COMPARISON OF AORTIC VALVE AREA OBTAINED BY CONTINUITY EQUATION AND PLANIMETRY USING INTRAOPERATIVE 2 DIMENSIONAL AND 3 DIMENSIONAL ECHOCARDIOGRAPHY IN AORTIC STENOSIS.

Thesis submitted for the partial fulfilment for the requirement of the Degree of DM (Cardiothoracic and Vascular Anaesthesia)

BY

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DECLARATION

I hereby declare that this thesis titled, **"COMPARISON OF AORTIC VALVE AREA OBTAINED BY CONTINUITY EQUATION AND PLANIMETRY USING INTRAOPERATIVE 2 DIMENSIONAL AND 3 DIMENSIONAL ECHOCARDIOGRAPHY IN AORTIC STENOSIS"** has been prepared by me under the capable supervision and guidance of **Dr. Rupa Sreedhar,** Professor and Head of the Department, Division of Cardiothoracic and Vascular Anesthesiology (CVTA), Sree Chitra Tirunal Institute for Medical Sciences & Technology (SCTIMST), Thiruvananthapuram, Kerala.

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CERTIFICATE

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Dr Prashanth P Bhaskar

CONTENTS

INTRODUCTION

INTRODUCTION

Severe Aortic Stenosis (AS) is defined as a valve area less than 1.0 cm^2 or mean aortic pressure gradient more than 40 mm Hg.[1] However, there are often discrepancies between planimetry, continuity equation-based aortic valve areas (AVA). The accuracy of AVA measured using the continuity equation depends primarily on the precise measurement of the left ventricular outflow tract (LVOT) [2]. Until now, the LVOT area has been calculated as, π (LVOT dimension /2)^2, assuming that LVOT has a circular shape. However, LVOT could actually be elliptical. [3, 4].

The hemodynamic calculations in echocardiography frequently involves measurement of LVOT stroke volume. The shape of LVOT is presumed to be circular for the estimation of cross sectional area. However, many recent studies based on 3D echocardiography have demonstrated that the LVOT shape may be elliptical (other than circular) on many occasions[6, 7]. Because of the differences observed on 2D and 3D echocardiography, the LVOT area –based hemodynamic calculations differ between the modalities. One such example would be the calculation of aortic valve area in patients with aortic stenosis using continuity equation. In cases of patients with coronary artery disease (CAD) and moderate to severe AS, these differences may affect intraoperative clinical decision making (Coronary artery bypass grafting (CABG) + AVR or CABG alone).

Computed tomography (CT) and magnetic resonance imaging (MRI) of the aortic root have established that the shape of LVOT may be circular or elliptical [4,5,9-13].Studies involving 3D Trans Esophageal Echocardiography(TEE) imaging of aortic root have reported that the LVOT may be elliptical in shape having major and minor

axes, rather than being circular in shape as has been presumed conventionally[6,7,].The 3D data allow the generation of an en-face view of the LVOT without any geometric assumptions to delineate the exact contour of LVOT from which the precise Cross Sectional Area(CSA) may be derived . Planimetry of an en-face view may yield a relatively larger LVOT area than estimations based on measurement of minor axis with 2D echocardiography [7]. Hence, 2D echocardiographic measurements result in smallest LVOT area[8], which in turn may overestimate the severity of AS when AVA is measured by continuity equation[14, 15].

Aortic Valve Replacement (AVR) is reasonable for patients with moderate AS who are undergoing other cardiac surgery (II a Class of recommendation) [16]. Hence, accurate estimation of AVA is necessary to take decision regarding the requirement for combined surgery.

The purpose of this intraoperative study is to compare the aortic valve area and LVOT geometry assessed by two dimensional (2D) and three-dimensional (3D) transesophageal echocardiography (TEE) and its impact on evaluating severity of AS.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

NECESSITY FOR ACCUARTE MEASUREMENT OF AVA

Degenerative aortic stenosis (AS) is one of the most common valvular heart diseases in the elderly population requiring valve replacement.[17, 18] The indication for surgery is based on symptoms and the severity of AS.[1] The severity of AS can be assessed by calculating the valve orifice using catheter-based invasive measurements or echocardiography. Transthoracic echocardiography is the currently most used tool as the standard for AS quantification based on the determination of flow-dependent variables and the effective aortic valve area (AVA). Quantification of AS should include measurement by both techniques. The symptomatic status of the patient is also crucial in assessing the necessity for valve surgery. The evaluation of LVOT area with 3D-TEE would be of great importance, especially when patients with AS who have discrepancy regarding the severity of AS assessed using different methods - mean pressure gradient, continuity equation-based AVA, and planimetry based AVA. The patients classified as severe aortic stenosis using 2-dimensional continuity equation-based methods or planimetry could actually be reclassified into moderate AS by 3D-TEE. Hence, the correct assessment of the severity of AS using 3D-TEE might result in

fewer patients being erroneously diagnosed as having severe AS and thus avoiding unnecessary operations or procedures.[8]

HISTORICAL PERSPECTIVE

The severity of AS was originally established by measurements obtained from cardiac catheterization and clinical outcomes based on these measurements.[19-23] Aortic valve area (AVA) was calculated by Gorlin's formula (AVA=cardiac output / heart rate× systolic ejection period ×44.3 × square root of mean gradient). Severe AS was defined by AVA <0.75 cm^2, based on the observation that significant hemodynamic changes occurred when the aortic orifice was less than one-quarter of its normal size.[24] In a study by Braunwald et al, it was found that AS patients with a mean gradient (MG) greater than 50 mm Hg had poor outcomes, and this MG value was considered highly specific in identifying severe AS.[25] Rapaport et al. demonstrated that outcomes were poorer when the AVA was less than 1 cm^2 than when it was more than 1 cm^2.[26]

The measurements for AS severity were extended to echocardiography with the assumption that AVA measured by Doppler and catheterization were equivalent. In general, simultaneously performed cardiac catheterization and echo techniques show a good correlation in AVA measurement.[27-29] AVA measured by catheterization tends to be slightly larger than the Doppler-measured AVA.[30-33]

ECHOCARDIOGRAPHIC VALVULAR MEASUREMENTS AND POTENTIAL LIMITATIONS

Echocardiography identifies aortic valve (AV) anatomy including bicuspid valves, rheumatic valvular disease, and degenerative sclerotic/calcified aortic valves (AVs). The presence of restricted valve mobility and the degree of calcification correlate with the severity of AS. These findings may be obvious in M-mode as well as in two-dimensional (2D) echo. The valve area can be directly measured by planimetry of the cross-sectional area (CSA) in either transthoracic echocardiography (TTE) in the parasternal short-axis, or transesophageal (TEE) in mid-esophageal short-axis views. However, planimetry methods have limitations. Proper measurements require the cross-sectional plane to be perpendicular to the vertical axis of the LVOT at the level of the valve tips during midsystole.[34]

Compared to TTE, TEE provides improved image quality due to close proximity of esophagus and cardiac structures including aortic valve. Also, unlike TTE there is no hindrance due to lung or bony interface between probe and cardiac structures.

In a number of cases, if the valve is heavily calcified, the valve orifice may not be easily measurable. The degree of stenosis is most commonly assessed by Doppler techniques. If the Doppler-based hemodynamic assessment does not correlate with the anatomic findings, the reasons for discrepancy should be determined. The major potential technical sources of errors in echo/Doppler techniques include errors in measurements of LVOT diameter, LVOT VTI, and peak velocity across the AV. (**Table 1**). An accurate measurement of LVOT is crucial in assessing AVA by the continuity equation and is the most common source of error in AVA calculation by 2D.[2] LVOT diameter should be measured at 0.5–1 cm proximal to the lowest hinge point of the aortic cusps. Any errors in LVOT measurement will be squared in the continuity equation, and underestimation of the LVOT will result in a smaller AVA.[35-37]

AS velocity >4 m/s and AVA >1 cm^2
1. Check LVOT diameter measurement and compare with previous studies
2. Check LVOT velocity signal for flow acceleration
3. Calculate indexed AVA when
a. Height is <135 cm (5'5")
b. BSA <1.5 m^2
c. BMI <22
3. Calculate indexed AVA when
a. Height is <135 cm (5'5")
b. BSA <1.5 m^2
c. BMI <22
4. Evaluate AR severity
5. Evaluate for high cardiac output
a. LVOT stroke volume
b. 2D LV EF and stroke volume
Likely causes: high cardiac output state, moderate-to-severe AR, large body size
AS velocity ≤4 m/s and AVA ≤1 cm^2
1. Check LVOT diameter measurement and compare with previous studies
2. Check LVOT velocity signal for distance from valve
3. Calculate indexed AVA when
a. Height <135 cm (5'5")
b. BSA <1.5 m^2
c. BMI <22
4. Evaluate for low transaortic flow volume
a. LVOT stroke volume
b. 2D LV EF and stroke volume
c. MR severity
d. Mitral stenosis
5. When EF <55%
a. Assess degree of valve calcification
b. Consider dobutamine stress echocardiography
Likely causes: low cardiac output state, severe MR, small body size

TABLE 1- Resolution of apparent discrepancies in measures of AS severity

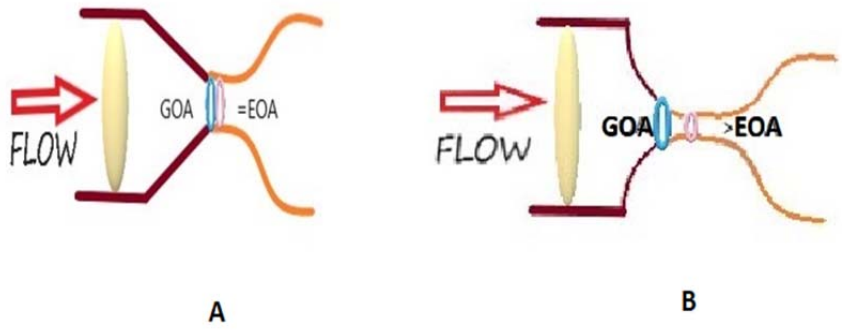
The accurate measurement of LVOT velocity/VTI should be performed by placing the sample volume at the level of the LVOT where its diameter was measured. If the sample volume is too close to the aortic cusps, calculated stroke volume (SV) may be overestimated due to flow acceleration. To obtain maximum peak instantaneous velocity across the aortic valve, the Doppler beam needs to be parallel to the aortic jet.

Contamination of continuous-wave Doppler signal from mitral regurgitation jet may overestimate the severity of AS. Any increase in angulation between the Doppler beam and the aortic jet will result in an underestimation of the jet velocity. When using TTE, the velocity measurements obtained from at least three different views (apical, right parasternal, and suprasternal) are recommended to obtain the highest peak velocity for AS.

Continuity Equation (CE) is a physiological method for valve area estimation based on the law of conservation in hydrodynamics. It is valid in a pulsatile chamber such as heart where the flow is equal through a stenotic valve as well as the left or right outflow tract in a single cardiac cycle. The method was initially used by Skjaerpe et al [27] in 1985 to quantify aortic valve area in cohorts with combined Aortic Stenosis (AS) and Aortic Regurgitation (AR). They tested its reliability in comparison to Gorlin's formula.

The AVA obtained using the continuity equation represents the physiologic effective orifice area (EOA), where the blood flow accelerates and forms the vena contracta. AVA derived from planimetry represents geometric orifice area (GOA). Generally, GOA is always greater than EOA. In the normal aortic valves, the flow jet forming vena contracta occurs adjacent, and downstream to GOA.[38] The ratio of EOA

and GOA is known as the contraction coefficient. The contraction coefficient depends on the three-dimensional shape of the valve leaflets, and it is significantly lower for flat valves compared to doming valves.[39] In severe AS, where the aortic valve plane is relatively flat, the flow jet continues to accelerate and forms vena contracta after it passes through the restrictive orifice (GOA). This phenomenon, therefore, sometimes causes vena contracta-based EOA distal to and smaller than the GOA (**Figure 1**).[40]



F I G U R E 1: Effect of valve shape on geometric orifice area (GOA) and effective orifice area (EOA). With more gradually narrowed orifice, GOA=EOA (A). With more abrupt narrowing and a flatter valve, the flow jet continues to accelerate and contract distal to restrictive orifice causing EOA to be less than GOA (B).

In some patients, baseline echocardiographic measurements obtained may indicate severe stenosis yet they remain asymptomatic.

Exercise stress test may help in unmasking symptoms. Abnormal response to exercise could be due to poor left ventricular contractile reserve, increased transvalvular gradient, and/or increased valvulo-arterial impedance during excersise.[41] In some small studies, an increase in MG of at least 20 mm Hg with exercise predicted poor outcomes in severe AS.[42,43] Additional exercise-related indices predicting poor outcome include abnormal blood pressure response (<20 mm Hg increase), ST-segment abnormalities, and ventricular arrhythmia.[43-46]

Resting pulmonary hypertension (systolic pulmonary arterial pressure >50 mm Hg) in patients with severe AS is not only associated with poor prognosis, [47, 48] but also is an independent predictor of hospital mortality and postoperative major adverse cardiovascular events.[49]

GUIDELINES IN DEFINING AORTIC STENOSIS SEVERITY

Guidelines in defining the severity of AS have continued to evolve over time. In their initial guidelines, the American College of Cardiology (ACC) and the American Heart Association (AHA) recommended that severe AS be defined primarily as AVA ≤1 cm^2.[50] Later, revised 2006 guidelines defined severe AS by MG >40 mm Hg, maximal aortic jet velocity >4 m/s, and AVA <1 cm^2.[1] The European Association of Echocardiography (EAE) and the American Society of Echocardiography

(ASE) agreed with these measures of severity.[2] Subsequently, the European Society of Cardiology (ESC) added aortic valve area index (AVAI) <0.6 cm^2/m^2, and Dimensionless velocity index (DVI) <0.25 to indicate severe AS. Dimensionless velocity index (DVI) is measured as left ventricular outflow tract velocity time integral (LVOT-VTI) to aortic velocity-time integral (VTI) ratio (LVOT VTI/Aortic VTI).[51] The most recent revised AHA/ACC guidelines include MG and maximal velocity as indicative of severe AS and suggest that an AVA of 0.8–1 cm^2 be closely monitored.[2] The three primary hemodynamic parameters indicative of severe AS include (1) AS jet velocity >4 m/s[44,52,53]; (2) MG >40 mm Hg[52,53]; and (3) aortic valve area<1 cm^2, derived either by Gorlin's formula, or planimetry or the continuity equation (AVA=LVOT-CSA×VTI LVOT/VTI AV) (**Table 2**).[22,35-37] These echocardiographic measurements have been validated in the outcome data in several studies.[28,31,54-56] In 2015, the guidelines were updated further to provide the framework for staging AS based on integration of hemodynamics with symptoms (**Table 3**).

	Aortic Sclerosis	Mild	Moderate	Severe
Aortic jet velocity (m/s)	≤2.5 m/s	2.6–2.9 m/s	3–4 m/s	>4 m/s
Mean gradient (mm Hg)	–	<30[a] (<20[b])	30–50[a] (20–40[b])	>50[a] (>40[b])
AVA (cm^2)	–	>1.5	1.0–1.5	<1
Indexed AVA (cm^2/m^2)		>0.85	0.6–0.85	<0.6
Velocity ratio		>0.5	0.25–0.5	<0.25

[a]ESC guidelines.
[b]AHA/ACC guidelines.

TABLE 2 → EAE/ASE guidelines in determining severity of AS.

Stage	Definition	Symptoms
A	At risk of AS	• None
B	Progressive AS	• None
C	Asymptomatic severe AS	
C1	Asymptomatic severe AS	• None: Exercise testing is reasonable to confirm symptoms status
C2	Asymptomatic severe AS with LV dysfunction	• None
D	Symptomatic severe AS	
D1	Symptomatic severe high-gradient AS	• Exertional dyspnea or decreased exercise tolerance • Exertional angina • Exertional syncope or pre-syncope
D2	Symptomatic severe low-flow/low-gradient AS with reduced LVEF	• HF • Angina • Syncope or presyncope
D3	Symptomatic severe low-gradient AS with normal LVEF or paradoxical low-flow severe AS	• HF • Angina • Syncope or presyncope

TABLE 3 → Staging of AS, definition and symptoms

AS- Aortic Stenosis, HF-Heart Failure

THREE-DIMENSIONAL ECHOCARDIOGRAPHY IN AORTIC STENOSIS

Three-dimensional echocardiography can be performed by either the transthoracic approach (3DTTE) or the transesophageal approach (3DTEE) and is valuable in the assessment of patients with AS.[57-61] The 3D data sets can be further cropped to obtain 2D images at any level or angle. 3D echo visualizes the AV surface from both aortic and ventricular aspects. It can also assess valve morphology, thickness, and calcification accurately. 3D TEE correctly identifies AV morphology that is consistent with surgical or pathological findings.[59]

Three-dimensional echo plays an important role in accurately measuring LVOT. AS LVOT could be a non-circular structure, its diameter by 2DTTE measures only the minor axis, resulting in underestimation of the LVOT area.[62,63] An inaccurate assessment of LVOT by 2D echocardiography may also result from annular calcification and poor visualization.[63-65]

Perez de Isla et al. demonstrated that LVOT assessed by 2DTTE is underestimated when compared to real-time 3DTTE.[64] AVA assessment can also be obtained by the continuity equation using LVOT measurements from 3D techniques.

Saitoh et al. demonstrated that AVA derived from the continuity equation as well as LVOT area measured using 2D-TTE were smaller when compared to those measured using 2DTEE, which in turn were smaller than those obtained from 3D-TEE. In their report, AVA obtained from the continuity equation by 3D-TEE correlated well with that obtained using planimetry by 3D-TEE.[6]

Similarly, Jainandunsing et al. demonstrated that AVA calculated from major and minor axes using 3D-TEE agreed well with that obtained using 3D planimetry. Eighteen percent of patients who had been originally classified as having severe AS by the 2D method and had undergone AVR, were reclassified to have moderate AS by 3D-TEE methods.[66] 3D-derived stroke volume (SV) is less angle-dependent and is particularly useful when LVOT geometry is irregular secondary to septal hypertrophy or prominent calcification.[67]

Aortic stenosis measurements by planimetry are directly obtained in 3D-TTE and 3D-TEE. AVA is measured by directly tracing the inner contour of the aortic cusps. This method is useful especially in irregularly shaped orifices or in AVs distorted by adjacent structures such as septal hypertrophy. Planimetry methods have been compared in small studies, demonstrating that 3D-TEE planimetry provides better correlation with AVA derived from catheterization when compared to 2D-TEE.[57,68]

Nakai et al. demonstrated that 3DTEE planimetered AVA correlated well with planimetry-derived AVA from 2DTEE. This result was confirmed by Furukawa et al.[69] Planimetry performed by both 3DTTE and 3DTEE was found to have good agreement (R=0.94).[58]

Khaw et al. demonstrated that planimetric assessment of LVOT and AVA by real-time three-dimensional echocardiography (RT3D) correlated well with assessment using invasive methods, with improved accuracy when compared with 2D-TTE.[70] 3D echocardiography may be especially helpful in accurately measuring LVOT and in obtaining direct planimetry measurements in heavily calcified valves.[70]

According to Utsunomiya et al, using 64 multidetector CT, the LVOT diameter measured by 2D echocardiography corresponded to the minor diameter of the ellipse. Hence, the LVOT cross-sectional area measured by a 2D-echocardiographic diameter derived method significantly underestimated the area when compared to that measured using multidetector CT planimetry.[14]

Recent Advances

The important measurements prior to Trans-catheter Aortic Valve Replacement (TAVR) include annular diameter, height of coronary ostia from the annulus, and the degree of calcification. The most important

aspect of evaluation in patients for TAVR is the accurate measurement of the aortic annulus, which in turn determines the valve size. Annulus anatomy is oval and is reshaped during cardiac systole and after balloon-expandable prosthesis implantation. The annular diameter used for determining prosthetic valve size in TAVR cases is not the anatomic diameter. Instead, it is formed by the lowest part of the hinge points of the aortic cusps as they connect to the wall of the aorta (virtual annulus) (**Figure 2**).[71] Three primary measurements are recommended for annulus assessment: (1) antero-posterior (A-P) diameter, lateral diameter, and the average diameter, (2) planimetry area of the virtual annulus with its corresponding diameter and (3) circumference of the virtual annulus with its corresponding diameter (**Figure 2**). Additional structures requiring assessment include the distance between the aortic valve (AV) and coronary ostia, the width of aortic sinuses, the sino-tubular junction, and the ascending aorta.

Undersizing the prosthesis can result in device migration or significant paravalvular aortic regurgitation. Oversizing predisposes to complications related to vascular access or to difficulties when crossing the native AV. The measurement of LVOT by 2D echo often causes underestimation of the size of the annulus due to the oval shape of LVOT. With 3D-TEE, the precise virtual aortic annulus can be obtained. With

3D TEE, visualization of aortic root and AV anatomy has become clearer with less likelihood of artefact from calcification. So 2D echocardiography is no longer accepted for valve selection in TAVR.

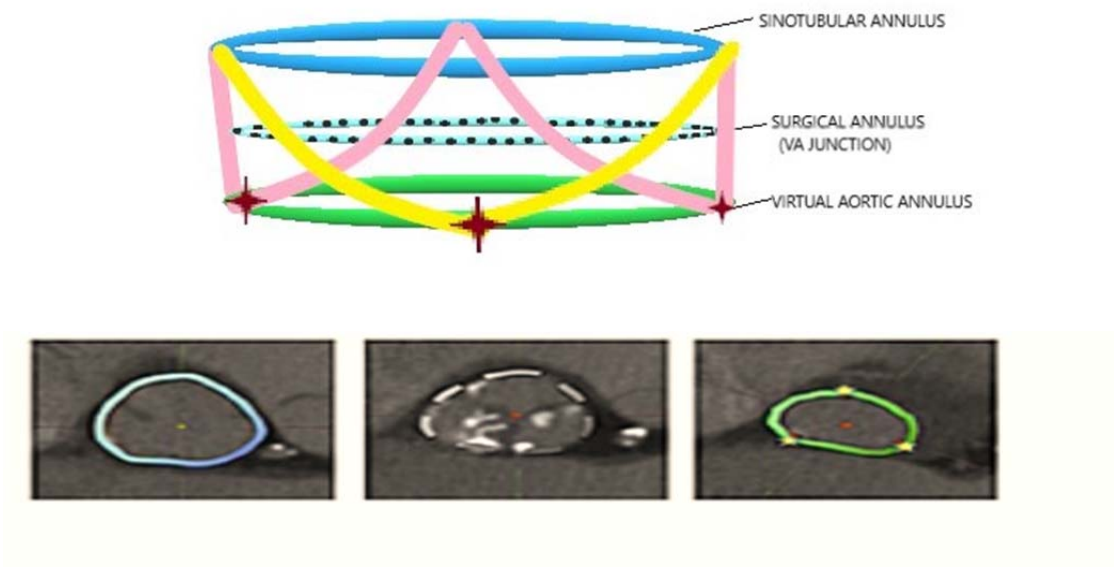


Figure 2 → Anatomy of the aortic root. The aortic root with the aortic valve, which is suspended in a crown like fashion within the root (3 circular rings –Sino tubular junction, surgical annulus and virtual aortic annulus).VA- Ventriculo-Arterial junction.

The accurate assessment of AVA may be difficult in some patients with AS who have a small aorta, subvalvular obstruction, significant aortic regurgitation or depressed left ventricular function.[23, 72-75] The use of reconstructive three-dimensional TEE has provided better results than standard TEE for AVA planimetry. However, this has not been widely adopted, partly because of the time-consuming off-line analysis.

When 3D TTE with matrix array probe was gaining growing interest, 3D TEE was still in infancy with multiplane probe using rotational approach. Earlier 3D TEE probe created images after lengthy acquisition time and processing, and were not free from artefacts. Real time 3D image visualisation was not feasible with early era TEE probes. Real time matrix array technology in 3D TEE (3D MTEE) came into use by 2008.

Normal aortic valve leaflet is having a complex three dimensional shape, which is further complicated in diseased leaflet especially with calcification and with procedures like valvotomy. Such asymmetric leaflets are difficult to profile using any technique which is based on 2D planar assumption. With the evolution of 3D technology, specifically Real Time 3D(RT3D) technology using matrix array probe there was a growing interest to apply this technique for studying the aortic leaflets in AS.

There is scarcity of literature for intraoperative comparison of 3D TEE in AS with other methods. There are only a few prospective studies available in the intra-operative pre-AVR period comparing 3D-TEE with 2D-TEE.

AIMS AND OBJECTIVES

AIMS AND OBJECTIVES

The AVA in patients with AS was measured using 4 methods, namely 2D planimetry, 2D-CE, 3D planimetry and 3D-CE.

Hypothesis

Considering 3D planimetry as the reference method for AVA measurement, we hypothesised that there was no difference in the AVA measured by other 3 methods in comparison with the reference method.

Primary Objective:

1. To compare the Aortic valve area obtained by continuity equation and planimetry using intraoperative 3D TEE with that obtained by 2D TEE.
2. To compare the AVA obtained by other 3 methods with the 3D planimetry (reference method).

Secondary Objectives

1. To assess the geometry of LVOT using 3D TEE.
2. To compare Aortic antero-posterior annular diameter in best views imaged on 2D and 3D echocardiography.

MATERIALS AND METHODS

MATERIALS AND METHODS

STUDY DESIGN

This prospective observational study was conducted in a tertiary referral center, University-level hospital, which performs 750 to 1000 CABG and 300 to 400 valve cases yearly. Our study was approved by the Technical Advisory Committee (TAC) and Institutional Ethics Committee (IEC).

[TAC registration no- SCT-/S/2016/543]

[IEC registration no- SCT/IEC/1001/DEC-2016]

Adult patients with AS with or without CAD, undergoing elective AVR or AVR with CABG were recruited as our study subjects.

Study Group

Number of patients (n) = 40

Inclusion criteria:

1) Adult patients with AS, without associated significant other valvular heart disease or coronary artery disease.
2) Optimal 2D and 3D-TEE images for analysis.

Exclusion criteria

1) Patient refusal.
2) Contraindication to TEE probe placement like esophageal strictures, esophageal varices, esophageal tumours, gastric ulcer, previous esophagectomy, esophageal diverticulum, tracheoesophageal fistula, previous

bariatric surgery, hiatus hernia, large descending thoracic aortic aneurysm, unilateral vocal cord paralysis, post□radiation therapy.

3) Emergency and re-do surgeries.

4) Patients with severe significant other valvular disease and coronary artery disease.

Study Protocol:

1) After obtaining approval from IEC, patients were enrolled in the study during the pre-anesthetic evaluation.
2) Patients were educated about the study in the presence of a witness. The witness could question the patient as to whether he/ she had really understood details of the proposed study. An informed consent form was signed by patient or relative of the patient as per the Institute protocol.
3) An adult-size TEE probe was inserted after induction of anesthesia and a comprehensive cardiac examination was done using a RT-3D-TEE probe and ultrasound machine. (Philips iE 33, Philips Ultrasound, Bothell, USA).
4) Comprehensive cardiac examination included the necessary views required for management of the patient.
5) All views necessary for measurement of AVA and LVOT area were acquired as a part of comprehensive examination. 3D analysis was performed using off-line 3DQ software.

2D Echocardiography protocol:

- The patients underwent a complete 2D TEE imaging, including color and spectral doppler study.
- Echocardiographic measurements were obtained in compliance with the guidelines published by the American Society of Echocardiography (ASE).
- The 2D images were acquired by echocardiographers trained in multiplane 2D-TEE evaluation. The aortic valve was examined in multiple image projections. Echo data which was stored in the hard disc of iE 33 ultrasound system was retrieved in compact disks (CDs) or hard disks and kept with the Principal Investigator.

2D Planimetry AVA

2D planimetry was performed using X-plane technique. Required frequency and gain adjustments were done to image the aortic valve in AV short and long axis views. X-plane technique was specifically used to localise the tip of the AV for the accurate measurement of AVA. 2D valve area was measured in mid systole using AV-short axis (SAX) zoomed view.

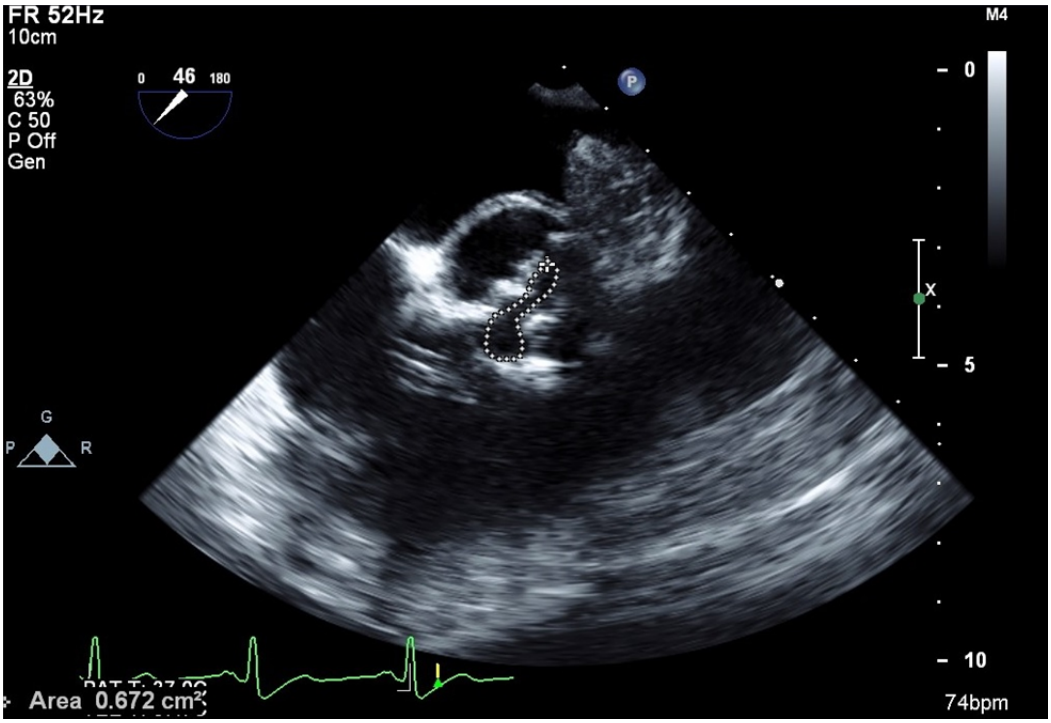


Figure 1: 2D planimetry of aortic valve in ME-AVSAX view is showing the en-face view of AV orifice where AVA was traced manually. ME-mid esophageal, SAX-short axis

AVA (2D) derived from Continuity Equation

Step 1: Measuring the Cross Sectional Area (CSA) of the LVOT (CSA-LVOT)

Using ME long axis view (LAX), LVOT was focused using zoom mode. LVOT diameter (D) measurement was taken from inner edge to inner edge during mid-systole. CSA was automatically calculated using the formula, CSA = $0.785 \times D^2$.

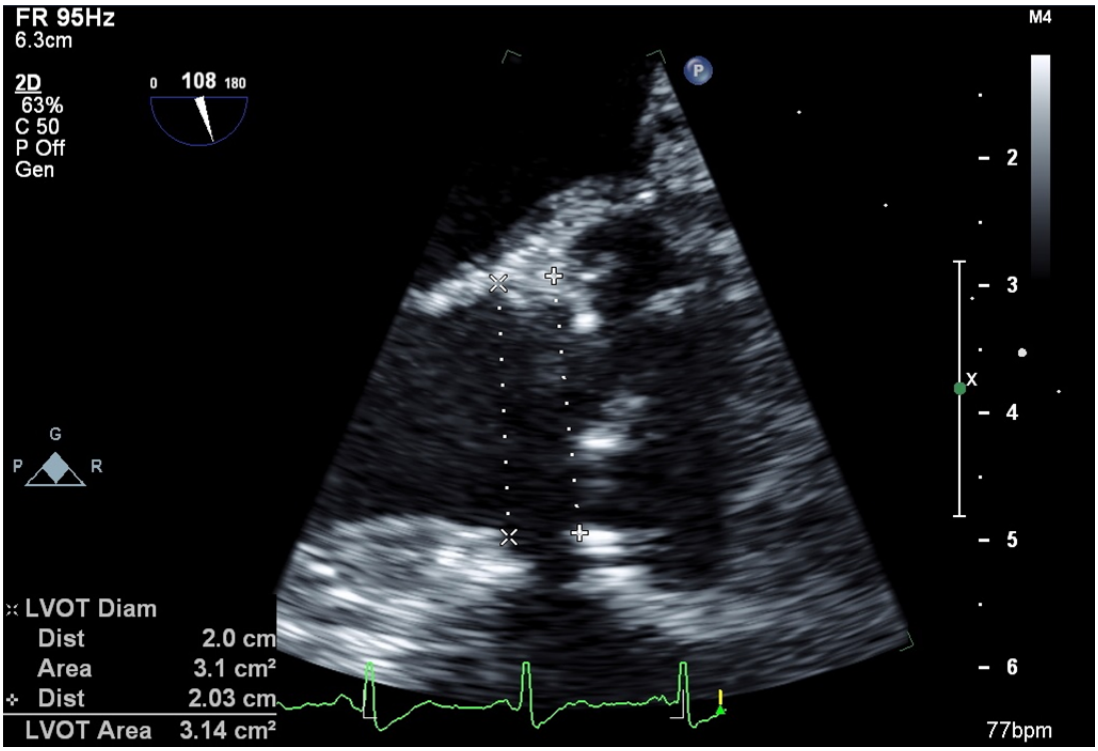


Figure 2: LVOT-CSA measurement at ME-AVLAX view is depicted in the figure. The LVOT diameter (D) and aortic annulus were measured in mid-systole and LVOT area was calculated using the formula, CSA = 0.785 × D^2.

Step 2: Measuring the Velocity Time Integral (VTI) of the LVOT (LVOT-VTI)

In the deep trans-gastric LAX view or trans-gastric long axis view, the Pulse Wave Doppler (PWD) beam was aligned parallel to the LVOT. Sample volume was placed approximately 0.5 cm proximal to aortic valve. PWD envelope was traced to obtain the LVOT-VTI.

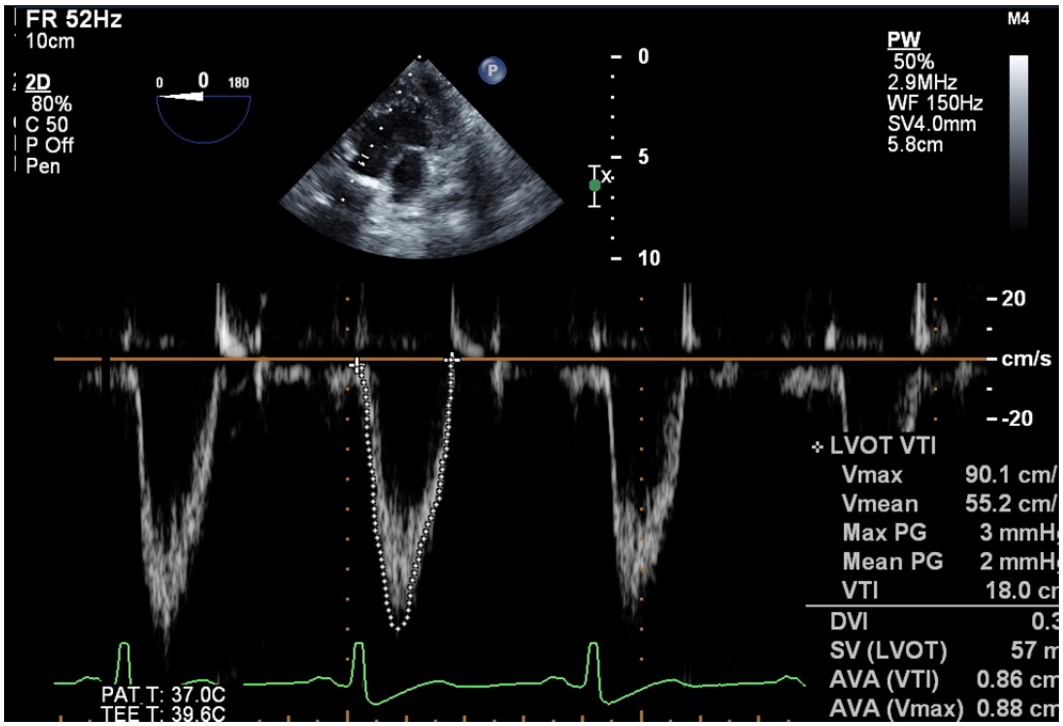


Figure 3: Method of LVOT-VTI measurement is displayed in the deep TG LAX view. Sample volume was placed approximately 0.5 cm proximal to aortic valve.

Step 3: Measuring the VTI of the Aortic Valve (AV-VTI)

In the deep trans-gastric LAX view or trans-gastric long axis view, Continuous Wave Doppler (CWD) beam was aligned parallel to the LVOT. CWD envelope was traced to obtain the AV-VTI.

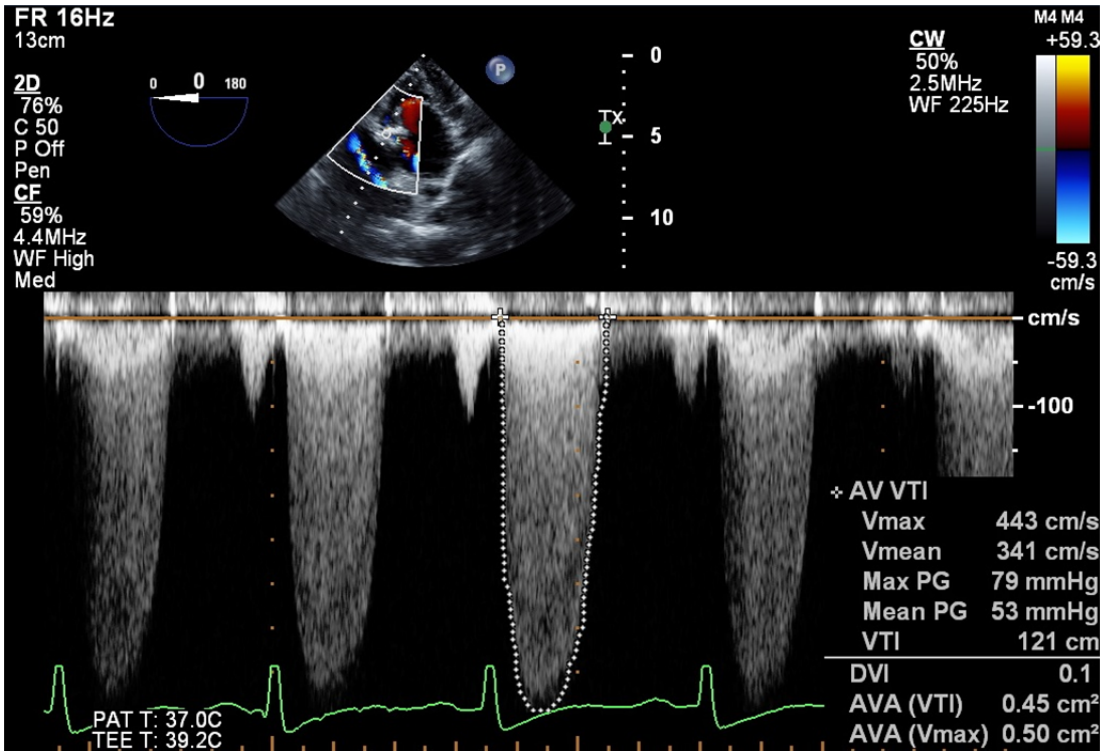


Figure 4: Figure shows method of AV-VTI measurement in deep TG LAX view. The ultrasound beam was placed parallel to the flow across the AV.

The AVA was estimated using the continuity equation (CE-AVA-2D) method as follows:

CE-AVA (2D) = [LVOT area (2D) × velocity-time integral of LVOT] ÷ Velocity-time integral of AV

3D Planimetry:

A full-volume dataset of aortic valve and LVOT were acquired after optimising gain, compression controls and time gain compensation over four consecutive heart beats. Reference planes for full volume acquisition were mid esophageal AV-LAX and mid esophageal AV-SAX views. 3DQ software (QLAB, Philips medical system) was used for Multi Planar Reconstruction (MPR) of aortic valve and LVOT.

In off-line analysis, LVOT Cross sectional area, geometry of LVOT and antero-posterior (AP) Aortic annular dimensions were measured. Planimetry for aortic valve area was also performed in MPR view.

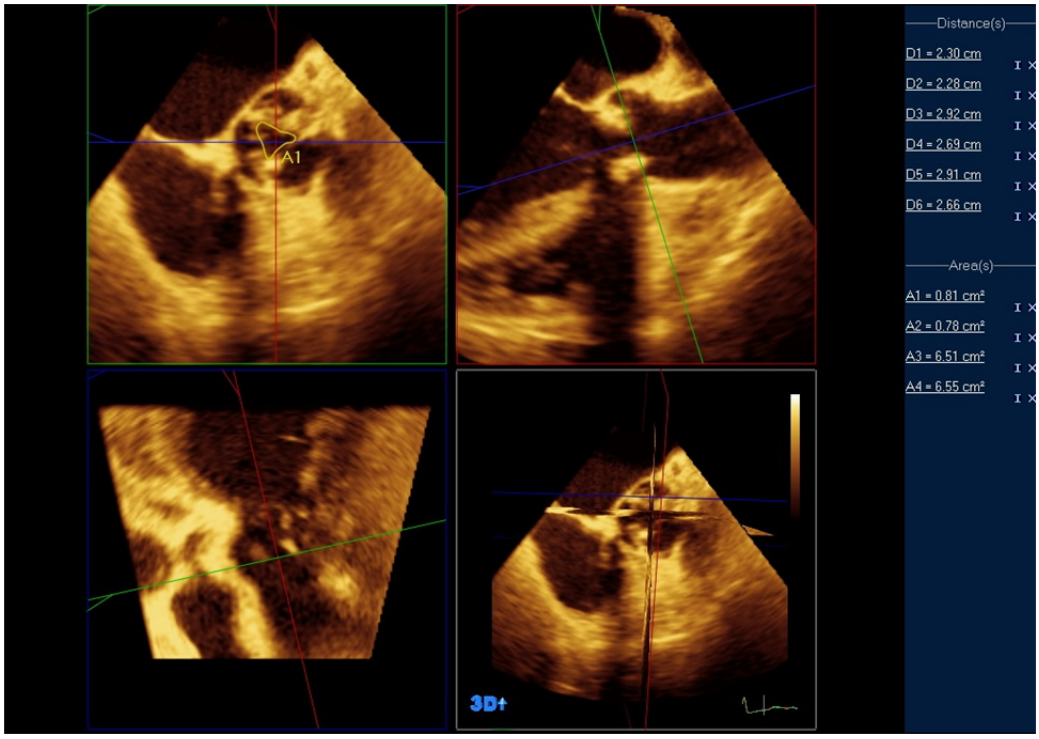


Figure 5: 3DQ offline method for AVA assessment is described in the figure. (A) Left upper panel shows mid esophageal AV-SAX view of AV. The AVA is outlined using planimetry. (B) and (C) are showing the appropriate adjustment of two orthogonal cropping planes passing through the tip of the aortic valve leaflets in mid-systole.(D) Right lower panel shows full volume of AV. The 3D-AVA planimetry measurement labelled here as A1 is depicted in first (A) image.

Continuity Equation (3D)

Doppler-VTI measurements of both AV and LVOT were common for the estimation of stroke volume using continuity equation.

The 3D-AVA was estimated using the continuity equation (CE-AVA-3D) method as follows:

CE-AVA (3D) =3D LVOT area x LVOT- VTI /AV-VTI.

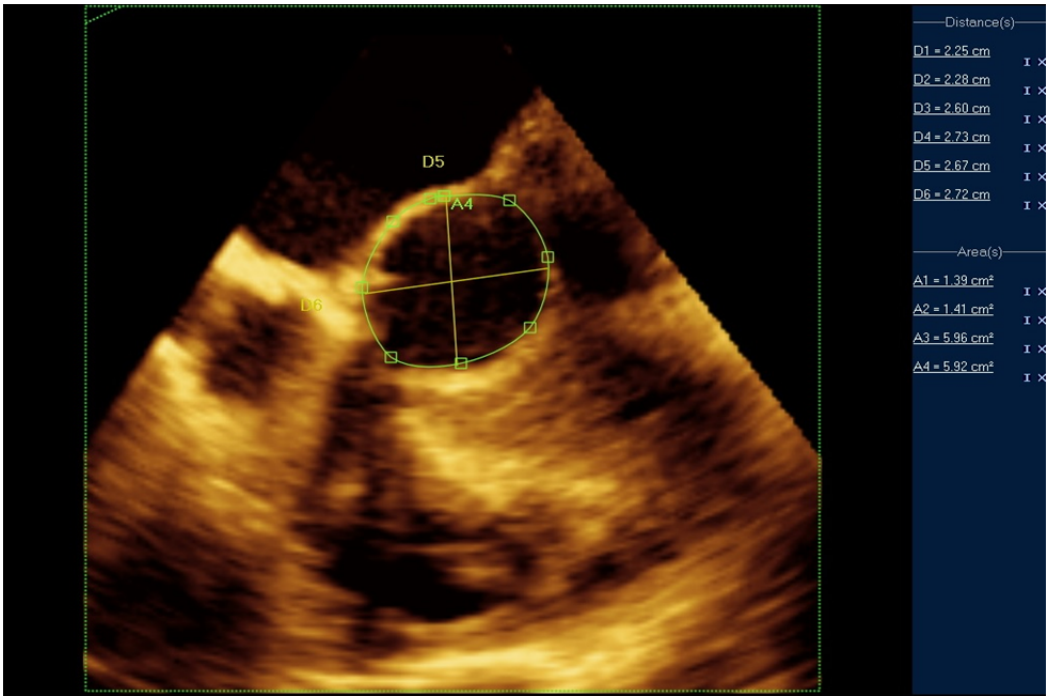


Fig 6: The figure depicts method of 3D evaluation of LVOT geometry, measurement of the LVOT CSA, and LVOT diameters in anteroposterior and medial-lateral planes. The short axis image was obtained by placing the green plane 5 mm below the aortic annulus. The AP (D5) and lateral -medial diameter (D6) are 26 mm and 27 mm respectively, suggesting that geometry of the LVOT is elliptical.

Measurement of CSA of LVOT using X plane (2D)

From ME long axis view, the reference image of LVOT was focused using zoom mode and X-plane was placed approximately 5 mm below the aortic annulus. The LVOT CSA was measured in the orthogonal plane during mid-systole.

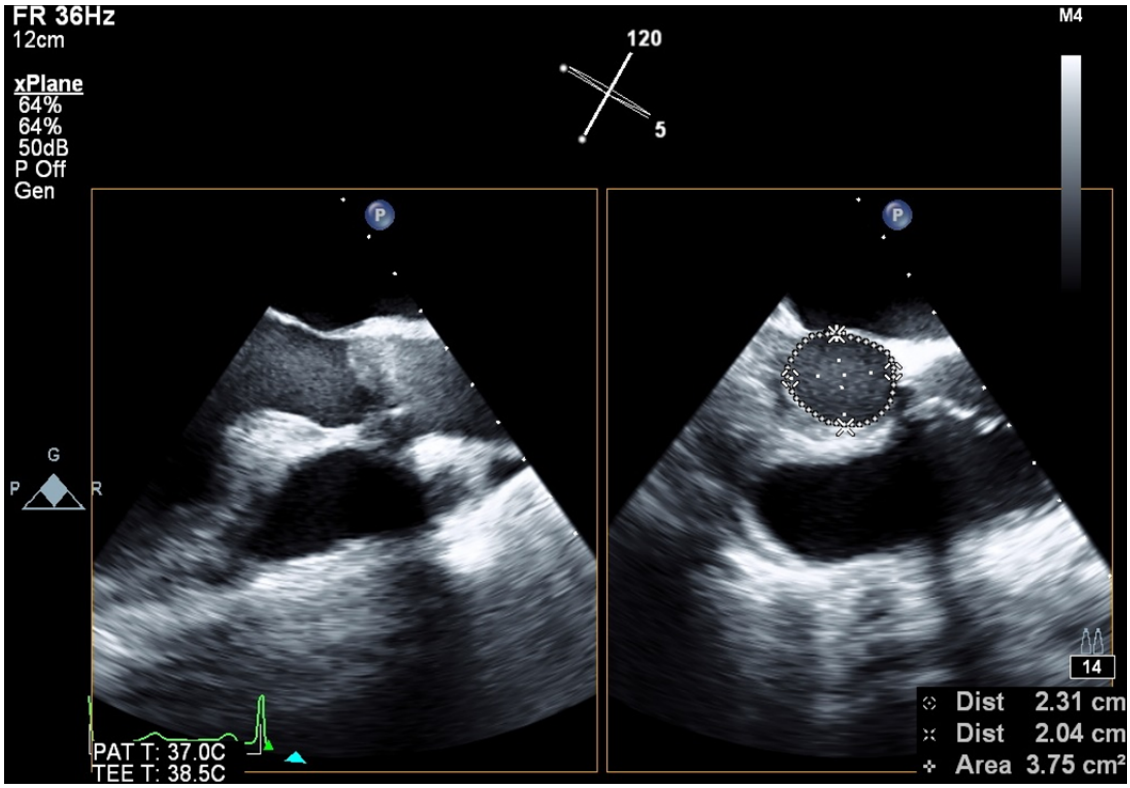


Fig 7: X-plane imaging of LVOT is shown in the figure. The reference image was acquired from ME-LAX view and the orthogonal image was seen in reversed ME-SAX view. The measurements performed were the CSA of LVOT (Area), AP diameter of LVOT and medial lateral diameter of LVOT.

Study Groups:

Single group in which all the parameters were evaluated by different observers separately.

Observations:

Please refer to Annexure page 2

Outcome parameters:

We obtained AVA by continuity equation (using 2D LVOT area and 3D LVOT area), 2D planimetry, and 3D planimetry which were compared among each other. The inter-observer variability was also calculated for the same.

STATISTICAL ANALYSIS

STATISTICAL ANALYSIS

Statistical analysis was done using SPSS software version 22 and Graph pad prism 5.2. Continuous variables are expressed as mean ± standard deviation (SD). Comparison of measurements between two groups was performed using Student's paired *t* test and Wilcoxon signed rank test. If the data did not follows the normal distribution, then we applied the non-parametric test, Wilcoxon signed rank test. Linear regression analysis was used to assess the relationship between 2D-AVA and 3D-AVA, and correlation coefficients were expressed as R values. Bland−Altman analysis was performed to assess agreement between the two methods, and the limits of agreement were defined as mean ± 1.96 SD of the average differences between the methods. Interobserver variations were assessed as Inter class correlation coefficients (*ICC*) with linear regression analysis and mean differences. A p-value < 0.05 was considered statistically significant.

We calculated the sample size anticipating a difference of 0.2 cm^2 between the areas measured using 2D and 3D TEE, with a significance level of 0.01 and power of 90%. Required sample size was 37, which was rounded to 40 patients.[77]

RESULTS

RESULTS

Feasibility of the study

46 consecutive patients fulfilling inclusive criteria were enrolled in the study. 3D AVA area assessment was feasible in 45 patients (97%). 1 patient had excessive calcium which hampered the offline assessment due to poor image quality. 2D assessment was practical only in 42 patients (91%). Among the 4 patients in whom 2D TEE planimetry failed due to heavy calcification or distortion of the leaflets, one was the patient who had inadequate 3D image. Satisfactory AV-VTI was not profiled in 2 other patients and hence they were excluded from the study resulting in CE method being successful in 40 patients (87%).

Population

Our study population included 40 patients with AS all the methods for valve area assessment remained feasible. Mean age of the study population was 57±8 years. 25 among the total patients were males. 26 patients presented with NYHA class II symptoms and 14 were having class III symptoms. One (2.5%) patient was in atrial fibrillation. 30 patients had grade I Left ventricular diastolic dysfunction (LV-DDF), 5 had grade II LV-DDF and 2 patients had grade III LV-DDF on pre-operative TTE. RV function was normal in 35 patients. 4 patients had mild and 1 had moderate RV dysfunction. 37 patients had mild mitral regurgitation (MR), 3 had moderate MR, 11 had mild aortic regurgitation (AR), 29 had moderate AR and 27 patients were diagnosed with mild tricuspid regurgitation (TR). Peak and mean gradients in pre-op 2D TTE were 94 ± 30 mm Hg and 56 ± 17 mmHg respectively.

Demographic and echocardiographic parameters of all patients are summarised in Table 4.

Table 4: Demographic & Echocardiographic parameters	
Male	25 (62%)
Female	15 (28%)
Age (yrs)	58 ± 8
Weight (kgs)	63 ± 10
NYHA	
Class II	26 (65%)
Class III	14 (35%)
Atrial Fibrillation	1 (2.5%)
LV diastolic dysfunction	
Normal	3 (7.5%)
Grade I	30 (75%)
Grade II	5 (12.5%)
Grade III	2 (5%)
Mild MR	28 (70%)
Mild AR	11 (27.5%)
Mild TR	27 (67.5%)
Data expressed as mean±SD or as n (%)	

Diabetes Mellitus (47.5%) and Hypertension (42.5%) were the most common comorbidities among patients in our study group. 11 out of 40 patients had associated CAD which required CABG along with AVR. Associated comorbidities are summarized in Table 5 and Figure 3.

Comorbidity	Number of Patients	Percentage
Diabetes Mellitus	19	47.5
Hypertension	17	42.5
Dyslipidemia	10	25.0
Hypothyroidism	2	5.0
Chronic Kidney Disease	1	2.5
Psychiatric Illness	3	7.5
Bronchial Asthma/Chronic Obstructive Pulmonary Disease	7	17.5
Coronary Artery Disease	11	27.5

Table 5: Percentage of Comorbidities in study population

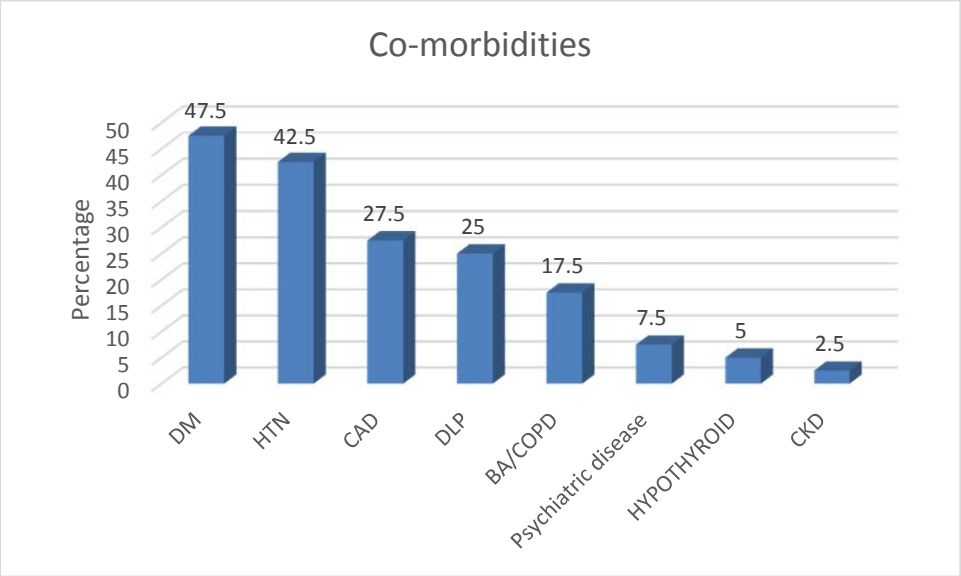


Figure 3: Percentage of Comorbidities in study population

DM-Diabetes Mellitus, HTN-Hypertension, CAD-Coronary Artery Disease, DLP-Dyslipidemia, BA-Bronchial Asthma, COPD-Chronic Obstructive Pulmonary Disease, CKD-Chronic Kidney Disease.

Percentage of severe AS (< 1 cm^2) detected by planimetry 2D, planimetry 3D, CE-2D and CE-3D were 87%, 90%, 90%, and 65% respectively (Figure 4).

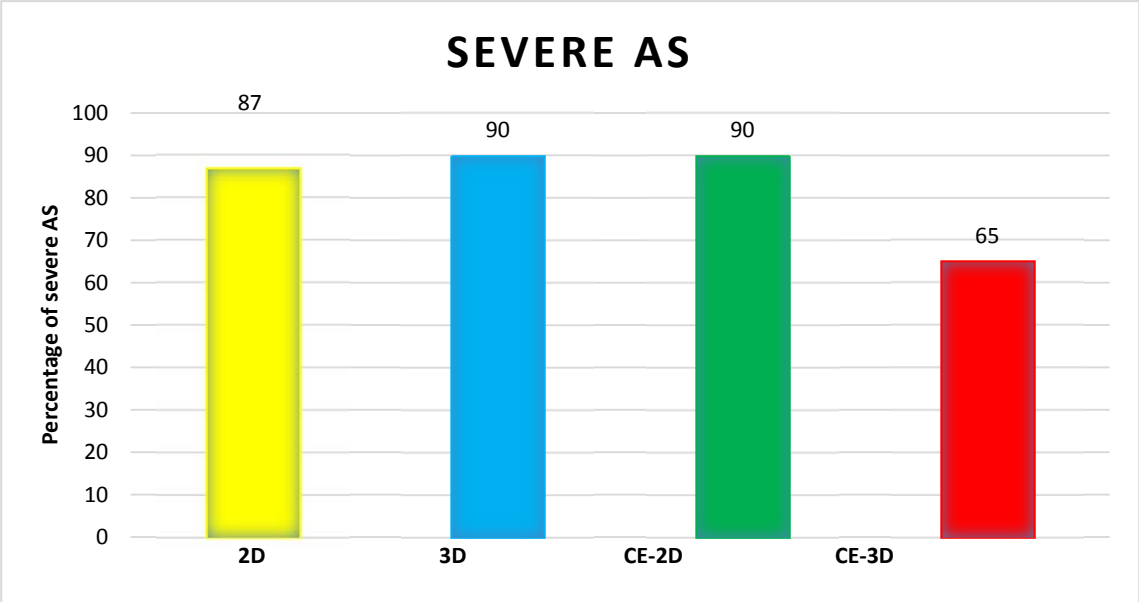


Figure 4: Percentage of severe AS detected by planimetry 2D, planimetry 3D, CE-2D and CE-3D.

CE: Continuity Equation, 2D: 2 dimensional planimetry, 3D: 3 dimensional planimetry

Inter-observer correlation for all methods of AVA and LVOT CSA assessment were excellent with an Inter Class Correlation ICC of >0.9 (**Table 6**).

[ICC; measurement of similarity between units belonging to same group. (<0.4 – poor correlation, 0.4- 0.59 – fair correlation, 0.6- 0.74 – good correlation, 0.75- 1.00 – excellent correlation)].

Variables compared	Inter class Correlation
P-AVA2D1 vs P-AVA2D2	**0.972**
P-AVA3D1 vs P-AVA3D2	**0.975**
LVOTCSA-2D1 vs LVOTCSA-2D2	**0.994**
LVOTCSA-3D1 vs LVOTCSA-3D2	**0.982**
CE-AVA-2D1 vs CEAVA-2D2	**0.963**
CE-AVA3D1 vs CE-AVA3D2	**0.940**

Table 6: Inter-observer variability among different AVA and CSA estimation methods

*P-AVA 2D1: 2 dimensional planimetry AVA observer 1, P-AVA 2D2: 2 dimensional planimetry AVA observer 2**;** P-AVA 3D1: 3 dimensional planimetry AVA observer 1, P- AVA 3D2: 3 dimensional planimetry AVA observer 2**;** LVOT-CSA-2D1:LVOT CSA observer 1(2D), LVOT-CSA-2D2:LVOT CSA observer 2(2D)**;** LVOT-CSA-3D1:LVOT CSA observer 1(3D), LVOT-CSA-3D2:LVOT CSA observer 2(3D)**;** CE-AVA 2D1: Continuity Equation AVA observer 1(2D), CE-AVA 2D2: Continuity Equation AVA observer 2(2D)**;** CE AVA 3D1: Continuity Equation AVA observer 1(3D), CE AVA 3D2: Continuity Equation AVA observer 2(3D).*

The shape of the LVOT was elliptical in mid systole by 3D TEE in all patients (Table 7). All patients had a larger medial–lateral diameter than anteroposterior diameter and no patients had an almost circular shape of the LVOT by 3D TEE. The anteroposterior diameter by 3D-TEE (median 2.1 cm, interquartile range 1.9 to 2.2) was not significantly different from the diameter by 2D-TEE (median 2.1 cm, interquartile range 2.0 to 2.2, p = not significant). The medial–lateral diameter of

LVOT by 3D-TEE (median 2.54 cm, interquartile range 2.3 to 2.7) was significantly more than the LVOT diameters measured by 2D-TEE ($p < 0.01$).

LVOT diameters-3D TEE	Number of patients	**Diameter (cm)**				
		Mean	SD	Median	25^{th} Percentile	75^{th} percentile
Antero-posterior diameter 3D	40	2.11	0.26	2.00	1.90	2.20
Medial-lateral diameter 3D	40	2.54	0.29	2.50	2.33	2.70

Table 7 – Comparison of Anteroposterior and medial-lateral diameters by 3D TEE. $p < 0.001$ (statistically significant)

Left ventricular outflow tract dimensions derived from different methods

Variable Value

Left ventricular outflow tract (LVOT) diameter (cm)

2-Dimensional transesophageal echocardiography → 2.1 (2.0–2.2)

3-Dimensional transesophageal echocardiography

Anteroposterior → 2.1 (1.9–2.2)

Medial–lateral → 2.54 (2.3–2.7)

Ellipticity by real-time 3-dimensional

Transesophageal echocardiography → 0.83 ± 0.06

{Ellipticity calculated by dividing anteroposterior with medial-lateral diameter}

The LVOT areas evaluated 2D-TEE (median 3.6 cm^2, interquartile range 3.1 to 4.0) were smaller than those by 3D-TEE (median 4.4 cm^2, interquartile range 3.6 to 5.0; $p < 0.001$ (Figure 5 and 6). 2D-TEE significantly underestimated the LVOT areas when compared to 3D-TEE (Table 8).

2D/3D-TEE	Number of patients	**LVOT CSA (cm^2)**				
		Mean	SD	Median	25^{th} Percentile	75^{th} percentile
2D TEE	40	3.57	0.85	3.27	3.14	4.06
3D TEE	40	4.44	1.06	4.05	3.62	5.02

Table 8: Comparison of LVOT CSA by 2D and 3D TEE, $p < 0.001$ – statistically significant.

LVOT CSA- Left ventricular outflow tract cross sectional area, 2D-Two dimensional, 3D- Three dimensional, TEE-Transesophageal echocardiography.

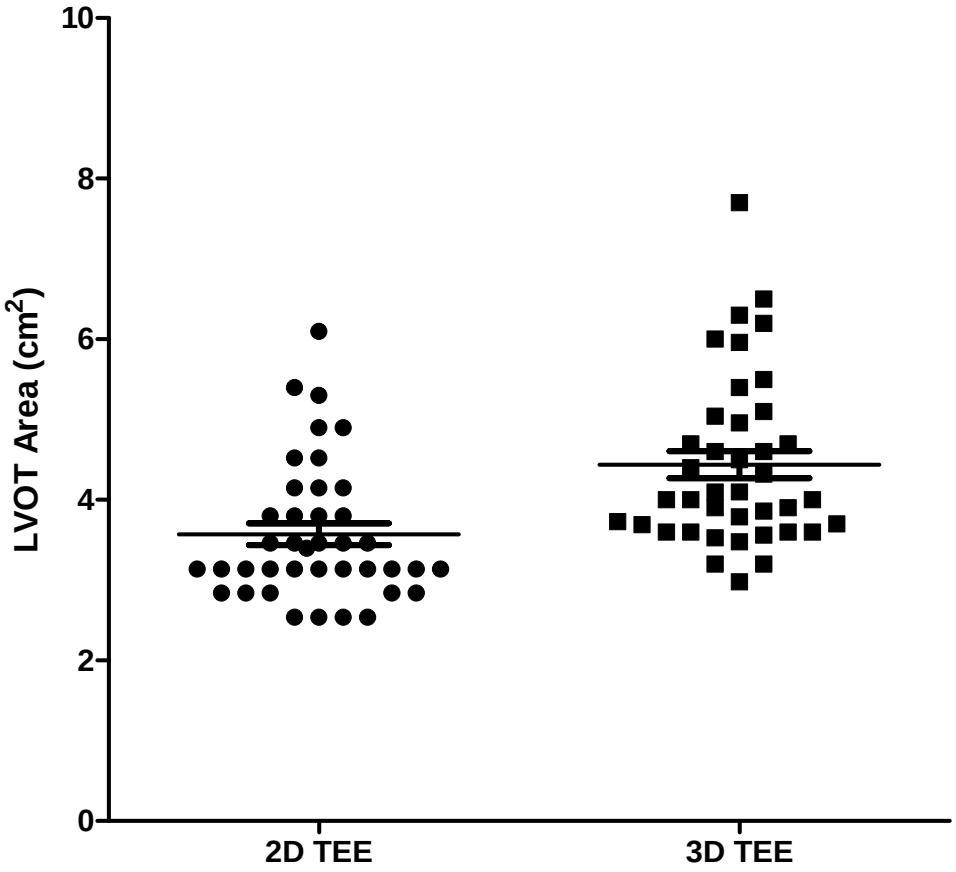


Figure 5: **Scatter plot comparing LVOT area using 2D TEE and 3D TEE. LVOT CSA measurement by 3D TEE was significantly more than that measured by 2D TEE.**

LVOT- Left ventricular outflow tract, 2D-Two dimensional, 3D- Three dimensional, TEE-Transesophageal echocardiography.

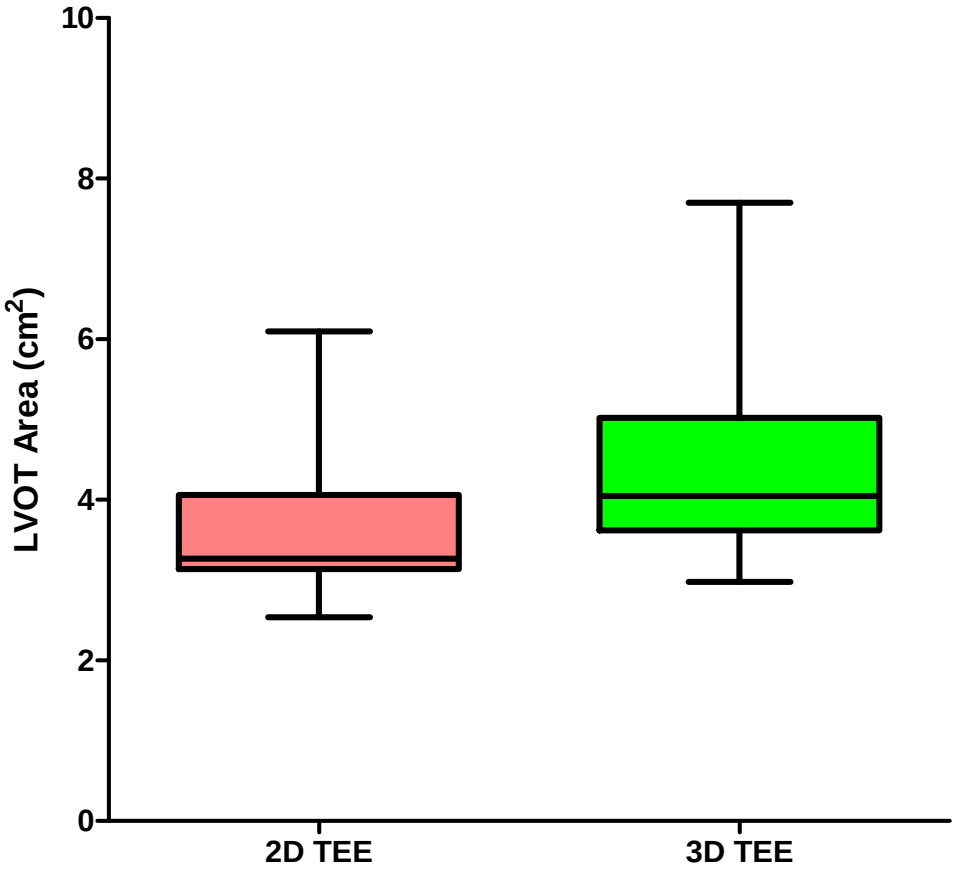


Figure 6 - Box and Whisker plot comparing LVOT area using 2D TEE and 3D TEE. LVOT CSA measurement by 3D TEE was significantly more than that measured by 2D TEE.

LVOT- Left ventricular outflow tract, 2D-Two dimensional,

3D-Three dimensional, TEE-Transesophageal echocardiography.

The medial–lateral diameter of LVOT by 3D-TEE (median 2.54 cm, interquartile range 2.3 to 2.7) was almost comparable with X-plane LVOT diameters (median 2.58 cm, interquartile range 2.32 to 2.78)measured by 2D-TEE (p =0.817). This is documented in Table 9 as well as Figure 7 and 8.

Observation	Number of patients	**Medial-lateral Diameter (cm)**				
		Mean	SD	Median	25^{th} Percentile	75^{th} percentile
X plane 2D TEE	40	2.54	0.30	2.5	2.3	2.7
3D TEE	40	2.58	0.42	2.5	2.32	2.78

Table 9: Comparison of medial-lateral diameter of LVOT by 2D X-plane and 3D TEE, p= 0.81(Statistically insignificant).

X plane - Biplane 2D imaging, 2D-Two dimensional, 3D- Three dimensional, and TEE-Transesophageal echocardiography.

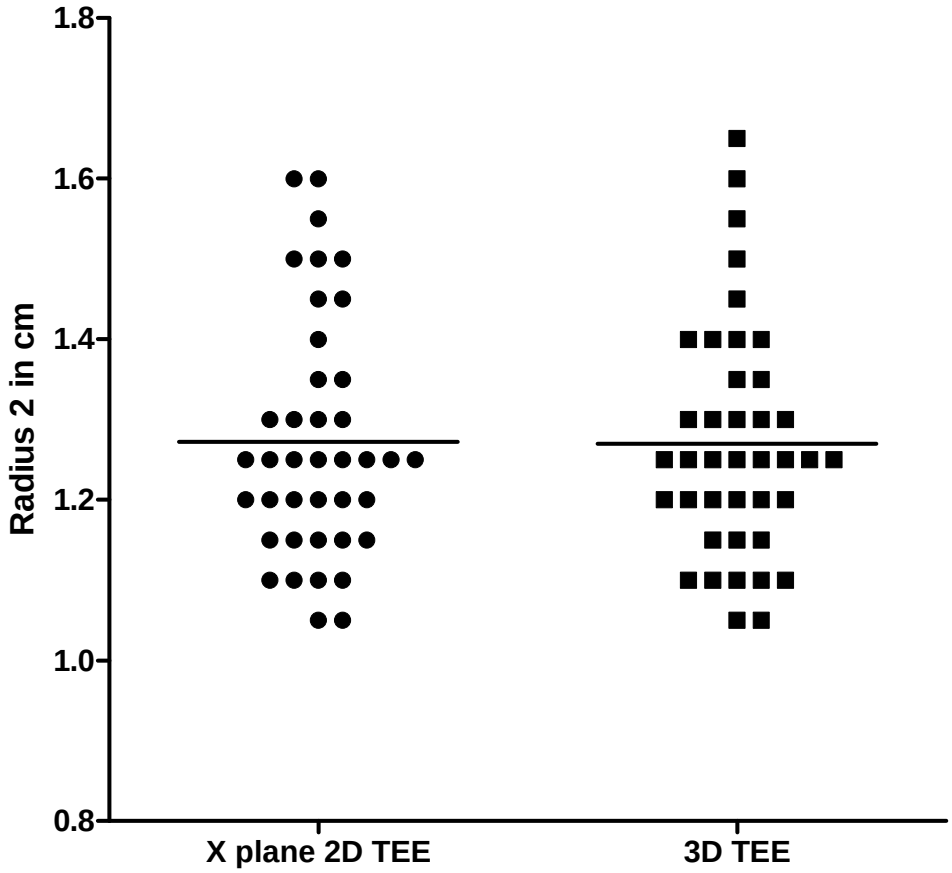


Figure 7: Scatter Plot comparing medial-lateral radii using X plane 2D TEE and 3D TEE. Medial-lateral radii measurement by 3D TEE was comparable to that of 2D X-plane TEE.

X-plane - Biplane 2D imaging, 2D-Two dimensional, 3D- Three dimensional, and TEE-Transesophageal echocardiography.

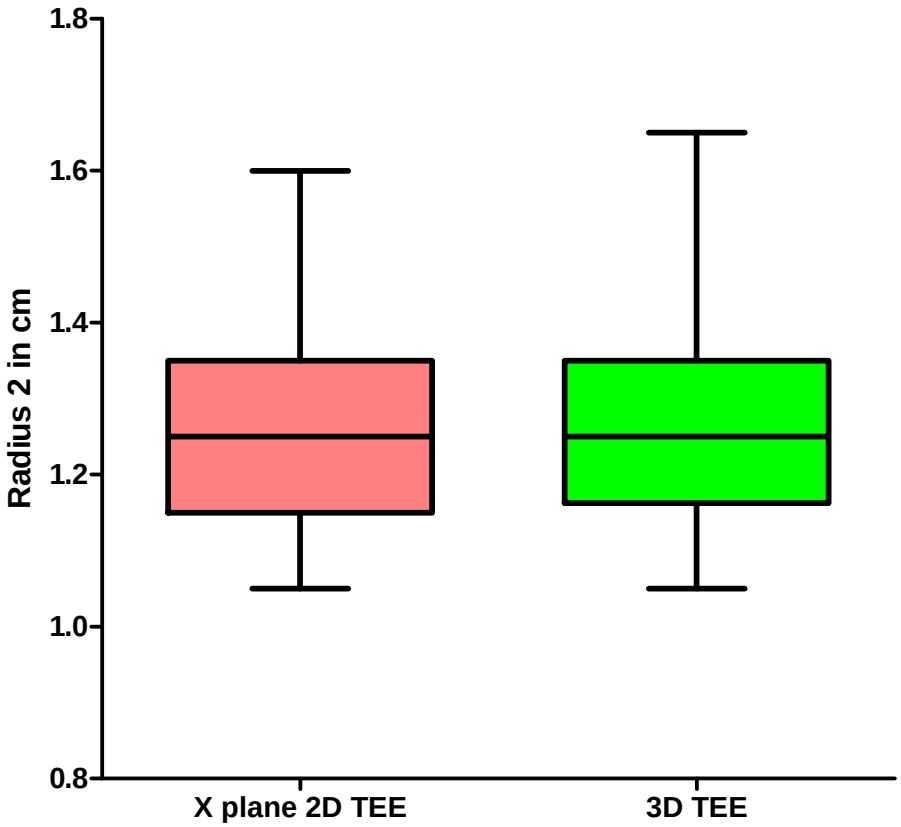


Figure 8: **Box and Whisker plot comparing medial-lateral radii using X-plane 2D TEE and 3D TEE). Medial lateral radii measurement by 3D TEE was comparable to that of 2D-X plane TEE.**

X-plane - Biplane 2D imaging, 2D-Two dimensional, 3D- Three dimensional, TEE-Transesophageal echocardiography.

Planimetric AVA comparison using 2D and 3D-TEE showed comparable valve areas with no significant statistical difference. p value > 0.05 (Table 10).

Observation	Number of patients	**AVA (cm^2)**				
		Mean	SD	Median	25^{th} Percentile	75^{th} percentile
Planimetry AVA-2D	40	0.74	0.21	0.74	0.57	0.88
Planimetry AVA-3D	40	0.72	0.21	0.70	0.54	0.87

TABLE: 10. Comparison of planimetric AVA by 2D and 3D-TEE, p=0.176 (Wilcoxon signed rank test), statistically insignificant.

AVA-Aortic valve area, 2D-Two dimensional, 3D-Three dimensional.

Comparison of Planimetric AVA (2D) with Continuity Equation AVA (2D) showed p-value of 0.037 which was statistically significant (Table 11). This difference in result probably occurred due to the measurement of effective orifice area (EOA) by continuity equation and geometric orifice area (GOA) by planimetry.

Observation	Number of patients	**AVA (cm^2)**				
		Mean	SD	Median	25^{th} Percentile	75^{th} percentile
Planimetry AVA -2D	40	0.74	0.21	0.74	0.57	0.88
CE-AVA 2D	40	0.68	0.24	0.66	0.47	0.84

TABLE: 11. Comparison of planimetric AVA by 2D and CE- AVA by 2D, p=0.037(Wilcoxon signed rank test), statistically significant.

CE: Continuity Equation, AVA-Aortic valve area, 2D-Two dimensional, 3D-Three dimensional.

Comparison of Continuity equation AVA (2D) with Continuity Equation AVA (3D) showed p value of < 0.001 which was statistically significant (Table: 12, Figure 9, 10 **)**. This significant difference is due to the differences in LVOT areas measured by 2D and 3D-TEE; 2D-TEE significantly underestimated the LVOT CSA. Even though there was statistically significant difference between the valve areas measured using 2D-CE and 3D-CE, linear regression analysis revealed there was good correlation between the same (when the AVA measured using 2D-CE increased or decreased the AVA measured by 3D-CE also did the same).

2D/3D TEE	Number of patients	**Continuity equation AVA (cm^2)**				
		Mean	SD	Median	25^{th} Percentile	75^{th} percentile
2D TEE	40	0.68	0.24	0.66	0.47	0.84
3D TEE	40	0.84	0.29	0.79	0.58	1.05

Table 12 - Comparison of Continuity equation AVA by 2D and 3D TEE, p<0.001(Statistically significant), R=0.979 (good correlation).

CE-Continuity Equation, AVA-Aortic valve area, 2D-Two dimensional, 3D-Three dimensional , TEE-Transesophageal echocardiography.

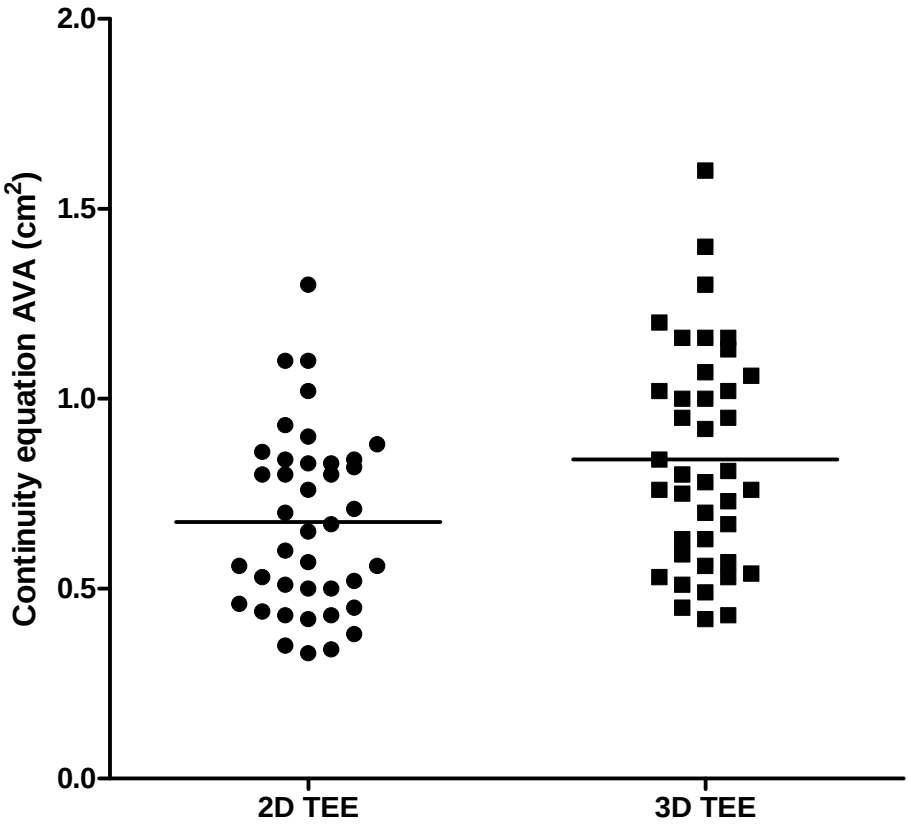


Figure 9: **Scatter plot comparing CE-AVA area using 2D-TEE and 3D-TEE. CE-AVA measurement by 3D-TEE was significantly more when compared to that measured by 2D-TEE.**

CE-Continuity Equation, AVA-Aortic valve area, 2D-Two dimensional, 3D-Three dimensional , TEE-Transesophageal echocardiography.

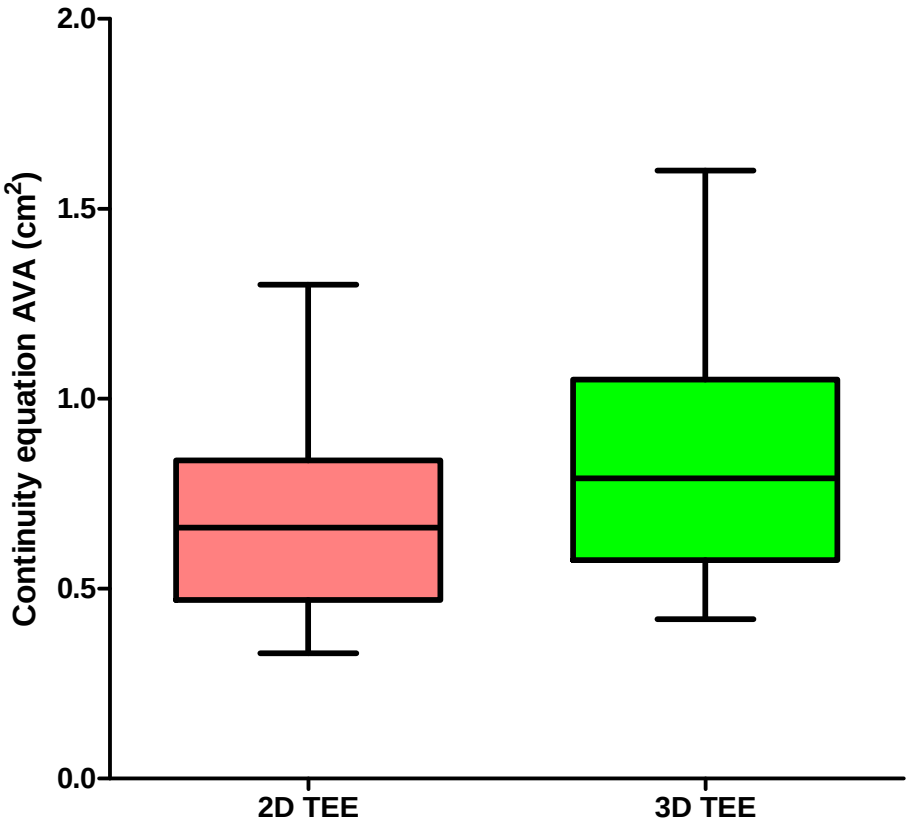


Figure 10 - Box and Whisker plot comparing CE-AVA area using 2D-TEE and 3D-TEE. CE-AVA measurement by 3D-TEE was significantly more when compared to that measured by 2D-TEE.

CE-Continuity Equation, AVA-Aortic valve area, 2D-Two dimensional, 3D-Three dimensional, TEE-Transesophageal echocardiography.

Bland- Altman analysis revealed that the difference in the LVOT areas was 0.87 ± 0.37 cm^2 (95% confidence interval 0.15 to 1.58) between 3D-TEE and 2D-TTE (Figure 11).

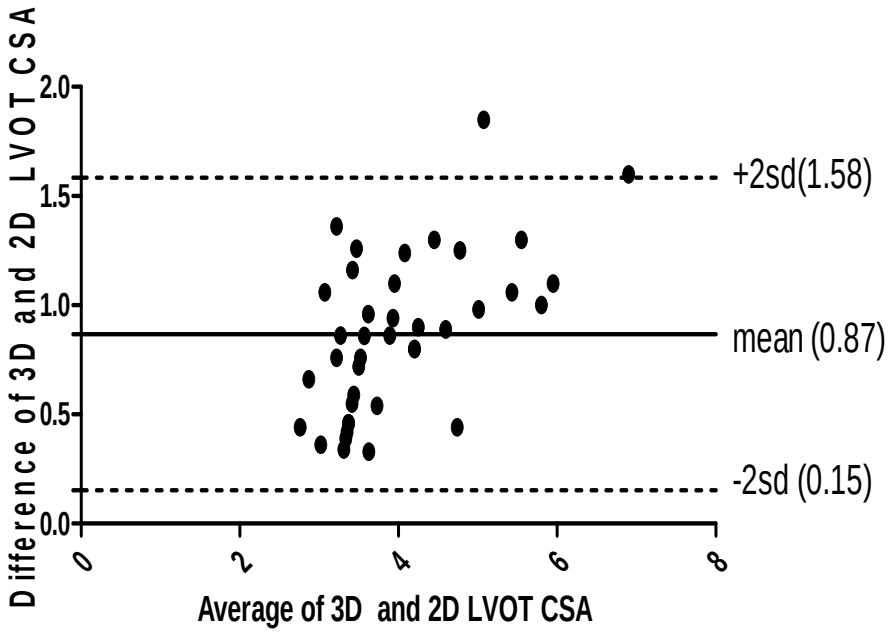


Figure 11 - Bland Altman plot showing difference in LVOT area using 2D and 3D TEE. *Solid lines* represent mean difference, and *broken lines* ±2 standard deviations. Range of 95% Confidence Interval as shown by broken lines in difference plot, are over a wider range from the baseline (1.58 to 0.16), signifying poor agreement between 2D and 3D-CSA measurement methods. Correlation coefficient: R=0.979, p<0.001(statistically significant).

LVOT- Left ventricular outflow tract, CSA- Cross sectional area, 2D-Two dimensional, 3D- Three dimensional, TEE-Transesophageal echocardiography.

By Bland Altman analysis the limits of agreement is superior when the range is less centred around the mean.

Comparison of antero-posterior aortic annulus measurement with (2D) and (3D) methods, showed a p value of 0.24 which was statistically not significant. (Table 13)

Observation	Number of patients	**ANNULUS**				
		Mean	SD	Median	25^{th} Percentile	75^{th} percentile
2D TEE	40	21.44	1.89	21.00	20.00	22.40
3D TEE	40	21.56	1.68	21.05	20.50	22.45

Table 13 - Comparison of Aortic annulus by 2D and 3D TEE, p=0.240 (Statistically not significant).

2D-Two dimensional, 3D-Three dimensional, TEE-Transesophageal echocardiography.

Considering the mean of all 40 patients, 2D planimetry (0.74 cm^2 ± 0.21), 3D planimetry (0.72 cm^2 ± 0.29) and 2D continuity equation AVA (0.68 cm^2 ± 0.24) underestimated the AVA in comparison to 3D CE-AVA (0.84 cm^2± 0.29). The underestimation was statistically significant with a p value of < 0.05 between each methods. Also 95% limits of agreement, as assessed by Bland –Altman method was low for LVOT-CSA measured by 2D -TEE in comparison to 3D TEE [figure 11].

CE-AVA measured by 2D-TEE was slightly less (0.68 cm^2 ± 0.24) in comparison to AVA measured by 3D planimetry (0.71 cm^2 ± 0.21), even though there was no statistical difference between the same.

DISCUSSION

DISCUSSION

Ours is the first prospective study which compared AVA assessment by 3D-TEE with X-plane 2D TEE and CE based aortic valve area measurement, in the intra-operative period. There were no particular complications during any of the TEE examinations. Our success rate of 2D measurement were 91%, which is comparable to or even higher than conventional 2D planimetry done by the previous studies.[6] There was excellent inter observer agreement for all the methods of AVA measurements. We made a comparison of peak and mean gradients done by the anaesthesiologist in the peri-operative with the same obtained by cardiologist in the pre-operative phase using TTE. There was a statistically significant difference between both the measurements. It indicates that the hemodynamic alteration caused by our surgical or anaesthetic manipulations could have influenced the measurement of gradients for AS severity classification.

We considered 3D planimetry as the reference standard for comparison based on interpretations from previous studies which showed superiority of 3D-TEE [98, 99] and computerised tomography (CT) [12, 13] over 2D-echocardiography. In comparison to 3D TEE, 2D TEE planimetry overestimated the AVA in our cohorts, but it was statistically not significant.

2D-TEE often makes an oblique cut through the valve leaflets rather than at the tip of the leaflets. Consequently, it is often technically difficult to capture the tip of the aortic valve leaflets at their maximal systolic opening using 2D-TEE with a fixed imaging plane.[57-59] In addition, 2D-TEE has the disadvantages of more fuzzy contours, shadow phenomena, and motion artefacts. The gain setting may affect the

measured AVA, especially in severely calcified valves.[59] Inability to localise the tip of AV leaflets in severe calcific AS may be the cause for overestimation of AVA when 2D echocardiography is used. Usage of X-plane method can overcome the inability to localise the tip, but application of the same in our study could not prevent the overestimation of AVA in comparison to 3D-TEE.

Effective orifice area differs from geometric orifice area. It occurs distal to actual orifice, were blood flows with maximal velocity and hence the blood column is maximally contracted. In AS the effect is pronounced and the functionally measured AVA should be slightly lower than anatomical AVA. This principle can be the reason behind slightly lower AVA measured by CE-2D in comparison to 2D/3D planimetry in our study.

The European Association of Echocardiography/American Society of Echocardiography guidelines now advocate LVOT diameters derived from 2-dimensional echocardiography to be used to estimate a continuity equation-based AVA.[2] However, the LVOT actually could be of elliptical shape, with a shorter anteroposterior diameter, casting a doubt on the accuracy of a continuity equation based AVA calculated by the assumption of a circular geometry. Our findings are similar to that of previous studies regarding LVOT geometry, which reported an elliptical LVOT with shorter anteroposterior diameter. [4,7,77]

Additionally, the ellipticity was able to be predicted using 2-dimensional X-plane parameters in our study. Therefore, 3D-TEE or X-plane 2D TEE should be used to evaluate LVOT geometry prior to cases of percutaneous aortic valve implantation.

Accurate assessment of LVOT geometry could affect the success of this procedure because the apical end of the new valve is attached to the LVOT.

The accuracy of Continuity equation-based AVA is important, particularly when severe calcification of the aortic valve makes it difficult to measure the planimetric AVA. The continuity equation based calculation of the AVA is "flow corrected," in other words, it is not affected by hemodynamic variations. The greatest source of error is the assumption of the circular shape of LVOT and this was clearly demonstrated in our study. In fact, 4 of the patients in our series had suboptimal aortic valve images by 2D-TEE for planimetric AVA estimation. However, we demonstrated that the calculation of continuity equation-based AVA using 2-dimensional echocardiography underestimated the real AVA owing to the elliptical shape of LVOT with its shorter anteroposterior diameter. Therefore, the evaluation of the LVOT area with 3D-TEE would be of great importance, especially when patients with aortic stenosis have discrepancy regarding the severity of the disease when assessed using different techniques such as measurement of mean pressure gradient, continuity equation-based AVA, and planimetry. In our study, 1/3rd of patients found to have severe aortic stenosis using 2-dimensional continuity equation-based methods were reclassified as having moderate AS when assessed by 3D-TEE. The correct assessment of the severity of aortic stenosis using 3D-TEE might result in fewer patients being erroneously diagnosed as having severe disease. This may avoid unnecessary operations or procedures in patients with unclear symptoms.

Recently, multidetector computed tomography and magnetic resonance imaging also have been used to visualize the morphology and motion of the aortic valve and precisely measure the aortic valve opening area. Planimetric AVA using

multidetector computed tomography and magnetic resonance imaging have been compared with TTE and TEE; both modalities have been shown to provide an accurate assessment of the AVA[78, 79]. The planimetric LVOT area measured using multidetector computed tomography was more than that quantified using 2D-TTE in patients with calcified aortic valve disease. Thus, the continuity equation-based AVA using TTE underestimated the planimetric AVA compared to multidetector CT.[14] However, multidetector CT with contrast study is contraindicated in patients with renal failure and hypersensitivity to iodine contrast, and magnetic resonance imaging cannot be used in patients with a pacemaker or implanted cardioverter defibrillator. Furthermore, multidetector CT without contrast study needs a flow Doppler data by echocardiography to calculate the continuity equation-based AVA. However, 3D-TEE can simultaneously evaluate the planimetric and continuity equation-based AVA and provide imaging of the 3-D geometry of the LVOT. Also, unlike multidetector CT or magnetic resonance imaging, RT 3D-TEE allows on-site or live evaluation of LVOT geometry and AV during Transcatheter aortic valve implantation to prevent paravalvular regurgitation after the procedure.

We, in our study, found that it was feasible to measure the LVOT area using X-plane technique. The newer matrix array probes allow simultaneous orthogonal plane imaging so that a secondary 2D image can be visualized simultaneously at a plane orthogonal to the primary imaging plane.[80] Further, the secondary plane can be tilted in the vertical or lateral axis to view a structure of interest. Use of simultaneous orthogonal plane imaging with tilt from the ME aortic valve long-axis view allows visualization of the LVOT in its short axis. Planimetry of this 2D image, which may not assume a circular structure, can be potentially more accurate since it is measured

at the same beat at a similar point in the cardiac cycle to avoid variation in LVOT volumes. Thus, in our study, we demonstrated the utility of simultaneous orthogonal plane imaging to obtain a 2D short-axis view of the LVOT for calculating LVOT CSA. There was good agreement between the 3D and the 2D X-plane planimetry assessments of the LVOT area. Measurement is done with live imaging (X-plane) and hence quicker compared to 3D imaging. The frame rate with 2D-TEE imaging is higher than obtained with 3D-TEE. However as 2D-TEE calculates the LVOT CSA assuming a circular shape, it under estimates the LVOT CSA. Whereas, X-plane 2D TEE enables accurate visualisation of LVOT in short axis and offers better temporal resolution thereby providing comparable measurements of LVOT-CSA with 3D TEE. This technique can be used to measure the area when the geometry of the LVOT is in doubt and can be accomplished more quickly than with 3D planimetry.

In our study, the anteroposterior aortic annular diameters were also compared using 2D and 3D TEE. We found statistically insignificant difference between the same. Measurement of the annular diameter in both the anteroposterior and medial-lateral planes is of paramount importance during Transcatheter Aortic Valve Implantation (TAVI) where the annular geometry and the LVOT geometry are key factors deciding the seating of the valve and thereby decreasing the incidence of paravalvular leaks.

One patient in our study who was worked up for TAVI and finally ended up in surgical AVR had CT imaging of aortic root, annulus and LVOT which correlated well with our 3D TEE and 2D X-plane findings of LVOT CSA and LVOT geometry. The CE-derived AVA (3D) in that patient using TEE was more comparable to the

planimetric-AVA derived using CT imaging, than to 3D-planimetric AVA obtained with TEE.

To summarise, with supportive evidence from the available literature we made the below mentioned interpretations.

(1) 2D-TEE underestimated the LVOT areas relative to 3D-TEE.

(2) LVOT shape was elliptical and transverse diameter was longer than AP diameter.

(3) The 3D-TEE yielded a larger continuity equation-based AVA than did the 2D-TEE.

(4) The aortic AP annular diameter measured using 2D and 3D-TEE were almost similar and the difference was statistically insignificant.

(5) Continuity equation-based AVA by 2D-TEE underestimated planimetric AVA by 2D (statistically significant).

(6) Although 3D planimetry AVA is considered as the reference method [ref], we found that continuity equation-derived AVA by 3D-TEE was more than that obtained with 3D planimetry and the difference is statistically significant.

Further studies are required with more subjects to support our interpretations.

Limitations

1. No true standard reference technique is available to determine the LVOT area and AVA. The essential message in our study is that the continuity equation-based AVA derived from 3D-TEE may not be consistent with the planimetry (3D) AVA. Except in one case, we did not have any CT or MRI data to compare the 3D data derived AVAs.
2. Planimetry and continuity equation-based AVA, at least theoretically, cannot be identical because the first measures the geometric orifice area and the second measures the effective orifice area at the vena contracta, which should result in smaller AVA values.[15] The use of the circular assumption of the LVOT geometry might have contributed in part to the underestimation of AVA by 2-D continuity equation methods compared to the 3-D CE method.
3. A fewer number of frame-rates in 3D-TEE (19.6 ± 6.6/s) might cause an underestimation of the AVA in relation to 2D-TEE (50 to 100/s). However, motion of the severely calcified aortic valve can be limited compared to normal; thus, the effect of the fewer frame-rates might not reduce the accuracy of the planimetric AVA measurement using 3D-TEE.
4. We did not perform catheter-based measurements of AVA using Gorlin's formula, which is considered a gold standard for the assessment of AVA.

CONCLUSION

CONCLUSION

All methods of AVA assessment are feasible and reproducible considering the excellent inter-observer variability among them.

1. a) 3D-TEE yielded a larger continuity equation-based AVA than did 2D-TEE and the difference was statistically significant.

   b) 3D planimetry AVA was slightly less when compared to 2D planimetry AVA and the difference was not statistically significant.

2. The 3D CE derived AVA was significantly more when compared to AVA derived by 3D-planimetry, 2D-planimetry, and 2D-CE and the differences were statistically significant.

3. 3D-TEE showed that the LVOT was elliptical in shape in all the cases and its area can be measured with direct 3D planimetry as well as with the X-plane 2D. Compared with 3D-TEE, 2D-TEE imaging underestimated the LVOT area (because LVOT was assumed to be circular), which in turn resulted in overestimation of the degree of AS. The use of 3D-TEE resulted in revision of the severity grades of AS in a significant number of patients.

4. The aortic AP annular diameter measured using 2D and 3D-TEE were almost similar and the difference was statistically insignificant.

We conclude that 3D-TEE AVA measurement using continuity equation as well as AVA measurement using orthogonal plane imaging of LVOT CSA using X-plane has the potential to impact intraoperative surgical decision making in patients with Aortic Stenosis.

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ANNEXURES

ABBREVIATIONS

2D	:	Two dimensional
3D	:	Three dimensional
AF	:	Atrial Fibrillation
AS	:	Aortic Stenosis
AR	:	Aortic Regurgitation
AV	:	Aortic Valve
AVA	:	Aortic valve area
AVR	:	Aortic Valve Replacement
CE	:	Continuity Equation
CSA	:	Cross sectional area
EF	:	Ejection Fraction
LV	:	Left ventricle
LVOT	:	Left Ventricular outflow tract.
LAX	:	Long Axis
SAX	:	Short axis
ME	:	Mid Esophageal
TG	:	Trans gastric
VTI	:	Velocity Time Integral
MPR	:	Multiplanar reconstruction.
RHD	:	Rheumatic Heart Disease
TEE	:	Trans esophageal echocardiography
TTE	:	Trans thoracic echocardiography

Observation chart

Preoperative:

Name of the Patient:

Age: Weight:

Sex: Height:

Hospital number: BSA (kg/cm^2) :

Diagnosis:

Preoperative assessment:

Comorbidities-

NYHA:

Heart rate and rhythm: Blood Pressure:
SPO2:

Pre Op Trans Thoracic Echo (TTE):

PARAMETERS	
LV EF	
AV PEAK VELOCITY	
PEAK GRADIENT	
MEAN GRADIENT	
AVA BY PLANIMETRY	
HEART RATE	
INTER VENTRICULAR SEPTAL THICKNESS	
POSTERIOR WALL THICKNESS	
LV DIASTOLIC FUNCTION	
RV FUNCTION	
OTHER	

INTRAOPERATIVE OBSERVATION

	OBSERVER 1	OBSERVER 1	OBSERVER 2	OBSERVER 2
	2D	3D	2D	3D
PLANIMETRY AVA				
LVOT CSA				
LVOT VTI				
STROKE VOLUME				
AV VTI				
Continuity Equation AVA				
AORTIC ANNULUS				
LVOT SHAPE				
RADIUS 1 (R1)				
RADIUS 2 (R2)				
OTHER				

BSA – Body Surface area

AV-Aortic Valve

SPO2-Saturation of blood

VTI-Velocity Time Integral

LVOT –Left Ventricular Outflow Tract

LV-Left Ventricle

NYHA-New York Heart Association

RV-Right Ventricle

LV EF- Left Ventricular Ejection Fraction

CSA-Cross Sectional Area

AVA-Aortic Valve Area

Consent form

TITLE: Comparison of Aortic Valve Area Obtained By Continuity Equation and Planimetry Using Intraoperative 2 Dimensional and 3 Dimensional Echocardiography in Aortic Stenosis.

Study numbers: We request you to participate in the study wherein we are planning to evaluate intraoperative echocardiographic characteristics of aortic stenosis using (2D and 3D) Trans-esophageal echocardiography. We hope to include 40 people from this hospital in this study.

What is aortic stenosis?
Heart valves lie at the exit of each of your four heart chambers and maintain one-way blood flow through your heart. The four heart valves make sure that blood always flows freely without obstruction in a forward direction and that there is no backward leakage . Aortic valve is one of the heart valves lying between left ventricle and aorta. The aortic valve normally opens and closes to let the blood pass away from the left ventricle to aorta. Aortic Stenosis means obstruction passage of blood from left ventricle to aorta. It occurs due to various reasons.

What is Trans-esophageal echocardiography?
Trans-esophageal echocardiography or TEE is a test that uses sound waves to create high-quality moving pictures of the heart and its blood vessels. This can pin point the problematic areas of the heart and helpful in assessing function of heart valves before and after valve replacement surgery. Usually echocardiography is performed via chest (transthoracic echocardiography). However, under anesthesia, transthoracic echocardiography cannot be performed during cardiac surgery as the surgeon will be operating in that area. Hence echocardiography probe is inserted via esophagus (food pipe). TEE involves a flexible tube (probe) with a transducer at its tip. The Anesthesiologist will guide the probe down your throat and into your esophagus (the passage leading from your mouth to your stomach). This will be done when you will be unconscious under anesthesia and it will not cause any discomfort to you. This approach allows your doctor to get more detailed pictures of your heart because the esophagus is directly behind the heart.

What is the role of Trans-esophageal echocardiography in Aortic Stenosis?
Trans-esophageal echocardiography (TEE) is a useful monitoring tool during cardiac surgery. American society of Anesthesiology and Society of cardiovascular Anesthesiologists have strongly recommended the use of intraoperative TEE in adult patients having aortic stenosis (AS). It helps to determine the cause of AS, to know how severe it is and plan the surgical procedure. Based on the TEE findings about AS, the anesthetic plan and course

of surgery may be changed. This is of great help in assessing the heart function during the operation.

How is Transesophageal echocardiography performed?
This will be done when you are under anesthesia and will not cause any discomfort to you. Your Anesthesiologist will insert the lubricated probe into your mouth. He or she will then gently guide it down your throat into your esophagus. Your esophagus lies directly behind your heart. During this process, Anesthesiologist will take care to protect your teeth and mouth from injury.

What are the risks and side-effects?
We do not expect that our study will cause any injury to you because our study protocol is a part of routine intraoperative TEE examination. You will be under the effect of anesthesia while the test is being performed, thus you are unlikely to experience any discomfort.

Why are we doing this study?
The purpose of this study is to assess the role of 3d echocardiography in assessment of aortic stenosis. It will also help to explore further its utility during cardiac surgery.

Can you withdraw from this study after it starts?
Your participation in this study is entirely voluntary and you are also free to decide to withdraw permission to participate in this study. If you do so, this will not affect your usual treatment at this hospital in any way.

What will happen if you develop any study related injury?
We do not expect any injury to happen to you because of our study as it is a part of routine examination during the surgery.

Will you have to pay for the study? No.

Will your personal details be kept confidential?
Your personal details will be kept confidential. The result of this study will be published in a medical journal but you will not be identified by name in any publication or presentation of results.
If you have any further questions, please ask:
Dr. Prashanth P Bhaskar, Senior Resident, Department of Anaesthesia (Ph No: 9495955259)
Dr. Rupa Sreedhar, Professor and Head of Department of Anaesthesia.
Dr. Shrinivas Gadhinglajkar, Professor, Department of Anaesthesia.
Dr Mala Ramanathan, Member Secretary IEC (Ph No-0471-2524234)

DECLARATION

I, _____,
Participant's name: Date of Birth / Age (in years)

Son / daughter of _____ (Please tick boxes) •

Declare that I have read the above information provide to me regarding the study:

TITLE: Comparison of Aortic Valve Area Using Intraoperative 2 Dimensional and 3 Dimensional Echocardiography in Aortic Stenosis.

- And have clarified any doubts that I had. [ ]
- I also understand that my participation in this study is entirely voluntary and that I am free to withdraw permission to continue to participate at any time without affecting my usual treatment or my legal rights [ ]
- I understand that the study staff and institutional ethics committee members will not need my permission to look at my health records even if I withdraw from the trial. I agree to this access [ ]
- I understand that my identity will not be revealed in any information released to third parties or published [ ]
- I voluntarily agree to take part in this study [ ]
- I received a copy of this signed consent form [ ]

Name: Name of Witness
Signature: Relation To Participant
Date:

(Person Obtaining Consent)

I attest that the requirements for informed consent for the medical research project described in this form have been satisfied. I have discussed the research project with the participant and explained to him or her in nontechnical terms all of the information contained in this informed consent form, including any risks and adverse reactions that may reasonably be expected to occur. I further certify that I encouraged the participant to ask questions and that all questions asked were answered.

Dr Prashanth P Bhaskar ,
Senior Resident, CVTA,
SCTIMST.

സമ്മതപത്രം

അയോർട്ടിക് സ്റ്റീനോസിസിൽ വാൽവ് ഏര്യ അളവ് **പ്ലാനിമെട്രിയും കൺടിന്യുയിറ്റി ഇക്വേഷൻ ഉപയോഗിച്ച്** ട്രാൻസ് ഇസോഫീഗൽ ഇക്കോ കാർഡിയോഗ്രാഫിയുടെ 2 ഡിയും 3 ഡിയും ഉപയോഗിച്ചുള്ള താരതമ്യ പഠനം

പഠന വ്യാപ്തി

ശസ്ത്രക്രിയ സമയത്ത്, ട്രാൻസ് ഇസോഫീഗൽ ഇക്കോ കാർഡിയോ ഗ്രാഫി ഉപയോഗിച്ച് അയോർട്ടിക് സ്റ്റീനോസിസിൽ വാൽവിന്റെ സ്വഭാവ വിശേഷത്തെപ്പറ്റി പഠിക്കുവാനും നിലവിലുള്ള 2ഡി 3ഡി ഉപാധികൾ കൊണ്ട് അയോർട്ടിക വാൽവ് ഏര്യ അളക്കാനും അത് തമ്മിലുള്ള താരതമ്യം നടത്തുവാനും ഉള്ള പഠനത്തിൽ പങ്കാളിയാകാൻ ഞങ്ങൾ താങ്കളോട് അഭ്യർത്ഥിക്കുന്നു. ഈ പഠനത്തിൽ ആശുപത്രിയിൽ നിന്നും 40 പേരെ പങ്കെടുപ്പിക്കാമെന്ന് പ്രതീക്ഷിക്കുന്നു.

എന്താണ് അയോർട്ടിക് സ്റ്റീനോസിസ്?

താങ്കളുടെ ഹൃദയത്തിന്റെ നാലറകളുടേയും പുറത്തേയ്ക്കുള്ള ഭാഗത്താണ് ഹൃദയവാൽവുകൾ സ്ഥിതിചെയ്യുന്നത്. താങ്കളുടെ ഹൃദയത്തിലേക്ക് ഒരു വശത്തേയ്ക്ക് മാത്രമുള്ള രക്തപ്രവാഹം നിലനിർത്തുന്നത് ഈ നാലു ഹൃദയവാൽവുകൾ രക്തം മുന്നോട്ട് അനായാസം ഒഴുക്കുകയും പുറകോട്ട് ഒരു ചോർച്ചയും ഇല്ലെന്ന് ഉറപ്പുവരുത്തുകയും ചെയ്യുന്നു. അയോർട്ടിക വാൽവ് സാധാരണ ഇടത്ത് വെൻട്രിക്കലിൽ നിന്നും അയോർട്ടയിലേക്ക് രക്തം കടന്നു പോകുവാൻ വേണ്ടി തുറക്കുകയും അടക്കുകയും ചെയ്യുന്നു. അയോർട്ടിക് സിനോസിസിൽ വെൻട്രിക്കലിൽ നിന്ന് അയോർട്ടയിലേക്ക് രക്തം ഒഴുക്കുന്നതിൽ തടസ്സമുണ്ടാകുകയും തന്മൂലം മുന്നോട്ട് ഒഴുക്കുക രക്തത്തിന്റെ അളവ് കുറയുകയും ചെയ്യുന്നു.

എന്താണ് ട്രാൻസ്ഇസോഫീഗൽ ഇക്കോകാർഡിയോഗ്രാഫി?

ട്രാൻസ് ഇസോഫീഗൽ ഇക്കോ കാർഡിയോഗ്രാഫി ശബ്ദവീചികൾ ഉപയോഗിച്ച് ഹൃദയത്തിന്റേയും രക്തക്കുഴലുകളുടേയും ചലിക്കുന്ന ഉന്നത ഗുണനിലവാരമുള്ള ചിത്രങ്ങൾ നിർമ്മിക്കുന്നതിനുള്ള ഒരു പരിശോധനയാണ്. ഇത് ഹൃദയത്തിലെ പ്രശ്നബാധിത പ്രദേശങ്ങളിൽ ചൂണ്ടിക്കാണിക്കുവാനും ഹൃദയവാൽവ് മാറ്റിവയ്ക്കുന്നതിന് മുമ്പും ശേഷവും ഹൃദയത്തിന്റെ പ്രവർത്തനത്തെ വിലയിരുത്താനും സഹായകരമാണ്. സാധാരണഗതിയിൽ ഇക്കോ കാർഡിയോഗ്രാഫി നെഞ്ചിലൂടെയാണ്. (ട്രാൻസ് തൊറാസിക് ഇക്കോ കാർഡിയോഗ്രാഫി) എന്നാലും മയക്കലിന് വിധേയമായ അവസ്ഥയിൽ ഹൃദയശസ്ത്രക്രിയയിൽ സർജൻ ആ സ്ഥലമാണ് തുറക്കുന്നത് എന്നതിനാൽ ട്രാൻസ് തൊറാസിക് ഇക്കോ കാർഡിയോഗ്രാഫി ചെയ്യാനാകില്ല. അതിനാൽ റ്റി.ഇ.ഇയിൽ അറ്റത്ത് ട്രാൻസ്ഡ്യൂസർ ഘടിപ്പിച്ച പ്രോബ് അന്നനാളത്തിലൂടെ കടത്തുന്നു. റ്റി.ഇ.ഇയിൽ അറ്റത്ത് ട്രാൻഡ്യൂസർ ഘടിപ്പിച്ച വഴക്കമുള്ള കുഴൽ ഉപയോഗിക്കുന്നു. അനസ്തേഷ്യോളജിസ്റ്റ് പ്രോബ് താങ്കളുടെ തൊണ്ടയിലൂടെ അന്നനാളത്തിലേയ്ക്ക് കടത്തുന്നു. ഇതു ചെയ്യുന്നത് താങ്കൾ അബോധാവസ്ഥയിലും മയക്കത്തിലുമായിരിക്കുമ്പോഴാണെന്നതിനാൽ താങ്കൾക്ക്

ബുദ്ധിമുട്ടൊന്നും തോന്നുകയില്ല. അന്നനാളം ഹൃദയത്തിന്റെ തൊട്ടുതാഴെയാണെന്നതിനാൽ താങ്കളുടെ ഡോക്ടർക്ക് ഹൃദയത്തിന്റെ കൂടുതൽ വിശദമായ ചിത്രം ഈ സമീപനത്തിനായി ലഭ്യമാകും.

അയോർട്ടിക് സ്റ്റീനോസിസിൽ ട്രാൻസ് തൊറാസിക് ഇക്കോ കാർഡിയോഗ്രാഫിയുടെ പങ്ക് എന്ത് ?

ട്രാൻസ് തൊറാസിക് ഇക്കോ കാർഡിയോഗ്രാഫി ഹൃദയ ശസ്ത്രക്രിയ സമയത്ത് ഉപകാരപ്രദമായ ഒരു നിരീക്ഷണ ഉപകരണമാണ്. അമേരിക്കൻ സൊസൈറ്റി ഓഫ് അനസ്തേഷ്യോജളിയും സൊസൈറ്റി ഓഫ് കാർഡിയോ വാസ്കുലർ അനസ്തേഷ്യോളജിസ്റ്റും പ്രായപൂർത്തിയായ അയോർട്ടിക സ്റ്റിനോസിസ് രോഗികളിൽ ശസ്ത്രക്രിയ സമയത്ത് റ്റി.ഇ.ഇ.യുടെ ഉപയോഗം ശക്തമായി ശുപാർശ ചെയ്യുന്നു. ആയത് അയോർട്ടിക സ്റ്റിനോസിസിന്റെ കാരണം വിലയിരുത്താനും അത് എത്ര ഗുരുതരമാണെന്നറിയാനും ശസ്ത്രക്രിയാ നടപടികൾ ആസൂത്രണം ചെയ്യാനും സഹായിക്കുന്നു. ശസ്ത്രക്രിയാ സമയത്ത് ഹൃദയത്തിന്റെ പ്രവർത്തനം വിലയിരുത്തുന്നതിൽ ഇത് വലിയ സഹായകമാണ്.

ട്രാൻസ് ഈസോഫാജിയൽ ഇക്കോ കാർഡിയോഗ്രാഫി എങ്ങനെയാണ് ചെയ്യുന്നത്?

ഇത് ചെയ്യുന്നത് താങ്കൾ മയക്കത്തിലായിരിക്കുന്നതിനാൽ ബുദ്ധിമുട്ടുകളൊന്നും തോന്നുകയില്ല. അനസ്തേഷ്യോളജിസ്റ്റ് താങ്കളുടെ വായിലൂടെ എക്കോ കാർഡിയോ ഗ്രാഫ് പ്രോബ് അന്നനാളത്തിലേക്ക് കടത്തും. താങ്കളുടെ പല്ലിനും വായ്ക്കും പരിക്കേൽക്കാതിരിക്കാൻ പ്രത്യേകം ശ്രദ്ധിക്കും.

എന്തെല്ലാം അപകടങ്ങളും പാർശ്വഫലങ്ങളും ഉണ്ടാകാം?

ശസ്ത്രക്രിയ സമയത്തുള്ള റ്റി.ഇ.ഇ. പരിശോധന സാധാരണമായുള്ളതിനാൽ ഞങ്ങളുടെ പഠനത്തിന്റെ ഭാഗമായി ഒരു പരിക്കും പ്രതീക്ഷിക്കുന്നില്ല. പരിശോധന നടത്തുമ്പോൾ താങ്കൾ മയക്കത്തിന് വിധേയനായതിനാൽ ബുദ്ധിമുട്ടൊന്നും അനുഭവപ്പെടുകയില്ല.

ഞങ്ങൾ എന്തിന് പഠനം നടത്തുന്നു?

അയോർട്ടിക് സ്റ്റീനോസിസിൽ നിലവിലുള്ള 2ഡി 3ഡി ഉപാതികൾ മൂലമുള്ള അയോർട്ടിക വാൽവ് ഏര്യ അളവിൽ ഓരോന്നിന്റേയും കൃത്യത വിലയിരുത്തുന്നതിനാണ് ഈ പഠനം. ഹൃദയ ശസ്ത്രക്രിയയിൽ ഭാവിയിൽ കൂടുതൽ അന്വേഷണങ്ങൾക്കും ഇത് സഹായിക്കും.

പഠനം ആരംഭിച്ച ശേഷം താങ്കൾക്ക് പിൻമാറാമോ?

താങ്കളുടെ പഠനത്തിലുള്ള പങ്കാളിത്തം പൂർണ്ണമായും സ്വമേധയായുള്ളതും പഠനത്തിൽ നിന്നും പിന്മാറാൻ സ്വാതന്ത്ര്യം ഉള്ളതുമാണ്. അങ്ങനെ ചെയ്യുന്നതുകൊണ്ട് ഈ ആശുപത്രിയിലെ താങ്കളുടെ സാധാരണ ചികിത്സയെ ബാധിക്കുകയില്ല.

പഠനാനുബന്ധിയായ അപകടമുണ്ടായാൽ എന്ത് സംഭവിക്കും?

ശസ്ത്രക്രിയാ സമയത്തുള്ള റ്റി.ഇ.ഇ. പരിശോധന സാധാരണമായുള്ളതിനാൽ പഠനത്തിന്റെ ഭാഗമായി ഒരുപരിക്കും പ്രതീക്ഷിക്കുന്നില്ല.

ഈ പഠനത്തിൽ താങ്കൾ പണം മുടക്കണമോ?

വേണ്ട

താങ്കളുടെ വ്യക്തിപരമായ വിവരങ്ങൾ രഹസ്യമായി വയ്ക്കാമോ?

പഠനഫലങ്ങൾ ഗവേഷണപ്രബന്ധത്തിന്റെ ഭാഗമായും, ഒരു വൈദ്യശാസ്ത്ര ജേർണലിലും പ്രസിദ്ധീകരിക്കുമെങ്കിലും താങ്കളുടെ പേരുവിവരങ്ങൾ ഉണ്ടാകില്ല. എന്നാലും താങ്കൾ പങ്കെടുക്കാൻ സമ്മതിച്ചാൽ താങ്കളുടെ വിവരങ്ങൾ പഠനവുമായി ബന്ധപ്പെട്ട ആളുകൾ താങ്കളുടെ പ്രത്യേക സമ്മതമില്ലാതെ പരിശോധിച്ചേക്കാം.

താങ്കൾക്ക് കൂടുതൽ എന്തെങ്കിലും ചോദ്യങ്ങൾ ഉണ്ടെങ്കിൽ ദയവായി ഞങ്ങളോട് ചോദിക്കുക?

ഡോ. പ്രശാന്ത് പി. ഭാസ്കർ, സീനിയർ റസിഡന്റ്, ഡിപ്പാർട്ട്മെന്റ് ഓഫ് കാർഡിയോതൊറാസിക് ആന്റ് വാസ്കുലാർ അനസ്തേഷ്യ (ഫോൺ: 9495955259)

ഡോ. രൂപ ശ്രീധർ, പ്രൊഫസർ ആന്റ് ഹെഡ്, ഡിവിഷൻ ഓഫ് കാർഡിയോതൊറാസിക് ആന്റ് വാസ്കുലാർ അനസ്തേഷ്യ

ഡോ. ശ്രീനിവാസ്, പ്രൊഫസർ, ഡിവിഷൻ ഓഫ് കാർഡിയോതൊറാസിക് ആന്റ് വാസ്കുലാർ അനസ്തേഷ്യ.

ഡോ. മാല രാമനാഥൻ ,ഐ.ഇ.സീ -മെമ്പർ സെക്രട്ടറി (ഫോൺ:0471 2524234)

പ്രസ്താവന

ഞാൻ .....(പങ്കെടുക്കുന്ന ആളിന്റെ പേര്, വയസ്സ്, ജനനതീയതി (വർഷത്തിൽ)

പഠനസംബന്ധിയായി എനിക്ക് നൽകിയ വിവരങ്ങൾ വായിച്ചു എന്നു ഞാൻ പ്രസ്താവിക്കുന്നു.

പഠനശീർഷകം: അയോർട്ടിക് സ്റ്റീനോസിസിൽ വാൽവ് ഏരിയ അളവ്: ട്രാൻസ് ഇസോഫീഗൽ ഇക്കോ കാർഡിയോ ഗ്രാഫിയുടെ 2 ഡിയും 3 ഡിയും ഉപയോഗിച്ചുള്ള താരതമ്യ പഠനം.

എന്റെ എല്ലാ സംശയങ്ങളും പരിഹരിച്ചു.( )

എന്റെ ഈ പഠനത്തിലുള്ള പങ്കാളിത്തം പൂർണ്ണമായും സ്വമേധയാ ഉള്ളതാണെന്നും എന്റെ ചികിത്സയേയോ നിയമാവകാശങ്ങളെയോ ബാധിക്കാതെ പഠനത്തിൽ നിന്നും പിൻമാറാമെന്നും ഞാൻ മനസ്സിലാക്കുന്നു. ( )

ഞാൻ ഈ പഠനത്തിൽ നിന്നും പിൻമാറിയാലും പഠനം നടത്തുന്നവർക്കും സ്ഥാപനത്തിലെ നൈതിക കമ്മറ്റി അംഗങ്ങൾക്കും എന്റെ ആരോഗ്യ രേഖകൾ പരിശോധിക്കുന്നതിനും എന്റെ അനുവാദ രേഖകൾ ആവശ്യമില്ലെന്ന് ഞാൻ മനസ്സിലാക്കുന്നു. അതിനോട് ഞാൻ യോജിക്കുന്നു. ( )

എന്നെ തിരിച്ചറിയാനുതകുന്ന വിവരങ്ങൾ ഒന്നും മറ്റുള്ളവർക്ക് നൽകുകയോ പ്രസിദ്ധീകരിക്കുകയോ ചെയ്യുകയില്ലെന്ന് ഞാൻ മനസ്സിലാക്കുന്നു. ( )

സമ്മതപത്രത്തിന്റെ ഒപ്പിട്ട് ഒരു കോപ്പി എനിക്ക് കിട്ടി. ( )

പേര് :

ഒപ്പ് :

തീയതി :

സാക്ഷിയുടെ പേര് :

പങ്കെടുക്കുന്ന ആളുമായുള്ള ബന്ധം :

മെഡിക്കൽ റിസർച്ച് പ്രോജക്റ്റിനാവശ്യമായ സമ്മതപത്രത്തിനുവേണ്ട എല്ലാ ഘടകങ്ങളും തൃപ്തികരമായി നിർവ്വഹിച്ചിരിക്കുന്നുവെന്ന് ഞാൻ ബോധ്യപ്പെടുത്തുന്നു. പഠന പങ്കാളിയുമായി ഗവേഷണപദ്ധതിയെപ്പറ്റി സാങ്കേതികേതര പദങ്ങൾ ഉപയോഗിച്ച് എല്ലാ വിവരങ്ങളെപ്പറ്റിയും ചർച്ച നടത്തുകയും പ്രതീക്ഷിക്കാവുന്ന അപകട സാദ്ധ്യതകളും പാർശ്വഫലങ്ങളും വിശദീകരിക്കുകയും ചെയ്തു. പങ്കാളിയെ ചോദ്യങ്ങൾ ചോദിക്കാൻ പ്രേരിപ്പിക്കുകയോ എല്ലാ ചോദ്യങ്ങൾക്കും ഉത്തരം നൽകുകയും ചെയ്തുയെന്നും ഞാൻ സാക്ഷ്യപ്പെടുത്തുന്നു.

സമ്മതപത്രം വാങ്ങുന്ന ആളിന്റെ പേരും ഒപ്പും :

Technical Advisory Committee (Clinical Studies)

SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES & TECHNOLOGY
THIRUVANANTHAPURAM – 695011, INDIA

TAC Registration No: SCT-/S/2016/543 **Date:24.11.2016**

Project title: COMPARISON OF AORTIC VALVE AREA OBTAINED BY CONTINUITY EQUATION AND PLANIMETRY USING INTRAOPERATIVE 2 DIMENSIONAL AND 3 DIMENSIONAL ECHOCARDIOGRAPHY IN AORTIC STENOSIS.

Principal Investigator:
Name: Dr. Prashanth P Bhaskar Degree: DNB. (Anaesthesiology), M.B.B.S. Senior Resident, Department of Anaesthesiology, SCTIMST
Co-Principal Investigator(s)
(1) Name: Dr Rupa Sreedhar, Professor, Department of Anaesthesiology, SCTIMST Degree: Post-Doctoral Certificate Course: Cardiothoracic Vascular and Neurosurgical Anesthesiology. M.D. (Anesthesiology), D.A. (Anesthesiology), M.B.B.S.
(2) Name: Dr. Shrinivas Gadhinglajkar, Professor, Department of Anaesthesiology, SCTIMST Degree: Post-Doctoral Certificate Course: Cardiothoracic Vascular and Neurosurgical Anesthesiology. M.D. (Anesthesiology), M.B.B.S.

Members who participated in the TAC meeting on 05/11/2016
Dr. Rupa Sreedhar (Chairperson)
Dr. Mathew Abraham
Dr. Prasantakumar Dash
Dr. Sankara Sarma. P
Dr. Sylaja P.N
Dr. Krishna Kumar K
Dr. Syam. K
Dr. Bijulal S
Dr. Jayadevan E.R.
Dr. Varghese T. Panicker
Dr. K. Shivakumar (Member Secretary)

Dr. Rupa Sreedhar, Dr. Bijulal S, Dr. Prasantakumar Dash and Dr. Jayadevan E.R stayed away from the proceedings when the projects in which they are involved (# 532,533,538,543,544,545,547,550,559) as investigators were discussed.

Risk Classification of the project (Minimum/ Moderate/ High): Minimum
Requirement of DSMB: No
Recommended members of DSMB: Not applicable

Recommendations of TAC:
Recommended for consideration of IEC in the light of the responses received from the investigator

The PI may note that there can be no additions / alterations in the documents approved by TAC when they are submitted to the IEC.

Signature of the Member Secretary, TAC (Clinical Studies)

Note for IEC
Copy of the investigator's responses to questions/suggestions from TAC is attached (Appendix-1).

श्री चित्रा तिरुनाल आयुर्विज्ञान और प्रौद्योगिकी संस्थान, त्रिवेन्द्रम
तिरुवनन्तपुरम - ६९५०११, केरल, इंडिया
SREE CHITRA TIRUNAL INSTITUTE FOR MEDICAL SCIENCES AND TECHNOLOGY, TRIVANDRUM
Thiruvananthapuram - 695 011, Kerala, India
(An Institute of National Importance under Govt. of India)
Grams : Chitramet, Phone : +91-471-2443152, Fax : +91-471-2550728 / 2446433, E-mail : sct@sctimst.ac.in, Website : www.sctimst.ac.in

Institutional Ethics Committee
(IEC Regn No. ECR/189/Inst/KL/2013)

SCT/IEC/1001/DECEMBER-2016 31.10.2017

Dr. Prashanth P Bhaskar
Senior Resident
Department of Anaesthesiology
SCTIMST, Thiruvananthapuram

Dear Dr. Prashanth P Bhaskar,

The Institutional Ethics Committee reviewed and discussed your application to conduct the study entitled "COMPARISON OF AORTIC VALVE AREA OBTAINED BY CONTINUITY EQUATION AND PLANIMETRY USING INTRAOPERATIVE 2 DIMENSIONAL AND 3 DIMENSIONAL ECHOCARDIOGRAPHY IN AORTIC STENOSIS" (IEC/1001) on 17th December, 2016.

The following documents were reviewed:

Original submission

1. *Covering letter addressed to the Chairman, IEC, SCTIMST, dated 25.11.2016 with checklist*
2. *TAC Approval Letter*
3. *IEC Application Form*
4. *Project Proposal*
5. *Informed Consent Forms in English and Malayalam*
6. *Observation chart*
7. *Declaration form*
8. *CV of Principal Investigator and Co- Principal Investigators*

Revised submission

1. *Covering letter addressed to the Chairman, IEC, SCTIMST, dated 30.10.2017 with checklist*
2. *TAC Approval Letter*
3. *IEC Application Form*
4. *Project Proposal*
5. *Informed Consent Forms in English and Malayalam*
6. *Observation chart*
7. *Declaration form*
8. *CV of Principal Investigator and Co- Principal Investigators*

The following members of the Ethics Committee were present at the meeting held on 17th December, 2016 at G. Parthasarathi Board Room, AMCHSS, SCTIMST

SL. No.	Member Name	Highest Degree	Gender	Scientific /Non Scientific	Affiliation with Institution(s)
1.	Justice Gopinathan. P.S	BSc. LLB	Male	Legal Expert (Chairperson)	No
2.	Dr. Harikrishna Varma PR	PhD	Male	Biomedical Scientist	Yes
3.	Dr. Meenu Hariharan	DM	Female	Clinician (Gastro-Enterologist)	No
4.	Dr. Rema M. N	MD	Female	Pharmacologist	No
5.	Dr. R V G Menon	PhD	Male	Lay Person	No
6.	Smt. Sathi Nair	MA	Female	Lay Person	No
7.	Dr. K R S Krishnan	ME, PhD	Male	Biomedical Scientist/Engineer	No
8.	Dr. Kala Kesavan. P	MD	Female	Pharmacologist	No
9.	Dr. Christina George	MD	Female	Psychiatrist	No
10.	Dr. P. Manickam	PhD	Male	Scientist - Epidemiologist	No
11.	Dr. Mala Ramanathan	MSc, PhD, MA	Female	Ethicist/Social Scientist (Member Secretary)	Yes

IEC Decision

The IEC approved the conduct of the study in the present form.

Remarks:
The Institutional Ethics Committee expects to be informed about the progress of the study, any SAE occurring in the course of the study, any changes in the protocol and patient information/informed consent and asks to be provided a copy of the final report.

There was no member of the study team who participated in voting / decision making process. The ethics committee is organized and operated according to the requirements of Good Clinical Practice and the requirements of the Indian Council of Medical Research (ICMR).

Sincerely,

Mala Ramanathan
Member Secretary, IEC

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INTRODUCTION Severe Aortic Stenosis(AS) is defined as a valve area less than 1.0 cm2 or mean aortic pressure gradient more than 40 mm Hg.1 However, there are often discrepancies between planimetry, continuity equation-based aortic valve areas (AVA). The accuracy of AVA measured using the continuity equation depends primarily on the precise measurement of the left ventricular outflow tract (LVOT)2.Until now, the LVOT area has been calculated as, p (LVOT dimension/2)2, assuming that LVOT has a circular shape. However, LVOT could actually be elliptical. 3, 4.

The hemodynamic calculations in echocardiography frequently involves measurement of LVOT stroke volume. The shape of LVOT is presumed to be circular for the estimation of cross sectional area. However, many recent studies based on 3D echocardiography have demonstrated that the LVOT shape may be elliptical (other than circular) on many occasions6, 7.

Because of the differences observed on 2D and 3D echocardiography, the LVOT area –based hemodynamic calculations differ between the modalities. One such example would be the calculation of aortic valve area in patients with aortic stenosis using continuity equation. In cases of patients with coronary artery disease (CAD) and moderate to severe AS, these differences may affect intraoperative clinical decision making (Coronary artery bypass grafting (CABG) + AVR or CABG alone).

Computed tomography (CT) and magnetic resonance imaging (MRI) of the aortic root have established that the shape of LVOT may be circular or elliptical [4,5,9-13].Studies involving 3D Trans Esophageal Echocardiography(TEE) imaging of aortic root have reported that the LVOT may be elliptical in shape having major and minor axes, rather than being circular in shape as has been presumed conventionally[6,7,].

Planimetry of an en-face view may yield a relatively larger LVOT area than estimations based on measurement of minor axis with 2D echocardiography 7. Hence, 2D echocardiographic measurements result in smallest LVOT area8, which in turn may overestimate the severity of AS when AVA is measured by continuity equation14, 15. Aortic Valve Replacement (AVR) is reasonable for patients with moderate AS who are undergoing other cardiac surgery (II a Class of recommendation)16.

Hence, accurate estimation of AVA is necessary to take decision regarding the requirement for combined surgery. The purpose of this intraoperative study is to compare the aortic valve area and LVOT geometry assessed by two dimensional (2D) and three-dimensional (3D) transesophageal echocardiography (TEE) and its impact on evaluating severity of AS.

Study Protocol: After obtaining approval from IEC, patients were enrolled in the study during the pre-anesthetic evaluation. Patients were educated about the study in the presence of a witness. The witness could question the patient as to whether he/ she had really understood details of the proposed study.

An informed consent form was signed by patient or relative of the patient as per the Institute protocol. An adult-size TEE probe was inserted after induction of anesthesia and a comprehensive cardiac examination was done using a RT-3D-TEE probe and ultrasound machine.(Philips iE 33, Philips Ultrasound, Bothell, USA). Comprehensive cardiac examination included the necessary views required for management of the patient.

The AVA was estimated using the continuity equation (CE-AVA-2D) method as follows: CE-AVA (2D) = [LVOT area (2D) × velocity-time integral of LVOT] ÷ Velocity-time integralof AV 3D Planimetry: A full-volume dataset of aortic valve and LVOT were acquired after optimising gain, compression controls and time gain compensation over four consecutive heart beats. Reference planes for full volume acquisition were mid esophageal AV-LAX and mid esophageal AV-SAX views.

Continuity Equation (3D) Doppler-VTI measurements of both AV and LVOT were common for the estimation of stroke volume using continuity equation. The 3D-AVA was estimated using the continuity equation (CE-AVA-3D) method as follows: CE-AVA (3D) =3D LVOT area x LVOT- VTI /AV-VTI. / Fig 6: The figure depicts method of 3D evaluation of LVOT geometry, measurement of the LVOT CSA, and LVOT diameters in anteroposterior and medial-lateral planes.

Observations: Please refer to Annexure page 2 Outcome parameters: We obtained AVA by continuity equation (using 2D LVOT area and 3D LVOT area), 2D planimetry, and 3D planimetry which were compared among each other. The inter-observer variability was also calculated for the same. STATISTICAL ANALYSIS Statistical analysis was done using SPSS software version 22 and Graph pad prism 5.2. Continuous variables are expressed as mean ±standard deviation(SD).

Range of 95% Confidence Interval as shown by broken lines in difference plot, are over a wider range from the baseline (1.58 to 0.16), signifying poor agreement between 2D and 3D-CSA measurement methods.Correlation coefficient: R=0.979, p<0.001(statistically significant). LVOT- Left ventricular outflow tract, CSA- Cross sectional area, 2D-Two dimensional, 3D- Three dimensional, TEE-Transesophageal echocardiography.

DISCUSSION Ours is the first prospective study which compared AVA assessment by 3D-TEE with X-plane 2D TEE and CE based aortic valve area measurement,in the intra-operative period. There were no particular complications during any of the TEE examinations. Our success rate of 2D measurement were91%, which is comparable to or even higher than conventional 2D planimetry done by the previous studies.6

In comparison to 3D TEE, 2D TEE planimetry overestimated the AVA in our cohorts, but it was statistically not significant. 2D-TEE oftenmakes an oblique cut through the valve leafletsrather than at the tip of the leaflets. Consequently, it is oftentechnically difficult to capture the tip of the aortic valveleaflets at their maximal systolic opening using 2D-TEE with a fixed imaging plane.57-59 In addition, 2D-TEE has thedisadvantages of more fuzzy contours, shadow phenomena,and motion artefacts.The gain setting may affect themeasured AVA, especially in severely calcified valves.59Inability to localise the tip of AV leaflets in severe calcific AS may be the cause for

overestimation of AVA when 2D echocardiography is used.

In AS the effect is pronounced and the functionally measured AVA should be slightly lower than anatomical AVA. This principle can be the reason behind slightly lower AVA measured by CE-2D in comparison to 2D/3D planimetry in our study. The European Association of Echocardiography/American Society of Echocardiography guidelines now advocate LVOT diameters derived from 2-dimensional echocardiography to be used to estimate a continuity equation-based AVA.2However, the LVOT actually could be of elliptical shape, with a shorter anteroposterior diameter, casting a doubt on the accuracy of a continuity equation based AVA calculated by the assumption of a circular geometry.

Our findings are similarto that of previous studies regarding LVOT geometry, which reported an ellipticalLVOT with shorter anteroposterior diameter.4,7,77 Additionally, the ellipticity was able to be predicted using 2-dimensional X-plane parameters in our study. Therefore, 3D-TEE or X-plane 2D TEEshould be used to evaluate LVOT geometry prior to cases of percutaneous aortic valve implantation.Accurate assessment of LVOT geometry could affect the success of this procedure because the apical end of the new valve is attached to the LVOT.

CONCLUSION All methods of AVA assessment are feasible and reproducible considering the excellent inter-observer variability among them. a) 3D-TEE yielded a larger continuity equation-based AVA than did 2D-TEE and the difference was statistically significant. b) 3D planimetry AVA was slightly less when compared to 2D planimetry AVA and the difference was not statistically significant. 2.

The 3D CE derived AVA was significantly more when compared to AVA derived by 3D-planimetry, 2D-planimetry, and 2D-CE and the differences were statistically significant. 3. 3D-TEE showed that the LVOT waselliptical in shape in all the cases and its area can bemeasured with direct 3D planimetry as well as with the X-plane 2D. Compared with 3D-TEE,2D-TEE imaging underestimated the LVOT area (because LVOT was assumed to be circular), which in turn resulted in overestimation of the degree of AS. The use of 3D-TEE resulted inrevision of the severity grades of AS in a significantnumber of patients. 4.The aortic AP annular diameter measured using 2D and 3D-TEE were almost similar and the difference was statistically insignificant.

We conclude that 3D-TEE AVA measurement using continuity equation as well as AVA measurement using orthogonal plane imaging of LVOT CSA using X-

plane has the potential to impact intraoperative surgical decision making in patients with AS.

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SlNo	AGE	GENDER	WEIGHT	HEIGHT	BSA	DIAGNOSIS	DM	HTN	DLP	HYPOTHYROID	CKD	PSY	BA/COPD	CAD	NYHA	PULSE	RHYTHM	SBP	DBP	SPO2	EF1	AV VEL1	PG1	MG1	HR	SW S1	SW D1	PW S1	PW D1	LV DF1	RV F1
1	58	1	59	166	1.6	BAV,SEV AS,SVD	0	0	0	0	0	0	0	1	2	60	1	120	80	100	70	4.5	98	60	60	17	15	16	12	0	0
2	63	1	67	164	1.76	BAV,SEV AS,MOD AR,MOD MR	1	1	0	0	1	1	0	0	2	70	1	146	80	100	66	4.4	87	50	70	17	15	15	13	1	0
3	63	1	53	155	1.51	CAD,CSA,DVD,SEV. AS,MILD AR	1	0	0	0	0	0	0	1	2	80	1	130	70	98	72	4.4	94	54	70	15	13	17	12	1	0
4	66	1	70	161	1.76	SEV. CAL AS,	1	1	1	0	0	0	0	0	3	60	1	140	86	98	38	3.5	54	32	60	15	13	12	10	2	2
5	60	1	71	160	1.78	BAV,SEV.AS, MILD AR	0	0	0	0	0	0	1	0	2	70	1	150	70	94	72	4	74	46	64	21	17	17	13	1	0
6	62	1	96	172	2.14	SEV. CAL AS MILD AR, MR ,PAH	0	1	1	0	0	0	1	0	3	80	1	140	84	96	54	4.2	72	49	90	15	14	14	12	1	0
7	45	2	48	153	1.41	RHD SEV AS MOD. MS/MR/AR	0	0	0	0	0	0	0	0	3	90	1	130	70	99	78	4.5	104	59	90	16	11	11	10	0	0
8	44	1	60	168	1.67	BAV, SEV CAL AS , FAIR LV	1	0	0	0	0	0	0	0	3	60	1	120	76	99	51	4.5	106	64	60	14	13	12	11	1	0
9	69	1	62	160	1.66	SEV. CAL AS, MILD AR , GD LV	1	0	0	0	0	1	0	0	2	76	1	140	74	100	70	4.5	100	52	80	19	14	16	10	2	0
10	61	2	76	156	1.78	SEV CAL AS GD LV,PRESYNCOPE	0	0	1	0	0	0	1	0	2	76	1	140	78	98	60	5.2	137	77	68	19	15	16	13	1	0
11	59	1	76	157	1.81	BAV,SEV CAL AS,GD LV	1	1	0	0	0	0	0	0	2	80	1	170	86	99	73	4	62	37	72	15	11	12	8	1	0
12	65	2	63	151	1.62	SEV CAL AS ,MILD AR,GD LV	0	1	0	0	0	0	0	0	2	66	1	160	84	100	66	4	71	42	66	18	10	16	11	1	0
13	68	2	63	155	1.64	SEV CAL AS MOD AR,GD LV	0	1	1	0	0	0	1	0	3	66	1	160	80	98	74	5	118	63	72	16	13	15	10	2	1
14	43	1	57	159	1.57	BAV SEV CAL AS,MOD AR	0	0	0	0	0	0	0	0	2	66	1	140	78	100	66	4.5	100	69	66	16	14	16	11	1	0
15	56	2	45	157	1.46	BAV SEV CALAS,MOD AR,MILD LVD	1	0	0	0	0	0	0	0	3	96	1	90	60	98	46	4	74	54	80	13	10	12	9	3	0
16	60	2	62	152	1.6	SV CAL AS NC	1	1	0	0	0	0	0	0	2	60	1	140	80	100	79	4.5	97	68	66	17	15	15	12	1	0
17	67	1	54	153	1.51	SCLERO DEG AS /MILD AR	0	1	0	0	0	0	0	0	2	70	1	160	76	98	70	4	71	36	66	14	10	14	10	1	0
18	60	1	58	167	1.63	BAV, SEV CALCIFIC AS, MILD AR	0	0	0	0	0	0	1	0	2	60	1	160	80	98	74	4.5	91	51	60	15	11	13	11	1	0
19	66	1	79	165	1.9	CAD, SVD, SEV CAL AS	1	0	0	0	0	0	1	1	2	70	1	140	76	100	65	4.5	97	64	70	15	12	14	12	2	0
20	75	1	72	166	1.82	SEV CAL AS,MOD AR,CAD	0	0	1	1	0	0	0	1	2	60	1	140	72	99	65	4.5	100	60	60	22	19	18	16	1	0
21	48	2	60	156	1.62	BAV ,SEV AS,GD LV	0	0	1	0	0	0	0	0	3	70	1	140	80	100	66	4	67	41	65	15	12	12	10	1	0
22	50	2	80	161	1.8	RHD,SEV AS,MOD AR	0	0	0	0	0	0	0	0	3	70	1	140	70	100	63	5	170	100	60	18	16	14	9	1	0
23	65	2	68	154	1.7	SEV CAL AS	1	1	0	0	0	0	0	0	2	70	1	142	80	97	67	5	160	90	64	19	14	17	13	1	0
24	49	1	52	152	1.5	SEV CAL AS MOD AR MOD MR	0	0	0	0	0	0	1	0	3	80	1	130	80	98	60	5	125	65	66	20	15	21	17	1	1
25	59	1	71	164	1.83	BAV,SEV AS,MILD AR,GD LV	0	0	1	0	0	0	0	0	2	66	1	120	78	99	61	4.5	104	60	60	25	20	21	17	1	0
26	54	2	55	156	1.54	SEV CAL AS MILD AR	0	1	0	0	0	0	0	0	3	80	1	140	74	100	66	5	134	74	70	16	13	14	11	1	0
27	51	1	61	169	1.7	SEV CAL AS MOD AR	0	0	0	0	0	0	0	0	3	70	1	160	80	100	76	4.5	97	57	70	25	20	17	13	1	0
28	60	1	49	159	1.45	SEV CAL AS, MILD AR	1	1	0	0	0	0	0	0	3	70	1	160	80	98	70	5	130	80	76	17	11	14	11	1	0
29	52	1	59	161	1.6	SEV CAL AS, MILD AR, SEV LVD	0	0	0	0	0	0	0	0	3	80	1	130	85	98	30	3.2	44	28	80	13	11	11	10	3	1
30	57	2	59	154	1.6	RHD, SEV AS, MOD MS/MR, PAH CAD, SVD	1	1	0	0	0	0	0	1	2	70	1	130	80	99	78	3.5	40	20	74	13	10	12	10	1	0
31	44	1	70	164	1.8	RHD, SEV AS, MOD MS/MR/TR, PAH	1	0	0	0	0	0	0	0	3	80	2	110	70	98	45	4	64	35	80	13	10	12	9	2	1
32	52	2	60	150	1.6	CAD, DVD, BAV, SEV AS, GOOD LV	0	1	0	0	0	0	0	1	2	66	1	140	70	99	55	4	60	40	70	14	11	12	9	1	0
33	59	1	60	160	1.65	CAD, RHD, CALCIFIC AS,CVA, GOOD LV	1	0	0	0	0	0	0	1	2	70	1	140	80	99	59	4	60	36	68	15	13	12	11	1	0
34	52	2	55	150	1.5	BAV, SEV CALCIFIC AS, MILD AR, SVD	1	1	0	0	0	0	0	1	2	80	1	130	76	98	65	5	130	80	90	16	12	12	11	0	0
35	58	2	59	154	1.6	BAV,SEV CAL AS, MILD AR, GD LV	0	1	0	0	0	0	0	0	2	70	1	130	80	99	56	4.5	92	50	70	14	10	12	10	1	0
36	71	1	65	160	1.8	SEV CAL AS, CAD,PPI GDLV	1	1	1	0	0	0	0	1	2	70	1	150	80	99	61	4.3	80	48	70	13	11	14	11	1	0
37	49	1	83	178	2	SEV CAL AS, CAD,GD LV	1	0	1	0	0	0	0	1	2	76	1	140	86	100	54	4.8	114	68	70	15	12	16	12	1	0
38	63	1	60	161	1.64	SEV CAL AS, SR, TIA	0	0	0	0	0	0	0	0	2	68	1	130	74	100	67	4.5	90	55	66	18	16	21	19	1	0
39	57	2	58	146	1.5	SEV CAL AS, MOD AR, PAH, CVA	1	1	1	1	0	1	0	0	2	68	1	160	95	95	69	4.8	116	68	66	18	14	22	18	1	0
40	48	1	66	163	1.7	SEV CAL AS, MILD AR, CAD, TVD	1	0	0	0	0	0	0	1	2	70	1	120	72	100	76	4.5	90	53	80	19	16	20	17	1	0

SlNo	MR1	AR1	TR1	ANN 1	P AVA 2D1	P AVA 3D1	P AVA 2D2	P AVA 3D2	LVOT CSA 2D1	LVOT CSA 3D1	LVOT CSA 2D2	LVOT CSA 3D2	LVOT VTI 2D1	LVOT VTI 3D1	LVOT VTI 2D2	LVOT VTI 3D2	SV 2D1	SV3D1	SV2D2	SV 3D2	AV VTI 2D1	AV VTI 3D1	AV VTI 2D2	AV VTI 3D2	C AVA 2D1	C AVA 3D1	C AVA 2D2	C AVA 3D2	ANN 2D1	ANN 3D1
1	1	2	0	25	0.74	0.66	0.7	0.63	4.52	4.96	4.52	4.8	25.3	25.3	24.2	24.2	114	125.5	109.4	116.2	132	132	123	123	0.8	0.95	0.82	0.98	23.4	22.8
2	3	2	1	23	1.2	1.3	1.24	1.31	4.9	5.96	4.9	5.92	23.5	23.5	23.2	23.2	115.2	140	113.7	137.3	82.6	82.6	74.5	74.5	1.3	1.6	1.35	1.7	23	22.8
3	1	2	1	21	0.47	0.56	0.5	0.58	3.14	3.86	3.14	3.8	15.2	15.2	16.8	16.8	47.7	58.6	52.7	63.8	109	109	105	105	0.43	0.53	0.5	0.61	19.6	20.6
4	1	2	2	21	0.52	0.54	0.45	0.5	3.46	4.7	3.46	5.1	25.4	25.4	22	22	87.8	119.4	76.1	112.2	171	171	167	167	0.51	0.7	0.45	0.67	20.5	20.7
5	1	1	1	25	0.85	0.8	0.9	0.85	4.15	5.04	4.15	5.12	22.8	22.8	24.3	24.3	94.6	114.9	100.9	124.4	113	113	115	115	0.83	1.02	0.87	1.08	24	23.5
6	2	2	1	24	0.76	0.81	0.84	0.78	5.4	6.5	5.4	6.55	18	18	22	22	97.2	117.9	118.8	144	104	104	120	120	0.93	1.13	0.99	1.2	24.4	23
7	02-Jan	2	1	22	1.01	0.96	1.04	0.92	3.46	4.4	3.46	4.33	22.4	22.4	21.7	21.7	77.5	98.6	75.1	93.9	92.6	92.6	89.8	89.8	0.84	1.07	0.83	1.05	22.5	22.3
8	1	2	1	24	0.73	0.62	0.7	0.6	5.3	6.3	5.3	6.2	19.7	19.7	18.2	18.2	114	124	96.6	112.5	117	117	109	109	0.88	1.06	0.89	1.03	24.6	23.7
9	2	2	0	21	0.64	0.58	0.56	0.53	3.14	3.53	3.14	3.5	16.1	16.1	15.6	15.6	50.5	56.8	49	54.6	102	102	100	100	0.5	0.56	0.49	0.55	21.6	22
10	1	2	1	21	0.5	0.42	0.52	0.44	2.54	3.9	2.54	3.8	16.2	16.2	16.7	16.7	41.15	63.2	42.4	63.46	111	111	109	109	0.38	0.57	0.4	0.58	20	21.2
11	1	1	1	24	0.66	0.69	0.67	0.74	3.14	3.56	3.14	3.6	18	18	16.2	16.2	56.5	64.1	50.8	58.3	67.4	67.4	65.7	65.7	0.83	0.95	0.77	0.89	20.2	20.4
12	1	2	1	19	0.61	0.59	0.71	0.64	2.84	3.2	2.84	3.4	14	14	17.9	17.9	39.8	44.8	50.8	60.9	71.2	71.2	75.6	75.6	0.56	0.63	0.67	0.8	19.5	20
13	1	2	1	21	0.82	0.8	0.8	0.77	3.14	3.69	3.14	3.62	31.2	31.2	29.5	29.5	97.9	115.1	92.6	106.8	95.3	95.3	91.7	91.7	1.02	1.2	1.01	1.16	19	19.2
14	1	2	1	25	0.9	0.84	0.86	0.83	4.52	5.5	4.52	5.55	16	16	15.8	5.8	72.3	88	71.4	87.7	86.3	86.3	81.2	81.2	0.84	1.02	0.88	1.08	22.4	21.7
15	2	2	1	22	0.86	0.76	0.82	0.72	4.15	5.4	4.15	5.5	13	13	14	14	54	70.2	58	77	75.7	75.7	68.5	68.5	0.71	0.92	0.84	1.12	22.4	23
16	1	1	2	21	0.58	0.55	0.56	0.54	3.14	4.1	3.14	4.3	17.3	17.3	15.6	15.6	54.3	70.9	48.9	67.1	120	120	115	115	0.45	0.59	0.43	0.58	20.4	20.5
17	2	2	1	20	0.85	0.9	0.8	0.86	3.46	3.79	3.46	3.68	15	15	18	18	51.9	56.8	62.3	66.2	67.5	67.5	66.3	66.3	0.76	0.84	0.92	1	20	20.5
18	1	2	1	20	0.57	0.47	0.6	0.5	3.14	3.48	3.14	3.38	11.5	11.5	12	12	36.1	38.9	37.7	40.5	85.6	85.6	83.9	83.9	0.42	0.45	0.45	0.48	20.4	20
19	1	1	0	24	0.56	0.53	0.63	0.6	3.4	4.5	3.4	4.2	13.8	13.8	13.9	13.9	46.9	62.1	47.3	58.8	145	145	138	138	0.33	0.43	0.34	0.42	24.2	24.4
20	1	2	1	20	0.88	0.83	0.81	0.8	2.84	4.1	2.84	4.2	17.9	17.9	19.6	19.6	50.8	73.9	55.6	83.5	97.6	97.6	94.7	94.7	0.52	0.76	0.58	0.8	20	21
21	1	2	1	20	1.15	1.05	1.2	1.1	3.14	3.9	3.14	4.2	16.6	16.6	17	17	52	65.6	53	71	86	86	79	79	0.6	0.75	0.64	0.8	19.8	20.4
22	1	2	0	21	1	0.96	0.95	0.9	2.84	3.6	2.84	3.4	30.2	30.2	30.4	30.4	85	108	86	104	112	112	110	110	0.8	1	0.75	0.95	21	21
23	2	2	0	22	0.36	0.4	0.46	0.42	2.54	3.2	2.54	3.25	18.4	18.4	14.6	14.6	46.7	59	37	47	138	138	105	105	0.34	0.42	0.35	0.45	20	20
24	3	2	2	22	0.43	0.5	0.45	0.47	2.84	4	2.84	4.1	22.5	22.5	23.6	23.6	64	90	67	96.7	184	184	198	198	0.35	0.49	0.34	0.48	20	21
25	1	2	1	22	0.78	0.7	0.75	0.65	3.8	4.7	3.8	4.5	28	28	27	27	106	131	102	121.5	132	132	136	136	0.8	1	0.75	0.9	20.8	21.1
26	1	2	1	21	0.46	0.4	0.5	0.45	3.46	4.32	3.46	4.6	22.5	22.5	19	19	78	97	65	90	119	119	112	112	0.65	0.81	0.6	0.8	21.4	21
27	1	2	1	21	0.84	0.94	0.9	0.96	3.8	5.1	3.8	4.9	21.6	21.6	20	20	82	111.5	76	98	96	96	102	102	0.86	1.16	0.75	1	21.8	21.6
28	1	2	1	23	0.7	0.73	0.65	0.66	3.14	3.73	3.46	3.85	13.5	13.5	20	20	42.4	50.3	69.2	77	79.5	79.5	76	76	0.53	0.63	0.7	0.9	21	22
29	2	2	2	25	0.56	0.65	0.6	0.7	6.1	7.7	5.8	7.4	9.2	9.2	12.2	12.2	56	70	70	89	85	85	92	92	0.7	0.8	0.75	0.95	26.5	26
30	2	2	2	21	0.9	0.82	0.92	0.9	2.84	3.7	2.84	3.8	20.5	20.5	19.6	19.6	58	76	55	75	65	65	63	63	0.9	1.16	0.9	1.15	20.8	21
31	3	2	2	21	0.9	0.88	0.96	0.92	3.14	4	3.14	3.82	12	12	15.6	15.6	38	49	49	59	66	66	65	65	0.57	0.73	0.67	0.8	21	20
32	1	1	1	19	0.6	0.52	0.56	0.53	2.54	2.98	2.54	2.8	14	14	15.4	15.4	35.8	42	39	43	82	82	75	75	0.43	0.51	0.52	0.57	18	17.5
33	1	1	1	24	0.9	1	0.96	1.15	4.9	6.2	5.3	5.5	17	17	17.5	17.5	84	106	92.7	96	77	77	79	79	1.1	1.4	1.1	1.23	26	26.2
34	1	1	1	22	0.6	0.53	0.7	0.65	3.46	4	3.46	3.74	13.3	13.3	15	15	46	53	52	55	99	99	100	100	0.46	0.53	0.5	0.58	22	22.2
35	1	2	1	21	1.2	1.18	1.25	1.2	3.14	3.6	3.14	3.7	25	25	24	24	79	91	74	90	71	71	70	70	1.1	1.3	1.05	1.06	21	20.8
36	0	1	0	22	0.88	0.9	0.9	0.88	3.8	4.6	3.8	4.7	13.6	13.6	13.5	13.5	52	62	51	65	93	93	100	100	0.56	0.67	0.51	0.65	22	22.1
37	1	1	1	22	0.72	0.78	0.74	0.8	4.15	6	4.15	6.1	16	16	19	19	68	101	80	122	134	134	132	132	0.5	0.76	0.61	0.88	22	22.5
38	1	1	1	20	0.46	0.44	0.45	0.44	3.8	4.6	3.8	4.65	17	17	18	18	65	79	68	84	150	150	145	145	0.44	0.54	0.46	0.58	20	21
39	1	2	2	22	0.8	0.68	0.78	0.66	2.54	3.6	2.54	3.7	35	35	35.5	35.5	89	126	90	131	108	108	106	106	0.82	1.16	0.84	1.2	19.6	20.4
40	1	1	1	20	0.62	0.69	0.65	0.73	3.14	3.6	3.14	3.8	18.5	18.5	16	16	58	66	50	61	86	86	83	83	0.67	0.78	0.6	0.73	20.8	21.1

SlNo	ANN 2D2	ANN 3D2	SHAPE 2D1	SHAPE 3D1	SHAPE 2D2	SHAPE 3D2	D1 2D1	R1 2D1	D1 3D1	R1 3D1	D1 2D2	R1 2D2	D1 3D2	R1 3D2	D2 2D1	R2 2D1	D2 3D1	R2 3D1	D2 2D2	R2 2D2	D2 3D2	R23D2	AR 2D1	AR 2D2	MR 2D1	MR 2D2	TR 2D1	TR 2D2	PG 2D1	PG 2D2	MG 2D1	MG 2D2	EF 2D1	EF 2D2	LVOT X PLAN 2D	X D1 2D
1	23.2	23	1	2	1	2	2.4	1.2	2.3	1.15	2.4	1.2	2.26	1.13	2.4	1.2	2.6	1.3	2.4	1.2	2.6	1.3	2	2	1	1	0	0	105	97	64	62	64	60	4.91	2.3
2	22.6	22.5	1	2	1	2	2.5	1.25	2.6	1.3	2.5	1.25	2.6	1.3	2.5	1.25	2.7	1.35	2.5	1.25	2.7	1.35	3	2	3	3	1	1	55	49	36	34	60	58	5.5	2.5
3	20	20.8	1	2	1	2	2	1	1.9	0.95	2	1	1.96	0.98	2	1	2.4	1.2	2	1	2.4	1.2	2	2	1	1	1	1	73	75	47	44	60	55	4.18	2
4	20.6	21	1	2	1	2	2.1	1.05	2.1	1.05	2.1	1.05	2.1	1.05	2.1	1.05	2.6	1.3	2.1	1.05	2.7	1.35	2	2	1	1	1	1	129	126	79	76	30	28	5.13	2.1
5	23.6	23.3	1	2	1	2	2.1	1.05	2.1	1.05	2.3	1.15	2.1	1.05	2.3	1.15	2.8	1.4	2.3	1.15	2.8	1.4	2	2	1	1	1	1	72	70	42	45	65	62	5.3	2.3
6	24	22.8	1	2	1	1	2.6	1.3	2.7	1.35	2.6	1.3	2.7	1.35	2.6	1.3	2.9	1.45	2.6	1.3	2.9	1.45	2	2	2	2	1	1	65	62	46	44	55	60	6.25	2.5
7	22.4	22.2	1	2	1	2	2.1	1.05	2	1	2.1	1.05	2.1	1.05	2.1	1.05	2.6	1.3	2.1	1.05	2.5	1.25	2	3	2	2	1	1	58	57	38	36	60	64	3.75	2
8	24.4	23.1	1	2	1	2	2.6	1.3	2.6	1.3	2.6	1.3	2.5	1.25	2.6	1.3	3.1	1.55	2.6	1.3	3	1.5	2	2	1	1	0	0	76	75	45	46	56	60	6.63	2.6
9	21	21.7	1	2	1	2	2	1	2	1	2	1	2	1	2	1	2.2	1.1	2	1	2.1	1.05	2	2	1	1	0	0	75	70	45	46	42	45	3.6	2
10	20.2	21.4	1	2	1	2	1.8	0.9	1.9	0.95	1.8	0.9	1.8	0.9	1.8	0.9	2.5	1.25	1.8	0.9	2.5	1.25	1	1	1	1	1	1	84	86	50	54	60	58	3.56	1.8
11	21	20.5	1	2	1	2	2	1	1.9	0.95	2	1	1.9	0.95	2	1	2.3	1.15	2	1	2.3	1.15	1	1	1	1	1	1	46	40	22	25	56	60	3.5	1.9
12	20	20.2	1	2	1	2	1.9	0.95	1.9	0.95	1.9	0.95	1.9	0.95	1.9	0.95	2.1	1.05	1.9	0.95	2.2	1.1	1	2	1	1	1	1	60	62	34	35	58	60	3.3	2
13	18.9	19	1	2	1	2	2	1	1.9	0.95	2	1	2	1	2	1	2.5	1.25	2	1	2.4	1.2	2	3	1	1	1	1	67	65	43	37	60	62	3.9	2
14	22	22.2	1	2	1	2	2.4	1.2	2.5	1.25	2.4	1.2	2.6	1.3	2.4	1.2	2.8	1.4	2.4	1.2	2.8	1.4	2	2	1	1	0	0	58	53	37	35	50	52	5.55	2.4
15	22.8	23.4	1	2	1	2	2.3	1.15	2.3	1.15	2.3	1.15	2.3	1.15	2.3	1.15	2.8	1.4	2.3	1.15	2.8	1.4	2	2	2	2	1	1	49	45	33	30	40	42	4.5	2.3
16	20.3	20.1	1	2	1	2	2	1	2	1	2	1	2	1	2	1	2.5	1.25	2	1	2.4	1.2	1	2	1	1	1	1	80	75	50	54	55	55	3.7	1.9
17	19.7	20.4	1	2	1	2	2.1	1.05	2	1	2.1	1.05	2	1	2.1	1.05	2.4	1.2	2.1	1.05	2.3	1.15	2	3	1	1	1	1	50	52	25	24	55	60	3.8	2
18	20	20.2	1	2	1	2	2	1	1.9	0.95	2	1	1.9	0.95	2	1	2.2	1.1	2	1	2.2	1.1	1	1	1	1		1	70	66	45	44	60	55	3.7	1.9
19	24	24.5	1	2	1	2	2.1	1.05	2.2	1.1	2.1	1.05	2.2	1.1	2.1	1.05	2.4	1.2	2.1	1.05	2.4	1.2	1	1	1	1	0	0	103	100	67	65	54	56	4.5	2.1
20	20	21.8	1	2	1	2	1.9	0.95	2.1	1.05	1.9	0.95	2	1	1.9	0.95	2.7	1.35	1.9	0.95	2.7	1.35	2	2	1	1	1	1	60	66	40	42	55	60	4.2	2.1
21	20	19.6	1	2	1	2	2	1	1.8	0.9	2	1	1.9	0.95	2	1	2.5	1.25	2	1	2.6	1.3	2	2	1	1	1	1	60	56	38	36	60	55	3.8	1.9
22	20	20	1	2	1	2	1.9	0.95	1.9	0.95	1.8	0.9	1.8	0.9	1.9	0.95	2.5	1.25	1.9	0.95	2.4	1.2	2	2	1	1	0	0	60	60	34	36	63	60	3.75	2.1
23	19.5	19.5	1	2	1	2	1.8	0.9	1.8	0.9	1.8	0.9	1.8	0.9	1.8	0.9	2.2	1.1	1.8	0.9	2.2	1.1	2	2	2	2	1	1	90	76	60	50	58	60	3.2	1.8
24	20.2	20.8	1	2	1	2	1.9	0.95	1.9	0.95	1.9	0.95	2	1	1.9	0.95	2.5	1.25	1.9	0.95	2.4	1.2	2	3	2	2	1	1	147	140	89	81	52	50	4	1.9
25	21	21.5	1	2	1	2	2.2	1.1	2.2	1.1	2.2	1.1	2.2	1.1	2.2	1.1	2.6	1.3	2.2	1.1	2.5	1.25	2	2	1	1	1	1	125	123	78	78	60	55	5	2.2
26	21.3	21.2	1	2	1	2	2.1	1.05	2.2	1.1	2.1	1.05	2.2	1.1	2.1	1.05	2.5	1.25	2.1	1.05	2.5	1.25	2	2	1	1	1	1	100	96	60	59	58	60	4.2	2.1
27	21	21.4	1	2	1	2	2.2	1.1	2.2	1.1	2.2	1.1	2.3	1.15	2.2	1.1	2.8	1.4	2.2	1.1	2.7	1.35	2	3	1	1	1	1	50	60	32	30	60	58	4.8	2.2
28	20.8	21	1	2	1	2	2	1	2	1	2.1	1.05	2.1	1.05	2	1	2.4	1.2	2.1	1.05	2.4	1.2	2	2	1	1	1	1	52	48	31	30	60	59	3.6	2
29	25.8	26	1	2	1	2	2.8	1.4	2.8	1.4	2.7	1.35	2.7	1.35	2.8	1.4	3.3	1.65	2.7	1.35	3.2	1.6	2	3	1	1	2	2	56	50	28	26	30	32	7.5	2.8
30	21	21.2	1	2	1	2	1.9	0.95	1.9	0.95	1.9	0.95	1.9	0.95	1.9	0.95	2.4	1.2	1.9	0.95	2.4	1.2	2	2	2	2	2	2	31	30	21	20	55	58	3.4	1.9
31	20.5	19.6	1	2	1	2	2	1	1.9	0.95	2	1	1.9	0.95	2	1	2.4	1.2	2	1	2.5	1.25	2	2	1	1	2	2	33	34	22	22	50	50	4.1	1.9
32	18.5	17.8	1	2	1	2	1.8	0.9	1.8	0.9	1.8	0.9	1.7	0.85	1.8	0.9	2.1	1.05	1.8	0.9	2.1	1.05	1	1	1	1	1	1	45	42	28	30	58	55	3	1.8
33	26.6	26.4	1	2	1	2	2.5	1.25	2.5	1.25	2.6	1.3	2.6	1.3	2.5	1.25	3.2	1.6	2.6	1.3	3	1.5	1	1	1	1	1	1	42	47	27	27	52	54	6.1	2.5
34	22	22.4	1	2	1	2	2.1	1.05	2.1	1.05	2.1	1.05	2.1	1.05	2.1	1.05	2.2	1.1	2.1	1.05	2.2	1.1	1	1	1	1	1	1	65	66	35	38	55	56	3.7	2.1
35	21.5	21.2	1	2	1	2	2	1	2	1	2	1	2	1	2	1	2.2	1.1	2	1	2.3	1.15	2	3	1	1	1	1	46	48	24	20	50	52	3.5	2
36	22.2	22	1	2	1	2	2.2	1.1	2.2	1.1	2.2	1.1	2.3	1.15	2.2	1.1	2.6	1.3	2.2	1.1	2.7	1.35	1	1	1	1	0	0	74	70	42	40	55	56	4.2	2.2
37	22.4	22.2	1	2	1	2	2.3	1.15	2.3	1.15	2.3	1.15	2.3	1.15	2.3	1.15	3	1.5	2.3	1.15	3.1	1.55	1	1	1	1	1	1	93	87	66	63	55	60	6	2.3
38	20.5	21	1	2	1	2	2.2	1.1	2.2	1.1	2.2	1.1	2.2	1.1	2.2	1.1	2.5	1.25	2.2	1.1	2.5	1.25	1	1	1	1	1	1	106	103	70	67	65	63	4.6	2.1
39	20	19.6	1	2	1	2	1.8	0.9	1.8	0.9	1.8	0.9	1.9	0.95	1.8	0.9	2.3	1.15	1.8	0.9	2.3	1.15	2	3	2	2	2	2	55	54	34	33	50	54	3.3	1.8
40	20.6	21	1	2	1	2	2	1	2	1	2	1	2	1	2	1	2.3	1.15	2	1	2.4	1.2	1	1	1	1	1	1	93	80	40	50	52	55	3.5	1.9

SlNo	X R12D	X D2 2D	XR2 2D	SW S 2D	SW D 2D	PW S 2D	PW D 2D	LV DF 2D	TAPSE 2D	OTHERS
1	1.15	2.6	1.3	20	16	15	12	0	17	
2	1.25	2.9	1.45	18	13	17	14	0	16	
3	1	2.5	1.25	16	14	14	12	1	17	
4	1.05	2.7	1.35	16	12	14	12	3	15	
5	1.15	2.9	1.45	22	16	16	13	1	16	
6	1.25	3	1.5	16	12	15	13	1	18	
7	1	2.3	1.15	16	12	12	10	1	16	MS 12/6 DVR
8	1.3	3.1	1.55	20	15	17	12	1	19	
9	1	2.3	1.15	19	14	15	12	3	18	
10	0.9	2.4	1.2	23	18	18	14	1	18	
11	0.95	2.5	1.25	18	15	15	12	1	19	BPH
12	1	2.5	1.25	18	12	15	11	1	18	
13	1	2.5	1.25	17	14	14	10	1	15	TRACHEOSTOMISED
14	1.2	2.8	1.4	16	12	14	11	1	18	
15	1.15	3	1.5	12	10	11	9	3	16	
16	0.95	2.3	1.15	16	13	15	12	1	20	
17	1	2.5	1.25	17	13	16	13	1	17	
18	0.95	2.4	1.2	18	14	14	12	1	18	
19	1.05	2.4	1.2	16	12	15	13	1	18	
20	1.05	2.6	1.3	20	18	18	16	1	18	
21	0.95	2.3	1.15	14	12	12	10	1	18	
22	1.05	2.5	1.25	19	17	15	11	1	16	
23	0.9	2.1	1.05	16	14	14	12	1	18	
24	0.95	2.4	1.2	20	16	17	14	2	12	DVR MR-3
25	1.1	2.7	1.35	21	17	119	15	1	16	CT ANN-22X26,LVOT 21X27
26	1.05	2.5	1.25	20	14	14	12	1	18	
27	1.1	2.6	1.3	18	16	17	14	1	18	
28	1	2.4	1.2	16	12	15	11	1	16	
29	1.4	3.2	1.6	14	11	11	9	3	14	DILATED ASC AORTA, PLASTY
30	0.95	2.2	1.1	13	11	12	10	1	16	MOD MS, DVR
31	0.95	2.4	1.2	12	10	12	10	3	12	DVR, MS3
32	0.9	2.1	1.05	14	12	12	10	1	18	
33	1.25	3.2	1.6	16	12	12	10	1	18	LF,LG,AS
34	1.05	2.2	1.1	16	12	12	10	1	16	
35	1	2.2	1.1	14	12	12	10	1	18	MOD AR
36	1.1	2.5	1.25	16	14	14	11	1	17	
37	1.15	3	1.5	16	12	15	11	1	22	
38	1.05	2.6	1.3	21	19	17	50	1	16	
39	0.9	2.3	1.15	18	13	16	14	1	18	
40	0.95	2.2	1.1	25	22	18	16	1	16	