RESEARCH ARTICLE

Study of aortic valve using multi slice computed tomography in patients presenting with chest pain

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Abstract

Objective: To determine aortic root dimensions in younger patients presenting with chest pain.

Method: The descriptive cross-sectional study was conducted at the Armed Forces Institute of Cardiology and the National Institute of Heart Diseases, Rawalpindi, Pakistan, from September 12, 2018, to March 11, 2019, and comprised patients of either gender aged 18-55 years presenting with chest pain falling into Canadian Cardiovascular Society class I-IV and dyspnoea falling into New York Heart Association class I-IV. Multi-slice computed tomography image acquisition was performed in a single breath-hold of about 5-10 seconds, while electrocardiogram gated synchronised data acquisition was done with 60-100ml contrast. Multiphase data-sets were reconstructed followed by data analysis. Required measurements were recorded with software caliper and tracer. Data was analysed using SPSS 23.

Results: Of the 330 patients, 236(71.5%) were males and 94(28.5%) were females. The overall mean age was 45.5±7.9 years. Bicuspid aortic valve was found in 3(0.9%) patients, while 327(99.1%) were tricuspid. Mean aortic valve area was 4.01±0.70cm^2, mean aortic annular size was 21.9±2.37mm, sinotubular junction diameter was 23.9±3.45mm, and mean sinotubular junction height was 21.09±2.77mm. The mean diameter at sinuses of valsalva was 33.0±3.99mm.

Conclusion: Mean aortic root dimensions and general morphology of the aortic valve was determined to establish normal reference values.

Keywords: Multi-slice computed tomography, MSCT, Aortic valve, Aortic root, Trans-catheter aortic valve replacement, TAVR. (JPMA 71: 2151; 2021)

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Introduction

In recent times we are observing an increase in the influx of younger patients at cardiology centres with the chief complaint being that of chest pain. Many of them are evaluated using non-invasive methods, such as multi-slice computed tomography (MSCT), which reliably determines the presence or otherwise of coronary artery disease (CAD) in low-probability patients. The use of MSCT also enables us to look for any other structural or functional abnormality of the heart and the lungs, that might be causing symptoms of chest pain or dyspnoea.[1]

MSCT is capable of providing three-dimensional (3D) views with better spatial resolution, rendering valuable information and reliability[2] excluding patients with moderate to severe aortic stenosis (AS).[3]

In recent years, a rise has been observed in cases with bicuspid aortic valve in Pakistan.[4] Moreover, in patients with stenosis of aortic valve, where aortic valve replacement was being done traditionally, is now being replaced by transcatheter aortic valve replacement (TAVR) in cases where surgery is not feasible.[5] TAVR has come out as an advanced modality for the management of severe AS and recently a lot of progress on it is seen in Pakistan as well. MSCT is the most comprehensive non-invasive imaging modality to evaluate candidacy for TAVR.[6]

It is capable of providing authentic information on anatomical aspects of the valve, aortic root and surrounding structures, such as coronaries, aorta and peripheral arterial vessels for alternative access.[7] It has been depicted in two of the studies that MSCT preferably with electrocardiogram (ECG) gating happens to be more practical and more reliable as a cover-all way for determining the cause of both typical and atypical chest pain in patients presenting in emergency rooms (ERs) and are rather stable.[8] In patients with suspected acute coronary syndromes (ACSs), MSCT can be valuable for triaging and initial diagnoses.[9] American College of Cardiology (ACC) and American Heart Association (AHA) guidelines for ACS and stable ischaemic heart disease (IHD) shed light on the role of MSCT in testing and risk stratifying low-probability/low-risk patients presenting

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with chest pain.[10]

As the aortic root is inherently moving, ECG gating while acquiring images during scan is mandatory to derive an image which is not distorted by the movement of artifacts and is of top quality. In addition, it helps in ascertaining different aortic root parameters that can be measured accurately during different phases i.e., either systole or diastole.[11] Moreover, we can limit the amount of intravenous (IV) contrast material by reducing the limit of structures observed and minimising the time for image procurement.[12]

MSCT is commonly performed for chest pain evaluation in younger subgroup of patients aged <55 years.[13]

In Pakistan, little contemporary data is available regarding the normal morphology and delineation of the parameters of the aortic valve. The current study was planned to evaluate the parameters related to aortic root and valve in the general population with the aim of ascertaining standard parameters of the root of aorta and its connection to the cardiac symptoms.

Patients and Methods

The descriptive cross-sectional study was conducted at CT Angiography Department of the Armed Forces Institute of Cardiology (AFIC) and the National Institute of Heart Diseases (NIHD), Rawalpindi, Pakistan, from September 12, 2018, to March 11, 2019, after getting ERB approval. Initially, a pilot study was done to determine the prevalence of outcome variables, as no similar study had been done in our population previously where bicuspid aortic valve was found in 1 (2%) patients and tricuspid in 44(98%). In addition, 31(68.8%) patients had zero calcium score, while 6(12.5%) had calcium involving valve cusps and 8(18.8%) had calcific commissures. The mean aortic valve area was 3.1±0.9cm^2, mean aortic annular size was 23±2.5cm^2, mean sinotubular junction diameter was 24±2.7mm, and mean sinotubular junction height was 17.0±2.2mm. The diameter at sinuses of valsalva was 31.8±3.4mm (unpublished data).

For the main study, the sample size was estimated by using the Cochran's formula 14, and the sample was raised using consecutive non-random sampling method from among the subjects who came for non-invasive evaluation of chest pain. Those included were patients of either gender aged 18-55 years presenting with chest pain falling into Canadian Cardiovascular Society (CCS)[14] class I-IV and dyspnoea falling into New York Heart Association (NYHA) class I-IV.[15] Those aged >55 years and <18 years and those with deranged renal function tests (RFTs) i.e., serum urea levels >50mg/dl and serum creatinine levels >1.3mg/dl, were excluded. Selection of subjects was preceded by informed consent. Charges of the tests were borne by hospital administration and not by the patients. MSCT angiography was performed on all the patients who met the inclusion criterion using a 64-slice state-of-the-art CT scanner (Toshiba Aquilion 64) which is known for imaging of any clinical site of the body with fast temporal resolution rendering 64 simultaneous slices of 0.5mm at 350ms revolution and 256 slices in one rotation with 0.5mm slice thickness with 13cm coverage in patient axis direction. Also, it comprises 40% radiation dose reduction and a 70kW high-frequency (HF) generator with 400ms scan speed.

MSCT acquisition was performed in a single breath-hold of about 5-10 seconds, retrospective ECG gated synchronised data acquisition with contrast about 60-100mL. Multiphase data-sets were reconstructed at each 10% of the R-R interval or at 20-35% and 75% after the R wave; systolic and diastolic phase, respectively.

Image analysis started with the reconstruction of a coronal and a single-oblique sagittal view of the aortic root. When both views were correctly oriented, it led to the achievement of double-oblique transverse view at the aortic valve level.

Required measurements were taken using Copyright Vitrea software calipers and tracers. Aortic annular size, diameter of sinotubular junction, diameter of the sinuses of valsalva and height of sinotubular junction were recorded by making use of the caliper. All measurements were preferably taken in the systolic phase (30%). The cuspidity of the aortic valve was determined. Calcification was noted at the sinuses, commissures or cusps of aortic valve. Aortic valve area was calculated by the planimetry method using Vitrea software during the systolic phase in the coronal plane where the maximal opening of aortic valve cusps was seen.

In addition to the above-mentioned indices, the extent of CAD was determined after analysing the coronaries in different phases. The particulars and results of MSCT angiography were recorded in a predesigned proforma.

Data was analysed using SPSS 23. Mean and standard deviation (SD) were calculated for continuous variables, like aortic annular size, height and diameter of sinotubular junction, sinuses of valsalva diameter and aortic valve area. Frequencies and percentages were calculated for qualitative variables, as Aortic valve cuspidity and distribution of calcium and extent of disease in the coronaries. The means of different parameters were

compared with respect to gender using independent sample t-test prior to which the data was checked for normality using Shapiro-Wilk test and it was found to be normally distributed as both skewness and kurtosis were within range. P<0.05 was taken as significant.

Results

Of the 330 patients, 236(71.5%) were males and 94(28.5%) were females. The overall mean age was 45.5±7.9 years (range: 24-55 years). Bicuspid aortic valve was found in 3(0.9%) patients, while 327(99.1%) were tricuspid. Of the 3(0/9%) patients having bicuspid aortic valve, 2(0.6%) were males and 1(0.3%) was female.

The valves of 319(96.7%) patients were non-calcific, while 1(0.3%) patient had calcium over the cusps. Also, 3(0.9%) patients had calcium deposition over commissures. Calcium over sinuses was seen deposited in 5(1.5%) cases. Calcium was seen at more than one place in 2(0.6%) cases.

Some level of CAD was detected in 116(35.15%) patients; 87(26.4%) males and 29(8.8%) females.

Mean aortic valve area was 4.01±0.70cm^2, mean aortic annular size was 21.9±2.37mm, sinotubular junction diameter was 23.9±3.45mm, and mean sinotubular junction height was 21.09±2.77mm. The mean diameter at sinuses of valsalva was 33.0±3.99mm (Table-1).

Mean diameters of aortic annulus, sinotubular junction and sinuses of valsalva were smaller in females compared to the males and also, the height of sinuses was lower and mean valve area was smaller in females compared to the males (Table-2).

Discussion

The current study elaborated the aortic diameters in our population and compared differences related to genders.[16] It also studied the presence and extent of CAD in the population. Similar studies were conducted in South Korean[17] and American population.[18] Little contemporary data was available on the matter in South Asia. As such, the current study also aimed at determining reference values for our population.

In view of that, a relatively larger population of 330 patients was selected, and the average of the measured parameters adequately show the true mean value and our belief is also strengthened by the fact that ECG gated multi-slice imaging was used to establish the values.

Aortic valve dimensions when measured using MSCT were found to be more precise and accurate compared to other imaging modalities.[19]

Also, with the advent of TAVR, the utility of MSCT in the evaluation of aortic root, and ascending and descending aorta, has further gained importance. It is critical for the accurate approximation of dimensions that can ultimately be helping in establishing the feasibility and practicality of the procedure. From the access site to valve deployment, the whole procedure depends upon the data derived from MSCT.[20]

Precise evaluation and analysis of the aortic root is vital for appropriate selection of prosthetic valve size and type to avoid unfavourable results, including valve damage.[21] These measurements have been conventionally performed by using 2D transthoracic echocardiography (TTE), angiogram of aorta, or trans-oesophageal echocardiography (TOE). But variance was observed between these measurements. Restrictions of these 2D modalities results from the fact that the annulus has an elliptical, rather than a spherical morphology.[22] The 2D echocardiography, whether transthoracic or

Table-1: Aortic root dimensions determined using 64-slice computed tomography (CT) scan in Pakistani population.

Aortic parameters	Aortic Annulus Diameter (mm)	Diameter of sinotubular junction (mm)	Diameter of sinuses of Valsalva (mm)	Height of sinotubular junction (mm)	Aortic Valve Area (cm^2)
Minimum	17.1	16.8	20.1	14.5	2.2
Maximum	32.5	38.1	47.5	33.1	7.4
Mean	21.9	23.9	33.0	21.0	4.0
Standard Deviation	2.37	3.45	3.99	2.77	0.70

Table-2: Determination of differences in aortic root dimensions based on gender.

Aortic root parameters	Males Mean±SD	Females Mean±SD	p value
Aortic Annulus Diameter (mm)	22.5±2.26	20.5±1.99	<0.001
Diameter of sinotubular junction (mm)	24.5±3.3	22.4±3.17	<0.001
Diameter of sinuses of Valsalva (mm)	33.9±3.94	30.7±3.18	<0.001
Height of sinotubular junction (mm)	21.7±2.5	19.3±2.67	<0.001
Aortic Valve Area (cm^2)	4.2±0.66	3.5±.57	<0.001

SD: Standard deviation.

transesophageal, will take a single diameter which is the shorter diameter of the elliptical aortic annulus.[23]

Echocardiography is an operator-dependent modality calculating the annulus diameter as a spherical orifice in comparison to 3D CT reformatting of the ellipsoid annulus with thorough evaluation of its minimum, maximum as well as average diameter. Echocardiography can provide supplementary information regarding the optimal size of the prosthetic device.[24]

Many projections are made use of for morphological evaluation. The coronal and reconstructed single-oblique sagittal views evaluate the morphology of the root of aorta and the alignment of the aortic annulus, valve leaflets and the ostia of coronaries in the systolic and diastolic phases.[25]

A study[5] has extensively elaborated the role of MSCT in establishing the aortic valve dimensions specially pre- and post-procedural assessment.

In addition, there is seen a rise in the diagnosis of bicuspid aortic valve,[26] with or without its associations and complications. MSCT is an ideal modality for evaluating valve anatomy, whether the valve is functionally bicuspid or a true bicuspid valve. Also, it can assist in establishing other known associations, such as aortic coarctation or ascending aortic aneurysms. Furthermore, it is useful for evaluation of any complications, such as aortic dissection or infective endocarditis. All in all, MSCT is an efficacious imaging technique that traverses invariably all areas of diagnoses and therapies pertinent to aortic valve. Its advantages included being comparably cost-effective, widely available, less time-consuming and being non-invasive, while limitations included exposure to excessive radiation. Also, it can be helpful in diagnosing concomitant CAD that can markedly alter patients' therapeutic strategy.[27,28]

The current study observed gender differences in aortic valve parameters, the valve areas and annuli being significantly smaller in females compared to males. Earlier studies[18,19] have shown similar outcomes.

Kazui et al.[29] evaluated the structure of root of aorta in 25 subjects in the absence of aortic root or valve pathology or previous myocardial infarction (MI) utilising 16-slice CT, and reported aortic annulus measurement in the systolic and diastolic phases to be 22.5±2.2mm and 22.1±2.2mm respectively. The results were similar to those of the current study.

Conclusion

The mean aortic root dimensions and general morphology of aortic valve was studied to determine normal reference values, which will later help in therapeutic strategies in patients suffering from aortic valve disease. MSCT was utilised in the assessment of these parameters, which proves to be an excellent rapid diagnostic tool providing detailed and precise assessment in a single examination. It is also beneficial for pre- and post-procedural evaluation of patients undergoing aortic valve procedures, proving great utility in all aspects of aortic valve pathologies.

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Conflict of Interest: None.

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