*Table 1. Patient Characteristics*

| Characteristic | CBT (n 8) | ILVA (n 10) | ARSCA (n 3) |
|---|---|---|---|
| Age (y) | 70.6 4.1 | 70.2 12.0 | 73.9 2.2 |
| Male/female | 4/3 | 3/7 | 1/2 |
| Cause | | | |
| Aortic aneurysm | 7 | 8 | 1 |
| Chronic dissection | 0 | 2 | 1 |
| ARSCA aneurysm | 0 | 0 | 1 |
| Preoperative diagnosis | 8 (100%) | 4 (40%) | 3 (100%) |

ARSCA aberrant right subclavian artery; CBT common brachiocepharic trunk; ILVA isolated left vertebral artery.

procedure without arch vessel anomaly. Therefore, this type of anomalous arch vessels did not pose any significant surgical challenge during TAR.

### *Isolated Left Vertebral Artery*

In the cases in which this particular anomaly was discovered intraoperatively, the vessel was simply clamped until the reconstruction of the ILVA was completed. Selective cerebral perfusion with two-vessel perfusion through the innominate artery and left common carotid artery was first used. Then the ILVA reconstruction was performed, after which rewarming was started. In the two cases in which the existence of the ILVA was diagnosed preoperatively with magnetic resonance angiography, direct cannulation and perfusion of the ILVA with an 8F balloon-tipped catheter was undertaken. The ILVA was the dominant arch vessel in these patients and was wide enough for the insertion of the catheter (Fig 2). However, cannulation of the ILVA was not undertaken in the other 2 patients who also had preoperative diagnosis of this vessel because the ILVA in those patients was not the dominant arch vessel. The techniques of ILVA reconstruction are shown in Figure 3. In 7 patients (70%), a side-hole was made on the left subclavian artery graft, and the ILVA was anastomosed to that hole. In 2 patients (20%), a side-hole was made on the native left subclavian artery, to which the ILVA was anastomosed (Fig 3B). In 1 patient (10%), the ILVA was reconstructed with an en-bloc technique (Fig 3C).

### *Aberrant Right Subclavian Artery*

Selective cerebral perfusion was established with three-vessel perfusion through the right common carotid artery, left common carotid artery, and left subclavian artery. The ARSCA, which originated as the fourth arch branch, was simply clamped. After the proximal descending aorta was circumferentially resected distal to the ARSCA orifice, a distal aortic anastomosis with a four-branched aortic arch graft was performed. The anastomoses of left subclavian artery and proximal aorta were performed next. The right subclavian artery was then exposed and resected on the right side of the trachea and esophagus, after which the right subclavian artery was anastomosed in an end-to-end fashion with another piece of 8-mm graft (Hemashield, Meadox Medical, Oakland, NJ). After completing this anastomosis, right subclavian artery perfusion was started through the graft. After reconstruction of the right common carotid artery and left common carotid artery was completed, the 8-mm graft of the right subclavian artery was anastomosed to the aortic graft as its most proximal branch (Fig 4).

## Results

There were no early or in-hospital deaths in the 21 patients with arch vessel anomalies who underwent TAR. There were no permanent or temporary neurologic complications attributable to the arch vessel anomalies. The extracorporeal circulation data of the 19 patients are as

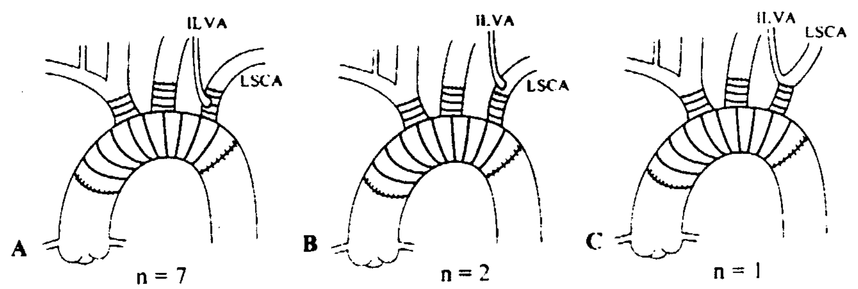


*Fig 3. (A) The isolated left vertebral artery (ILVA) is anastomosed to the side-hole of the left subclavian artery (LSCA) graft. (B) The isolated left vertebral artery is anastomosed to the native left subclavian artery. (C) The isolated left vertebral artery and left subclavian artery are reconstructed with en-bloc technique.*

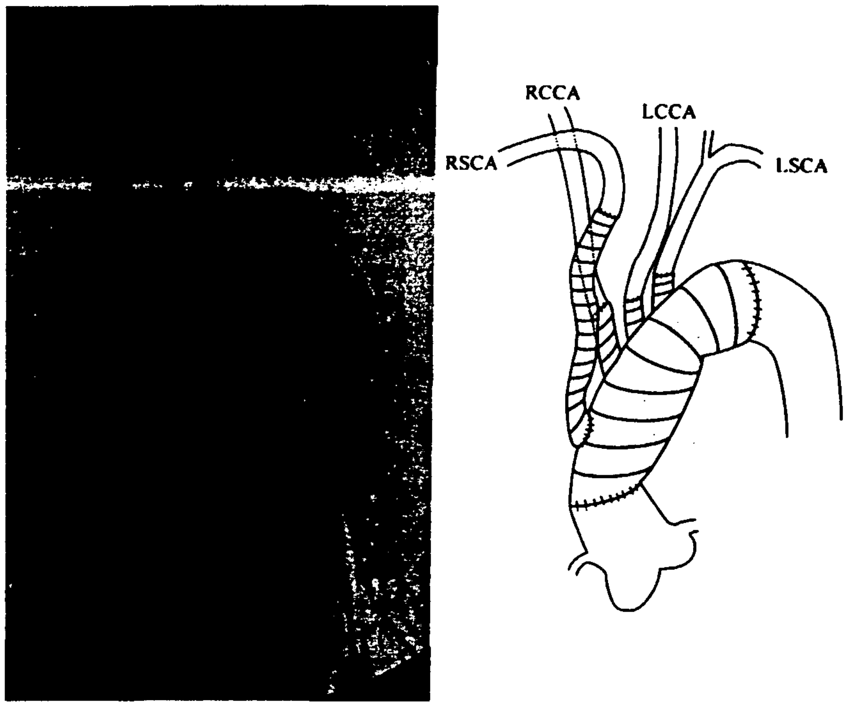


*Fig 4. (Left) Digital subtraction angiogram with schematic after total arch replacement in a patient with aberrant right subclavian artery (ARSCA). (Right) The right subclavian artery (RSCA) was reconstructed on the right side of the trachea and esophagus. (LCCA left common carotid artery; LSCA left subclavian artery; RCCA right common carotid artery.)*

follows: the mean total pump time was 208.3 97.8 minutes; the mean SCP time, 95.6 20.3 minutes; and the circulatory arrest time, 41.9 15.4 minutes. The data were not significantly different from those of the patients having TAR without arch vessel anomalies.

## Comment

Adachi [1] classified the branching pattern of the aortic arch into seven groups (groups A through G) on the basis of his experience with the dissection of 516 Japanese cadavers. The arch vessel anomalies most frequently encountered were CBT (type B), ILVA (type C), and ARSCA (type G). According to his report, the frequency was 10.9% for CBT, 4.3% for ILVA, and 0.2% for ARSCA [1]. Williams and Edmonds [2] reported their findings about arch vessel anomalies after dissecting 407 human cadavers: 191 American whites and 216 blacks. According to their report, the frequencies of arch vessel anomalies in white and black populations were 17.8% and 37.8% for CBT, 2.6% and 2.0% for ILVA, and 1.0% and 0% for ARSCA, respectively. The above data suggest that the incidence of the CBT variety of arch vessel anomaly might be higher among the black population. Obviously, the finding needs to be validated against larger data sets. Unfortunately, there has been a relative paucity of data in this area of research.

In dealing with the CBT variety, we separated the innominate artery and the left common carotid artery from the common trunk to ensure a more precise arch vessel cannulation for antegrade SCP during arch repair. We were concerned that the insertion of a single cannula in the common trunk might sometimes result in accidental slippage of the cannula into any one of the branches, resulting in inadequate perfusion in the other. Another reason behind the separation of the two vessels was that we wanted to perform the anastomosis at a site that was free from atherosclerotic changes. The short common trunk as well as the bifurcation often has such atherosclerotic changes. Separation of the two vessels was easily accomplished, and, thereafter, no special device or strategy was necessary for cerebral protection and arch reconstruction. Among all types of arch vessel anomalies, the ILVA is the most difficult to diagnose preoperatively. Therefore, they are most often discovered intraoperatively. In the present study, only 4 of the 9 patients (40%) with ILVA could be diagnosed preoperatively. The ILVA is usually a small vessel and is often obscured by other larger arch branches, making its preoperative detection considerably more difficult. Of the 4 patients in whom a preoperative diagnosis was possible, 3 had their diagnosis made with the help of magnetic resonance angiography and 1 with three-dimensional computed tomographic scan. In our experience, magnetic resonance angiography and three-dimensional computed tomographic scan were very useful in the diagnosis of ILVA and in interpreting the dominance of vertebral arteries. However, as ILVA is usually revealed intraoperatively, it is necessary to take special precaution while the arch branches are dissected and exposed. It is difficult to insert the perfusion catheter into the ILVA because of its small diameter. Therefore, in most cases, the vessel has to be simply clamped. However, this entails the risk of neurologic deficit owing to poor perfusion to the brainstem or cerebellum if the arterial communication at the circle of Willis is inadequate. Thus, it is important that the systemic temperature is sufficiently lowered. When the ILVA was discovered intraoperatively, we reasoned that the ILVA should be reconstructed rather than sacrificed because the dominance of the vertebral artery was unknown. The reconstructive procedures of the ILVA are shown in Figure 3. Although anastomosis with the native left subclavian artery as depicted in Figure 3B is the most advantageous from the viewpoint of long-term patency, this requires wide exposure of the left subclavian artery and anastomosis at a very deep position. When the origin of the ILVA is close to the left subclavian artery, the en-bloc technique as shown in Figure 3C is easy and useful. However, severe atherosclerotic changes are usually present at this site, and the ILVA or the left subclavian artery is often involved in aneurysmal dilatation of the aorta. As a result, the en-bloc technique, despite its advantages, cannot be used in most patients with ILVA, even when the latter originates near the left subclavian artery. The technique of left subclavian artery anastomosis shown in Figure 3A may, therefore, be the easiest and most useful.

It is not difficult to diagnose ARSCA preoperatively. With our cerebral protection method, the bilateral common carotid arteries and left vertebral artery were perfused under hypothermia. Although this proved sufficient in avoiding neurologic complications, additional ARSCA perfusion might be needed if the right vertebral artery is found to be dominant on preoperative magnetic resonance angiography. Even when the aneurysmal change does not extend to the orifice of the ARSCA, or the ARSCA itself does not expand to form an aneurysm, distal aortic anastomosis should be performed distal to the ARSCA orifice, and the right subclavian artery should be reconstructed distal to its intersection with the trachea and esophagus. This will circumvent the possibility of aneurysmal dilatation of the orifice of this vessel as well as the vessel itself in the future and prevent tracheoesophageal compression symptoms. In fact, the patients with ARSCA in our series did have aneurysmal dilatation of the ARSCA orifice with degenerative changes in the artery itself. Others have also reported similar findings [5, 6].

In conclusion, surgical treatment of anomalous arch vessels can be accomplished with a satisfactory outcome if a precise preoperative diagnosis can be established. Magnetic resonance angiography and three-dimensional computed tomographic scan may be useful tools for diagnosing arch vessel anomalies, particularly the ILVA variety. When TAR is performed in patients with arch vessel anomalies, it is important to select the most appropriate method for cerebral protection and arch vessel reconstruction. As the ILVA is often revealed intraoperatively, careful manipulation of the arch branches and adequate systemic cooling during SCP are very important for avoiding neurologic complications.

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Gen Thorac Cardiovasc Surg (2007) 55:502–504
DOI 10.1007/s11748-007-0174-y

CASE REPORT

# Successful repair of ascending aortic pseudoaneurysm using autograft patch from fascia lata and saphenous vein

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Received: 20 June 2007 / Accepted: 14 August 2007


**Abstract** An 80-year-old man developed a pseudoaneurysm in the ascending aorta due to mediastinitis following cardiac surgery. We successfully repaired the pseudoaneurysm with an autograft patch harvested from fascia lata and the saphenous vein. The repair, which was carried out in two layers, can be expected to be durable.

**Key words** Pseudoaortic aneurysm · Fascia lata · Mediastinitis

## Introduction

Infectious aortic pseudoaneurysm is an intractable disease. Artificial material used for the repair is poorly tolerated in this situation. Although homograft repair can be a good option,[1] its use is limited. We performed a successful double-layer repair of an ascending aortic pseudoaneurysm using an autograft patch harvested from fascia lata and saphenous vein.

## Case

The patient was an 80-year-old man who had undergone mitral valve repair and coronary artery bypass grafting using a saphenous vein graft. Mitral valve replacement using a bioprosthesis was required for progressive hemolytic anemia 3 weeks later. The latter surgery was complicated by mediastinitis caused by methicillin-resistant *Staphylococcus aureus*. Because of major bleeding from the saphenous vein graft, emergent re-sternotomy was done, and ligation of the saphenous vein, débridement, irrigation, and omentopexy were performed. Despite the prolonged use of injectable antibiotics, an aortic pseudoaneurysm in the ascending aorta was detected 2 months later (Fig. 1A). The pseudoaneurysm was located at the arterial cannulation site. We planned pseudoaneurysm repair with an autograft patch under deep hypothermic circulatory arrest.

After establishing extracorporeal circulation using femoral artery and venous cannulations, cooling was started. Cardiac massage was done to prevent possible distension of the left ventricle under ventricular fibrillation. The fascia lata and saphenous vein were harvested from the left thigh. The autograft patch was constructed by affixing the two materials with each other and was then sized and arranged in two layers in such a way that the saphenous vein formed the inner layer and the fascia lata the outer layer. When the rectal temperature dropped to 20°C, sternotomy with omental dissection was performed. After circulatory arrest, the pseudoaneurysm was opened (Fig. 2A). Due to the use of deep hypothermic circulatory arrest technique, extensive dissection was not required. The aortic defect was repaired using an autograft patch measuring 2 cm in width (Fig. 2B). Circulatory arrest time was 15 min.

The mediastinal infection was controlled, and no recurrence of the pseudoaneurysm was detected 5 years after the operation.

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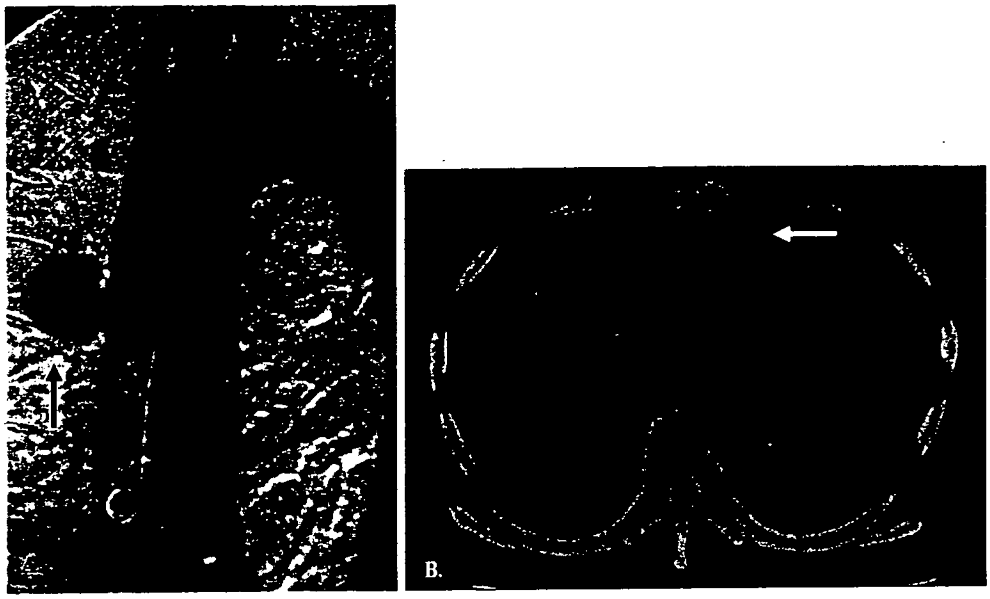


**Fig. 1** **A** Preoperative aortogram. *Arrow* indicates a pseudoaneurysm in the ascending aorta. **B** Preoperative computed tomogram. *Arrow* indicates a pseudoaneurysm in the ascending aorta

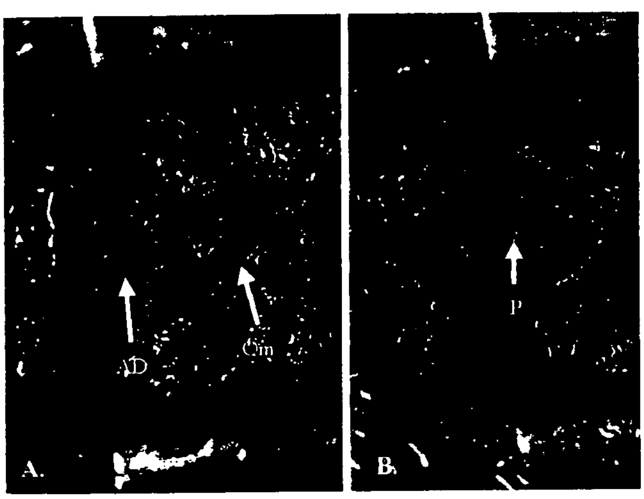


**Fig. 2** Operative findings. **A** Peudoaneurysm is opened, and aortic edge is trimmed under deep hypothermic circulatory arrest. **B** *AD*, aortic defect; *Om*, dissected omentum. **B** Patch repair with autograft is performed. *P*, autograft patch

## Discussion

There have been several reports of ascending aortic pseudoaneurysm following cardiac operations.[2] Among them, pseudoaneurysms after mediastinitis are particularly intractable. Yamazaki et al. reported two cases of successful repair of pseudoaneurysm in the ascending aorta using a fascia lata patch.[3] They used double-folded fascia lata, which was found to be durable. We also successfully repaired a pseudoaneurysm in the ascending aorta with autograft patches consisting of fascia lata and saphenous vein in layers. The durability of both patches was satisfactory. Papadimitriou et al. documented 2-year durability of the fascia lata patch used to replace a short segment of the ascending aorta in a canine study.[4] Wylie et al. described experimental and clinical use of fascia lata for major artery repair.[5] We thought that the layer of saphenous vein might be useful with regard to aortic wall strength and antithrombosis. Therefore, we arranged a two-layered autograft patch by putting fascia lata over a sutured venous patch.

Fascia lata is usually used in general thoracic surgery for filling defects in the chest wall,[6] diaphragm,[7] and pericardium.[8] We have previously examined in an experimental model the tensile strength of fascia lata used for diaphragm reconstruction.[9] Based on the results of that experimental study, we thought that suture line strength of fascia lata should be adequate even when it is used for aortic reconstruction.

A double-layer autograft patch consisting of fascia lata and saphenous vein may be an effective material for reconstruction of an infective aortic pseudoaneurysm.

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EDITORIAL

# What Expectations are Realistic in the Surgical Outcome of Acute Type-A Aortic Dissection?

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Acute type-A aortic dissection is a life-threatening condition in which emergency surgical intervention is almost always required to prevent sudden death from aortic rupture or vital-organ malperfusion. In-hospital mortality following this complex surgery is reported to be 15–30%, although a few centers have reported less than 10%. Improved surgical outcome is said to be closely related to the surgeon's experience, diagnostic advances such as the use of transesophageal echocardiography and computed tomography (CT) resulting in earlier surgical referral, and appropriate surgical techniques. Surgical techniques include the use of graft exclusion, open distal anastomosis, biological glue such as gelatin resorcin formaldehyde (GRF) and Bioglue, collagen-impregnated Dacron grafts, improved cerebral protection such as deep hypothermic circulatory arrest with or without retrograde cerebral perfusion and antegrade selective cerebral perfusion, antegrade systemic perfusion after the distal graft anastomosis, and axillary or subclavian artery cannulation to avoid malperfusion of the vital organs. Better perioperative and anesthetic care has also significantly improved surgical outcome.

However, recent reports on surgical outcome following acute type-A aortic dissection repair are not particularly encouraging. Data from the International Registry of Acute Aortic Dissection Investigators provides a good example. Compiled from 526 patients at 18 referral centers world-wide and published in 2005, the report shows an in-hospital mortality of 25.1%[1]—a figure that appears unchanged in 3 decades. Are we missing something here? Why have these major centers been unable to reduce in-hospital mortality for this particular condition to an acceptable level despite continuous effort? Can these centers somehow have not benefited from advances over the years? This becomes a reasonable question when we look at the Annual Report of the Japanese Association for Thoracic Surgery for 2003. In a cohort of 2,247 patients operated on for acute type-A aortic dissection at 385 institutions across Japan, in-hospital mortality was 14.5%.[2] What is responsible for this gap? Are Japanese surgeons somehow practicing superior surgical techniques or are centers participating in the International Registry operating under somewhat different circumstances? What, then, are the realistic expectations for in-hospital mortality following surgery for acute type-A aortic dissection?

Established determinants of in-hospital mortality following this surgical intervention include preoperative conditions such as shock, organ malperfusion (coronary, cerebral, abdominal visceral), comorbidities such as renal dysfunction and chronic obstructive pulmonary disease (COPD), and surgical techniques including cerebral protection. The type and location of the institution is also considered important in determining outcome. A primary care center with an active emergency department must deal with all sorts of cases. A tertiary referral center, however, may never see the moribund patients who die before reaching the hospital—a type of "natural selection." Such natural selection has almost no positive influence on the surgical outcome at tertiary centers, however. Last but not least is the case volume of a given institution or surgeon. Even the busiest of centers usually conduct fewer than 15 cases involving acute type-A dissection a year, although their routine open-heart cases such as coronary artery bypass grafting (CABG) and valve replacement procedures may exceed 1,000 a year. If 5 staff surgeons work at such centers and cases are evenly distributed among them, this becomes a mere 2–3 cases of acute type-A dissection per surgeon per year, which is simply not enough for surgeons to improve their skill and expertise.

Indeed, the surgeon's experience greatly affects in-hospital mortality following acute type-A aortic dissection surgery. Westaby et al. reported 6% in-hospital mortality in his single-surgeon experience with this

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condition.[3] In my experience, in-hospital mortality is 1.5%—a single mortality in a recent personal series of 65 consecutive patients. As Dr. Bachet first pointed out, however, surgical outcome cannot be expected to be as satisfactory when young, less-experienced surgeons on-call at midnight or on the weekends are asked to deal with cases coming at these times.[4] It is thus reasonable to assume that the impact of such factors on surgical outcome is not reflected in published data.

If we agree that preoperative conditions are comparable among published series, the factor left explaining these gaps in outcome is case-volume-related—the experience and expertise of surgeons. This means that surgical risk must be evaluated considering relatively unexplored factors such as type and location and case volume of a given institute and individual surgeons' experience to gain greater insight into why many institutions have been unable to achieve the required success in surgical management of acute type-A aortic dissection.

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# 2．胸部大動脈瘤外科治療の最近の成績

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**key words**　thoracic aortic aneurysm, cerebral protection, spinal cord protection, paraplegia, extended aortic replacement, stent-graft

近年，胸部大動脈瘤に対する手術成績は良好なものになってきたが，置換部位によりその手術成績は大きく異なっている．2003年日本胸部外科学会の集計による本邦での胸部大動脈瘤に対する待機手術の部位別の手術関連死亡率は上行大動脈置換1.8%，上行～弓部大動脈置換5.8%，弓部～下行大動脈置換8.0%，下行大動脈置換3.6%，胸腹部大動脈置換13.4%であった[1]．手術成績が向上したとはいっても依然として弓部大動脈置換，胸腹部大動脈置換の病院死亡率が高く，また弓部大動脈置換では脳梗塞，胸腹部大動脈置換では脊髄梗塞による術後対麻痺がいまだ完全には解決されない問題として残されている．大動脈基部に対する手術は自己大動脈弁温存術式が注目され，その遠隔期成績も報告されるようになってきた．また広範囲大動脈置換を要する症例に対しての一期的手術の報告もみられるようになってきた．ステントグラフト治療の目覚しい進歩も認め，近年，大動脈外科治療体系の一つの手段として期待されるようになった．

以上のことを踏まえ，体外循環時の動脈送血部位，大動脈基部再建法，弓部大動脈手術における脳保護法，胸腹部大動脈手術における脊髄保護法，急性大動脈解離，広範大動脈置換，ステントグラフトの項目に分け，最近の進歩について述べたい．

## A．体外循環時の動脈送血部位

体外循環を確立するにあたり，胸部大動脈瘤症例では，全身の動脈硬化が強い可能性を念頭において動脈送血部位を選択しなければならない．上行大動脈の性状不良な場合には上行大動脈送血は好ましくなく，大腿動脈からの送血では逆行性に塞栓物質が吹き上がり脳梗塞発生に関与していることが指摘されている．近年，送血部位として右腋窩動脈の有用性が報告されるようになった．Strauchは右腋窩動脈送血が上行大動脈および弓部大動脈手術において選択的脳灌流法が容易に行うことができ，脳塞栓症の予防の点でも有用であると指摘しており[2]，直接カニュレーションでの成功率は95%で，カニュレーションに伴う合併症として上腕神経叢損傷（0.7%），局所的解離（1%）を認めたことも報告している．Sabikは右腋窩動脈送血を行った392例を検討した結果，術後合併症を低下させることが可能であったと報告している[3]．なお，直接カニュレーションするよりも人工血管を吻合してからカニュレーションすることを推奨している．Svenssonは1352例の循環停止

法を併用した手術を検討し，右腋窩動脈送血症例での脳梗塞発生率の低下を報告している[4]．また以前から急性A型大動脈解離においても右腋窩動脈送血の有用性が報告されているが，一方，Fuscoは急性A型大動脈解離において大腿動脈送血は多くの場合安全であり，臓器灌流不全は2.5%にすぎなかったと報告している[5]．

## B. 大動脈基部再建法

composite valve conduitを用いた大動脈基部置換術は，手術成績だけでなくその遠隔成績も良好であり確立された術式となっている[6]．一方，近年，reimplantation法あるいはremodeling法による自己弁温存術式の中期成績も報告されるようになった．Betheaは65例の自己弁温存術式を検討し，reimplantation法が弁輪拡大を防止し，大動脈弁逆流の発生頻度を低下させることを報告している[7]．またreimplantation法の際には，大動脈弁の動きをより自然に近いものとし弁のストレスを軽減する目的でDePaulis Valsalva graftが考案されている[8]．DePaulis Valsalva graftは全ての基部再建において緊張のかからない冠動脈再建が可能であり，優れた人工血管であることが報告されている[9]．Marfan症候群に対しても自己弁温存術式を選択すべきは議論のあるところであるが，症例を選択して reimplantation法を用いることで良好な成績が期待できることが報告されている[10,11]．

また当科では初回にcomposite graft replacementが施行されたMarfan症候群において遠隔期に大動脈基部または弓部大動脈に対して再手術を要した14例を検討した結果，冠動脈吻合部の合併症を予防するためには冠動脈ボタンを大きくしないこと，またDeBakey I型大動脈解離症例では弓部大動脈全置換を併施することが望ましいことを報告した[12]．

## C. 脳保護法

弓部大動脈手術おける脳保護法が確立してきたことは外科治療成績の向上に大きな貢献をもたらしたといえる．欧米では以前から脳保護法としてその簡便性から超低体温循環停止法あるいは超低体温併用の逆行性脳灌流法を用いる施設が多かった．しかし，最近になり逆行性脳灌流法はむしろ神経心理学的検討では障害を起こす可能性が高いことが指摘され[13]，循環停止時間が30分以上の症例には脳神経障害の発生頻度が高く，脳保護時間が長時間に及ぶ場合にはいずれの方法も好ましくないことが認識されるようになった．一方，最近では選択的脳灌流法の有用性が広く世界に認められるようになってきた[14,15]．選択的脳灌流の有用性は日本において実験的および臨床的に実証されてきているが，近年海外からその有用性を述べた文献が多数みられている．Kouchoukosは脳の循環停止を短時間とし，右腋窩動脈からの一側脳灌流補助下に弓部分枝再建を先行する弓部全置換術を推奨している[16]．Neriはcerebral autoregulationの観点から他の脳保護法と比較して選択的脳灌流法が優れていることを報告している[17]．Strauchは実験的検討において，脳血流，酸素消費量，頭蓋内圧の点で選択的脳灌流の有用性を再確認しており[18]，また臨床的にも低体温と選択的脳灌流の併用が術後脳障害を防止する上で有用であり，特に腋窩動脈送血を推奨している[19]．Di Eusanioはmulticenter studyを行い，選択的脳灌流補助下に弓部大動脈手術を施行した588症例の在院死亡率8.7%，permanent neurological dysfunction 3.8%であり，選択的脳灌流法が優れた脳保護法であることを報告した[20]．当科でも330例の選択的脳灌流法を用いた手術症例を検討しpermanent/temporary neurological dysfunction 4.2%/2.4%で，特に複雑で時間を要する手術手技の際には有益であることを報告した[21]．

また選択的脳灌流法の際に体温をどの程度下げるべきかは依然として議論の残るところである．Strauchは実験的検討を行い，超低体温併用選択的脳灌流法を施行したほうが術後のbehavioral scoreが良好であったことを報告している[22]．術後のQOL（quality of life）の観点からの検討も行われており，Immerは脳保護を要した胸部大動脈手術症例に対してSF36（36 Health Survey Questionnaire）を用いた術後QOLの評価を行い，20分以上を要した超低体温循環停止法でQOL低下を認め，特に35分以上を要した症例で顕著であったが，選択的脳灌流法を用いた症例では良好であったと報告している[23]．

また弓部大動脈置換術の手術手技に関しては，本邦では以前から分枝付グラフトを用いたseparated graft techniqueが使用されてきたが，欧米においても近年その有用性に注目し使用されるようになってきた[24]．en bloc techniqueと比較し，再建分枝の止血が容易で，また弓部分枝分岐部に多発する動脈硬化性病変を完全に切除できるため脳塞栓防止の点からも有利と考えられている．Di Euanioは選択的脳保護法を補助手段として用いて，230例のseparated graft technique例と122例のen bloc technique例とを比較検討し，separated graft techniqueはen bloc techniqueに比較して優るとも劣らない結果であり，その有用性を示唆している[25]．またSpielvogelは独自の三分枝人工血管を作成してその有用性を報告している[26]．Kouchoukosも最近ではarch first techniqueにおいて4分枝付人工血管を使用していると報告している．

急性A型大動脈解離に対する上行～弓部大動脈置換術を施行する場合でも脳保護法として選択的脳保護法を用いることにより，良好な手術成績が得られることが報告されている[27,28]．当科では選択された症例に対して積極的にseparated graft techniqueによる上行～弓部大動脈全置換術を施行してきたが，早期および遠隔期成績は良好であり，弓部大動脈に対する遠隔期再手術を減少させ，かつ下行大動脈以下の再手術を容易にすることを報告した[29]．

## D. 脊髄保護法

胸腹部大動脈置換手術における術後対麻痺の予防は現在の大動脈外科において最大の課題といってもよい．術後対麻痺の原因としては脊髄虚血に由来するが，その脊髄虚血の誘因は多元的であることから，単一の方法にて予防することが可能ではなく，種々の方法が併用されており，また新しい試みもなされているが，いまだ確立された予防法がないのが現状である．脊髄虚血の対策として現在では，術前のAdamkiewicz動脈の同定，遠位大動脈灌流，低体温，肋間動脈再建，脳脊髄液ドレナージ，神経保護薬の使用，術中MEP（motor-evoked potential）モニター等が用いられている．術中の脊髄虚血モニターとして，MEP測定がSEP（somatosensory evoked potential）に比較してより有用であり，広く使用されるようになってきたが，最近false-negativeの症例があることが指摘されている．Kakinohanaは灰白質に広範な梗塞をきたしても$\alpha$ motor neuronが正常に保たれている場合にはfalse-negativeになり得ることを実験的に明らかにしている[30]．

神経保護薬としてShiはNa/Caチャンネル遮断薬であるNS-7の脊髄保護効果を実験的に立証し報告している[31]．Kiziltepeは赤ワインに含まれるポリフェノールであるresveratrolの脊髄保護効果を過酸化脂質であるmalondialdehydeの抑制の観点から報告している[32]．Toumpoulisらはischemic preconditioningの有用性を実験的に再検討し，45分虚血に対しても有用であったと報告している[33]．Isbirはischemic preconditioningとnicotinamide投与を併用することで脊髄保護

効果が上がることを実験的に検討している[34].

Coselliは遠位大動脈灌流の必要性をretrospectiveに検討し，下行大動脈置換において左心バイパスを補助手断として用いた群を，clamp and sewで施行した群と比較し，脊髄傷害の頻度はほぼ同様であり，左心バイパスが術後対麻痺減少に寄与していないことを報告している[35]．しかし，広範大動脈置換を要するCrawford II型胸腹部大動脈瘤に対する手術においては，遠位大動脈灌流が脊髄虚血の予防に有利であることは指摘されている．Kouchoukosは超低体温循環停止法による192例の下行大動脈および胸腹部大動脈置換症例を検討し，早期対麻痺発生はCrawford I型で1/36，II型で0/42，III型で2/31であり，その脊髄保護効果の有意性を報告している[36].

胸腹部大動脈瘤術後の脊髄障害による対麻痺はAdamkiewicz動脈の再建の問題だけでなく，術中低血圧，側副血行路の問題等の複数の要因が指摘されている．StrauchはAdamkiewicz動脈だけでなく腰動脈，仙骨正中動脈，鎖骨下動脈の血流の重要性を実験的に検討し報告している[37]．Biglioliは剖検51例を検討し，全ての症例で前脊髄動脈の連続性は保たれており，70.5%の症例で腰動脈からAdamkiewicz動脈が分岐していたと報告している[38]．またステントグラフト治療における対麻痺の頻度は，手術による人工血管置換と比較し低いことが報告され，周術期の低血圧（MAP＜70mmHg）だけがステントグラフト後対麻痺の危険因子であったと報告している[39].

## E. 急性大動脈解離

近年，いくつかの施設から良好な治療成績が報告されているが，The International Registry of Acute Aortic Dissection Experienceの検討では，急性A型大動脈解離に対する手術成績は在院死亡率25.1%で高率であり，循環動態が不安定であった群では31.4%であったと依然としてその治療成績は不良であると報告している[40].

80歳以上の超高齢者における急性A型大動脈解離の手術成績はきわめて不良で年齢は手術適応を決定する一つの因子になり得ることが以前報告されていたが，近年は高齢者に対しても良好な手術成績が散見されている．Eusanioは多施設共同研究において，脳保護として選択的脳灌流法と使用すると75歳以上の急性A型大動脈解離症例であっても手術成績が変わらないことを報告した[41]．またChiappiniは70歳以上の症例の手術成績は，70歳以下と同様であったことを報告している[42].

Takaharaは弓部大動脈に内膜亀裂を有する症例に弓部大動脈全置換術を行う際にelephant trunk法を用いて遠位側大動脈吻合を施行し，下行大動脈の偽腔閉塞率は73.5%であったことを報告している[43]．一方Mizunoは急性A型大動脈解離でstented elephant trunkを施行した9例を検討し，下行大動脈の偽腔閉塞には寄与したが2例に術後対麻痺をきたしたと報告している[44].

## F. 広範大動脈置換術

広範胸部大動脈瘤に対する手術手技のアプローチに関しては従来より議論の多いところである.

広範大動脈置換での二期的アプローチにおけるelephant trunk techniqueの有用性も再確認され，Svenssonらは142例のelephant trunk techniqueを検討し，二期的な下行大動脈または胸腹部大動脈置換またはステントグラフト治療に有用かつ安全であったと報告している[45]．Safiは321例のelephant trunk techniqueを検討し，二期的手術に有効であり，手術完遂後の5年生存率は71%であったと報告している[46].

近年，一期的に胸部大動脈を広範囲に置換し，良好な成績が報告されるようになった．以前，胸

骨正中切開からpull-through法での一期的置換術を施行し，二期的手術での最終的な治療成績と相違ないものであったとの報告もみられたが，Kouchoukosは両側前方開胸アプローチ（clam-shell）から弓部分枝を先に再建するarch-first techniqueを用いた一期的広範胸部大動脈置換術を報告している[47] 46症例を検討した報告では在院死亡率6.5%，術後脳梗塞はなく5年生存率75%であった[48].

Karckはfrozen elephant trunk techniqueと称して，ステントグラフトを下行大動脈に挿入することで広範囲胸部大動脈の治療を試みている[49]．また慢性大動脈解離例に対して広範胸腹部大動脈置換を施行する場合，左心バイパスではなくF-Fバイパスを用いる際に臓器灌流不全が危惧されるようであれば腹部大動脈から先に再建を行うretrograde repairも有用である[50].

最終的に大動脈全置換または大動脈亜全置換となった症例の多くはMarfan症候群の症例であるが，対麻痺を発症しなければQOLは比較的良好で[51]，今後このような全置換症例の増加が予想される．Iguchiらは18年間のMarfan症候群に対する手術成績を振り返り22症例に計42回の大動脈手術を施行し（7例で大動脈全置換），5生率90.2%，10生率74.4%であったと報告している[52].

## G. ステントグラフト

ステントグラフト治療の比較的良好な報告がなされているものの，遠隔期の問題点として，endoleak，durability，migrationがあげられ，根治的治療という点では問題が残されている．近年，徐々に胸部大動脈瘤に対する中期成績が報告されてきており，その治療の位置づけが明確化しつつある．また下行大動脈だけでなく，弓部大動脈に対するステントグラフト治療の試みも行われるようになってきている．

下行大動脈に対するステントグラフト治療は解剖学的に留置が比較的容易であるため臨床例において多く試みられてきたが，動脈硬化の強い症例では塞栓症，endoleak，migrationが問題とされ，その遠隔期成績は今後の検討を待たなければならない．Brandtはopen surgeryと比較し，手術関連死亡，ICU滞在期間，入院期間の早期手術成績では有意にステントグラフト治療が優れていたことを報告している[53]．Neuhauserは動脈硬化性下行大動脈瘤に対するステントグラフト治療31例（待機18例，緊急13例）の中期成績（平均15カ月）を報告し，周術期死亡率19%，technical success rate 55%，経過観察中に新たにtype I endoleakをきたした症例が23%であったと報告している[54]．Bortoneは132例の下行大動脈瘤症例を検討し，ステントグラフト治療における早期死亡率は3.9%，平均20.92カ月のfollow-up期間中に6.3%の死亡を認めたのに対して，内科的治療群では死亡率40.9%であったと報告している[55].

胸部大動脈瘤破裂はいまだに救命率は低く，治療における課題の多い疾患である．胸部大動脈破裂症例に対するopen surgeryを施行した群とステントグラフト治療を施行した群を比較検討した文献では，周術期死亡率はopen surgery群で17.8%であったのに対して，ステントグラフト群では3.1%であり，著明に急性期救命率を改善していたが，follow up中のreinterventionやlate complicationはステントグラフト群で多い傾向にあり引き続き注意深い観察が必要であると結論している[56].

弓部大動脈瘤に対する外科治療成績は，脳保護法の確立に伴い前述のごとく良好なものとなってきたが，従来の外科治療ではhigh riskの弓部大動脈瘤症例に対してステントグラフト治療が試みられている．Czernyは弓部分枝をtranspositionした後に弓部大動脈瘤に対して行うステントグラフト治療は，open surgeryが不可能な症例に対

する第一選択になり得ることを示唆している[57]．また左鎖骨下動脈に限ってはtranspositionを施行しなくても機能障害を残すことはなかったことも報告されている[58]．

Shimonoは下行大動脈に内膜亀裂を有する急性および慢性大動脈解離に対するステントグラフト治療の在院死亡率2.7%であったと報告している[59]．その後同施設からの中期遠隔期成績では[60]，ステントグラフト留置から2年後のCTにおいて，急性期に治療を施行した症例の76%，慢性期に施行した症例の36%で偽腔の消失を認めていた．しかしながら急性期に施行した症例の21.9%において経過中に追加手技を要していたことにも注意を払わなくてはならない．またDuebenerは破裂や臓器灌流不全等の致死的合併症を伴う急性B型大動脈解離に対する急性期救命処置としてのステントグラフト治療の有用性を報告している[61]．

また比較的限局した大動脈病変である外傷やPAU（penetrating atherosclerotic ulcer）はステントグラフト治療のよい適応ではないかと考えられている．Rousseauは外傷性大動脈損傷76例を検討し，ステントグラフト治療は通常のopen surgeryが危険と思われる症例においては有効な治療であることを報告している[62]．またDemerはPAUに対してステントグラフト治療を行った26例を検討し，初期成功率92%，5年生存率70%，5年の治療成功率65%としているが，遠隔期のステントグラフト関連合併症のために注意深い経過観察を要することを報告している[63]．

## むすび

以上，カニュレーション法，大動脈基部再建法，脳保護法，脊髄保護法，急性大動脈解離，広範大動脈置換，ステントグラフトの項目に分け，胸部大動脈瘤外科治療の最近の進歩につき述べた．

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doi:10.1510/icvts.2006.144428

INTERACTIVE CARDIOVASCULAR AND THORACIC SURGERY

Interactive CardioVascular and Thoracic Surgery 6 (2007) 283-287

www.icvts.org

Institutional report - Vascular thoracic

# Total arch replacement for aneurysm of the aortic arch: factors influencing the distal anastomosis☆

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Received 16 September 2006; received in revised form 26 January 2007; accepted 29 January 2007

**Abstract**

Total arch replacement (TAR) for aneurysm of the aortic arch through the midsternotomy has several advantages over left thoracotomy. The purpose of this study was to identify the factors that might have an effect on the distal anastomosis through midsternotomy. From October 1999 to August 2005, 125 patients underwent TAR for aneurysm of the aortic arch through midsternotomy. Ninety-four patients with antegrade cerebral perfusion were selected. Distal anastomosis was performed under circulatory arrest (CA) of the lower body. Preoperatively, the diameter of aneurysm, the depth of distal end of aneurysm from anterior skin surface and the anteroposterior diameter of body trunk were measured. Postoperatively, the distance from the carina to the distal anastomosis was measured. There were six early deaths (6.4%). Duration of CA was 37±7.6 min. Diameter of the aneurysm was 60.6±13.2 mm and the depth of the distal end of aneurysm was 139±20.6 mm. There was no correlation between CA time and these factors. The anteroposterior diameter of body trunk was 200±18.0 mm and has a correlation with CA time. The depth of distal end of aneurysm from anterior skin surface was the only factor that affected duration for distal anastomosis.


*Keywords:* Total arch replacement; Arch aneurysm; Circulatory arrest; Midsternotomy

## 1. Introduction

Surgical treatment of arch aneurysms has remarkably improved in recent years [1, 2]. Total arch replacement (TAR) for aneurysm of the aortic arch through the midsternotomy has several advantages [1]. However, in TAR, distal anastomosis through midsternotomy is sometimes compromised because of a fragile aortic wall, and narrowed or deep working space. In anecdotes, midsternotomy was used for the aneurysm of arch approximately at the level of tracheal bifurcation and if the aneurysm extended more distal, left thoracotomy was employed [1]. The definitive indications of midsternotomy for arch aneurysm were not reported. The purpose of this study was to identify the factors that might affect on the distal anastomosis when the arch aneurysm was entered from the midsternotomy.

## 2. Patients and methods

### 2.1. Patients

From October 1999 to August 2005, 130 consecutive patients with non-dissected aneurysm of the aortic arch underwent TAR in our institution. In 125 patients, the aneurysms could be approached through midsternotomy alone. For brain protection, selective antegrade cerebral perfusion (SCP) was used in 94 patients and deep hypothermia circulatory arrest, with retrograde cerebral perfusion in 31 patients. In this study, patients who had SCP were selected. Mean age was 74±6 (57–86) years. Aneurysm shapes were 51 fusiform and 43 saccular.

### 2.2. Operative techniques

Cardiopulmonary bypass (CPB) was established by using ascending aortic cannulation and bicaval drainage. Both antegrade and retrograde cardioplegia were used to myocardial protection. Aneurysm was opened under deep hypothermic (nasopharyngeal temperature 23 °C) circulatory arrest (CA). SCP for the cerebral protection was started with balloon-tipped catheters which were selectively inserted in all three arteries. The orifice of the descending aorta, which was distal to the aneurysm, was transected from inside of the aneurysm without touching the left vagal nerve and the left recurrent nerve. Aggressive dissection and division of the esophageal branches, bronchial arteries, and upper intercostal arteries facilitated adequate mobilisation of the descending aorta. A quadrifurcated Dacron graft was used and distal anastomosis was performed with 4-0 polypropylene suture with reinforcement of a Teflon

☆ Presented at the joint 20th Annual Meeting of the European Association for Cardio-thoracic Surgery and the 14th Annual Meeting of the European Society of Thoracic Surgeons, Stockholm, Sweden, September 10–13, 2006.

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Fig. 1. (a) Aneurysm was opened after circulatory arrest. (b) Selective antegrade perfusion (SCP) was started with selective three balloon catheters. The descending aorta was transected from inside of the aneurysm. (c) Using a quadrifurcated graft, distal anastomosis was performed with 4-0 polypropylene suture with Teflon felt reinforcement under deep hypothermic (23) circulatory arrest of the lower body. (d) During rewarming, the ascending aorta was anastomosed, then individual reconstruction of arch vessels to the graft branches was performed.

felt strip. Rewarming was started after the distal anastomosis. In patients without intra- or extra-cranial vascular lesions, the ascending aorta to graft anastomosis was achieved and the coronary arteries were reperfused. Finally, individual anastomosis of the left subclavian artery, the left common carotid artery, and the brachiocephalic artery to the graft branches were performed with 5-0 polypropylene suture. For patients who had cranial vascular obstructive lesion, reconstruction of arch vessels was performed prior to rewarming and to the proximal anastomosis (Fig. 1).

### 2.3. Measurements

Preoperatively, the diameter of aneurysm (Fig. 2), the depth of distal end of aneurysm from anterior skin surface (Fig. 2b) and the anteroposterior diameter of body trunk (Fig. 2c) were measured using computed tomography (CT). During the operation, the aortic wall was subjectively evaluated according to the severity of atherosclerosis in the point of aortic fragility and calcification, and classified into three grades (1: mild, 2: moderate, 3: severe). Postoperatively, distance from the middle point of the tracheal bifurcation to the distal end of the anastomosis was measured by CT (Fig. 3).

### 2.4. Statistical analysis

All analyses were performed using the Stat view version 4.5 statistical package (Abacus Concepts Inc., Berkeley, CA) and Sigmastat software.

Continuous data are expressed as the mean $\pm$ standard deviation. Multivariate logistic regression was used to identify independent predictors of prolonged CA and the correlations between CA time and four factors (a~d) were analysed. A $P$-value of 0.05 or less was considered significant.

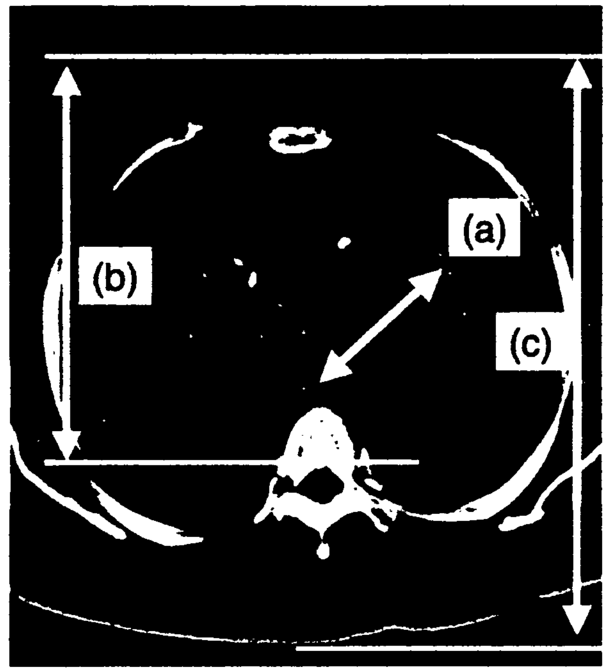


Fig. 2. The diameter of aneurysm (a), the depth of distal end of aneurysm from anterior body surface (b), and the anteroposterior diameter of body trunk (c), was measured by computed tomography.

## 3. Results

The overall in-hospital mortality was 6.4% (6 of 94 patients). No patients required additional skin incision or left pleurotomy. Two patients died due to respiratory dysfunction, two multi-organ failures, one low output syndrome and one sepsis. As the morbidity, 5 patients (5.3%) had respiratory dysfunction, 3 (3.2%) mediastinitis, 3 (3.2%) renal dysfunction, and 3 (3.2%) neurological dysfunction, and 4 (4.3%) hoarseness.

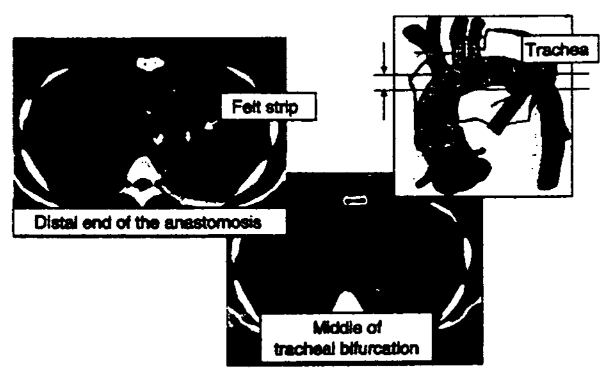


Fig. 3. The postoperative distance from tracheal bifurcation to the distal end of the anastomosis by CT.

Table 1
The measurements of anatomical, operative and postoperative factors

| | |
|---|---|
| Preoperative measurements (mm) | |
| Diameter of aneurysm | 60.6±13.2 (25–91) |
| Depth of the end of aneurysm from anterior skin level | 139±20.6 (80–180) |
| Anteroposterior diameter of body trunk | 200±18.0 (160–240) |
| Depth ratio | 0.70±0.08 (0.39–0.85) |
| Operative measurements (min) | |
| Surgery time | 391±128 (225–845) |
| Cardiopulmonary bypass time | 168±61 (115–263) |
| Aorta cross-clamp time | 70±30 (38–195) |
| Circulatory arrest time | 37±7.6 (24–49) |
| Aortic wall score | 1.92±0.9 |
| Postoperative measurements (mm) | |
| The distance from the distal end of the anastomosis to the tracheal bifurcation | 10.7±7.9 (−10 to 30) |

### 3.1. Preoperative measurements

The mean diameter of aneurysm was 60.6±13.2 mm. The mean distance between distal end of aneurysm and anterior skin level was 139±20.6 mm (Table 1).

### 3.2. Intra-operative measurement

Duration of lower body CA was 37±7.6 min. The aortic wall score at the distal anastomosis, which was subjectively evaluated by a surgeon (Y.O.), was grade one (normal or trivial) in 24 patients, grade two (moderate) in 25, and grade three (severe) in 36. The mean aortic score was 1.92±0.9. Eighteen patients required a longer CA time (over 40 min). The main reasons for this time consuming was fragile aortic wall; two had aortic injury, one needed concomitant endoarterectomy, and one had adhesion to pleura. In five patients, the surgeon subjectively felt that the distal anastomosis was very deep (Tables 1 and 2).

Table 2
The factors which prolonged circulatory arrest time over 40 min

| | |
|---|---|
| Aortic wall quality | n=11 |
| Poor aortic wall | 9 |
| Endoarterectomy | 1 |
| Aortic injury due to poor aorta | 2 |
| Other | n=6 |
| Adhesion to pleura | 1 |
| Surgeon's feeling to be deep | 5 |

### 3.3. Postoperative measurements

The distance from the distal end of the anastomosis to the mid-portion of the tracheal bifurcation was 10.7±7.9 (−10 to 30) mm (Table 1).

### 3.4. Correlation

The correlation between CA time and the five factors: the diameter of aneurysm (Fig. 4a), the depth of the distal end of aneurysm from anterior skin (Fig. 4b), the antero-posterior diameter of body trunk (Fig. 4c), and the distance between the distal end of the anastomosis and the tracheal bifurcation (Fig. 4d) were analysed. There was no significant correlation between CA time and the diameter of aneurysm, the anteroposterior diameter of body trunk, and the distance from the distal end of the anastomosis to the tracheal bifurcation. However, a weak correlation between the depth of distal end of aneurysm from the anterior skin and with CA time was found ($P=0.0085$, $R^2=0.11$).

The logistic regression for multivariate analysis demonstrated that the depth of distal end of aneurysm from the anterior skin level over 150 mm was the only risk factor (OR: 28.1; CI: 1.73–456.9; $P=0.02$) for CA time over 40 min (Table 3).

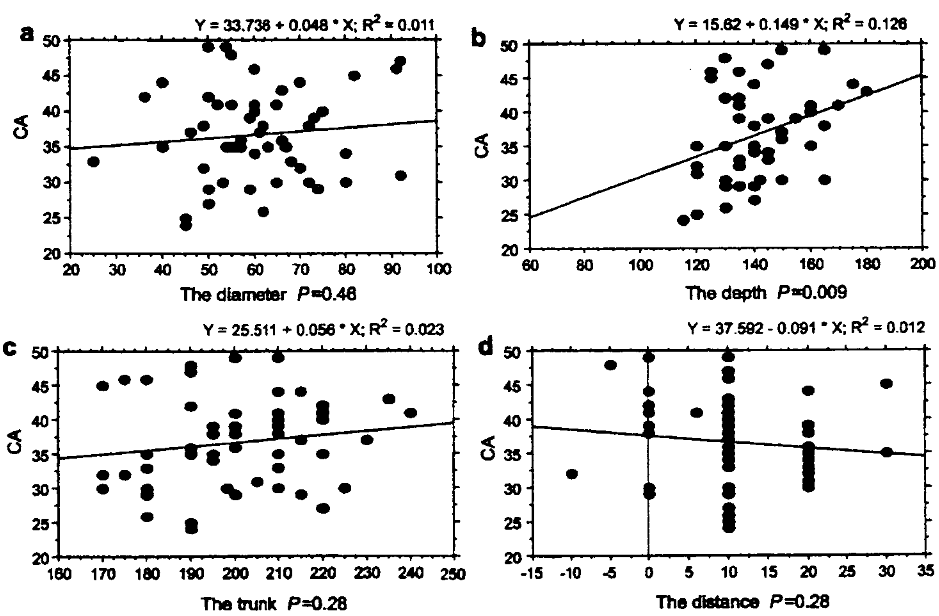


Fig. 4. The correlation between the CA time and (a) the diameter of aneurysm, (b) the depth of distal end of aneurysm from anterior body skin level, (c) the anteroposterior diameter of body trunk, (d) the distance from tracheal bifurcation to the distal end of the anastomosis.