

# Patient prosthesis mismatch after aortic valve replacement: An Indian perspective

Shreedhar S. Joshi, T. Ashwini, Antony George, A. M. Jagadeesh

Department of Cardiac Anaesthesia, Sri Jayadeva Institute of Cardiovascular Sciences and Research, Bengaluru, Karnataka, India

## ABSTRACT

**Context:** Perioperative period. **Aims:** Occurrence of PPM after AVR, factors associated with PPM, impact on mortality. **Settings and Design:** Tertiary Care Referral Cardiac Centre. **Materials and Methods:** A retrospective analysis of AVR procedures at a single centre over 4 years was conducted. Demographic, echocardiographic and outcome data were collected from institute database. Rahimtoola criteria of indexed effective orifice area (iEOA) were used to stratify patients into PPM categories. Patients with and without PPM were compared for associated factors. **Statistical Analysis Used:** Independent *t*-test, chi-square test, logistic regression analysis, ROC-AUC, Youden index. **Results:** 606 patients with complete data were analysed for PPM. The incidence of mild, moderate and severe PPM was 6.1% (37), 2.5% (15) and 0.5% (3) respectively. There was no impact of PPM on all-cause in-hospital mortality. PPM was observed more with Aortic Stenosis (AS) compared to Aortic Regurgitation (AR) as etiology. Aortic annulus indexed to BSA (iAA) had a very good predictive ability for PPM at  $<16\text{mm}^2/\text{m}^2\text{BSA}$ . **Conclusions:** PPM has lower incidence after AVR in this Indian population and does not increase early mortality. Patients with AS and  $iAA < 16\text{mm}^2/\text{m}^2\text{BSA}$  should be cautiously dealt with to prevent PPM.

**Key words:** Aortic annulus indexed to body surface area; Aortic valve replacement; Patient prosthesis mismatch

Received: 31-12-14  
Accepted: 25-11-15

## INTRODUCTION

Patient prosthesis mismatch (PPM) was conceptualized in 1978 by Rahimtoola, who stated “Mismatch can be considered to be present when the effective orifice area (EOA), after insertion into the patient, is less than that of normal valve. Occasionally, it can be a severe problem because the patient may be hemodynamically and symptomatically worse after valve replacement.”<sup>[1]</sup> It is unlikely that any prosthetic valve can achieve an area equal to that of native aortic valve of  $3.5\text{--}4.5\text{ cm}^2$ . The EOA is further reduced by endothelialization and tissue ingrowth *in vivo*. Hence, it is not the size of the prosthesis that matters, but rather it's EOA and in whom it's implanted. The PPM is an extremely important variable that predicts morbidity and mortality.<sup>[2]</sup>

Rao *et al.* demonstrated that indexed EOA calculated at the time of surgery was an independent predictor of postoperative

mortality. Rahimtoola had hinted at the need for correction of EOA for body surface area (BSA) in his pioneer papers on PPM. Based on that, PPM is considered severe if  $iEOA < 0.65\text{ cm}^2/\text{m}^2$  and mild if  $> 0.85\text{ cm}^2/\text{m}^2$ . Review of literature reveals that the reports of occurrence, and factors predicting the outcomes of PPM, are mainly from Western

**Address for correspondence:** Dr. Shreedhar S. Joshi, Chief Consultant Cardiac Anaesthesia, Department of Cardiac Sciences, Nayati Healthcare Multi-Specialty Hospital and Research Centre, Mathure, Uttar Pradesh, India.  
E-mail: shreedhar.8181@gmail.com

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work non-commercially, as long as the author is credited and the new creations are licensed under the identical terms.

**For reprints contact:** reprints@medknow.com

**Cite this article as:** Joshi SS, Ashwini T, George A, Jagadeesh AM. Patient prosthesis mismatch after aortic valve replacement: An Indian perspective. *Ann Card Anaesth* 2016;19:84-8.

Access this article online

Website: [www.annals.in](http://www.annals.in)

DOI:  
10.4103/0971-9784.173025

Quick Response Code:



countries. The published works on PPM in Indian population are surprisingly scant.<sup>[3,4]</sup>

This study was carried out to determine the incidence of PPM and to identify the patient subgroups, which are prone to PPM after aortic valve replacement (AVR) and the factors contributing to it.

## METHODOLOGY

All isolated (AVR) procedures from Jan 2010 to Jan 2013 were enrolled for assessment of PPM. Demographic and echocardiographic data, valve sizes and types, and cardiopulmonary bypass (CPB) parameters were collected retrospectively from inpatient case files. All patients were classified as PPM using valve size, valve type, and EOA. Depending on the type and size of the valve and indexed EOAs (iEOA), the subjects were categorized into four groups, no PPM, mild PPM, moderate PPM and severe PPM as per Rahimahtoola criteria.<sup>[1]</sup> EOA for a particular valve type and size was determined by the standard reference charts which were then indexed for the given patient.<sup>[5]</sup> Patients were also divided into those with concentric hypertrophy and those with Eccentric hypertrophy based on their relative wall thickness (RWT) as derived by the formula,  $\text{relative wall thickness (RWT)} = 2 \text{ PWT/LVIDd}$ , PWT is the posterior wall thickness, and LVIDd is the left ventricular (LV) internal diameter at end diastole.<sup>[6,7]</sup>

An increased  $\text{RWT} \geq 0.42$  suggests concentric hypertrophy, whereas a normal  $\text{RWT} < 0.42$  indicates the presence of eccentric hypertrophy. LV mass was derived from LVIDd, septal wall thickness (SWT) and PWT by the following formula,  $\text{LV mass (grams)} = 1.04 \times [(\text{LVIDd} + \text{SWTd} + \text{PWTd})^3 - \text{LVIDd}^3] \times 0.8 + 0.6$ .<sup>[8]</sup> Postoperative echocardiographic data was collected from the echocardiography done at the time of discharge. Demographic data were analyzed for comparison between patients without PPM and PPM. A multivariate regression analysis was conducted to assess factors associated with PPM. Transvalvular aortic mean gradients  $> 30$  mHg were considered as significant aortic stenosis (AS). Patients were assorted into predominant AS and aortic regurgitation (AR). All-cause in-hospital mortality was defined as death in the hospital before discharge after AVR.

### Data analysis

Continuous variables were described as mean with standard deviations and categorical variables as

percentages. Independent *t*-test was used to compare means among continuous data, and Chi-square test was used to compare proportions among categorical data. Two-tailed  $P < 0.05$  was considered as statistically significant. Multiple regression analysis by step-wise method was performed to study the effect of PPM on mortality adjusting for all possible confounding factors. The ability of indexed aortic annulus (IAA) to predict the occurrence of PPM in a patient was analyzed using receiver operating characteristics area under the curve (ROC-AUC). The criterion value corresponding with the Youden Index J was derived. Statistical analyses were conducted with SPSS version. 16.0 and MedCalc 12.7.0.0 for Windows.

## RESULTS

A total of 668 patients who had undergone isolated AVR were analyzed, of which, 62 patients were excluded due to lack of data about the type and size of the prosthetic valve, which were necessary for the calculation of iEOA. The incidence of PPM was 9.1% (55), whereas stratified mild, moderate, and severe PPM was 6.1% (37), 2.5% (15), and 0.5% (3), respectively. Demographic data of patients with PPM, without PPM and overall population are compared in Table 1.

It was observed, that patients with PPM were older, had higher BSA, higher AS incidence and had smaller aortic annuli for their BSA (iAA) as compared to those without PPM. All-cause in-hospital mortality was not different between the PPM and without PPM groups.

In comparison to patients with predominant AR, predominant AS patients belonged to the older age group and were associated with, concentric hypertrophy, smaller iAA, and had the smaller aortic prosthetic valve replaced [Table 2]. Their preoperative LV mass and ejection fractions (EF) were comparable. LV regression of  $> 150$  g at the time of discharge was seen in more number of cases in AR. PPM was not associated with mortality on logistic regression analysis ( $P = 0.831$ ).

On multivariate analysis for factors associated with PPM, predominance of AR versus AS (odds ratio [OR] 0.3, 95% confidence interval [CI] 0.0536–1.6795,  $P = 0.17$ ), iAA (OR 0.5, CI 0.37–0.57,  $P < 0.0001$ ) and prosthetic valve size (OR 0.8, CI 0.61–1.0097,  $P = 0.05$ ) were statistically significant.

Based on these data, iAA was analyzed for its predictive ability for PPM with ROC-AUC analysis [Figure 1]. The

**Table 1: Demographic and echocardiographic data of the whole cohort and stratified by presence of patient prosthesis mismatch**

Variable	Total (606)	No PPM (551)	PPM (55)	P
Age (years)	46.89±15.05	46.39±15.09	51.96±13.88	0.009
Gender - female (%)	36	27	23	0.829
BSA (m <sup>2</sup> )	1.29±0.3	1.25±0.26	1.77±0.33	<0.001
BMI (kg/m <sup>2</sup> )	22.15±4.29	21.65±3.92	20.51±1.63	<0.001
Mortality alive/dead (%)	597/9 (1.4)	543/8 (1.45)	54/1 (1.81)	0.83
Predominant AS (%)	72	30	94	<0.001
Preoperative EF (%)	54.56±8.08	54.29±8.21	57.13±6.31	0.022
Postoperative EF (%)	52.11±7.7	51.8±7.92	54.89±4.77	0.011
Preoperative iAA (mm/m <sup>2</sup> )	18.14±4.9	18.71±4.76	12.63±2.2	<0.0001
Preoperative LV mass (g)	257.23±89.3	255.35±89.7	274.7±85.17	0.163
Postoperative LV mass (g)	176.7±105.8	149.06±42.38	176.71±105.8	0.403
LV regression (>150 g) yes/no (%)	88/518 (14.52)	83/468 (15)	5/50 (9.09)	0.231

AS: Aortic stenosis, AR: Aortic regurgitation, iAA: Indexed aortic annulus, EF: Ejection fraction, LV: Left ventricle, PPM: Patient prosthesis mismatch, BSA: Body surface area, BMI; Body mass index

**Table 2: Demographic and echocardiographic parameters of aortic stenosis and aortic regurgitation**

Variable	AS	AR	P
Gender - female (%)	28.3	27	0.084
Age (years)	51.3±15.02	35.3±13.9	<0.001
Concentric/eccentric hypertrophy	282/156	17/151	<0.001
Preoperative iAA (mm/m <sup>2</sup> )	17.29±3.93	20.6±6.4	<0.0001
PPM (%)	11.9	1.8	<0.0001
AVR prosthetic size (mm)	20.85±1.99	22.74±2.07	<0.0001
Preoperative EF (%)	54.90±7.95	53.69±8.40	0.143
Postoperative EF (%)	53.98±6.3	47.18±8.17	<0.001
LV regression (>150 g) (%)	45	60	0.149

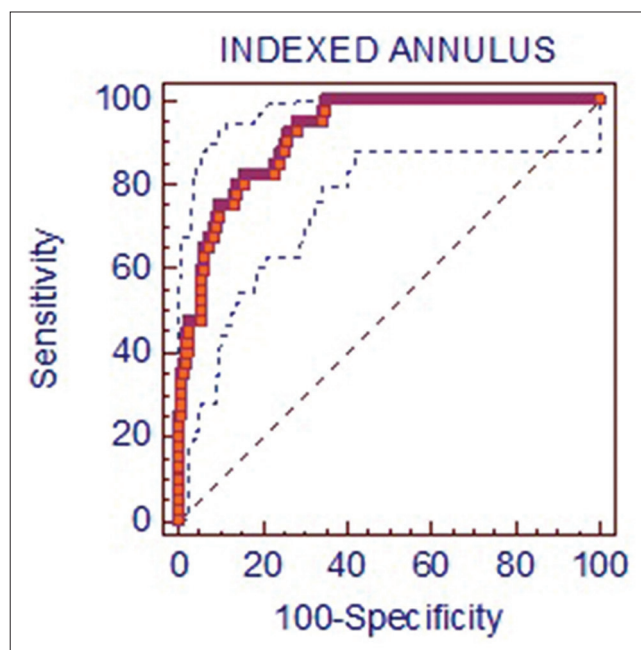
iAA: Indexed aortic annulus, EF: Ejection fraction, LV: Left ventricle, AS: Aortic stenosis, AR: Aortic regurgitation, PPM: Patient prosthesis mismatch, AVR: Aortic valve replacement

AUC was observed to be 0.92 (CI 0.88–0.94, *P* < 0.0001). The Youden Index J (0.67) was observed at an associated criterion of iAA < 16 mm/m<sup>2</sup> BSA (with sensitivity 90% and specificity 75%).

## DISCUSSION

The incidence of PPM in the present cohort was 9.1% with severe PPM only in 0.5% of cases. AR was associated with a significantly low incidence of PPM. iAA of < 16 mm/m<sup>2</sup> BSA had a good predictive ability toward PPM.

There has been awareness on PPM as a clinical entity and its impact on short and long-term outcomes after AVR after Rahimatoola's first description of this entity.<sup>[1]</sup> The impact of PPM is huge. To enumerate a few, higher gradients, persistent LVH, decreased postoperative cardiac index, decreased the quality of life. Aortic root enlargement (ARE) procedures are used to prevent



**Figure 1:** Figure depicts receiver operating characteristics area under the curve of indexed aortic annulus for predicting patient prosthesis mismatch

PPM in smaller aortic annuli. Most of these techniques demand skill and are associated with complications including longer CPB and cross-clamp times, increased rates of reoperations for bleeding, and increased operative mortality.<sup>[9,10]</sup> Moreover, the risk-benefit ratio of ARE procedures to avoid PPM is unclear.<sup>[10]</sup>

The incidence of PPM in the present cohort is less than most other observations.<sup>[11]</sup> Aortic annulus diameters are an essential factor for PPM occurrence. The need to index aortic annulus to BSA is essential due to the obvious differences in anthropometry of subjects of

across varied origins. iAA was observed to be different for western reference subjects to Indian subjects as studied by Rajendran *et al.*<sup>[12]</sup> The average aortic annulus indexed to BSA in the present our study (18.4 mm at 1.29 BSA) was comparable to their observation (18.1 mm at 1.21–1.3 BSA).<sup>[12]</sup> The paucity of iAA dimensions in most studies hampers comparison of PPM between them and the present cohort. We believe an adequately sized aortic annulus for a given BSA ( $18.14 \pm 4.9 \text{ m}^2$ ) in the present cohort could explain a lower incidence of PPM.<sup>[11,13]</sup> Patients with PPM had higher BSA ( $1.77 \pm 0.33 \text{ m}^2$ ) and smaller iAA ( $12.63 \pm 2.2 \text{ mm}$ ). Incidence of PPM was higher in AS subgroup as compared to AR subgroup (11.9% vs. 1.8%,  $P < 0.0001$ ), which could be explained by the differences in their iAA ( $17.2 \pm 3.93 \text{ mm}$  vs.  $20.6 \pm 6.4 \text{ mm}$ ,  $P < 0.001$ ). This finding is also substantiated by the AVR prosthetic valve sizes ( $22.74 \pm 2.07 \text{ mm}$  in AR vs.  $20.8 \pm 1.99 \text{ mm}$  in AS,  $P < 0.001$ ). Price *et al.* studied 98 patients with AR in comparison with AS or mixed lesions for the incidence of PPM.<sup>[14]</sup> PPM was 50% less in AR compared to AS/mixed lesions. They hypothesized the lower incidence to larger annuli in AR as compared to AS. Moreover, most AR cases in their cohort were nonrheumatic in origin.

Pibarot *et al.* have discussed in detail the long and short-term impact of PPM after AVR.<sup>[15,16]</sup> The impact of PPM on early mortality has been studied by many authors with equivocal results.<sup>[2,17-22]</sup>

In this study, there has been no association of PPM with early (all-cause in-hospital mortality). Urso *et al.* in their meta-analysis highlighted that only severe PPM was associated with an increased early mortality.<sup>[22]</sup> They also highlighted an absence of association between moderate or mild PPM with early mortality except in patients with poor EF. The lower incidence of severe PPM in the present study could have led to a lack of association on early mortality. Decreased LV regression resulting in persistence of symptoms after AVR is associated with PPM. LV regression of more than 150 g at the time of discharge has been associated with improved long-term outcome as compared to <150 g regression.<sup>[23]</sup> In this study, a higher percentage of patients without PPM had significant LV regression (15% no PPM vs. 9% in PPM,  $P = 0.231$ ).

Predominant AS, small iAA and smaller prosthetic valve size were associated with increased incidence of PPM. These observations suggest a cautious approach to valve type and size selection preoperatively in

patients with these risk factors. Furthermore, iAA of <16 mm/m<sup>2</sup> BSA has a very good predictive ability for PPM. Indexing aortic annulus to BSA may be a more rational approach than considering only aortic annulus size before deciding on ARE procedures. Further studies should consider the use of aortic annulus indexed to BSA when assessing occurrence and prevention of PPM.

This study highlights the low incidence of PPM in an Indian population. The importance of iAA in relation to PPM and also the caution of the high incidence of PPM at iAA of <16 mm/m<sup>2</sup> BSA.

Despite being first of its kind analysis in Indian population, it is a retrospective analysis and limitations of bias inherent to such analyses exist. iEOA based on continuity equation at later follow-up would be the ideal method as suggested by rahimtoola.<sup>[24]</sup> The pitfalls associated with the evaluation of iEOA by continuity equation are in measuring the LV outflow tract dimension due to the reverberations of the prosthetic valves, pressure recovery in the aorta and complex relationship of mean gradients across the prosthetic valve. These pitfalls may make this method questionable for routine use. Impact of PPM on long-term mortality was not studied.

## CONCLUSION

PPM exists but with a lower incidence and had no impact on early mortality. PPM was more common with AVR for AS than AR. Aortic annulus indexed to BSA is an important indicator of PPM with the high prediction of PPM at <16 mm/m<sup>2</sup> BSA.

## Financial support and sponsorship

Nil.

## Conflicts of interest

There are no conflicts of interest.

## REFERENCES

1. Rahimtoola SH. The problem of valve prosthesis-patient mismatch. *Circulation* 1978;58:20-4.
2. Blais C, Dumesnil JG, Baillot R, Simard S, Doyle D, Pibarot P. Impact of valve prosthesis-patient mismatch on short-term mortality after aortic valve replacement. *Circulation* 2003;108:983-8.
3. Choudhary SK, Mathur A, Venugopal P, Airan B, Sharma R, Bhan A, *et al.* Prosthesis size in aortic valve replacement: Surgeon-related variable. *Asian Cardiovasc Thorac Ann* 2000;8:333-8.

4. Kumar AS. Valve prosthesis-patient mismatch: A surgeon's solution. *Asian Cardiovasc Thorac Ann* 2014;22:647-8.
5. Zoghbi WA, Chambers JB, Dumesnil JG, Foster E, Gottdiener JS, Grayburn PA, *et al.* Recommendations for evaluation of prosthetic valves with echocardiography and doppler ultrasound: A report From the American Society of Echocardiography's Guidelines and Standards Committee and the Task Force on Prosthetic Valves, developed in conjunction with the American College of Cardiology Cardiovascular Imaging Committee, Cardiac Imaging Committee of the American Heart Association, the European Association of Echocardiography, a registered branch of the European Society of Cardiology, the Japanese Society of Echocardiography and the Canadian Society of Echocardiography, endorsed by the American College of Cardiology Foundation, American Heart Association, European Association of Echocardiography, a registered branch of the European Society of Cardiology, the Japanese Society of Echocardiography, and Canadian Society of Echocardiography. *J Am Soc Echocardiogr* 2009;22:975-1014.
6. Ganau A, Devereux RB, Roman MJ, de Simone G, Pickering TG, Saba PS, *et al.* Patterns of left ventricular hypertrophy and geometric remodeling in essential hypertension. *J Am Coll Cardiol* 1992;19:1550-8.
7. Gaasch WH, Zile MR. Left ventricular structural remodeling in health and disease: With special emphasis on volume, mass, and geometry. *J Am Coll Cardiol* 2011;58:1733-40.
8. Gottdiener JS, Bednarz J, Devereux R, Gardin J, Klein A, Manning WJ, *et al.* American society of echocardiography recommendations for use of echocardiography in clinical trials. *J Am Soc Echocardiogr* 2004;17:1086-119.
9. Castro LJ, Arcidi JM Jr, Fisher AL, Gaudiani VA. Routine enlargement of the small aortic root: A preventive strategy to minimize mismatch. *Ann Thorac Surg* 2002;74:31-6.
10. Dhadeshwar J, Sundt TM 3<sup>rd</sup>, Dearani JA, Schaff HV, Cook DJ, Orszulak TA. Aortic root enlargement: What are the operative risks? *J Thorac Cardiovasc Surg* 2007;134:916-24.
11. Head SJ, Mkhles MM, Osnabrugge RL, Pibarot P, Mack MJ, Takkenberg JJ, *et al.* The impact of prosthesis-patient mismatch on long-term survival after aortic valve replacement: A systematic review and meta-analysis of 34 observational studies comprising 27 186 patients with 133 141 patient-years. *Eur Heart J* 2012;33:1518-29.
12. Rajendran HS, Seshayyan S, Victor A, Rajapandian G. Aortic valve annular dimension in Indian population. *J Clin Diagn Res* 2013;7:1842-5.
13. Evangelista A, Flachskampf FA, Erbel R, Antonini-Canterin F, Vlachopoulos C, Rocchi G, *et al.* Echocardiography in aortic diseases: EAE recommendations for clinical practice. *Eur J Echocardiogr* 2010;11:645-58.
14. Price J, Lapiere H, Ressler L, Lam BK, Mesana TG, Ruel M. Prosthesis-patient mismatch is less frequent and more clinically indolent in patients operated for aortic insufficiency. *J Thorac Cardiovasc Surg* 2009;138:639-45.
15. Pibarot P, Dumesnil JG. Prosthesis-patient mismatch: Definition, clinical impact, and prevention. *Heart* 2006;92:1022-9.
16. Pibarot P, Dumesnil JG. Valve prosthesis-patient mismatch, 1978 to 2011: From original concept to compelling evidence. *J Am Coll Cardiol* 2012;60:1136-9.
17. Rao V, Jamieson WR, Ivanov J, Armstrong S, David TE. Prosthesis-patient mismatch affects survival after aortic valve replacement. *Circulation* 2000;102 19 Suppl 3:III5-9.
18. Hanayama N, Christakis GT, Mallidi HR, Joyner CD, Femes SE, Morgan CD, *et al.* Patient prosthesis mismatch is rare after aortic valve replacement: Valve size may be irrelevant. *Ann Thorac Surg* 2002;73:1822-9.
19. Connolly HM, Oh JK, Schaff HV, Roger VL, Osborn SL, Hodge DO, *et al.* Severe aortic stenosis with low transvalvular gradient and severe left ventricular dysfunction: Result of aortic valve replacement in 52 patients. *Circulation* 2000;101:1940-6.
20. Jamieson WR, Ye J, Higgins J, Cheung A, Fradet GJ, Skarsgard P, *et al.* Effect of prosthesis-patient mismatch on long-term survival with aortic valve replacement: Assessment to 15 years. *Ann Thorac Surg* 2010;89:51-8.
21. Cotoni DA, Palac RT, Dacey LJ, O'Rourke DJ. Defining patient-prosthesis mismatch and its effect on survival in patients with impaired ejection fraction. *Ann Thorac Surg* 2011;91:692-9.
22. Urso S, Sadaba R, Aldamiz-Echevarria G. Is patient-prosthesis mismatch an independent risk factor for early and mid-term overall mortality in adult patients undergoing aortic valve replacement? *Interact Cardiovasc Thorac Surg* 2009;9:510-8.
23. Christakis GT, Joyner CD, Morgan CD, Femes SE, Buth KJ, Sever JY, *et al.* Left ventricular mass regression early after aortic valve replacement. *Ann Thorac Surg* 1996;62:1084-9.
24. Daneshvar SA, Rahimtoola SH. Valve prosthesis-patient mismatch (VP-PM): A long-term perspective. *J Am Coll Cardiol* 2012;60:1123-35.