Extended replacement of the thoracic aorta

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Abstract

OBJECTIVES: We present our experience of total aortic arch replacement.

METHODS: Twenty-nine patients (21 males and 8 females; mean age 63.3 ± 13.3 years) with extended thoracic aortic aneurysms underwent graft replacement. The pathology of the diseased aorta was non-dissecting aneurysm in 11 patients, including one aortitis and aortic dissection in 18 patients (acute type A: one, chronic type A: 11, chronic type B: six). Five patients had Marfan syndrome. In their previous operation, two patients had undergone the Bentall procedure, three had endovascular stenting, one had aortic root replacement with valve sparing and 12 had hemi-arch replacement for acute type A dissection. Approaches to the aneurysm were as follows: posterolateral thoracotomy with rib-cross incision in 16, posterolateral thoracotomy extended to the retroperitoneal abdominal aorta in seven, mid-sternotomy and left pleurotomy in three, anterolateral thoracotomy with partial lower sternotomy in two and clam-shell incision in one patient. Extension of aortic replacement was performed from the aortic root to the descending aorta in 4, from the ascending aorta to the descending aorta in 17 and from the ascending to the abdominal aorta in eight patients. Arterial inflow for cardiopulmonary bypass consisted of the femoral artery in 15 patients, ascending aorta and femoral artery in seven, descending or abdominal aorta in five and ascending aorta in two. Venous drainage site was the femoral vein in 10, pulmonary artery in eight, right atrium in five, femoral artery with right atrium/pulmonary artery in four and pulmonary artery with right atrium in two patients.

RESULTS: The operative mortality, 30-day mortality and hospital mortality was one (cardiac arrest due to aneurysm rupture), one (rupture of infected aneurysm) and one (brain contusion), respectively. Late mortality occurred in three patients due to pneumonia, ruptured residual aneurysm and intracranial bleeding. Actuarial survival at 5 years after the operations was 80.6 ± 9.0%. Freedom from the subsequent aortic events was 96.0 ± 3.9% at 5 years.

CONCLUSIONS: Our treatment method for extensive thoracic aneurysms achieved satisfactory results using specific strategies and appropriate organ protection according to the aneurysm extension in the selected patients.

Keywords: Extended thoracic aneurysm • Posterolateral left thoracotomy • Anterolateral left thoracotomy

INTRODUCTION

An aortic arch aneurysm usually appears as an isolated lesion, while multiple aneurysms are not commonly encountered. Extensive arch aneurysms most often occur due to the extensive atherosclerosis or aortic dissection [1, 2]. A one-stage operation of an extensive arch aneurysm requires wide exposure of the aneurysm and dissection, secure organ protection and sound haemostasis [3, 4]. A staged operation is often a preferable choice, with safety as the priority. However, this strategy may result in a greater than expected mortality, considering the combined mortality of the first and second operation, as well as death in the interval between operations [5, 6]. Several options of surgical approach for the extensive aneurysm are available, such as median sternotomy with left pleurotomy or left anterolateral thoracotomy, a clam-shell incision, left posterolateral thoracotomy, etc. In this report, we present our surgical strategy for an extensive aortic arch aneurysm. This study was approved by the internal review board at Kobe University.

METHODS

Twenty-nine patients (21 males and eight females; mean age 63.3 ± 13.3 years) with extended thoracic aortic aneurysms, including those in the thoracoabdominal aorta, underwent graft replacement during June 2002–June 2011. Retrospectively reviewed profiles of the patients are shown in Table 1. The pathology of the diseased aorta was non-dissecting aneurysm in 11 patients, including one aortitis, and aortic dissection in 18 patients (acute type A: 1, chronic type A: 11, chronic type B: 6). Five patients had Marfan syndrome and four had annulo-aortic ectasia. Two patients needed
emergent intervention due to ruptured aneurysm or dissection and one was resuscitated from the cardiopulmonary arrest. One patient had acute type A aortic dissection complicated by a rupture of the descending aorta and right leg malperfusion. Nine patients had chronic type B dissection. Eight patients had extensive dilation further down to the thoracoabdominal aorta.

With regard to their previous operations, two patients had undergone the Bentall procedure, three had endovascular stenting in the descending aorta (two with chronic type B dissection and one with non-dissection), one had aortic root replacement with valve sparing, 12 had hemi-arch replacement for acute type A dissection and three had AAA grafting. Chronic type A dissection (n = 11) was the major aortic pathology in patients who had undergone ascending aortic replacement and had progressive enlargement of residual dissection of the aortic arch and the descending aorta. Three had undergone endovascular thoracic aortic repair from the aortic arch to the descending aorta, followed by progressive aortic dilatation due to type I endoleak (Table 1). Remaining comorbidities are listed in the Table 1.

**SURGICAL PROCEDURE**

Approaches to the aneurism were by posterolateral thoracotomy with rib-cross incision in 16 patients [7], posterolateral thoracotomy extended to the abdominal retroperitoneal in seven, mid- sternotomy and left pleurectomy in three, anterolateral thoracotomy with partial lower sternotomy (ALPS) in two and clam-shell incision in one (Table 2). The details of posterolateral left thoracotomy for these lesions have already been described in our previous reports. With the patient in the right recumbent position, the entire thoracic aorta was exposed through the fourth or fifth intercostal spaces with transection of several ribs (rib-cross thoracotomy) [8]. In cases with lesions in the thoracoabdominal aorta (Fig. 1), the retroperitoneal space was entered after transecting the costal arch. In all cases, there was no sternum transection and the left internal thoracic artery was preserved. The ALPS or clam-shell incision was utilized to expose the aortic root. In the ALPS incision, the sternum was split from the xyphoid process to the third intercostal level, the left half of the sternum was transected and the left internal mammary artery was ligated. Further, an anterolateral left thoracotomy was performed through the third intercostal space to the left mid-axillary line. A bilateral fourth intercostal anterior thoracotomy was performed with a clam-shell approach.

The extent of the thoracic aortic replacement was from the aortic root, ascending aorta and arch to the mid-descending aorta in four patients, from the ascending aorta and arch to the mid-descending aorta in 17 and from the ascending aorta down to the thoracoabdominal aorta in eight patients (as shown in Table 1 and Fig. 2).

Arterial inflow for cardiopulmonary bypass consisted of the femoral artery in 15, ascending aorta and femoral artery in seven, descending or abdominal aorta in five and ascending aorta in two patients. The venous drainage site was the femoral vein in 10, pulmonary artery in eight, right atrium in five, femoral vein with right atrium/pulmonary artery in four and pulmonary artery with right atrium in two patients. Patients were cooled down to 22.9 ± 3.1°C (range: 16–28°C), temperatures measured by a tympanic...
thermometer. An aortic cross-clamping was performed on the mid part of the descending aorta, maintaining lower body perfusion (Table 3).

Plication of the sinotubular junction was performed in three, valve-sparing root replacement in one and aortic valve replacement in one patient, from the mid-line incision in all cases. In patients with a left lateral approach, the aorta was opened from the proximal descending aorta to the ascending aorta mainly up to the previous prosthetic graft for the ascending aortic replacement. Cardioplegic solution was administered from the inside of the ascending aorta with a balloon-tipped catheter, and selective cerebral perfusion was established using balloon-tipped catheters from the inside of aortic arch. First a Dacron graft was anastomosed to the ascending graft or the ascending aorta, then arch reconstruction followed. Brain protection was provided by antegrade selective cerebral perfusion in 25 patients, while in four patients before 2002 we used deep hypothermic circulatory arrest with complementary retrograde cerebral perfusion in some cases (Table 3). Systemic rewarming was initiated after the reconstruction of the arch vessels. Perfusion of the heart and brain was re-established through the side branch of the prosthetic graft. The distal descending aorta was transected at a normal calibre, and the graft was anastomosed to both the true and false lumen. Eight patients with a dilated thoracoabdominal aorta underwent additional replacement down to the previous abdominal Y graft or the terminal aortic bifurcation under the selective perfusion of visceral organs. Intercostal arteries were reattached in 12 patients and 7 patients had reconstruction of the visceral arteries.

**STATISTICAL ANALYSIS**

Data are shown as mean ± SD. Actuarial survival was assessed by the Kaplan–Meier method using the SPSS package for Windows (SPSS Inc., Chicago, IL, USA).
EARLY RESULTS

One patient with a ruptured aneurysm and cardiac arrest died immediately after the operation (operative mortality rate was 3.3%); one patient died 2 weeks after operation because of a ruptured infected aneurysm in the descending aorta (30-day mortality rate was 6.6%) and one patient with coagulopathy died during hospitalization from traumatic brain bleeding on Day 145 (hospital mortality rate was 9.9%).

The cardiopulmonary bypass time was $226.2 \pm 74.0$ min, myocardial ischaemic time was $85.1 \pm 40.3$ min, selective cerebral perfusion time was $78.6 \pm 33.0$ min and CA with retrograde cerebral perfusion time was $37.7 \pm 6.8$ min (Table 3). The average duration of ventilation support was $21.5 \pm 18.7$ h (range: 4–62 h) and the respiratory failure, defined as the necessity of more than 48 h of support by mechanical ventilation, was observed in three patients. Intractable endo-bronchial bleeding was not observed. The length of ICU stay was $3.7 \pm 2.1$ days. The post-operative profiles of the patient groups are shown in Table 2. A reversible ischaemic neurological deficit manifested by right forearm paralysis was observed in one patient, but no other brain complications were noted. One patient, who underwent extended aneurysm replacement down to the thoracoabdominal aorta, had temporary paraparesis and ischaemic colitis, but had recovered completely by discharge.

FOLLOW-UP

Follow-up was 100% completed. The average follow-up was $28.2 \pm 27.3$ months (range: 0.3–83.1 months). During follow-up, late mortality occurred in three patients due to pneumonia, ruptured residual aneurysm and intracranial bleeding. One patient died of pneumonia 19 months after surgery, one of residual distal aneurysm 73 months after surgery and one of the rupture of a pre-existing middle cerebral artery aneurysm 4.9 months after surgery. Actuarial survival rate at 5 years after the operation was $80.6 \pm 9.0\%$ (Fig. 3). Freedom from the subsequent aortic events was $96.0 \pm 3.9\%$ at 5 years (Fig. 4).

DISCUSSION

Patients with mega-aorta syndrome usually present with extensive arch aneurysm or multiple aortic lesions and few clinical surveys have been done in this subset of patients [9]. Crawford et al. [10] reported that the 5-year survival rate of patients with diffuse aneurysmal disease and distal operation was 65%, and 39% in patients who did not have total or subtotal aortic replacement. Patients who underwent ascending aorta or hemi-arch replacement for acute type A dissection sometimes had extensive thoracic aortic aneurysms due to a residual patent false lumen in the distal false lumen. Halstead et al. [11] reported that among 89 patients who had surgery for acute type A aortic dissection, reoperation of the distal aorta was necessary in 6% of the patients at 5 years and 16% at 10 years after the initial operation. Patients often have multiple-staged operations using elephant trunk installation in the descending aorta for the extensive aortic lesions. However, not only the mortality in each staged operation but also the mortality while waiting for the next stage operation should not be forgotten. Safi et al. [5] reported that the initial mortality rate was 6.3% among 254 patients, only 45% of them reached the second-stage surgery and the mortality rate at the second surgery was 9.6%. Similarly, Wong et al. [12] reported that the first-stage mortality rate was 12.2% among 148 patients, 51% reached the second-stage operation and the second-stage mortality rate was 3.9%. Svensson et al. [2] stated that the first-stage mortality rate was 2.1% among 94 patients and 50% reached the second-stage operation with a mortality rate of 8.5%. Scheepens et al. [13] reported that 44% of the patients among 100 patients reached the second-stage operation, whereas it was only 33.3% among 72 patients in the Hannover series [14]. We performed the second-stage operation in another cohort of 81 patients with extensive aortic lesions, with a hospital mortality rate of 9.9%.

In comparison with the staged operation, the single-stage operation is an attractive strategy in terms of providing a rather simple solution when patients are carefully selected. Still, a single-staged operation for extensive aneurysm is accompanied by greater invasiveness and the risk of higher mortality or...
morbidity. In the earlier series of Crawford et al. [15], a higher early mortality rate (16%) was reported in 25 patients with extensive aortic aneurysms; Massimo et al. also reported 14% in 21 patients [16], Minale et al. 12% in 16 patients [17] and Safi et al. 29% in 21 patients [18]. However, a recent series of Kouchoukos et al. [4] demonstrated that the early mortality rate in these entities falls to 7% when using the clam-shell technique. In comparison with other reports, our patients cohort was relatively young and very few had major preoperative comorbidities, such as myocardial infarction, chronic lung disease and renal or hepatic disorders.

Open stenting or the frozen elephant trunk method may be one of the options to reduce the risk of requiring further operation in the arch or in the descending aorta in patients with an acute type A dissection. However, in the chronic stage, the compressed narrow true lumen precludes the use of endovascular stent-grafting in patients who have a dilated residual patent false lumen [19]. Patients with mega-aorta syndrome often have a suitable landing zone between the aortic lesions for endovascular stent-graft, but the shape and diameter of the aneurysm sometimes become determinant factors to proceed to open surgery. In elderly patients with multiple comorbidities staged endovascular procedures may be beneficial, including a debranching technique for the aortic arch or for the thoracoabdominal aorta.

Wide surgical exposure is mandatory and of primary importance to achieve a secure anastomosis in one-stage treatment for extensive thoracic aneurysms. A median sternotomy is the gold standard to access the aortic arch; however, exposure to the mid-descending aorta is limited unless an additional left pleurotomy or left anterolateral thoracotomy is applied. Patients with extensive aortic arch aneurysms from the ascending aorta, aortic arch and extending to the descending aorta usually require left posterolateral thoracotomy without dividing the sternum or left internal mammary artery. In the majority of the current series, we could approach the ascending aorta, aortic arch and the entire descending aorta through the left posterolateral thoracotomy alone [8]. When patients have dilatation of the infra-diaphragmatic aorta, the posterolateral incision can be extended to the left retroperitoneal space, and reconstruction of the visceral arteries or reattachment of the intercostal arteries is technically feasible. Regarding patients with aortic root dilatation, we applied the left ALPS in two and the clam-shell incision in one sometime. Sueshiro et al. [20] and Kouchoukos et al. [4] described the ALPS or clam-shell approach as an excellent procedure for one-stage extended aortic arch replacement especially for patients requiring root replacement and CABG. Massimo et al. [16] and Hu et al. [21] reported the efficacy of multiple independent incisions for the exposure of thoracic and thoracoabdominal aneurysms. As we reported before, left-side rib-cross thoracotomy is another and better option to expose the entire thoracic or thoracoabdominal aorta although meticulous reconstruction of the ribs is required.

During the wide range reconstruction of the thoracic aorta, protection of the multiple organs, such as the myocardium, brain, spinal cord and visceral organs was a crucial issue for the successful outcome in our study. Extracorporeal circulation was basically established with femoral artery return and right atrial drainage through the right femoral vein. In the right decubitus position, femoral vein cannulation was usually sufficed by applying negative pressure. Sometimes additional main pulmonary artery drainage was necessary to obtain good venous drainage. Myocardial protection was reliably obtained by cardioplegic solution delivered through a balloon-tipped catheter placed in the ascending aorta. Maintaining the circulation of the lower extremities by clamping the descending aorta and by perfusion from the femoral artery can eliminate the necessity for profound hypothermia. The efficacy of the antegrade cerebral perfusion was proved by the absence of permanent neurological deficits with the exception of only one patient with temporary right-hand paralysis.

The major concern with the left posterolateral thoracotomy was intraoperative endo-bronchial haemorrhage under a fully heparinized condition. In the majority of cases, mild endo-bronchial haemorrhage was observed, but resolved without respiratory failure. The mean duration of intubation was 19.4 ± 17.0 h, and prolonged respiratory assistance over 48 h was required in three cases (cases 4, 7 and 16), one of which was due to phrenic nerve palsy. Pulmonary complications were observed in six patients (37.5%), but none was lethal. We believe that this is an acceptable rate of pulmonary complications. Redo left thoracotomy in the staged approach should have higher risks of pulmonary complications because of possible adhesion of the lung to the aneurysm or to the graft [22].

There were two postoperative mortalities due to the aortic events. One had rupture of the infected descending aortic aneurysm 2 weeks after the initial operation, due to an unrecognized infection. One patient died of the rupture of the residual dissecting aneurysm 73 months after the surgery. The patient was a 76-year-old male and had end-stage kidney disease with haemodialysis. The routine 6 month-interval follow-up computed tomography (CT) scan showed enlarging dissecting aneurysm in the descending aorta; however, he refused to have further surgeries.

Our study has several limitations. First, a retrospective non-comparative study of a single-stage operation does not strongly confirm advantages over staged surgery for extensive aortic lesions. Secondly, we mostly selected patients without serious preoperative comorbidities. Thirdly, the postoperative follow-up was not long enough to determine the long-term results in this patient cohort.

In conclusion, our treatment method achieved satisfactory results and can be an attractive option for managing extensive thoracic aneurysms by combining specific strategies for appropriate organ protection according to the extent of the aneurysm in patients selected.

Conflict of interest: none declared.

REFERENCES


### APPENDIX. CONFERENCE DISCUSSION

**Dr P. Urbanski (Bad Neustadt, Germany):** I have a comment and a question. Even if the number of patients at risk, which is almost 0 at 5 years, hardly allows the 5-year estimation of survival, I’m convinced that the results presented remain durable because conventional surgery offers definitive treatment in most cases. I am not convinced, however, whether it is possible to focus on a combined surgical approach to a particular surgical approach. In Dr. Okita’s population, 76% of patients needed, in addition to arch repair, a replacement of the descending or even thoraco-abdominal aorta but only 14% needed aortic root repair. This explains the majority of posterolateral thoracotomy among all approaches. Only a few patients with concomitant valve or coronary artery surgery would have changed the ratio considerably.

Nevertheless, I am convinced that the results presented are the result of a well-considered surgical approach. A well-considered surgical approach is a very important part of surgical strategy, not least important than perfusion or organ protection methods. Such a strategy that is based on profound experience is the key to successful surgery of complex aortic arch pathology.

My question to Dr. Okita is regarding the temperature management that apparently changed over the study time. It seems to me that you moved from hypothermia to the brain and brain protection by perfusion. What core temperature and what blood temperature do you use during organ perfusion currently?

**Dr Okita:** Regarding the temperature, in the beginning we started very low, say 20 degrees. But nowadays we have raised the temperature. And as I said in my presentation, recently we perfused the patient at 30 degrees tympanic temperature and the rectal is recorded at about 32 or 33. We’re changing. And regarding the additional coronary bypass or root surgery, these are very selected patients. We excluded all the combined surgery, and patients with comorbidity or other complicated heart procedures. So this is a highly selected, good-risk patient cohort.