Original Article

AORTIC ANNULUS DIAMETER ON ECHOCARDIOGRAPHY AND COMPUTED TOMOGRAPHY ANGIOGRAPHY COMPARED WITH PER OPERATIVE DIAMETER

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ABSTRACT:

BACKGROUND AND OBJECTIVE: In patients undergoing Aortic valve replacement, an important consideration is measurement of aortic valve diameter which can be measured pre-operatively using Echocardiography or CT angiography but is confirmed per-operatively. The objective of this study was to determine the mean difference of aortic annulus diameter measured on echocardiography and CT Angiography from per operative measurement of the same.

METHODS: This was a cross sectional study conducted at Punjab Institute Of Cardiology, Lahore from March to August, 2013. Patients undergoing AVR were selected from outpatient, inpatient and emergency departments. Aortic annulus diameter was measured separately by using Echocardiography and computed tomographic angiography and both were compared with per-operative diameter. The mean differences of both pre-operative measurements from the per-operative measurement were noted.

RESULTS: Thirty patients were studied out of which 20 (66 %) patients were male. Mean age was 28.93 years. The mean aortic annulus diameter on echocardiography and Cardiac CT was 21.93 mm and 23.36 mm respectively whereas the mean diameter of the aortic annulus per operatively was 23.27 mm. The mean aortic diameter on Echocardiography differed from per operative measurement by 1.33 mm and that on CT Angiography differed by 0.093 mm.

CONCLUSION: The aortic annulus diameter measured on cardiac CT was closer to the intra-operative sizing as compared to Echo derived annular diameter.

KEY WORDS: Aortic annulus diameter , Echocardiography , CT Angiography, Cardiac CT.

INTRODUCTION

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Abnormalities of aortic valve are among the commonest cardiac valvular problems. Around one fourth of individuals suffer aortic valve sclerosis among those who are older than 65 years and prevalence of aortic stenosis in the same age group is between 2 and 9%.[1] Aortic valve involvement is commonly of congenital, rheumatic and degenerative origin.[1]

The aortic annulus is a structure made of fibers that connect the aortic root to the left ventricle. Aortic annulus is attached to the myocardium in 50% of its circumference. The shape of aortic annulus is scalloped.[2] The fitting position of prosthetic valve sizers is determined by the aortic annulus and therefore, pre-operative determination of annulus is routinely done.[3]

To determine the pre operative echocardiographic diameter of Aortic annulus is a common practice. Terrible intra-opertaive complications, such as embolization of valve, annulus rupture and para-valvular leak can be encountered due to incorrect measurement of the aortic annulus. After gaining more experience with transcatheter aortic valve implantation (TAVI) and preoperative imaging, it became obvious that echocardiography might be misleading due to its limitation of two-dimensional imaging only, whereas some individuals may have an oval-shaped annulus. Computed tomography (CT) is the more sophisticated imaging modality as it allows the three dimensional assessments. [4-7]

CT imaging has gained key role in aortic valve replacement (AVR) surgery, because accurate measurement of aortic annulus sizes preoperatively is pivotal for selection of proper prosthesis sizes.[8]

A considerable workup is required before the implantation of valve to determine artic root for the sizing of the valve. The accurate evaluation of the aortic annulus diameter is done with

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CT Angiography.[4] The aortic annulus diameter determination with CT Angiography gives adequate dimensions similar to that of per-operative measurements.[9] According to a recent study, to improve the outcome and safety of upcoming AVR procedures aortic annulus determination using CT Angiography should be included into regular protocol. [10]

In study, mean difference for transthoracic echocardiography (TTE) from intraoperative was 0.38 mm and that of CT from intraoperative value was -0.56.[11]

Cross-sectional CT parameters have been shown to have the highest discriminatory value for post-TAVR paravalvular regurgitation and traditional echocardiographic measures were nondiscriminatory in this regard.[11] The outcome variable is the mean difference of aortic annulus sizing by echocardiography and CT Angiography taking per operative dimension as reference.

The shape of the annulus is crown like and extends to the level of the aortic sinuses. It connects to ventricular septum anteriorly.[12] Underestimation of the aortic annulus diameter is one of the drawbacks of two dimensional transthoracic echocardiography. Aortic annulus diameter assessment from CT provides adequate assessment similar to operative findings.[10]

A few studies showed that in several patients the shape of aortic annulus is not circular but in fact oval shaped which can be the major cause of failure to evaluate Aortic Annulus accurately in a single image plane.[13]

MATERIALS AND METHODS

This was a cross sectional study, conducted at outpatient, inpatient and emergency departments of Punjab Institute Of Cardiology, Lahore from 6-03-2013 to 6-09-2013. The study included 30 patients with indication for aortic valve replacement .Non probability purposive sampling technique was used. Both male and female patients with age > 16 years & < than 70 years were enrolled. The patients excluded from the study were those who had impaired renal functions, allergy to contrast, atrial fibrillation, BMI of > 30 kg/m^2 and could not hold breath. The aortic annulus was measured in parasternal long axis view by Transthoracic Echocardiography. The distance between the hinge points of aortic valve leaflets including all calcification was measured in a two dimensional zoomed up view. The most caudal attachment of aortic valve in the double oblique transverse view was defined as the aortic annulus on CT Angiography. Per operatively, the Aortic valve was excised. After excision the decalcified aortic annulus was measured using metric sizers.

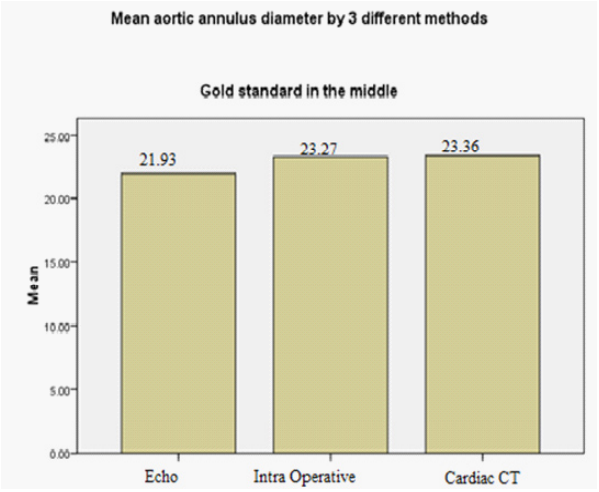
Echocardiographic, CT angiographic and per-operative diameters of aortic annulus for each patient were recorded on a data sheet. Echocardiographic and CT angiographic diameters of aortic annulus were compared with per-operative diameter and difference was noted.

Data was analyzed using SPSS Version 11.0. Quantitative data like age, aortic annulus diameter on echocardiography , CT Angiography and per operatively was presented as mean $\pm$ S.D . Qualitative variable like gender was presented in the form of frequency and percentage. The mean difference of Echocardiographic and CT angiographic aortic annulus diameter from per-operative was calculated by subtracting per operative measurement from that on echocardiography and CT Angiography and mean $\pm$ S.D was calculated for these mean differences of aortic annulus diameter.

RESULTS

Out of the 30 patients studied, 20 (66 %) patients were male & 10 (33%) were female. Mean age was 28.93 years and the age range was 18-47 years. Out of 30 patients, 24 (80 %) patients presented with the complaint of Shortness of breath (SOB), 4 (13.3%) patients presented with palpitations and 2 (6.66%) patients presented with chest pain.

The mean of aortic annulus diameter on echocardiography was 21.93 mm and the range was 18-29mm .The mean aortic annulus diameter on CT Angiography was 23.36 mm and the range was 19-29 mm .The mean diameter of the aortic annulus per operatively was 23.27 mm, while range was 19-29 mm. The mean aor-



tic diameters by three methods are compared in Figure 1.

The mean difference of Echocardiography from per operative measurement was 1.33 mm and the mean difference of CT Angiography was 0.093 mm. The mean aortic annulus diameter on CT Angiography was thus closer to the intra-operative sizing.

DISCUSSION

This single centre study showed that Cardiac CT is more reliable than Echocardiography for predicting the size of aortic valve prosthesis that will be used while doing aortic valve replacement surgery. The choice of prosthesis size during AVR is based on intra-operative direct sizing of the aortic annulus, whereas determination for aortic annulus diameter is based on imaging techniques. Inaccurate valve sizing might lead to deleterious outcomes. The small valve selection may lead to severe para-valvular leak or valve embolization. [14,15] On the other hand, annular rupture can occur with selection of larger prosthetic valve [10]. These serious complications demand for more accurate preoperative imaging methods. On the other hand, the annulus (defined as the basal hinge points where the three cusps are attached) is not circular in all individuals; it can be oval in configuration.[4,7,8,16]

A disadvantage of echocardiography is the two-dimensional view which may lead to underestimation of the aortic annulus diameter , particularly in patients with a pronounced oval-shaped annulus.

The comparison of two imaging techniques (TTE and Cardiac CT) with direct intra-operative sizing is given in the present study. The systolic transthoracic echocardiographic diameter, routinely used for AVR patient screening, showed minor difference of aortic annulus diameter as compared to aortic annulus diameter measured intra-operatively. The diameter calculated by CT scan showed even less difference from the intra-operative sizing. Therefore, aortic annulus measurement using the CT imaging should be included in routine practice for AVR procedures, which can lead to improvement in the outcomes of this procedure.[6,17] There may be concern about use of contrast in Cardiac CT but it is shown that preoperative CT scan does not affect postoperative renal function [18].

The CT scan provides a three-dimensional view for the aortic annulus and facilitates assessment of the annular configuration.[2] An accurate assessment is provided with the application of the diameter based on the area. [6,17]

Parasternal long-axis aortic valve view is used to measure the aortic annulus dimension in two dimensional Echocardiographic study. The Echocardiographic projection of the long-axis view of aortic valve can show the coronet-shaped aortic annulus within the sinus as the hinge points of the visible leaflets , giving the clinician the false impression of having annulus measurement. Thus, single plane echocardiography is not appropriate to evaluate the basal annular ring[10,19] Both transthoracic and transoesophageal two-dimensional echocardiography can determine the shorter diameter of the oval aortic annulus . There is growing and worthwhile data on prosthesis sizing in TAVR given by CT and integrating CT-derived measurements of the aortic annulus may improve outcome of the procedure. It is therefore well accepted that 3D imaging technique of CT, gives more precise and accurate aortic annulus dimensions than echocardiography.

In one study, the predicted aortic annulus measurement , derived from transthoracic echocardiography & multidetector computed tomography were compared with that measured at surgery and it was found that predicted aortic annulus diameter measured by multidetector computed tomography agreed best with that measured at surgery.[20]

For TAVR preparation , measurements of aortic annulus diameter done with calibrated aortic angiography, transthoracic echocardiography (TTE), or transesophageal echocardiography (TEE) was evaluated and discordance between these measurements was commonly encountered .[21,22]

Measurement of aortic annulus with two-dimensional echocardiography is shorter in diameter when aortic annulus is oval. This is the reason for the inaccurate Echocardiographic evaluation in the two-dimensional view. The TTE Parasternal long axis view and the midesophageal long-axis view on TEE are equivalent to the single oblique sagittal view on CT Angiography.[4]

Therefore, TTE views are less accurate and will result in underestimation when compared with the three-dimensional view of the annular plane. So, AVR surgery preceded by aortic annular assessment with cardiac CT may result in improved outcome in valve performance and prevention of complications. Due to the complex 3-dimensional anatomy and elliptical shape of the aortic annulus, the echo and CT dimensions of aortic annulus were close but not identical. Thus, cardiac CT is superior among the available modalities for measurement

of aortic annulus diameter. This superiority of MDCT has made it "gold standard" for preoperative evaluation of the aortic root and annulus prior to transcatheter aortic valve implantation. [5,6,7,4,9,10,13,17,22-24]

In conclusion, findings of the present study indicate that in patients undergoing AVR, the CT derived aortic annulus diameter is more accurate. Therefore, aortic annulus measurement using multidetector cardiac CT should be included in routine pre-operative evaluation of patients undergoing AVR and this approach may improve the outcome and safety of upcoming AVR procedures.

Author's Contribution

SK: Conducted the study and collected the data. SK : Wrote the article. SYH: Helped in proof reading of the article.BM: Analysis of data and its interpretation SY & BM: Re-arranged data and corrected article. SK: Tables and figures. SK & AMA: Consultant incharge of the study and corrected article and did proof reading.

REFERENCES

1)Faggiano P, Antonini-Canterin F, Baldessin F, Lorusso R, D'Aloia A, Cas LD. Epidemiology and cardiovascular risk factors of aortic stenosis. Cardiovasc Ultrasound. 2006;4:27. Published 2006 Jul 1. doi:10.1186/1476-7120-4-27

2)Kim H, Bergman R, Matyal R, Khabbaz KR, Mahmood F. Three-dimensional echocardiography and en face views of the aortic valve: technical communication. J Cardiothorac Vasc Anesth. Apr 2013;27(2):376-80.

3)Sutton JP, 3rd, Ho SY, Anderson RH. The forgotten interleaflet triangles: a review of the surgical anatomy of the aortic valve. Ann Thorac Surg 1995;59:419-27

4)Tops LF, Wood DA, Delgado V, Schuijf JD, Mayo JR, Pasupati S et al. Noninvasive evaluation of the aortic root with multislice computed tomography implications for transcatheter aortic valve replacement. JACC Cardiovasc Imaging 2008; 1:321-30

5)Wood DA, Tops LF, Mayo JR, Pasupati S, Schalij MJ, Humphries K et al.Role of multislice computed tomography in transcatheter aortic valve replacement. Am J Cardiol 2009; 103:1295–301.

6)Schultz CJ, Moelker A, Piazza N, Tzikas A, Otten A, Nuis RJ et al. Three dimensional evaluation of the aortic annulus using multislice computer Tomography: are manufacturer's guidelines for sizing for percutaneous aortic valve replacement helpful. Eur Heart J 2010; 31:849-56

7)Piazza N, de Jaegere P, Schultz C, Becker AE, Serruys PW, Anderson Anatomy of the aortic valvar complex and its implications for transcatheter implantation of the aortic valve. Circ Cardiovasc Interv 2008;1:74–81.

8)Doddamani S, Grushko M, Makaryus A, Jain V, Bello R, Friedman M, Ostfeld R, Malhotra D, Boxt L, Haramati L, Spevack D. Demonstration of left ventricular outflow tract eccentricity by 64-slice multi-detector CT. Int J Cardiovasc Imaging 2009; 25: 175–181.

9)Dashkevich A, Blanke P, Siepe M, Pache G , Langer M, Schlensak C, MD, Beyersdorf F . Preoperative Assessment of Aortic Annulus Dimensions: Comparison of Noninvasive and Intraoperative Measurement. Ann Thorac Surg 2011;91:709-714.

10) Kempfert J , Linden A V,Lehmkuhl L , Rastan J A , Holzhey D , Blumenstein J , Mohr F W & Waither T . Aortic annulus sizing: echocardiographic vs. computed tomography derived measurements in comparison with direct surgical sizing. Eur J Cardio Thora surg adv acc 2012; 1:1-7

11) Jilaihawi A, , Kashif M, Fontana G , Furugen A, Shiota T, Friede G, Makhija R, Niraj , Martin B. Leon, and Raj R. Makkar. Cross-Sectional Computed Tomographic Assessment Improves Accuracy of Aortic Annular Sizing for Transcatheter Aortic Valve Replacement and Reduces the Incidence of Paravalvular Aortic Regurgitation. J Am Coll Cardiol 2012; 59: A17-A20

12)Hamdan A, Guetta V, Konen E, Goitein O, Segev A, Raanani E, et al. Deformation dynamics and mechanical properties of the aortic annulus by 4-dimensional computed tomography: insights into the functional anatomy of the aortic valve complex and implications for transcatheter aortic valve therapy. J Am Coll Cardiol. Jan 10 2012;59(2):119-27.

13)Messika-Zeitoun D, Serfaty JM, Brochet E, Ducrocq G, Lepage L, Detaint D, Hyafil F, Himbert D, Pasi N, Laissy JP, Iung B, Vahanian A: Multimodal assessment of the aortic annulus diameter: implications for transcatheter aortic valve implantation. J Am Coll Cardiol 2010, 55:186-194.

14)Astarci P, Desiron Q, Glineur D, El Khoury G. Transapical explantation of
an embolized transcatheter valve. Interact Cardiovasc Thorac Surg 2011;13:1–2.

15)Tay EL, Gurvitch R, Wijeysinghe N, Nietlispach F, Leipsic J, Wood DA et al. Outcome of patients after transcath-

eter aortic valve embolization. JACC Cardiovasc Interv 2011;4:228–34
16)Van Linden A, Kempfert J, Rastan AJ, Holzhey D, Blumenstein J, Schuler G et al. Risk of acute kidney injury after minimally invasive transapical aortic valve implantation in 270 patients. Eur J Cardiothorac Surg 2011; 39: 835–42.
17)Blanke P, Siepe M, Reinohl J, Zehender M, Beyersdorf F, Schlensak C et al. Assessment of aortic annulus dimensions for Edwards SAPIEN Transapical Heart Valve implantation by computed tomography: calculating average diameter using a virtual ring method. Eur J Cardiothorac Surg 2010;38:750–8.
18)Van Linden A, Kempfert J, Rastan AJ, Holzhey D, Blumenstein J, Schuler G et al. Risk of acute kidney injury after minimally invasive transapical aortic valve implantation in 270 patients. Eur J Cardiothorac Surg 2011; 39: 835–42.
19) Wahab M, Zahn R, Horack M et al. German Transcatheter Aortic Valve Interventions Registry Investigators. Aortic Regurgitation after TAVI: Incidence and Early Outcome. Heart 2011;97:899-906
20)M .Yano, K Nakamura, H Nagahama, M Matsuyama , M Nishimura, T Onitsuka . Aortic annulus diameter measurement: what is the best modality? Ann Thorac Cardiovasc Surg. 2012;18(2):115-20.
21)Altiok E, Koos R, Schr€oder J, Brehmer K, Hamada S, Becker M, Mahnken AH, Almalla M, Dohmen G, Autschbach R, Marx N, Hoffmann R: Comparison of two-dimensional and three-dimensional imaging techniques for measurement of aortic annulus diameters before transcatheter aortic valve implantation. Heart. 2011;97:1578–84.
22)Gurvitch R, Webb JG, Yuan R, Johnson M, Hague C, Willson AB, Toggweiler S, Wood DA, Ye J, Moss R, Thompson CR, Achenbach S, Min JK, Labounty TM, Cury R, Leipsic J: Aortic annulus diameter determination by multidetector computed tomography: reproducibility, applicability, and implications for transcatheter aortic valve implantation. JACC Cardiovasc Interv. 2011;4:1235–45.
23)Willson AB, Webb JG, Labounty TM, Achenbach S, Moss R, Wheeler M et al. 3-dimensional aortic annular assessment by multidetector computed tomography predicts moderate or severe paravalvular regurgitation after transcatheter aortic valve replacement: a multicenter retrospective analysis. J Am Coll Cardiol. 2012; 59(14):1287-1294.
24)Leipsic J, Gurvitch R, Labounty TM, Min JK, Wood D, Johnson M et al. Multidetector computed tomography in transcatheter aortic valve implantation. JACC Cardiovasc Imaging 2011;4:416-29.

Corrigendum

In previous issue (J Cardiovasc Dis 2018;14(3):58 - 63) of the journal, the introduction of Dr Amna Kamran, as author , on page 58 is corrected as under:

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