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DOPPLER ECHOCARDIOGRAPHIC ASSESSMENT OF HAEMODYNAMIC INDICES AFTER AORTIC VALVE REPLACEMENT

Cardiology

Dr. Bijumon PR Department of Cardiology, General Hospital, Kanjirappally 686506, Kerala, India

Dr. Stanley George* Department of Cardiology, Pariyaram Medical College, Kannur 670503, Kerala, India
*Corresponding Author

ABSTRACT

Objective: The present study was postulated to assess the haemodynamic parameters after aortic valve replacement(AVR) using Doppler echocardiography.

Methods: This was a prospective, single-centred, observational study which included a total of 50 patients who underwent AVR. Post-operative Doppler echocardiography was done prior to discharge for assessment of various haemodynamic parameters for critical estimation prosthetic valve function. The univariant analysis was performed for indexed EOA with DVI, AT and AT/ET to establish correlation among them.

Results: The current study included patients of varied age from 20-80 years. Indexed EOA was >0.85 in 48 patients, between 0.65-0.85 in 1 patient and <0.65 in 1 patient. A total of 36% patients were found to have higher trans-valvular gradient in the immediate post AVR period. But on assessment after 6 month of AVR, trans-valvular gradient was normalized in 88% patients. Only 2 out of 50 patients remained high with echo-doppler parameters, suggested presence of prosthesis patient mismatch(PPM). A strong positive correlation was observed between indexed EOA and DVI with a *p*-value of 0.0001 and r^2-value of 0.8.

Conclusion: The post-operative assessment as well as long-term follow-up should be taken in the patients who underwent AVR to reduce occurrence of early and late complications.

KEYWORDS

Doppler Echocardiography, Aortic Valve Replacement, Indexed Effective Orifice Area, Prosthesis Patient Mismatch

INTRODUCTION

The valvular heart disease (VHD) has been a source of great health burden worldwide. Among all the existing valves in heart, aortic valve has a crucial role to play in cardiac well-being [1]. In developing country like India, the preponderance rate of aortic valve disease (AVD) was estimated to be 2.8% and was found to be increasing with age[2]. The prevalence of AVD was found to be approximately 1.0% at age 75 years which increased to 7.1% by the age of 85-95 years[2]. The AVD occurs due to aortic valve stenosis (AS) which results in the obstruction of left ventricular outflow or due to aortic valve regurgitation (AR) which causes backflow of blood owing to inadequate closing of valve[2].

From decades, surgical aortic valve replacement (SAVR) was the only treatment available for AS, but as all patients cannot cope with surgery, therefore non-invasive technique called trans-catheter aortic valve replacement (TAVR) was developed. The TAVR has now emanated as the recommended treatment for patients at high risk of surgery for AS and studies are going on for patients at intermediate or low risk of surgery to improve mortality and morbidity rate after AVR[3,4].

Doppler echocardiography has remained as the main method for evaluation of native as well as prosthetic AS **[5].** Follow-up post-TAVR should be taken for each patient to reduce the risk of development of early or late complications **[5].** Through echocardiography, various parameters can be assessed including visual appearance, haemodynamic parameters and cardiac functions which help to determine the cause of prosthetic stenosis or dysfunctioning[6].

Doppler echocardiography is the essential method for assessment of non-invasive haemodynamic which can be directly correlated with the invasive haemodynamic assessments **[5].** High gradient after AVR can be due to left ventricular (LV) obstruction or without LV obstruction [7]. Hence, possible cause of high gradient should be assessed and carefully evaluated before making clinical determination. Therefore, the present study was postulated to assess the haemodynamic parameters after AVR using Doppler echocardiography.

MATERIALS AND METHODS

This was a prospective, single-centred, observational study conducted at the tertiary care centre of South India. It included a total of 50 patients who underwent aortic valve replacement. The study was approved by the local ethics committee of the institute and informed consent was received from all the patients before the start of the study.

The patients who underwent double valve replacement, CABG along with AVR, Bentall procedure, associated with mitral valve disease or with LV dysfunction were not included in the study. Follow-up was taken 6 months after AVR.

Post-operative Doppler echocardiography was performed prior to discharge with critical assessment of the type and size of prosthesis used and prosthetic valve function. The haemodynamic parameters were studied which includes peak gradient, mean gradient, shape of spectral doppler, acceleration time, ejection time, ratio of acceleration time and ejection time (AT/ET), left ventricular outflow tract (LVOT) diameter, LVOT velocity time integral (VTI), aortic VTI, dimensionless valve index (DVI), effective orifice area (EOA) and indexed EOA.

The results were represented as frequency and percentage, calculated using Statistical Package for the Social Sciences (USA, Chicago; Version-15). The univariant analysis was performed for indexed EOA with DVI, AT and AT/ET to establish correlation among them.

RESULTS

The present study included total 50 patients who underwent aortic valve replacement. The baseline characteristics are depicted in the **Table 1**.

The current study included patients of varied age from 20-80 years. In this study, maximum 28 (56%) patients were between the age of 41-60 years, followed by 12 (24%) patients between the age of 61-80 years, 8 (16%) patients between 21-40 years and 2 (4%) patients with the age ≤20 years. The study included 72% males and 28% females. Among the 50 patients, 32 patients underwent AVR due to AS, 15 (30%) patients underwent AVR due to AR and 3 (6%) patients due to presence of AS and AR both. In 44 patients, aortic valve was replaced with single leaflet tilting disc mechano-prosthetic valve and in 6 patients aortic valve was replaced with bovine pericardial bioprosthetic valve.

Various haemodynamic parameters for evaluation of prosthetic valve function were examined using Doppler echocardiography and are epitomised in **Table 2**. The peak velocity was found to be greater than 3 m/s in 18 (36%) patients, where as in 32 (64%) patients it was found to be less than or equal to 3 m/s. The mean gradient was found to be ≤20 mmHg in 40 patients and >20 mmHg in 10 patients.

Acceleration time was found to be <80 msec in 46% patients, 80-100 msec in 30% patients and >100 msec in 24% patients. The AT/ET ratio was greater than 0.4 in 27 (54%) patients and was less than or equal to 0.4 in 23 (46%) patients. Two (4%) patients had DVI <0.25, other 2 (4%) had 0.25-0.3 and remaining 46 (92%) patients had DVI >0.3.

Indexed EOA was more than 0.85 in 48 patients, between 0.65-0.85 in 1 patient and less than 0.65 in 1 patient.

The univariate analysis was performed for estimating correlation of indexed EOA with DVI, AT and AT/ET. A strong positive correlation was observed between indexed EOA and DVI with a *p*-value of 0.0001 and correlation co-efficient of 0.8. Indexed EOA was found to be significantly associated with AT (p = 0.015) but was found to have weak correlation (r^2 = 0.342). On other hand, AT/ET ratio was not found to be significantly correlated with indexed EOA (p = 0.114 and r^2 = 0.226).

Table 1: Baseline characteristics of patients

Parameters	Observations (n=50)
Age distribution (years)	
≤20	2 (4%)
21-40	8 (16%)
41-60	28 (56%)
61-80	12 (24%)
Gender	
Males	36 (72%)
Females	14 (28%)
Indication for AVR	
AS	32 (64%)
AR	15 (30%)
AS + AR	3 (6%)
Type of Prosthesis	
Mechano-prosthesis	44 (88%)
Bovine pericardial bioprosthetic valve	6 (12%)

AVR: aortic valve replacement, AS: aortic stenosis and AR: aortic regurgitation

Table 2: Frequency of Echo-doppler parameters after AVR among the study patients

Parameters	Observations (n=50)
Peak velocity	
≤3 m/s	32 (64%)
>3 m/s	18 (36%)
Mean gradient	
≤20 mmHg	40 (80%)
>20 mmHg	10 (20%)
Spectral Doppler pattern	
Early peaking	40 (80%)
Late peaking	10 (20%)
Acceleration time	
<80 msec	23 (46%)
80-100 msec	15 (30%)
>100 msec	12 (24%)
AT/ET ratio	
≤0.4	23 (46%)
>0.4	27 (54%)
Dimensionless valve index	
<0.25	2 (4%)
0.25-0.3	2 (4%)
>0.3	46 (92%)
Effective Orifice Area	
<0.8 cm^2	0
0.8-1.2 cm^2	2 (4%)
>1.2 cm^2	48 (96%)
Indexed EOA	
<0.65 cm^2/m^2	1 (2%)
0.65-0.85 cm^2/m^2	1 (2%)
>0.85 cm^2/m^2	48 (96%)

AVR: aortic valve replacement AT/ET ratio: acceleration time/ejection time and EOA: effective orifice area

Table 3: Univariant analysis for indexed EAO with DVI, AT and AT/ET

Parameter	P-value	Correlation co-efficient (r^2-value)
Dimensionless valve index (DVI)	0.0001	0.8
Acceleration time (AT, msec)	0.015	0.342
Acceleration time / Ejection time (AT/ET)	0.114	0.226

DISCUSSION

Prosthetic heart valves have been auspiciously used since 4 decades in heart valve replacement and are broadly categorized as biologic and mechanical valves [5,8]. Doppler echocardiography has remained as the chief imaging modality for the compendious and optimum assessment of prosthetic valve function [5,8]. A thorough examination of prosthetic aortic valve function includes the echocardiographic estimations of various haemodynamic parameters. The quantitative assessment of replaced aortic valve relies on flow-dependent (peak velocity, mean gradient, AT, AT/ET) and flow-independent parameters (EOA and DVI) [3,5].

In the newly implanted prosthetic aortic valve, a peak velocity of >3 m/s and mean gradient of greater than 30 mmHg would be considered as significantly hightrans-valvular gradient which may indicate presence of significant stenosis [9]. High gradient can be due to LV outflow obstruction or measurement error or a high-flow state or presence of pressure recovery [7]. Among the potential cause of LV outflow obstruction, patient prosthetics mismatch (PPM) and subvalvular obstructions should be present early after AVR [7]. In the present study, 36% patients were found to have higher trans-valvular gradient in the immediate post AVR period. But on assessment after 6 month of AVR, trans-valvular gradient was normalized in 88% patients. The pressure gradient across a newly implanted aortic valve may initially be aberrantly high in normally working prosthesis; hence for the adequate assessment of prosthetic aortic valve function, other quantitative parameters which are less dependent on flow should be taken into consideration [5].

The contour of the velocity, AT and AT/ET ratio were also used for estimation of prosthetic aortic valve function in conjugation with other flow-independent indices. In the prosthetic valve obstruction, a late peaking with prolonged AT (> 100ms) and AT/ET ratio (> 0.4) has been observed [5]. In the current study, late peaking was observed in 20% patients with the value of AT >100ms in 24% patients and in 54% patient AT/ET ratio was found to be >0.4. All these above values suggested the possibility of trans-valvular stenosis, but other flow-dependent parameters need to be considered for confirmation, as these are only supportive indices and thus could not independently predict stenosis.

The EOA is the most authenticated parameter for identification of PPM and is used to assess the functional status of valve and in contrast to gradients, it offers accurate evaluation of severity of trans-valvular obstruction [6-8]. The EOA is calculated as the product of LVOT and LVOT-VIT and is expected to be dependent on the size of implanted prosthetic valve [5,7]. For valve of any size, significant stenosis is conjectured when valve area is <0.8cm^2. In this study, no patient was found to have EOA <0.8cm^2, which represented a virtuous sign that there was no possibility of presence of obstruction initially after AVR.

The DVI is the ratio of proximal velocity in the LVOT to the flow velocity through the prosthesis and unlike EOA, it is independent of the valve size. The value of DVI gets reduced to less than or equal to 0.3 in case of prosthetic aortic valve stenosis. The DVI can be particularly helpful in the screening of valve function if the cross-sectional area of LVOT or valve size is not known [5,8]. In the current study, 2 patients were found to have DVI <0.25 and 2 patients were found to have DVI in between 0.25-0.30, which suggested presence of mild stenosis in those patients.

The PPM is demarcated as the insufficient valve orifice area for individual patient although prosthesis functions normally [7]. Indexed EOA was estimated in the present study which is calculated as EOA divided by body surface area (BSA) and it is considered as the most valuable indices for characterisation of PPM [5,8]. The PPM increases when the EOA of the prosthesis is too small as compared to patient's body size, resulting in aberrantly high postoperative gradients [10,11]. The PPM is considered to be haemodynamically insignificant if the indexed EOA is >0.85 cm^2/m^2, moderate if between 0.65-0.85 cm^2/m^2 and severe if <0.65 cm^2/m^2 [10-12].

It has been stated in various previous studies that PPM is associated with increased risk of perioperative and overall mortality and post-operative i.e. early and late complications. In the recent meta-analysis by Dayan V et al. **[12]** they found that moderate PPM was allied with 1.5-fold and severe PPM was allied with 2.5-fold increase in the risk of 30-day mortality after AVR. Furthermore, it was also reported in

various studies that the incidence of PPM were less frequent after TAVR as compared to SAVR [13-15]. The reason for this difference between trans-catheter and surgical valves may be due to presence of thinner stent in trans-catheter valve with absence of sewing rings in the annular space, which reduced the obstruction of blood flow **[14,16].**

It has been found in the meta-analysis by Dayan V et al. **[12]** that patient with age ≤70 years were more prone for development of PPM. The potential explanation given for this included: i) the augmented metabolic demand which causes requirement of higher cardiac output in younger patient, ii) younger patient has a longer life expectancy and hence manifested to risk of PPM and LV overload for longer time; and iii) elderly patients often have other co-morbidities which may mask the negative influence of PPM.

It has been stated in the study by Mohty et al. **[17]** that PPM is the powerful predictor of the overall mortality with a BMI <30 kg/m^2. This was associated to the fact that, as the in overweight and obese patients, the cardiac output requirement does not increase in proportion to the increase in BSA; hence the indexed EOA may sometimes overemphasize the degree of PPM in patients with large BMI. Thus, for the obese patient the cut-off values of indexed EOA were recommended as <0.70 cm^2/m^2 for moderate PPM and <0.60 cm^2/m^2 for severe PPM [18]. It was also reported that there was 3-folds raise in the risk of PPM by the use of bio-prosthetic valves compared to mechanical valves due to difference in their design [12]. The occurrence of PPM can widely be reduced by the calculation of projected indexed EOA of the prosthesis to be inserted[5].

In the present study, univariant analysis was performed for indexed EOA with DVI, AT and AT/ET. The DVI was found to have strong correlation with indexed EOA ($r^2 = 0.8$ and $p = 0.0001$), while AT and AT/ET have shown weak correlation with indexed EOA ($r^2 = 0.342$ and $r^2 = 0.226$, respectively). Hence, it can be stated that with modulation in DVI value there may be impact in the value of indexed EOA.

The major late complications associated after AVR includes thromboembolism, valve degeneration, infective endocarditis, pannus formation and haemolysis. Hence, long term follow-up should be taken after AVR for assessment of the functioning of prosthesis implanted using Doppler echocardiography to reduce mortality rate and occurrence of late complication.

CONCLUSION

Doppler echocardiography has been the gold standard for the assessment various haemodynamic indices to evaluate prosthetic aortic valve function after AVR. Among all the parameters, EOA and DVI can be considered as prime indices as they are flow independent and were found to be directly associated with occurrence of early and late complications after AVR. Hence, post-operative assessment as well as long-term follow-up should be taken in the patients who underwent AVR.

STUDY LIMITATIONS

The shortcoming with the present study was a small sample size. It should include a data of long term follow-up after AVR to study the functioning of prosthesis.

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