The changes of aortic diameter after aortic repair with aortic tailoring technique for chronic type B aortic dissection

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Abstract

OBJECTIVES: Aortic repair with aortic tailoring of the false lumen can preserve the true lumen and intercostal arteries naturally. It is a useful surgical strategy to prevent paraplegia. However, aortic remodelling of tailored segments in a late phase after surgery is another concern. This study investigates the destiny of aortic remodelling of tailored aorta.

METHODS: From June 2004 to April 2013, 21 consecutive patients underwent aortic tailoring operation for chronic type B aortic dissecting aneurysm. The mean age at operation was 60 ± 10 years (range, 43–77). The tailored aortic segments were followed by serial CT scanning with the mean follow-up period of 46 ± 32 months (range, 2–103).

RESULTS: There were no operative deaths but paraplegia in 1, stroke in 1 and reversible renal failure in 2 patients. There were two late deaths: one due to pneumonia and the other due to aneurysmal rupture of the abdominal aorta. Eighteen patients revealed a completely thrombosed false lumen and no expansion of the tailored aorta, with it remaining less than 40 mm in diameter during follow-up. However, 3 cases were associated with a patent false lumen and 2 cases revealed aortic events. The aortic event-free rate at 5 years was 95 ± 5.1% in all patients and 66 ± 27% in patients in the patent false lumen group.

CONCLUSIONS: Aortic tailoring is a useful surgical technique for chronic type B aortic dissection. Paraplegia and ischaemia of other visceral organs could less likely occur. Patients with a completely thrombosed false lumen revealed no aortic events; however, a patent false lumen was associated with a high risk of aortic events.

Keywords: Aortic tailoring • Chronic type B aortic dissection • Paraplegia

INTRODUCTION

The surgical management of chronic type B aortic dissections is increasing in diversity. Thoracic endovascular aortic repair (TEVAR) has been introduced in 1994 for type B aortic dissections [1–3]. The short-term benefits of TEVAR for acute type B aortic dissec- tions are acceptable; however, its long-term advantage for chronic type B dissections is still controversial [4].

Open surgical repair, on the other hand, is still the gold stand- ard strategy and can eliminate the risk of aneurysmal rupture in the treated segment. There has been a significant decrease in mortality and morbidity during the last 15 years in the open surgi- cal treatment of chronic type B aortic dissection [4, 5]. However, paraplegia and paraparesis are still disastrous complications [6, 7]. To avoid these devastating complications, many possibly effective

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methods have been reported and applied such as cerebrospinal fluid drainage, hypothermia, monitoring of evoked spinal cord activity, segmental aortic clamping with optimization of arterial perfusion or neurochemical protection.

Several operative techniques that can preserve the intercostal arteries have also been reported and applied. We have applied the aortic tailoring technique, which reconstructs a true lumen with aortic wall tailoring of the false lumen to maintain blood flow of the maximum number of intercostal arteries possible [8–12]. The reconstructed true lumen is used as an aorta or an interposed graft for reimplantation of intercostal arteries. The former was reported as aortic repair with the aortic tailoring technique and the latter was done as a vascular tube technique for intercostal artery reconstruction [12, 13].

Indication of aortic tailoring is important. Patients with simple and a limited number of entries are better candidates for aortic repair with the aortic tailoring technique. Large and complicated entries are hard to be closed, and less than 2.5 cm in length is feasible for this technique. Non-fragile intima, most of intercostal arteries being branched from the true lumen and a round-shaped true lumen with good blood flow are also better anatomical conditions for the aortic tailoring technique. On the other hand, the vascular tube technique can be applied on complex types of aortic dissection with multiple entries. Aortic repair with aortic tailoring can preserve the patient’s own aorta and intercostal arteries naturally. However, remodelling of the tailored segments of the aorta in a late phase after surgery is another concern. This study evaluated the early and mid-term results of aortic repair with aortic tailoring to investigate the destiny of remodelling of the tailored segments of the aorta.

MATERIALS AND METHODS

Patient selection

Direct aortic repair via a left thoracotomy under a spiral incision was performed in 46 cases from June 2004 to April 2013. Sixteen cases were staged operations after aortic arch repairs with a long elephant trunk procedure via median sternotomy. Twenty-one of 46 cases underwent direct aortic repair with aortic tailoring and 25 cases with tube replacement, 15 of which underwent tube replacement with the vascular tube technique.

The clinical records of 21 consecutive patients who underwent direct aortic repair with aortic tailoring for chronic type B aortic dissection were retrospectively reviewed. Seven cases were staged operations after aortic arch repairs with an elephant trunk. Seven cases had a history of previous aortic repair for acute type A dissection. There were 15 males and 6 females with a mean age at operation of 60 ± 10 years (range, 43–77 years).

Characteristics of the preoperative condition of the patients include hypertension in 18, diabetes in 2, chronic obstructive pulmonary disease in 2 and renal dysfunction in 2 cases. There were no connective tissue diseases including Marfan's syndrome. All cases were principally followed up by CT scanning at 1 month, 3 months, 6 months and every 1 year after surgery. Any findings about aortic events and aortic diameter were recorded. The mean follow-up period was 46 ± 32 months (range, 2–103 months).

Operative management

Our surgical indications for chronic type B aortic dissection were a diameter greater than 6 cm, expansion greater than 5 mm in diameter in the last 6 months or impending rupture with chest pain. Most of patients without deep hypothermia underwent monitoring of spinal cord function by evoked cortical potentials (somatosensory-evoked and motor-evoked potentials). Thirteen patients underwent cerebrospinal fluid drainage.

According to the indications we mentioned above, the site and length of application of aortic tailoring were determined by pre- operative enhanced CT scanning. The sites of application of aortic tailoring included the distal segment of the descending thoracic aorta in almost all cases in our series. The critical intercostal arter- ies such as Adamkiewicz artery were often branched from this segment. Tube replacement was combined on the segment that was anatomically unsuitable for aortic tailoring.

The aortic segments, which were tailored or grafted, are shown in Fig. 1. Twenty patients underwent aortic tailoring for the des- cending thoracic aorta and 1 patient (case 1) for the abdominal aorta containing the visceral and renal arteries. This latter case had a previous Y-graft replacement of the abdominal aorta. Seven patients were repaired only by tailoring for the descending thor- acic aorta. Thirteen patients underwent tailoring for the distal segment of the descending thoracic aorta and graft replacement. In 5 of 13 patients, the proximal segment of the descending aorta was replaced with a graft concurrently; 3 patients had graft re- placement of the proximal descending thoracic aorta, 1 patient (case 2) with Crawford type II aneurysm had graft replacement of the whole descending thoracic and abdominal aorta except a short segment at the diaphragm level 1 patient (case 3) had a Y-graft replacement of the abdominal aorta. Eight of 13 patients had previous surgery for the proximal half of the descending aorta: elephant trunk in 7 and graft replacement in 1.

Operative technique

The aortic tailoring technique primarily consists of complete entry closure, closing the false lumen on the distal end and suitable trimming of the aortic wall of the false lumen to the optimal size (Fig. 2). Complete closure of all entries and re-entries in the tailoring segment is essential to prevent postoperative residual patent false lumen. A proximal aortic clamp was principally applied on the healthy aorta above the dissected aorta and a distal aortic clamp was usually done just above the diaphragm. The false lumen was opened longitudinally (Fig. 2A), and all entries were closed using interrupted pledgeted mattress sutures or a small patch (Fig. 2B). Most of the entries were placed on the edge of the false lumen and the adventitia of the false lumen was usually used to cover entries as a patch. The distal side of the tai- lored portion was reconstructed with closing of the false lumen. The end of the tailored aortic portion was principally transected, and the intima and adventitia were conjugated with reinforce- ment of felt strip to close the false lumen. A short piece of Dacron graft can be applied on the end of tailored segment to close the false lumen and also on the segment that was anatomically unsuit- able for aortic tailoring.

Then, the distal aortic clamp was removed and no bleeding points were confirmed by perfusion of the true lumen. The aortic wall of the false lumen was trimmed and plicated just to cover the true lumen (Fig. 2C). The aortic wall of the false lumen was closed with continuous mattress sutures and over-and-over sutures. After completion of aortic tailoring, the aortic clamps were removed [10–12]. The diameters of the tailored aortic portions were usually around 3 cm.

In patients who underwent the elephant trunk procedure or with sufficient space for aortic clamping on the proximal descending aorta, partial cardiopulmonary bypass (CPB) was established with groin cannulation, and mild hypothermia was applied. Proximal and distal clamps were applied on the target aorta, which was reconstructed. On the other hand, in patients without space for aortic clamping on the distal arch, circulatory arrest was applied

after establishment of total CPB under deep hypothermia with right subclavian artery or ascending aortic perfusion. The aforemen- tioned aortic tailoring was performed under circulatory arrest or low-flow perfusion. Partial CPB was applied with mild hypothermia in 12 patients. Total CPB was applied in 9 patients, with moderate hypothermia in 6 cases and deep hypothermia in 3 cases.

Statistical analysis

All statistical analyses were conducted with SPSS Statistics (V.23.0 for Mac OS). Data were presented as raw numbers with percent- age or mean±standard deviation. Changes of aortic diameters were evaluated using paired t-tests. Cumulative survival rates and postoperative aortic event-free rates were computed using the Kaplan–Meier equations. P-values <0.05 were considered statistic- ally significant.

RESULTS

Early results

The mean operative time was 9.4 ± 4.0 h (5–21). The mean pump time was 221 ± 155 min (73–699). The mean initial ventilation time was 111 ± 248 h (5–1176). The mean ICU stay was 4.9 ± 4.4 days (1– 16). The mean length of hospital stay was 50.6 ± 31.3 days (17–128). All patients survived the operative procedure. There was no hospital mortality and no 30-day mortality. There were several perioperative incidents of morbidity, including stroke (n = 1), paraplegia (n = 1), reversible renal failure (n = 2) and prolonged ventilation longer than 72 h (n = 7). One patient underwent re-exploration for haematoma removal in the left thorax at postoperative day 8. Paraplegia oc- curred in 1 case of Crawford type II aneurysm. This case underwent graft replacement of the whole aneurysm except the short dia- phragmatic segment where the tailoring method was applied.

Changes of aortic diameter

Figure 3 showed the changes in aortic diameter of the tailored segments on serial CT scanning. In 18 patients, the false lumen disappeared, and the tailored aorta did not expand with the diam- eter remaining less than 40 mm (Fig. 3A). The mean aortic diam- eter of the tailored segment was 58 ± 15.8 mm (35–109) before operation, 33 ± 5.4 mm (22–42) at 1 month after surgery, 32 ± 5.6 mm (23–40) at 1 year and 32 ± 6.3 mm (23–39) at 3 years after surgery. The aortic diameter was significantly decreased in all patients ($P < 0.001$). The postoperative aortic diameter was signifi- cantly decreased at 1 year ($P = 0.029$) and

did not show increase at 3 years (P = 0.405). However, the false lumen was still patent in 3 patients (Fig. 3B). One patient revealed re-expansion of the false lumen with a diameter of 52 mm and required TEVAR 6 months after surgery. TEVAR covered recurrent entry at the distal end of the elephant trunk. The other 2 cases showed no expansion of the tailored aorta; however, one of them revealed expansion of the abdominal aortic aneurysm.

Mid-term results

There were two late deaths. One died of pneumonia at 22 months. Another died due to rupture of the abdominal aortic an- eurysm remote from the tailored segment at 6 years after surgery. This case was 78 years of age and did not agree with reoperation for the aneurysmal expansion. The survival rate was 92.9 ± 6.9% at 5 years and 74.3 ± 17.5% at 7 years. Two of 3 patients with a patent false lumen revealed aortic events. One patient required TEVAR at 6 months after surgery. Another died at 6 years after surgery as mentioned above. There was no aortic event in the successful false lumen closure group. The aortic event-free rate at 5 years was 95 ± 5.1% in all patients and 66 ± 27% in the persistent false lumen perfusion group (log-rank test, P = 0.018) (Fig. 4).

DISCUSSION

The optimal surgical management of chronic type B aortic dissec- tions remains controversial [14–16]. The short-term outcomes of modern open surgery are acceptable, although they appear slight- ly poorer compared with TEVAR [4]. A recent meta-analysis reported outcome data from TEVAR and from open surgery of chronic type B aortic dissection [17, 18]. For TEVAR, the pooled rates of early mortality, stroke and spinal ischaemia were 6.6, 1.9 and 1.5%, respectively. The 1-year survival rates were 73–91.3%. The 5-year survival rates were reported to range from 77.7 to 84.4%, and the freedom from reintervention rate was _83% at 1 year and 59–73% at 3 years. For open surgery, the pooled rates of early mortality, stroke and spinal cord ischaemia were 8.0, 5.7 and 5.5%, respectively. The 1-year survival rates were 78%. The 5-year survival rates were ranging from 68 to 92%, and the freedom from reintervention rate was 99% at 1 year and 85–93% at 5 years. The 1- and 5-year survival rates were similar to the rates following TEVAR, whereas rates of reintervention were much lower in the first year (freedom rate of 99%). For aortic tailoring in our series, the rates of early mortality, stroke and spinal ischaemia were 0.0, 4.8 and 4.8%, respectively. The 1-year and 5-year survival rates were 100 and 92.9%, respectively. The freedom from reinterven- tion rate was 94.7% at 1 year and 94.7% at 5 years.

Despite the lower mortality and morbidity of TEVAR, mid-term outcomes are less encouraging, with considerable rates of proced- ural failure due to endoleaks, persistent

false lumen perfusion with aneurysmal dilatation and the need for reintervention [17, 19]. In a recent study using Medicare data in the USA, the authors concluded that despite short-term benefits, TEVAR was associated with poorer outcomes in the long term compared with open surgery [14].

Open surgical repair, on the other hand, can eliminate the risk of aneurysm-related deaths in treated segments [4]. While historical surgical series have demonstrated high mortality rates, contempor- ary series show more acceptable patient outcomes by improve- ment in operative technique and surgical modification [4, 20–25]. However, paraplegia and paraparesis are still disastrous complica- tions. To avoid these serious complications, many possibly effective methods and surgical techniques have been applied.

While graft replacement has been the standard open surgical technique, entry closure with aneurysm plication by aortic tailor- ing is another useful surgical technique to maintain blood flow of the maximum number of intercostal arteries possible. We have applied aortic repair with the aortic tailoring technique in selected cases. With respect to indication for aortic tailoring in the present series, suitable conditions of the aorta include limited size (less than 2.5 cm) and number of entries, non-fragile intimal mem- brane between the true and false lumen, most of the intercostal arteries being branched from the true lumen and good blood perfusion and anatomical shape of the true lumen.

In the AHA/ACC guidelines, open repair is recommended as a Class I recommendation for patients with chronic aortic dissection and a descending thoracic diameter exceeding 5.5 cm; however, the use of TEVAR in case of chronic type B dissection is not recom- mended, because stent grafting is an off-label treatment for aortic dissection [26]. The ESC statement recommends that the treatment of aneurysm in case of chronic type B aortic dissection should be discussed as a multidisciplinary team approach, considering the use of TEVAR versus open surgery [27].

We essentially perform open surgery for the treatment of chronic type B aortic dissection. In the Japanese Circulation Society (JCS) guidelines, entry closure with TEVAR for chronic type B aortic dis- section is recommended where surgery is indicated (Class IIa), in patients having high surgical risk (Class IIb) or where the main branch vessels are perfused from the false lumen (Class III). While the use of TEVAR is recommended only by the JCS guidelines in Japan [28], surgical decision-making for individual patients should be done according to multidisciplinary discussions as recom- mended by EACTS, ESC and EAPCI.

Kölbel T et al. reported that standard TEVAR for chronic type B aortic dissection, which covers the proximal entry alone, has shown unsatisfactory results with one-third of the patients devel- oping further false lumen growth and a mortality rate of 36% at 3 years. Introduction of adjunctive endovascular techniques to prevent distal false lumen back flow is essential [29].

The aortic tailoring technique has the same concept as TEVAR on the point of closure of entries; however, the aortic tailoring technique can shut off retrograde blood flow to the false lumen from re-entries and also effect diameter and volume reduction of the false lumen to reduce the radical force of the aneurysm. There are no comparative studies between aortic tailoring and TEVAR; however, the aortic tailoring technique can shut off the blood flow into the false lumen. It should contribute to a better aortic event-free rate.

Williams [8, 9] and Stone et al. [9] reported tailored aortoplasty in 1993 and 1994, which allows the reduction of ischaemic time of the spinal cord, renal and visceral organs and reperfusion of all patent intercostal and superior lumbar arteries. This technique includes removal of the membrane separating the true and false lumen through a left posterolateral aortotomy from the lower one-third of the descending aorta to the renal arteries. After mem- brane excision, the aortotomy is closed to create a single lumen of 2.5–3.0 cm in diameter. They did not use this tailored approach in cases where there was marked aortic dilatation (>6 cm). In our series, there is no limitation of the diameter itself of the aneurysm. The maximum preoperative diameter of the aorta was 109 mm in our series. Kawashima et al. [30] reported entry closure and aneur- ysmal wall plication by using axillofemoral bypass without CPB. The diameter of the plicated aorta was 2 cm or less in their series. Their operative mortality rate was 20% but no cases of paraplegia occurred. Miyamoto et al. performed a similar technique using CPB, and the diameter of the plicated aorta was 2–3 cm [10]. There was no in-hospital mortality in their series. However, there were several incidents of morbidity, including stroke, recurrent nerve palsy, tracheostomy, repeat operation for bleeding, pneumonia and wound infection. There was no paraplegia or paraparesis complica- tion after surgery. There were 14 of 40 late deaths. The survival rate was92±4%at5yearsand64±9%at10years.

The major advantage of the aortic tailoring technique is that all intercostal and superior lumbar arteries branched from the true lumen are preserved naturally and in relatively short time, and paraplegia is less likely to occur in comparison to other surgical techniques [10–12]. Paraplegia complicated 1 case of Crawford type II aneurysm in our series. This case underwent graft replace- ment of the whole aneurysm except the short diaphragmatic segment that was tailored to preserve intercostal arteries. The reason of paraplegia could not be clarified but it may have been due to hypotension after weaning from CPB.

The aortic tailoring technique brought acceptable short-term and mid-term surgical outcomes in our series. The destiny of the tailored aorta in a late phase after surgery is another concern. In 18 patients with a completely thrombosed false lumen, the tai- lored aorta showed no expansion in the mid-term phase. In cases with a patent false lumen due to unsuccessful entry closure, however, the risk of enlargement of the false lumen still remains. Blood flow of the false lumen was persistent in 3 cases in our series. Although the tailored aortic segment revealed no expan- sion in 2 of 3 patients, 1 patient revealed re-expansion of the false lumen and required TEVAR at 6 months after surgery. The entry was closed and the false lumen thrombosed completely after that. Cautious follow-up by serial CT scanning is mandatory especially on cases with a patent false lumen. The

long-term destiny of the tailored aortic segment has to be clarified even in patients with a completely thrombosed false lumen. Correct surgical manage- ment with complete entry closure and suitable trimming and reinforcement of both aortic ends of the tailoring site is consid- ered to be especially important to shut off retrograde blood flow and to avoid persistent false lumen perfusion and postoperative aneurysmal dilatation. TEVAR may be an effective method to prevent re-expansion of the tailored aorta when patients have a patent false lumen after surgery.

Another concern is blood perfusion to the lower extremities. Miyamoto et al. [10] reported a few cases that necessitated add- itional permanent axillofemoral bypass because of inadequate peripheral perfusion. However, there was no case of peripheral malperfusion or requiring axillofemoral bypass in our series. Patient selection is also important to avoid malperfusion. Good blood perfusion and anatomical shape of the true lumen are suit- able for this procedure.

Many entries and re-entries, fragile membrane between the true and the false lumen, inadequate blood perfusion and irre- versible deformation of the true lumen are not suitable for aortic repair with aortic tailoring [10–12]. The vascular tube technique can be applied on such types of anatomy.

Certain limitations are present in our study. First, we have per- formed aortic tailoring for the treatment of chronic type B aortic dissection mainly more than 6 months after the onset and applied this technique in selected patients as mentioned above. Second, we do not have a suitable control group of TEVAR in our hospital, and a comparative analysis of aortic tailoring and TEVAR is difficult. With respect to surgical strategy, we primarily have performed aortic tailoring for the treatment of chronic type B aortic dissec- tion to close the entries, plicate the false lumen and preserve the main intercostal and lumbar branches. We have performed TEVAR only for the patients having a high surgical risk. Surgical decision-making for individual patients should be done according to multi- disciplinary discussions.

In conclusion, aortic repair with aortic tailoring is a useful surgi- cal technique for chronic type B aortic dissection and resulted in good early and mid-term outcomes. Paraplegia and other visceral ischaemia could less likely occur. Patients with a completely thrombosed false lumen revealed no aortic events; however, a patent false lumen was associated with a high risk of aortic events. Cautious follow-up by serial CT scanning is mandatory, especially on such cases. This technique could be optimal surgical manage- ment in selected patients instead of or combined with conven- tional graft replacement. Further investigation is required to determine long-term benefits of aortic tailoring, as well as the appropriate indication for this procedure.

Conflict of interest: none declared.

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