Antero-lateral partial sternotomy for extensive thoracic aortic aneurysm

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Abstract

OBJECTIVES: Surgical strategies for patients with extensive thoracic arch aneurysm extending to the descending aorta remain controversial. The antero-lateral partial sternotomy (ALPS) approach has been developed as a less invasive alternative single-stage strategy for extensive thoracic arch aneurysm (ETAA).

METHODS: From September 2007 to April 2011, 18 patients underwent elective total arch replacement for ETAA by the ALPS approach (ALPS group). In this approach, a skin incision was made from the bottom of the xiphoid to the anterior axillary line at the third intercostal space with a convex curved line. The thorax was entered through the third intercostal space and a partial lower sternotomy was done. Surgical outcomes were compared with those of 22 patients with ETAA who underwent elective total arch replacement by median sternotomy alone (MS) with regard to the level of distal anastomosis, postoperative complications and mortality.

RESULTS: In the ALPS group, no hospital mortality occurred and one patient experienced pneumonia. No significant difference between the ALPS and MS groups was seen in operative time (384.1 ± 41.6 min vs 402.3 ± 85.3 min P = 0.423) and cardiopulmonary bypass time (220.8 ± 47.1 min vs 236.9 ± 45.4 min P = 0.286). In contrast, distal anastomosis was at a significantly lower vertebral level in the ALPS than in the MS group (5.5 ± 0.4 vs 4.3 ± 0.9, respectively: P < 0.0001).

CONCLUSIONS: The ALPS approach provides good surgical exposure for distal aortic arch aneurysms extending to the descending aorta and ensures the accurate reconstruction of the distal anastomosis without major complications.

Keywords: Extensive thoracic arch aneurysm • Antero-lateral partial sternotomy • Aortic arch

INTRODUCTION

Total arch replacement for thoracic aneurysms is usually approached via median sternotomy [1–4]. However, surgical strategies for patients with extensive thoracic arch aneurysm (ETAA), namely those extending from the aortic arch to the proximal descending thoracic aorta, remain controversial. A single-stage total arch replacement procedure via median sternotomy with a left anterolateral thoracotomy or bilateral anterolateral thoracotomy (clam shell) approach provides good exposure for distal anastomosis at the level of the fourth intercostal space [5]. However, the large incision carries a substantial risk of respiratory complications and delayed wound healing or physical recovery, particularly in elderly patients [6]. Although a two-stage approach with an elephant trunk has also been used, this strategy has disadvantages in the cumulative risk of two major procedures, as well as the additional risk of rupture between the two procedures.

Recently, thoracic endovascular aortic repair (TEVAR) and a hybrid repair method consisting of open surgery with endovascular techniques have been developed as treatment options for thoracic aortic aneurysm. However, many patients with ETAA have other atherosclerotic diseases, including coronary artery disease, carotid artery disease or aortic valve insufficiency. Although endovascular aortic repair and hybrid aortic repair have the benefits of early recovery and surgical healing time compared with open repair, cardiac procedures cannot be performed concomitantly. Additionally, neurological complications associated with a retrograde catheter insertion should be considered, and these endovascular techniques are limited to the complete repair of aortic aneurysm caused by chronic dissection.

Sueshiro et al. [7, 8] have reported surgical cases of acute aortic dissection that were successfully treated using the antero-lateral partial sternotomy (ALPS) approach. ALPS provides excellent exposure of the heart, brachiocephalic arteries and descending thoracic aorta and enables the conduct of concomitant cardiac procedures. Here, we reviewed our surgical experience with the ALPS approach for ETAA and compared surgical outcomes with those of the conventional median sternotomy approach with regard to hospital mortality, morbidity and level of the distal anastomosis.
MATERIALS AND METHODS

This study was approved by the Review Ethics Board of Showa University, Tokyo, which also waived the need for individual consent for participation.

Patients

A total of 124 patients underwent total arch replacement at our institute from September 2007 to April 2011, of whom 40 with ETAA were reviewed. ETAA was defined as an aneurysm that continues from the ascending to the descending aorta, including atherosclerotic aneurysm and type B dissection with dilatation of the ascending aorta. The approach was determined by the operative surgeon according to personal preference; however, the ALPS approach was selected when the distal anastomosis was expected to be distal to the bronchial carina on preoperative computed tomography (CT). Patients with a distal anastomosis above the bronchial carina without severe atherosclerotic change or with a distal thoracic aneurysm for which total arch replacement was not indicated were excluded. Type A dissection and emergency procedures for rupture or impending rupture were also excluded.

Surgical procedure

In the ALPS approach, patients were intubated with a double lumen tube and a skin incision was made from the bottom of the xiphoid to the anterior axillary line at the third intercostal space with a convex curved line. The thorax was entered through the third intercostal space and a partial lower sternotomy was done. The sternum was divided longitudinally along about one-third of its full length. In patients undergoing concomitant coronary artery bypass grafting (CABG), the left internal thoracic artery was harvested after partial lower sternotomy before the sternum was transversely divided. The self-retractor (Condor®, Medicalteknik, Salzkotten, Germany) was introduced and the surgical field was exposed. Under single-lung ventilation, the distal end of the aneurysm was exposed and adhesions were dissected away from the aneurysm itself.

Cardiopulmonary bypass (CPB) was established via a cannula placed in an 8-mm Dacron graft sewn onto the right axillary artery and cannulas in the superior and inferior venae cavae. Core temperature was cooled to 25°C. An antegrade cardioplegia cannula was inserted into the ascending aorta and a retrograde cardioplegia catheter was placed through the right atrium. An additional cannula was inserted into the right superior pulmonary vein to the left ventricle for venting. After clamping of the ascending aorta, cardioplegic cardiac arrest was achieved by the antegrade cardioplegia and maintained by retrograde CP (Fig. 1). The artificial graft (Triplex®, Terumo Co., Tokyo, Japan) was emplaced on the ascending aorta. When the core temperature reached 25°C, circulatory arrest and antegrade selective cerebral perfusion were established. The descending aorta was easily exposed at about the fifth or sixth thoracic vertebral level without pressing the left lung because it was decompressed naturally during CPB. The elephant trunk procedure, in which a vascular graft is invaginated inward and inserted into the descending aorta in a stepwise fashion [4], was used at the distal anastomosis in patients with atherosclerotic change. Direct anastomosis with the double barrel technique was indicated in some patients with chronic aortic dissection. After the distal anastomosis was completed, the circulatory arrest was terminated and antegrade selective cerebral perfusion was also terminated in sequence along with individual reconstruction of the cerebral branches during rewarming. In the MS group, patients were intubated with a single lumen tube and the heart, ascending aorta, aortic arch and arch vessels were exposed through median full sternotomy alone. The other operative procedures, in terms of CPB time, operative technique for the proximal and distal anastomoses and cerebral protection were the same with the ALPS procedure.

Data and statistical analysis

The length of aneurysms was measured using the central line with an open source image analysis software program (OsiriX, v 3.9) on preoperative CT and the diameter of the aorta at the distal anastomosis site and the level of the distal anastomosis were determined by postoperative CT in all patients. Means and standard deviations of each parameter were calculated for the
MS and ALPS groups separately. Group comparisons used the unpaired t-test and Mann–Whitney test as appropriate for numerical data and the χ²-test for categorical data. A P-value of <0.05 was considered significant. All analyses were performed using JMP 9 (SAS, Inc., Cary, NC, USA).

RESULTS

Preoperative patient profiles are summarized in Table 1. The ALPS group consisted of 14 males and 4 females with a mean age of 70.4 ± 4.5 years (range: 59–79). There were two different pathologies, atherosclerotic aneurysm in 13 patients and chronic type B dissection in 5. Intraoperative variables and postoperative course are summarized in Table 2. Concomitant cardiac procedures were performed in 5 patients (27.8%). No cases of hospital mortality, wound infection or ischaemic stroke occurred, but one patient developed postoperative pneumonia and required prolonged mechanical ventilation. The ALPS and MS groups were compared in Tables 1 and 2. The groups did not differ with regard to the length of aneurysm (33.2 ± 3.8 mm in the ALPS group vs 33.2 ± 3.8 mm in the MS group, P = 0.286) or other background factors. One patient in the MS group had a history of cardiac operation (ascending aortic replacement). No significant differences between the ALPS and MS groups were seen in concomitant cardiac procedures, operative time (384.1 ± 41.6 min vs 402.3 ± 85.3 min P = 0.423), CPB time (220.8 ± 47.1 min vs 236.9 ± 45.4 min P = 0.286) or selective cerebral perfusion time (54.4 ± 9.5 min vs 57.4 ± 13.0 min P = 0.439). No hospital mortality occurred in either group. Postoperative morbidities are listed in Table 2. No surgical wound infection or necrosis occurred in either group. One patient in the MS group developed ischaemic stroke postoperatively. Prolonged mechanical ventilation management of >72 h occurred in 1 patient in the ALPS group (5.6%) and 2 in the MS group (9.1%).

Table 1: Preoperative patients profiles

<table>
<thead>
<tr>
<th>Variable</th>
<th>ALPS (n = 18)</th>
<th>MS (n = 22)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>70.4 ± 4.0</td>
<td>73.1 ± 11.6</td>
<td>0.414</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>28.2 ± 4.5</td>
<td>27.4 ± 5.2</td>
<td>0.689</td>
</tr>
<tr>
<td>EF (%)</td>
<td>54.3 ± 5.4</td>
<td>54.3 ± 7.5</td>
<td>0.176</td>
</tr>
<tr>
<td>Hypertension</td>
<td>13 (72.2%)</td>
<td>15 (68.2%)</td>
<td>0.126</td>
</tr>
<tr>
<td>Diabetes</td>
<td>14 (77.8%)</td>
<td>19 (86.3%)</td>
<td>0.075</td>
</tr>
<tr>
<td>Renal failure</td>
<td>1 (5.5%)</td>
<td>1 (4.5%)</td>
<td>0.654</td>
</tr>
<tr>
<td>COPD</td>
<td>2 (11.1%)</td>
<td>3 (13.6%)</td>
<td>0.091</td>
</tr>
<tr>
<td>Previous PCI</td>
<td>1 (5.5%)</td>
<td>1 (4.5%)</td>
<td>0.654</td>
</tr>
<tr>
<td>Previous cardiac operation</td>
<td>1 (5.5%)</td>
<td>0 (0%)</td>
<td>0.478</td>
</tr>
<tr>
<td>Length of aneurysm (mm)</td>
<td>121.4 ± 6.0</td>
<td>116.8 ± 3.5</td>
<td>0.511</td>
</tr>
<tr>
<td>EuroSCORE II</td>
<td>2.41 ± 0.6</td>
<td>2.58 ± 0.8</td>
<td>0.836</td>
</tr>
<tr>
<td>Stroke</td>
<td>1 (5.5%)</td>
<td>2 (9.0%)</td>
<td>0.207</td>
</tr>
<tr>
<td>Chronic aortic dissection</td>
<td>5 (27.8%)</td>
<td>7 (31.8%)</td>
<td>0.438</td>
</tr>
</tbody>
</table>

ALPS: antero-lateral partial sternotomy; MS: median sternotomy; BMI: body mass index; EF: ejection fraction; COPD: chronic obstructive lung disease; PCI: percutaneous coronary intervention; EuroSCORE II: European system for cardiac operative risk evaluation II.

One patient in each group developed postoperative pneumonia (5.6 vs 4.5%, P = 1.000). Aortic diameter at the level of distal anastomosis was greater in the MS than in the ALPS group (33.2 ± 3.8 mm in the MS group vs 30.4 ± 2.8 mm in the ALPS group, P = 0.049), while the vertebral level of the distal anastomosis was significantly lower in the ALPS (5.5 ± 0.4) than MS group (4.3 ± 0.9; P < 0.0001). No patient underwent a second-stage operation.

DISCUSSION

The conventional approach to total arch replacement for aortic arch aneurysm is median sternotomy, which carries an operative mortality of 0.8–5.3% [1–4], indicating that an optimal surgical technique for extensive disease of the thoracic aorta has to be established. The distal anastomosis through a median sternotomy is feasible at the level of the bronchial carina or about the level of the fourth thoracic vertebra [5]. However, it is technically difficult to expose the distal reconstruction site in aortic aneurysms arising from the ascending aorta or aortic arch and extending to the descending aorta and in distal arch aneurysm with an embolizing shaggy aorta, both of which carry the risk of cerebral infarction. In our study, although aeurysmal length was the same between the two groups, the vertebral level of distal anastomosis was lower in the ALPS group. This may imply that the ALPS approach allowed the distal anastomosis to be performed at a narrower, normalized location of the descending aorta.

Inappropriate manipulation of the distal anastomosis can result in uncontrollable anastomotic bleeding, residual aneurysm or pseudoaneurysm. Further, limited exposure of the left pleural space may lead to an excessive manipulation of the left lung, which might in turn lead to intraoperative pulmonary haemorrhage under systemic heparinization.

Table 2: Intraoperative variables and postoperative course

<table>
<thead>
<tr>
<th>Variable</th>
<th>ALPS (n = 18)</th>
<th>MS (n = 22)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCP (min)</td>
<td>54 ± 10.4</td>
<td>57 ± 14.2</td>
<td>0.456</td>
</tr>
<tr>
<td>CPB (min)</td>
<td>232 ± 55.9</td>
<td>245 ± 39.7</td>
<td>0.414</td>
</tr>
<tr>
<td>Operative time (min)</td>
<td>452 ± 104.7</td>
<td>404 ± 85.7</td>
<td>0.689</td>
</tr>
<tr>
<td>Exutubation (h)</td>
<td>42 ± 37.3</td>
<td>38 ± 29.5</td>
<td>0.176</td>
</tr>
<tr>
<td>ICU stay (days)</td>
<td>4 ± 3.1</td>
<td>4 ± 2.5</td>
<td>0.136</td>
</tr>
<tr>
<td>Hospitalization (days)</td>
<td>27 ± 7.5</td>
<td>26 ± 10.4</td>
<td>0.875</td>
</tr>
<tr>
<td>Concomitant procedure (%)</td>
<td>4 (22.2%)</td>
<td>8 (36.4%)</td>
<td>0.654</td>
</tr>
<tr>
<td>CABG (%)</td>
<td>4 (22.2%)</td>
<td>5 (22.7%)</td>
<td>0.456</td>
</tr>
<tr>
<td>Root remodelling (%)</td>
<td>1 (5.6%)</td>
<td>2 (9.1%)</td>
<td>0.207</td>
</tr>
<tr>
<td>AVR</td>
<td>1 (5.6%)</td>
<td>4 (18.2%)</td>
<td>0.261</td>
</tr>
<tr>
<td>Mortality</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>-</td>
</tr>
<tr>
<td>Morbidity</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0.209</td>
</tr>
<tr>
<td>Stroke</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0.383</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>1 (5.6%)</td>
<td>1 (4.5%)</td>
<td>0.654</td>
</tr>
<tr>
<td>Diameter of aorta at</td>
<td>30.4 ± 2.8</td>
<td>33.2 ± 3.8</td>
<td>0.049</td>
</tr>
<tr>
<td>distal anastomosis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thoracic vertebra of</td>
<td>5.5 ± 0.5th</td>
<td>4.3 ± 0.7th</td>
<td>0.0007</td>
</tr>
<tr>
<td>distal anastomosis</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

One conventional strategy for ETAA is a two-staged operation, in which the transverse aortic arch is replaced with an elephant trunk in the first stage, followed after a recovery period by replacement of the descending aorta as the second stage. The well-known disadvantage of this two-staged operation is its high cumulative mortality, which includes in-hospital mortality for the two procedures. Rupture occurring between the two procedures is a risk, and some patients do not complete the staged operation [9]. Several surgical approaches or techniques for a single-stage surgery for ETAA have been reported, including the left thoracotomy approach [10, 11], the bilateral anterolateral thoracotomy (clam shell) approach [12, 13] and the TEVAR [14]. Left thoracotomy is usually used in patients with aortic aneurysm arising from distal aortic arch. Although concomitant coronary bypass operation for left anterior descending or left circumflex coronary artery is also feasible, concomitant aortic root operation and right coronary artery bypass grafting with single left thoracotomy are likely difficult [10]. Even by using the open proximal method, anastomosis of an atherosclerotic and fragile aorta carries the risk of cerebral infarction. Recent publications have reported a stroke rate of 4.0–5.0% after the thoracic aortic replacement using the left lateral approach with deep hypothermic circulatory arrest (DHCA), while antegrade aortic perfusion decreases the incidence of neurological deficit to 7% compared with the 28% reported using retrograde aortic perfusion by femoral artery cannulation [10]. Kouchoukos et al. [12] reviewed surgical outcomes with the clam shell approach for extensive thoracic aneurysm; although they demonstrated low in-hospital mortality (7.2%), the incidence of respiratory complications was high, with rates of prolonged mechanical ventilation for 72 h of 50% and of temporary tracheostomy of 13–18%. Currently, the thoracic endovascular aortic repair (TEVAR) technique, i.e., the frozen elephant technique using total debranching TEVAR, is used for extensive aortic arch aneurysm. The evolution of TEVAR, i.e., frozen elephant technique or total debranching TEVAR for extensive aortic arch aneurysm has been continued. TEVAR is aimed at high-risk or emergent patients who are unsuitable candidates for open single-stage repair. Although many patients with thoracic aortic aneurysm require other concomitant cardiac procedures for the treatment of atherosclerotic diseases, these cannot be performed at the same time as TEVAR. Additionally, cerebral embolic risk caused by retrograde catheter manipulation is unavoidable, and the complete exclusion of aortic aneurysm caused by chronic dissection is limited. Importantly, reported mortality and morbidity rates for this method range widely, from 0 to 11% and 0 to 22%, respectively [14], while the most common procedural cause of late morbidity appears to be different types of endoleaks. Single-stage open surgery for ETAA should therefore be considered for patients who require concomitant cardiac procedures or for young patients expecting better long-term outcomes.

The elephant trunk technique introduced by Borst et al. [15] has greatly facilitated the use of the two-staged operation technique for extended aortic aneurysm, and its modification of the stepwise technique [4] provides the latter with a better operative field for distal anastomosis in single-stage operations. However, although the elephant trunk technique is beneficial in preventing anastomotic bleeding or pseudoaneurysm, graft insertion into an aneurysm with atheroma carries the risk of dislodging a mural atheroma.

The ALPS approach provides excellent exposure from the ascending to descending thoracic aorta and branches. This degree of exposure enables an accurate distal anastomosis, as well as concomitant procedures, including aortic root operation, coronary artery bypass using the left internal thoracic artery and valve operation. Additionally, extensive total arch replacement can be achieved by the ALPS approach without excessive manipulation of the left lung, which can cause respiratory complications perioperatively. In this regard, the descending aorta was, in fact, easily exposed without pressure manipulation of the left lung until about the fifth or sixth vertebral level. This lower invasiveness for the left lung and partial lower sternotomy might be beneficial in stabilizing the left thorax cavity and preserving the postoperative function of the left lung. No significant difference in respiratory complication including prolonged mechanical ventilation and pneumonia, which may accompany the left thoracotomy approach, was seen in the two approaches in our present study. In addition to respiratory complications, no differences between the ALPS and MS groups were seen with regard to other perioperative complications, namely deep sternal infection, stroke, acute kidney injury and myocardial infarction. In this study, the 2 patient cohorts differed in some characteristics, such as with regard to the non-randomized selection of patients receiving ALPS procedure and the diameter of the aorta at the distal anastomosis site. The important point is not which approach is superior, but rather the fact that compared with the median sternotomy approach, the ALPS approach extends the distal anastomosis by one thoracic vertebral width or ~5 cm distally. This 5-cm advantage might enable an effective distal reconstruction of the non-diseased descending aorta without atherosclerotic change. Furthermore, it might also allow the avoidance of the risk of dislodging a mural atheroma in cases in which the elephant trunk technique is employed, and might also help prevent anastomotic bleeding perioperatively, as well as residual aneurysm or pseudoaneurysm because of an incomplete distal reconstruction in the longer term.

Limitations

Several limitations of this study warrant mention. First, the number of patients was low, hampering the comparison between the two groups. A more comprehensive evaluation requires the accumulation of clinical experience with the long-term follow-up. Further, the study was conducted with a retrospective design, and should be compared with other methods in a prospective randomized study.

In conclusion, we confirmed the suitability of the ALPS approach as an alternative surgical method in patients with extensive thoracic arch aneurysm. This approach allows the anastomosis to be performed more distally to the bronchial carina than with the median sternotomy approach, and the opportunity for concomitant cardiac surgery.

Conflict of interest: none declared.

REFERENCES


