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Comparative Assessment of Aortic Annulus Diameters between 3D Transesophageal Echocardiography and Cardiac MDCT in Patient with Sclerocalcific Aortic Stenosis

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ABSTRACT

Background: As alternative to open heart surgery, transcatheter aortic valve implantation is a therapeutic option for individuals with high surgical risk. Effectiveness of TAVI depends on accurate aortic annulus measurement, which enables choice of appropriate prosthesis and precise result prediction. There are many imaging techniques available for measurement, but it is noted a significant variation among various modalities**.**

Aim: This study aims to compare between 3D-Transeosophegeal echocardiography and computed tomography angiography in assessment of aortic annulus diameters in patients with significant sclerocalcific aortic stenosis.

Patients and Methods: This was a prospective observational research that was conducted on 30 studied cases [nineteen males and eleven females] with sclerocalcific aortic valve stenosis who came for 2D echocardiography at cardiology department, Al-Azhar University Hospital. For all patients, a complete history, general and local clinical examination, and resting surface 12 lead ECG were performed.

Results and conclusion: There were no variation among 3D transesophageal echo and MDCT regarding aortic annulus maximum, minimum diameters, circumference, area and LVOT minimum diameter, circumference, area and coronary ostial heights. The 3D-TEE correlates well with MDCT in measuring aortic annular dimensions and LVOT minimum diameter, circumference area and coronary ostial height. 3D-TEE could replace MDCT if the latter is unavailable or contraindicated.

Keywords: Aortic stenosis; Transcatheter; Imaging; Multi-detector computer tomography; Three-dimensional transesophageal echocardiography.

INTRODUCTION

Aortic stenosis [AS] has become the most common primary heart valve disease and an important cause of cardiovascular morbidity and mortality. Echocardiography is the key tool for the diagnosis and evaluation of AS, and is the primary non-invasive imaging method for AS assessment. Diagnostic cardiac catheterization is no longer recommended except in rare cases when echocardiography is non-diagnostic or discrepant with clinical data [1]. Clinical decision-making is based on the echocardiographic assessment of the severity of AS, so it is essential that standards be adopted to maintain accuracy and consistency across echocardiographic laboratories when assessing and reporting AS. Recommendations for the echocardiographic assessment of valve stenosis in clinical practice were published by the European Association of Echocardiography and the American Society of Echo-cardiography in 2009 [2].

It is essential in clinical practice to use an integrative approach when grading the severity of AS, combining all Doppler and 2D data as well as clinical presentation, and not relying on one specific measurement [3].

The most common causes of valvular AS are calcific stenosis of a tricuspid valve, a bicuspid aortic valve with superimposed calcific changes, and rheumatic valve disease. Congenital aortic stenosis owing to a unicuspid aortic valve is rare in adults with usually marked dysmorphic features including severe thickening and calcification and associated with significant concomitant aortic regurgitation [AR]. In Europe and North America, calcific AS represents by far the most frequent etiology with the prevalence of bicuspid vs. tricuspid aortic valves as underlying anatomy being highly age dependent. While tricuspid valves predominate in the elderly [>75 years] bicuspid valves are more common in younger patients [age < 65 years]. While rheumatic AS has become rare in Europe and North America, it is still prevalent worldwide [4].

Intricate three-dimensional ring with three anchors at nadir of each aortic cusp is known as aortic annulus. By replacing native valve with bio prosthetic valve, severe symptomatic aortic stenosis can be treated in high-risk, intermediate-risk, and recently low-surgical risk studied cases. Transcatheter aortic valve replacement has been developed as a safe and effective intervention alternative to surgical aortic valve replacement [5]**.** But improper valve selection has been associated with paravalvular aortic regurgitation, device embolization, aortic root rupture, conduction problems, and prosthesis-patient mismatch [6]. The gold standard method for pre-TAVR planning is suggested to be multidetector computed tomography procedure since it can precisely estimate dimensions of ascending aorta, aortic root, and aortic annulus [7]**.** But studied cases with impaired renal function should not have MDCT since it raises risk of contrast-induced nephropathy [8].

To provide accurate measurements of aortic root and geometry in place of MDCT, three-dimensional transesophageal echocardiography, which does not require iodinated contrast, can be valuable imaging tool throughout TAVR [9].

THE AIM OF THE WORK

This study aimed to compare between 3D-Trans-eosophegeal echocardiography and computed tomography angiography in assessment of aortic root diameters in studied cases with significant sclerocalcific aortic stenosis. And to access Accuracy of 3D-Transeosophegeal echocardiography as an alternative to MDCT in renal compromised patient or other contraindications to contrast

PATIENTS AND METHODS

Consecutive studied cases that visited cardiology department at Al-Azhar University Hospital for 2D echo and were found to have sclerocalcific aortic valve stenosis were included in this prospective observational research. All studied cases were provided with informed consent, and Al-Azhar University Hospital's ethics committee granted its permission. Al-Azhar University faculty of medicine's medical ethical and research committee provided ethical approval. Every studied case was asked to give their written informed permission.

Inclusion Criteria: We included all patients with: Significant Sclerocalcific aortic valve stenosis, Sinus rhythm and Normal renal function.

Exclusion Criteria: Poor Echocardiographic window, congenital aortic valve disease, rheumatic aortic valve disease, allergy towards contrast medications, glomerular filtration rate less than 45 mL/min and atrial fibrillation patients

The following was performed for each patient after consent: Thorough history, General and local clinical examination, and Resting surface 12 lead ECG will be done for all patients.

Echocardiography: studied cases underwent 2D-TTE and 3D-TEE procedures at Al-Azhar University Hospital's Echo-Lab for cardiology. Before transferring the image data to personal computer for analysis, we employed hard disc to store it. throughout mid-systole, 2D-TEE was used to assess aortic annulus in mid-esophageal 3-chamber view [between 120° and 135°]. Through concurrent orthogonal views and biplane imaging, maximum diameter of aortic annulus was found. Additionally, measured and stored for offline multi-plane reconstruction analysis was major and minor diameters, annular circumference [perimeter], and area. At 3 aortic cusp insertions, aortic root indices were measured in 2 orthogonal parallel planes that split the aortic valve into long and short axes.

Multi-detector CT [MDCT]: 160-slice Dual-Source CT scanner [Toshiba] was used to acquire MDCT images that were gated by electrocardiogram. ULTRAVIST [iopromide] [twenty–fifty ml] was injected into antecubital vein, followed by thirty-ml saline bolus, to increase contrast. After image reconstruction, at timing of 200ms from R wave of ECG, we were able to get three cross-sectional views [axial view, sagittal view, and coronal view]. Then, utilizing cutting pictures of aortic root obtained along short axis, maximum minimum and diameters and aortic root areas and coronary ostial height were measured. The TEE operator was blind for the CT measurement and The CT operator was blind for the TEE measurement. Another senior TEE operator repeated the measurement unthinkingly for the first operator, and the same for the CT measurements, and checked for the two measurements before comparing TEE to the CT measurements

Statistical analysis: Statistical analysis was done by SPSS version 28 [IBM Co., Armonk, NY, USA]. Quantitative data were presented as mean, standard deviation and range. Paired student t-test \ were used to compare between 3DTEE and MDCT measurements of the same patient. Categorical data were presented as frequency and percentage [%]. Bland-Altman analysis was performed to analyze agreement among 3D transesophageal echo and MDCT. Pearson's relationship coefficient was calculated to assess degree of correlation among the two methods. A two-tailed P value < 0.05 was considered statistically significant.

RESULTS

This research was conducted on 30 studied cases [nineteen males and eleven females] with sclerocalcific aortic valve stenosis. Their ages ranged from 53 to 89 years with mean age of 76.45 ± 6.85 years and BMI ranged from 19 to 34.1 kg/m2 with a mean of 27.75 ± 3.23 kg/m2 as shown in Table [1].

As shown in Table 2, the most common comorbidity was dyslipidemia elicited by 82.8% of the studied patients, hypertension in 58.6%, DM and CAD elicited by 51.7%, each. Out of 30 patients, 20.7% had prior MI/PCI1.

As shown in Table [3], there was no statistically significant difference between 3D transesophageal echo and MDCT regarding the aortic annulus maximum, minimum diameters, circumference and area. As shown in Table [4], there was no variation among 3D transesophageal echo and MDCT regarding the LVOT annulus minimum diameter, circumference, and area. On the other hand, 3DTEE showed a significantly larger maximum diameter as compared to MDCT [24.9 ± 2.52 vs 24.67 ± 2.47 mm, P=0.004]. As shown in **Table 5**, there was no variation among 3DTEE and MDCT in terms of distance to LCA and RCA orifices.

As demonstrated by Bland-Altman plot, there was a good degree of agreement among 3DTEE and MDCT in maximum aortic annulus diameter with a mean bias of 0.34, LOA from -1.47 to 2.15 [1]. Moreover, there was a positive relationship among maximum aortic annulus diameters by the two techniques [r=0.9, P<0.001] [**Figure** 2]. As demonstrated by Bland-Altman plot, there was a good degree of agreement among 3DTEE and MDCT regarding aortic sinus to RCC diameter with a mean bias of -0.04, LOA from -1.14 to 1.05. Also, a significant positive relationship was found among two techniques [r=0.96, P<0.001] [**Figure** 3].

Table [1]: Demographic data of studied patients [n=30]

		Total patients [n=30]
Age [years]	**Mean ± SD**	76.45 ± 6.85
	Range	53 – 89
Gender	**Male**	19 [63.3%]
	Female	11 [36.6%]
BMI [kg/m^2]	**Mean ± SD**	27.75 ± 3.23
	Range	19 - 34.1

Data are presented as frequency [%] unless otherwise mentioned, BMI: Body mass index.

Table [2]: Clinical data of the studied patients [n=30]

	N	%
Dyslipidaemia	24	82.8
HTN	17	58.6
DM	15	51.7
CAD	15	51.7
Smoking	11	37.9
Heart Failure	9	31
Prior MI/PCI1	6	20.7

HTN: Hypertension, DM: Diabetes mellitus, CAD: Coronary artery disease, MI: Myocardial infarction, PCI: Percutaneous coronary intervention

Table [3]: Comparison between 3D transesophageal echo and MDCT in the evaluation of aortic annulus

		3D transesophageal echo	MDCT	P value
Maximum diameter [mm]	Mean±SD	27.85 ± 1.84	27.52 ± 2.14	0.059
	Min.- Max.	24.5 - 31.2	23.99 - 31.4	
Minimum diameter [mm]	Mean±SD	22.31 ± 2.34	22.38 ± 2.49	0.654
	Min.-Max.	19 - 26.6	19.1 - 28.2	
Circumference [mm]	Mean±SD	77.75 ± 5.91	75.82 ± 6.29	0.785
	Min.-Max.	69 – 88	69.7 - 89.2	
Area [cm^2]	Mean±SD	48.15 ± 8.85	47.6 ± 7.5	0.445
	Min.-Max.	38.9 - 75.8	37.9 - 59	

Table [4]: Comparison between 3D transesophageal echo and MDCT in the evaluation of LVOT annulus

		3D transesophageal echo	MDCT	P value
Maximum diameter [mm]	Mean±SD	24.9 ± 2.52	24.67 ± 2.47	**0.004***
	Min.- Max.	20 – 29	20 - 29	
Minimum diameter [mm]	Mean±SD	21.01 ± 1.72	21.22 ± 2.14	0.555
	Min.- Max.	16.1 - 23.1	16.2 - 27.7	
Circumference[mm]	Mean±SD	69.1 ± 6.29	68.25 ± 6.55	0.071
	Min.- Max.	57.9 - 78.2	57 - 78.6	
Area [cm^2]	Mean±SD	41.12 ± 6.78	41.18 ± 6.78	0.822
	Min.- Max.	30.7 - 53.6	31 - 52.1	

Data have been shown as mean ± SD and range, *: Statistically significant as P value<0.05.

Table [5]: Comparison between 3D transesophageal echo and MDCT in the evaluation of the distance to CA orifice

	3D transesophageal echo	MDCT	P value
LCA [mm]			0.252
Mean ± SD	13.16 ± 1.29	13.04 ± 1.32	
Range	10.4 - 15.1	10.2 - 15	
RCA [mm]			0.337
Mean ± SD	13.52 ± 2.02	13.44 ± 1.95	
Range	9.1 - 18.5	8.8 - 18.8	

Data have been shown as mean ± SD and range, LCA: Left coronary artery, RCA: Right coronary artery.

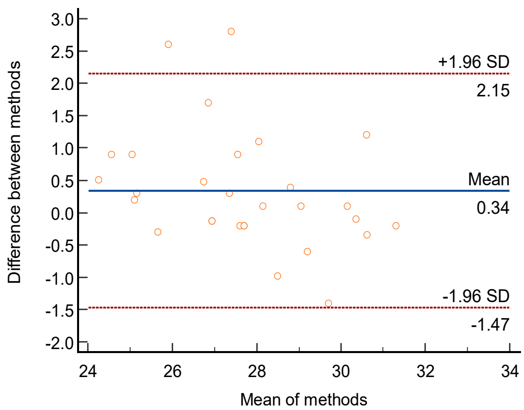

Figure [1]: Bland-Altman plot for maximum aortic annulus diameters by both methods

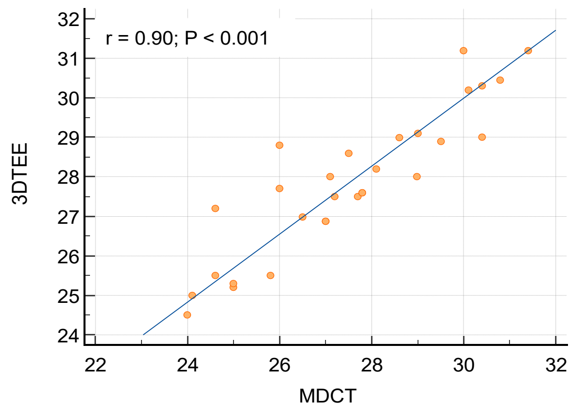

Figure [2]: Scatter plot for the correlation between maximum aortic annulus diameters by both methods

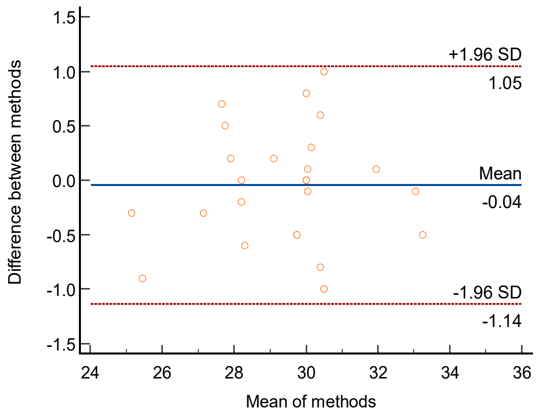

Figure [3]: Bland-Altman plot for aortic sinus to RCC diameter by both methods.

DISCUSSION

Aortic stenosis [AS] is the most common valvular lesion in the developed world. Symptomatic AS is lethal with aortic valve replacement being the only durable treatment option. Accurate measurement of the aortic annulus diameter before aortic surgery is very helpful for surgeons performing aortic valve replacement or valve sparing surgery. If we know the precise aortic annulus size by preoperative imaging, surgical strategies could be more accurately planned [10]. More recently, transcatheter aortic valve replacement [TAVR] has become a safe, feasible treatment option for patients at high and intermediate surgical risk. That is routinely practiced worldwide. The indications for TAVR, while currently restricted to patients deemed high risk or inoperable in the United States, are rapidly increasing. In addition, novel TAVR devices allow an increasing spectrum of patients to receive treatment [11].

Moreover, an emerging medical technology for high-risk aortic valve stenosis, transcatheter aortic valve replacement [TAVR], needs accurate preprocedural quantification of the aortic annulus diameter. Incorrect sizing may cause serious complications including paravalvular leakage, aortic root rupture, and valve dislodgement [12].

Several imaging techniques have been used in clinical practice. Two-dimensional transesophageal echocardiography [2D-TEE] has been traditionally the most commonly used modality for this purpose; however, 2D images allow the analysis of the annulus diameter in just one view and may underestimate the maximal valve annulus diameter [13].

At the moment, 3D imaging modalities including three-dimensional transesophageal echocardiography [3D-TEE], multidetector computed tomography [MDCT], and magnetic resonance image [MRI] are considered more accurate than 2D methods and have been associated with improved outcomes, but they still have some limitations, such as the risk of contrast nephropathy and radiation dose with MDCT, This issue is especially relevant to patients with severely reduced creatinine clearance. Clinical outcomes of TAVR in patients with new-onset renal replacement therapy post-TAVR have been shown to be worse, and long examination times, incompatibility with various medical devices, availability or price with MRI [14].

A specialized TEE reconstruction tool has recently been introduced, which automatically configures a geometric model of the aortic root from the images obtained by 3D-TEE and performs a quantitative analysis of these structures. However, the accuracy of this method compared with the standard imaging techniques has not been yet evaluated [15].

Some investigators have suggested three-dimensional transesophageal echocardiography [3DTEE] as an alternative in providing accurate cross-sectional area and perimeter measurements for patients undergoing TAVR. Although others have cautioned that 3DTEE annulus cross-sectional measurements are severely underestimated when compared to MDCT [16].

The aim of this study is to compare 3D-Transeosophegeal echocardiography and computed tomography angiography in assessment of aortic root in patients with significant sclerocalcific aortic stenosis. This study was conducted on 30 patients [19 males and 11 females] with sclero-calcific aortic valve stenosis. Their ages ranged from 53 to 89 years with a mean age of 76.45 ± 6.85 years and BMI ranged from 19 to 34.1 kg/m^2 with a mean of 27.75 ± 3.23 kg/m^2.

In this study we found that the most common comorbidity was dyslipidemia elicited by 82.8% of the studied patients, hypertension in 58.6%, DM and CAD elicited by 51.7%, each. Out of 29 patients, 20.7% had prior MI/PCI. In this study we demonstrated that there was no statistically significant difference between 3D transesophageal echo and MDCT regarding the aortic annulus maximum, minimum diameters, circumference and area.

Tamborini *et al.* [17] reported the identical AA areas measured by 3D-TEE and MDCT [443.2 ± 97.0 mm^2 [Qlab] vs. 442.5 ± 94.8 mm^2]. **Calleja *et al.***[18] compared a cohort of normal aortic roots either accessed by 3D-TEE or MDCT, and the results were 23.3 ± 1.7 mm [Autovalve] vs. 22.3 ± 2.5 mm.

Hafiz *et al*. [19] found that the mean aortic annular area by MDCT was 4.44±0.88 cm^2, while by 3DTEE it was 4.33±0.78 cm^2. There was a strong positive linear correlation between the MDCT aortic annular area and the 3DTEE aortic annular area [ρ=.833, 95% CI=0.757-0.885], with mild underestimation by 3DTEE.

In this study we illustrated that there was no statistically significant difference between 3D transesophageal echo and MDCT regarding the LVOT annulus minimum diameter, circumference and area. On the other hand, 3DTEE showed a significantly larger maximum diameter as compared to MDCT [24.9 ± 2.52 vs 24.67 ± 2.47 mm, P=0.004].

Tsuneyoshi *et al.* [20] found that MDCT showed larger annulus sizes than shown by other modalities such as TEE or TTE. One of the reasons is a lack of standardization across MDCT workstations. Many platforms lack adequate smoothing algorithms which may result in perimeter values that are significantly larger than those in reality. Another possible reason why MDCT may overestimate the annulus is the influence of contrast media, which causes halation between the aortic annulus muscle and the left ventricle cavity. In perimeter measurements of the aortic annulus, the outer boundary of contrast media was manually traced. The halation of contrast media may lead observers to make larger measurements.

Pontone *et al.* [21] found that the length of left coronary, right coronary, and noncoronary leaflets by MDCT were 13.9 ± 2.2, 13.3 ± 2.1, and 13.4 ± 1.8 mm, respectively, whereas the score of aortic leaflet calcifications was 2.9 ± 0.8. Finally, the distances between AoA and left main and right coronary artery Ostia were 16.1 ± 2.8 and 16.1 ± 4.4 mm, respectively. Regarding AoA area, transthoracic and transesophageal echocardiography showed an underestimation [$p < 0.01$], with a moderate agreement [r: 0.5 and 0.6, respectively, $p < 0.01$] compared with MDCT.

In this study we found that: a good degree of agreement between 3DTEE and MDCT regarding the distance from annulus to LCA ostium. Also, there was a significant positive correlation between the distances from annulus to LCA ostium. In addition, we found that as regards STJ diameter, 3DTEE showed a significantly smaller maximum diameter as compared to MDCT [27.76 ± 1.68 vs 27.99 ± 1.39 mm, P=0.029] while both methods showed similar minimum STJ diameters. **Wiley *et al.*** [22] took 141 consecutive patients with severe AS who underwent TAVR at a single-center institution and selected 74 who had both MDCT and intra-TAVR 3DTEE information available. 3DTEE showed a significantly smaller STJ diameter as compared to MDCT.

Zhang *et al.* [23] showed excellent intra-and inter-observer agreements for AA, SOV and STJ diameter measurements, either using the MDCT or 3D-TEE modeling methods. Similarly, **Hafiz *et al.*** [19] found that there was a significantly strong positive linear correlation and good agreement in terms of STJ minimum diameter [r = 0.793, p < 0.01, CCC= 0.723, and ICCC = 0.728].

In this study we cleared that there was a good degree of agreement between 3DTEE and MDCT in aortic annulus diameter with a mean bias of 0.34, LOA from -1.47 to 2.15. Moreover, there was a significant positive correlation between aortic annulus diameters by the two methods [r=0.9, P<0.001].

Dima *et al.* [8] found that there were only slight differences between annular diameter measurements obtained via MDCT [2.25±0.19 cm] and 3D TEE [2.25 ± 0.15 cm]. The mean difference between aortic annular diameter measured by MDCT and TEE was 0.001 cm. The Bland–Altman analysis indicated there was no proportional bias between 3D TEE and MDCT measurements.

Librera *et al.* [24] showed a good agreement between the two methods across the whole range of aortic annulus diameters. **Garcia *et al.*** [25] found that there was an excellent correlation between the measurement of the AA mean diameter by MDTC and by TEE: ICC: 0.941 [0.761–0.985], r: 0.901, P< 0.001 with good agreement between both measurements.

Elkaryoni *et al*. [26] reported a strong correlation for annular area [r = 0.84, p < 0.001], mean perimeter [r = 0.85, p < 0.001], and mean diameter [r = 0.80, p < 0.001] between 3D-TEE manual and MDCT.

Rong *et al*. [27] reported the strong correlations between 3D-TEE manual and MDCT for annular area [0.86 [95% CI, 0.80–0.90]], annular perimeter [0.89 [95%CI, 0.82–0.93]], and mean annular diameter [0.80 [95%CI, 0.70–0.87]] measurements.

In this study we found that there was a good degree of agreement between 3DTEE and MDCT regarding aortic annulus circumference with a mean bias of -0.1, LOA from -2.8 to 2.7. Moreover, there was a significant positive correlation between aortic annulus circumferences by the two methods [r=0.98, P<0.001]. **Tamborini *et al.*** [28] found that 3DTEE AA-Circumference [r = 0.83] and LCC [r = 0.69] significantly correlated with MDCT.

Conclusion: 3D-TEE correlates well with MDCT in measuring aortic annular dimensions, and LVOT minor diameter, area, circumference and coronary ostial height. So 3D-TEE can replace MDCT if the latter is unavailable or contraindicated. Whether or not this can affect clinical outcomes is yet to be determined.

Disclosure: None to be disclosed

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