

Management of Prosthesis-patient Mismatch After Aortic Valve Replacement

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Abstract

Valve prostheses have played an important role in the past four decades in the management of patients with valvular heart disease. Many of the devices have been used for valve replacement and they have introduced new clinical problems. One of these problems is prosthesis-patient mismatch (PPM) which is associated with increased mid- and long-term mortality after surgical aortic valve replacement (AVR) and transcatheter aortic valve implantation. The aim of this study was to systematically review the literature on the importance,

prevention and feasibility of PPM in AVR and percutaneous-AVR. The articles about PPM published between 2003-2018 were analyzed. The results of surgical and transcatheter methods were discussed together to prevent PPM.

Keywords: Surgical aortic valve replacement, percutaneous aortic valve replacement, prosthesis-patient mismatch, valvular heart disease, transcatheter aortic valve implantation

Introduction

Prosthesis-patient mismatch (PPM) was first described in 1978 by Rahimtoola as an effective prosthetic valve area is smaller than a normal human valve area⁽¹⁾. PPM results in an abnormally high postoperative transvalvular

gradient⁽²⁾. Increased transvalvular gradient causes structural deformation of the prosthesis with calcific degeneration, thrombosis, pannus, or endocarditis⁽³⁾.

Effective orifice area (EOA), cross-sectional area of the trans-prosthetic blood flow jet, is easily measured



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with Doppler echocardiography. Indexed EOA (EOAI) which is gained by dividing patients' EOA to the body surface area [EOAI=EOA/body surface area (BSA)] is optimal parameter to determine PPM⁽⁴⁾. An EOAI <0.85 is now considered the threshold for PPM. If this value is between 0.65 and 0.85, it is classified as moderate PPM and if it is below 0.65 it is classified as severe PPM⁽¹⁾.

After surgical aortic valve replacement, prevalence of moderate and severe PPM was reported as 20-70% and 2-11%, respectively⁽⁵⁾. It has been shown that PPM following AVR has some negative effects on left ventricular (LV) mass regression, recovery of LV systolic function, functional class, quality of life and bioprosthetic valve durability. While left ventricular mass regression was 23% in patients with EOAI >0.8 cm²/m², it was reported as 4.5% in patients with an EOAI <0.8 cm²/m²⁽⁴⁾. Furthermore, PPM also is associated with increased rates of perioperative and long term morbidity and mortality. Late congestive heart failure, bleeding complications caused by abnormalities of the von-Willebrand factor and early structural valve deterioration might develop related to the PPM⁽⁶⁾.

There are two theories for the development of PPM: Decreased size of the aortic annulus due to calcification and fibrosis and relative obstruction of the structural support of the prosthesis⁽⁷⁾. Preoperative risk factors for the development of PPM are old age, smaller prosthesis, valvular stenosis, increased BSA and body mass index⁽⁴⁾.

Transcatheter aortic valve implantation (TAVI), which is used in the treatment of severe aortic stenosis, has been increasingly used in recent years and it has comparable results in the patients with moderate surgical risk compared to surgical AVR^(8,9). In the literature there is restricted information about PPM after the TAVI procedure. In this article, we have analyzed a systematic review of the incidence, predictive approaches and outcomes of PPM in a comprehensive and quantitative way to be valid for both methods.

Materials and Methods

In this review, we analyzed English-language literature for reported PPM and aortic valve replacement by PubMed® search using the terms of “aortic valve replacement, PPM and EOA”. We reviewed published original articles about “PPM and AVR between 2003-2018”. Reference lists of original articles were also included. Case reports and congress presentations were not included.

Results

There were almost 50 studies about PPM in the literature. The study included 42 eligible studies after extracting the overlapping articles. PPM is a strong and independent predictor of short-term mortality in the patients who had undergone AVR. The mortality rates in non-significant, moderate and severe PPM were reported as 3%, 6% and 26%, respectively. Compared to non-significant PPM, severe PPM 11-fold increases the mortality risk⁽¹⁰⁾.

Impact of PPM is more important in early term mortality rather than the late term mortality since left ventricle is more vulnerable during the early postoperative period. Operative mortality was increased 1-2% with PPM⁽¹¹⁾. In the patients with poor left ventricular function, increased afterload does not well tolerated⁽⁴⁾. The mortality rate of PPM in the patients with preoperative left ventricular ejection fraction (LVEF) below 40% is 77 times higher than the patients with normal LVEF (Figure 1)⁽¹⁰⁾.

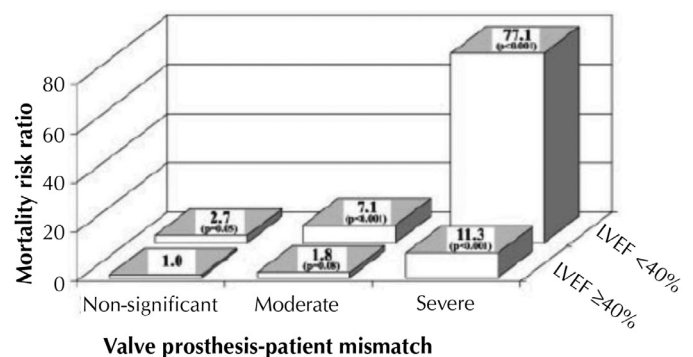


Figure 1. Mortality risk of patients according to the prosthesis-patient mismatch and ejection fraction⁽¹⁰⁾
LVEF: Left ventricle ejection fraction

The impact of PPM on late term survival is still controversial. Several recent studies confirm that PPM is independent risk factor for reduced late survival, where as others report the opposite. Head et al. found that there was a statistically significant increase in all-cause and cardiac-related mortality in moderate and severe PPM in the long-term with the evaluation of more 27,000 patient and 133,000 patient years (Table 1)⁽¹²⁾. Similarly EOA <0.75 cm²/m² is reported a risk factor for mortality after 12 years follow-up of the 2,500 patients⁽¹³⁾. Twelve years survival of minimal, moderate and severe PPM was reported as 77%, 63% and 47%, respectively⁽⁴⁾.

In the evaluation of 312 patients with stress echocardiography at postoperative six month, Bleiziffer et al. found that exercise capacity was significantly decreased in patients with PPM⁽¹⁴⁾. In addition it was clearly demonstrated that structural valve deterioration was more prominent in the patient with PPM and started two or three years after the surgery⁽¹⁵⁾.

How can we prevent the development of PPM?

After calculating the patient’s body surface area (BSA), we can multiply by 0.85 cm²/m² to calculate the minimum EOA required to avoid PPM using the appropriate prosthesis. Bioprosthesis have smaller EOA than the mechanical prosthesis⁽⁷⁾. It should be kept in mind while deciding valve prosthesis especially in the patients with small aortic annulus. EOAs of different types of prostheses are shown at Figure 2⁽¹⁶⁾. Trifecta valve has 10-

fold lower risk for the development of PPM⁽¹⁷⁾. If there is a risk of moderate to severe PPM, it is an option to implant prosthesis with a larger EOA (mechanical, prosthetic, homograft) or to perform aortic root enlargement to place larger valve prosthesis. Aortic root enlargement procedures increase the operative mortality 3.5-7%⁽¹¹⁾. Although increased surgical risks, root enlargement has excellent results in the follow-up period. According to some authors root enlargement does not increase the rates of 30-day mortality, stroke, reoperation for bleeding or myocardial infarction. In the evaluation of 114 patients, it was concluded that aortic root enlargement might be performed with minimal additional risk to prevent PPM in the patients with small aortic root. In a study the operational risk of aortic valve replacement with or

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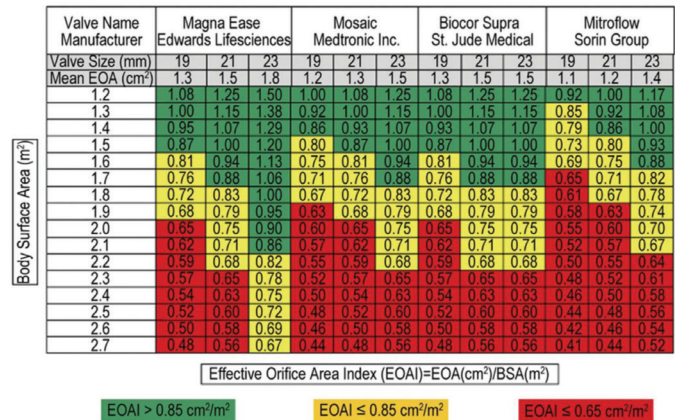


Figure 2. Effective orifice area of different valve prosthesis⁽¹⁶⁾
EOA: Esophageal obturator airway, BSA: Body surface area

Table 1. Results of studies about prosthesis-patient mismatch

Study	n	PPM incidence	Surgical method	Short term results	Long term results	Conclusion
Blais et al.	1266	38% moderate or severe	AVR	Mortality: Severe PPM 26% Moderate PPM 6%		Independent risk factor of short term mortality
Head et al.	27186	44.2%	AVR		In severe PPM HR increased to 6.5	Increased all-cause and cardiac-related mortality in long term
Bleiziffer et al.	312	34.3%	AVR		Reduced exercise capacity	Reduced exercise capacity
Flemeng et al.	648	49% Moderate 4% Severe	AVR			Independent risk factor for SVD

AVR: Aortic valve replacement, HR: Hazard ratio, PPM: Prosthesis-patient mismatch, SVD: Structural valve deterioration, n: Number of the patients

without root dilatation was investigated in 2,300 patients to protect from PPM. Finally, it was found that aortic root enlargement itself did not increase the risk of surgery, but was mostly performed among high-risk patients⁽¹⁸⁾. In conclusion recent new generation prosthesis decreased requirement of aortic root enlargement procedures with better hemodynamics. In the comparison of 339 patients with Trifecta valve and 963 patients with other bioprosthesis the PPM rates was found extremely low in the patients with Trifecta prosthesis. All differences; EOA, EOAI and mean transaortic gradients were statistically significant lower with Trifecta bioprosthesis⁽¹⁷⁾.

Can TAVR be an alternative to avoid PPM?

Some recent studies have reported that TAVI is superior to surgical AVR to provide valve hemodynamics in a subset of patients with small aortic annulus⁽¹⁹⁾. After TAVI procedure in the patients with severe aortic stenosis and small aortic annulus hemodynamic and clinical results were found to be acceptable and severe PPM was observed in only 6% of the patients⁽¹⁹⁾. In other study the rate of the moderate and severe PPM of TAVI procedure was reported as 31% and 9%, respectively. And, 5-year survival rates were similar between the patients with PPM and without PPM⁽²⁰⁾. However, improvement of the functional status was 98.5% without PPM and 63%

with PPM⁽²¹⁾. In the comparison of the hemodynamic performance of TAVI and surgical AVR; TAVI was found to have superior hemodynamic performance in terms of prevention severe PPM and to decrease transprosthetic gradient. In this study rate of PPM was 11% for TAVI, 26% for stented AVR, 28% for stentless AVR⁽²²⁾.

Similarly in the PARTNER study, that comparing the rate of PPM between the TAVI and surgical AVR and evaluating effect of PPM on LV hypertrophy and mortality regression, PPM was more common after surgical AVR (Table 2)⁽¹³⁾.

What about sutureless valves?

Sutureless valves easily replaced with minimally invasive approach. It gives opportunity to extract calcified tissue, but has disadvantages of requirement of cardiopulmonary bypass. Sutureless valves have advantages in geriatric patients, especially those with small aortic annulus compared to conventional biological valves in the short and mid term⁽²³⁾. These valve prosthesis are also ideal for patients with excessive calcification.

Conclusion

Surgery is still the gold standard for the treatment of aortic stenosis. Surgical treatment of aortic valve

Table 2. Results of studies comparing transaortic valve implantation and aortic valve replacement*

Study	n	Surgical method	Aortic root size	Prosthesis	PPM (%)	Conclusion
Kalavrouziotis et al.	35	TAVI	<20 mm	23 mm Edwards Saphien	Severe 6%	Good postoperative valve hemodynamics in high risk patients with AS and small annulus
Clavel et al.	50	TAVI	Mean 20.1 mm	Crible Edwards/ Edwards Saphien	7 (<20 mm) 14 (>20 mm)	Lower transvalvular gradient and severe PPM with TAVI
	50	AVR-SL		Medtronic	36 (<20 mm) 18 (>20 mm)	
	50	AVR-ST		Edwards	29 (<20 mm) 25 (>20 mm)	
Pibarot et al.	270	AVR	<20 mm		19 severe	Higher severe PPM with AVR in high risk patients and severe AS
	304	TAVI-RCT			33.7 severe	
	1637	TAVI-NRCA				

AS: Aort stenosis, AVR: Aortic valve replacement, AVR-SL: Aortic valve replacement-stentless, AVR-ST: Aortic valve replacement-stented, TAVI: Transaortic valve implantation, RCT: Randomized controlled trial, PPM: Prosthesis-patient mismatch, n: Number of the patients, NRCA: Non-randomized continued access

might be performed both by conventional surgery and percutaneously with lower perioperative mortality and morbidity rates. After the surgery, quality of life improves in patients of all ages accept surgical with lower operative risk.

Transprosthetic gradient and EOA is important to relief the symptoms and improve functional capacity after the surgery. To indicate optimal surgical procedure and prosthesis is important to improve postoperative outcome and patients' satisfaction. The most important complication after AVR is PPM. PPM is a widespread and modifiable risk factor that causes poor hemodynamic functions in postoperative period, less recovery of ventricular functions, more cardiac events and lower survival. The EOAI foreseen to avoid PPM must be systematically calculated. In this description EOAI is indicator of the effective valve area. Pibarot and Dumesnil declared three steps to reduce the PPM after the aortic valve surgery: Calculating BSA, determining the minimum ($0.85 \text{ cm}^2/\text{m}^2$) EOA to provide the minimum required EOAI, selecting the appropriate prosthesis⁽¹³⁾. Decision of EOAI is changes according to patient's clinical condition and expectation from the surgery. While moderate PPM might be acceptable in elderly and sedentary patients with normal EF, avoiding of PPM is important in the young and active patients⁽⁴⁾.

The prevalence of severe PPM tends to decrease in the last decade due to awareness and recognition of PPM, more widespread implementation of preventive strategies, improved design and hemodynamic performance of new generation prostheses. In patients who are expected to develop PPM, alternative options should be considered in the light of the patient's general clinical status. In the last decade, several tissue heart model valves have been introduced in line with the developing technology. Thrombogenicity and valve destruction risk is decreased with new generated bioprosthetic valves with improved hemodynamic performance. The Trifecta aortic valve, developed as a new generation bioprosthesis, decreased the incidence

of PPM by approximately 10 times compared to other bioprostheses. PPM is almost eliminated in patients with aortic annulus 21 mm or greater with this new generation valve⁽¹⁷⁾.

Percutaneous AVR is a good alternative in the patients with comorbid factors. After the TAVI procedure patients had larger EOAI than the patients with surgical AVR⁽²²⁾. This result is encouraging to perform TAVI procedure in high-risk patients.

PPM is associated with increased postoperative morbidity and mortality during the aortic valve replacement. Management of the surgical procedure is important to avoid PPM. Evaluating of the patient's clinical condition and determining optimum prosthesis improve postoperative outcomes.

Ethics

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: E.D., Concept: E.D., Design: E.D., Data Collection or Processing: İ.D., Analysis or Interpretation: E.D., İ.D., M.U., Literature Search: E.D., İ.D., M.U., Writing: E.D., İ.D., M.U.

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