ORIGINAL ARTICLE

Three-Dimensional Echocardiography Compared with cardiac Computed Tomography to assess Mitral Annulus Size before surgical mitral valve replacement

Wael A. Mohammed [a], Hani A. Khalaf [a], Mohamed Abdelfattah[b], Ahmed Fouad [a], Ahmed M. Khairy [a,*]

[a] Department of Cardiology, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt
[b] Department of Radiology, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt

Abstract

Background: ***Although Echocardiography is still considered the gold standard imaging to evaluate the function of the mitral valve, multidetector computed tomography (MDCT) is the gold standard for mitral annulus evaluation. transoesophageal Echocardiography also used for assessment of geometry of mitral valve apparatus with added benefit of three dimensions measurements of the mitral valve.***

Aim: ***To correlate three-dimensional Echocardiography and computed tomography in sizing the mitral valve annulus before surgical mitral valve replacement.***

Methods: ***This study included 42 patients (53 ± 8 years old, 79% female) who are eligible for MVR underwent 3D TEE and MDCT. Assessment of mitral annulus, including mitral annular area (MAA), perimeter, anteroposterior (AP) and antrolateral-postromedial (AL-PM) diameters, were measured using 3D TEE and MDCT, and were correlated with intraoperative measurements.***

Results: ***Compared to MDCT, MAA, perimeter, AL-PM, and AP diameters measured on 3D TEE were larger (10.6 ± 1.25 vs. 9.9 ± 1.09 cm2 for MAA; 120.3 ± 6.04 vs. 116 ± 6.03 mm for perimeter, 36 ± 2.95vs. 31.83 ± 3.24 mm for AL-PM distance, and 30.05 ± 3.05 vs. 26 ± 2.97 mm for AP distance, all p < 0.001). There was a positive correlation between mitral annular measurements by 3DTEE and MDCT, and these measurements correlated well with measurements of the prosthetic valve size.***

Conclusion: ***This study showed good correlation between 3D-TEE and MDCT in evaluating mitral valve annulus before mitral valve replacement, although 3D-TEE provided larger measurements compared with MDCT.***

Keywords: MV annulus; MDCT; 3D-TEE; MV prosthesis

1. Introduction

The mitral valve anatomically consists of: The annulus, Leaflets, Chordae tendinae, papillary muscles, walls of the left atrium and left ventricle .[1]

Mitral valve annulus represents leaflets' attachment to the muscular fibres of the atrium and ventricle and is directly attached to the fibrous skeleton of the heart, which is a fixed, thick, collagenous framework as an attachment to the valve, atrium, and ventricular muscle .[1] The mitral valve annulus is not a circular structure, but indeed it is; it is a structure, so it can't be assessed well with two-dimensional imaging modalities.[2]

Mitral regurgitation (MR) is considered the commonest disease affecting the mitral valve, and its prevenance increases with age. In MR the blood flows backward from left ventricle to left atrium through the valve, producing characteristic systolic murmur at the apex area.[3]

Moreover, rheumatic heart disease is the main cause of mitral stenosis and is still highly prevalent in developing countries. Other rare causes are degenerative mitral valve disease or calcifications, congenital stenosis of the mitral valve, thickening of the valve due to endocarditis, calcifications, endomyocardial fibroelastosis, malignant carcinoid syndrome, systemic lupus erythematosus .[4]

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* Corresponding author at: Cardiology, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt.
E-mail address: Ahmadkhairy@azhar.edu.eg (A. M. Khairy).

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Although Echocardiography still considered the gold standard imaging for evaluation of mitral valve function, multidetector computed tomography (MDCT) is the gold standard for mitral annulus evaluation .[5]

Multidetector computed tomography (MDCT) can provides good measurements of mitral annulus, including area, perimeter, anteroposterior diameter inter trigonal diameter.[6]

Transoesophageal Echocardiography also used for assessment of geometry of mitral valve apparatus with added benefit of three dimensions measurements of the mitral valve .[7]

The goal of our study was to correlate MDCT and 3D TEE in measurements of the mitral annulus.

2. Patients and methods

This prospective cohort study was carried out at Al-Azhar University hospitals from April 2023 to October 2024. It included 42 patients eligible for mitral valve replacement according to the guidelines. Patients with an allergy to the contrast material, impaired renal function, patients with esophageal disease that interferes with the TEE study, poor Echocardiographic window, patients with atrial fibrillation, inability to control HR before cardiac CT, and patients who refused the study were excluded from the study. Informed written consent was taken after full explanation of the purpose and nature of the study. Detailed medical history taking, history of rheumatic fever, and symptoms of pulmonary venous congestion. Detailed general and local clinical examination, including the assessment of vital signs, measurement of height, weight, and body surface area (BSA). Routine laboratory investigations: especially blood urea and serum creatinine before cardiac CT. Resting twelve-lead surface electrocardiogram (ECG) and long strip to detect heart rhythm and rate. Transthoracic Echocardiography was done on the patients of the study using a GE 95 ultrasound machine. Then all acquired images are stored and analyzed according to the recent recommendations .[8] Assessment of LV internal dimensions and assessment of left ventricular function were performed using modified Simpson's method .[9] The severity and grade of mitral valve disease, either stenosis or regurgitation, was assessed according to the current recommendations .[10,11] Assessment of aortic valve (TV) affection was done according to the recent recommendation.

Tranosophageal Echocardiography was performed using the GE 95 ultrasound system, 3D zooming on the mitral valve was acquired in surgical view of the mitral valve with ch,oosingthe choicediastolic frame. Then, landmark set points are at the attachment of the anterior mitral valve leaflet to the annulus, the attachment of the posterior mitral valve leaflet to the annulus, at the point of coaptation, posteromedial, anterolateral coordinates, and finally at the aorta. Then the mitral annulus geometry was automatically defined, which may be manually readjusted. Then, after approval, all mitral annular measurements were available automatically.

Patients included in the study underwent CT angiography scanning using a Toshiba Aquilion PRIME CT scanner (Toshiba Medical Systems Corporation, Japan) with 160 slices, 0.5 mm × 80 detector row, 0.35 sec gantry rotation time, 72 kW Generator, and 78 cm gantry bore. A retrospective bolus tracking imaging protocol was used to scan all patients. Then, selecting the mid-diastolic frame, the mitral annulus was traced manually by defining 16 points around the mitral annular plane. Then, we identified both trigons. Lastly, MAA, perimeter, anteroposterior diameter, and anterolateral-postromedial dimeters were calculated. Finally, an intraoperative measurement of the size of the mitral valve prosthesis was obtained.

Normally distributed data is represented as mean ± standard deviation, while not normally distributed data is represented as median ± interquartile range. We used Spearman correlation to assess the correlation in mitral annular measurements by both modalities, with the correlation coefficient (R). $p < 0.05$ was considered statistically significant. All data was analyzed statistically using SPSS V 26 and Colab software.

3. Results

Patients Characteristics

A total 42 patients with age ranged from 31 to 62 years with a mean value (± SD) of 52.8 (±7.92) years. There were 9 (21.43%) males and 33 (78.57%) females. The weight ranged from 68 to 105 kg with its mean (± SD) of 86.6 (±9.95) kg. The height ranged from 157 to 178 cm with its mean (± SD) of 165.43 (±5.26) cm. The BSA ranged from 1.73 to 2.14 m2 with its mean (± SD) of 1.9 (±0.11) m2. Regarding comorbidities, 4 (9.52%) patients had hypertension, 3 (7.14%) patients were smokers, and 3 (7.14%) patients had diabetes mellitus. 3 (7.14%) patients had prior BMC. NYHA class was II in 9 (21.43%) patients, III in 26 (61.9%) patients and IV in 7 (16.67%) patients.

Table 1. Demographic data, prior PMC and NYHA class of the studied patients

		(N=42)
AGE (YEARS)	Mean ± SD	52.8 ± 7.92
	Range	31 - 62
SEX	Male	9 (21.43%)
	Female	33 (78.57%)
WEIGHT (KG)	Mean ± SD	86.6 ± 9.95
	Range	68 - 105

HEIGHT (CM)	Mean ± SD	165.43 ± 5.26
	Range	157 - 178
BSA (M²)	Mean ± SD	1.9 ± 0.11
	Range	1.73 - 2.14
COMORBIDITIES	Hypertension	4 (9.52%)
	Smoking	3 (7.14%)
	Diabetes mellitus	3 (7.14%)
PRIOR PMC		3 (7.14%)
NYHA CLASS	II	9 (21.43%)
	III	26 (61.9%)
	IV	7 (16.67%)

BSA: Body surface area, PMC: percutaneous mitral commissurotomy, NYHA: New York heart association classification.

Echocardiographic measurements

Pathology of MV was RHD in 32 (76.19%) patients and MVP in 10 (23.81%) patients. 38 (90.48%) patients had mitral regurgitation, and 10 (23.81%) patients had mirtal stenosis. AV was normal in 32 (76.19%) patients, moderate in 3 (7.14%) patients and severe in 7 (16.67%) patients. TV was mild in 23 (54.76%) patients, moderate in 8 (19.05%) patients and severe in 11 (26.19%) patients. The LVIDd ranged from 43 to 59 mm, its (mean± SD) of (52.8±4.05) mm. The LVIDs ranged from 25 to 42 mm, its (mean± SD) of (37.6±3.73) mm. The LA ranged from 45 to 59 mm, its (mean± SD) of (51.6±3.5) mm. The EF ranged from 50 to 67 %, its (mean± SD) of (59.3±4.3) %. The MVA planimetry ranged from 0.8 to 1.2 cm2, its (mean± SD) of (1±0.15) cm. The Wilkins score ranged from 11 to 13, its (mean± SD) of (11.9±0.88). The mean PG ranged from 13 to 17, its (mean± SD) of (14.8±1.23).

Table 2. Transthoracic echocardiography of the studied patients.

		(N=42)
PATHOLOGY OF MV	RHD	32 (76.19%)
	MVP	10 (23.81%)
MITRAL REGURGITATION AND MITRAL STENOSIS	MR	38 (90.48%)
	MS	10 (23.81%)
AV	Normal	32 (76.19%)
	Moderate	3 (7.14%)
	Severe	7 (16.67%)
TV	Mild	23 (54.76%)
	Moderate	8 (19.05%)
	Severe	11 (26.19%)
LVIDD (MM)	Mean ± SD	52.8 ± 4.05
	Range	43 - 59
LVIDS (MM)	Mean ± SD	37.6 ± 3.73
	Range	25 - 42
LA (MM)	Mean ± SD	51.6 ± 3.5
	Range	45 - 59
EF (%)	Mean ± SD	59.3 ± 4.3
	Range	50 - 67
MVA PLANIMETRY (CM²) (FOR MS PATIENTS)	Mean ± SD	1 ± 0.15
	Range	0.8 - 1.2
WILKINS SCORE (FOR MS PATIENTS)	Mean ± SD	11.9 ± 0.88
	Range	11 - 13
MEAN PG (FOR MS PATIENTS)	Mean ± SD	14.8 ± 1.23
	Range	13 - 17

MV: Mitral valve, RHD: Rheumatic heart disease, MVP: Mitral valve prolapse, LVIDd: Left ventricular internal diameter at end-diastole, LVIDs: Left ventricular internal diameter at end-systole, LA: Left atrium, EF: Ejection fraction, MVA: Mitral valve area.

MA measurements by MDCT and 3D TEE:

There was positive correlation between MAA, perimeter, AP diameter and PM-AL diameters measured by 3DTEE and MDCT (P<.001).

Table 3. Correlations between CT measurements and TTE measurements

		MAA 3D (CM²)	MAA 2D (CM²)	PERIMETER (MM)	AP DIAMETER (MM)	PM-AL DIAMETER (MM)
MAA CT (CM²)	r	0.816	0.821	0.733	0.794	0.787
	P value	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
PERIMETER CT (MM)	r	0.628	0.633	0.947	0.685	0.658
	P value	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
AP DIAMETER CT (MM)	r	0.786	0.786	0.565	0.976	0.944
	P value	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*
AL-PM DIAMETER CT (MM)	r	0.680	0.692	0.549	0.902	0.895
	P value	<0.001*	<0.001*	<0.001*	<0.001*	<0.001*

AL-PM: anterolateral-posteromedial , AP: anteroposterior, CT: computed tomography, MAA: mitral annular area, 3D: three dimensions, 2D: two dimensions

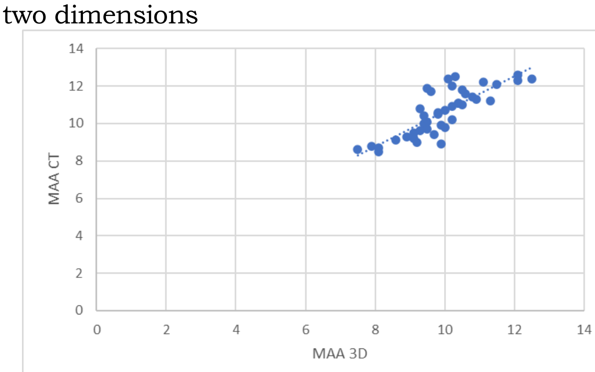

Figure 1. Correlations between MAA CT and MAA 3D

MAA: mitral annular area, CT: computed tomography, 3D: three dimensions

Prosthetic valve size and MAA

There was positive correlation between prosthetic valve size and MAA 3D TEE with p value <0.001

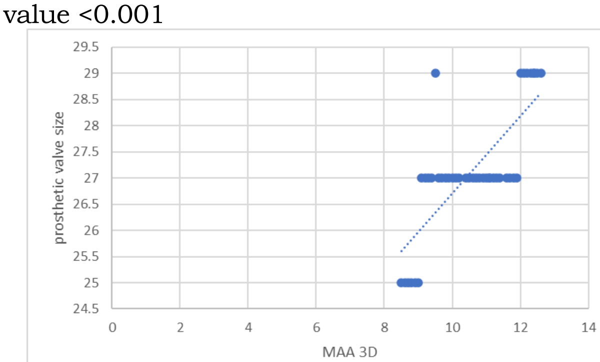

Figure 2. Correlations between prosthetic valve size and MAA 3D

MAA: mitral annular area, 3D: three dimensions

Also There was positive correlation between prosthetic valve size and MAA MDCT with p value <0.001

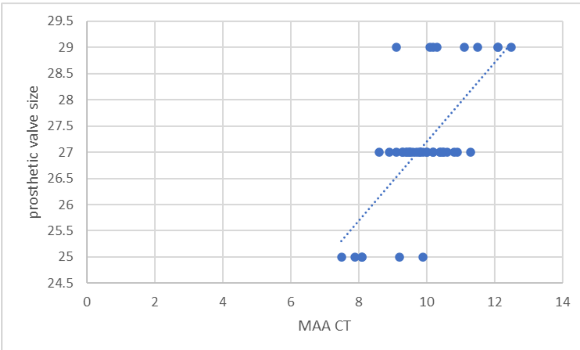

Figure 3. Correlations between prosthetic valve size and MAA CT

MAA: mitral annular area, CT: computed tomography

There was positive correlation between prosthetic valve size and BSA (P<0.001).

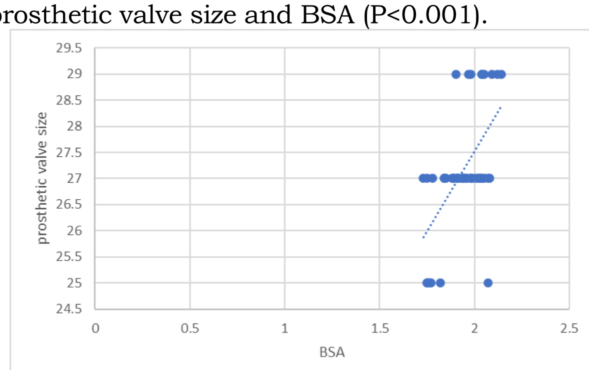

Figure 4. Correlations between prosthetic valve size and BSA

BSA: body surface area

There was positive correlation between BSA and MAA measured with 3D-TEE and MDCT (P<0.001).

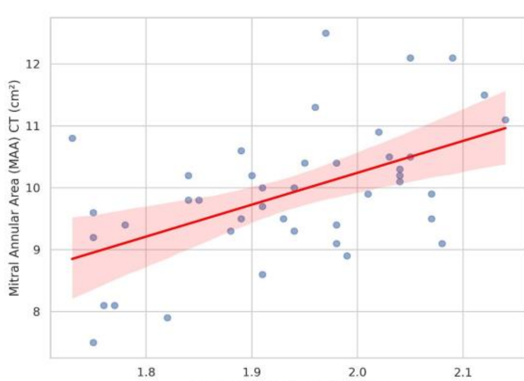

Figure 5. Correlations between BSA and MAA (CT)

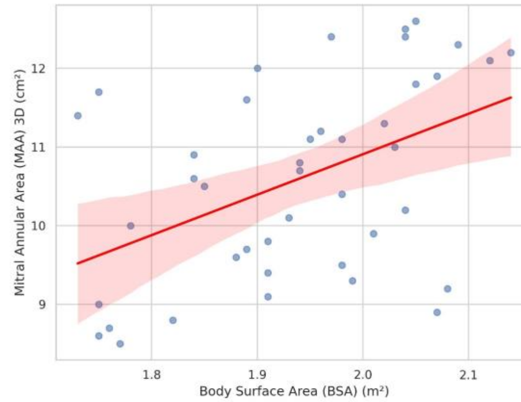

Figure 6: Correlations between BSA and MAA (3D-TEE)

4. Discussion

The mitral valve annulus is not a circular structure, but indeed it has a three-dimensional geometry, so it can't be assessed well with two-dimensional imaging modalities .[2]

The shape of mitral valve annulus is not a circular. But it's considered a saddle shaped structure with well-defined highest and lowest points .[12]

Although Echocardiography still considered the gold standard imaging for evaluation of mitral valve function, multidetector computed tomography (MDCT) is the gold standard for mitral annulus evaluation .[5]

MDCT can provides accurate measurements of mitral annulus, including area, perimeter, anteroposterior diameter inter trigonal diameter.[6]

Accurate measurements of mitral annular dimensions, including area, perimeter, AP diameter and inter trigonal diameter is very crucial step before transcatheter MV replacement.[13]

transoesophageal Echocardiography also used for assessment of geometry of mitral valve apparatus with added benefit of 3D TEE-derived MV measurements .[7]

The aim of the study was to assess the correlation between measurements of mitral annulus by 3D TEE and MDCT.

The study demonstrated a strong positive correlation between 3D TEE and MDCT in measurements of the mitral annulus.

This was concordant with a study conducted by Chiang et al., which prospectively analysed patients presented to St Paul's hospital from 2022 to 2024 with moderate to severe MR who were eligible for transcatheter mitral valve repair. 3D TEE and MDCT were performed on all patients, with all measurements done in the diastolic phase, specifically in diastole, and demonstrate good correlation between MDCT and 3D TEE in measurements of the mitral valve annulus. With further validation, 3d auto MV quantification may be considered as a good option for assessment of mitral annulus before transcatheter replacement .[14]

This was also concordant with a study conducted by Mark et al., which evaluated 41 patients with severe mitral regurgitation and were eligible for transcatheter mitral valve replacement (TMVR) who underwent MDCT and 3-dimensional transoesophageal Echocardiography (3D-TEE) , and concluded that there was a positive correlation between 3D-TEE and cardiac CT in the assessment of the D-shaped MA .[15]

This result was also conducted by Hirasawa et al. which studied 105 patients (79 ± 9 years old, 52% male) who were eligible for transoesophageal Echocardiography and cardiac CT 3D for accurate measurements of mitral annular parameters, and all parameters were measured carefully using 3D TEE and MDCT and there was positive correlation between the two modalities in all mitral annular measurements, However in our study mitral annular measurements measured with 3D TEE were larger than those measured with MDCT, this is opposite finding of the same study where MA dimensions measured with MDCT were larger.

This may be explained by the depth of three-dimensional Echocardiography increases the annulus size than usual two-dimensional nature of CT, so our results the mitral annulus measured in 3DTEE were relatively larger than measured with cardiac CT .[16]

transcatheter aortic valve replacement (TAVR) is now successful procedure, so transcatheter mitral valve replacement (TMVR) have been developed in last few years .[17]

Multiple devices have been described for transcatheter mitral valve replacement (TMVR) for those who are candidate for replacement of the valve due to severe mitral regurgitation. But this technique needs very accurate assessment of mitral annulus, and it's saddle shaped structure so accurate assessment with 3D Echocardiography became crucial for the procedural success and to avoid complications.[18]

Multiple studies considered that the multidetector computed tomography (MDCT) is the gold standard for planning that procedure.[15,19]

However, the need for dye as a contrast material for MDCT may be a source of complication, especially for elderly patients with deteriorated renal function, which is a large number of patients referred to (TMVR). Also, it carries radiation hazards. In contrast, 3D TEE provides accurate measurements of mitral annular geometry and avoids exposing patients to the hazards of contrast media and radiation. So it may be used as the imaging of choice before mitral valve replacement, either surgically or transcatheter, and MDCT may be limited to some situations when additional information is needed.

Our study result was also concordant with Vo et al., between January 2018 and December 2019, on 96 patients who were eligible for mitral valve replacement through a minimally invasive procedure. There was good agreement between measurements of the mitral annulus by SD TEE and MDCT.[20]

In our study, there was a positive correlation between prosthetic valve size and CT measurements (MAA CT, perimeter CT, AP diameter CT, and AL-PM diameter CT) ($P<0.05$).

Also, there was a positive correlation between prosthetic valve size and TEE measurements (MAA 3D, MAA 2D, perimeter, AP diameter, and AL-PM diameter CT) ($P<.05$).

These results were concordant with Vo et al., between January 2018 and December 2019, on 96 patients who were eligible for mitral valve replacement through a minimally invasive procedure, and concluded that the size of mitral valve prosthesis may be predicted according to the measurements of mitral geometry by MDCT, and 3D TEE.[20].

This result can decrease the incidence of patient prosthesis mismatch in the mitral position. PPM may also present after mitral valve replacement. And diagnosed if the effective orifice area index (EOAI) is ≤1.2 to 1.25 cm2/m2. In that situation, it is considered to have the same pathophysiology as mitral stenosis, resulting in increased left atrial pressure, pulmonary hypertension, and right-sided failure .[21]

Furthermore, PPM can significantly affect the long-term outcomes of mitral valve replacement.[20]

PPM is characterized by increased transvalvular pressure gradient despite a normal prosthetic valve structure. PPM is accompanied by complications and poor hemodynamics with less decrease in left ventricular hypertrophy and an increase in cardiac events and the rate of death after aortic valve replacement. These complications, especially mortality, occur more often with a depressed left ventricular ejection fraction. As in aortic valve PPM is seen also after replacement of the mitral valve, with its complications and sequelae like persistence of pulmonary hypertension, and may increase mortality.[21]

Lam et al. have described patient prosthesis mismatch after mitral valve replacement as not uncommon; it causes a serious complication with persistence of pulmonary hypertension and heart failure and increases mortality rates, so it's crucial to choose a more suitable valve prosthetic size before replacement of the mitral valve .[22]

Accurate measurement of the MV annulus with 3D-TEE or cardiac CT is important before MV repair.

Before selecting the accurate size of prosthetic ring, two important issues should be considered. Avoidance of functional mitral stenosis (FMS) and prevention of mitral regurgitation. the main cause of functional mitral stenosis is small size of the valve ring .[23]

No data suggesting that the size of the mitral valve ring may contribute to mitral regurgitation control .[24]

So the goal when selecting optimal ring size is to prevent functional mitral stenosis.

So, Preoperative accurate measurements of the annulus with transoesophageal echo may determine postoperative FMS after MV repair .[25]

Although degenerative mitral valve pathology is common worldwide, rheumatic affection of the mitral valve remains common in developing countries.[26] In our study, the pathology of mitral affection was either due to rheumatic heart disease 32, 76.19%) or mitral valve prolapse 10, 23.81%).

In this situation, degeneration of mitral valve may occur on top of rheumatic affection and makes its repair is difficult and should be replaced.

The affection of the mitral valve may be caused by its stenosis, regurgitation, or both. Surgical mitral valve replacement is still the mainstay of the management of severe forms of mitral stenosis and regurgitation. Recently, mitral valve replacement through a minimally invasive procedure has been developed for mitral valve surgery and has many advantages over the usual procedure in terms of pain and blood loss, as well as short hospital stays with good postoperative patient compliance .[27]

In our study, there was a positive correlation between prosthetic valve size, mitral annular size, and BSA (P<0.001).

This was concordant with Sonne et al. which studied 120 subjects (52 females, 68 males, age: 37 ± 20 years) with good ejection fraction, with nearly normal mitral valve function with no more than mild regurge and demonstrated that there was positive correlation between body surface area and mitral annulus, also with inter-papillary distance and interregional distance .[28]

This also (positive correlation between mitral annulus size and BSA) was concordant with Rajendran et al. which studied 406 Indian patients, out of which 252 were males and 154 were females, The annulus of mitral valve showed positive correlation with BSA, as it increases with the increase of body surface area, so BSA alone has the best correlation with mitral valve measurements. The results obtained from the Indian population were lower than the lower end of the standard values.[29]

The current study has limitations related to a relatively small number of patients, which may limit the generalizability of the results, being a single centre study, and also, we excluded patients with atrial fibrillation, which were the main limitations of our study.

4. Conclusion

This study showed good agreement between 3D-TEE and MDCT derived MA measurements although 3D-TEE systematically provided larger measurements compared with MDCT. Also, MAA measured with 3D-TEE or MDCT showed good correlation with prosthetic valve size.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

Authorship

All authors have a substantial contribution to the article

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Conflicts of interest

There are no conflicts of interest.

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