Surgery for ruptured sinus of Valsalva aneurysm: 25-year experience with 55 patients

Sabit Sarkaya, Taylan Adademir, Ahmet Eligol, Fuat Büyükbayrak, Alper Onk and Kaan Kirali*

Department of Cardiovascular Surgery, Kosuyolu Heart and Research Hospital, Istanbul, Turkey

* Corresponding author. Kartal Kosuyolu Yüksek Eğitim ve Araştırma Hastanesi, 34846 Kartal, Istanbul, Turkey. Tel: +90-216-4594440; fax: +90-216-4596321; e-mail: imkkirali@yahoo.com (K. Kirali).

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Abstract

OBJECTIVES: Different surgical strategies have been evolved for the surgical treatment of ruptured sinus of Valsalva aneurysm (RSVA) from simple primary closure to patching of the rupture site by a dual chamber approach. We reviewed our 25-year experience and current literature regarding the efficacy of different surgical approaches.

METHODS: A retrospective review identified 55 patients who underwent RSVA repair between 1985 and 2011. The mean age was 30.9 ± 12.1 years. The RSVA originated from the right coronary sinus in 43 patients (78.2%), from the non-coronary sinus in 11 (20.0%) and from the left in 1. Rupture into the right ventricle was the most common result (n = 38). Dual-chamber exposure (the involved chamber and aorta) was used in 67.3% of the patients and isolated trans-aortic approach was used in 32.7%. RSVA was repaired with either a patch (n = 43) or direct sutures (n = 12), whereas the aortic valve was replaced in eight patients among the last group.

RESULTS: The hospital mortality rate was 3.6%. The follow-up was available in 94.3% (50 patients) of survivors ranging from 1 month to 25 years (mean 15.3 ± 4.1 years). There were five late deaths. Recurrence of the fistula was seen in two primarily repaired (two of four patients) and none of the patched-closed patients. Actual survival was 93.4 ± 3.7% at 10 years and 87.1 ± 5.6% at 15 years. Freedom from reoperations was 81.6 ± 6.1% at 15 years.

CONCLUSIONS: Surgical treatment for RSVA carries an acceptably low operative risk and long-term freedom from death and reoperation. Surgical approach must be chosen according to the ruptured chamber and associated lesions. Patch repair of RSVA must be preferred.

Keywords: Great vessels · Congenital–acyanotic · Sinus of Valsalva aneurysm · Ruptured aneurysm · Patch repair · Aortico-cardiac fistula · Aortic root

INTRODUCTION

Sinus of Valsalva aneurysm (SVA) occurs infrequently, with an incidence of 0.14–3.5% in patients undergoing open heart surgery. It may be congenital or acquired in origin and may rupture into any of the cardiac chambers, usually the right-sided ones, to form an aortico-cardiac fistula. Once rupture has occurred, the mean survival period for untreated patients is 1–2 years, which favours the need for early surgical intervention [1].

Since Lillehei reported the first successful surgical treatment by means of cardiopulmonary bypass with interrupted silk stitches from the chamber involved in 1957, various surgical strategies of the closure technique (primary closure vs patch closure) and surgical approach (trans-aortic, dual or chamber involved) have been used [2]. This report summarizes our 25-year experience with congenital ruptured sinus of Valsalva aneurysm (RSVA), along with a systemic review of previously published reports.

MATERIALS AND METHODS

Kosuyolu Heart and Research Hospital database was searched (from January 1985 to December 2010) for all patients with a diagnosis of SVA and only those patients with congenital RSVA were included in this study. Patients with non-ruptured SVA, a history of previous aortic root surgery, trauma or infection were excluded. Data collection was in accordance with regulations and approved by the Institutional Review Board of our hospital. A retrospective review of inpatient charts and clinic follow-up records of patients with RSVAs who met these criteria were reviewed for details. The patients were followed up at our outpatient department. Telephone calls were made, and questionnaires were sent to the patients for data collection when necessary.

The literature review included a search in MEDLINE. We searched the PubMed and EMBASE databases for studies after 1997. Keywords were ‘sinus of Valsalva aneurysm’ and ‘surgical repair’. The search was primarily limited to English language articles. To be considered for inclusion, publications had to be original articles. We included all studies up to October 2011. We retrieved and assessed potentially relevant articles, and checked the reference lists of all papers of interest to identify additional relevant publications. At least two of the authors selected and extracted the studies followed by double checking both literature searches and data extraction. Studies were only included if they met specified criteria (large studies with descriptors of cardiac
surgery in RSVA, with or without long-term follow-up with the exclusion of case reports and small series). Twenty reports were deemed relevant [3–22]. The review findings are listed in Table 1.

Patients

Congenital RSVA was identified in 55 patients, 47 men and 8 women, with a mean age of 30.9 ± 12.1 years (range 10–65 years). The clinical symptoms ranged from asymptomatic to frank heart failure. Thirteen patients presented with acute onset of symptoms and five were asymptomatic. At the time of admission, 30 of the 55 patients were in New York Heart Association (NYHA) function class III or IV (Table 2). All patients were operated on an elective basis at an interval of 1–6 months (mean 2.3 ± 1.3 months). Echocardiography was performed on all patients; in addition, six (all aged >40 years) underwent cardiac catheterization and angiography before surgery to evaluate associated coronary artery disease. The origin of RSVA was the right coronary sinus in 43 patients, and SVA ruptured into the right ventricle in 38 (Table 3). Single or multiple holes, measuring 0.75 ± 0.22 cm (range 0.2–2.5 cm) in diameter, were found in the ruptured sacs. Associated findings included a ventricular septal defect (VSD; 20 cases), moderate to severe aortic insufficiency (11 cases), atrial septal defect (five cases), right ventricle outflow tract obstruction (RVOTO; six cases) and tricuspid insufficiency (three cases).

Surgical procedure

Cardiopulmonary bypass and moderate hypothermia were used in all cases. Direct coronary ostial antegrade hypothermic blood cardioplegia was used until 1993 for myocardial protection, but since then continuous retrograde isothermic blood cardioplegia has been employed. An oblique aortotomy was performed to check the pathology of the aneurysm, the aortic cusps and the associated cardiac anomaly in all cases. Only the aortotomy approach was preferred in patients who had isolated RSVA ruptured into the left ventricle (n = 2) or right ventricle without VSD (n = 16). The double-chamber approach was used in the remaining 37 patients with RSVA into the right atrium (n = 15) or the right ventricle associated with a right ventricular lesion (VSD, RVOTO; n = 22). The RSVA was repaired with a patch, primarily or with aortic valve replacement (AVR; Table 4). Direct closure of the aneurysm was done in 12 patients (21.8%). Eight of them received AVR, in which the prosthetic annulus was used as part of the reinforcing material to secure the aneurysmal repair. The ruptured side of the aortic annulus was closed using pledged sutures that were placed in the left ventricular cavity (sub-annular). In the remaining four patients, the RSVA was closed with interrupted Teflon-buttressed in three cases, and without Teflon-buttressed in one in the early stage of the series. Patch (autologous treated peri cardiac or Dacron) closure was performed in the remaining 43 patients. Eight of the 11 patients with aortic regurgitation received AVR. The aortic valve could be spared by re-suspension of the cusps in the other three patients. VSDs were always approached through a right ventriculotomy and were always closed with a patch [pericardial patch (n = 17) or Dacron (n = 3)]. The associated surgical procedures with RSVA closure are listed in Table 5.

Statistical analysis

This study was designed to investigate the long-term survival and freedom from complications after surgical repair of SVA. Analysis with regard to actuarial survival was done by the Kaplan–Meier method by using the SPSS software (release 16.0, SPSS Inc., Chicago, IL, USA). The log-rank test is used for statistical analysis and P-value <0.05 is considered significant. Data were presented as mean ± standard deviation.

RESULTS

Early mortality and postoperative complications

Early mortality was 3.6% (2 patients). One patient died because of neurological complications on the 14th postoperative day. Computed tomography showed generalized brain ischaemia and herniation. The second patient died because of acute renal failure and septic shock on the 21st postoperative day. Temporary AV block developed in 10 patients and none of them required a permanent pacemaker. No ventricular arrhythmias or sudden cardiac death developed in any patient in this series. Minor neurological complications occurred in three patients, but all recovered completely. The mean duration of the postoperative hospital stay was 10.3 ± 4.2 days (range 4–35 days). All 53 survivors were NYHA class I or II at hospital discharge (Table 2).

Postoperative follow-up

Follow-up was available in 94.3% (50 patients) of survivors, ranging from 1 month to 25 years (mean 15.3 ± 4.1 years) and three patients (5.7%) referred from other institutions were lost during follow-up. There were five late deaths (10%). Two of them died because of cerebral thromboembolism 2 and 13 years after the operation. Two non-cardiac late deaths occurred; one due to hepatic coma in an alcoholic patient 6 years after the operation and the other due to metastatic lung carcinoma 11 years after the operation. One patient with RSVA repair, AVR and VSD patch repair had peri-prosthetic valve leakage 2 years after the operation. Reoperation was advised, but the patient did not accept it, and died as a result of progressive heart failure at 4 years postoperatively. Survivals at 10 and 15 years were 93.4% ± 3.7% and 87.1% ± 5.6%, respectively (Fig. 1). Concomitant AVR showed marginal correlation with long-term survival. Long-term survival of patients with concomitant AVR was 57.1% ± 18.7% at 15 years. In contrast, in patients without concomitant AVR, the survival was 93.4% ± 4.6% at 15 years. All survivors were found to be in NYHA class I–III at last follow-up shown in Table 3. The mean class improved significantly after surgery.

A total of three patients required reoperations. Freedom from reoperation was 81.6% ± 6.1% at 15 years. Recurrence of fistula was seen in two of the four (50%) primarily repaired patients without AVR (one with and one without Teflon pledged). One of them underwent reoperation for recurrent fistula 7 years postoperatively and secondary repair was done using a patch. The other patient, in whom the RSVA had been closed with Teflon pledgeted sutures, developed a recurrence 4 months after the operation. The shunt ratio measured by echo-cardiography was 1:1 and the patient is still under follow-up. Two of the three...
Table 1: Review of previous large studies on RSVs

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of RSV/SVA</th>
<th>Most common SVA origin (%)</th>
<th>Most common SVA rupture site (%)</th>
<th>Surgical approach</th>
<th>Closure technique</th>
<th>Associated VSD repair (%)</th>
<th>Associated AVR / AV repair (%)</th>
<th>Perioperative mortality</th>
<th>Long-term survival after surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choudhary et al. [3]</td>
<td>92/104</td>
<td>RCS in 77</td>
<td>RV in 59</td>
<td>24 (23%)</td>
<td>0</td>
<td>32 (31%)</td>
<td>46 (44)</td>
<td>2 (2%)</td>
<td>97% at 20 years</td>
</tr>
<tr>
<td>Au et al. [4]</td>
<td>53/53</td>
<td>RCS in 77</td>
<td>RV in 72</td>
<td>0</td>
<td>4 (8%)</td>
<td>17 (32%)</td>
<td>26 (49)</td>
<td>0</td>
<td>84% at 15 years</td>
</tr>
<tr>
<td>Takach et al. [5]</td>
<td>64/129</td>
<td>RCS in 52</td>
<td>RV in 60</td>
<td>-</td>
<td>-</td>
<td>52 (40%)</td>
<td>15 (12)</td>
<td>-</td>
<td>77% at 15 years</td>
</tr>
<tr>
<td>Kirali et al. [6]</td>
<td>20/20</td>
<td>RCS in 90</td>
<td>RV in 70</td>
<td>0</td>
<td>0</td>
<td>18 (90%)</td>
<td>6 (30)</td>
<td>4 (20%)/</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Naka et al. [7]</td>
<td>15/27</td>
<td>RCS in 63</td>
<td>RV in 33</td>
<td>2 (7%)</td>
<td>7 (26%)</td>
<td>5 (19%)</td>
<td>21 (78)</td>
<td>-</td>
<td>3 (11%)/13 (48%)</td>
</tr>
<tr>
<td>Azakie et al. [8]</td>
<td>34/34</td>
<td>RCS in 79</td>
<td>RV in 68</td>
<td>14 (41%)</td>
<td>0</td>
<td>24 (71%)</td>
<td>18 (53)</td>
<td>5 (15%)/6 (18%)</td>
<td>0</td>
</tr>
<tr>
<td>Vural et al. [9]</td>
<td>34/53</td>
<td>RCS in 71</td>
<td>RV in 59</td>
<td>0</td>
<td>0</td>
<td>21 (40%)</td>
<td>18 (53)</td>
<td>4 (8%)/3 (6%)</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>Dong et al. [10]</td>
<td>67/67</td>
<td>RCS in 78</td>
<td>RV in 58</td>
<td>0</td>
<td>38 (57%)</td>
<td>63 (94%)</td>
<td>32 (48)</td>
<td>12 (18%)/</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>Murashita et al. [11]</td>
<td>35/35</td>
<td>RCS in 86</td>
<td>RV in 69</td>
<td>1 (3%)</td>
<td>7 (20%)</td>
<td>16 (46%)</td>
<td>19 (54)</td>
<td>-/-</td>
<td>0</td>
</tr>
<tr>
<td>Li et al. [12]</td>
<td>187/216</td>
<td>RCS in 90</td>
<td>RV in 80</td>
<td>13 (6%)</td>
<td>197 (91%)</td>
<td>151 (70%)</td>
<td>143 (66)</td>
<td>12 (6%)/6 (3%)</td>
<td>8 (4%)</td>
</tr>
<tr>
<td>Zhao et al. [13]</td>
<td>37/37</td>
<td>RCS in 70</td>
<td>RV in 51</td>
<td>-</td>
<td>-</td>
<td>30 (81%)</td>
<td>21 (57)</td>
<td>2 (5%)/6 (16%)</td>
<td>0</td>
</tr>
<tr>
<td>Lin et al. [14]</td>
<td>17/17</td>
<td>RCS in 71</td>
<td>RV in 71</td>
<td>-</td>
<td>-</td>
<td>7 (41)</td>
<td>6 (35%)/2 (12%)</td>
<td>0</td>
<td>94% at 10 years</td>
</tr>
<tr>
<td>Harkness et al. [15]</td>
<td>19/22</td>
<td>RCS in 61</td>
<td>RA in 50</td>
<td>9 (41%)</td>
<td>2 (9%)</td>
<td>21 (95%)</td>
<td>6 (27)</td>
<td>4 (18%)/</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Moustafa et al. [16]</td>
<td>29/86</td>
<td>RCS in 76</td>
<td>RV in 59</td>
<td>-</td>
<td>-</td>
<td>6 (21%)</td>
<td>27 (31)</td>
<td>18 (21%)/14 (16%)</td>
<td>6 (7%)</td>
</tr>
<tr>
<td>Wang et al. [17]</td>
<td>83/83</td>
<td>RCS in 89</td>
<td>RV in 63</td>
<td>5 (6%)</td>
<td>49 (59%)</td>
<td>37 (45%)</td>
<td>38 (46)</td>
<td>6 (7%)/4 (5%)</td>
<td>0</td>
</tr>
<tr>
<td>Jung et al. [18]</td>
<td>56/56</td>
<td>RCS in 82</td>
<td>RV in 73</td>
<td>17 (30%)</td>
<td>39 (70%)</td>
<td>49 (88%)</td>
<td>41 (73)</td>
<td>3 (5%)/5 (9%)</td>
<td>0</td>
</tr>
<tr>
<td>Yan et al. [19]</td>
<td>94/100</td>
<td>RCS in 76</td>
<td>RV in 62</td>
<td>5 (5%)</td>
<td>60 (60%)</td>
<td>57 (57%)</td>
<td>42 (42)</td>
<td>14 (14%)/8 (8%)</td>
<td>3 (3%)</td>
</tr>
<tr>
<td>Mo et al. [20]</td>
<td>31/31</td>
<td>RCS in 87</td>
<td>RV in 58</td>
<td>4 (13%)</td>
<td>24 (77%)</td>
<td>17 (55%)</td>
<td>9 (29)</td>
<td>-/-</td>
<td>0</td>
</tr>
<tr>
<td>Guo et al. [21]</td>
<td>41/45</td>
<td>NCS in 93</td>
<td>RA in 93</td>
<td>0</td>
<td>32 (71%)</td>
<td>45 (100%)</td>
<td>4 (9)</td>
<td>3 (7%)/-</td>
<td>0</td>
</tr>
<tr>
<td>Liu et al. [22]</td>
<td>210/210</td>
<td>RCS in 81</td>
<td>RV in 62</td>
<td>12 (6%)</td>
<td>136 (65%)</td>
<td>149 (71%)</td>
<td>108 (51)</td>
<td>43 (20%)/9 (4%)</td>
<td>1 (0.5%)</td>
</tr>
</tbody>
</table>

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DISCUSSION

VSD is a rare cardiac anomaly with an incidence of 0.09% on post-mortem examination and 0.38–1.5% among cardiac operations. The occurrence of these aneurysms can be secondary to events and conditions that weaken the juncture between the media and the annulus fibrosus of the aorta by trauma, bacterial endocarditis, syphilis, cystic medial necrosis and atherosclerosis. Most frequently, it is congenital in origin due to either a congenital absence of continuity between the aortic media and the annulus fibrosus, or a developmental structural defect in the aortic annulus itself, which can gradually give way under aortic pressure to form an aneurysm. The aneurysm can rupture into a low-pressure cardiac chamber [23]. An analysis of a published case series by Chu et al. [24] found that the incidence is approximately five times higher in far eastern patients than in westerners. Most studies, including ours, found that right coronary sinus is most frequently affected, followed by the non-coronary sinus. Rupture of the aneurysm most often occurs into the right ventricle, followed by the right atrium and rarely into the left ventricle, pulmonary artery or interventricular septum. The left coronary cusp does not usually arise from the bulbar septum, as do the right and non-coronary cusps, thus explaining the rarity of ruptured left SVA. Fifty-one percent to 88% of patients with SVA are male. Diagnosis can occur at any age, explaining the rarity of ruptured left SVA. Fifty-one percent to 88% of patients with SVA are male. Diagnosis can occur at any age, ranging from 2 to 80 years (mean age 31.89 years) [3–22]. In the present study, the mean age was 30.9 years and 85% were male.

The natural history of either ruptured or non-ruptured SVAs is difficult to determine due to the rarity of these lesions. Sawyers et al. [25] documented a mean survival of 3.9 years in patients with untreated ruptured SVA. Therefore, early surgical intervention is needed in these patients. Surgery is also recommended in symptomatic, non-ruptured aneurysms, but optimal management of an asymptomatic, non-ruptured SVA is less clear. In the report of Takach et al. [5], a patient who refused to have surgery with an asymptomatic non-coronary SVA and trace aortic regurgitation; had severe AR, dilation of the aortic annulus and extension of the aneurysm to the right and left aortic sinuses 4 years later. A condition that might originally have been treated with patch closure finally required aortic root replacement and re-implantation of coronary ostiums. On the other hand, Martin et al. followed up on a non-ruptured, asymptomatic SVA for >19 years. The patient’s lesion neither expanded nor caused clinical symptoms [23].

VSD is the most common coexisting cardiac anomaly with RSVA and occurs in 9%–78% of reported patients [3–22]. The incidence may be slightly higher in patients treated surgically as the sinus aneurysm frequently obscures the VSD in preoperative studies. A meticulous search is recommended during operations for VSD even if none is reported [3]. In our series, the prevalence
of patients with VSD was 36% (20 of 55), and all were closed with a patch. No recurrent VSD was subsequently identified. Aortic valve abnormalities and incompetence are common in patients with RSA. AVR may be required at the time of RSA closure if the cusps are highly deformed and not suitable for repair. The incidences of AVR and repair were 5–35 and 3–48%, respectively. In our series, the incidence of moderate to severe aortic insufficiency was 20%. Aortic valve was replaced in eight patients (15%) and repaired in three (5%). On rare occasions, almost any congenital cardiac defect may coexist with SVA. RSA fistulas and, when present, associated aortic insufficiency may not permit effective myocardial protection through the standard aortic root administration of cardioplegia; thus, we have been using retrograde coronary sinus perfusion to protect the myocardium since 1993.

The goals of RSA repair procedures are to close the RSA securely, remove the aneurysmal sac and repair any associated defects without causing heart block or aortic valve dysfunction. Different surgical strategies have been evolved for this purpose; because of the rarity of RSAs, there have been no clinical trials to show the one surgical repair technique is superior to another. Intervventional closure in the catheterization laboratory is another option. The optimal surgical approach, however, still remains to be defined. Controversies among surgical centres about RSA are closure techniques (primary closure vs patch closure) and surgical approach (dual, trans-aortic, chamber involved). Primary closure of SVA can be sufficient and routinely used (38.9% ± 25.9% of cases in reviewed reports) for the repair of small, ruptured and un-ruptured cases. It has potential disadvantages like (i) deforming the aortic sinus and interrupting aortic competence; (ii) suture line stress, may eventually cause recurrent rupture. A few reports have correlated primary closure with recurrent rupture and worsening aortic regurgitation [4, 6, 8, 15, 22]. On the other hand, Au et al. [4] note that using Teflon buttress at both ends of the RSV A is easier and more suitable than patching the aortic sinus for small RSVs; however, Azakie et al. [8] used selective, buttressed closure in 10 patients with four recurrences of the fistula. Several authors recommended using patch to close SVA (60.3% ± 26.4% of cases in reviewed reports) in all cases because it avoids deforming the aortic valve and reduces stress on the suture line [6, 8–12, 15, 22]. In our study, recurrent fistula developed in two patients, and both received primary closure (one with Teflon buttered, one without). We believe that primary closure would be predisposed to recurrent fistula formation as two of four (50%) patients treated primarily had recurrent fistula formation.

The aortic root, competence and the severity of pathological changes of the aortic valve, proper position of RSA and coronary ostia can easily be exposed by the trans-aortic surgical approach. It allows the accurate placement of the suture without fear of injury to the coronaries or the aortic cusps. This method was used in 11.3% ± 14.4% of cases in reviewed reports and has some potential disadvantages like, VSDs that generally appear right below the aneurysm and are not easy to notice through this approach. Additionally, Jung et al. [18] note that the trans-aortic repair may cause postoperative aortic regurgitation by progressive distortion of the sinus geometry; however, no association was found between the surgical approach and aortic regurgitation by Liu et al. [22]. Chamber involved (only) technique was used in 38.3% ± 33.1% of cases in reviewed reports and should be reserved only for those patients without significant aortic regurgitation. By not closing the origin of RSA, (i) no foreign material is left in the aortic sinus; (ii) the risk of distortion of the aortic sinus is minimized. But leaving a communication between the aorta and aneurysm sac has same theoretical disadvantages: (i) bacterial colonization or thrombus formation inside the aneurysm, (ii) recurrent fistula formation or rupture of aneurysmal sac left [18]. In the dual approach surgical strategy, both the aorta and the chamber involved are used. It is more time consuming but has all theoretical advantages that each one has. The aneurysm sacs are closed from both ends, without leaving any communication between the blood and sac [3, 6, 9, 11, 14, 17]. This approach was used in 49.7% ± 32.7% of cases in reviewed reports. Our surgical strategy is to perform an obliterate aortotomy to check the pathology of the aneurysm, the aortic cusps and the associated cardiac anomaly. If an SVA ruptures into the left ventricle or right ventricle without associated cardiac lesions, it is repaired through aortotomy by using a patch. If an SVA ruptures into the right atrium or right ventricle with associated cardiac lesions, dual-chamber exposure (the involved chamber and aorta) is used and the defect repaired from both sides.

In our study, we used a dual-chamber exposure in 37 patients (67.3%) and a trans-aortic approach in the remaining 18 (32.7%). In this study, we reviewed 20 large studies that were reported during the last 15 years. There is an increasing tendency to use patch repair in recent years. Among 1351 patients treated surgically, 810 (60%) had patch repair, 524 (39%) had direct repair and 17 (1%) are not known. Most of the studies [3, 6, 9, 11, 14, 17] recommended the use of the dual approach, but only 452 (39%) of 1153 patients were treated with this method. The trans-aortic (only) approach was used in 106 (9%) and chamber involved (only) was used in 595 (52%). In 198 patients, the surgical approach was not mentioned in the reports. We use the case-specific surgical approach and patch repair form the aortic end has been routine since 2001.

The operative mortality is generally low (0.5–11%) and the prognosis after the surgical repair of sinus Valsalva aneurysms is satisfactory [3–19, 22]. In the present report, operative mortality was 3.6% and the actual survival rate was 93.4 and 87.1% at 10 and 15 years, which was similar to earlier reports (Table 1).
Our report has similar limitations as the others, being retrospective in design, and not using randomization as the condition is uncommon.

**CONCLUSIONS AND RECOMMENDATIONS**

Surgical repair of an RSV A is associated with an acceptably low operative risk and long-term freedom from death and reoperation. When RSV A is diagnosed, the treatment of choice should be surgical repair and the patient operated on as soon as possible. We recommend a case-specific surgical technique starting with aortotomy. A patch, preferentially pericardial, should be used at the aortic end, which minimizes aortic leaflet distortion and the resultant defect if opened, be repaired either by direct suturing or patch closure, according to the size and location.

**Conflict of interest:** none declared.

**REFERENCES**


