Extensive primary repair of the thoracic aorta in Stanford type A acute aortic dissection by means of a synthetic vascular graft with a self-expandable stent

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Objectives: To minimize any residual false lumen when operating on patients with an acute type A aortic dissection, we tried to perform extensive primary repair of the thoracic aorta with the modified elephant trunk technique. The early and midterm results of these surgical interventions are reported and evaluated.

Methods: Among the acute type A aortic dissections with extensive false lumen encountered since December 1997, 19 consecutive patients, 15 DeBakey type I with the tear in the ascending, transverse, or both aortas, and 4 DeBakey type III-D with the tear located in the descending aorta, underwent insertion of a synthetic graft with a distally anchored stent in the descending thoracic aorta. The interpolation method was used as an introducer combined with total replacement of the aortic arch by using a synthetic branching graft with only a median sternotomy.

Results: One patient died, and 18 were discharged after full recovery. Postoperative computed tomographic scans showed that no residual false lumina were present proximal to the diaphragmatic level, and no false lumina were found in 10 patients. Two patients with acute ischemia of the right kidney caused by narrowing of the true lumen, as demonstrated by radiographic computed tomography, improved significantly after surgical intervention with restoration of blood flow in the true lumen. Paraplegia was not observed in any patient.

Conclusions: In emergency operations for an acute type A aortic dissection, the operation is often limited to replacing the ascending aorta because priority is given to saving the patient's life. However, it is possible to perform extensive primary repair of the thoracic aorta with relative safety by interpolating a synthetic graft with a self-expandable stent.

An acute type A aortic dissection frequently requires emergency surgical treatment. Extensive primary replacement of the thoracic aorta,^{1,2} if it is performed with the conventional method, is highly invasive, which makes the risk of this procedure very high in many cases, whereas the main purpose of an emergency operation is to save the patient's life. The scope of the operation is often limited also. When a false lumen remains distal to the descending thoracic aorta

TABLE 1. Patient profile

Patient No. (age [y], sex)	DeBakey	Preoperative complications	Prehospital treatment	Operative time	ECC time	Stent graft diameter	Stent graft length	Distal end of stent graft	Outcome	Follow- up
1 (66, F)	III-D	Atrophy of right kidney		6 h 25 min	245 min	28 mm	8 cm	Th7 mid	Alive and well	38 mo
2 (64, M)	I	Ischemia of RCA		9 h 44 min	234 min	28 mm	12 cm	Th8 upper	Alive and well	37 mo
3 (53, M)	I	Cardiac tamponade		12 h 10 min	316 min	24 mm	12 cm	Th7 lower	Alive and well	37 mo
4 (71, M)	I	Cardiac tamponade		10 h 10 min	330 min	26 mm	12 cm	Th8 mid	Alive and well	34 mo
5 (66, F)	I			8 h 55 min	215 min	24 mm	12 cm	Th8 lower	Alive and well	32 mo
6 (67, F)	I	Cardiac tamponade	Endotracheal intubation; pericardial drainage	12 h 5 min	370 min	24 mm	12 cm	Th8 mid	Operative death	
7 (63, F)	III-D	Ischemia of right kidney and both lower limbs		7 h 5 min	254 min	22 mm	12 cm	Th8 lower	Alive and well	26 mo
8 (71, F)	I	Atrophy of right kidney	Endotracheal intubation	5 h 55 min	240 min	24 mm	12 cm	Th9 lower	Alive and well	24 mo
9 (71, F)	I			6 h 40 min	206 min	26 mm	12 cm	Th8 mid	Alive and well	23 mo
10 (69, F)	I			6 h 5 min	210 min	28 mm	12 cm	Th7 lower	Alive and well	23 mo
11 (76, F)	I	COPD with O ₂ inhalation	Endotracheal intubation	7 h 50 min	238 min	26 mm	12 cm	Th7 mid	Alive and well	22 mo
12 (47, M)	III-D	Ischemia of right kidney and right lower limb		11 h 45 min	256 min	24 mm	15 cm	Th9 lower	Alive and well	21 mo
13 (76, M)	I	Cardiac tamponade		5 h 45 min	221 min	30 mm	12 cm	Th7 mid	Alive and well	20 mo
14 (79, F)	I			8 h 35 min	316 min	22 mm	10 cm	Th7 lower	Alive and well	15 mo
15 (73, M)	I			7 h 30 min	179 min	28 mm	10 cm	Th7 mid	Alive and well	9 mo
16 (70, F)	I			6 h 8 min	236 min	26 mm	10 cm	Th8 upper	Alive and well	8 mo
17 (48, M)	III-D			8 h 10 min	260 min	24 mm	10 cm	Th7 lower	Alive and well	5 mo
18 (67, F)	I			7 h 40 min	261 min	26 mm	12 cm	Th7 lower	Alive and well	3 mo
19 (61, F)	I			7 h 0 min	223 min	24 mm	12 cm	Th7 lower	Alive and well	2 mo

ECC, Extracorporeal circulation; RCA, right coronary artery; COPD, chronic obstructive pulmonary disease; Th, Thoracic vertebral body.

after the operation, it can significantly affect the long-term prognosis.³ Therefore, it would be desirable if the initial operation could be performed safely while keeping the residual dissection as small as possible. Recently, we performed extensive primary repair of the thoracic aorta using a synthetic graft with a self-expandable stent and obtained good results.

Methods

Subjects

The subjects were 19 patients with a Stanford type A acute aortic dissection treated for over 38 months beginning in December 1997 (Table 1). In 15 patients the primary intimal tears were located in the ascending aorta, aortic arch, or both (DeBakey type I), whereas in 4 patients the primary intimal tears were found distal to the left

subclavian artery with retrograde extension of the dissection into the aortic arch and the ascending aorta (DeBakey subtype III-D).⁴ All patients had extensive false lumina beginning from the ascending thoracic aorta distal to the descending thoracic or abdominal aorta, and diagnosis was confirmed only by means of computed tomography (CT) with or without echocardiography. The patients consisted of 7 men and 12 women 47 to 79 years of age, with a median age of 66.2 ± 8.9 years. The intervals from the onset of symptoms to the commencement of the operation varied from 3 hours to 7 days, with an average of 27.4 hours. Four of the patients had cardiac tamponade and preoperative shock, whereas 3 had undergone endotracheal intubation before admittance to our hospital. Other preoperative complications were recognized, such as chronic respiratory failure ($n = 1$, chronic obstructive pulmonary disease requiring oxygen inhalation), unilateral renal ischemia demonstrated by means of enhanced radiographic CT ($n = 2$), and limb ischemia ($n = 2$). Apparent narrowing of the true lumen was noted in 2 patients (Nos. 7 and 12). All operations were performed within 3 hours after the diagnosis was confirmed.

Operative Method

A median sternotomy was performed after achievement of general anesthesia. An arterial perfusion cannula was inserted into the femoral artery, the right axillary artery, or both; venous drainage cannulas were inserted into the superior and inferior venae cavae from the right atrium; and total extracorporeal circulation was commenced. Hypothermic circulation was used to reduce the rectal temperature to 22°C . A left ventricular vent tube was inserted from the right superior pulmonary vein, and aspiration was performed. A crossclamp was applied to the peripheral part of the ascending aorta, a small incision was made in the right atrium, and retrograde cardioplegia was performed under direct vision. The ascending aorta was dissected transversely at the proximal end. Gelatin-resorcin-formol glue (Cardial; Technopole, Saint-Etienne, France) was injected into the false lumen on the proximal side of the ascending aorta, and then the false lumen was dosed. When it was confirmed that the rectal temperature had fallen to 22°C , total circulatory arrest was achieved. The clamp was removed, and the aortic arch was incised longitudinally until immediately before the origin of the left subclavian artery. At the end point, the aortic arch was dissected transversely. Three balloon catheters were inserted into the brachiocephalic artery, the left common carotid artery, and the left subclavian artery for perfusion at a rate of 300, 200, and 100 mL/min, respectively, to maintain perfusion of the brain. A ball-shaped sizer was inserted into the true lumen of the descending thoracic aorta from the transverse incision of the aortic arch, and then the exact diameter of the true lumen was measured. A synthetic graft 8 to 15 cm long, which was previously attached by means of a self-expandable Z-shaped stent with the tip 5 cm on the distal side, was selected with a diameter 3 mm larger than that measured. Then the distally stented graft was placed in a 30F introducer, which was inserted into the descending aorta according to the method reported by Kato and colleagues.⁵ The graft was fixed in the true lumen of the descending aorta by expansion of the Z-shaped stent. The graft was pulled to the transverse dissection line in the distal aortic arch and trimmed to match the dissection line. The left subclavian artery was dissected transversely at the proximal end, and the proximal stump was closed with 4-0 mono-

Figure 1. Schematic diagram of the operation.

filament sutures. The adventitia of the aortic stump was covered with a felt strip 2 cm wide, and the stump was reinforced with continuous 4-0 monofilament sutures. A synthetic graft with 4 branches was anastomosed end to end to the stump of the distal aortic arch with continuous 3-0 monofilament sutures. Then the third branch was anastomosed to the left subclavian artery. The proximal graft was crossclamped, antegrade systemic perfusion from the fourth branch was started, and the patient was rewarmed by means of extracorporeal circulation. Next the proximal graft was anastomosed to the stump of the ascending aorta, and coronary circulation was started after discontinuation of retrograde coronary perfusion. The left common carotid artery and the brachiocephalic artery were anastomosed to respective branches of the graft in succession. This completed the procedure (Figure 1). The mean aortic clamping time, the duration of extracorporeal circulation with selective cerebral perfusion, the total extracorporeal circulation time, and the operating time were 116 ± 31 , 102 ± 22 , 253 ± 48 , and 491 ± 126 minutes, respectively (Table 1). The diameter, length, and distal end of each stent graft are shown in Table 1.

Results

Operative death occurred in one patient. This patient underwent endotracheal intubation at another hospital because of a cardiac tamponade and shock, and accumulation of a large amount of blood in the airways was observed after completion of the surgical procedure. The patient did not recover from respiratory failure caused by hemorrhage that was due

Figure 2. Radiographic CT of patient 7 before the operation: A, Acute type A dissection is noted; B, extreme narrowing of true and false lumina; C, right kidney is not opacified.

to damage to the airway mucosa, which occurred at the time of intubation. The other 18 patients recovered and were discharged.

Postanastomotic bleeding during the operation was the most common cause for prolonging the length of the surgical procedure, and rehemostatic procedures were required in 2 patients. One patient required temporary hemodialysis, and 2 patients with respiratory failure required a temporary tracheostomy. The average duration of intensive care unit stay was 113 hours. Paraplegia was not observed in any patient.

There were no strokes or temporary neurologic dysfunctions after the operation except for postoperative delirium in 2 patients. Endoleakage of the graft with the stent was not observed. Postoperative digital subtraction angiography showed that the primary intimal tears were completely resected in 14 patients of the DeBakey I group or were excluded by the stent graft in 4 patients of the DeBakey III-D⁴ group. Two patients with ischemia of the right kidney caused by narrowing of the true lumen, as demonstrated with radiographic CT, improved significantly after the operation and had blood flow in the true lumen restored. Figure 2 shows the radiographic CT findings of patient 7, who had extreme narrowing of the true lumen of approximately the whole descending aorta and poor opacification of the right kidney before the operation. However, a fully dilated true lumen and a well-opacified right kidney are recognized after the operation in Figure 3, although the

patient underwent permanent axillobifemoral bypass grafting subsequently because of the severe ischemia of both limbs, which was suspected before the operation. Follow-up continued for 2 to 38 months postoperatively, and about every 6 months, examinations with radiographic CT scanning were performed to evaluate the states of the false lumina in 18 discharged patients. The results of the last examination of the respective patients are shown in Table 2.

The false lumen disappeared completely in 10 patients. In 6 patients (Nos. 2, 3, 8, 14, 18, and 19) a persistent false lumen was observed distal to the diaphragm in the descending aorta without any subjective symptoms, and the maximum diameter was 39 to 45 mm, with no enlargement compared with those before the operation, and in 3 of these patients (Nos. 3, 8, and 18), the false lumina at the diaphragmatic level have become thrombosed between from the third and twentieth months after the operation. There was a patent distal false lumen limited in the abdomen of 3 patients (Nos. 3, 8, and 12) in the superior mesenteric artery, but the diameter was only 29 to 32 mm, whereas a patent false lumen exists in one stretch from distal thoracic aorta in 3 patients (Nos. 2, 14, and 19). An additional operation was not considered necessary. All survivors are followed up at our outpatient clinic with only antihypertensive therapy.

Discussion

An acute type A aortic dissection poses a high risk to survival and often necessitates an emergency operation. If

Figure 3. Radiographic CT of patient 7 four months after the operation: **A**, Fully dilated true lumen by stent is noted; **B**, no false lumen is present; **C**, right kidney is well opacified.

TABLE 2. State of false lumen with the last radiographic CT follow-up study

No.	Time after operation (mo)	Hilar level	Diaphragmatic level	SMA origin level
1	38	Disappeared	Disappeared	Disappeared
2	35	Disappeared	Patent; D: 39 mm; T: 20 mm	Patent; D: 32 mm; T: 20 mm
3	27	Disappeared	Thrombosed; D: 45 mm; T: 27 mm	Patent; D: 30 mm; T: 12 mm
4	33	Disappeared	Disappeared	Thrombosed; D: 30 mm; T: 8 mm
5	32	Disappeared	Disappeared	Disappeared
6	Operative death			
7		Disappeared	Disappeared	Disappeared
8		Disappeared	Thrombosed; D: 39 mm; T: 4 mm	Patent; D: 29 mm; T: 12 mm
9		Disappeared	Disappeared	Disappeared
10	21	Disappeared	Disappeared	Disappeared
11	14	Disappeared	Disappeared	Disappeared
12	17	Disappeared	Disappeared	Patent; D: 32 mm; T: 10 mm
13	16	Disappeared	Disappeared	Not involved
14	2	Disappeared	Patent; D: 42 mm; T: 12 mm	Patent; D: 31 mm; T: 12 mm
15	7	Disappeared	Disappeared	Disappeared
16	1	Disappeared	Disappeared	Not involved
17	2	Disappeared	Disappeared	Not involved
18	2	Disappeared	Thrombosed; D: 39 mm; T: 12 mm	Not involved
19	2	Disappeared	Patent; D: 44 mm; T: 22 mm	Patent; D: 29 mm; T: 10 mm

SMA, Superior mesenteric artery; D, aortic diameter; T, thickness of false lumen.

the intimal tear is localized in the ascending aorta, even if the dissection extends to the distal part of the thoracic aorta, only the ascending aorta is usually replaced^{3,6} to limit surgical invasion because the first priority is to save the patient’s life. However, it has been reported that the distal false lumen remained patent in 50% to 70% of patients who underwent ascending aortic replacement for acute type A aortic dissection.^{6,7} Reoperation is often required for dilatation of the false lumen distal to the proximal aortic arch. Therefore, in recent reports total replacement of the aortic

arch at the same time in the same surgical field during the first operation is performed in such a patient, even if the primary intimal tear is located at the ascending aorta.^{8,9} However, if the anastomotic leakage or a small tear in the proximal descending thoracic aorta exists, the false lumen is susceptible to dilation because of shear stress on the proximal descending thoracic aorta, and reoperation may become necessary. Therefore, Ando,¹⁰ Kazui,¹¹ and their co-workers have reported that when the descending thoracic aorta up to the midportion is repaired with a synthetic graft by using the elephant trunk technique as the initial operation, later dilation of the most susceptible parts of the residual false lumen is prevented, and the rate of thrombosis of the false lumen in the descending aorta is higher without any necessity of further operation. However, the diameter of the interpolated graft with the elephant trunk procedure is likely smaller than the distally stented graft in accordance with their reports. A distally anchored stent graft allows insertion of a larger diameter and longer length of elephant trunk. In patients with an intimal tear in the descending thoracic aorta with retrograde false lumen as far as the ascending aorta, it is necessary to extend the operation to the proximal descending thoracic aorta¹² in addition to total replacement of the aortic arch. In such patients this interpolation method, which permits extensive replacement of the thoracic aorta without a left thoracotomy, is much less invasive than conventional methods. These patients are often elderly and have chronic obstructive pulmonary disease. Therefore, postoperative respiratory failure, including a pulmonary hemorrhage, is frequently fatal. Our method does not require a left thoracotomy, and it is very beneficial in this respect. However, dilation of the true lumen of the descending thoracic aorta along with dilation of the false lumen by means of blind insertion of a synthetic graft containing the self-expandable stent, poses the risk of creating a new intimal tear. To prevent this, we determined the most appropriate size of stent graft by measuring the diameter of true lumen with a ball-shaped sizer during systemic circulatory arrest and performed the interpolation and dilation procedures under transesophageal ultrasound guidance.¹³ No intimal tears occurred in the dilated region.

When a long synthetic vascular graft is inserted into the descending thoracic aorta, the risk of paraplegia caused by sacrificing the spinal arteries must be considered. In our experience synthetic grafts with stents have been inserted as far as the Th9 level, and we did not measure the spinal potentials or take any other measurements to predict the occurrence of paraplegia because the patients were treated under hypothermic conditions (22°C). At present, we only

apply knowledge obtained from thoracoabdominal aortic replacements performed with conventional methods, as well as the safety range for percutaneous implantation of stented grafts into the descending thoracic aorta, but we think that we had better not insert the stent graft beyond the level of Th9. In addition, we also believe it is important that we perfuse all 3 branches of the aortic arch and the descending thoracic aorta through 2-way balloon cannulas during selective cerebral perfusion under hypothermic conditions.

In summary, it is possible to perform extensive primary repair of the thoracic aorta for type A aortic dissection with relative safety by interpolating a synthetic graft with a self-expandable stent, and this may lead to less necessity of a second operation for the distal descending aorta.

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