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Original Article

Partial aortic root remodeling for root reconstruction in patients with acute type A dissection

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Abstract

In the present study, we reported our experience with partial aortic root remodeling for root reconstruction in patients with acute type A dissection, which involves in non-coronary sinus and/or the right coronary sinus with just one trimmed Dacron graft. Between February 2001 and May 2010, we performed partial aortic root remodeling in 40 patients, who underwent emergency surgical intervention. The dissected sinuses were excised leaving a 3-5 mm rim of the aortic wall from the attached aortic valve cusps. A short piece (4-5 cm) of collagen coated woven polyester vascular prosthesis was trimmed with one or two "tongues" to reconstruct the non-coronary sinus and/or the right coronary sinus, but without using separated patches. Additional procedures were including hemi-arch replacement in 11 patients, and total arch replacement plus stent-elephant trunk in 20 patients. The mean follow-up time was 36.4±3.6 months. In-hospital mortality was only 5.0% (2/40); furthermore, 3 (8.6%) patients underwent re-operation of the aortic valve and 2 (5.7%) patients died during follow-up. At the end of follow-up, trivial or no aortic regurgitation was found in 33 patients, but mild aortic regurgitation was found in 2 patients. Our data suggest that the early and mid-term results of partial aortic root remodeling were favorable, and it restored valve durability and function. Thus, the use of technique for root reconstruction in patients with acute type A dissection should be vigorously encouraged.

Keywords: aortic dissection, aortic root remodeling, valve function

Introduction

Aortic root reconstruction is still challenging in patients with acute dissection in which part of the aortic wall in the coronary sinus is involved[1]. Importantly, it is quite common that the non-coronary sinus and the right coronary sinus are involved in the aortic dissection. Traditionally, transection of the aorta just above the sinotubular junction and super coronary anastomosis is a choice for root reconstruction. However, stitches in the dissected aortic wall may lead to bleeding, and may result in an even worse disaster[2-3]. Root replacement with valve conduit is not recommended for this procedure as it takes longer and sacrifices the normal aortic valve and influences the long term prognosis and quality of life[4-5]. Therefore, it is of critical importance to explore the novel technique

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for aortic root reconstruction in patients of acute type A dissection.

Abundant studies suggested that compared with standard composite conduits with either a mechanical or a biological valve, aortic valve-sparing procedures in patients with acute type A dissection are supposed to be a superior therapeutic option[6-9]. Valve-sparing root remodeling and coronary re-implantation is technically more demanding in patients with normal aortic annular and no displacement of the coronary ostia. In this study, we describe a critical technique for selective replacement of one or two of the native aortic sinuses (33 and 7 patients, respectively), and then assess the long-term outcomes after this partial remodeling technique at a single center.

Patients and methods

Patients

Between February 2001 and May 2010, a total of 40 patients with acute type A dissection underwent partial aortic root remodeling procedure at the authors' affiliated hospital. Their mean age was 50.7±9.0 years (range from 29 to 70 years), including 36 males and 4 females. The mean size of preoperative aortic anulus, aortic sinus and left ventricular end diastolic diameters (LVEDD) was 23.5±2.8 mm (range from 21 to 28 mm), 34.3±2.5 mm (range from 30 to 49 mm), and 48±7 mm (range from 45 to 60 mm), respectively. The clinical characteristics of patients are shown in ***Table 1***. The Ethic Committee of the authors' affiliated institution approved this study and waived individual consent for this retrospective analysis.

Preoperatively, transthoracic echocardiographic and computed tomography (CT) scans were routinely performed in all patients. Aortic regurgitation was assessed semiquantitatively as follows: 0, none; 1, minimal; 2, mild; 3, moderate; 4, severe. The decision to undertake valve-sparing techniques was independent of the presence of aortic insufficiency. Moreover, intraoperative transesophageal echocardiography (TEE) was performed in all patients. In all cases, the final decision to preserve the aortic valve was performed intraoperatively by the surgeon after inspection of the aortic cusps and the root geometry.

Table 1 **Pre-operative data of patients.**

Variable	Data
Age in years (range)	50.7±9.0 (29-70)
Male/female	36/4
Previous cardiac surgery	1
Functional class	
NYHA Ⅰ	31
NYHA Ⅱ	8
NYHA Ⅲ	1
Associated diseases (No.)	
Marfan syndrom	5
Hypertension	40
Cardiogenic shock	3
Oliguria	2
Acute renal dysfunction	1
Paralysis	1
Cornornary disease	2
Ejection fraction (%)	53.0±6.4
LVEDD (mm)	49.3±4.5
Aortic valve	
Aortic root diameters (mm)	
Anulus	23.5±2.8
Sinus	34.3±2.5
Sinotubular junction	27.4±2.7
Ascending aorta	27.8±1.7
Aortic regurgitation	
None	12
Minimal insufficiency	19
Mild insufficiency	5
Moderate insufficiency	4
Mean grade	1.0±0.9

Surgical techniques

For those acute type A dissection patients receiving hemiarch replacement or total arch replacement with stented elephant trunk implantation, all procedures were carried out by a median sternotomy and total cardiopulmonary bypass (CPB) with selective cerebral perfusion (SCP). Cannulation of the right axillary artery was used for CPB and SCP. The arterial line was bifurcated for the right axillary artery and for antegrade perfusion through 1 limb of a 4-branch prosthetic graft. Circulatory arrest was instituted if the nasopharyngeal temperature reached 18°C to 22°C. Unilateral SCP was started through the right axillary artery after the brachiocephalic arteries were cross-clamped and the brain was perfused. Partial aortic root remodeling for root reconstruction was performed during cooling. The aortic root and valve were inspected via a transverse aortic incision. Most of these patients have the non-coronary sinus and the right coronary sinus involved by the aortic dissection. The remodeling technique consisted of excision of the intima of dissected aortic sinuses, leaving 3-5 mm of aortic wall attached to the annulus (the adventitia was preserved for subsequent Cabrol procedure). A Dacron tube with 1 or 2 tongue-shaped processes was then used to resuspend the aortic valve and reconstitute the sinuses (***Fig. 1***). The diameter of the prosthesis was based on direct measurement of the sinotubular junction

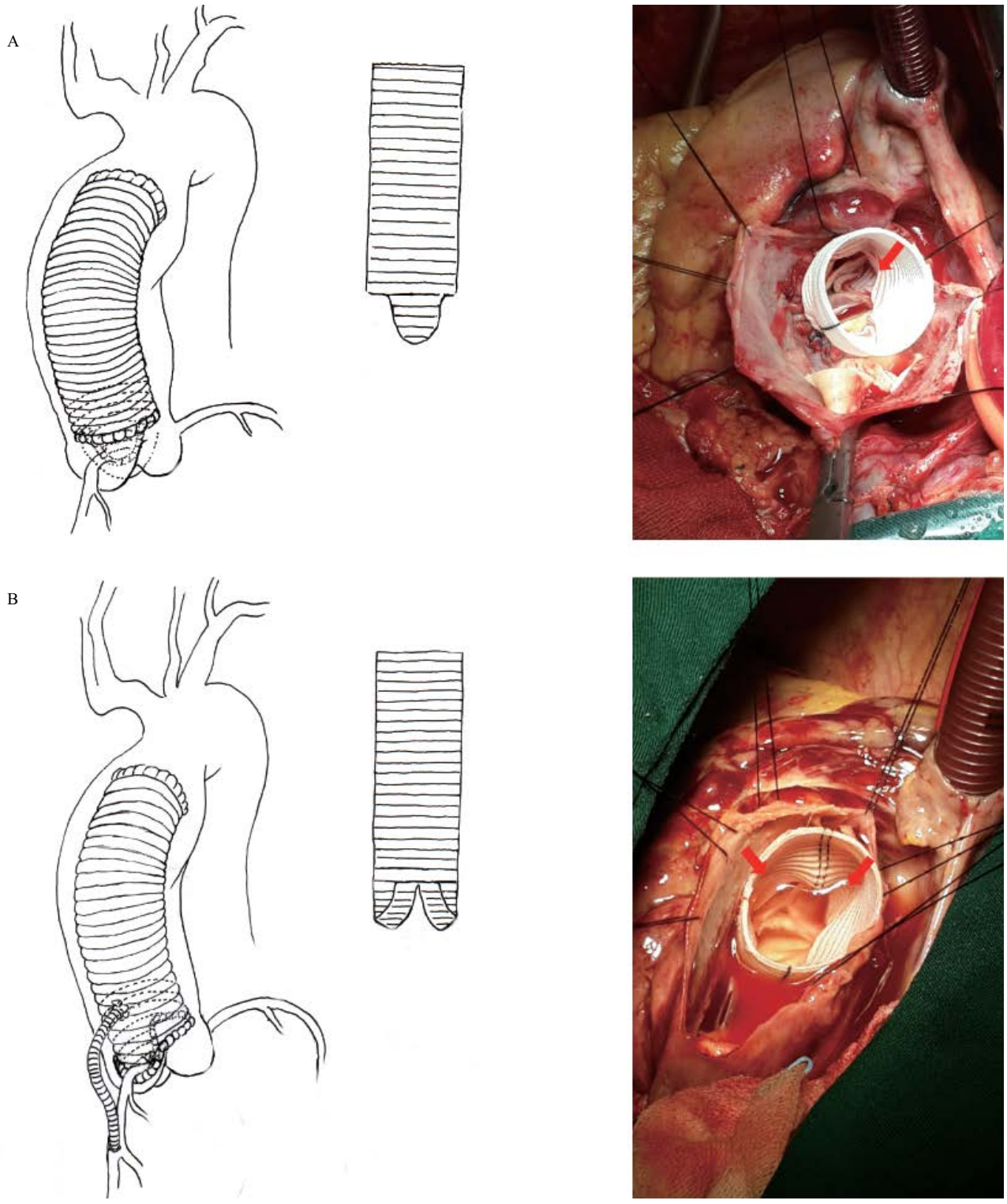

Fig. 1 **Partial aortic root remodeling for root reconstruction in patients with acute type A dissection.** A Dacron tube is performed to resuspend the aortic valve and reconstitute the sinuses. A: A Dacron tube with 1 tongue-shaped process was then performed to resuspend the aortic valve and reconstitute the sinuses. B: A Dacron tube with 2 tongue-shaped processes was then performed to resuspend the aortic valve and reconstitute the sinuses.

when the 3 commissures were pulled upward and approximated until the cusps touch each other centrally by insertion of a mechanical valve sizer. Acutely, the height of the sinuses should be approximately equal to the diameter of the graft. By using a 5/0 prolene suture, the patches were sewn to the 2-3 mm rim of the aortic wall, starting from the nadir of the sinuses towards the commissures in a continuous fashion. The suture line was placed in the firm aortic anulus along the line of attachment of the cusps as Yacoub[18] recommended

previously. The coronary arteries were reimplanted in a standard button fashion using a 5/0 prolene suture if necessary. Further procedures depending on the accompanying pathology in patients with pathological replacement of the arch were performed under hypothermic circulatory arrest (HCA). Until 2008, deep HCA was under 22°C, and later on moderate HCA (25°C-27°C). Selective antegrade cerebral perfusion (SACP) was performed. The surgical results were assessed by intra-operative trans-oesophageal echocardiography. We preferred to preserve the native aortic adventitia and in cases of excessive bleeding, wrapped this around the composite graft (inclusion method). After aortic valve reconstruction, the patients were anticoagulated with coumadin or aspirin (at the discretion of individual surgeons) to prevent thromboembolic complications only for 3 months. Thereafter, the anticoagulation therapy was discontinued unless otherwise indicated.

Follow-up

The patients were followed up by direct outpatient clinic visits or by telephone interview with the patients and the referring physicians. Patients were assessed according to the New York Heart Association (NYHA) functional class. Valve performance, complications, and outcome analysis were reported according to the guidelines of the American Association for Thoracic Surgery and the Society of Thoracic Surgeons. Aortic valve function in all survivors was assessed by transthoracic echocardiography before discharge from the hospital and every 12 months thereafter. All patients received oral aspirin for the first 3 months following surgery. A questionnaire about infectious, thromboembolic and bleeding complications was also recorded.

Statistical analysis

All values were expressed as mean±standard deviation (SD). Risk factors were evaluated for association with aortic valve re-operation using univariate analyses; Fisher's exact test was used for evaluation of survival and the risk for reoperation. A value of $P<0.05$ was statistically significant. Statistical analysis was performed using the SPSS for windows software package (SPSS 17.0).

Results

Perioperative results

In the present study, we reported on a low failure rate of aortic root remodeling in patients with acute type A dissection at the early postoperative period, and there were 2 early death in patients with acute type A dissection, and the overall early (30-day) mortality was only 5.0%. Of those, one patient died from acute inferior myocardial infarction and severe right heart failure 5 days after operation, and the other one was not awake after operation and died owing to severe pulmonary infection and multi-organ failure in the early phase. Notably, 3 patients received re-thoracotomy with bleeding. In addition, delayed awareness occurred in 3 cases (2 recovered completely), cerebral infarction was observed in 1 patient and died of multi-organ failure as mentioned above. Two patients had renal failure after operation and recovered completely after 2 months. Reasons for early mortality were myocardial failure, cerebral ischemia, multiorgan failure, sepsis, and abdominal ischemia due to malperfusion.

During operation, the mean CPB time was 190.8±37.3 minutes (range from 110 to 260 minutes), and the mean aortic cross-clamp time was 136.6±24.5 minutes (range from 89 to 187 minutes). Nasopharyngeal temperature was decreased to approximately 22°C to 25°C during lower body arrest and SCP. We performed

Table 2 **Operative data.**

Variable	Value
Aortic valve morphology	
Tricuspid	40
Bicuspid	0
Sinus replaced	
Non coronary	33
Non coronary and right	7
Prosthesis diameter (mm)	
26	33
28	5
30	2
Concomitant procedures	
Hemi-arch replacement	11
Total arch replacement with stented elephant trunk	20
Coronary bypass surgery	7
Clossclamp time (minute)	136.6 ± 24.5
Cardiopulmonary bypass time (minute)	190.8 ± 37.3
Selective cerebral perfusion time (minute)	16.5 ± 5.0
ICU stay (day)	2.9 ± 6.1
Drain of thoracic cavity (mL)	758 ± 365
Packed red blood cells (unit)	8.5 ± 2.8
Fresh frozen plasma (liter)	0.8 ± 0.3
Platelets (unit)	1.4 ± 0.6
Echocardiographic results of aortic Regurgitation	
None	23
Minimal insufficiency	12
Mild insufficiency	5
Mean grade	0.6 ± 0.7

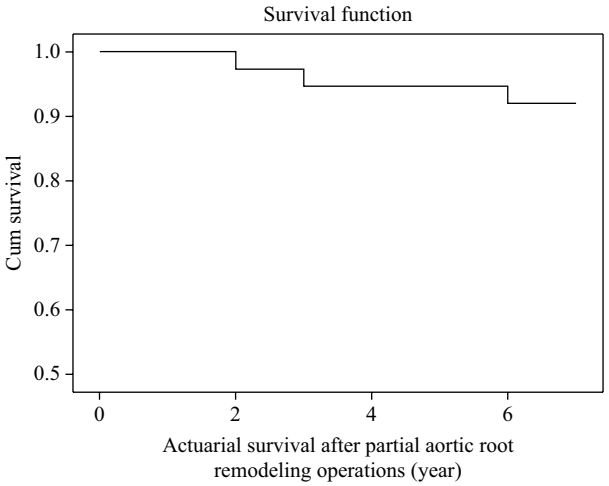

***Fig. 2* Actuarial survival after partial root remodeling operations.** The average survival rate at 1, 5, and 10 years after partial root remodeling operations.

hemi-replacement in 11 patients, total arch replacement with stented elephant trunk implantation in 3 patients, and coronary artery bypass grafting in 7 patients. The aortic valve function and anatomy of the aortic root were assessed by intraoperative TEE, and we detected moderate aortic regurgitation in 1 patient, mild aortic regurgitation in 4 patients, minimal aortic regurgitation in 12 patients and no aortic regurgitation in 23 patients, and the operative data are shown in ***Table 2***.

Follow-up

Thirty-eight patients were discharged from the hospital and were followed up in our outpatient clinic or with telephone interviews. The mean follow-up time was 36.4±31.6 months (range from 5 to 116 months). Three patients were lost to follow-up, and the mean follow-up time was 36.3±32.1 months (range from 5 to 116 months). In the follow-up phase, 2 (5.7%) patients died in the late: one died from cancer 7 years after surgery and the other died from renal failure 4 years after surgery. Moreover, upon the postoperative echocardiogram, 3 (8.6%) patients owing to severe valve regurgitation had to undergo re-operation of the aortic valve (2 patients underwent replacement with composite graft, and 1 patient with mechanic valve). The time from the initial operation to re-operation was 18, 23, and 62 months, respectively. One patient died from renal failure 2 years after re-operation and the other 2 patients were still alive. In total, 3 patients died in the follow-up phase.

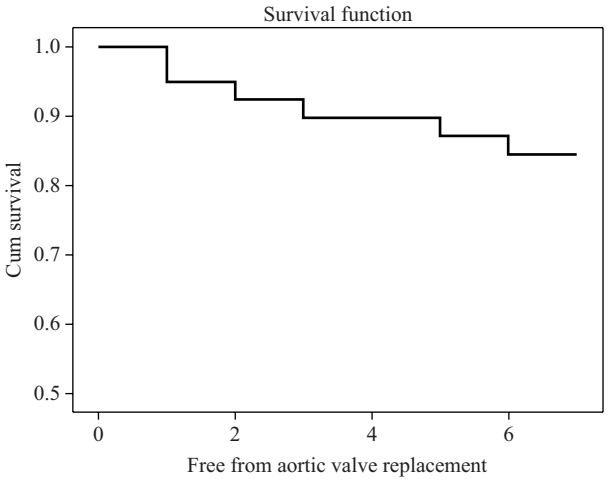

***Fig. 3* Freedom from aortic valve replacement.** Freedom from valve replacement at 1, 5, and 10 years after partial root remodeling operations.

Collectively, we detected that the average survival rate at 1, 5, and 10 years was 97%, 86%, and 75%, respectively (***Fig. 2***). Freedom from valve replacement at 1, 5, and 10 years was 97%, 91% and 89%, respectively (***Fig. 3***). More importantly, base on univariate analysis, aortic anulus diameters >27 mm and diagnosis with Marfan syndrome were the risk factors associated with aortic valve re-operation (P<0.05, ***Table 3***). There were no significant differences in patient age, sex, sinus diameters, sinus replaced numbers, and preoperative aortic regurgitation level between the two groups

***Table 3* Univariate analysis of the association between perioperative factors and aortic valve reoperation.**

Variable	Patients (n)	Aortic valve reoperation (No.)	%	P value
Age (year)				
29-64	36	2	5.6	
65-70	4	1	25.0	0.277
Sex				
Female	4	1	25.0	
Male	36	2	5.6	0.277
Marfan syndrome				
Yes	5	2	40.0	
No	35	1	2.86	0.036
Anulus diameters				
<27mm	33	1	3.0	
≥27mm	7	2	28.6	0.044
Sinus Diameters				
<45mm	34	1	2.9	
≥45mm	6	2	33.3	0.054
Sinus replaced (N.)				
One	32	2	6.3	
Two	8	1	12.5	0.498
Aortic regurgitation				
≤Minimal insufficiency	35	2	5.7	
≥Mild insufficiency	5	1	20.0	0.338

(P>0.05). At the end of follow-up, trivial, minimal or no aortic regurgitation was demonstrated in 29 patients and mild in 2 patients.

Discussion

Acute aortic dissection type A is the most lethal disease of the aorta and has a high morbidity and mortality[10]. Management of the aortic root during type A aortic dissection also involves many techniques and many choices[8]. Type A dissection must be considered as an emergency; immediate operation is mandatory to increase survival. Importantly, the aim of surgical treatment of type A dissection is to save the life of patient, and ascending supra-coronary aortic replacement by a tube graft with aortic valve resuspension is the simplest, shortest, and safest method, whereas the incidence of re-operation of the aortic root following this technique ranges between 3.3% and 16% after 5 years and up to 20% after 10 years[11]. Most of these patients develop aneurysms, re-dissection, or a combined lesion of the aortic root, and present with clinical symptoms that ultimately require re-operation. However, the total number of symptomatic and nonsymptomatic aortic root aneurysms may reach as high as 33%[12-13]. Furthermore, significant aortic valve regurgitation in patients after supracommissural tube graft replacement has been reported to attain 20% to 45%[14].

Notably, a more aggressive surgical resection down to the diseased aortic root may help to reduce the number of late reinterventions after surgery for acute type A dissection. Nevertheless, composite graft replacement is associated with an increased risk of thromboembolic events, hemorrhage due to anticoagulation, and reoperation for replacement of degenerated biological valve substitutes[15]. Taking the evidence from the literature into account and considering the reported hospital mortality of 13% to 33% after reoperation of the aortic root following previous surgery for acute type A dissection[16-17], valve-sparing aortic root replacement may be an appealing approach to reduce the need for reoperation and long-term anticoagulation.

Valve-sparing aortic root reconstruction, first described by Yacoub *et al.* (remodelling) and David (reimplantation) in the early 1990s has been gaining acceptance over time[18-19]. Indication for this technique has been aneurysm of the aortic root or ascending aorta causing aortic insufficiency by outward displacement of the commissures, a tricuspid aortic valve without gross structural defects, and absence of severe cusp prolapse or asymmetry[20]. Moreover, avoidance of lifelong anticoagulation and excellent hemodynamics are major advantages of this technique, which stimulates expansion of its indications away from the original concept of morphological intact cusps, particularly for patients with Marfan syndrome and type A aortic dissection[21].

Abundant studies have demonstrated that acute type A aortic dissection in the current patient with intimal tear extending into the noncoronary sinus of Valsalva that did not affect the aortic valve annulus or the valve leaflets[3,21]. The noncoronary sinus is most commonly affected in the standard type of dissection, followed by the right and left in that order. Thus, the partial aortic root remodeling would be sufficient for most of patients, according to our operation experience[22]. We were able to perform the aortic valve commissural resuspension and the partial aortic root remodeling, therefore, a composite graft was unnecessary. Encouraged by those results, we began to adopt this technique in February 2001, and 40 acute type A dissection patients were treated by this technique until May 2010. In our present study, the mean follow-up time was 36.3±32.1 months (range, 5-116 months), 38 patients were free of aortic regurgitation greater than grade minimal. Three patients required aortic valve replacement with mechanical prosthesis or composite graft for aortic regurgitation and the other aortic sinuses enlarged at postoperative 18, 23 and 62 months. More importantly, freedom from reoperation was 91.4%.

The advantage of remodeling technique, in contrast with the original reimplantation technique, is the creation of the sinuses of Valsalva and thereby anatomic reconstruction of the aortic root and normal leaflet motion and stresses. In our series of aortic valve-sparing operations to treat aortic regurgitation with aortic dissection, these operations provided excellent long-term survival. Aortic valve function remained stable during the first 10 years of follow-up in most cases. These results are similar to those reported by other surgeons. Only 5 patients left the operating room with mild aortic valve insufficiency. The remaining patients had no more than mild aortic valve regurgitation at the end of the procedure or at the time of hospital discharge. Importantly, this consequence might be attributed to 5 reasons. First, we have replacement 1 or 2 sinus of the aortic valve. The intima involved by the dissection was removed thoroughly, which is prone to further dilation. Furthermore, dilatation of the lesion sinus intima could be a potential cause of recurrent aortic insufficiency. Second, this procedure simplified aortic valve repair. Third, the normal anatomy and function of the aortic root is better preserved after aortic root remodeling compared with aortic root reimplantation. It was discussed that this could impact on the longevity of the repair due to the normal anatomy of the aortic root promotes normal valvular function, and reduces leaflet stress and strain. Fourth, the need for proximal reoperation is likely related to both patient factors as

well as operative technique. We believe that some of the operative factors include incomplete excision of the tear, failure to obliterate the false lumen, and proximal redissection. Proximal re-dissection may increase the risk of late dilatation of the sinuses of Valsalva and late aortic insufficiency. Thus, our technique consisted of excision of the intima of dissected aortic sinuses thoroughly and only leaving 3-5mm of aortic wall attached to the annulus. Finally, we paid particular attention to the morphology of the cusps during reconstruction of the root, making sure that they coapted for several millimeters and well above the level of the aortic annulus, just as Yacoub *et al.* suggested[18].

However, still 3 patients developed either moderate or severe aortic insufficiency (AI) during follow-up and needed reoperation. Review of the intraoperative postrepair echocardiograms in those 3 cases revealed that the annulus ≥27 mm, with Marfan sydrome, and preoperative regurgitation are the clues why the valve became incompetent (***Table 3***). The principal superiority of the reimplantation technique to the remodeling technique is stabilization of the annulus. This is particularly important for patients with connective tissue disorders such as Marfan syndrome, in which the annulus may dilate over time. David *et al.* reported that reimplantation of the aortic valve is more appropriate to treat patients with Marfan syndrome than remodeling of the aortic valve[5,23]. Collectively, our experience also appear to support this idea.

Importantly, the decision to perform valve-sparing surgery is usually based upon the diameter of the aortic sinus (<35 mm), and 1 or 2 aortic border avulsion lead to mild or moderate aortic valve insufficiency. In addition, the intimal tear extended into the non-coronary and/or the right coronary sinus of Valsalva that did not affect the aortic valve annulus or the valve leaflets. Exclusion criteria includes that the diameter of the aortic sinus ≥50 mm. Moreover, the diameter ranges 35 mm from 50 mm but intimal tear progress to sinus-tube joint with severe aortic insufficiency. Therefore, complete removal of diseased tissue, excellent hemostasis, and avoidance of lifelong anticoagulation are clear advantages for treatment of the aortic root pathology in selected patients with morphologically unimpaired valve cusps. Importantly, if the patients with acute aortic dissection cannot meet the requirements for use of the reimplantation technique in emergency, we also adopt Bentall type operation.

In conclusion, the early and mid-term results of valve-sparing operations were favorable, and durability of the preserved valve should encourage use of this technique in patients with acute type A dissection involving repair of the aortic root. A low prevalence of morbidity and mortality was obtained in our study population. This is a retrospective study with a small sample size and early to mid-term results. Larger series and longer follow-up are warranted to determine the late results with the valve-sparing technique in the future. If the aortic valve leaflets are normal by echocardiography and an aortic valve-sparing operation can be performed, a more aggressive approach may be justifiable, particularly in patients with Marfan's syndrome, preoperative regurgitation or the annuls ≥27 mm to prevent the reoperation for aortic valve replacement.

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