Stented elephant trunk procedure combined with ascending aorta and arch replacement for acute type A aortic dissection

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Abstract

Objectives: Despite steadily improving outcomes, surgery for acute type A aortic dissection has several unresolved problems such as expansion of the residual false lumen in the descending aorta. We performed transaortic stented graft implantation into the descending aorta combined with the ascending aorta and aortic arch replacement for acute type A aortic dissection. We review the efficacy and outcomes of this procedure with respect to the residual false lumen and postoperative neurologic complications we encountered. Methods: Nine consecutive patients with acute type A aortic dissection underwent this procedure. The stented elephant trunk graft was implanted through the aortic arch under hypothermic circulatory arrest. The stented graft was 15 cm long in six patients, and 10 cm long in three patients. Enhanced computed tomography (CT) was performed 1 month after surgery and once each year after discharge to evaluate the postoperative time course of the residual false lumen. Results: Cardiopulmonary bypass (CPB) time was quite long because of slow cooling and rewarming [352 ± 92 (mean ± SD) min], and average lower-body arrest time was 54 ± 10 min. The intima in one patient was injured at the time of implantation, and a small leak was created. One patient died of multiorgan failure postoperatively. One patient suffered cerebral injury, and two suffered spinal cord injury perioperatively. Average follow-up time was 40.4 months (range, 13–66 months). One patient died of cerebral infarction during follow up, and the other seven survived and remain well. Postoperative enhanced CT scans showed that the dissected descending aortas attached to the stented grafts and the aortas near the stented grafts returned to normal. In one patient with no re-entry, the false lumen completely closed with thrombi and the entire aorta returned to normal. The diameter of the descending aorta decreased or did not change in six of the seven patients (85.8%) and increased by only 2 mm in one of them (14.2%) during follow up. Conclusions: Implantation of a stented elephant trunk into the descending aorta combined with replacement of the ascending aorta and total arch for acute type A aortic dissection is effective in closing the residual false lumen of the descending aorta and in preventing expansion of the descending aorta. However, further technical modifications, such as using a short stented elephant trunk, eliminating aortic clamping, shortening CPB and spinal cord ischemic time, and reconstruction of left subclavian artery, are needed to prevent neurologic complications. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Stented graft; Elephant trunk; Acute aortic dissection; Aortic arch replacement

1. Introduction

Although many surgical procedures for acute type A aortic dissection involving the distal arch have been attempted and outcomes have improved steadily, morbidity and mortality rates remain high. There are also several unresolved problems regarding treatment of acute type A aortic dissection: whether ascending aorta replacement or ascending aorta and total arch replacement is the better treatment option, and how to avoid postoperative expansion of the residual false lumen, for example. Sabik et al. [1] described that residual distal dissected aorta was not associated with decreased survival after replacement of ascending aorta for aortic dissection, but they also reported that there were late deaths and re-operations associated with distal aortic problems. Takahara et al. [2] described that nine of the 37 patients had patent residual false lumen and four of them had progression of their aneurysms after replacement of ascending aorta and aortic arch using the elephant trunk technique.

Kato et al. [3] developed a new surgical technique for repair of the aortic aneurysm or dissection involving the distal aortic arch. The method involves stented graft implantation to the descending aorta and is less invasive than are other conventional methods. Pulma et al. [4] performed surgical implantation of a stented graft in two patients...
with acute type B aortic dissection, and Sueda et al. [5] performed this procedure in eight patients with distal arch aneurysm. However, there is no report discussing the results of replacement of the ascending aorta and aortic arch combined with a stented graft implantation into the descending aorta for acute type A aortic dissection. We performed this surgical procedure, with some technical modifications, in nine consecutive patients with acute type A aortic dissection. We report the outcomes and problems we encountered.

2. Material and methods

2.1. Patient population

The patients were nine adults who underwent replacement of their ascending aorta and aortic arch with a stented elephant trunk graft for acute type A aortic dissection at our hospitals between February 1996 and February 2002. The patients comprised five men and four women ranging in age from 52 to 83 years (mean, 66.2 ± 9.3 years). Eight of these operations were done within 24 h of the onset of acute aortic dissection. Most patients had some type of preoperative complications (Table 1).

2.2. Stented graft

The stented graft consisted of a Gianturco-type self-expandable metallic stent (Cook Inc., IN, USA) and a high-porosity woven Dacron graft (Intervascular OLP, Intervascular Inc., FL, USA). In the first six patients, a triple-tandem Gianturco stent (2.5 × 3 cm) was attached to the distal portion of the graft with interrupted 5-0 monofilament sutures, and 15 cm of the stented graft was implanted. In the remaining three patients, a double-tandem stent (2.5 × 2 cm) was attached to the graft, and 10 cm of the graft was implanted.

2.3. Operative procedures

After induction of general anesthesia, a transesophageal echocardiography (TEE) probe was inserted in the esophagus to help guide the stented graft to the appropriate site. An arterial cannula was inserted into the femoral artery, and a dual-stage atrio caval cannula was placed at the right atrium. Cardiopulmonary bypass (CPB) flow was maintained between 2.2 and 2.4 l/min/m², and patients were cooled to a rectal temperature of 18–20°C.

In the first five patients, the distal ascending aorta was clamped during cooling. Under cardiac protection with cold blood cardioplegia, the ascending aorta just distal to the sino-tubular junction was transected and plicated with two Teflon strips and gelatin-resorcin-formalin (GRF) glue to reinforce the dissected wall, and an artificial Dacron graft with four side branches was anastomosed to the ascending aorta. And then, the brachiocephalic artery was anastomosed to one of the side branches of the graft. The coronary and brachiocephalic arteries were then, reperfused via an artificial graft branch which was connected to the CPB circuit. The left common carotid artery was anastomosed to the next side branch and reperfused. CPB was discontinued at a rectal temperature of 18–20°C, but the heart and brain continued to be perfused via the graft branch. The transverse aortic arch was transected between the left common carotid and left subclavian arteries. A 30-Fr catheter sheath containing the stented graft was inserted into the appropriate segment of the descending aorta under TEE guidance, and the stented graft was deployed with the pushing rod. After the graft was positioned, the stent was expanded with a Foley balloon. The distal end of the artificial graft was anastomosed to the trans- ected transverse aortic arch containing the intraluminal stented graft, using a strip of Teflon felt and GRF glue. Antegrade systemic reperfusion was begun via the graft branch and started re-warming. The left subclavian artery, which was occluded by the stented graft, was ligated and resected at its ostium, and the artery was anastomosed to the remaining side branch in an end-to-end fashion (Fig. 1). This method required clamping of the aorta and the arch vessels many times, and the operative field of the distal anastomosis was not clearly visible.

2.4. Modified total arch operation

We modified the above procedure to eliminate aortic

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (year)</th>
<th>Sex</th>
<th>Preoperative complications</th>
<th>Distal end of aortic dissection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>65</td>
<td>M</td>
<td>Aortic regurgitation</td>
<td>Infrarenal</td>
</tr>
<tr>
<td>2</td>
<td>73</td>
<td>F</td>
<td>Malignant lymphoma</td>
<td>Infrarenal</td>
</tr>
<tr>
<td>3</td>
<td>83</td>
<td>M</td>
<td>–</td>
<td>Thoracic descending</td>
</tr>
<tr>
<td>4</td>
<td>52</td>
<td>M</td>
<td>Aortic regurgitation, left limb ischemia, infrarenal aneurysm</td>
<td>Iliac</td>
</tr>
<tr>
<td>5</td>
<td>66</td>
<td>F</td>
<td>Aortic regurgitation, congestive heart failure, severe asthma</td>
<td>Thoracic descending</td>
</tr>
<tr>
<td>6</td>
<td>60</td>
<td>M</td>
<td>–</td>
<td>Infrarenal</td>
</tr>
<tr>
<td>7</td>
<td>59</td>
<td>M</td>
<td>–</td>
<td>Infrarenal</td>
</tr>
<tr>
<td>8</td>
<td>74</td>
<td>F</td>
<td>–</td>
<td>Infrarenal</td>
</tr>
<tr>
<td>9</td>
<td>64</td>
<td>F</td>
<td>–</td>
<td>Infrarenal</td>
</tr>
</tbody>
</table>

*a M, male; F, female.*
clamping and to obtain a visible operative field on distal anastomosis in the last four patients (patients 6–9). Under circulatory arrest at a rectal temperature of 18–20°C, the ascending aorta and transverse aortic arch were opened. Three cerebral perfusion cannulas were inserted into the internal lumen of the arch vessels, and antegrade selective cerebral perfusion was established immediately. The transverse aortic arch was transected, and the stented graft was inserted into the proximal descending aorta under TEE and endoscopic (LTF TYPE V, Olympus Co. Ltd, Tokyo, Japan) guidance. The distal end of the artificial graft was anastomosed to the transected transverse aortic arch containing the inserted stented graft. After distal anastomosis was completed, antegrade systemic perfusion was begun through one of the graft branches. Selective antegrade cerebral perfusion continued until reconstruction of the arch vessels was finished. Just before reconstruction of each arch vessel was completed, each perfusion cannula was removed. The arch vessels were not clamped at the anastomosis. After reconstruction of all arch vessels, proximal anastomosis was performed during re-warming.

2.5. Postoperative computed tomography (CT) scans

Postoperative enhanced CT scans were performed about 1 month after surgery and once each year after discharge in seven of the nine patients. The maximal diameter of the descending aorta was measured at the point where the residual false lumen remained.

3. Results

3.1. Operative techniques

All stented grafts were placed in the appropriate segment of the descending aorta under TEE or endoscopic guidance. We performed all operations via median sternotomy without left thoracotomy. Additional operations included three aortic valve suspensions. The left subclavian artery in patients 7 and 8 could not be reconstructed.

CPB time in this series of patients averaged 352 ± 92 (mean ± SD) min (range, 273–574 min). Average lower-body arrest time in the nine patients was 54 ± 10 min (range, 40–71 min). The cerebral perfusion time averaged 103.2 min (range, 70–144 min) in patients 6–9. Brain circulatory arrest time, which was used for transection of the aortic arch and establishment of the selective antegrade cerebral perfusion in patients 6–9, averaged 8.5 min (Table 2).

3.2. Operative mortality

Surgery-related death occurred in one case (patient 5). Lung oxygenation deteriorated during surgery in this patient due to severe asthma and preoperative congestive heart failure. She needed the support of an extracorporeal membrane oxygenator for 12 h after surgery. The patient died of multiorgan failure on the 24th postoperative day. Patient 3 suffered cerebral infarction 32 months after surgery and died. The other seven patients survived and remain well.

3.3. Operative morbidity

There was one graft-associated complication. The postoperative angiography in patient 4 showed minor leakage from the distal end of the stented graft into the residual distal false lumen. This leakage may have resulted from a small intimal tear made during implantation of the stented graft.

Table 2

<table>
<thead>
<tr>
<th>Patient</th>
<th>Stented graft diameter (mm)</th>
<th>CPB time (min)</th>
<th>Lower-body arrest time (min)</th>
<th>Distal end of stented graft</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>392</td>
<td>64</td>
<td>Th8</td>
<td>–</td>
</tr>
<tr>
<td>2</td>
<td>28</td>
<td>279</td>
<td>58</td>
<td>Th9</td>
<td>–</td>
</tr>
<tr>
<td>3</td>
<td>28</td>
<td>284</td>
<td>44</td>
<td>Th10</td>
<td>Right cerebral infarction</td>
</tr>
<tr>
<td>4</td>
<td>22</td>
<td>366</td>
<td>42</td>
<td>Th7</td>
<td>–</td>
</tr>
<tr>
<td>5</td>
<td>24</td>
<td>574</td>
<td>40</td>
<td>Th8</td>
<td>Respiratory failure, MOF spinal cord injury</td>
</tr>
<tr>
<td>6</td>
<td>30</td>
<td>326</td>
<td>71</td>
<td>Th8</td>
<td>Left recurrent laryngeal nerve palsy</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>345</td>
<td>54</td>
<td>Th8</td>
<td>Spinal cord injury (Th5/6)</td>
</tr>
<tr>
<td>8</td>
<td>26</td>
<td>333</td>
<td>57</td>
<td>Th8</td>
<td>Renal dysfunction</td>
</tr>
<tr>
<td>9</td>
<td>26</td>
<td>271</td>
<td>56</td>
<td>Th7</td>
<td>Renal dysfunction</td>
</tr>
</tbody>
</table>

* CPB, cardiopulmonary bypass.
and the small leakage is still present. The leakage and the diameter of the residual false lumen are evaluated by CT every 6 months.

Two patients suffered postoperative acute renal dysfunction, and one developed left recurrent laryngeal nerve palsy. Patients 7 and 8, whose left subclavian arteries were not reconstructed, had no complaint associated with left arm ischemia except for a slight discomfort in the left arm. One patient (patient 3) suffered perioperative brain injury. His postoperative brain CT scans showed right middle and posterior cerebral artery embolisms. He recovered with little palsy.

Perioperative spinal cord injury occurred in two patients (patients 5 and 7). The distal end of the stented graft was at the Th 8 level in both instances. The postoperative course of the patient had no complication except for paraplegia. Magnetic resonance imaging could not be used to estimate the amount of injury because the stent interfered with imaging of the spinal cord.

3.4. Postoperative CT findings

Average follow-up time in our patient series, excluding patient 5, was 40.4 months (range, 13–66 months). Postoperative enhanced CT was performed in seven of the nine patients. The false lumen of the descending aorta was completely closed, and the entire aorta returned to normal in one patient, who had had no re-entry (patient 3). In the other patients, the descending aorta at the point of stented graft attachment and the aorta surrounding the stented graft returned to normal; the false lumen near the implanted graft closed with thrombus. The residual false lumens distal to the stented graft were enhanced on CT only from re-entry point at the abdominal aorta (Fig. 2), but the diameter of the descending aorta decreased in four patients and did not change in two patients, and increased by only 2 mm in one patient on late postoperative CT scans (Table 3).

The intercostal arteries occluded by the stented graft were situated between levels Th 7 and Th 10; i.e. the distal ends of the implanted stented grafts were located between levels Th 7 and Th 10, as evaluated on postoperative chest X-ray and CT scans (Table 2).

4. Discussion

In this procedure, the sutured distal anastomosis is posi-

![CT scans from patient 6.](image-url)
tioned just distal to the left carotid artery, but the sutureless distal end of the anastomosis can be located anywhere in the descending aorta, depending on the extent of the disease. Surgical access is needed only to the mid-portion of the arch, making left thoracotomy unnecessary. A dissection entry point located in the ascending or transverse aortic arch can be treated by graft replacement, and an entry point located distal to the left subclavian artery can also be closed by the stented graft. The possibility for phrenic or recurrent nerve injury is decreased, and postoperative pulmonary complications may also be lessened.

The false lumen of the descending aorta covered by the stented graft is securely closed because the true lumen is restored to its original size by the self-expanding stent. Any antegrade blood leakage from the sutured anastomosis into the residual false lumen can also be completely prevented by the stented graft. In our study, the descending aortic wall in seven of nine patients visualized on postoperative CT scans had returned to normal. The residual false lumen was filled with thrombi, and any retrograde blood flow could be seen only around the re-entry point of the false lumen. Ando et al. [6] reported that the false lumen in their patients had been closed after the simple elephant trunk procedure but that the aortic wall did not return to normal and was thickened with thrombus. Takahara et al. [2] described that nine of the 37 patients had patent residual false lumen and four of them had progression of their aneurysms. Compared with these reports, almost all descending aorta did not expand after surgery. The diameter of the descending aorta in our series decreased in four of seven patients and did not change in two patients. The diameter increased by only 2 mm in the other one. Thus, the stented elephant trunk procedure can prevent expansion of the residual false lumen if the re-entry point remains open, though the reasons have been unknown. The stented graft procedure may be more effective and reliable.

Although surgical stented graft implantation is easier to perform than the conventional arch operation and is more effective and more reliable for closing the residual false lumen and preventing the expansion, this procedure did not prevent neurologic complications in our patients. Postoperative cerebral accidents occurred in one (Patient 3) of the nine patients in our series, in two of the ten patients in Kato’s aneurysm series, and in one of the eight patients in Sueda’s aneurysm series. In comparison, Svensson et al. [7] and Coselli et al. [8] reported lower-stroke rates, 7 and 3.1%, respectively, after conventional aortic arch operations. Circulatory arrest time to the brain was very short in our procedures, and we believe that there was little possibility that the stroke in patient 3 resulted from blood arrest or low blood flow to the brain. Hypothesizing that perioperative cerebral stroke results from clamping of the atherosclerotic aorta and arch vessels in the primary procedure, we modified the operation in our last four patients to eliminate aortic clamping; these patients did not suffer postoperative cerebral injury.

Spinal cord injury is the most serious problem associated with this stented elephant trunk procedure. This complication was not reported by Kato et al., and there are few reports giving postoperative paraplegia rates after arch repair with the elephant trunk procedure. Crawford and co-workers reported the rate to be 2% [4,9–11]. The number of the patients in our series was too small to analyze the risk factor for postoperative paraplegia for this method statistically, but several factors in combination could be responsible for this problem.

The mean lower-body arrest time in our series was 54 min at a temperature of 18–20°C. Lower-body arrest time was used for transection of the aortic arch, establishment of antegrade selective cerebral perfusion in patients 6–9, plication of the dissected aortic wall with a Teflon strip and GRF glue, implantation of the stented elephant trunk, and completion of the distal anastomosis. About 15 min were needed to implant the graft in the appropriate segment and plicate the dissected wall. Although the lower-body arrest time of patient 5 was 40 min, paraplegia occurred. This factor may not be the main reason for the injury, but the lower-body arrest time should be shortened to reduce ischemia-reperfusion injury of the spinal cord.

Occlusion of multiple intercostal arteries by the stented...
gastri is another possible cause of spinal cord injury. The anterior spinal artery at the level of the middle thoracic spinal cord is narrow and can play a critical role in spinal cord ischemia [12,13]. Kirklin and Barrat-Boyes [14] reported that even the elephant trunk, which is floating in the descending aorta and is not attached to the aortic wall, should be 12–15 cm long. In later operations, we used a 10-cm-long stented graft, and the graft was shown to be as effective as the longer stented graft in closing the false lumen. A 10-cm stented elephant trunk graft may be the best option for acute aortic dissection.

Left subclavian artery, which supplies blood to the spinal cord via the vertebral artery, should be perfused continuously and reconstructed if possible. After stented graft implantation without reconstruction of left subclavian artery, the blood supply to the upper spinal cord may be completely blocked.

Perioperative blood pressure is also an important causal factor in spinal cord injury. Schepens et al. [15] reported that temporary reduction in perfusion pressure to the spinal cord during or after surgery causes paraplegia, and it has been demonstrated experimentally that maintaining a high distal aortic pressure preserves spinal cord blood flow [16]. From that point of view, CPB time should be shortened. The CPB time in our series was quite long. Too much time was spent on cooling, re-warming, and reconstruction of the left subclavian artery. Cooling and re-warming was slowly induced and took about 120 min in all cases. It also took much time to reconstruct the left subclavian artery because it was difficult to expose the artery by this method. Consequently, the reconstruction was given up in two patients. This suboptimal hemodynamics may also have been a factor in the spinal cord injury. In comparison to surgical stented graft implantation, endovascular stented graft implantation for thoracic aortic disease, during which the blood pressure is stable, reportedly decreases the paraplegia rate (0–5%) [17,18].

This method for treating acute type A aortic dissection is still developing. Many surgical modifications, such as using a short stented elephant trunk, eliminating aortic clamping, shortening CPB and spinal cord ischemic time, and reconstruction of the left subclavian artery are needed to resolve postoperative neurologic complications.

5. Conclusions

Replacement of the ascending aorta and total arch combined with stented graft implantation into the descending aorta is effective for preventing from expansion of the residual false lumen, but the risk of perioperative brain and spinal cord injury is still unresolved. Modification of the operation by using a short stented elephant trunk, eliminating aortic clamping, shortening CPB and spinal cord ischemic time, and reconstruction of the left subclavian artery may reduce neurologic complications associated with this procedure.

References