Durability of bioprosthetic valves in the pulmonary position: Long-term follow-up of 181 implants in patients with congenital heart disease

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Objectives: Durability of bioprosthetic valves in the pulmonary position is not well defined. We examined the durability of bioprosthetic valves in the pulmonary position and risk factors associated with bioprosthetic pulmonary valve failure.

Methods: Between 1993 and 2004, 181 patients underwent pulmonary valve replacement using bioprostheses. Patients who underwent valved conduit or homograft implantation were excluded. Mean age was 14.2 ± 9.8 years and median valve size was 23 mm (range, 19–27 mm). Types of bioprosthesis used were Hancock II (n = 83), Perimount (n = 53), Freestyle (n = 23), Carpentier–Edwards porcine valve (n = 18), and others (n = 4).

Results: There were 3 early and 7 late deaths. Follow-up completeness was 88.6% and mean follow-up duration was 7.3 ± 2.9 years. Forty-three patients underwent redo pulmonary valve replacement. Overall freedom from redo pulmonary valve replacement at 5 and 10 years was $93.9\% \pm 1.9\%$ and $51.7\% \pm 8.6\%$, respectively. Overall freedom from both valve failure and valve dysfunction at 5 and 10 years was $92.2\% \pm 2.1\%$ and $20.2\% \pm 6.7\%$, respectively. In multivariable analysis, younger age at operation, diagnosis of pulmonary atresia with ventricular septal defect, and use of stentless valve were identified as risk factors for redo pulmonary valve replacement.

Conclusions: Durability of bioprosthetic valves in the pulmonary position was suboptimal. Valve function was maintained stable until 5 years after operation. By 10 years, however, about 80% will require reoperation or manifest valve dysfunction. In our experience, the stentless valve was less durable than stented valves. (J Thorac Cardiovasc Surg 2011;142:351-8)

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Pulmonary valve replacement (PVR) is frequently performed during repair of various congenital heart diseases. Chronic pulmonary regurgitation after repair of tetralogy of Fallot is a typical situation that necessitates PVR. There are several surgical options for PVR, including bioprostheses, homografts, mechanical valves, and hand-sewn polytetrafluoroethylene valves.¹⁻⁵ Among these, bioprosthetic valves are probably the most widely used, because they are readily available and they do not need permanent

anticoagulation therapy. However, most of these bioprostheses will eventually fail and require replacement mainly owing to structural valve deterioration, more specifically, leaflet calcification. Although modern design technique and anticalcification treatments applied to currently available bioprosthetic valves have greatly improved the durability of bioprostheses implanted into adult patients,^{6,7} dystrophic calcification leading to early bioprosthetic valve failure is still a great problem in children and young adults. A dominant risk factor predictive of early bioprosthetic pulmonary valve failure is younger age at the time of initial PVR, as reported in previous studies.^{1,8} However, long-term actual durability of bioprosthetic pulmonary valves implanted into children and young adults is not well defined owing to the small number of patients or relatively short duration of follow-up in previous studies.^{1-3,9-13} Furthermore, many studies^{2,10,11,14} are limited to a single valve type, and there are few reports^{3,13} dealing with durability of different types of bioprostheses.

Since 1993, we have performed over 280 initial PVR in patients with various congenital heart defects using different types of bioprostheses. To better elucidate the fate of bioprosthetic pulmonary valves, we examined the long-term durability of these valves and risk factors associated with bioprosthetic pulmonary valve failure.

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Abbreviations and Acronyms

PA = pulmonary atresia
 PVR = pulmonary valve replacement
 VSD = ventricular septal defect

PATIENTS AND METHODS

By searching the database of our institution, we identified 281 patients who had undergone initial PVR using bioprosthetic valves between 1993 and 2009. From among these patients, we selected 181 patients who had undergone PVR between 1993 and 2004 to examine the long-term results of bioprosthetic PVR. Excluded from this study were patients who had undergone valved conduit or homograft implantation. The medical records of these patients were reviewed. The institutional review board at our institution has approved this retrospective study and waived the need for individual patient consent.

The mean age at the time of PVR was 14.2 ± 9.8 years (Figure 1, A) and 112 patients (61.9%) were male. Fundamental diagnoses were tetralogy of Fallot ($n = 97$), pulmonary atresia (PA) with ventricular septal defect (VSD) ($n = 39$), double-outlet right ventricle ($n = 10$), transposition of the great arteries ($n = 9$), pulmonary stenosis ($n = 8$), congenitally corrected transposition of the great arteries ($n = 6$), absent pulmonary valve syndrome ($n = 6$), and others ($n = 6$). Indications for PVR were pulmonary regurgitation ($n = 112$), pulmonary stenosis ($n = 43$), combined pulmonary stenosis and regurgitation ($n = 14$), and as a part of corrective surgery ($n = 12$). The mean number of operations before PVR was 1.5 ± 0.8 and the mean interval between initial right ventricular outflow tract reconstruction and PVR was 9.1 ± 5.0 years.

Choice of bioprosthetic valves was at the discretion of the surgeon. Valve types used were Hancock II (Medtronic, Inc, Minneapolis, Minn; $n = 83$), Carpentier–Edwards Perimount (Edwards Lifesciences, Irvine, Calif; $n = 53$), Freestyle (Medtronic; $n = 23$), Carpentier–Edwards porcine valves (Edwards Lifesciences; $n = 18$), and others ($n = 4$). For the entire cohort, the median valve size was 23 mm (range, 19–27 mm) and the distribution of valve sizes is shown in Figure 1, B. So that valve sizes could be compared across a broad range of age groups, Z-scores were calculated according to the formulas developed by Zilberman, Khoury, and Kimball.¹⁵ The median Z-score was 1.3 (range, –0.5 to 3.6). Concurrent procedures were performed in 141 (77.9%) patients and are summarized in Table 1. The mean cardiopulmonary bypass time was 184 ± 77 minutes and the mean aortic crossclamp time ($n = 77$) was 95 ± 57 minutes. Post-operative pressure data were available for 96 (53%) patients, and the mean systolic pressure ratio between the right and left ventricles was 0.39 ± 0.13 .

Patient follow-up data were obtained through review of medical records and direct telephone contact between March 8, 2010, and March 16, 2010. Follow-up was considered complete if the patient's status was determined after July 2008. The mean duration of follow-up was 7.3 ± 2.9 years (range, 0.1–16.0 years [1148 patient-years]), and 84.8% of hospital survivors had complete follow-up. Follow-up completeness measured by calculating the index devised by Clark and associates,¹⁶ as previously described, was 88.6%. Prosthetic valve failure was defined as the need for redo PVR or interventional catheter procedure. Prosthetic valve dysfunction was defined as a peak pressure gradient equal to or greater than 40 mm Hg or at least a moderate amount of pulmonary regurgitation on the latest echocardiography.

Data collection and statistical analyses adhered to the guidelines for reporting mortality and morbidity after cardiac valve interventions.¹⁷ Categorical variables were expressed as frequencies and percentages. Continuous variables were expressed as means $\pm$ standard deviations or medians with ranges as appropriate. Comparison between groups was performed using 1-way analysis of variance with post hoc test. Survival and time-to-event analyses were performed using the Kaplan–Meier actuarial method. Stratified Kaplan–Meier curve comparisons were performed using the log rank test. The Cox proportional hazard model was used to determine both univariable and multivariable relationships between explanatory variables and time-to-event.

RESULTS**Early and Late Mortality**

There were 3 early deaths (30-day hospital mortality, 1.7%). A 38-year-old man with underlying liver cirrhosis, who had undergone repair of tetralogy of Fallot at the age of 33 years, died of massive tracheal bleeding 11 days after the operation. An 11-year-old boy with preoperative ventricular dysfunction, who had undergone a conventional Rastelli procedure for congenitally corrected transposition of the great arteries, VSD, and pulmonary stenosis at the age of 5 years, died of ventricular dysfunction on the day of the operation. A 10-year-old boy, who had undergone repair of tetralogy of Fallot at the age of 3 years, died of ischemic brain damage 8 days after the operation. There were 7 late deaths. The causes of late death were accident in 2 patients, ventricular dysfunction in 1 patient, multiorgan failure in 1 patient, endocarditis in 1 patient, and unknown in 2 patients. Overall actuarial survival (including early deaths) at 5 and 10 years was $96.1\% \pm 1.5\%$ and $93.7\% \pm 2.0\%$, respectively.

FIGURE 1. A, Distribution of patient ages at the time of pulmonary valve replacement. B, Distribution of bioprosthetic valve sizes used.

TABLE 1. Concurrent procedures

Procedure	No.	Percent
PA angioplasty	88	48.6
TAP/TVP	41	22.7
VSD closure	30	16.6
Arrhythmia surgery	10	5.5
ASD closure	9	5.0
AVP	5	2.8
LVOT widening	4	2.2
Pacemaker	2	1.1
Others	8	4.4

PA, Pulmonary artery; TAP, tricuspid annuloplasty; TVP, tricuspid valvuloplasty; VSD, ventricular septal defect; ASD, atrial septal defect; AVP, aortic valvuloplasty; LVOT, left ventricular outflow tract.

Reoperation, Interventional Catheter Procedure, and Prosthetic Valve Dysfunction

Among 178 hospital survivors, 43 patients required reoperation for a failed pulmonary valve prosthesis. Indications for reoperation were pulmonary stenosis ($n = 30$), endocarditis ($n = 7$), and combined pulmonary stenosis and regurgitation ($n = 6$). The linearized rate of endocarditis was 0.6% per year. The majority of reoperations were associated with some degree of pulmonary stenosis and the clinical thresholds for consideration of reoperation have somewhat varied between individual patients over the study period. For patients who underwent reoperation owing to pulmonary stenosis, the median peak pressure gradient assessed by echocardiography or cardiac catheterization was 63 mm Hg (range, 31–114 mm Hg). The median time interval between initial PVR and redo PVR was 6.4 years (range, 0.5–13.6 years). Overall freedom from redo PVR at 5 and 10 years was $93.9\% \pm 1.9\%$ and $51.7\% \pm 8.6\%$, respectively (Figure 2, A).

Ten patients underwent interventional balloon valvuloplasty for prosthetic valve stenosis (median peak pressure gradient of 55 mm Hg [range, 42–80 mm Hg]), and 8 of these eventually required reoperation. Excluding the patients who underwent redo PVR or interventional balloon

valvuloplasty, 22 patients showed prosthetic valve dysfunction on the latest echocardiogram. Overall freedom from both prosthetic valve failure and dysfunction at 5 and 10 years was $92.2\% \pm 2.1\%$ and $20.2\% \pm 6.7\%$, respectively (Figure 2, B).

Valve Type–Stratified Analysis

To compare the durabilities of different types of bioprostheses, we categorized them into 3 groups: stented porcine valve (Hancock II, Carpentier–Edwards porcine, and others; $n = 105$), stented bovine pericardial valve (Carpentier–Edwards Perimount, $n = 53$), and stentless porcine valve (Freestyle, $n = 23$). Stentless porcine valve was associated with a lower mean age and a smaller mean valve size (Table 2). Stented bovine pericardial valve was associated with a smaller mean valve Z-score and a shorter mean follow-up duration (Table 2). Freedom from redo PVR at 10 years was $48.5\% \pm 10.9\%$ for stented porcine valve, $84.6\% \pm 7.8\%$ for stented bovine pericardial valve, and $31.2\% \pm 10.4\%$ for stentless porcine valve (Figure 3, A). Freedom from redo PVR for stentless porcine valve was significantly lower than those for stented porcine ($P < .001$) and stented bovine pericardial valve ($P < .001$). The difference between stented porcine and stented bovine pericardial valve could be due to chance ($P = .293$). Freedoms from both prosthetic valve failure and dysfunction are plotted in Figure 3, B. Freedom from valve failure and dysfunction for stentless porcine valve was significantly lower than those for stented porcine ($P < .001$) and stented bovine pericardial valves ($P = .015$). There was no significant difference between stented porcine and stented bovine pericardial valve ($P = .311$).

Diagnosis–Stratified Analysis

We categorized underlying diagnoses into 3 groups; tetralogy of Fallot ($n = 97$), PA with VSD ($n = 39$), and others ($n = 45$). Diagnosis of PA with VSD was associated with a lower mean age, a smaller mean valve size, and a larger

FIGURE 2. A, Overall freedom from reoperation. B, Overall freedom from both prosthetic valve failure and dysfunction. Numbers above the x-axis represent patients remaining at risk.

TABLE 2. Comparison among 3 different types of bioprostheses

	Stented porcine	Stented bovine	Stentless porcine	P value
Mean age (y)	14.8 ± 10.6	15.5 ± 8.3	8.3 ± 4.9	.007
Mean valve size (mm)	23.2 ± 2.5	23.3 ± 2.6	21.1 ± 2.4	.001
Mean valve Z-score	1.5 ± 0.8	1.1 ± 0.8	1.6 ± 0.7	.027
Mean FU (y)	7.8 ± 3.1	6.1 ± 2.2	7.6 ± 2.7	.003

FU, Follow-up.

mean valve Z-score (Table 3). There was no significant difference in follow-up duration among the 3 groups (Table 3). Freedoms from redo PVR according to the underlying diagnosis are plotted in Figure 4, A. Freedom from redo PVR for tetralogy of Fallot was significantly higher than those for PA with VSD ($P < .001$) and other diagnoses ($P = .008$). There was no significant difference between PA with VSD and other diagnoses ($P = .235$). Freedoms from both prosthetic valve failure and dysfunction are plotted in Figure 4, B. Freedom from valve failure and dysfunction for tetralogy of Fallot was significantly higher than those for PA with VSD ($P < .001$) and other diagnoses ($P = .007$). There was no significant difference between PA with VSD and other diagnoses ($P = .173$).

Age-Stratified Analysis

Freedom from redo PVR at 10 years was $17.8\% \pm 7.1\%$ for patients younger than 10 years and $90.6\% \pm 4.1\%$ for patients older than 10 years ($P < .001$; Figure 5, A). Freedom from both prosthetic valve failure and dysfunction at 10 years was $6.2\% \pm 4.2\%$ for patients younger than 10 years and $12.6\% \pm 10.8\%$ for patients older than 10 years ($P < .001$; Figure 5, B).

Risk Factors for Redo PVR

In univariable analysis, younger age at operation, underlying diagnosis of PA with VSD, use of stentless porcine

valve, and larger valve Z-score were identified as risk factors associated with decreased time to redo PVR (Table 4). In multivariable analysis, younger age, diagnosis of PA with VSD, and use of stentless porcine valve were identified as independent risk factors for redo PVR (Table 4).

DISCUSSION

Surgical repair of obstructive lesions of the right ventricular outflow tract in children usually leaves the native pulmonary valve incompetent or requires placement of a conduit between the right ventricle and pulmonary artery. As these patients grow, many of them will require PVR owing to chronic pulmonary regurgitation or a failed conduit. There are several surgical options for PVR, including bioprostheses, homografts, mechanical valves, and hand-sewn polytetrafluoroethylene valves. The homograft has a drawback of limited availability, and there are limited experiences about implanting mechanical valves in the pulmonary position.^{4,18} For these reasons, bioprosthetic valves are widely used and they have been our first choice for PVR in patients who can accommodate an adult-sized bioprosthesis.

Bioprosthetic PVR can be performed with low operative mortality as evidenced by our result (30-day hospital mortality of 1.7%). However, almost all of these bioprostheses will eventually fail and require replacement owing to structural valve deterioration. Structural valve deterioration in the form of leaflet calcification is accelerated in children and young adults, resulting in early prosthetic valve failure. Compatible with previous studies,^{1,8} our study also demonstrated that younger age was a significant risk factor for early prosthetic pulmonary valve failure (hazard ratio: 0.85 per year, $P = .001$). Currently, the exact cause and mechanism of an accelerated bioprosthetic valve failure in children are not completely understood. Traditionally, active calcium metabolism of rapidly

FIGURE 3. Valve type-stratified Kaplan-Meier curves. A, Freedom from reoperation. B, Freedom from both prosthetic valve failure and dysfunction. Numbers below the graph represent patients remaining at risk. SP, Stented porcine valve; SB, stented bovine pericardial valve; SL, stentless valve.

TABLE 3. Comparison among 3 diagnostic groups

	TOF	PA with VSD	Others	P value
Mean age (y)	16.2 ± 9.7	10.2 ± 5.6	13.5 ± 11.6	.005
Mean valve size (mm)	23.7 ± 2.5	22.2 ± 2.7	22.2 ± 2.4	.001
Mean valve Z-score	1.3 ± 0.7	1.7 ± 0.9	1.3 ± 0.8	.027
Mean FU (y)	6.8 ± 3.1	7.5 ± 3.0	7.6 ± 2.8	.281

TOF, Tetralogy of Fallot; PA, pulmonary atresia; VSD, ventricular septal defect; FU, follow-up.

growing children has been regarded as a culprit. More recently, however, some evidences suggest that the greater immune system competence of children and young adults may contribute to an accelerated bioprosthetic valve failure.¹⁹⁻²¹

The primary objective of our study was to better define the durability of bioprostheses in the pulmonary position through long-term follow-up. Although many previous studies have dealt with this issue, most of them had limitations of relatively small patient numbers or short duration of follow-up (Table 5). Caldarone and coworkers⁸ reported a large series of PVR using 455 bioprostheses. However, their study also included 490 valved conduits and they did not make a separate analysis on the durability of bioprostheses. In our experience, bioprosthetic valve function was maintained stable until 5 years after the operation, as evidenced by overall freedom from redo PVR of 94% and freedom from valve failure and dysfunction of 92% at 5 years. This result is fairly compatible with those of previous studies^{3,22-24} reporting 5-year freedom from redo PVR (92%–100%, Table 5). At 10 years after operation, however, the result was disappointing with freedom from redo PVR of 52% and freedom from valve failure and dysfunction of only 20%. Although previous studies^{1,25} reporting 10-year freedom from redo PVR gave somewhat higher values (70%–86%, Table 5) compared with ours, their mean ages were higher and this might be able to explain

the differences. Certainly, all of these results, including ours, are suboptimal when considering the results from old-aged adult patients.^{6,7}

Valve type–stratified analysis revealed an interesting finding, that is, inferior durability of stentless porcine valve (Freestyle) compared with those of stented porcine or bovine valves. The Freestyle valve was considered as an attractive alternative for right ventricular outflow tract reconstruction in children owing to its presumed favorable hemodynamic characteristics and anticalcification treatment using amino oleic acid.^{10,14} Previous studies dealing with PVR using different kinds of stentless porcine valves consistently reported excellent early results in terms of freedom from redo PVR (Table 5). However, our long-term follow-up result (mean follow-up duration of 7.6 years) was disappointing, with freedom from redo PVR of only 31% at 10 years (Figure 3, A), although our patients were younger and had smaller valves implanted (Table 2). Kanter and coworkers¹⁰ reported excellent early results with the Freestyle valve for right ventricular outflow tract reconstruction in children with only 1 reoperation out of 56 patients during a mean follow-up of 2.5 years. However, they observed a mean peak systolic gradient of 19.7 mm Hg across the valves and questioned the significance of this finding in the long term. Other studies dealing with PVR using stentless valves also reported similar echocardiographic findings (mean peak systolic transvalvular gradients of 25–26 mm Hg) and also questioned the significance of their findings in the long term.^{14,23,24} Although it was anticipated hopefully that the anticalcification treatment applied to the Freestyle valve could delay the onset of calcification and, as such, would improve the durability of this valve in children, this was not the case, at least in our experience. Most of the explanted Freestyle valves showed variable degrees of leaflet calcification. Of note, in 3 patients, we found at the time of reoperation that the

FIGURE 4. Diagnosis-stratified Kaplan-Meier curves. A, Freedom from reoperation. B, Freedom from both prosthetic valve failure and dysfunction. Numbers below the graph represent patients remaining at risk. TOF, Tetralogy of Fallot; PA, pulmonary atresia; VSD, ventricular septal defect.

FIGURE 5. Age-stratified Kaplan-Meier curves. A, Freedom from reoperation. B, Freedom from both prosthetic valve failure and dysfunction. Numbers below the graph represent patients remaining at risk.

valves were compressed by the overlying sternum. All of these patients had previously undergone implantation of a conduit for right ventricular outflow tract reconstruction before PVR. We speculate that nonorthotopic implantations of Freestyle valves in these patients might have caused compression by the sternum, further reducing the durability of these valves. Whether the inferior durability of Freestyle valves is simply a reflection of our patients' characteristics or a true long-term fate of this valve remains elusive, although our multivariable analysis identified this valve type as an independent risk factor for early redo PVR. Long-term follow-up studies from other groups with different patient populations will be helpful to clarify this point. Currently, we no longer use the Freestyle valve for right ventricular outflow tract reconstruction. Instead, we use hand-sewn polytetrafluoroethylene (0.1-mm thickness) bicuspid valve as described by Quintessenza and

coworkers⁵ or stented bovine pericardial valve depending on the surgeon's preference.

Diagnosis-stratified analysis revealed superior durability of bioprosthetic valves when implanted into patients with tetralogy of Fallot (Figure 4). In most of the patients with a diagnosis of tetralogy of Fallot, the indication for PVR was chronic pulmonary regurgitation, and it was almost always possible to implant a bioprosthesis in the orthotopic position. On the contrary, a substantial portion of patients with other types of diagnosis underwent PVR owing to failure of a pre-existing conduit used for right ventricular outflow tract reconstruction. Accordingly, many of these patients had their valves implanted in a nonorthotopic position, and this might have contributed to the inferior durability of the bioprostheses implanted into these patients. It is our speculation that turbulent blood flow across a nonorthotopically implanted bioprosthesis can lead to early valve

TABLE 4. Risk factors associated with redo PVR

Variable	Univariable analysis			Multivariable analysis		
	HR	95% CI	P value	HR	95% CI	P value
Sex						
Male		Reference category				
Female	1.27	0.69–2.33	.449			
Age (y)	0.86	0.81–0.91	<.001	0.85	0.78–0.93	.001
Diagnosis						
TOF		Reference category			Reference category	
PA/VSD	4.31	1.95–9.54	<.001	3.24	1.44–7.26	.004
Others	2.78	1.25–6.20	.012	1.58	0.65–3.83	.313
Valve type						
Stented P		Reference category			Reference category	
Stented B	0.53	0.18–1.53	0.238	0.79	0.26–2.36	.671
Stentless	3.73	1.91–7.29	< 0.001	3.10	1.39–6.90	.006
Z-score	1.81	1.29–2.54	0.001	0.81	0.50–1.33	.411

PVR, Pulmonary valve replacement; HR, hazard ratio; CI, confidence interval; TOF, tetralogy of Fallot; PA, pulmonary atresia; VSD, ventricular septal defect; P, porcine; B, bovine.

TABLE 5. Summary of reported results for bioprosthetic PVR

Author	Patients No.	Age (y)	Valve type	Valve size (mm)	FU (y)	Freedom from redo PVR
Fiore et al ³	49	23.0	Porcine	25	1.7	78% at 5 y
Kanter et al ⁹	38	11.4	Porcine	26	4.9	100% at 8 y
Allen et al ²²	48	11.0	Bovine	26	3.6	100% at 5 y
Morales et al ¹¹	26	20.3	Bovine	23	1.6	100% at 2.5 y
Fiore et al ³	18	22.0	Bovine	24	3.5	92% at 5 y
Hawkins et al ²³	150	15.8	Stentless	27	—	99% at 5 y
Kanter et al ¹⁰	56	11.8	Stentless	24	2.5	1 reoperation
Hartz et al ¹⁴	47	14.2	Stentless	25	3.5	1 reoperation
Black et al ²⁴	21	24.5	Stentless	27	3.1	100% at 5 y
Yemets et al ²⁵	79	19.6	Mixed	—	5.8	86% at 10 y
Discigil et al ¹	33	22.0	Mixed	25	7.8	70% at 10 y

Age, valve size, and follow-up duration are expressed as a mean value. PVR, Pulmonary valve replacement; FU, follow-up.

failure by adding hemodynamic stress on the valve leaflets. In multivariable analysis, diagnosis of PA with VSD was identified as an independent risk factor for redo PVR.

When stratified by age, it appears that bioprostheses implanted into patients older than 10 years have quite excellent durability in terms of reoperation (Figure 5, A). However, if we consider both valve failure and dysfunction together, it was very interesting to find that the two curves for each age group had very similar pattern except a slightly longer initial stable period observed in older children (Figure 5, B). Certainly, bioprostheses implanted into older children also have suboptimal durability and will require reoperations in the near future.

CONCLUSIONS

Overall durability of bioprosthetic valves in the pulmonary position was suboptimal. Valve function can be expected to remain stable until 5 years after the operation. By 10 years, however, about 80% will require reoperation or manifest valve dysfunction. Younger age and diagnosis of PA with VSD were identified as independent risk factors for redo PVR. In our experience, the stentless porcine valve was less durable than stented valves.

Limitations of the Study

This study is limited by its retrospective design and inclusion of patients managed over a 16-year period. Choice of bioprosthetic valves was at the discretion of the surgeon. Also, it is important to acknowledge that the follow-up was incomplete (89%).

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