A New Aortic Root Reinforcement Technique for Acute Type A Aortic Dissection Surgery

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Summary
Reinforcing the dissected and fragile aortic root is critical in acute type A aortic dissection (ATAAD) surgery. This study introduces our new aortic root reinforcement technique and reports our early operative results and midterm follow-up results.

A retrospective analysis study was performed on 235 patients (aged 53.2 ±15.5 years) who were admitted to our hospital for ATAAD surgery and underwent the procedure with our new technique between October 2011 and June 2016. Two vascular graft rings were placed inside and outside aortic root, followed by a running horizontal mattress suture, placed just above the coronary artery ostiums and aortic valve commissures, with another horizontal suture at distal end of the aortic root stump, to reinforce the inner vascular graft, aortic wall, and outside vascular graft. Then additional 3-5 vertical mattress sutures were placed for further reinforcement within the reconstructed aortic root. Computed tomography angiography was performed at discharge and annually during follow-up.

The patients' 30-day mortality was 5.1% (12/235). There was no uncontrollable intraoperative bleeding from the aortic root, and re-exploration for bleeding occurred in 0.79% (2/235). The survival rate was 90.2% during follow-up of 4.2 ± 2.1 years. There were no requests for aortic root reoperations during follow-up. All patients were free from aortic root disruptions, proximal anastomosis complications, and re-dissections of the reconstructed aortic root.

Our new aortic root reinforcement technique provides a safe and effective technique for aortic root in ATAAD surgery, by reinforcing friable aortic root tissues and minimizing aortic root complications.

Key words: Surgical technique, Treatment

Acute type A aortic dissection (ATAAD) is a catastrophic disease, and the risk of death without treatment increases approximately 1% per hour in the first 48 hours. Despite recent advances in surgical techniques and perioperative management, ATAAD surgical mortality remains high. However, morbidities and adverse sequelae after repair, such as postoperative bleeding, residual patent false lumen, and the risk of future proximal aortic reoperations, remain challenging among cardiac surgeons.

Proper reinforcement of the dissected and fragile aortic root is important in ATAAD surgery to minimize bleeding from anastomosis sites and to reduce long-term re-interventions. Failure to reinforce the fragile tissues of the proximal aortic root may lead to excess operative time, anastomotic dehiscences, or proximal aortic root re-operations. During the past twenty years, various strategies have been applied to reinforce fragile aortic root tissues and to assist hemostasis. Classic ascending aortic replacement techniques include reinforcement of the proximal aortic stump with Teflon felt or bovine pericardial patch. Besides, surgical glues have also been used extensively to facilitate ATAAD repair and anastomosis of aorta. They have been proven effective under proper indications; however, the current techniques still had some limitations and could not totally rule out the possibility of intraoperative bleeding and long-term aortic root related complications.

We propose a new, yet simple, approach for proximal aortic root reinforcement. The purpose of this study is to review our experience and to illustrate this technique in detail. Early operative results and midterm follow-up results are also reported.
performed, and blood clots in the false lumen were com-
dissected layers of aortic root were reinforced with our
dioplegia infusion, repeated every 30 minutes.

achieved with antegrade or retrograde cold blood car-
clamped proximal to the innominate artery and transected
right superior pulmonary vein. The ascending aorta was
and venous cannulas in the superior and inferior vena
tential tamponade. CPB was initiated through arterial can-
and the pericardium was carefully opened to relieve po-

Surgical procedure:

The latest follow-ups were conducted in June 2018.

Early mortality and morbidity: 30-day mortality was
5.1% (12 of 235): 7 patients experienced multiple organ
failure, 3 developed sepsis, 1 had acute renal failure, and
1 had circulatory failure. New onset of postoperative para-

Methods

Patients: This study was approved by the ethics board of the
Second Hospital of Jilin University, China. All patients
provided written informed consent. Between October 2011
and June 2016, 235 patients (aged 53.2 ±15.5 years) with
ATAAD underwent surgical repair in our hospital using
our new technique; 156 (66.4%) were male, and 10
(4.3%) had been diagnosed with Marfan syndrome. A history
of hypertension was present in 181 patients (77.0%) and 3
(1.3%) had previous cardiac surgery. Pericardial ef-
fusions were found in 65 patients (27.7%). All patients
had fewer than 14 days from symptom onset to surgery,
and the diagnosis for all ATAAD was based on preopera-
tive computed tomography angiography (CTA). Table I
summarized the preoperative characteristics in our study
group.

All data were collected and reviewed retrospectively
from each patient’s medical chart. Follow-up was obtained
from visit to outpatient clinic or by telephone interview.
The latest follow-ups were conducted in June 2018.

Surgical procedure: After general anesthesia, two arterial
pressure lines (one left radial artery and one pedal artery)
were placed. Transthoracic echocardiography was routi-

Table I. Preoperative Data

<table>
<thead>
<tr>
<th>Preoperative Data</th>
<th>Number of patients Total (n = 235) (%)</th>
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</thead>
<tbody>
<tr>
<td>Age</td>
<td>53.2 ± 15.5</td>
</tr>
<tr>
<td>Male/ Female</td>
<td>156/79 (66.4%/33.6%)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>181 (77.0%)</td>
</tr>
<tr>
<td>Cerebrovascular disease</td>
<td>22 (9.4%)</td>
</tr>
<tr>
<td>Chronic kidney disease</td>
<td>17 (7.2%)</td>
</tr>
<tr>
<td>Previous cardiac surgery</td>
<td>3 (1.3%)</td>
</tr>
<tr>
<td>Marfan syndrome</td>
<td>10 (4.2%)</td>
</tr>
<tr>
<td>Malperfusion syndrome</td>
<td>41 (17.4%)</td>
</tr>
<tr>
<td>Coronary</td>
<td>20 (8.5%)</td>
</tr>
<tr>
<td>Renal</td>
<td>12 (5.1%)</td>
</tr>
<tr>
<td>Leg</td>
<td>8 (3.4%)</td>
</tr>
<tr>
<td>Cerebral</td>
<td>5 (2.1%)</td>
</tr>
<tr>
<td>Visceral</td>
<td>3 (1.3%)</td>
</tr>
<tr>
<td>Multiple</td>
<td>7 (3.0%)</td>
</tr>
</tbody>
</table>

fully observed and measured, a vascular graft with appro-
priate size was chosen (Vascutek Limited, UK), from
which we cut three 1.5-2 cm wide vascular rings. One
vascular ring was placed inside the aortic root and at-
tached to the intima of the aortic wall, situated above the
aortic valve commissures. The other two vascular rings
were split longitudinally and placed on the outside surface
of the aortic root wall. Three 4-0 polypropylene mattress
sutures were placed at the aortic valve commissures for
valve resuspension. These served as the starting points for
a running horizontal mattress suture to achieve an initial
reinforcement of all three layers of the proximal ascend-
ing aorta: the inner vascular graft, the native aortic wall,
and the outer vascular graft (Figure 1A, B). This running
horizontal suture line was situated just above the level of
the three aortic valve commissures and coronary artery
orifices to close the false lumen from the beginning of the
ascending aorta. The other three layers were reinforced
with a continuous running 4-0 polypropylene suture
placed at the distal end of the aortic root (Figure 2A, B).
Then 3 to 5 additional 4-0 polypropylene vertical mattress
sutures were positioned between the proximal and distal
horizontal sutures, within the proximal reconstructed aor-
tic root, to further split the false lumen into pieces and
promote false lumen thrombosis (Figure 3A, B). Thus, the
aortic root reinforcement procedure was completed.

We routinely performed bilateral antegrade selective
cerebral perfusion through canulas in the right axillary
and left common carotid artery for brain protection during
ATAAD surgery. When the rectal temperature reached
25°C or 28°C, we replaced the ascending aorta and sim-
plified aortic arch repair with the frozen elephant trunk
procedure. Then the reconstructed aortic root was anasto-
mosed to the vascular graft of the ascending aorta replace-
ment with a running 4-0 polypropylene running suture.
The rest of the surgical procedure was performed as usual,
including hemostasis and incision closures.

Statistical analysis: Continuous data are presented as
mean ± standard deviation, and categorical data are pre-

Results

Surgical data: There was no intraoperative death; the
mean CPB time and circulatory arrest time, respectively,
of 145.6 ± 32.7 minutes and 39.3 ± 7.4 minutes. There
was no uncontrollable intraoperative bleeding from the
aortic root or proximal aortic anastomosis site, and no ex-
ternal aorta warp or right atrial shunt procedure was per-
formed. No surgical glue was used in the study. Aortic
valve replacement was performed in 12 patients (5.1%).
The surgical data and concomitant procedures were listed
shown in Table II.

Table II. Surgical Data

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Number of patients Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic root reinforcement</td>
<td>235 (100%)</td>
</tr>
<tr>
<td>Valve replacement</td>
<td>12 (5.1%)</td>
</tr>
<tr>
<td>Aortic arch repair</td>
<td>22 (9.4%)</td>
</tr>
<tr>
<td>Total</td>
<td>25 (10.6%)</td>
</tr>
</tbody>
</table>
Proximal horizontal reinforcement of the aortic root stump: after placing a vascular graft ring outside and inside aortic stump, three 4-0 polypropylene mattress sutures (red arrows in A) were placed at the aortic valve commissures for valve resuspension and served as the starting points for a running horizontal mattress suture, to achieve an initial reinforcement of all three layers of the proximal ascending aorta. A: Schematic diagram of the procedure. B: Operative photos of the procedure.

Distal horizontal reinforcement of the aortic root stump: the three aortic root layers were reinforced with a continuous 4-0 polypropylene running suture on the distal end of the aortic root. A: Schematic diagram of the distal reinforcement suture. The arrow points to the continuous running suture; B: Operative pictures of the distal aortic root stump reinforcement.

Plegia occurred in 2 patients (0.79%), in which 1 patient died from the above-mentioned circulatory failure and 1 patient was discharged from hospital with lower extremity plegia. New onset stroke occurred in 9 patients (3.8%) and postoperative temporary neurological dysfunction (such as delirium and dysphoria) occurred in 12 patients (5.1%). Acute kidney injury requiring renal replacement therapy occurred in 22 patients (9.4%). Extracorporeal membrane oxygenation (ECMO) was used in 7 patients (2.98%) because of postoperative low cardiac output syndrome. There were 2 re-explorations (0.79%) for bleeding in the study (both patients were with postoperative ECMO support). According to intraoperative observations, they both suffered from extensive surgical field erthesis because of coagulation disorders from ECMO support. Chest tube drainage of first 24 hours was $364.9 \pm 130.7$ mL. The mortality and morbidity were listed in Table III.

Follow up: Of the 235 patients in our study, 223 patients were discharged from the hospital. 204 patients (93.6%) were followed up for mean $4.2 \pm 2.1$ years (range 2.0-6.7 years). The survival rate was 90.2% during the follow-up (184/204), including 17 non-aortic related deaths, 2 unidentified sudden deaths, and 1 sepsis-related mediastinal infection death (Figure 4).

The patient who was left with paraplegia before discharge recovered normal physical strength 16 months postoperatively. For the 9 patients who experienced postoperative new onset of stroke, 4 were still left with hemiparesis while the other 5 recovered normal physical strength during follow-up. All other patients resumed nor-
After horizontal reinforcement of the proximal and distal aortic root, three to five additional vertical mattress sutures were placed within the reconstructed aortic root to further ensure false lumen closure of the aortic root. 

**Figure 3.** After horizontal reinforcement of the proximal and distal aortic root, three to five additional vertical mattress sutures were placed within the reconstructed aortic root to further ensure false lumen closure of the aortic root. A: Schematic diagram of the aortic root after reinforcement. Arrows point to the vertical mattress sutures. B: Operative pictures of the procedure. Arrows point to vertical mattress sutures.

**Table II.** Operative Data and Surgical Procedures

<table>
<thead>
<tr>
<th>Variable</th>
<th>n (%)</th>
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<tbody>
<tr>
<td>Cardiopulmonary bypass time, minutes</td>
<td>145.6 ± 32.7</td>
</tr>
<tr>
<td>Aortic clamp time, minutes</td>
<td>111.8 ± 29.7</td>
</tr>
<tr>
<td>Circulatory arrest time, minutes</td>
<td>39.3 ± 7.4</td>
</tr>
<tr>
<td>Operative time, minutes</td>
<td>389.4 ± 79.6</td>
</tr>
<tr>
<td>Total aortic arch repair with frozen elephant trunk</td>
<td>235</td>
</tr>
<tr>
<td>Aortic valve replacement</td>
<td>12 (5.1%)</td>
</tr>
<tr>
<td>Aortic sinus plasty</td>
<td>8 (3.4%)</td>
</tr>
<tr>
<td>Aortic valve plasty</td>
<td>4 (1.7%)</td>
</tr>
<tr>
<td>Coronary artery bypass</td>
<td>14 (5.9%)</td>
</tr>
<tr>
<td>Other concomitant procedures</td>
<td>11 (4.7%)</td>
</tr>
</tbody>
</table>

**Table III.** Early Mortality and Morbidity

<table>
<thead>
<tr>
<th>Variable</th>
<th>n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-day mortality</td>
<td>12 (5.1%)</td>
</tr>
<tr>
<td>Permanent neurologic deficit</td>
<td></td>
</tr>
<tr>
<td>Paraplegia</td>
<td>2 (0.79%)</td>
</tr>
<tr>
<td>Stroke</td>
<td>9 (3.8%)</td>
</tr>
<tr>
<td>Temporary Neurologic deficit</td>
<td>12 (5.1%)</td>
</tr>
<tr>
<td>Renal replacement therapy</td>
<td>22 (9.4%)</td>
</tr>
<tr>
<td>Reexplanation for bleeding</td>
<td>2 (0.79%)</td>
</tr>
<tr>
<td>Chest tube drainage, mL/24 hours</td>
<td>364.9 ± 130.7</td>
</tr>
</tbody>
</table>

CTA before discharge was available in 186 patients (83.4%), in which all patients gained complete aortic root false lumen closure. CTA was respectively available in 174 patients (85.3%), 146 patients (71.6%), 138 patients (67.6%) and 112 patients (54.9%) at the 1st year, 2nd year, 3rd year, and more than 3 years postoperatively.

Among all the available CTAs, no residual false lumen in the aortic root and no aortic root enlargement was found. There were no requests for reoperations of aortic roots during the follow-ups. No patient was found with aortic root disruptions or proximal anastomosis complications. Also no re-dissection of the reconstructed aortic root or pseudoaneurysm originating from anastomosis site was observed during follow-up.

**Discussion**

Repair of aortic root is a crucial step in ATAAD surgery. Although a certain increase in external diameter is frequently found in ATAAD, most aortic roots have normal pre-existing structures. In these situations, root dimensions can be expected to return to normal after removing blood and clots in the proximal false lumen. However, inappropriate management will lead to adverse operative results and reoperations of aortic root in the long term. Besides, persistent blood flow in the aortic root false lumen after surgical repair can compress coronary artery origins, which may cause myocardial ischemia. Therefore, aortic root reinforcement is critical in ATAAD treatment, and despite efforts to reduce complications, aortic root management remains a challenge for cardiac sur-
During the past twenty years, a number of strategies have been used to reinforce fragile aortic root tissues and to assist hemostasis in ATAAD patients. The traditional sandwich technique, as well as variations on it (such as usage of felt strip, adventitial inversion technique, neomedia technique), were often used to reduce anastomosis complications in ATAAD surgery.\(^\text{1,2}\) But intraoperative bleeding from aortic root and residual patent false lumen in aortic root may not be totally eliminated, which has been reported to be around 9-26% by different studies.\(^\text{3,4}\) Therefore, the external wrap procedure and Cabrol shunt procedure have been often performed. The external wrap procedure could help decrease intraoperative bleeding, but a hematoma within the wrap could result in coronary hypoperfusion in many cases, which has been reported to result in higher mortality and greater risk of false aneurysms in aortic dissection patients.\(^\text{1,5-13}\) Besides, the wrap or Cabrol shunt may also result in heart failure in the long term due to the left-to-right shunt.\(^\text{14}\)

Surgery glue is another technique commonly used for aortic root reinforcement, such as using the gelatin-resorcin-formaldehyde (GRF) glue, fibrin glue, or bio-glue.\(^\text{15}\) Using GRF glue improved short-term outcome of type A aortic dissection surgery, but was associated with a high incidence of intima necrosis and false aneurysm formation at the anastomosis site. Other complications, such as glue embolization and re-dissection of the aortic anastomotic sites, have also been reported, while reoperation at re-dissected aorta was more difficult because of aortic intima necrosis.\(^\text{16-20}\) Although using Bioglue may provide benefits, the risks of toxicity, embolism and unintended spillage should also be considered.\(^\text{21-23}\)

In order to solve the problems left in the above techniques, we proposed a new aortic root reinforcement technique. In our proposed new technique, the thrombus was first taken out of the false lumen, and the dissected aortic root was repaired with double vascular prosthetic rings placed both inside and outside the aortic root. The proximal running horizontal mattress suture closed the false lumen of the aortic root from the beginning of the ascending aorta, followed by another running horizontal mattress suture placed at the distal end of the aortic root. Then, according to the intima density, 3 to 5 additional portrait mattress sutures were used to divide the residual false lumen into segments, to further reinforce the fragile aortic root.

Our technique has several advantages in terms of early operative results. With vascular graft rings placed inside and outside aortic root, the risk of creating a new intima tear during anastomosis would be avoided, which would decrease uncontrollable bleeding during anastomosis. Therefore, the need for a Cabrol shunt or aortic root wrapping would be ruled out. In addition, the false lumen was divided into pieces by 3 to 5 vertical mattress sutures, which would quickly promote false lumen thrombosis, thus reducing the possibility of the coronary orifices compressed by false lumen. Furthermore, our technique of reinforcing the aortic root was performed during systemic cooling or rewarming time and would not prolong the whole operative time. In our series, no uncontrollable intraoperative bleeding or coronary artery compressions occurred, and no external wrap procedure or Cabrol shunt procedure was performed. Two patients out of 235 (0.79%), who suffered from a coagulation disorder resulting from postoperative ECMO support, required re-explorations for bleeding. Chest tube drainage during the first 24 hours was satisfactory with a mean of 364.9 ml in our study.

Preservation of the dissected aortic root always raises the question of recurrence of aortic root complications in the long term, such as recurrent aortic root dissection, aortic root aneurysm due to enlargement, pseudoaneurysms originating from anastomosis sites, severe aortic insufficiency, reoperations, and death.\(^\text{24}\) It was reported that, of the approximately 10% to 20% of patients using surgical glue, 23% using Teflon felt required a late reoperation.\(^\text{25-27}\) For the traditional sandwich technique, suture line dehiscence and pseudoaneurysm formation might also occur, leading to reoperation.\(^\text{28-30}\) Using our new technique, the aortic root was securely reinforced and stabilized with two vascular graft rings placed both inside and outside the aortic root. Satisfactory midterm follow-up results were also achieved using our new technique, with no request for reoperations of aortic root during the follow-up. Among all our follow-up CTAs of a mean of 4.2 years, no aortic root complications were found, such as residual patent false lumen, aortic root disruptions or proximal anastomosis complications. Another advantage of our technique was that the vascular graft rings would also stabilize and remodel STJ, which would further prevent aortic insufficiency and aortic root aneurysm formation due to STJ enlargement.

**Limitations:** First, this is a retrospective study. Second, the follow-up and CTA were not available in all patients. Third, the follow-up period was short, and long term follow-ups are needed.

**Conclusions**

Our new aortic root reinforcement technique provides a safe and effective technique for aortic root in ATAAD surgery, by reinforcing friable aortic root tissue and mimicking aortic root complications.

**Disclosures**

**Conflicts of interest:** We have nothing to declare.

**References**

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