Original Article

Comparison of Flow-Independent Parameters for Grading Severity of Aortic Stenosis Using Intraoperative Transesophageal Echocardiography – A Prospective Observational Study

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Abstract

Introduction: Discrepancies have been reported in grading of severity of aortic stenosis. We propose to compare Aortic valve area by continuity equation, Dimensionless Index and Acceleration time/Ejection time in patients with documented severe aortic stenosis with normal left ventricular function by TEE after induction of anesthesia. This might give use insight about the best parameter we can rely on intra-operatively for decision making. **Methodology:** 60 patients with severe AS undergoing elective cardiac surgery were enrolled in our study. Post intubation trans-thoracic echocardiography (TEE) was performed and above mentioned parameters was noted. **Results:** 96.7 % of patients continued in severe AS category when AS was measured using AVA as echo parameter. So there is 3.3 % disparity. There was disparity in 13.3% of cases when DI was considered. And there was 43.3% disparity when AT/ET was considered. **Conclusion:** Perioperative grading of aortic stenosis continues to be a challenge for cardiac anesthesiologists. Multiple echocardiographic parameters have to be considered. We have found AVA and DI to have less disparity compared to AT/ET.

Keywords: *Acceleration time/ejection time, aortic stenosis, dimensionless index*

Introduction

Aortic stenosis (AS) is one of the most common valvular heart diseases in the world with an estimated prevalence of 3.4% in elderly people.[1] Severe AS is defined by echocardiography as mean gradient >40 mmHg, aortic valve area (AVA) <1 cm^2, and peak aortic jet velocity >4.0 m/s.[2]

However, discrepancies have been reported in grading of severity of AS. Even in patients with normal ejection fraction, the mean gradient let to underestimation of severity of AS in around 35% of patients.[3] Pre-cardiopulmonary bypass (CPB) transesophageal echocardiography (TEE) has a discrepancy rate of up to 35% when the mean gradient was used as a parameter to assess AS.[4]

Intraoperative TEE has said to have influenced surgical decision-making in 7% of cases.[5] Flow-dependent variables aortic valve peak velocity and mean gradient have been found to reduce significantly during intraoperative TEE.[6]

AVA by continuity equation has also led to disparity in grading AS. Studies have found that using AVA by TEE led to reduction in severity of AS in 14% of patients.[7]

Dimensionless index (DI) which is the ratio of velocity time integral (VTI) across LVOT and aortic valve has been found to provide better identification of patients with severe AS.[8] DI might be particularly useful in patients in whom the estimation of the LVOT cross-sectional area (CSA) is difficult.[9]

Acceleration time (AT), which is the time from the beginning of ejection to peak velocity across aortic valve, is mainly dependent on AVA and heart rate (HR). Ejection time (ET) depends on the stroke volume. Hence, it is hypothesized that the ratio of AT/ET is not affected by flow across the valve. The same was tested in a study where they used transthoracic echocardiography and found good correlation between AT/ET and other flow-independent parameters.[10]

We propose to compare AVA by continuity equation, DI, and AT/ET in patients with documented severe AS with normal left

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ventricular function by TEE after induction of anesthesia. This might give useful insight about the best parameter we can rely on intraoperatively for decision-making.

Methodology

Institutional Ethical Committee approval was obtained and this prospective observational study was conducted in our institute between January 2017 and December 2017. Informed written consent was taken, and 60 patients posted with severe AS for elective aortic valve replacement (AVR) or coronary artery bypass grafting (CABG) with AVR were enrolled in our study.

Inclusion criteria

The inclusion criteria included adult patients 18–75 years of age posted for elective AVR with severe AS documented preoperatively by transthoracic echo, with left ventricular ejection fraction of >55% in normal sinus rhythm.

Exclusion criteria

The inclusion criteria included moderate to severe aortic/mitral regurgitation, moderate to severe mitral stenosis, hemodynamic instability, contraindication for TEE probe placement, and patient's refusal.

All patients had TTE done to confirm severe AS before surgery. All of them received standard anesthesia induction protocol, and after intubation Phillips X7-2t TEE probe was inserted. Once HR and invasive blood pressure (IBP) where within 20% of the preoperative values, TEE was performed, and AVA using continuity equation, DI, and AT/ET ratio was noted.

All patients had AVA was calculated via the continuity equation:

$$AVA\ (cm^2) = (CSA_{LVOT})(VTI_{LVOT})$$

$$VTI_{AV}$$

To determine the CSA of the left ventricular outflow tract (LVOT), the LVOT diameter was obtained using the midesophageal aortic valve long-axis view. LVOT diameters obtained were within 0.5–1.0 cm of the valve orifice at the location of the LVOT. VTI of the LVOT and AVA were measured via pulsed-wave Doppler (PWD) and CWD, respectively, in deep transgastric view.

DI is LVOT VTI divided by AV VTI. The time taken from the onset of ejection to peak ejection velocity was taken as the AT and this divided by the total ET gives AT/ET.

The values were taken by or under supervision of a trained cardiothoracic anesthesiologist. The grading of severity of AS was done using Table 1. The highest grading obtained was to be considered.

Statistical analysis

The sample size was calculated from a previous study[9] using correlation of −0.49, α of 0.05, β of 0.10, and power of study as 90%. The sample size obtained was 40. We have included 60 patients in our study. Data were analyzed using STATA/IC (Stata Statistical Software, TX, USA; Statcorp LP) 14.2 software. Data were expressed as mean ± standard deviation for continuous variables and percentage for categorical variables. Comparison between echocardiographic parameters was calculated by Pearson's correlation.

Results

A total of 60 patients with severe AS are included in our study. The demographic variables of our studied patients are given in Table 2. Out of 60 patients, 58 patients fell into severe AS category using AVA as the echo parameter on TEE. So there is 3.3% disparity [Table 3 and Figure 1]. Out of 60 patients, 58 patients had AVA <1.0 cm^2 on TEE examination. Thus, 96.7% of the patients continued in severe AS category when AS was measured using AVA as the echo parameter. So there is 3.3% disparity [Table 3 and Figure 1].

About 52 patients fell into severe AS category if DI was used, making it 86.7% of patients still with severe AS. There was disparity in 13.3% of cases.

Table 1: Grading of aortic stenosis[6,10]

Measurement	Mild AS	Moderate AS	Severe AS
AVA (cm^2)	>1.5	1-1.5	<1
Dimensionless index	>0.5	0.25-0.50	<0.25
AT/ET			>0.35

AS=Aortic stenosis; AVA=Aortic valve area; AT=Acceleration time; ET=Ejection time

Table 2: Demographic variables of study population

Patient characteristics	*n*=60
Age (years)	61.4±18.2
Male sex	44 (73.33%)
BSA	1.6±0.16
Surgical procedure	
AVR	44 (90%)
CABG + AVR	6 (10%)
Cause	
Degenerative	30 (50.0%)
BSV	22 (36.6%)
RHD	8 (13.3%)

BSA=Body surface area; AVR=Aortic valve replacement; CABG=Coronary artery bypass grafting; BSV=Bicuspid aortic valve; RHD=Rheumatic heart disease

Table 3: Disparity of each parameter

Echo parameter	No of severe AS preoperatively	No of severe AS intraoperatively	Percentage
AVA	60	58	96.7
DI	60	52	86.7
AT/ET	60	34	56.7

AVA=Aortic valve area; DI=Dimensionless index; AT=Acceleration time; ET=Ejection time

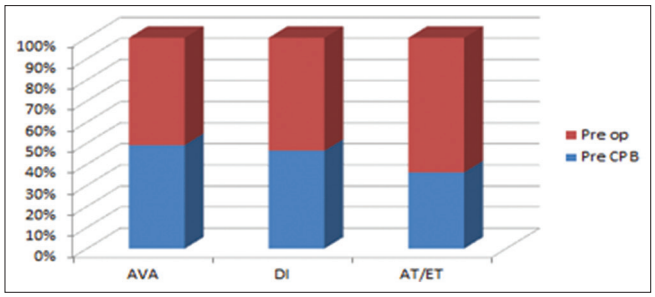

Figure 1: Percentage of patients who remained in severe AS category with each variable compared with pre-operative data

Over 34 patients were in severe AS if AT/ET was used. Thus, only 56.7% of patients remained in severe AS grade. There was disparity in 43.3% of patients.

Discussion

AS using peak velocity and mean gradient is flow-dependent and can lead to underestimation of severity of AS under general anesthesia. Thus, intraoperative assessment by TEE using these measurement can lead to disparity.[11]

AVA by continuity is also said to be impacted by blood flow. Blood pressures have been found to affect AVA inversely due to changes in transvalvular flow.[12] In study by Whitener *et al*., they found 8% disparity with AVA in grading of AS.[13] In a prospective study, there was no significant difference in AVA measurement.[11] In this study as well, there was only 3.3% disparity in grading AS when using AVA as the echocardiographic parameter.

AVA measurement is also subjected to errors. It is mainly affected by accurate LVOT measurement. LVOT is said to be more elliptical than circular and the exact site of its measurement is also not certain.[14] In spite of these limitations, LVOT measurements have been found to have accurate reproducibility while comparing TTE and TEE.[15]

DI is less flow-dependent and less dependent on the angle of spectral Doppler to flow across aortic valve.[14] Uda *et al*. in their study have found more than 80% agreement in grading of AS between preoperative TTE and intraoperative TEE using DI.[6] In our study also, we have found an agreement in more than 85% of cases.

Delayed AT and prolonged ET measured by echocardiography are associated with severity of AS.[16] AT/ET has been found to be relatively flow-independent.[17] We obtained a 43.3% disparity with AT/ET ratio pointing toward its flow dependency. Few reasons for this might be that ejection phase and thus AT/ET ratio are also affected by HR and to a lesser extend stroke volume.[18] We could not standardize HR and stroke volume while doing TEE and TTE. Thus, further studies are required to judge the flow independence of AT/ET.

Limitation

It is an observational study and thus may be subjected to more bias. Randomized trials with more sample size are required to come to a concrete conclusion.

Conclusion

Perioperative grading of AS continues to be a challenge for cardiac anesthesiologists. Multiple echocardiographic parameters have to be considered. We have found AVA and DI to have less disparity compared with AT/ET.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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