

Does the Type of Prosthesis Influence the Incidence of Permanent Pacemaker Implantation Following Isolated Aortic Valve Replacement

Maqsood M. Elahi, MRCS,¹ Khalid A. Osman, MRCS,¹ Manoj Bhandari, MRCP,²
Ramana Rao V. Dhannapuneni, FRCS (CTh)¹

Departments of ¹Cardiothoracic Surgery and ²Cardiology, Glenfield General Hospital,
Leicester, United Kingdom

ABSTRACT

Background: The incidence of conduction disorders requiring permanent pacing (PPM) in patients operated on for aortic valve replacement (AVR) has been reported to be 5.7%. However, perioperative risk predictors for PPM following AVR are not well characterized and debate exists regarding selection of the prosthesis-type most likely to minimize this incidence. The aim of the study was to assess whether the type of the prosthesis used influences the prevalence of PPM following aortic valve replacement.

Methods: A total of 782 consecutive patients with predominant aortic stenosis accepted for isolated non-emergent AVR were studied over a 3 year period; of which 305 patients (Group A) received mechanical prostheses, 335 received stented tissue prostheses (Group B), and the remaining 142 received stentless tissue valves (Group C). A stepwise logistic regression analysis was used to identify the independent predictors for PPM and statistical significance was accepted at a level of $P < .05$.

Results: Univariate and multivariate analyses showed a significant relationship between the preoperative factors (poor ejection fraction $<35\%$; $P < .001$), left atrial enlargement (LAE; $P < .001$) and left bundle branch block (LBBB; $P < .001$), the perioperative variables (bypass time >100 minutes with x-clamp time >70 minutes; $P < .001$) and the incidence of PPM.

Conclusions: The proposed predictive model correlated highly with actual pacemaker use, suggesting that the requirement for PPM results from either operative trauma or increased ischemic burden and the incidence of PPM is independent of prosthesis-type implanted.

INTRODUCTION

Aortic valve disease manifests as stenosis and/or valve incompetence that may trigger cardiac hypertrophy to compensate for the altered workload. In the adult population, the main causes of aortic valve incompetence are rheumatic disease, medio-necrosis, congenital malformation, bacterial endocarditis, deposition of calcium within the collagen network of the aortic valve leaflets, and trauma [Breisch 1984, Jalil 1989].

Epidemiological and electrophysiological studies demonstrated that aortic valve disease has been associated with both prolonged atrioventricular conduction times and higher degrees of atrioventricular block. It is believed that damage to the sinoatrial node or conduction system of the heart during mechanical trauma of surgery represents the subsequent need for PPM insertion in the early or late post-operative period. Henceforth, complete heart block may be transient and sometimes permanent complication of aortic valve replacement (AVR) [Del Rizzo 1996, Gordon 1998, Limongelli 2003].

Approximately 5% of the 100,000 patients who undergo cardiac valve surgery each year require postoperative PPM implantation before discharge [Braunwald 2000]. This requirement for PPM implantation is more frequent post valve surgery (ranging from 3% to 6%) rather than after isolated coronary artery bypass grafting (.8%) [Kvidal 2000]. Previously, we identified that redo operations, greater cumulative cross-clamp time, multiple valve surgery, and absence of preoperative sinus rhythm are the risk factors associated with a requirement for PPM implantation post-AVR surgery [Elahi 2005]. Whether this is the complication of the surgery per se or an exacerbation of the pre-existing conduction system disease is still unknown.

Given that, with development of the improved techniques and in an attempt to improve the hemodynamic features, debate exists regarding the selection of the best valve prosthesis to enhance early left ventricular mass regression. In this context, tissue valves have recently become the focus of much interest. Because obstructing stents and sewing rings are eliminated, the stentless porcine aortic bioprosthesis

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Address correspondence and reprint requests to: Maqsood M. Elahi,
Department of Cardiothoracic Surgery, Glenfield General Hospital,
Leicester, LE3 9QP, United Kingdom; (e-mail: Maqsood@doctors.org.uk).

results in superior hemodynamic function compared to stented xenografts and mechanical prostheses for preserving native tissue of the heart in aortic valve disease. In comparison with conventional stented AVR, it is possible to implant significantly larger stentless valves in patients matched for body surface area thus avoiding the enlargement of the aortic root [Goldman 1994, Blais 2003].

Albeit, there is evidence that the stentless valve results in good hemodynamics and regression of left ventricular hypertrophy, what is not clear is whether it also influences the incidence of PPM implantation postoperatively. Hence, we aim to assess whether the type of the prosthesis used influences the prevalence of PPM following aortic valve replacement.

PATIENTS AND METHODS

Patient Selection

A total of 782 consecutive patients undergoing first time isolated aortic valve replacement at our institution between April 2001 and March 2003 were included in the study; of which 305 patients (Group A) received mechanical prostheses, 335 received stented tissue prostheses (Group B), and the remaining 142 received stentless tissue valves (Group C). Baseline demographic and clinical data were available for all the patients through the case notes.

Inclusion criteria were presence of pure or predominant aortic stenosis, according to echocardiographic criteria. Patients with mild hypertension controlled with medical therapy were included in the study. Normotension (<140/90) in these patients was confirmed before surgery and during the follow-up period. Exclusion criteria were the presence of a permanent pacemaker, redo-operations, undergoing multiple valve surgery, concomitant procedures including coronary artery bypass grafting, and undergoing aortic root enlargement. The underlying aortic diseases were either isolated aortic stenosis (degenerative calcification, calcification of the bicuspid valve, other) or combined aortic regurgitation (rheumatic disease, bicuspid valve, endocarditis, and other conditions).

Echocardiographic Assessment

This was performed by means of M-mode and Doppler studies 1 week, 3–6 months, and 1 year after operation. Measurements included peak and mean aortic gradients, effective orifice area (EOA), performance index (DPI), and calculation of left ventricular mass. The competence of the valve was noted. Data collection was completed at the time of the hospital discharge.

Operative Techniques

Standard anesthesia and surgical techniques were employed. The preoperative medications were continued up to the day of surgery. Acetylsalicylic acid was discontinued at least 1 week before surgery. Myocardial protection was achieved by the direct infusion into the coronary ostium of cold (6°C to 10°C) crystalloid or blood cardioplegia and core cooling down to 28°C was undertaken in order to achieve hypothermia. The left ventricle was vented through the right superior pulmonary vein. The aortic valve was completely

excised in all cases; annulus debridement of calcium was done in a blunt fashion with forceps.

Statistical Analysis

All the variables were considered to test their potential impact on the development of the postoperative irreversible block requiring PPM. They included clinical characteristics of the patient, drug treatment, surgical techniques, and perioperative protocols and postoperative complications. Data were variably expressed as mean with or without range and either standard deviation or range. Linear regression analysis and Spearman rank correlation were used to compare the different parameters determined. *P* values <.05 were considered to be significant.

RESULTS

The clinical characteristics of the study patients are summarized in Table 1, which outlines the clinical demographics of the 3 groups. There were no significant differences observed in terms of gender, dyspnea status, left ventricular function, myocardial infarction, type of cardioplegia, and type of valve used.

Relevant operative and postoperative data along with the medications data are detailed in Tables 2 and 3. There was no difference in valve sizes implanted between the valve types. Cumulative cardiopulmonary bypass times were comparable between the 3 groups. Aortic cross-clamp time was longer for stentless valves than for the stented and the mechanical valves (*P* < .05). Implantation time for the mechanical and the stented valves was similar. Patients in Group C had a much higher proportion of PPM postoperatively compared to its counterparts (*P* < .05). Patients who required insertion of PPM following open heart surgery were on average ventilated 2.2 days longer (*P* < .05), spent 3.5 more days in intensive care unit (*P* < .05), and remained in the hospital for an additional 10 days (*P* < .05), more than their non-paced counterparts.

By multivariate logistic regression (odds ratio and *P* value in parentheses), left atrial enlargement, preoperative left bundle branch block, poor left ventricular function (<35%), increased cumulative cardiopulmonary bypass time, and cross-clamp time were found to be independent predictors of PPM requirement post-surgery (Table 4).

DISCUSSION

Aortic valve replacement is recommended as standard management for patients with symptomatic valve disease, independent of age [Boughaleb 1994, Lewis 1998]. It is reported that following surgery, patients usually have a dramatic improvement in their cardiovascular status and have improved survival rates at 5, 10, and 15 years [Keefe 1985]. The occurrence of intraventricular conduction defects and particularly left ventricular conduction defects following prosthetic aortic valve replacement has previously been reported [Gordon 1998, Limongelli 2003]. Henceforth, persistent rhythm disturbances following valve surgery requiring PPM implantation are not uncommon and have

Table 1. Preoperative Clinical and Demographic Characteristics (n = 782)

Variables	Group A (Mechanical) n = 305	Group B (Stented) n = 335	Group C (Stentless) n = 142
Age, y (mean)	58.9 ± 11.7 (35-72)	70.43 ± 7.2 (59-77)	61.7 ± 12.3 (48-73)
Sex (F/M)	140/165	160/175	67/75
Angina status (CCS)			
CCS 3	21 (6.9%)	34 (10.1%)	10 (7.0%)
CCS 4	4 (1.3%)	7 (2.1%)	11 (7.7%)*
Dyspnea status (NYHA)			
NYHA 3	120 (39.3%)	141 (42.1%)	55 (38.7%)
NYHA 4	30 (9.8%)	44 (13.1%)	15 (10.5%)
Ejection fraction, <30-40%	23 (7.5%)	22 (7.2%)	8 (5.6%)
Myocardial infarction	16 (5.2%)	11 (3.6%)	5 (3.5%)
Diabetes mellitus (DM)	26 (8.5%)	26 (7.8%)	18 (12.6%)*
Hypercholesteremia	71 (23.3%)	181 (54.0%)*	32 (22.5%)
Creatinine, mmol/L (>200)	5 (1.6%)	6 (1.8%)	0
Normal sinus rhythm	300 (98.3%)	312 (93.1%)	136 (96.0%)
Atrial fibrillation	5 (1.6%)	23 (7.0%)	6 (4.2%)
Chamber enlargement			
LAE	23 (7.5%)	25 (7.5%)	18 (12.6%)
LVH	73 (23.9%)	98 (29.3%)	22 (15.5%)
Conduction disturbances			
1° AV block	17 (5.5%)	15 (4.5%)	5 (3.5%)
LBBB	12 (3.9%)	20 (6.0%)	2 (1.4%)
RBBB	14 (4.6%)	15 (4.5%)	10 (7.0%)
Operative priority			
Elective	271 (88.8%)	255 (76.1%)	69 (48.6%)
Urgent	34 (32.4%)	80 (24.0%)	5 (3.5%)
Maximum AV gradient (mm Hg)	80.4 ± 18.7 (48-112)	83.6 ± 19.1 (51-115)	87.9 ± 20.1 (53-120)

*P < .05.

significant impact on both the patient and the healthcare resources.

Previous reports have already evaluated perioperative risk predictors of PPM after cardiac surgery in large cohorts of patients with different diseases [Gordon 1998, Lewis 1998, Limongelli 2003]. However, there are only scanty data on the development of irreversible AV block requiring PPM after AVR especially in the presence of different types of prostheses. In our series of 782 patients we found severe heart block requiring PPM in 9.5% of patients that increased to 19% just in patients receiving stentless valves (Group C) as compared to those with mechanical and stented valves implanted (Table 2). Using logistic regression analysis, we identified several important clinical predictors for the need of PPM following aortic valve surgery (Table 4).

Studies have demonstrated that chronic cardiac hypertrophy is a major independent risk factor for the morbidity and mortality in the general population [Muiesan 1995, Verdecchia 1998] and that aortic valve disease is associated with hypertrophic remodeling of the heart due to the left ventricular diastolic and systolic dysfunction. This may lead to the development of congestive heart failure [Pfeiffer 1990, Morisco 2003] associated with oxidative stress [Sia 2002] and the release of inflammatory factors such as C-reactive proteins [Gerber 2003]. Evidence in the literature has also shown that aortic valve disease may be associ-

ated with severe annulus ectasia, which imposes chronic and progressive mechanical stretch on the nearby AV node and His bundle. In this regard, the presence of pulmonary hypertension acting on the right ventricular dimensions,

Table 2. Perioperative Data (n = 782)

Variables	Group A (Mechanical) n = 305	Group B (Stented) n = 335	Group C (Stentless) n = 142
Cumulative bypass time, min	83.4 ± 15.5	81.3 ± 13.4	107.5 ± 20.7*
Cumulative x-clamp time, min	56.8 ± 12.5	57.1 ± 11.6	78.9 ± 16.9*
Concomitant surgery of the aorta	0	5 (1.5%)	13 (9.2%)
Prosthetic valve size ≤ 21 mm	156 (51.1%)	145 (43.3%)	12 (8.5%)
Maximum AV gradient, mm Hg	22.6 ± 10.5	21.8 ± 10.7	15.1 ± 7.3*
Mean AV gradient	14.3 ± 5.9	13.0 ± 4.8	7.8 ± 4.3*
Aortic valve area, cm ²	1.32 ± .66	1.31 ± .39	1.27 ± .76
Postoperative atrial arrhythmia	59 (19.3%)	62 (18.5%)	13 (9.2%)
Complete heart block	8 (2.6%)	10 (2.9%)	8 (5.6%)
Junctional rhythm	18 (5.9%)	20 (6.0%)	5 (3.5%)
Hospital stay, d	8.6 ± 3.2	9.0 ± 3.1	8.9 ± 4.1
PPM	22 (7.2%)	25 (7.5%)	27 (19.0%)*

*P < .05.

Table 3. Medications (n = 782)

	Variables	Group A (Mechanical)	Group B (Stented)	Group C (Stentless)
No PPM	Calcium antagonist	45%	42%	46%
	Beta blockers	32%	28%	30%
	ACE inhibitor	10%	13%	9%
	Nitrates	8%	12%	9%
	Digitalis	5%	5%	6%
PPM	Calcium antagonist	41%	43%	44%
	Beta Blockers	30%	28%	26%
	ACE Inhibitor	10%	13%	10%
	Nitrates	12%	12%	12%
	Digitalis	7%	4%	8%

shape, and interventricular septal thickness could affect the conduction system by altering the electrophysiological properties of its fibers. Moreover, a previous myocardial infarction may contribute to further injury of the conduction system. On the background of structural heart disease, external triggering factors such as electrolytic disorders could play a part in the development of irreversible conduction disorders [Limongelli 2003].

In the original series by Boughaleb and colleagues dealing exclusively with aortic valve disease, a pre-existing conduction defect, a decrease in ejection fraction, and aortic annulus calcification were found to be independent predictors of PPM following AVR [Boughaleb 1994]. Surgical manipulation of anatomical structures near the AV node in patients with aortic stenosis and calcified aortic annulus may be a source of mechanical trauma to the conduction system, precipitating pre-existing conduction defects or generating new ones [Boughaleb 1994]. Given that, multivariate logistic

regression analysis in our series demonstrated left atrial enlargement, poor left ventricular function (<35%), increased cumulative cardiopulmonary bypass time and cross-clamp time as independent predictors of PPM requirement post-surgery.

This is one of the first studies to evaluate the impact of different aortic valve prosthesis on the conduction disorders and the need of PPM thereafter. The major finding of this study is that the requirement for postoperative permanent pacing tended to occur in older patients and was reflected in significantly prolonged cardiopulmonary bypass and aortic cross-clamp times [Gordon 1998]. Postoperatively, such patients experienced significantly longer intensive care unit and hospital stays in comparison to their nonpaced counterparts. We have identified that the incidence of PPM is not related to the type of valve per se rather to increased ischemic burden and operative trauma. Although cold blood cardioplegia represents an independent risk factor for PPM requirement, this finding does not appear to be related to the difference in the type of cardioplegia and the temperature in our series [Del Rizzo 1996].

Despite the retrospective nature, this study provides substantial evidence that the presence of increased ischemic burden rather than prosthesis-type implanted is a marker of poor prognosis with an increased risk of conduction disorders and requirement of PPM in the early postoperative period. The expected corollary of this is that decreased operative trauma and early management leading to less ischemic burden results in an improvement in prognosis. In conclusion, the extent of the early incidence of PPM after aortic valve replacement in patients with pure aortic valve disease is not influenced by the type of valve prosthesis implanted. This may have important clinical implications on prosthesis-type selection. Further longitudinal clinical trials to accurately evaluate hemodynamic parameters are needed to establish the effects of differing valve prostheses on ventricular remodeling with time and its influence on the conduction disorders.

Table 4. Predictors of PPM in Univariate and Multivariate Analysis for the Whole Cohort (n = 782)*

	No. of Patients with Variable (%)	Univariate Analysis		Multivariate Analysis	
Variable		P	Risk Ratio (95% CI)	P	Risk Ratio (95% CI)
Preoperative variables					
Age, y	782 (100)	.01	1.03 (1.0-1.13)		
NYHA functional class IV	22 (2.8)	<.001	3.7 (2.0-6.6)		
Diabetes	70 (8.9)	.04	1.7 (1.3-3.2)		
Previous myocardial infarction	32 (4.1)	<.0001	3.0 (1.4-5.5)	.003	
Creatinine, mmol/L (>200)	11 (1.4)	.001	2.6 (1.4-4.6)		
Preoperative arrhythmias	47 (6.0)	.04	2.2 (1.01-3.8)		
LV ejection fraction <40%	53 (6.7)	<.0001	3.3 (1.7-6.2)	.007	2.6 (1.3-5.2)
LAE	66 (8.4)	<.0001	2.5 (1.5-4.5)	.001	2.5 (1.5-4.3)
LBBB	34 (4.3)	.0003	2.7 (1.7-4.9)	.002	3.7 (1.6-7.6)
Operative variables					
CPB time ≥ 100 min	189 (24.1)	<.0001	9.2 (3.4-24.6)	.001	5.8 (1.9-17.7)
X-clamp time ≥ 70 min	112 (14.3)	<.0001	2.8 (1.6-4.9)	.001	2.7 (1.5-5.0)
Prosthetic valve size ≤ 21 mm	313 (40.5)	.004	1.8 (1.01-3.3)		
Concomitant Ao surgery	18 (2.3)	.0003	2.5 (1.3-4.6)	.003	2.4 (1.4-4.2)

*Only the variables that are significantly associated are shown in this table.

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REFERENCES

- Blais C, Dumesnil JG, Baillot R, Simard S, Doyle D, Pibarot P. 2003. Impact of valve prosthesis-patient mismatch on short term mortality after aortic valve replacement. *Circulation* 108:983-8.
- Boughaleb D, Mansourati J, Genet L, Barra J, Mondine P, Blanc JJ. 1994. Permanent cardiac stimulation after aortic valve replacement: incidence, predictive factors and long-term prognosis. *Arch Mal Coeur Vaiss* 87:925-30.
- Braunwald E. 2000. Aortic valve replacement; an update at the turn of the millennium. *Eur J Heart* 21:1032-3.
- Breisch EA, White FC, Bloor CM. 1984. Myocardial characteristics of pressure overload hypertrophy. A structural and functional study. *Lab Invest* 51:333-42.
- Del Rizzo DF, Nishimura S, Lau C, Sever J, Goldman BS. 1996. Cardiac pacing following surgery for acquired heart disease. *J Cardiovasc Surg* 11:332-40.
- Elahi MM, Lee D, Bhandari M, Dhannapuneni RV, Sosnowski AW. 2005. Permanent pacemaker implantation after valve surgery: assessing its need in early postoperative period: our experience in a tertiary centre. *Br J Cardiol* (in press).
- Gerber IL, Stewart RA, Hammett CJ, et al. 2003. Effect of aortic valve replacement on C-reactive protein in nonrheumatic aortic stenosis. *Am J Cardiol* 92:1129-32.
- Goldman BS, David TE, Del Rizzo DF, Sever J, Bos J. 1994. Stentless porcine bioprosthesis for aortic valve replacement. *J Cardiovasc Surg* 35:105-10.
- Gordon RS, Ivanov J, Cohen G, Ralph-Edwards AL. 1998. Permanent cardiac pacing after a cardiac operation: predicting the use of permanent pacemakers. *Ann Thorac Surg* 66:1698-704.
- Jalil JE, Doering CW, Janicki JS, et al. 1989. Fibrillar collagen and myocardial stiffness in the intact hypertrophied rat left ventricle. *Circ Res* 64:1041-50.
- Keefe DL, Griffin JC, Harrison DC, Stinson EB. 1985. Atrioventricular conduction abnormalities in patients undergoing isolated aortic or mitral valve replacement. *Pacing Clin Electrophysiol* 8:393-8.
- Kvidal P, Bergstorm R, Malm T, et al. 2000. Long term follow up of morbidity and mortality after aortic valve replacement with mechanical valve prostheses. *Eur Heart J* 21:1099-111.
- Lewis JW Jr, Webb CR, Pickard SD, Lehman J, Jacobsen G. 1998. The increased need for a permanent pacemaker after reoperative cardiac surgery. *J Thorac Cardiovasc Surg* 116:74-81.
- Limongelli G, Ducceschi V, D'Andrea A, et al. 2003. Risk factors for pacemaker implantation following aortic valve replacement: a single centre experience. *Heart* 89:901-4.
- Morisco C, Sadoshima J, Trimarco B, Arora R, Vatner DE, Vatner SF. 2003. Is treating cardiac hypertrophy salutary or detrimental: the two faces of Janus. *Am J Physiol Heart Circ Physiol* 284:H1043-7.
- Muiesan ML, Salvetti M, Rizoni D, Castellano M, Donato F, Agabiti-Rosei E. 1995. Association of change in left ventricular mass with prognosis during long-term anti-hypertensive treatment. *J Hypertens* 13:1091-5.
- Pfeiffer MA, Braunwald E. 1990. Ventricular remodeling after myocardial infarction. Experimental observations and clinical implications. *Circulation* 81:1161-72.
- Sia YT, Lapointe N, Parker TG, et al. 2002. Beneficial effects of long-term use of the antioxidant probucol in heart failure in rat. *Circulation* 105:2549-55.
- Verdecchia P, Schillaci C, Borgoni C, et al. 1998. Prognostic significance of serial changes in left ventricular mass in essential hypertension. *Circulation* 273:2161-8.