Surgery for acute type A dissection using total arch replacement combined with stented elephant trunk implantation: Experience with 107 patients

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Objective: In patients with acute type A dissection, it is controversial whether to use a more aggressive strategy with extended aortic replacement to improve long-term outcome or to use a conventional strategy with limited ascending aortic or hemiarch replacement to circumvent a life-threatening situation.

Methods: Between April 2003 and June 2007, 107 patients (17 women, 90 men; mean age, 45 ± 11 years; range, 17–78 years) with acute type A dissection underwent total arch replacement combined with stented elephant trunk implantation under hypothermic cardiopulmonary bypass and selective cerebral perfusion. Computed tomography was performed to evaluate the residual false lumen in the descending aorta during follow-up.

Results: Thirty-day mortality was 3.74% (4/107 patients), and in-hospital mortality was 4.67% (5/107 patients). Spinal cord injury was observed in 3 patients (1 patient with left lower-extremity paraparesis and 2 patients with paraplegia). Cerebral infarction was observed in 3 patients, ventilator support exceeding 5 days was required in 9 patients, and rebleeding was observed in 4 patients. During a mean follow-up of 35 ± 14 months, 3 patients died and 3 patients were lost to follow-up. On postoperative computed tomography, complete thrombus formation was observed around the stented elephant trunk in 95% of patients (95/100) and at the diaphragmatic level in 69% of patients (69/100).

Conclusion: Low morbidity and mortality were achieved using total arch replacement combined with stented elephant trunk implantation. These encouraging surgical results and postoperative outcomes favor this more aggressive procedure for acute type A dissection. (*J Thorac Cardiovasc Surg* 2009;138:1358–62)

The outcome of surgical repair of acute type A dissection has substantially improved because of advances in diagnosis, surgical technique, anesthesia, and perioperative care, but acute type A dissection continues to be associated with high morbidity and mortality.¹ The optimal surgical strategy for acute type A dissection is controversial. Therapy spans the more conservative approaches using only replacement of the ascending aorta with or without resection of the intimal tear to more aggressive methods using total replacement of the ascending aorta and aortic arch.^{2–4} Compared with conservative approaches, concomitant distal aortic resection has been reported to increase surgical risk.⁵ Total replacement of the ascending aorta and aortic arch for acute type A dissection has been a challenging problem.

In recent years, we have tended toward a more aggressive distal aortic approach using total replacement of the ascending aorta and aortic arch combined with stented elephant trunk implantation in patients with acute type A dissection. We report our experience of surgical management of acute type A dissection using this procedure.

PATIENTS AND METHODS

Patient Data

Between April 2003 and June 2007, 107 patients (90 male and 17 female; mean age, 45 ± 11 years; range, 17–78 years) with acute type A dissection underwent total arch replacement combined with stented elephant trunk implantation within 2 weeks of symptom onset. This was via a median sternotomy under hypothermic cardiopulmonary bypass (CPB) with selective cerebral perfusion (SCP) at Fuwai Hospital. This procedure was approved by the institutional review board of the Chinese Academy of Medical Science and Peking Union Medical College, Beijing, China. Preoperative informed consent was obtained from each patient. Nine patients experienced preoperative cardiogenic shock, necessitating at least temporary inotropic support. Only 1 patient was intubated preoperatively in this group. A history of hypertension was the most common preoperative finding (Table 1).

The tear site was at the ascending aorta in 45 patients, the transverse arch in 24 patients, and the proximal descending thoracic aorta in 33 patients; an entry tear was not detected in 5 patients. The dissection extended into the distal descending thoracic aorta in 11 patients and into the abdominal aorta in 96 patients. Postoperative computed tomography (CT) with contrast enhancement was performed routinely to assess the residual false lumen and the aortic diameter during follow-up.

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Abbreviations and Acronyms

- CPB = cardiopulmonary bypass
- CT = computed tomography
- SCP = selective cerebral perfusion

Surgical Procedure

The surgical procedure developed by our research group has been described in detail.^{6,7} A stent-graft (MicroPort Medical Company Limited, Shanghai, China) and 4-branched prosthetic graft (Meadox Hemashield Platinum 4 Branch Graft, Boston Scientific Inc, Boston, MA) were used in total arch replacement combined with stented elephant trunk implantation. Patients underwent a median sternotomy and total CPB; 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 via 1 limb of a 4-branched prosthetic graft. During the cooling phase, the ascending aorta was clamped. The proximal ascending aorta was longitudinally opened, and antegrade perfusion of cold-blood cardioplegic solution was directly infused into the coronary ostia. Aortic root procedures were done if necessary. Circulatory arrest was established when the nasopharyngeal temperature reached 18°C to 22°C. SCP was started through the right axillary artery, and the brain was perfused. The ascending aorta and transverse arch were opened. The primary intimal tear in the proximal descending aorta was sealed using the stented elephant trunk, and the distal aorta was transected circumferentially close to the proximal margin of the origin of the left subclavian artery to avoid recurrent laryngeal nerve injury. The stented elephant trunk was then inserted into the true lumen of the descending thoracic aorta in a bound, compressed state. The proximal edge of the residual aorta was trimmed to match the proximal end of the stent graft. The anastomosis between the 4-branched prosthetic graft and the distal aorta containing the intraluminal stented graft was carried out using the “open” aortic technique. After the anastomosis was completed, blood perfusion of the lower body was started via the perfusion limb of the 4-branched prosthetic graft. One limb of the prosthetic graft was then anastomosed to the left common carotid artery in an end-to-end fashion. After the anastomosis was accomplished, SCP was discontinued, CPB was gradually resumed to normal flow, and rewarming was started. The innominate and left subclavian arteries were anastomosed to the respective limbs of the 4-branched prosthetic graft in an end-to-end style. The proximal segment of the left subclavian artery was oversewn with a continuous suture. The prosthetic graft was anastomosed to the proximal aortic stump, which had already been reconstructed.

RESULTS

Surgical Data

All patients with acute type A dissection underwent total replacement of the ascending aorta and aortic arch replacement combined with stented elephant trunk implantation under hypothermic CPB with SCP. The CPB time was 120 to 379 minutes (mean, 190 ± 42 minutes), aortic crossclamp time was 52 to 198 minutes (mean, 107 ± 28 minutes), and SCP time was 12 to 75 minutes (mean, 25 ± 10 minutes). Concomitant procedures are summarized in Table 2.

Mortality and Morbidity

Thirty-day mortality was 3.74% (4/107), and in-hospital mortality was 4.67% (5/107). Two patients died of multiple-organ failure after surgery. One patient had mesenteric

TABLE 1. Clinical profiles of patients with acute type A aortic dissection

Variables	No.
Age (y)	45 ± 11
Male	90
Female	17
Hypertension	81
Marfan syndrome	17
Diabetes mellitus	4
Acute myocardial infarction	1
Chronic myocardial infarction	1
Myocardial ischemia	3
Acute cardiac tamponade	3
Acute left-sided heart failure	2
Cerebral ischemia	1
Acute visceral ischemia	3
Acute renal dysfunction	4
Chronic renal dysfunction	3
Lower-extremity ischemia	4

ischemia, and 1 patient had mesenteric ischemia and acute renal failure. One patient with preoperative acute mesenteric ischemia and acute cardiac tamponade died after being in a coma after surgery. One patient with preoperative acute renal failure received peritoneal dialysis and ceased treatment after 3 reoperations for uncontrollable bleeding. One patient died of preoperative brain infarction 60 days after surgery for extensive cerebral infarction.

Injury to the spinal cord was observed in 3 patients. One patient had paraparesis in the left lower extremity. The patient with preoperative lower-extremity ischemia had subdural hematoma as evaluated by CT. Lower-extremity paraparesis may have been related to preoperative ischemia or postoperative subdural hematoma. Paraplegia was observed in 2 patients. One patient had limb ischemia and acute cardiac tamponade before surgery. Cerebral infarction was observed in 3 patients, but they recovered before hospital discharge. Ventilator support for more than 5 days was required in 9 patients. Reoperation was indicated for 4 patients with bleeding and for 1 patient with pericardial sac drainage.

Imaging

CT was performed in 100 patients during follow-up. Complete thrombus formation was observed around the stented elephant trunk in 95% of patients (95/100) and at the diaphragmatic level in 69% of patients (69/100) (Figure 1). The descending aorta returned to normal in 63 patients during follow-up after remodeling the aortic wall (Figure 1). Obvious enlargement of the abdominal aorta was not observed at the level of the superior mesenteric artery compared with preoperative imaging. Thrombus obliteration of the false lumen, reabsorption of false-channel thrombosis, enlargement of the true lumen, and shrinkage in the diameter of the entire aorta developed in a continuous dynamic process until the aorta returned to normal.

ACD

TABLE 2. Concomitant procedure

Variables	No.
Bentall procedure	20
Cabrol procedure	1
Sinus of Valsalva reconstruction	13
Aortic valve plasty	14
Replacement of the aortic valve	2
Coronary artery bypass graft	13
Axillary–axillary artery bypass	1
Ascending aorta–axillary artery bypass	1
Ascending aorta–femoral artery bypass	1

A patent false lumen around the stented elephant trunk was observed in 5 patients (2 patients with Marfan syndrome and 3 patients without Marfan syndrome). The distal end of the stent-graft entering the false lumen was observed in 2 patients with Marfan syndrome, and close follow-up was initiated. This may have been related to the small true lumen of the descending aorta, the abnormally fragile tissue, an inexperienced surgeon, or a combination of these factors.

Follow-up

Three deaths of unknown cause occurred 7, 14, and 6 months after surgery during a mean follow-up of 35 ± 14 months. Three patients were lost to follow-up. One patient with paraparesis in the left lower extremity was lost to follow-up after hospital discharge. One patient with paraplegia could walk, but the other patient with paraplegia could not walk during follow-up. Injury to the spinal cord was not observed during follow-up. Reoperation related to residual dissected aorta was not carried out. Patients resumed normal activities with antihypertensive therapy after hospital charge.

DISCUSSION

Acute type A dissection is one of the most serious cardiovascular diseases. Emergency surgical treatment is to prevent aortic rupture, to avoid or correct aortic valve insufficiency, and to restore flow to compromised branch vessels. Complete resection of the intimal tear and reapproximation of the proximal and distal edges of the dissected aorta were the primary objectives of surgery. Surgical results have improved dramatically because of recent improvements in surgical technique and cerebral protection methods, but surgery for acute type A dissection is still associated with high morbidity and mortality.¹

Various procedures have been developed for repair of acute type A dissection, ranging from conservative to aggressive methods. The conservative strategy with simple replacement of the ascending aorta was initially recommended in acute type A dissection regardless of the extent of tear. This left diseased and dissected aorta proximal and distal to the replaced segment. Incomplete resection of the primary tear carried high morbidity and mortality, and

a high prevalence of patent false lumen was observed when the intimal tear originated in or extended into the aortic arch.⁸ Limited replacement of the ascending aorta with resection of the intimal tear has therefore been the standard surgical procedure for type A dissection. Ascending aortic replacement^{4,9} was performed only when the intimal tear was in the ascending aorta. Hemiarach replacement or total arch replacement was performed only when the intimal tear originated in or extended into the aortic arch.^{9–11} To improve late surgical outcome, a more aggressive strategy with total aortic replacement was recommended for initial surgical treatment of acute type A dissection irrespective of the location of the intimal tear.^{2,12–14} Simultaneous replacement of the ascending aorta and transverse aorta did not increase surgical morbidity and mortality.^{2,12} Extended aortic replacement has become an accepted surgical method in patients with acute type A dissection involving the aortic arch.^{2,12,15}

To achieve a stronger distal anastomosis and facilitate subsequent operations on the downstream aorta, total aortic grafting with the conventional elephant trunk was recommended in patients with acute type A dissection.^{16,17} Complications such as kinking and obstruction of the graft, embolization, and paraplegia have been observed using the conventional elephant trunk procedure,¹⁸ so modifications of the elephant trunk procedure were made by our research group.⁷ A stented elephant trunk was implanted into the descending aorta before total replacement of the ascending aorta and aortic arch (we called it “Sun’s procedure”), and initial results were encouraging.⁷

The indications for this procedure for acute type A dissection with dissection extending to the descending aorta or abdominal aorta were as follows: (1) intimal tear located in the aortic arch or proximal descending aorta (retrograde dissection); (2) involvement of the arch vessels; (3) aneurysmal dilatation of the aortic arch or descending thoracic aorta (≥ 40 mm); and (4) Marfan disease. The contraindication is that it is difficult to apply the stented elephant trunk in the true lumen of the distal aorta under deep hypothermic circulatory arrest with SCP.

Whether total replacement of the ascending aorta and aortic arch combined with stented elephant trunk implantation increases the risk of surgical mortality is controversial. Compared with the conservative approach, which had a 30-day mortality of 5.3%,⁴ the mortality in this group was low (3.87%, 4/107). Mesenteric ischemia, mesenteric ischemia and acute renal failure, mesenteric ischemia and acute cardiac tamponade, and acute renal failure were manifested in 30-day mortalities before surgery. Distal malperfusion was associated with significant in-hospital mortality, particularly in patients with mesenteric malperfusion.¹⁹ This technique was therefore not associated with increased surgical risk. Concomitant irreversible organ ischemia was responsible for in-hospital death. The severity of the preoperative

FIGURE 1. CT scan of a patient with acute type A dissection 2 weeks (A, B, and C) and 4 years (D, E, and F) after surgery. Thrombus formation in the false lumen was observed around the stented graft (A), distal to the edge of the stented graft (B), and at the diaphragmatic level (C) 2 weeks after surgery. The stented graft (A) and true lumen (B and C) were compressed by the false lumen. After remodeling of the aortic wall for 4 years, the false-channel thrombosis was nearly or fully reabsorbed, and the 2 dissected layers were approximated to obliterate the false lumen (D, E, and F). The stented graft expanded to its full diameter, and the true lumen in the descending aorta was resumed (D, E, and F). The descending aorta returned to normal size after the aortic wall had been remodeled to a normal shape (D, E, and F). The prosthetic graft is somewhat long in this case. The part of the prosthetic graft wall with less curvature is remodeled and folded on using the suture line (D).

condition, not the extent of distal aortic resection, affects surgical outcome.²

Patients experienced permissible postoperative complications using this procedure. Postoperative cerebral morbidity remains one of the critical complications in patients with total arch replacement. Cerebral infarction was observed in 3 patients who recovered before hospital discharge. Acceptable cerebral complications were attributed to SCP, branched graft technique,² and this procedure. This procedure facilitates the anastomosis between the 4-branched prosthetic graft and the descending aorta after implantation of the stented elephant trunk into the descending aorta. It also contributed to the anastomosis between the distal end of the stented graft and the Dacron prosthesis if late thoracoabdominal aortic replacement was required. Injury to the spinal cord remained one of the most severe complications in this procedure, with 3 patients affected. The distal end of the stented graft was above the Th8 level, as demonstrated by postoperative chest radiography or CT. We thought the critical intercostal arteries originating from the false lumen were interrupted when the false lumen was thrombosed. Inadequate collateral circulation in the acute phase, together with other factors (eg, spinal cord ischemia during the lower body arrest, sacrifice of intercostal arteries that do not directly supply spinal cord blood flow but augment

collateral blood flow,²⁰ embolism to intercostal arteries, perioperative hypotension), led to spinal cord injury. We speculated that spinal cord injury was mainly related to rapid thrombosis of the false lumen in patients with intercostal arteries arising from the false lumen. Collateral circulation did not have a compensatory role in patients with acute type A dissection. We thought that shortening of the stented elephant trunk was in vain in this situation. Spinal cord injury was also observed in patients with total arch replacement and ascending aortic replacement,²¹ and thrombosis of the false lumen rapidly occurred. Protection of the spinal cord (eg, drainage of spinal fluid, evoked potentials) was not used in these patients. Cerebrospinal fluid drainage was effective in these patients, as reported by Kawanishi and colleagues.²¹ Cerebrospinal fluid drainage may be an effective way to treat spinal cord injury using this technique. The severe complication of the distal end of the stent-graft entering the false lumen was observed in 2 patients with Marfan syndrome. The small true lumen of the descending aorta, the abnormally fragile tissue, and an inexperienced surgeon were the probable causes of this complication. To avoid this severe complication in patients with Marfan syndrome, we recommend that this procedure be carried out with the true lumen of the descending aorta more than 10 mm in diameter.⁶

Whether this technique improves postoperative outcome merits discussion. Reoperation was unnecessary during a mean follow-up of 35 ± 14 months. This may be attributed to the high prevalence of resection or seal of the primary tear, complete resection of the entire native arch tissue, which is prone to further dilation, and high prevalence of obliteration of the false lumen in the descending aorta in this study. Injury to the spinal cord or visceral malperfusion was not observed during follow-up. The primary limitation of this study was that comparisons between the total arch replacement group and the total arch replacement with stented elephant trunk group were not made. Although the preliminary data were encouraging with a mean follow-up of 35 ± 14 months, it is necessary to evaluate whether this technique for acute type A dissection improved long-term outcome. Spinal cord injury with this technique was a problem.

CONCLUSIONS

A more aggressive approach to surgical treatment of acute type A dissection using total replacement of the ascending aorta and aortic arch combined with implantation of a stented elephant trunk demonstrated low mortality and morbidity, and low incidence of reoperation, patent distal false lumen, and late vascular events.

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