

The Concept of Patient-Prosthesis Mismatch

Claudio Muneretto, Gianluigi Bisleri, Alberto Negri, Jacopo Manfredi

Division of Cardiac Surgery, University of Brescia Medical School, Brescia, Italy

The Journal of Heart Valve Disease 2004;13 (Supplement 1): S59-S62

Valve replacement represents the standard therapy for the surgical treatment of diseased valves that cannot be repaired. The final goal of valve replacement should be to replace the diseased valve with a competent and non-stenotic prosthesis.

The concept of patient-prosthesis mismatch (PPM) was originally introduced by Rahimtoola in 1978, and defined "...to be present when the effective prosthetic valve area, after insertion into the patient, is less than that of a normal valve." (1).

The issue of choosing the most adequate valvular prosthesis in patients with a small aortic root and a large body surface area (BSA) has been widely debated, since it still represents a common problem in routine surgical procedures on the aortic valve (2-4). However, the evaluation of PPM has not been sufficiently emphasized in common practice, in spite of the fact that failure of its recognition may lead to a significant hemodynamic impairment and worsening of the clinical status in time.

Postoperative echocardiographic evaluation of patients after aortic valve replacement has often demonstrated the presence of high transvalvular gradients even at rest and in patients with reduced BSA, despite normal prosthetic function (2,5,6). This finding appears to be influenced by two main factors: first, the in-vitro area of the majority of valve prostheses (especially with an internal diameter <23 mm) is less than that of the normal human valve area; and second, the in-vivo prosthetic area may be further reduced by interventricular septum hypertrophy, anatomical interactions, progressive endothelialization and tissue ingrowth. As a consequence, it is not uncommon that aortic prosthetic devices may be functionally stenotic.

The choice of a reliable predictor appears, therefore, mandatory in order to identify patients at risk of developing postoperative prosthesis mismatch.

The parameter often used in order to define the presence of PPM has been the geometric orifice area (GOA) - that is, a measurement deriving from the internal diameter of the prosthesis and measured in vitro by the valve manufacturer. However, the GOA has been shown to overestimate the 'functional area' of a valve prosthesis. Following the introduction of echo-Doppler studies, a more reliable parameter has been validated in clinical practice, termed the effective orifice area (EOA) (7,8).

Examples of differences between the GOA (as provided by the manufacturer) and the EOA (as calculated using echocardiography) of two commonly implanted prostheses are detailed in Table I.

Transvalvular gradients observed postoperatively are related not only to the EOA but also to the transvalvular flow. In turn, transvalvular flow is related to cardiac output, that at rest is primarily related to the patient's body size. As a consequence, the most reliable parameter to estimate the hemodynamic properties of the valve is the indexed effective orifice area (iEOA) (9,10).

The iEOA is obtained from the relationship (EOA/BSA), with the EOA being calculated using the continuity equation:

$$EOA = SV / VTI,$$

where SV is the stroke volume and VTI is the velocity-time integral of the aortic jet Doppler signal.

It is accepted worldwide that moderate aortic valve stenosis is present when the iEOA is <0.9 cm²/m², and this concept should apply also to valve prostheses. In fact, several studies have demonstrated that when a prosthetic iEOA is <0.9 cm²/m², a significant transvalvular gradient is present at rest (10,11).

It is well known that mechanical valve prostheses have a more favorable relationship between their external diameter and the EOA if compared to a stented bioprosthesis, as clearly depicted in Table I. In particular, it is clear from the data in Table II that the use

Presented at *The ideal human heart valve substitute: 50 years between perceptions and realities* meeting, September 2003, Naples, Italy

Address for correspondence:
Claudio Muneretto MD, UDA Cardiochirurgia - Spedali Civili di Brescia, P. le Spedali Civili, 1, 25123 Brescia, Italy
e-mail: munerett@master.cci.unibs.it

Table I: Comparison of geometric orifice area (GOA) and effective orifice area (EOA) values among different sizes of a commonly implanted bioprosthetic and mechanical valve.

Parameter	CE-19	SJM-19	CE-21	SJM-21	CE-23	SJM-23
GOA	1.96	1.63	2.9	2.06	3.9	2.55
EOA	0.9	1.1	1.1	1.5	1.5	2.13

CE: Carpentier-Edwards pericardial valves; SJM: St. Jude Medical Standard mechanical valves.

of a stented bioprosthesis smaller than 23 mm may result in a PPM in the majority of cases, and even the use of a 23-mm bioprosthesis may lead to a significant mismatch in patients with a BSA >1.8 m². Stentless valves present an additional therapeutical option: in fact, despite the stentless EOA value for any assigned size between the mechanical and bioprosthetic EOA, it is usually possible to use one size superior to the corresponding bioprosthesis, thus resulting in a lower risk of mismatch.

In addition to the intrinsic properties of aortic valve prostheses, specific patient characteristics have been also associated with a higher risk of developing PPM. In fact, mismatch is more likely to occur in patients with a larger body size, with aortic valve stenosis as the predominant lesion at the time of operation (in relation to the smaller annular size, as is the case for aortic insufficiency), and advanced age (aortic stenosis being the predominant valvular lesion in elderly patients) (12).

As already indicated, the hemodynamic consequence of PPM is the development of high postoperative transvalvular gradients; therefore, the residual relative stenosis does not relieve the left ventricle from any preoperative work overload, and consequently the regression of hypertrophy may be jeopardized. Several authors have reported that long-standing persistence of left ventricular hypertrophy has a negative impact on survival, and therefore avoidance of PPM appears to be the primary goal of aortic valve replacement (13-15).

The relationship of PPM with a higher risk of post-

operative complications, such as thromboembolism, hemorrhage, structural valve deterioration and reoperation, remains a topic of conflict among several authors (15-17). However, there is increasing evidence that a reduced iEOA negatively affects both short- and long-term survival and actuarial freedom from cardiac related events, especially in presence of significant left ventricular dysfunction (ejection fraction <40%) (18,19).

In order to evaluate the clinical relevance of PPM, it is important to differentiate mismatch into three different degrees: mild ($0.9 < iEOA < 1 \text{ cm}^2/\text{m}^2$), moderate ($0.6 < iEOA < 0.9 \text{ cm}^2/\text{m}^2$), and severe ($iEOA < 0.6 \text{ cm}^2/\text{m}^2$), as proposed by Rahimtoola (20).

In order to avoid PPM, Pibarot and Dumesnil (12) suggested the use of a three-step algorithm during the preoperative evaluation:

Step 1: Calculation of the patient's BSA.

Step 2: Reference to the specific table for identification of the adequate valvular EOA according to the patient's BSA.

Step 3: Selection of the most appropriate type and size of valve prosthesis according to the target iEOA.

Additionally, different surgical strategies have been advocated in order to minimize the risk of PPM, including routine enlargement of the aortic root, supra-annular prosthesis implantation, and the use of stentless bioprostheses, aortic homografts, or pulmonary autografts (12,21,22).

In conclusion, the avoidance of PPM is of primary

Table II: Effective orifice area values of commonly used prosthetic valves.

Valve type	Prosthesis size (mm)			Reference(s)
	19	21	23	
SJM Standard	1.04 ± 0.19	1.73 ± 0.38	2.13 ± 0.61	23,24
SJM HP	1.3 ± 0.3	2.01 ± 0.17	-	24,25
CarboMedics Standard	1.0 ± 0.4	1.54 ± 0.31	1.63 ± 0.3	26
Medtronic Intact	0.85	1.02 ± 0.1	1.27 ± 0.11	9
CE Pericardial 2900	1.10	1.3	1.5	27
Medtronic Freestyle	1.29 ± 0.19	1.46 ± 0.32	1.79 ± 0.33	28
Prima Edwards	0.8	1.10	1.5	29

importance in the surgical treatment of aortic valve disease, as its occurrence is associated with less symptomatic improvement, worse hemodynamic status, impaired regression of left ventricular hypertrophy, and a negative impact on short- and long-term survival. Therefore, a specific surgical strategy targeted towards each patient should be planned before surgery in order to minimize the risk of PPM.

References

1. Rahimtoola SH. The problem of valve prosthesis-patient mismatch. *Circulation* 1978;58:20-24
2. Wortham DC, Tri TB, Bowen TE. Hemodynamic evaluation of the St. Jude Medical valve prosthesis in the small aortic annulus. *J Thorac Cardiovasc Surg* 1981;81:615-620
3. Sintek CF, Fletcher AD, Khonsari S. Stentless porcine aortic root: Valve of choice for the elderly patient with small aortic root? *J Thorac Cardiovasc Surg* 1995;109:871-876
4. Medalion B, Blackstone EH, Lytle BW, White J, Arnold JH, Cosgrove DM. Aortic valve replacement: Is size important? *J Thorac Cardiovasc Surg* 2000;119:963-974
5. Shigenobu M, Sano S. Criteria to select proper valve prosthesis for aortic valve replacement via continuous wave Doppler echocardiography. *J Cardiovasc Surg* 1993;34:203-208
6. Wang Z, Grainer N, Chambers J. Doppler echocardiography in normally functioning replacement heart valves: A literature review. *J Heart Valve Dis* 1995;4:591-614
7. Pibarot P, Dumesnil JG, Cartier PC, Metras J, Lemieux MD. Patient-prosthesis mismatch cannot be predicted at the time of operation. *Ann Thorac Surg* 2001;71:S265-S268
8. Dumesnil JG, Pibarot P. The approach does not disqualify prosthesis-patient mismatch. *Eur J Cardiothorac Surg* 2002;21:157-158
9. Dumesnil JG, Honos GN, Lemieux M, Beauchemin J. Validation and applications of indexed aortic prosthetic valve areas calculated by Doppler echocardiography. *J Am Coll Cardiol* 1990;16:637-643
10. Pibarot P, Dumesnil JG, Jobin J, Lemieux M, Honos G, Durand LG. Usefulness of the indexed effective orifice area at rest in predicting an increase in gradient during maximum exercise in patients with a bioprosthesis in the aortic valve position. *Am J Cardiol* 1999;83:542-546
11. Pibarot P, Dumesnil JG, Jobin J, Cartier P, Honos G, Durand LG. Hemodynamic and physical performance during maximal exercise in patients with an aortic bioprosthesis: Comparison of stentless versus stented bioprostheses. *J Am Coll Cardiol* 1999;34:1609-1617
12. Pibarot P, Dumesnil JG. Hemodynamic and clinical impact of prosthesis-patient mismatch in the aortic valve position and its prevention. *J Am Coll Cardiol* 2000;36:11131-11141
13. Hoffmann A, Burckardt D. Patients at risk for cardiac death late after aortic valve replacement. *Am Heart J* 1990;120:1142-1147
14. Sullivan JM, Zwaag RV, El-Zeky F, Ramanathan KB, Mirvis DM. Left ventricular hypertrophy: Effect on survival. *J Am Coll Cardiol* 1993;22:508-513
15. Devereux RB, De Simone G, Ganau A, Roman MJ. Left ventricular hypertrophy and geometric remodeling in hypertension: Stimuli, functional consequences and prognostic implications. *J Hypertension* 1994;12(Suppl.):S117-S127
16. Pibarot P, Honos GN, Durand LG, Dumesnil JG. The effect of patient-prosthesis mismatch on aortic bioprosthetic valve hemodynamic performance and patient clinical status. *Can J Cardiol* 1996;12:379-387
17. Pibarot P, Dumesnil JG, Lemieux M, Cartier P, Metras J, Durand LG. Impact of prosthesis-patient mismatch on hemodynamic and symptomatic status, morbidity and mortality after aortic valve replacement with a bioprosthetic heart valve. *J Heart Valve Dis* 1998;7:211-218
18. Blais C, Dumesnil JG, Baillot R, et al. Impact of valve prosthesis-patient mismatch on short-term mortality after aortic valve replacement. *Circulation* 2003;108:983-988
19. Rao V, Jamieson WRE, Ivanov J, Armstrong S, David TE. Prosthesis-patient mismatch affects survival after aortic valve replacement. *Circulation* 2000;102(Suppl.III):III-5-III-9
20. Rahimtoola SH. Valve prosthesis-patient mismatch: An update. *J Heart Valve Dis* 1998;7:207-210
21. Castro LJ, Arcidi JM, Fisher AL, Gaudiani VA. Routine enlargement of the small aortic root: A preventive strategy to minimize mismatch. *Ann Thorac Surg* 2002;74:31-36
22. Jin XY, Pepper JR. Do stentless valves make a difference? *Eur J Cardiothorac Surg* 2002;22:95-100
23. Chafizadeh ER, Zoghbi WA. Doppler echocardiographic assessment of the St. Jude Medical prosthetic valve in the aortic position using the continuity equation. *Circulation* 1991;83:213-223
24. Zingg U, Aeschbacher B, Seiler C, Althaus U, Carrel T. Early experience with the new masters series of St. Jude Medical heart valve: In vivo hemodynamic and clinical results in patients with narrowed aortic annulus. *J Heart Valve Dis* 1997;6:535-541
25. De Paulis R, Sommariva L, DeMatteis GM, et al. Hemodynamic performances of small diameter CarboMedics and St. Jude valves. *J Heart Valve Dis*

- 1996;5(Suppl.III):339-343
26. Chambers J, Cross J, Deverall P, Sowton E. Echocardiographic description of the CarboMedics bileaflet prosthetic heart valve. *J Am Coll Cardiol* 1993;21:398-405
27. Salomon NW, Okies JE, Krause AH, Page US, Bigelow JC, Colburn LQ. Serial follow-up of an experimental bovine pericardial aortic bioprosthesis: Usefulness of pulsed Doppler echocardiography. *Circulation* 1991;84(Suppl.III):140-144
28. Yun KL, Sintek CF, Fletcher AD, et al. Aortic valve replacement with the Freestyle stentless bioprosthesis: Five-year experience. *Circulation* 1999;100(Suppl.II):17-23
29. Dossche K, Vanermen H, Daenen W, Pillai R, Konertz W. Hemodynamic performance of the PRIMA Edwards stentless aortic xenograft: Early results of a multicenter clinical trial. *J Thorac Cardiovasc Surg* 1996;44:11-14