Surgery for paravalvular abscess in children

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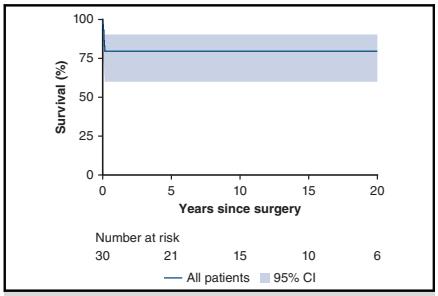
ABSTRACT

Objective: To investigate the outcomes of surgery in children with paravalvular abscess at our institution.

Methods: A retrospective review of all patients who underwent surgery for paravalvular abscess was performed.

Results: Between 1989 and 2020, 30 patients underwent surgery for paravalvular abscess, of whom 5 (16.7%) had an intracardiac fistula and 6 (20.0%) had a pseudoaneurysm. Aortic annulus abscesses were most common, occurring in 23 patients (76.7%). Aortic root replacement was performed in 17 patients (56.7%), root reconstruction was performed in 4 (13.3%), and reconstruction of the central fibrous body was required in 5 (16.7%). Postoperatively, 7 patients (23.3%) required extracorporeal membrane oxygenation (ECMO) support, and 1 patient (3.3%) required permanent pacemaker insertion. There were 6 early deaths, 5 of whom were on ECMO, and no late deaths, with a 15-year survival of 79.7% (95% confidence interval [CI], 60.2%-90.3%). Deaths were from sudden cardiac arrest resulting in brain death in 3 patients, inability to wean from ECMO due to severe cardiac dysfunction in 2 patients, and cerebral mycotic aneurysm and hemorrhage in 1 patient. Freedom from reoperation was 40.0% (95% CI, 17.0%-62.3%) at 15 years Reoperation due to recurrence was rare, occurring in only 2 patients (6.7%). *Streptococcus pneumoniae* (hazard ratio [HR], 9.2; 95% CI, 1.6-51.7) and preoperative shock (HR, 6.4; 95% CI, 1.3-32.0) were associated with mortality. Central fibrous body reconstruction was associated with reoperation (HR, 4.4; 95% CI, 1.2-16.1).

Conclusions: Although paravalvular abscess in children is associated with high early mortality, hospital survivors have good long-term survival. Reoperation is frequent, but is rarely due to recurrence of endocarditis. (JTCVS Open 2023;16:648-55)



Surgery for paravalvular abscess is associated with high early mortality but good long-term survival.

CENTRAL MESSAGE

Despite high early mortality, surgery for paravalvular abscess is effective, with hospital survivors demonstrating good long-term survival, often without recurrence of endocarditis.

PERSPECTIVE

Paravalvular abscess often necessitates complex surgical techniques, which have been associated with high operative mortality and persistent infection in adults. Evidence on outcomes of surgery in children is limited. Our results demonstrate good long-term survival and few instances of recurrence; however, early mortality is high, and reoperations are frequent.

Paravalvular extension of infective endocarditis, including annular abscess, pseudoaneurysm, and intracardiac fistula formation, is a challenging complication requiring urgent surgical management.[1] Given the extensive tissue destruction, complex reconstructive techniques are often required.[2] In adults, operative mortality is high, and infections may persist despite surgical intervention.[2-4] In children, however, outcomes of surgery for paravalvular abscess are poorly described, with surgical guidelines and approaches based on those for adults. Therefore, we sought to

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Abbreviations and Acronyms
ECMO = extracorporeal membrane oxygenation
PA = pulmonary artery
RV = right ventricle

investigate the outcomes of surgery in children with infective endocarditis with paravalvular extension at our institution.

METHODS

This study was approved by the Human Research Ethics Committee at the Royal Children's Hospital, Melbourne, Australia (approval 36250A; August, 30, 2016). All patients who underwent surgery for infective endocarditis with paravalvular extension between 1989 and 2020 were included. Patients were identified if they demonstrated evidence of paravalvular extension, including abscess, pseudoaneurysm, and intracardiac fistulae, on preoperative echocardiography or intraoperatively. Data were obtained retrospectively from medical records. Follow-up was performed by reviewing correspondence from a patient's general practitioner or cardiologist providing information on their current status.

Definitions

Early mortality was defined as death within 30 days of surgery or prior to initial hospital discharge, and early reoperation was defined as reoperation within 30 days of surgery or prior to initial hospital discharge. All other deaths and reoperations were considered late.

The date of diagnosis of infective endocarditis was defined as the time at which the patient initially met the Duke criteria or the starting date of intravenous antibiotic administration, whichever occurred first.

Statistical Analysis

All data were analyzed using Stata MP version 16 (StataCorp). Categorical variables are expressed as number (%) and compared using the χ^2 test or Fisher exact test for a group size <10. Continuous variables are expressed as median with interquartile range (IQR). Kaplan-Meier survival analysis was used to analyze time-related endpoints. Cox regression analysis were used to identify relationships between variables. A P value < .05 was considered statistically significant.

RESULTS

Between 1989 and 2020, 30 patients underwent surgery for paravalvular abscess, of whom 5 (16.7%) had an intracardiac fistula and 6 (20.0%) had a pseudoaneurysm. Aortic annulus abscesses were most common, occurring in 23 patients (76.7%). Mitral annulus abscesses occurred in 5 patients (16.7%), right ventricle (RV)-to-pulmonary artery (PA) conduit abscesses occurred in 2 patients (6.7%), and tricuspid annulus abscesses occurred in 1 patient (3.3%).

The patients' baseline characteristics are detailed in Table 1. The median age was 7.6 years (IQR, 1.2-12.6 years), median height was 123 cm (IQR, 80-155 cm), and median weight was 22.6 kg (IQR, 10.8-39.8 kg).

History of Congenital Heart Disease

Congenital heart disease was present in 21 patients (70.0%). Aortic stenosis and bicuspid aortic valves were the most common disorders, occurring in 7 patients each (23.3%), followed by ventricular septal defect in 4 patients (13.3%); truncus arteriosus and patent foramen ovale in 3 patients each (10.0%); and Ebstein's anomaly, patent ductus arteriosus, double-outlet right ventricle, and pulmonary atresia in 1 patient each (3.3%). Previous cardiac surgery was performed in 13 patients (43.3%), 4 of whom had previous valve replacement, and 8 patients (26.7%) had intracardiac prosthetic material present prior to surgery for paravalvular extension of infective endocarditis.

Microbiology

Twenty-six patients (86.7%) had positive blood or tissue cultures. Gram-positive organisms were the most commonly isolated, occurring in 92.3% (24 of 26) of positive cultures. *Staphylococcus aureus* was isolated from 10 patients (33.3%), with 9 cultures growing methicillin-sensitive *S aureus* and 1 culture growing methicillin-resistant *S aureus*.

Streptococci were also common, with *Streptococcus viridans* grown in 4 of 30 cultures (13.3%), *Streptococcus pneumoniae* grown in 3 cultures (10.0%), coagulase-negative staphylococci and Group B streptococci grown in 2 cultures each (6.7%), *Streptococcus mitans* grown in 1 culture (3.3%), and other streptococci species grown in 1 culture (3.3%). *Corynebacterium* and *Kingella* were cultured from 2 patients each (6.7%), and *Pseudomonas*, *Klebsiella*, and *Enterococcus* were isolated from 1 patient each (3.3%).

Preoperative Course

The majority of patients (96.7%; 29 of 30) presented acutely septic with fever or an elevated serum C-reactive protein level. The remaining patient presented with acute heart failure. One-third of the patients required preoperative intensive care admission due to heart failure, with 16.7% (5 of 30) admitted for cardiogenic shock. All patients had large intracardiac lesions or intracardiac fistulae on imaging, which, together with their clinical presentation, was concerning for abscess formation, prompting consideration for urgent surgery. The median time from diagnosis to surgery was 3.0 days (IQR, 1.0-7.3 days).

Complications of heart failure occurred in 13 patients (43.3%), leaflet perforation occurred in 10 patients (33.3%), and cardiogenic shock was seen in 5 patients (16.7%). Embolization occurred in 9 patients (30.0%), including cerebral embolization in 3 (10.0%); renal embolization in 3 (10.0%); and splenic embolization in 2 (6.7%). Neurologic symptoms due to cerebral embolization were present in 2 patients (6.7%). No patients required preoperative dialysis.

On preoperative echocardiography, the majority of patients (93.3%; 28 of 30) had valve regurgitation. More than one-half (53.3%; n = 16) had moderate or greater

TABLE 1. Patient baseline demographic data (N = 30)

Characteristic	Result
Sex, n (%)	
Male	18 (60.0)
Female	12 (40.0)
Height, cm, median (IQR)	123 (80-155)
Weight, kg, median (IQR)	22.6 (10.8-39.8)
Indigenous Australian, n (%)	3 (10.0)
Preexisting congenital heart disease, n (%)	21 (70.0)
Prior episode of infective endocarditis, n (%)	1 (3.3)
Prior rheumatic heart disease, n (%)	1 (3.3)
Prior cardiac operation, n (%)	13 (43.3)
Cardiac anomalies, n (%)	
Bicuspid aortic valve	7 (23.3)
Aortic stenosis	7 (23.3)
Ventricular septal defect	4 (13.3)
Truncus arteriosus	3 (10.0)
Patent foramen ovale	3 (10.0)
Ebstein anomaly	1 (3.3)
Patent ductus arteriosus	1 (3.3)
Double-outlet right ventricle	1 (3.3)
Pulmonary atresia	1 (3.3)

IQR, Interquartile range.

aortic regurgitation on latest preoperative echocardiography, 20.0% (n = 6) had moderate or greater mitral regurgitation, and 6.7% (n = 2) had moderate or greater tricuspid regurgitation.

Operative Technique

Operations performed and their associated outcomes are summarized in Table 2. Aortic root replacement was performed in 17 patients (56.7%), with 9 patients (30.0%) undergoing homograft root replacement and 8 patients (26.7%) undergoing a Ross procedure. Aortic root reconstruction was performed in 4 patients (13.3%). Mechanical aortic valve replacement was performed in 3 patients (10.0%). Five patients (16.7%) required concomitant reconstruction of the central fibrous body.

Five patients had a mitral annulus abscess, of whom 3 patients (60.0%) underwent mitral valve repair and 2 (40.0%) underwent mitral valve replacement, 1 patient with a mechanical valve and the other with a bioprosthetic valve. Mitral valve repair was performed through abscess debridement and annuloplasty in 1 patient, by ring annuloplasty and neochordae formation in 1 patient, and by abscess debridement in 1 patient. One patient (3.3%) with a tricuspid annulus abscess underwent tricuspid valve repair involving annulus resection and ring annuloplasty.

Two patients (6.7%) had involvement of previously inserted RV-PA conduits necessitating RV-PA conduit replacement. One RV-PA conduit replacement was performed concomitantly with a homograft aortic root replacement.

Postoperative Course

Postoperatively, 7 patients (23.3%) required extracorporeal membrane oxygenation (ECMO) support, and 1 patient (3.3%) required permanent pacemaker insertion following deliberate resection of infected conduction tissue. Among the 7 patients requiring ECMO support, 2 patients (40.0%) had undergone reconstruction of the central fibrous body. Heart block occurred postoperatively in 1 patient (3.3%), which resolved, and in 2 patients (6.7%) who experienced early death. Two patients (6.7%) required a brief period of peritoneal dialysis. Six patients had postoperative embolization, including 5 cerebral embolisms (83.3%) and 1 pulmonary embolism (16.7%).

Mortality

There were 6 early deaths, 5 of whom were on ECMO prior to death, and no late deaths, with a survival rate of 79.7% (95% confidence interval [CI], 60.2%-90.3%) at 5, 10, and 15 years (Figure 1, *A*). Death occurred from sudden cardiac arrest resulting in brain death in 3 patients, an inability to wean off of ECMO due to severe cardiac dysfunction in 2 patients, and cerebral mycotic aneurysm and hemorrhage in 1 patient.

On Cox regression analyses, *Streptococcus pneumoniae* (hazard ratio [HR] 9.2; 95% CI, 1.6-51.7) and preoperative shock (HR, 6.4; 95% CI, 1.3-32.0) were independently associated with mortality.

There were 2 deaths (25.0%) in patients who underwent a Ross procedure and 3 deaths (37.5%) in patients who underwent a homograft root replacement, including 1 death (33.3%) in a patient undergoing a mechanical aortic valve replacement for an aortic root abscess, with concomitant mitral valve replacement and central fibrous body reconstruction. In patients who underwent central fibrous body reconstruction, there were 2 deaths (40%), following a period of ECMO support in both cases. There were no deaths in patients with mitral annulus, tricuspid annulus, or RV-PA conduit abscess.

Freedom From Reoperation

Freedom from reoperation was 60.6% (95% CI, 38.9%-76.7%) at 5 years, 50.0% (95% CI, 28.3%-68.4%) at 10 years, and 40.0% (95% CI, 17.0%-62.3%) at 15 years (Figure 1, *B*). There were 5 early reoperations (16.7%) owing to an aneurysmal dilation of the aortic root, revisions of the aortic and mitral prostheses, development of vegetations in the RV-PA conduit, development of a ventricular pseudoaneurysm, and right heart failure in 1 patient each.

TABLE 2. Operations performed and associated outcomes (N = 30)

Operation	Result, n (%)	Deaths, n (%)	Reoperations, n (%)
Homograft aortic root replacement	9 (30.0)	3 (10.0)	5 (16.7)
Ross procedure	8 (26.7)	2 (6.7)	2 (6.7)
Reconstruction of the central fibrous body	5 (16.7)	2 (6.7)	3 (10.0)
Aortic root reconstruction	4 (13.3)	0 (0)	1 (3.3)
Mechanical aortic valve replacement	3 (10.0)	1 (3.3)	0 (0)
Mitral valve repair	3 (10.0)	0 (0)	0 (0)
Mitral valve replacement	2 (6.7)	0 (0)	1 (3.3)
RV-PA conduit replacement	2 (6.7)	0 (0)	1 (3.3)
Tricuspid valve repair	1 (3.3)	0 (0)	0 (0)

RV, Right ventricle; *PA*, pulmonary artery.

There were 14 late reoperations performed in 8 patients. There were 8 aortic valve replacements, including 7 mechanical valve replacements and 1 Ross procedure, due to worsening aortic stenosis or regurgitation. Four patients underwent reoperation following an initial homograft root replacement, including 3 patients who underwent mechanical valve replacement and 1 patient who underwent the Ross procedure, due to progressive valve deterioration in 3 patients and acute onset valve regurgitation from recurrence of endocarditis in 1 patient. In contrast, 2 patients underwent reoperation who had an initial Ross procedure, 1 patient because of annular dilation and the other for conduit stenosis.

Mitral valve repair was required in 1 patient owing to progressive annulus dilation following an initial homograft aortic root replacement, and mechanical mitral valve replacement was required twice in 1 patient owing to culture-negative infective endocarditis in the initial replacement, occurring concomitantly with a mechanical aortic valve replacement, and mitral stenosis in the subsequent replacement. There were 2 pulmonary valve replacements, 1 each due to right ventricular outflow tract dilation and pulmonary stenosis, and 1 RV-PA conduit replacement.

Reoperation due to recurrence of infective endocarditis was rare, occurring in only 2 patients (6.7%). Freedom from reoperation due to recurrence was 91.1% (95% CI, 68.9%-97.7%) at 5, 10, and 15 years (Figure 1, *C*).

In the 9 patients undergoing homograft root replacement, there were 5 reoperations (55.6%), whereas in the 8 patients who underwent a Ross procedure, there were 2 reoperations (25.0%). This difference did not reach statistical significance, however.

Late reoperations were required in 3 of the 5 patients (60.0%) undergoing reconstruction of the central fibrous body. Cox regression analysis identified this as a predictor of reoperation (HR, 4.4; 95% CI, 1.2-16.1).

Among the patients with mitral annulus abscesses, 1 patient, who underwent an initial valve replacement with a bioprosthetic valve, required a late redo mitral valve replacement for mitral stenosis, followed by a mechanical aortic valve replacement. No reoperations were required in patients with a tricuspid annulus abscess or RV-PA conduit abscess.

Follow-up

Follow-up was complete for 95.8% of the surviving patients (23 of 24). The median follow-up was 9.25 years (IQR, 2.8-17.7 years). Of the 24 survivors, 18 (75.0%) were in New York Heart Association (NYHA) class I at late follow-up. Ongoing neurologic deficits were reported in 2 survivors (8.3%). No patients required dialysis on late follow-up.

DISCUSSION

Despite significant associated morbidity and mortality, there are few reports on the surgical management of paravalvular abscess in children. Therefore, recommendations for treatment of these children are derived largely from adult guidelines. This study aimed to further demonstrate the outcomes of surgery for paravalvular abscess in children. A graphical abstract of the study is presented in Figure 2.

Early mortality was high in our cohort (20.0%; 6 of 30), as expected, given both the extent of infection and the surgical complexity. This is consistent with studies in adults, with operative mortality of 15.5% reported by David and colleagues[4] and 13% reported by d'Udekem and colleagues.[2] In contrast, the long-term survival was excellent with no late deaths, and the majority of patients were in NYHA class I at late follow-up.

Only 1 other study, by Chaturvedi and colleagues,[5] has evaluated children undergoing surgery for aortic root abscess, with results similar to our current study. In a cohort of 5 children who underwent homograft aortic root replacement, there was 1 early death (20.0%), and all 4 surviving children were in NYHA class I at final follow-up.[5] Reoperations were frequently required, but few were due to recurrence of endocarditis. In adults, d'Udekem and colleagues[2]

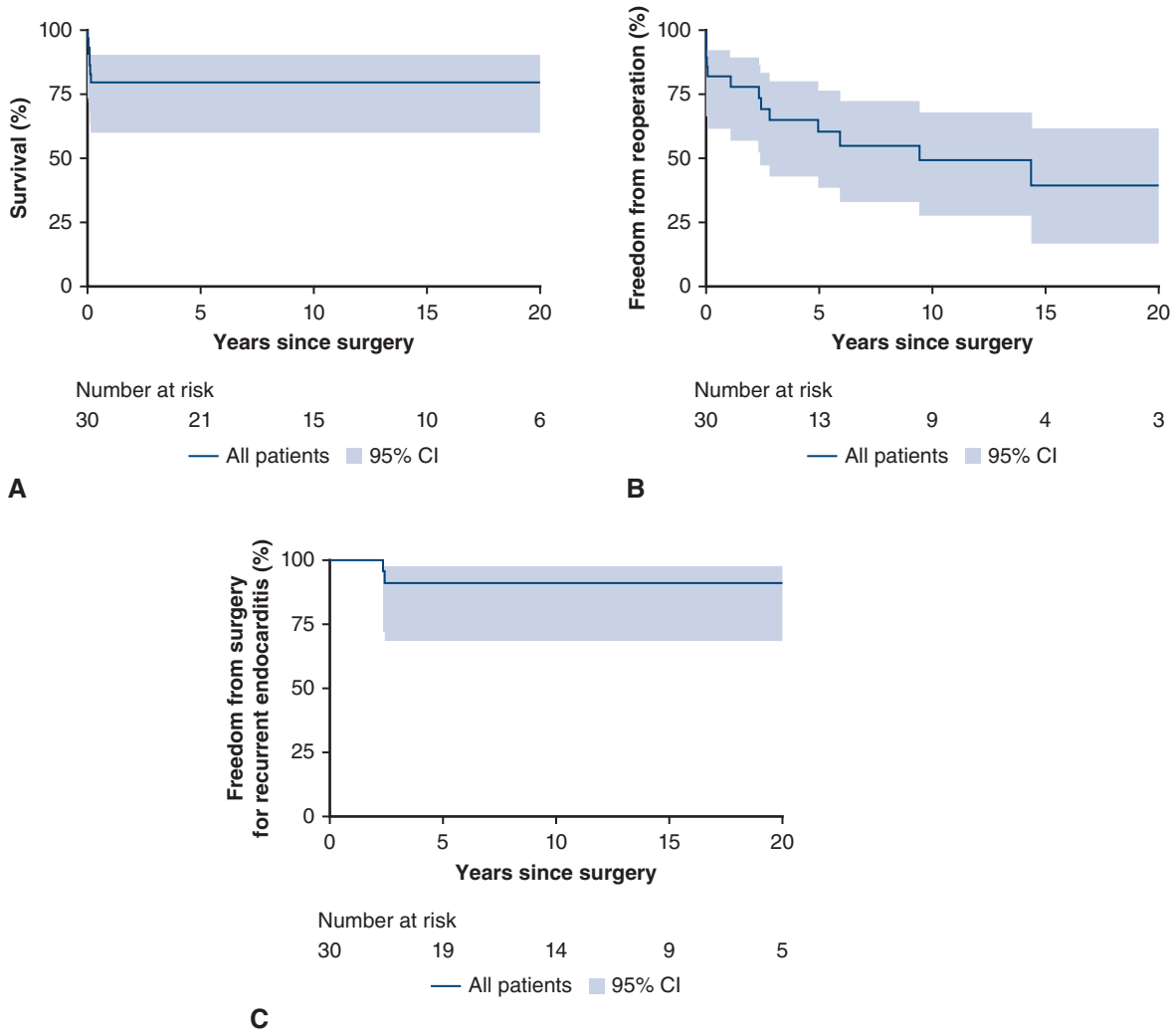

FIGURE 1. Kaplan-Meier curves for overall survival (A), freedom from reoperation (B), and freedom from reoperation due to recurrence of endocarditis (C). *CI*, Confidence interval.

reported survival of 64% and freedom from recurrent endocarditis of 76% at 8 years following radical resection of the abscess and any infected or inflamed tissue.[2] Similarly, Spiliopolous and colleagues[6] reported that radical surgical management was associated with acceptable mortality and no recurrence of endocarditis in their cohort.[6] Based on our results, radical resection of all infected tissue yields similar outcomes in children. This approach likely ensures complete removal of the infective source, facilitating recovery in the septic child and reducing the risk of reinfection. Moreover, the acceptable late survival rate both in adults and in our cohort of children suggests that a radical approach is effective in the management of paravalvular abscess.

In particular, reconstruction of the central fibrous body or aortomitral curtain, also known as the commando procedure, is necessary in only the most extensive cases of disease. Previous reports in adults have shown high operative mortality and satisfactory long-term survival and freedom from reoperation and recurrence.[7,8] In our cohort of children, one-third of the early deaths occurred in those requiring ECMO support following a commando procedure. There were no late deaths, but 60.0% (3 of 5) required late reoperation. The commando procedure was identified as a risk factor for reoperation. Although the high early mortality was likely due to both the severity of infection and invasive nature of the procedure, these results further reinforce the efficacy of radical resection in hospital survivors.

Preoperative shock was associated with an increased risk of mortality, as expected. *S aureus* was the most commonly isolated microorganism but was not found to be significantly associated with mortality. However, *S pneumoniae* was a predictor for death and has been previously identified

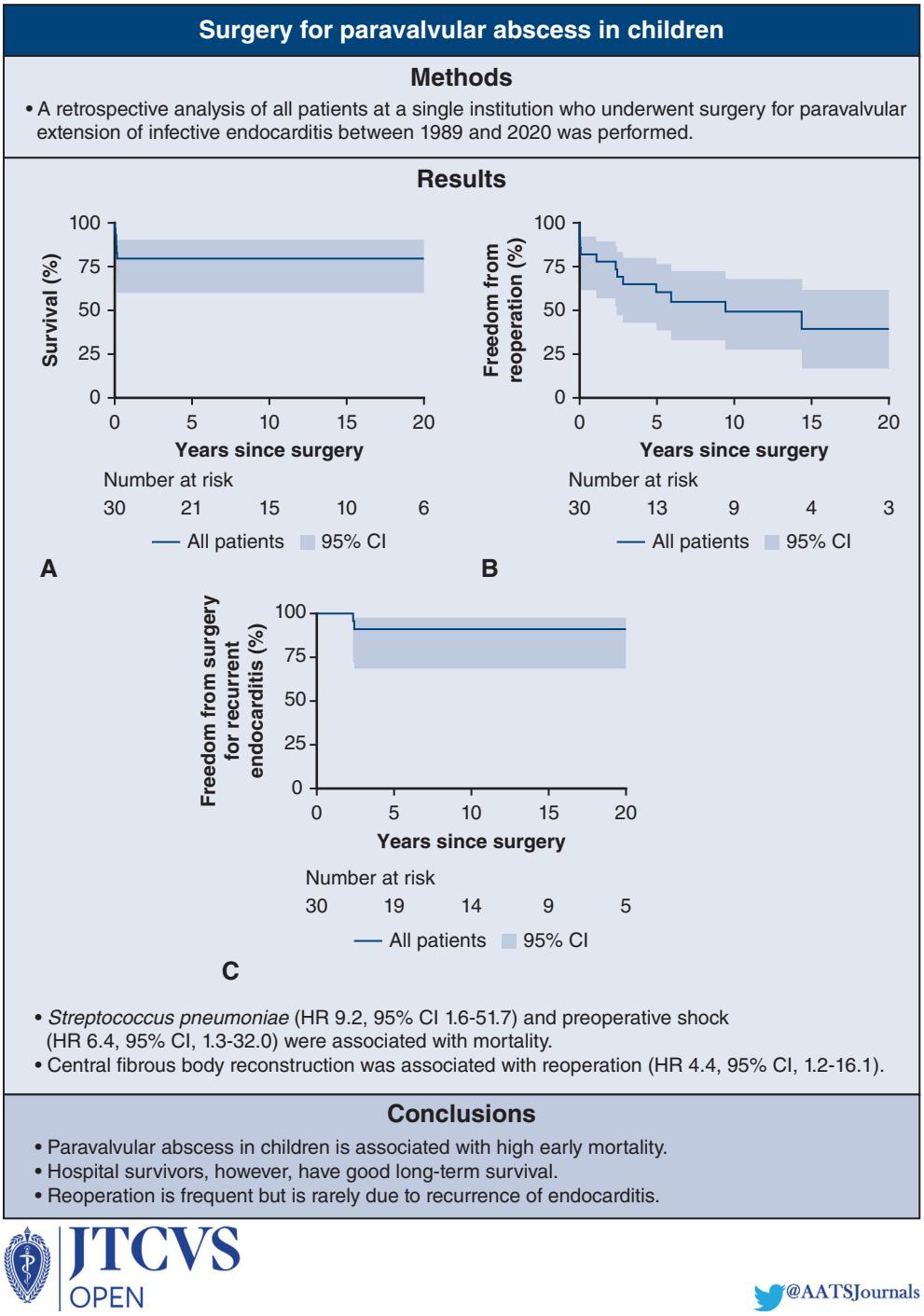

FIGURE 2. Graphical abstract. *CI*, Confidence interval; *HR*, hazard ratio.

as a cause of rapidly progressive endocarditis and mortality.[9-11]

Heart block has been reported as a common complication of paravalvular abscess due to the mass effect on conduction tissue of an enlarging abscess.[12,13] In our group, no patients were identified with heart block preoperatively. Postoperatively, only 1 patient required permanent pacemaker insertion, demonstrating that extensive reconstructive surgery does not necessarily result in complete heart block. This may be attributed to our preference for early identification of abscess and early surgery, with a median time from diagnosis to surgery of 3 days, before the abscess

encroaches on conduction tissue. Transesophageal echocardiography has been shown to more accurately identify paravalvular abscess compared with transthoracic echocardiography.[14] Therefore, at our institution, patients suspected of having infective endocarditis are routinely screened with transesophageal echocardiography preoperatively, allowing for early identification of paravalvular extension. Urgent surgery in acutely septic children with infective endocarditis also has been shown to be safe and appears to carry a lower risk compared to adults, resulting in a move toward earlier intervention.[15-18] Chaturvedi and colleagues[5] adopted a similar approach of urgent operation, with all 4 of their surviving patients in sinus rhythm at late follow-up.[5] It is possible that early intervention reduces the risk of complete heart block by limiting the extent of tissue destruction.

The Ross procedure has become an increasingly attractive option in children because of its somatic growth potential and resistance to infection,[19] although there are concerns about the procedure's feasibility in sepsis given its technical complexity.[5,20] We recently identified the Ross procedure as the preferred alternative in children with infective endocarditis when aortic valve repair is not feasible; recurrence was rare, and the Ross procedure was shown to be superior to homograft root replacement with respect to freedom from reoperation.[21] In the present study, mortality was comparable between the Ross procedure and homograft root replacement, but reoperations appeared to be more prevalent in the homograft group, although the difference did not reach statistical significance. Thus, it appears that the Ross procedure may be the preferred option for aortic root replacement in children presenting with paravalvular abscess.

There are few reports on mitral annulus, tricuspid annulus, and RV-PA conduit abscesses in both adults and children. In our limited subset of these patients, long-term postoperative outcomes appeared acceptable. Notably, the only patient requiring reoperation had received a bioprosthetic mitral valve. We have also previously shown that mitral valve repair is feasible in the majority of cases of pediatric infective endocarditis, and it is reassuring that despite annular involvement, repair was possible in more than one-half of the cases in our cohort.[16]

Limitations

This study is limited primarily by its relatively small sample size, with few adverse outcomes over a long time period. Therefore, our statistical analysis might not have properly identified all associations between variables. Moreover, owing to further reductions in sample size and outcomes, analyses of specific subgroups, such as patients with aortic root abscesses, did not generate any meaningful results.

CONCLUSIONS

Although paravalvular abscess in children is associated with high early mortality, hospital survivors have good long-term survival. Reoperation is frequent but is rarely due to recurrence of endocarditis.

Conflict of Interest Statement

Dr Brizard serves on the advisory board of Admedus. All other authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: paravalvular abscess, infective endocarditis, cardiac surgery, children