections. The LVV was measured by using the zoom mode with and semi-automated border detection until the optimum cross-section of the LVV was reached at its maximal systolic and diastole.

The Aortic area was calculated as follows:

$$\textit{Aortic area } (cm^2) = \frac{SV\ 3D\ (cm^3)}{TVI\ AO\ (cm^3)}$$

Statistical analysis

The SPSS version 26 was used by a specialist. Data were displayed by using frequency, percentage, mean, standard deviation, and the minimum-maximum values.

The level of agreement and correlation were expressed as ICC and Lin's coefficient and Paired samples t-test was carried out for the comparing mean values. The statistical significance was considered whenever p-value was equal or less than 0.05.

Results

Demographics and clinical characteristics of study participants

Of 33 patients admitted to Cardiology Department/ Echocardiology laboratory during the study period, about half of them were males (51.6%) and the majority of them were in the age range of 56-75 years old (61.3%), while (25.8%) were in the age range of 36-55 years old, and the rest (12.9%) were over 75 years old. The Mean age of participants was 64.13 and the standard deviation was 12.662 years old (Table 1).

Figure 1 displays the distribution of patients with mild Mitral regurgitation about (55%), while (42%) of them had mild Aortic regurgitation.

Table 1: Demographic characteristics of participants

Demographic characteristics		Number (N = 33)	%
Age	36 - 55 years old	8	24.4
	56 - 75 years old	20	60.6
	> 75 years old	5	15.5
Age (Mean±SD)	64.2±12.67		
Sex	Male	17	51.6
	Female	16	48.4

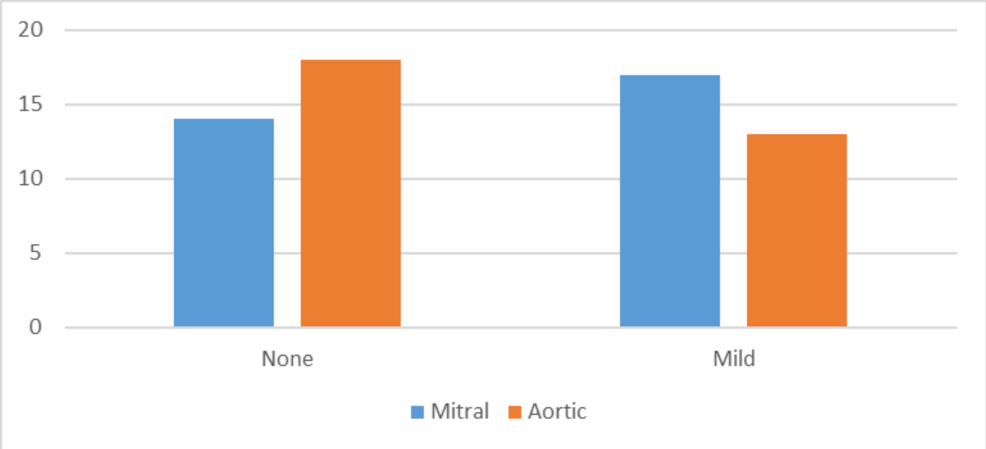

Figure 1: Distribution of Mitral and Aortic regurgitation

Table 2 lists the participant Echo parameters as mean and standard deviation of (Ejection Fraction, mean pulmonary gradient (MPG) on quation Area, and 3D area) as (63.39±4.814, 46.08±20.544, 0.755±0.547, and 0.759±0.503), respectively.

Table 2: Echo parameters of participants

Echo characteristics		Number (N = 33)	%
EF (Mean±SD)	63.39±4.814		
Mitral regurgitation	None	15	45.8
	Mild	18	55
Aortic regurgitation	None	19	58.1
	Mild	14	42
MPG mmHg	46.08±20.544		
Cont. Equation Area	0.755±0.547		
3D Area	0.759±0.503		

Three-dimensional echo shows better liner association with 2D/3D area planimetry (r=0.895, 95% CI) than with two-dimensional method (r= 0.714) (Table 3).

3D was the best absolute that was agreed with 2D/3D planimetry (ICC= 0.913, Lin's coefficient= 0.902) and it was better than 2D method (ICC=0.747, Lin's coefficient = 0.729), while 3D echo and 2D methods were less (ICC= 0.854, Lin's coefficient = 0.843) (Table 3).

Paired samples t-test confirmed that a slight non-significant difference in underestimate the area compared 2D with 3D planimetry in two-dimensional Echo methods. The 2D Echo method had a considerable bias (-0.101 –0.118 cm^2). However, the 3D method considerably reduced this underestimate area (0.048 –0.073 cm^2) (Table 4).

Table 3: Correlation and absolute agreement (expressed as ICCa and Lin's coefficient) between different echocardiographic methods studied for aortic valve calculation

Correlation and absolute agreement		2D/3D planimetry	Two-dimensional method (cm^2)
Two-dimensional method (cm^2)	Pearson's correlation ICCa Lin's coefficient	0.714 (0.535– 0.868) 0.747 (0.537–0.869) 0.729	
Three-dimensional echo (cm^2)	Pearson's correlation ICCa Lin's coefficient	0.895 (0.822– 0.958) 0.913(0.829–0.957) 0.902	0.830 (0.715– 0.928) 0.854 (0.717–0.926) 0.843

Table 4: Paired samples t-test for comparison of means

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

Discussion

As a result of increased aging in population, aortic stenosis is now one of the most common valvular heart diseases. Thus, using different modalities and techniques of Echocardiography for early recognition and management of aortic stenosis is vital because if the symptomatic severe disease of the valve is not treated, leads to a fatal condition. Therefore, our study put emphasis on the physician orientation to use all these techniques, diagnosis, and management.

This study revealed that about 50% of the included patients in our study were males and this was almost the same as described by Juan Luis Gutiérrez-Chico *et al*. [7,8] and about 56.1% of males in his study were about the AS area calculation.

According to the result in our study, there was mild aortic and mitral regurgitation (42% & 55%), respectively with no moderate or severe regurgitation and this was higher than what was mentioned by Darae Kim et al. (9) that about 38% was trace or mild aortic regurgitation, while our result was much lower than what reported by Juan Luis Gutiérrez-Chico *et al*. [10] as his study showed that this was only 10% for moderate aortic regurgitation and only 5% was for moderate mitral regurgitation.

The differences might be due to small sample size in addition to the differences in the sampling technique of studies.

The ejection fraction in our study was 63.39(±4.81) and this was almost the same as the result mentioned by Harald P Kühl *et al.* [11] The majority of patients had EF of more than 50%. Besides, Tasneem Z Naqvi *et al*. [12] mentioned that the mean LV was 57.1%.

The Cont. Equation Area in our study revealed that means (SD) 0.75(±0.54) was less than the result of Tarun Kumar Mittal *et al*. [13] as 1.08(±0.51), while Caroline Morbach *et al*. [14,15] indicated that the result of fifteen of our patients underwent the evaluation of aortic stenosis was (0.78±0.14) and that was almost the nearest result to our study.

While 3D Area in our study was 0.75(±0.50) and this result was consistent with findings of M. J. Monaghan *et al*. [15] in which the area was 0.75(±0.15).

However, the 3D-Echo approach revealed that iteration was good and possible in most patients. The results from statistical analysis showed a high agreement across all AVA methods (3D/2D, 3D, and 2D). In spite of this point, in the patients with LV insufficiency, higher LVOT, gradients jet in a bicuspid aortic valve, or accompanied a substantial aortic regurgitation, the Doppler technique has certain disadvantages [16].

In this study, there was a good agreement between two techniques on 3D-Echo method comparing with 2D. However, the 3D method had a good agreement with 2D/3D planimetry as the intra-class correlation (ICC) was found to be

0.913. In statistics, 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*. [17] as he found that the 3D with 3D/2D planimetry ICC was 0.99.

Comparting with the 2D method and the 2D/3D planimetry, ICC was 0.746 in our study. The result of ICC in See Hooi Ewe *et al*. [17] study was 0.96, and this might be due to the limitation of sample size in our study. Furthermore, while the AS severity is not evident in our study, this observation concludes that AVA generated in 3D was probably more accurate than 2D AVA. Therefore, this technique can be utilized in patients with an AVA evaluation difference.

Finally, RAJESH MG *et al.* [18] mentioned that 2D AVA was overestimating the AVA considering 3D/2D planimetry as the reference method and this was the same conclusion as we found in our study and it was similar to the trend to the area underestimation compared with 2D/3D planimetry in 2D Echo methods, while 3D the underestimation reduced considerably [19, 20].

On other hand, arrhythmia suggests the prognostic of patients more with aortic stenosis as a marker of advanced valve disease rather than the thromboembolic risk. The outcome is therefore likely to have a poor prognostic impact of mitral stenosis in patients with palpitation and also the same in those patients with alcohol and nicotine intake, heavy exercise, and cardiac stimulants may initiate the episodes [5, 21].

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 a greater repeatability. 3D area of the aortic valve was considered as a non-invasive method which gave the AS quantitative evaluation that is accurate and reliable.

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Authors' contributions

All authors contributed to data analysis, drafting, and revising of the paper and agreed to be responsible for all the aspects of this work.

Conflict of Interest

The authors declared no conflict of interest.

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