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Research Article

Comparison of Aortic Annulus Measurements by Echocardiography and CT Scan with the Intraoperative Valve Sizing

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Abstract

Introduction: Proper sizing of the aortic annulus is vital in selecting the most appropriate valve size during open aortic valve replacement. The aortic annulus diameter measured by preoperative transthoracic echocardiography or CT scan, often yields different values than the prosthetic valve annulus measured intraoperatively and the same has been implicated in frequent paravalvular leakage, PPM, thromboembolism and endocarditis. In our study we evaluated the accuracy of valve sizing obtained by preoperative CT scan and echocardiography by comparing these measurements with direct intraoperative sizing.

Methods: Total 100 patients undergone standard open surgical valve replacement in our institution between January 2019 to December 2019 were retrospectively analyzed. Their maximum aortic annulus diameter determined by preoperative CT scan and echocardiography were individually compared and correlated statistically with the implanted valve size.

Results: The systolic annulus diameter by transthoracic echocardiography and the effective diameter by CT scan correlated better with the intraoperative sizing.

Conclusion: The effective diameter measured by CT scan correlates most with the intraoperative sizing so it can serve as an indicator for deciding the most appropriate size of prosthetic valve intraoperatively.

***Keywords:** Transthoracic Echocardiography; CT Scan; Effective Diameter; Intraoperative Sizing; Systolic Diameter*

Introduction

The aortic annulus is a virtual ring at the base of the aortic root. The level of the aortic annulus is defined by the three nadirs (lowest points in the direction of the left ventricular outflow tract) of the U-shaped attachments of each aortic cusp [1]. Accurate preoperative measurement of aortic annular diameter is useful for surgical aortic valve replacement (AVR) which enables surgeons to know which size of prosthesis is required to avoid patient-prosthesis mismatch, annulus rupture or valve embolization and whether aortic annular enlargement (AAE) is necessary [2-8]. Direct intraoperative sizing during open-heart surgery may be regarded as the empirical standard for aortic annular measurement [9], although sizer dimensions have been reported to differ slightly from actual precision measurements [10]. During surgical aortic valve replacement (AVR), sizing using a dedicated sizer instrument is performed prior to implantation during cardiac and the appropriate size of the prosthetic valve is selected according to the result of this procedure. Aortic annulus diameter by transthoracic echocardiography (TTE) yields systematically lower values than transesophageal echocardiography (TEE) or CT scan [11].

Even CT scan is able to provide detailed information about the shape of the aortic annulus and its surrounding structures [12], enough studies are not available at the moment to support the evidence as to which of the clinically applied methods of aortic annulus measurement correlates better with the true annulus dimensions. Therefore, in this study we compared and tried to draw correlation between aortic annulus dimensions obtained by preoperative TTE and CT scan to direct intraoperative surgical sizing during open-heart aortic valve surgery. These data may yield precise estimation of aortic valve annulus preoperatively and help in surgical management of patients undergoing aortic valve replacement (AVR).

Patients and Methods

Total 100 patients with preoperative CT scan and TTE undergone elective open surgical aortic valve replacement from January 2019 to December 2020 were analyzed retrospectively. All the patients were adults and had only aortic valve replacement. The patients who had additional cardiac surgeries with AVR, other coexisting cardiac disease, previous cardiac surgeries, hemodynamic instability, active myocarditis and aortic root enlargement procedures were excluded. The aortic annulus diameter measurement in the routine preoperative transthoracic echocardiographic (TEE) examination was obtained from parasternal long-axis cross-sections of the left ventricular outflow tract and aortic valve both in end systole and end diastole. The diameter was measured inner-edge to inner-edge from the hinge point of the right coronary aortic cusp orthogonal to the direction of flow, toward the commissure of left and non-coronary cusp, as recommended in echocardiographic guidelines [13] by the same team of 2 cardiologists blinded for the study. All the preoperative measurements were done within 4 days prior to surgery.

For CT scan measurement, end-systolic and end-diastolic CT scans were analyzed by a cardiac-radiologist experienced in CT imaging and blinded to clinical data. The aortic annulus was defined as the plane of the virtual circumferential ring containing the basal attachment points of the 3 aortic valve leaflets. At this level, the minimum (CTmin), maximum diameter (CTmax) were measured and mean of these two measurements was taken as mean diameter (CTmean). As the functional outcome of prosthetic valve is determined by the effective surface area, we correlated the effective surface area through effective diameter (CTeff) calculated as the diameter of a circle with the exact same area (area as the measured area of the annular circumference reconstructed from the CT scan data.

Open AVR was performed were according to indications by ACC/AHA guidelines. After median sternotomy and establishment of CPB, the native aortic leaflets and calcified parts of the aortic annulus were excised through oblique aortotomy. After complete excision of the aortic leaflet and decalcification of the aortic annulus, the annular size was measured using the manufacturer's prosthesis sizers. The annular size was determined based on the diameter of the largest sizer that could be barely passed through the annulus. The type of prosthesis implanted was mechanical valves such as St Jude Medical Regent series. The prosthetic valve size was selected corresponding to the intraoperatively measured annular size, and ranged from 19 mm to 29 mm. The intraoperative aortic annulus diameter was defined as the outer diameter of the manufacture's sizer of selected prosthesis.

Statistical analysis was performed using the IBM SPSS statistical package version 22. Quantitative variables were expressed as mean ± standard deviation (SD) or median (inter-quartile range) and qualitative variables as percentages. The different diameter measurements in the same patient were compared using the Student's t-test for paired data. Linear regression analysis was performed using Pearson's correlation coefficient. Bland-Altman analysis with 95% limits of agreement was used to compare the different imaging techniques. Any differences with P-values < 0.05 were considered statistically significant.

Results

As per the exclusion criteria, total 100 patients were included in the study who underwent surgical AVR and their data were analyzed retrospectively. The patient demographic features are enlisted in table 1.

Age (years)	(18 y - 62), (mean ± SD = 43.5 ± 11.5)
Sex	Males- 62, females-38
Body surface area (mean ± SD)	1.57 ± 0.6
Biologic/mechanical valve prosthesis	19/81
Primary pathology	
Aortic stenosis (AS)	33
Aortic regurgitation (AR)	29
AS+AR	38
Valve size implanted (mm)	19 - 31, (average size- 25)
Valve sizes	
19 mm	05
21 mm	13
23 mm	23
25 mm	28
27 mm	19
29 mm	11
31 mm	01

Table 1: *Demographic parameters of the patients included in the study.*

In the analysis we found the mean aortic annulus diameter at end-diastole was 23.5 ± 3.9 mm and mean diameter at end-systole was 25.4 ± 4.1 mm measured by TTE. The mean diameter for intraoperative direct sizing was 25.5 ± 3.1 mm. The maximum, minimum, mean and effective diameters measured by CT scan were 32.2 ± 3.5, 18.1 ± 2.2, 25.4 ± 2.9 and 25.1± 3.0 mm, respectively. Dividing maximum CT-diameters by minimum CT-diameter results in a number > 1 in every patient, indicating the oval shape of the annulus. The mean ratio between maximum and minimum CT-diameter was 1.37.

All preoperative values of TTE and CT scan were compared with intraoperative direct sizing of the prosthetic valves as shown in table 2. The systolic annulus size measured by echocardiography and the effective CT diameter showed the better correlation and good agreement with intraoperative sizing in the Bland-Altman analysis as shown in table 2.

Technique	Mean diameter (mm) ± SD	p-value for difference between means	Correlation	p-value for correlation	mean of difference	Limits of agreement
TTE systolic	25.4 ± 4.1	0.004	0.88	<0.001	-1.10	-3.1-1.9
TTE diastolic	23.5 ± 3.9	<0.001	0.79	<0.001	1.78	-4.5-2.4
CTmax	32.2 ± 3.5	0.02	0.92	<0.001	2.23	-4.1-3.1
CTmin	18.1 ± 2.2	0.01	0.83	<0.001	-3.34	-3.9-2.2
CTeffective	25.1± 3.0	0.004	0.86	<0.001	-0.96	-4.7-2.3
Intraoperative	25.4 ± 4.1					

Table 2: *Comparison of the three imaging techniques to intraoperative direct sizing.*

As the end-systolic TTE measurement and effective CT diameter correlated better with the intraoperative sizing, we further compared these two parameters with each other. The Bland Altman analysis showed a mean difference of -1.10 mm (range -3.1-1.9 mm) with a limit of agreement of -4.7 to 2.3 mm for TTE systolic vs intraoperative and a mean difference of -0.96 mm (range: -3.5 to 4.4) with a limit of agreement of -3.0 to 1.9 mm for CT effective vs intraoperative diameter. Bland Altman analysis showed the TTE diastolic measurement was undersized as compared to the intraoperative measurement and the CT effective diameter correlated best with the intraoperative measurements even as compared to the TTE systolic diameter.

Discussion

Optimal valve sizing is important in surgical aortic valve replacement. Even the aortic annulus is measured by different non-invasive diagnostic modalities, intraoperative sizing serves as the direct and appropriate sizing for valve replacement. Annular under sizing may give rise to complications like paravalvular leak, leaflet dysfunction, worsened hemodynamics, or possible patient-prosthesis mismatch and significant annular oversizing may result in inability to seat the valve, annular rupture or coronary obstruction [14]. These possible complications urge the appropriate intraoperative valvular sizing.

The aortic annulus (defined as the basal hinge points where the three cusps are attached-nadirs) is not circular in all patients, but oval shaped in various configurations [15]. The routinely performed echocardiography has disadvantage of being in two-dimensional view which might lead to underestimation of the true aortic annulus diameter, especially in patients with oval-shaped annulus. In such cases, 3D echocardiography or CT scan becomes a useful indicator to estimate the appropriate intraoperative valve sizing which provides a three-dimensional view to the aortic annulus and facilitates visualization of the annular plane and its configuration (circular-oval). In a previous study, it was found that the preoperative CT scan does not seem to negatively affect postoperative renal function [16]. In view of the non-uniformity of aortic annulus, the effective diameter measurement becomes more meaningful and precise in determining the required aortic annulus [17].

In this study, we compared the preoperative 2D echocardiography and CT scan aortic annulus measurements with the annulus of aortic valve implanted intraoperatively. We found the end-diastolic echocardiographic measurements as well as the minimum, maximum and mean CT diameter showed no sufficient agreement to intraoperative sizing (mean differences -1.1). The end-systolic echocardiographic diameter demonstrated sufficient agreement to intraoperative sizing with better limits of agreement in the Bland-Altman analysis. The effective diameter calculated from the circumferential area in CT scan ('effective') showed the best agreement to intraoperative sizing and the strongest correlation. Also, the annulus of implanted valves correlated better with the CT effective diameter measured preoperatively. On comparison between the systolic diameter on echocardiography and CT scan effective diameter, we found CT effective diameter correlated better with intraoperative valve sizing. Thus, annular diameter assessment and subsequent surgically implanted prosthesis size selection seemed to be the most accurate when based on 'effective' CT-based measurements, which might result in improved outcome in regard to valve performance and avoidance of complications. Similar results were found in the study of Kemfert J., *et al* [18]. Willmann and colleagues [19] demonstrated good agreement aortic annulus assessment in CT and measurement during aortic valve replacement by comparing only plane view of aortic annulus in CT, formally equal to measurements with TEE with the intraoperative data. Wiseth., *et al*. studied 34 patients and found a strong correlation between 2D echo measurements and intraoperative sizing (r = 0.88), with small underestimation by TTE (limits of agreement, -0.9 to -2.0 mm) [20].

For the purpose of surgical AVR, the conflicting results of different imaging modalities does not matter significantly, since sizing is performed intraoperatively directly. Even with the lesser degree of correlation, standard echocardiography remains the first and, in the majority of cases, the only necessary imaging modality in the assessment of aortic valve disease. The measurement of annulus size intraoperatively after decalcification and excision of the valve may be the cause of discrepancy between the preoperative and intraoperative measurements, which might be the limitation of our study. As the CT scan measurements correlating better, further the 3-dimensional printing to aid intraoperative planning may become possibly more widespread in assessment of valve anatomy, sizing, orientation, and other difficulties associated with Surgical AVR.

Conclusion

Both the 'effective' CT diameter and end-systolic TTE (transthoracic echocardiography) diameter can be considered as reliable measurement techniques for preoperative estimation of aortic annulus size and the later correlates better with the surgical 'gold-standard' intraoperative direct sizing. Therefore, aortic annulus measurement using the 'effective' CT diameter should be included into routine practice for aortic valve replacement, which can give an idea of choosing the appropriate prosthesis so that the complications due to improper prosthesis can be avoided.

Conflict of Interest

None declared.

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