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
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\cite{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.

**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. The remodeling technique consisted of excision of the intima of dissected aortic sinuses, leaving 3-5 mm of aortic wall attached to the anulus (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.

**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 syndrome                 | 5             |
| Hypertension                     | 40            |
| Cardiogenic shock                | 3             |
| Oliguria                         | 2             |
| Acute renal dysfunction          | 1             |
| Paralysis                        | 1             |
| Coronary disease                 | 2             |
| Ejection fraction (%)            | 53.0±6.4      |
| LVEDD (mm)                       | 49.3±4.5      |
| Aortic valve                     |               |
| 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       |
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\textsuperscript{[18]} recommended.

\textbf{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.
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 |
| Crossclamp 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 |
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 36.3±31.6 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.

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.

![Survival function](image1)

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

![Survival function](image2)

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

| 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     |

**Table 3 Univariate analysis of the association between perioperative factors and aortic valve reoperation.**
increase survival. Importantly, the aim of surgical treat-
as an emergency; immediate operation is mandatory to
and up to 20% after 10 years [11]. Most of these patients
technique ranges between 3.3% and 16% after 5 years
plesst, shortest, and safest method, whereas the inci-
a tube graft with aortic valve resuspension is the sim-
distance of type A dissection is to save the life of patient,
ascending supra-coronary aortic replacement by
aortic root aneurysms may reach as high as 33% [12-13].
patients after supracommissural tube graft replacement
Furthermore, significant aortic valve regurgitation in
patients following 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
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 following 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 num-
ber of late reinterventions after surgery for acute type A
dissection. Nevertheless, composite graft replacement
is associated with an increased risk of thromboemb-
olic events, hemorrhage due to anticoagulation, and
reoperation for replacement of degenerated biological
valve substitutes [15]. Taking the evidence from the lit-
erature into account and considering the reported hos-
pital 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 pro-
lapse or asymmetry [20]. Moreover, avoidance of lifelong
anticoagulation and excellent hemodynamics are major
advantages of this technique, which stimulates expan-
sion 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 resus-
pension and the partial aortic root remodeling, there-
fore, 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 cre-
ation 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 dis-
section, 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 aor-
tic 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 dissec-
tion was removed thoroughly, which is prone to fur-
ther 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

(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 dis-
ease of the aorta and has a high morbidity and mor-
tality [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 treat-
ment of type A dissection is to save the life of patient,
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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 syndrome, 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 unpaired 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 annulus ≥27 mm to prevent the reoperation for aortic valve replacement.

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