Outcomes of Patients Undergoing Surgical Management of Multiple Ventricular Septal Defects

Michael Daley, BVSc,[,†] Christian P. Brizard, MD, MS,[*,†,‡] Igor E. Konstantinov, MD, PhD,[*,†,‡] Johann Brink, MBBS,[*] Andrew Kelly, MBBS, DCH,[§] Bryn Jones, MBBS,[†,‡,‖] Diana Zannino, MSc(Res),[†] and Yves d'Udekem, MD, PhD[*,†,‡]*

Surgical treatment of multiple ventricular septal defects (VSDs) has advanced significantly in recent years, yet remains technically challenging. With high rates of complications and reoperations, we sought to assess the outcomes of patients undergoing a variety of management techniques for multiple VSDs. From 1988 to 2015, 157 consecutive patients underwent surgical management of multiple VSDs at a median age of 2.2 months (2 days–16 years). Sixty-nine patients (44%) had exclusively multiple VSDs, 62 patients (39%) had multiple VSDs with concomitant intracardiac anomalies, and 26 patients (17%) had multiple VSDs with aortic arch anomalies. The predominant techniques used at the initial operations were patch closure (84 patients), pulmonary artery band (83 patients), suture closure (37 patients), and sandwich technique (13 patients). Eighteen patients underwent ventriculotomies. There were 3 hospital deaths (2%). Mean follow-up time was 8.6 ± 6 years (1 day–22 years). Four patients died during follow-up, whereas freedom from reoperations was 52% (95% confidence interval 42–61%) at 16 years. Freedom from reoperation was significantly lower in the 1988–2002 era than in the post-2002 era (38% vs 73%, $P = 0.016$). Pacemaker implantation was ultimately required in 9% (14 of 150) of patients. No deleterious impact of a ventriculotomy could be detected. Surgical treatment of multiple VSDs can be performed with excellent short- and long-term survival, and normal late functional outcome, however, carries a significant rate of reoperation. The recent inclusion of absorbable pulmonary artery bands and the sandwich technique appear safe and are useful adjuncts in these patients.

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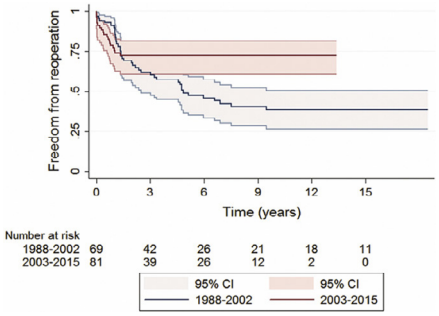
Keywords: Ventricular septal defects, Multiple VSD, Surgical repair of VSD, Long-term outcomes



Outcomes of surgical management of multiple ventricular septal defects are improving in the current era.

Central Message

Multiple ventricular septal defect management outcomes are improving, although continue to carry significant complications. More recent techniques appear safe and useful in these patients.

Perspective Statement

Multiple ventricular septal defects carry a significant burden with unplanned reoperations, complete heart block, and ventricular dysfunction reported as common complications. Although several management techniques exist, novel techniques introduced at our institution appear safe and useful in these patients.

*Department of Cardiac Surgery, The Royal Children's Hospital, Melbourne, Victoria, Australia
†Murdoch Children's Research Institute, Melbourne, Victoria, Australia
‡Department of Paediatrics, The University of Melbourne, Melbourne, Victoria, Australia
§Department of Cardiology, Women's and Children's Hospital, Adelaide, South Australia, Australia
‖Department of Cardiology, The Royal Children's Hospital, Melbourne, Victoria, Australia

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Yves d'Udekem is a consultant for companies MSD and Actelion. Christian P. Brizard is a member of the advisory board for Admedus.

Address reprint requests to Yves d'Udekem, MD, PhD, Royal Children's Hospital, 50 Flemington Rd, Melbourne, Victoria 3052, Australia. E-mail: yves.dudekem@rch.org.au

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INTRODUCTION

Surgical treatment of multiple ventricular septal defects (VSDs) remains technically challenging since being first reported as a significant entity in 1965.[1] Residual defects, complete heart block (CHB), and ventricular dysfunction have been reported as common complications, with patients experiencing higher rates of unplanned reoperations and early mortality compared with patients with a single VSD.[2–4]

With numerous surgical techniques described, concrete guidelines for the management of these patients are currently lacking.[5] Through a generally accepted right atrial approach to the muscular interventricular septum, the trabecular morphology of the right ventricle can restrict visualization and hinder complete closure of the defects. More recently, studies have suggested that techniques previously considered to have poor outcomes, such as left ventriculotomies, may be well tolerated in the current era.[6,7]

Long-term outcomes of surgical management in the current era have been poorly described. We retrospectively analyzed all patients at our institution who underwent surgical management of multiple VSDs to assess the various techniques employed, their long-term effects and complications, and rate of reoperations.

METHODS

The design of the study was approved under the Network Agreement for Paediatric Acquired and Congenital Heart Disease and Adult Congenital Heart Disease Research and by the Hospital Research Ethics Committee. The need for consent was waived because of the retrospective nature of the study. A total of 157 patients aged 2 days–16.2 years (median 2.2 months) underwent management of multiple VSDs at the Royal Children's Hospital (RCH) in Melbourne, Australia, between 1988 and 2015. Data were obtained through review of hospital databases, patient files, and operation reports, whereas follow-up was extracted from hospital outpatient clinic follow-up and letters from current cardiologists. Follow-up for patients who had moved interstate was obtained through contact with local pediatric cardiologists.

Definitions

Operative mortality was defined as death occurring before hospital discharge or within 30 days of an operation for multiple VSDs. Late mortality was defined as death occurring after discharge from hospital and more than 30 days after an operation for multiple VSDs.

Reoperations were documented if they were in relation to the integrity of the interventricular septum or any complications arising from previous VSD operations. Early reoperation was defined as return to the operating theater before discharge or within 30 days of an operation for multiple VSDs.

For all end points, time was measured from the initial operation for the purpose of multiple VSDs. Integrity of the interventricular septum was determined by transthoracic echocardiography in an outpatient cardiology setting. Intracardiac shunts were deemed hemodynamically significant if the cardiology report determined it was significant, or if the patient was undergoing antifailure medication.

Clinically significant arrhythmias were defined as arrhythmias requiring medication, permanent pacemaker, or implantable cardiac defibrillator. Complex intracardiac anomalies were defined as intracardiac anomalies other than multiple VSDs or aortic arch obstruction (coarctation, transverse arch hypoplasia, or interrupted aortic arch). Simple defects such as patent foramen ovale, ostium secundum atrial septal defects, or patent ductus arteriosus were not included.

Patients were determined to have a "Swiss-cheese" septum if the term was used in echocardiography or operative reports ($n = 14$).

Operative Techniques and Strategies

The open management of all VSDs was performed through a midline sternotomy approach. Standard cardiopulmonary bypass was used for all intracardiac repairs. Two patients underwent a period of deep hypothermic circulatory arrest of 18 and 19 minutes during their initial operation, both of which involved aortic arch repairs.

Surgical techniques included patch closure, direct closure, pulmonary artery band (PAB) placement, sandwich technique, and perventricular device closure. Patch closure of VSDs predominantly involved the use of autologous pericardium; however, polyethylene terephthalate (Dacron; C.R Bard, Haverhill, MA) and expanded polytetrafluoroethylene (Gore-Tex; W.L. Gore & Associates, Inc., AZ) were occasionally used. Direct closure of VSDs involved the placement of horizontal mattress pledgeted sutures. The re-endocardialization technique described by Alsoufi et al[8] was not used in this cohort. Procedures involving the sandwich technique for VSD closure were performed as described by Brizard et al.[9] Many operations involved multiple techniques.

During the first part of the study, patients with multiple VSDs were treated with conventional treatment of a classical PAB without bypass if there was no concomitant surgery. The second part of the study saw the introduction of the absorbable PAB. At the same time, we opted for a strategy of closing the larger defects at the time of the initial operation. In case of multiple VSDs undergoing VSD closures, a Qp:Qs is calculated at the end of the operation by harvesting blood in the right atrium and the main pulmonary artery (MPA), and patients with a Qp:Qs > 1.5 underwent additional PA banding (Fig. 1). Both nonabsorbable (Gore-Tex) and absorbable PABs (polydioxanone tape, 10-mm PDS; Johnson & Johnson, New Brunswick, NJ) were used, with the majority of nonabsorbable PABs placed before 2003, after which point the unit preferred the use of absorbable PABs. All PABs were tightened, where hemodynamically tolerated, reducing MPA pressure distal to the band to between a third and a half of systemic arterial pressure. The bands were secured with either 5/0 or 6/0 polypropylene sutures or 2 ligating clips (LIGACLIP; Johnson & Johnson) with conventional method of PAB placement, ensuring that it caused no obstruction of the left and right pulmonary arteries.

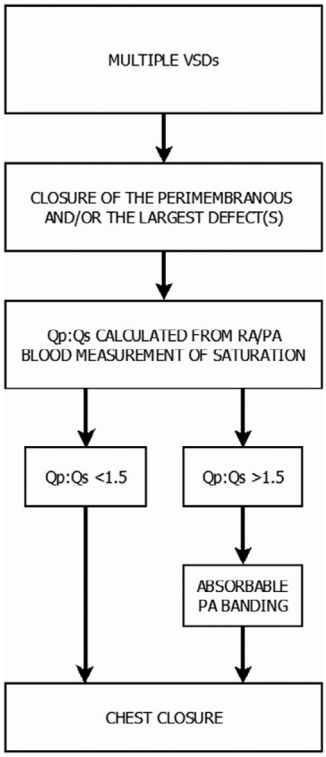


Figure 1. Current RCH strategy for patients with multiple VSDs.

Interventional or perventricular closure of VSDs involved the use of either a Rashkind double umbrella device (USCI Angiographics, Billerica, MA) or an Amplatzer muscular VSD occluder (AGA Medical Corporation, Golden Valley, MN).

Concurrent intracardiac and aortic arch defects were repaired at initial operation, unless the purpose was to postpone definitive repair by means of PAB placement.

Statistical Analysis

All analyses and graphs were performed in Stata version 13 (StataCorp, College Station, TX). Mean (±standard deviation) or median (with interquartile range [IQR] and range) was reported for continuous variables, and counts and percentages for categorical variables. Freedom from reoperation was measured from the date of the first surgical attempt of VSD closure to the date of first reoperation and was estimated using the Kaplan-Meier method. The log-rank test was used to compare Kaplan-Meier curves.

RESULTS

Patient Demographics

One hundred fifty-seven consecutive patients underwent surgical management of multiple VSDs between 1988 and 2015, with their characteristics summarized in Table 1. The median age at first surgical management was 2.2 months (interquartile range 21 days−4.2 months); 52% (81/157) were male and 48% (76/157) were female. Twenty-one patients had genetic abnormalities as follows: 3% (5/157) had trisomy 21, 3% (5/157) had Holt-Oram syndrome, 2% (3/157) had 22q11 microdeletion, 1% (1/157) had VACTERL, and 4% (7/157) had nonspecific or undiagnosed syndromes.

The multiple VSDs included the perimembranous septum in 52% of patients (82/157), the midmuscular septum in 86% (135/157), apical septum in 52% (81/157), inlet muscular septum in 25% (40/157), and outlet septum in 10% (16/157). Sixty-nine patients (44%) had multiple VSDs alone, 26 patients (17%) had multiple VSDs in conjunction with aortic arch anomalies (coarctation, hypoplastic transverse arch, or interrupted aortic arch), and 62 patients (39%) had multiple VSDs with complex intracardiac anomalies (Table 1). Two patients underwent preoperative interventional closure of a VSD 1 and 6 days before the initial operation. Because of residual defects, one of these patients subsequently underwent patch and suture closure of multiple remaining VSDs. The second patient underwent nonabsorbable PAB placement and multiple reinterventions.

Catheter-derived Qp:Qs ratios were available in 37 patients, 21 of which were before the initial operation. The mean preoperative Qp:Qs in these patients was 3.0 ± 1.1 (range 1.3−5). Two patients had clinically significant arrhythmias preoperatively (CHB and 2:1 second-degree atrioventricular block) necessitating permanent pacemaker implantation (PPM) at the time of the initial VSD operation.

Table 1. Patient Demographics

	All Patients	1988−2002	2003−2015
Patients, *n*	157	73	84
Age at initial operation in months (median [IQR])	2.2 [0.7−4.2]	2.6 [1.0−6.0]	1.8 [0.6−3.4]
Sex			
Male, *n* (%)	81 (52)	37 (51)	44 (52)
Female, *n* (%)	76 (48)	36 (49)	40 (48)
Genetic syndrome, *n* (%)	21 (13)	13 (18)	8 (10)
Weight at initial operation (kg) (median [IQR])	4 [3.4−5.8]	4.5 [3.4−7.4]	3.9 [3.3−5.2]
Previous interventional VSD closures, *n* (%)	2 (1)	2 (3)	0 (0)
Cardiac diagnosis, *n* (%)			
Multiple VSDs exclusively	69 (44)	29 (40)	40 (48)
Multiple VSDs with complex intracardiac anomalies	62 (39)	31 (42)	31 (37)
Multiple VSDs with aortic arch anomaly	26 (17)	13 (18)	13 (15)

Table 2. Initial Intraoperative Details

	All Patients	1988–2002	2003–2015
Bypass time (min)	152 ± 75	142 ± 63	158 ± 82
Cross-clamp time (min)	95 ± 50	80 ± 37	105 ± 55
Ventriculotomy			
Right, *n* (%)	15 (10)	8 (13)	7 (8)
Left, *n* (%)	2 (1)	2 (3)	0 (0)
Both, *n* (%)	1 (1)	1 (1)	0 (0)
VSD repair technique, *n* (%)			
Patch closure of VSD	84 (54)	30 (41)	54 (64)
Nonabsorbable PAB placement	40 (25)	37 (51)	3 (4)
Absorbable PAB placement	43 (27)	0 (0)	43 (51)
Direct closure of VSDs	37 (24)	24 (33)	13 (15)
Sandwich technique	13 (8)	5 (7)	8 (6)
Perventricular device closure	3 (2)	0 (0)	3 (4)
Resection of RV trabeculations, *n* (%)	17 (11)	9 (12)	8 (10)

RV, right ventricle.

Operative Data

Operative data are summarized in Table 2. Of the 109 patients requiring cardiopulmonary bypass for their initial operation (including concurrent cardiac and aortic anomaly repair), the mean bypass time was 151.5 ± 75.4 minutes and the mean aortic cross-clamp time was 94.9 ± 49.7 minutes. Two patients underwent deep hypothermic circulatory arrest, as previously mentioned. Eighteen patients (11%) required a ventriculotomy: 15 right, 2 left, and 1 both ventricles.

Eighty-three patients (53%) had the placement of a PAB incorporated in their initial operation, with 54 patients (34%) undergoing exclusive placement of a PAB for their VSDs. Of these 83 patients, 43 involved the use of an absorbable PAB at initial operation. Three of 40 patients (8%) receiving a nonabsorbable PAB had concurrent VSD closure, whereas 26 of 43 patients (63%) undergoing absorbable PAB placement had concurrent VSD closure. A total of 25 sandwich procedures were performed from 2000 to 2015.

Initial Operation Outcomes

Operative mortality occurred in 3 patients (2%), all of whom presented in congestive heart failure. One patient with multiple VSDs alone decompensated 1 day after the initial operation and underwent emergent chest reopening. No evidence of bleeding was found, and the patient died in 1996 despite resuscitative measures. The second patient had multiple VSDs and critical aortic stenosis. Despite extensive patch closure of the VSDs, significant residual shunting remained and PAB was not tolerated. The patient was placed on postoperative extracorporeal membrane oxygenation and died of multiorgan failure after 8 days in 1999. The final patient presented with a transposition of the great arteries and multiple VSDs and underwent an arterial switch, direct closure of a VSD, and placement of an absorbable PAB for residual VSDs. Postoperatively, the patient's state was complicated by low cardiac output, and despite removal of the absorbable PAB, he eventually died of sepsis and multiorgan failure in 2013.

Ten patients (6%) underwent early reoperations after the initial procedure. Techniques used in these reoperations included (1) the sandwich technique in 3 patients for residual apical shunting, (2) adjustment or removal of the absorbable PAB in 4 patients, (3) absorbable pulmonary band placement in 2 patients, (4) patch closure of residual VSD in 2 patients, and (5) direct closure of a residual VSD in 1 patient. Two of these patients required a right ventriculotomy during the reoperation. Additionally, 1 patient underwent the placement of 2 further interventional VSD occluding devices 20 days postoperatively.

Late Operative Outcomes

Four patients were lost to follow-up and 3 patients died in hospital as previously described. Follow-up was available in the remaining 150 patients. Mean follow-up was 8.6 ± 6 years (1 day–22 years). All-cause survival was 95% (95% confidence interval [CI] 89–98%) at 18 years (Fig. 2). Six patients died during this period. One patient with aortic coarctation,

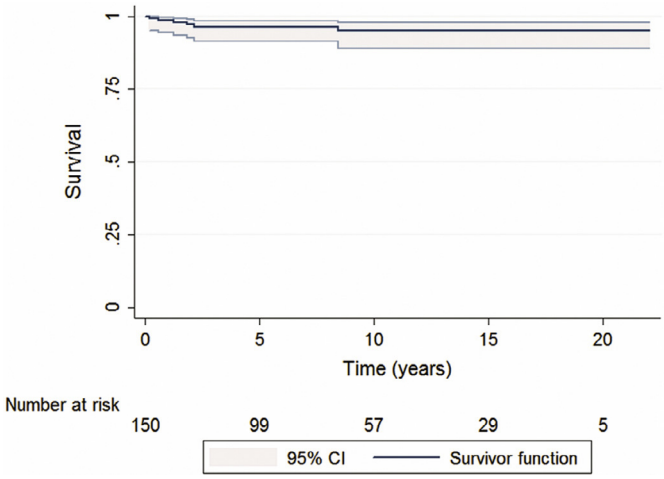


Figure 2. Overall survival. (Color version of figure is available online.)

multiple VSDs, and left ventricular noncompaction originally had an arch repair and a nonabsorbable PAB placed. The patient required eventual removal of the band, reconstruction of the pulmonary trunk, and patch closure of a midmuscular VSD. Because of significant postoperative residual shunting, the patient underwent a sandwich procedure 7 days later. The patient died of sepsis and congestive heart failure 4 years later at 8 years of age. One patient with double discordance and multiple VSDs, provisionally managed with an absorbable PAB, ultimately died of sepsis in the setting of deteriorating heart failure. Another patient with complete atrioventricular septal defect and multiple apical VSDs underwent absorbable PAB placement resulting in spontaneous closure of most defects and a significant reduction in the interventricular shunting. The patient died from ischemic brain injury after mechanical valve replacement at the age of 17 months. One patient with transposition of the great arteries who underwent arterial switch operation and absorbable PAB placement presented to their local emergency department with sudden deterioration and died soon after initial discharge. The death was attributed to a viral illness. The cause of death in the other 2 patients could not be determined.

At latest follow-up, 6 patients were on antifailure therapy for hemodynamically significant VSDs. Four of these 6 patients had undergone multiple operations for VSD closure. Fifty-five patients (37%) were noted to have trivial shunting at latest follow-up. Overall, complete integrity of the interventricular septum was noted in 89 patients (59%).

Reoperations and Reinterventions

Fifty-two patients required reoperations after initial discharge for the purpose of further VSD closure or complications arising from the initial VSD procedure. Reoperation details (early and late) have been summarized in Table 3. Reoperations unrelated to the VSDs or VSD management were not considered. All patients initially receiving a nonabsorbable PAB ($n = 40$) required a reoperation for removal of the band, with 2 patients undergoing early reoperation (1 patch closure, 1 sandwich technique). Twenty-nine of these patients (73%) underwent a patch closure of a residual VSD at the time of band removal, 6 (15%) underwent the sandwich technique, and 2 (5%) underwent direct VSD closure; the remaining 3 patients solely had the PAB removed. Three of these patients required a third procedure: 1 direct closure, 1 patch closure, and 1 sandwich technique.

Table 3. All Reoperation Details ($n = 60$)

Time to reoperation (y) (median [IQR])	1.3 [0.8–3.1]
VSD repair technique, *n* (%)	
Patch closure of VSD	42 (70)
Sandwich technique	12 (20)
Direct closure	4 (7)
Nonabsorbable PAB placement	2 (3)
Absorbable PAB placement	3 (5)
Adjustment or removal of PAB	4 (7)
Ventriculotomy, *n* (%)	
Right	13 (22)
Left	1 (2)
Both	2 (3)
Resection of trabeculations, *n* (%)	12 (20)
Patients requiring removal of nonabsorbable PAB	40
Patch closure of VSD at band removal, *n* (%)	29 (73)
Sandwich technique at band removal, *n* (%)	6 (15)
Direct VSD closure at band removal, *n* (%)	2 (5)
Removal of the band, *n* (%)	3 (8)

Follow-up was available in 39 patients discharged with an absorbable PAB from their initial operation. Additionally, 2 patients received an absorbable PAB at reoperation for their VSDs. Nine patients (22%) required reoperation after placement of their absorbable PAB.

Of the 110 patients who did not receive a nonabsorbable PAB at initial operation, 14 patients required a late reoperation. Ten reoperations involved a patch VSD closure, 2 involved the replacement of a PAB, and 2 included the sandwich technique.

Four of 14 patients with a "Swiss-cheese" septum required a reoperation for their VSDs, 2 of whom also underwent interventional VSD occlusion. The sandwich technique was used in 3 of these 4 patients at reoperation.

Notably, of the 23 patients with follow-up who received the sandwich technique (13 at initial procedure, 1 at early reoperation, 8 at late reoperation, 1 at third operation), only 1 patient (4%) required a subsequent operation for VSD closure.

Fourteen patients underwent a ventriculotomy at reoperation: 11 right ventricle only, 1 left ventricle only, and 2 involving both ventricles. Two of these patients had already received a right ventriculotomy at the initial operation.

Freedom from late reoperations was 58% (95% CI 48–66%) at 16 years (Fig. 3A). To identify the rate of reoperation with our more recent strategies, we removed patients receiving nonabsorbable PAB. However, after removing patients undergoing reoperations with nonabsorbable PABs, freedom from late reoperations was 84% (95% CI 73–90%) at 16 years (Fig. 3B).

Overall, freedom from all reoperations (early and late) was 52% (95% CI 42–61%) at 16 years (Fig. 4A). After removing patients with nonabsorbable PABs, freedom from all reoperations was 77% (95% CI 66–85%) (Fig. 4B).

Ten patients (7%) underwent additional interventional VSD occlusion throughout the course of their management, including the 2 preoperative patients mentioned previously. Five of these patients received further interventional VSD occlusion on another occasion. Two patients suffered catheter-related complications: 1 patient had LV perforation requiring emergency sternotomy and 1 patient had device dislodgement. One additional patient had a failed catheter occlusion as the guidewire was unable to traverse the VSD. All catheter interventions in these patients were performed before 2002.

Comparison by Era

Because of advances in surgical management of multiple VSDs, such as the introduction of absorbable PABs and the use of the sandwich technique, the patient cohort was divided into

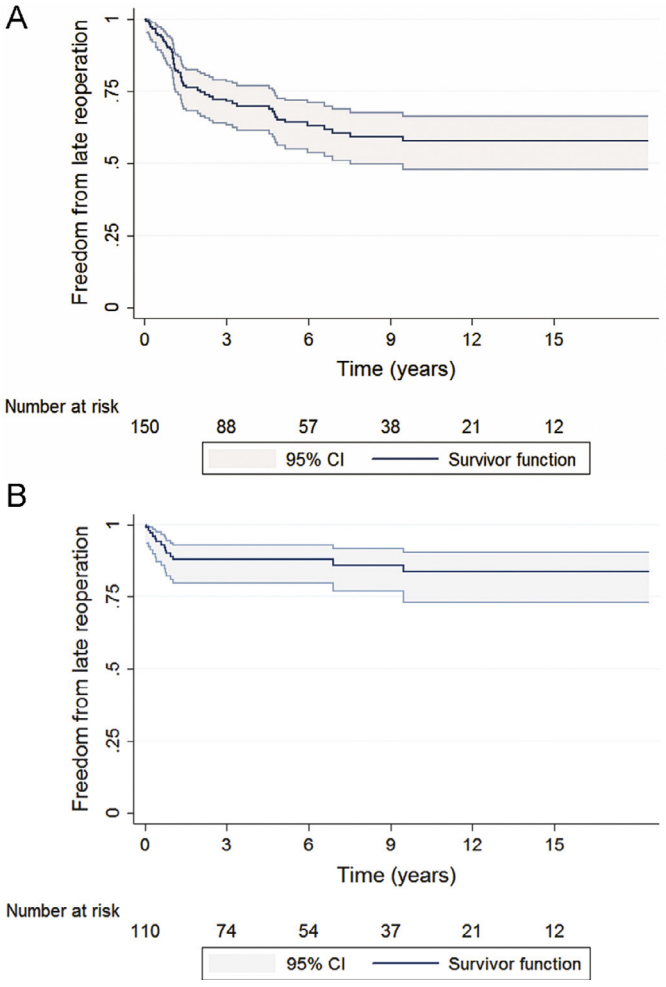


Figure 3. (A) Freedom from late reoperation. (B) Freedom from late reoperation—excluding nonabsorbable PAB patients. (Color version of figure is available online.)

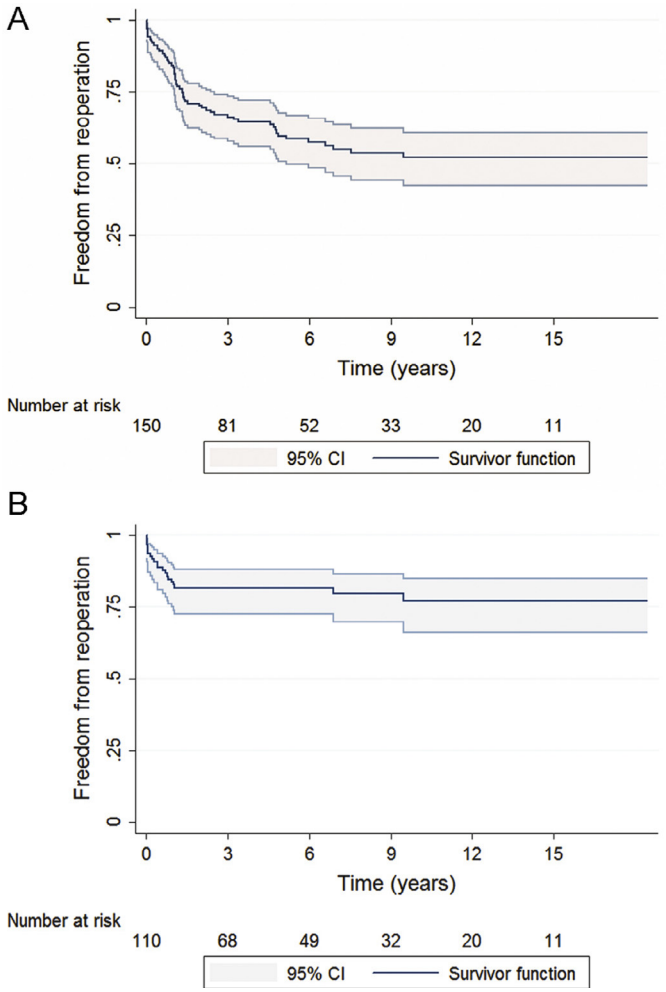


Figure 4. (A) Freedom from all reoperation (early and late). (B) Freedom from all reoperation (early and late)—excluding non-absorbable PAB patients. (Color version of figure is available online.)

2. As the use of absorbable PABs at the unit began in 2003, this year was chosen as a division, resulting in a 1988–2002 cohort of 69 patients and a 2003–2015 cohort of 81 patients. Patients undergoing management during the recent era required significantly less reoperations than the 1988–2002 cohort ($\chi^2 = 5.78$, $P = 0.016$) (Fig. 5). Freedom from reoperation in the 1988-2002 cohort was 38% (95% CI 26–50%) at 16 years, compared with 73% (95% CI 61–81%) in the 2003–2015 at 10 years. This difference was also significant when assessing only late reoperations ($\chi^2 = 11.04$, $P = <0.001$).

Arrhythmias and Pacemaker Implantation

Six patients developed postoperative arrhythmias that did not require intervention: 5 patients developed first-degree atrioventricular block and 1 patient who had temporary complete heart block. Permanent pacemaker implantation was required in 14 patients postoperatively. The indications for pacemaker implantation were CHB (8 patients), temporary CHB (4 patients), and sinus node dysfunction (2 patients). Thirteen patients had deep sutures placed in the interventricular septum, from either patch or direct VSD closure, whereas 1 patient developed CHB after left ventricular outflow tract obstruction resection. Eleven of these patients had the PPM implanted during the early postoperative period, whereas 3 patients underwent late PPM implantation at 10 months, 13 months, and 12 years from most recent operation. Two of the patients with temporary heart block have since had their PPM removed.

Ventricular Function

The mean left ventricular end-systolic and left ventricular end-diastolic diameter *z*-scores were available in 75 patients and were 0.6 ± 1.6 and 0.9 ± 1.8, respectively. Of the 30 patients requiring a ventriculotomy, no deleterious effects were noted on clinical follow-up or echocardiography.

Twenty-nine patients required division or resection of trabeculations in the right ventricle to facilitate VSD closure. At latest follow-up, none of these patients have heart failure or displayed evidence of ventricular dysfunction.

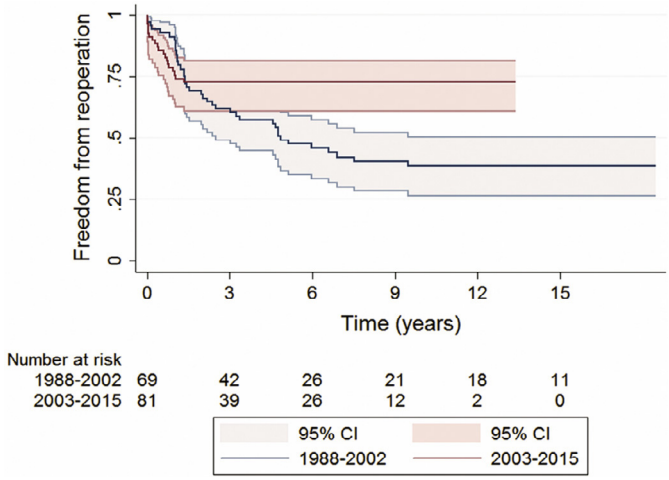


Figure 5. Freedom from all reoperation by era (1988–2002 in blue, 2003–2015 in red). (Color version of figure is available online.)

DISCUSSION

VSDs are commonly regarded as one of the simpler forms of congenital cardiac defects. However, with multiple defects, the numerous variables including number, size, location, and complexity in addition to concurrent cardiac anomalies render a standardized approach exceedingly difficult. With arrhythmias and heart block, ventricular dysfunction, and residual VSDs as common complications, these patients carry significantly worse outcomes than patients with a single VSD.[2,4,8]

Previously, there have been 2 large studies on patients with multiple VSDs. Serraf et al have reported on a large series of 130 patients with multiple VSDs, noting an operative mortality rate of almost 8%, with a mean follow-up of 5 years.[2] Additionally, Alsoufi et al reviewed 116 patients with median follow-up of 3.8 years, also noting a high rate of operative mortality (9%) and CHB (12%).[8] In these 2 series, like in all, the mortality has improved in recent years. Konstantinov and Coles have equally mentioned a high rate of CHB of 11% in these patients.[10]

More recent additions to the surgical armamentarium are translating to improving outcomes. Within our unit, the use of absorbable PABs and sandwich technique has demonstrated significant benefits.[9,11,12] Although not frequently employed at RCH, Melbourne, perventricular device closure and adjunctive transcatheter occlusion have also carried improved results.[13–15] Additionally, re-endocardialization via a transatrial approach has also produced promising results in patients with Swiss-cheese septum and vulnerable conduction tissue; however, we do not have experience with this technique at our center.[8] Large patch closures of apical VSDs that sequester a portion of the right ventricle were not performed and have been associated with poor long-term outcomes.[16]

The sandwich technique has become a widely accepted option for multiple VSD management following positive initial results.[4,7,9,17] The technique avoids the need for trabecular resection and ventriculotomy, although can involve considerable patch material. Similar to standard patch closure, the volume of patch material has been associated with ventricular and septal dysfunction.[18–20] Our current review of the sandwich procedure in this cohort did not result any clinically significant dysfunction. With only 1 patient (4%) requiring a reoperation, the sandwich technique remains a useful technique in surgical management of trabecular VSDs.

Despite the benefits of the sandwich procedure, our cohort of patients did not suffer from any clinical adverse outcomes from right or left ventriculotomies. This finding is consistent with more recent reports and may reflect limited incision sizes and advances in surgical procedure and intraoperative myocardial protection.[6,7,21]

The use of absorbable PABs has produced significant benefit in select patients who were previously obliged to undergo a reoperation on the banded PA with conventional nonabsorbable bands.[12,22] A recent review at our unit revealed that 32 of 41 patients (78%) with an absorbable PAB avoided a reoperation for their VSDs or the band.[11] The median time to resorption of the band was 7.2 months. Residual MPA stenosis was noted in 4 patients, of which 1 patient required balloon dilatation. The indications for the use of absorbable PABs have been predominantly to avoid cardiotomy and promote spontaneous closure of VSDs. The technique may also benefit patients at risk of global or septal dysfunction by avoiding excessive patch material. The production of these absorbable PA bands has now been ceased by the company and our unit is currently using remaining polydioxanone bands. Without appropriate absorbable material, we may concentrate on other surgical techniques to improve outcomes in these patients. Replacement absorbable material with properties similar to these polydioxanone bands will need to be explored.

LIMITATIONS

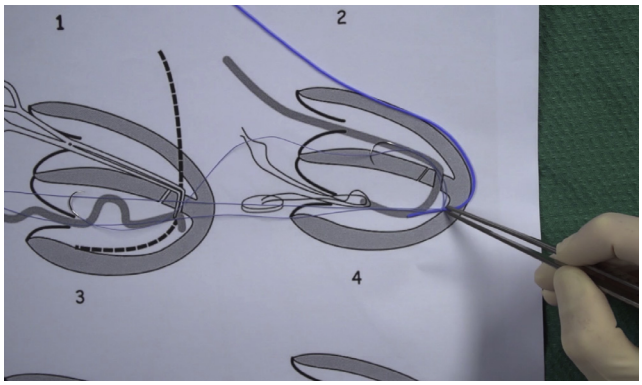
The obvious limitations of a retrospective study applied to this review. As an example, this is not a comparative study between absorbable and nonabsorbable PAB, as our strategy evolved during the time. As we started to use the absorbable PABs, we also started to close, at the first operation, the larger VSD. Therefore, we cannot compare the efficiency between the 2 materials. Additionally, the number of patients with Swiss-cheese septum is likely underestimated because of the difficulty in identifying the specific number of VSDs per patient.

CONCLUSION

In conclusion, surgical treatment of multiple VSDs can be performed with excellent short- and long-term survival and normal late functional outcome. However, this surgery carries a significant rate of reoperation and risk of complete heart block.[8,10,23] The addition of newer techniques may decrease the need for reoperations in these patients. A surgeon should be aware of the armamentarium of various techniques for these patients to make a best case-by-case management decision.

SUPPLEMENTARY MATERIAL

The following is the supplementary data to this article:



Video 1. Prof. Yves d'Udekem discusses our operative technique and current surgical management strategy for multiple VSDs.

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