



Open repair of thoracoabdominal aneurysm in the endovascular era

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Abstract

In this endovascular era, open repair of thoracoabdominal aneurysm is a rare operation in regional hospitals. Adjuncts to the repair including left heart bypass and spinal cord protection remain controversial. This is a presentation of a successful case of open repair of a type II thoracoabdominal aneurysm in a local hospital, and a discussion of the overviews of current medical practice on this issue including the experience of our institute.

Keywords: Thoracoabdominal aneurysm, open repair, left heart bypass

Case

A 46-year-old lady had Bentall's procedure performed 12 years ago for ascending aortic aneurysm, postoperatively complicated by acute subdural hemorrhage and recovered well. She also had open ovarian cystectomy performed 20 years ago for a benign ovarian cyst. She had Asherman's syndrome presented with premature menopause.

The patient was asymptomatic. However, follow-up computer tomography scan showed fusiform aneurysmal dilatation of the descending aorta. The widest part of the aneurysm was at the diaphragm hiatus and extending to the abdominal aorta at the renal level, measuring 6.3cm x 5.8cm in axial plane and 6cm in coronal plane. The widest part of ascending aorta was 4.7cm in caliber, and the arch was 3.3cm in diameter (**Figure 1**). The echocardiogram showed ejection fraction to be 65-70% with no significant atrial regurgitation or pericardial effusion.

Open repair of thoracoabdominal aneurysm was performed instead of endovascular stenting due to the large caliber of thoracic aorta. Lumbar drain was inserted by the anesthetist one day before the operation. The cerebrospinal fluid (CSF) pressure was kept in close monitoring during the operation. Intraoperatively, the patient was noted to have a type II thoracoabdominal aneurysm extending from the descending aorta to the aortic bifurcation. The widest part of the aneurysm was at the suprarenal and renal region, measuring 6.2cm in diameter. The distal aortic arch and proximal descending aorta were 4.2 to 4.5cm in caliber. The aneurysm involved the celiac artery, superior mesenteric artery (SMA) and both renal arteries.

The operation was performed together with the cardiothoracic surgeons. The patient was under one-lung ventilation with the left lung deflated. The patient was held in right side down position, with the shoulders at 60 degrees and the hips at 30 degrees. Risberg left thoracoabdominal incision was made from the fifth intercostal space to the left paramedian line. Preperitoneal space was dissected lateral to the left colon.

The aorta was exposed after developing the avascular plane anterior to the psoas muscle and posterior to the left kidney. The diaphragmatic crus was divided. The inferior mesenteric artery was ligated and divided. Left heart bypass (LHB) was used to provide distal perfusion during the proximal part of the repair. The left inferior pulmonary vein was cannulated as the outflow for oxygenated blood, and distal inflow returned to the distal descending aorta (**Figure 2**). Proximal clamp was applied distal to the left subclavian artery, while the distal clamp was applied across the aorta at T4 level. Incision was made at the thoracic descending aorta (**Figure 3**). Back bleeding was controlled by plication of the intercostal arteries. The aorta was transected 2cm distal to the proximal clamp and separated from the esophagus. Proximal anastomosis was carried out using continuous 3-0 polypropylene suture with a 26mm straight Gelsoft Dacron graft (Vascutek, UK) (**Figure 4**). After the first anastomosis, the proximal clamp was repositioned onto the graft, and the distal clamp was repositioned to the distal abdominal aorta just above the bifurcation. The aneurysm was opened with the incision staying posterior to the left renal artery (**Figure 5**). Chronic thrombus was removed. Perfusion of the viscera with normothermic LHB blood was resumed after insertion of Fr 9 balloon perfusion catheters into the origins of celiac artery and SMA (**Figure 6**). Fr 9 balloon perfusion catheters were also placed within the origins of the renal arteries. Intermittent cold saline at 4°C with methylprednisolone and mannitol was delivered to both kidneys. An oval shaped graftomy was made for the reattachment to the island of T8 to L2 intercostal arteries by inclusion technique with continuous 4-0 polypropylene suture in a circumferential pattern (**Figure 7**). The aortic clamp was then repositioned distal to this anastomosis to reperfuse the intercostal arteries. Another similar island patch was reimplanted to the celiac artery and SMA orifices. The right renal artery was too weak for anastomosis. The LHB was continued until the last several bites of the anastomosis. The left renal orifice was reimplanted separately with a cuff. A 14mm straight Gelsoft



Figure 1. Computer tomography scan showed fusiform aneurysmal dilatation of the descending aorta. The widest part of the aneurysm was at the diaphragm hiatus and extending to the abdominal aorta at the renal level, measuring 6.3cm x 5.8cm in axial plane and 6cm in coronal plane. The widest part of ascending aorta was 4.7cm in caliber, and the arch was 3.3cm in diameter.

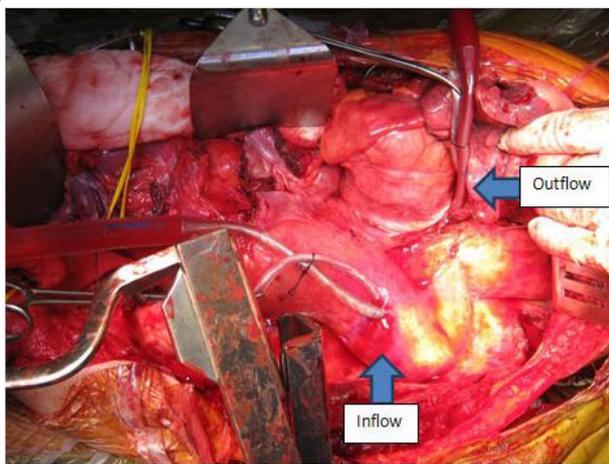


Figure 2. Left heart bypass (LHB) was used to provide distal perfusion during the proximal part of the repair. The left inferior pulmonary vein was cannulated as the outflow for oxygenated blood, and distal inflow returned to the distal descending aorta.

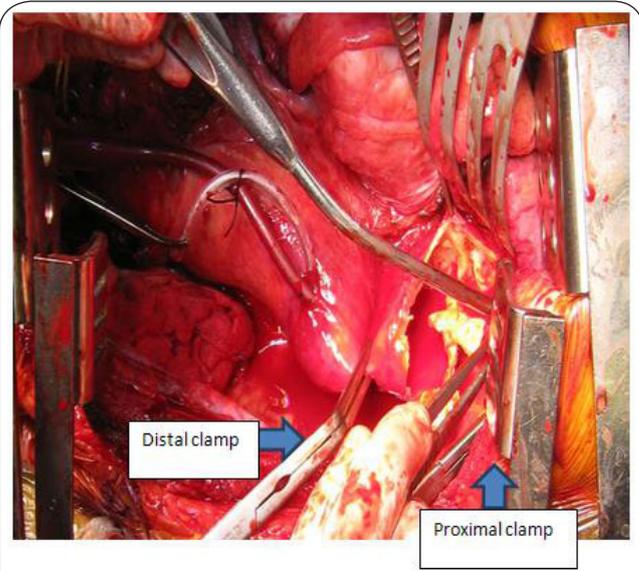


Figure 3. Proximal clamp was applied distal to the left subclavian artery, while the distal clamp was applied across the aorta at T4 level. Incision was made at the thoracic descending aorta.

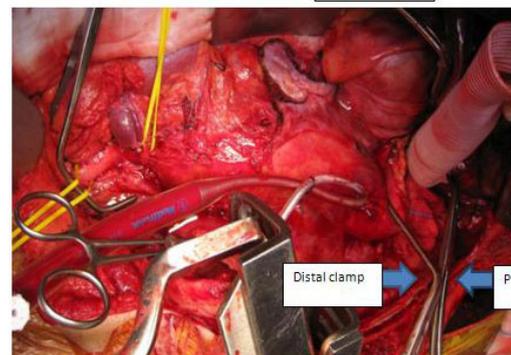
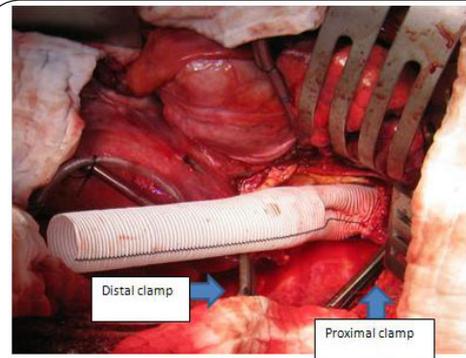


Figure 4. The aorta was transected 2cm distal to the proximal clamp. Proximal anastomosis with a 26mm straight Gelsoft Dacron graft was performed.

Dacron graft (Vascutek, UK) was connected to the 26mm graft by end-to-end anastomosis. The left renal artery was anastomosed to the 14mm graft with the Carrel patch technique [1] using continuous 5-0 polypropylene suture. The aortic clamp was repositioned distal to these vessels

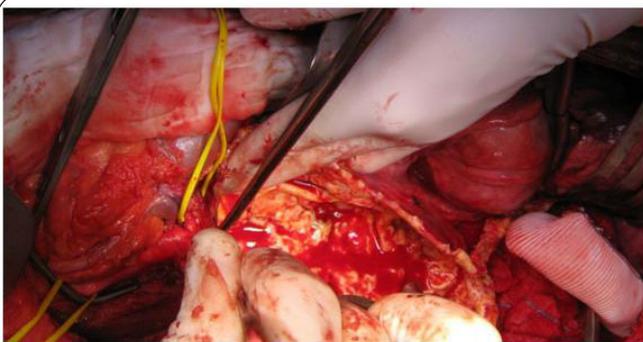


Figure 5. The aneurysm was opened with the incision staying posterior to the left renal artery.



Figure 6. Fr 9 balloon perfusion catheters were inserted into the origins of celiac artery and SMA for the perfusion of the viscera.

after completion of the anastomosis. The aneurysm repair was completed by end-to-end anastomosis of the graft to the distal abdominal aorta just above the bifurcation.

Post operatively, the patient stayed in the intensive care unit for ten days. Inotropic support was given for three days. Afterwards, nitroglycerin infusion was given to lower the blood pressure. She needed ventilator support in the first week after operation. All distal pulses were present. Renal function was impaired in the first three weeks requiring hemodialysis. Afterwards, her serum creatinine level improved from 660 μ mol/l to 109 μ mol/l, and she did not requiring dialysis upon discharge.

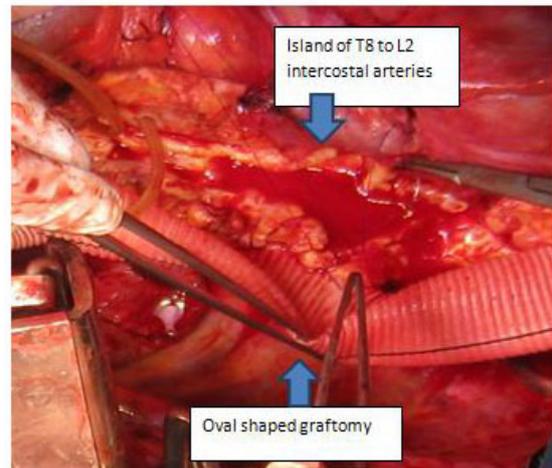
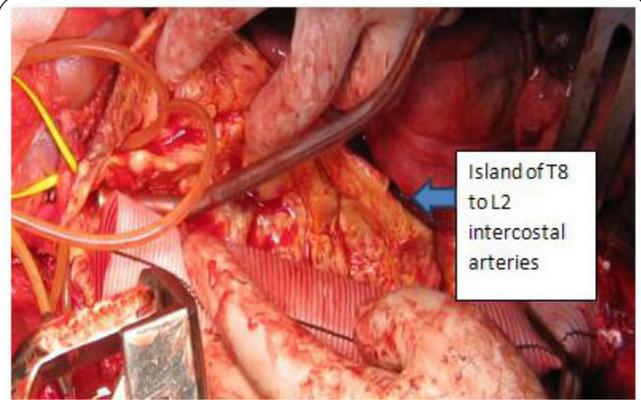


Figure 7. An oval shaped graftomy was made for the reattachment to the island of T8 to L2 intercostal arteries by inclusion technique with continuous 4-0 polypropylene suture in a circumferential pattern.

She developed hypertension and she was put on amlodipine and metoprolol. The patient was discharged from hospital 42 days after the operation.

Discussion

In this endovascular era, open repair of TAAAs is a rare operation in regional hospitals. Adjuncts to the repair also remain controversial. There were only two cases in our institution in the past ten years. Adequate preoperative planning and thorough review of the literature are important in this operation. Multidisciplinary approach with collaboration with the cardiothoracic surgeons, anesthetists, perfusionist and intensive care physicians have made this operation successful.

Thoracoabdominal aortic aneurysm (TAAA) is a formidable challenge to vascular surgeons, anesthetists and intensive care physicians. The Crawford classification classifies TAAAs based on the extent of aortic involvement [2]. Accurate classification of TAAAs is important, because the operative strategy, risks and results vary based upon the extent of aortic replacement. Despite recent advances in endovascular approaches to localized aortic aneurysms, open repair

remains the procedure of choice for management of these extensive aneurysms. Variable pathology, extensive aortic involvement, comorbidities and invasiveness of the operation have contributed to this challenge.

Etheredge et al., first reported successful replacement of upper abdominal aorta involving the celiac artery and SMA using an aortic homograft and temporary aortic bypass with a polyethylene tube in 1955 [3]. Crawford revolutionized TAAA repair by introducing the graft inclusion technique in 1965 [4]. Refinements in this technique over the subsequent 35 years, together with the introduction of clamp and sew technique, have further improved the operative efficiency and expediency [5].

The operative mortality of open repair of TAAAs was reported to be in the 10% range due to massive blood loss and disseminated intravascular coagulopathy. The overall spinal cord ischemic complications were in the 16% range, in which half of them sustained devastating paraplegia [6]. In the recent largest series of 2286 patients by Coselli et al., the operative mortality was reported to be 6.6%. Complications included pulmonary complications in 32.1%, cardiac events 7.9%, renal failure requiring hemodialysis 5.6%, paraplegia or paraparesis 3.8%, and stroke in 1.7% [7].

Preoperatively, it is prudent to have an extensive cardiac workup for coronary disease. A chest X-ray or CT scan should be examined for evidence of left mainstem bronchus compression by the aneurysm. If it is present, placement of a left sided double lumen tube may be difficult. Hoarseness may represent aneurysm induced recurrent laryngeal nerve dysfunction [8]. Blood products should be available, including ten units of packed red blood cells, fresh frozen plasma and platelet concentrate. Novoseven (recombinant coagulation factor VIIa) (Novo Nordisk Inc., USA), tissue adhesives such as the Vivostat system (autologous fibrin sealant) (Vivostat A/S, Denmark) may be required. Cell saver- a blood scavenging and recycling system should be employed.

Single lung ventilation is necessary to improve the surgical exposure. It also lessens the postoperative pulmonary dysfunction associated with lung retraction, as retraction of ventilated lung tissue may cause pulmonary contusion, or even causing pulmonary hemorrhage in heparinized patients. Intraoperative monitoring consists of electrocardiography, pulse oximetry and nasopharyngeal temperature. Blood pressure is monitored with a radial artery cannula and a contralateral arm blood pressure cuff. Large bore intravenous access via the internal jugular veins or the femoral veins is introduced. Transesophageal echocardiography (TEE) is used to monitor the cardiac output. Methylprednisolone (2g) and mannitol (12.5 g) are administered after induction to protect the spinal cord and kidneys. During cross clamping, mean arterial blood pressure should be maintained at 60 to 65 mmHg with nitroglycerin and nitroprusside infusions [8,9].

There are three different surgical techniques for TAAAs. The first is clamp and sew technique. The aorta is clamped

proximally and the anastomoses are performed as rapidly as possible. Back bleeding of the intercostal, mesenteric, renal and iliac arteries can produce substantial blood loss. This method relies on the surgical speed to limit end organ ischemia. The second is partial bypass or shunts. While the heart is beating, blood is partially diverted from either the left atrium or proximal aorta distally into the femoral artery. This technique relies on the patient's lung function, cardiac function and volume status. The third is extracorporeal circulation. Blood is circulated in the lower body distal to the aortic clamp via the femoral vein to femoral artery bypass [8]. In our case, we adopted the first and second methods. These techniques aim to limit ischemic time and to maximize perfusion to the viscera and lower extremities.

To set up a LHB circuit, systemic heparin (1mg/kg) is administered after the thoracoabdominal incision. The left inferior pulmonary vein is cannulated with a Fr 26 USCI aortic right-angled cannula (C.R. Bard, Inc, Tewksberry, MA), and the supraceliac aorta is cannulated with a Fr 20 USCI aortic right-angled cannula. LHB is achieved with a centrifugal pump. The primary focus is on the coordination of upper and lower body blood flow. Effective communication between the anesthetist and the perfusionist is important. As the left atrial blood volume must supply both the left ventricle (for the upper body perfusion) and the bypass circuit (for the lower body perfusion), excessive pump flow may compromise proximal pressure and perfusion to the brain and heart. TEE is invaluable in providing constant evaluation of the left ventricular filling status. After the application of the proximal aortic clamp distal to the left subclavian artery and the application of distal aortic clamp across the aorta at T4 to T7 level, the aneurysm is opened between the two clamps. The distal aortic perfusion is maintained at a rate of 1.5 to 2.5 L/min. After completing the distal anastomosis, heparin is reversed with protamine [2,8,9].

The incidence of postoperative acute renal failure is 3 to 14%. Patient mortality is up to 30 to 60% for those who need dialysis permanently. Patients with increased risk include those with pre-existing renal compromise, advanced age, long cross clamp time, hypovolemia, decreased cardiac output, and when shunting or bypass techniques are not utilized [8]. Selective renal perfusion using LHB can help in providing renal protection. Two separate balloon perfusion catheters are inserted into the renal arteries. The perfusate is normal saline solution with mannitol (12.5g/L) and methylprednisolone (125mg/L) cooled to 4°C. A bolus infusion of 400 to 600ml is instilled into the renal arteries, followed by intermittent infusions of 200ml in every 15 minutes. A total of 1.0 to 1.5L of solution is infused to achieve a renal temperature of 15°C. Larger volumes are avoided due to fluid overload and severe systemic hypothermia. It has been shown by a randomized clinical trial that when using LHB during repair of extensive TAAAs, selective cold crystalloid perfusion offers superior renal protection when compared with conventional normothermic blood perfusion. Multivariate analysis also confirmed that the

use of cold crystalloid perfusion was independently protective against acute renal dysfunction [9].

Paraplegia occurs after seemingly successful operations, and its incidence is up to 22% of patients after type II repair [10]. Paraplegia results from prolonged spinal cord ischemia, disruption or embolization of the radicular blood supply during aneurysm repair. The spinal cord receives blood supply via the anterior spinal artery and two posterior spinal arteries. These in turn are supplied by the segmental radicular arteries from the cervical, thoracic and lumbar arteries. Thus, back bleeding from an intercostal artery into the aorta implies a patent radicular artery. The largest of the radicular arteries is the artery of Adamkiewicz, often given off from the T10 level but varying in position from T7 to L4. This artery supplies the conus. It is given off by the left intercostal or lumbar artery. There is usually a rich networking of smaller arteries that interlink the two posterior spinal arteries, but only very little communication between the anterior and posterior spinal networks, therefore anterior spinal artery occlusion causes anterior horn ischemia and paraplegia. Prolonged cross clamp time, perioperative hypotension, intercostal artery or radicular arteries not reimplanted, previous infrarenal aneurysm repair with lumbar artery ligation, internal iliac artery (IIA) disease or ligation increase the risk of postoperative paraplegia [8,11].

There are four techniques during surgical repair for prevention of paraplegia. The first is revascularization of the spinal cord. It has been shown in retrospective series that reimplantation of significant patent arteries is associated with lower paraplegia rates, with the revascularization of arteries around T11/T12 level being the most important [12]. It is also important to consider the superior and inferior blood supply to the cord via the subclavian arteries and IIAs. Either one of the IIAs and the left subclavian artery should be maintained. The second is reduction of spinal cord ischemic time. The incidence of paraplegia was noted to be 27% in those with cross clamp time more than 60 minutes, falling to 8% in those less than half an hour. The clamp and sew technique, the LHB supplemented by selective perfusion of the celiac artery, SMA and renal arteries after cross clamping and opening of the abdominal aorta have been shown to reduce the paraplegia rates. The third is CSF drainage. The goal is to decrease CSF pressure. After cross clamping, the mean arterial pressure (MAP) can drop to as low as 30mmHg and the CSF pressure (CSFP) can rise up to 25mmHg due to dural venous engorgement. The spinal cord perfusion pressure (SCPP) (which is equal to MAP minus CSFP) decreases compromising the spinal cord perfusion. The CSFP should be maintained at 10 mmHg via drainage. This technique can double the perfusion pressure to the spinal cord. A lumbar drain is inserted preoperatively. The patient is placed in the lateral position. A 14 gauge Tuohy needle is inserted into the subarachnoid space at L3/4 or L4/5 level. This is confirmed by free flow of CSF. The lumbar drainage catheter is then inserted through the needle. 5 to 7cm of the catheter should be placed in the subarachnoid

space. The drain should be clamped if the patient is moved. The drain should be remained in place for 72 hours. The catheter should not be removed until the coagulation status is corrected postoperatively [8,11]. In a randomized controlled trial of 145 patients by Coselli et al., there was a significant difference in paraplegia rates- 13% in the control group and 2.6% in the CSF drainage group. This is an 80% reduction in the relative risk of postoperative deficit [13]. The fourth is spinal cord hypothermia. This can be achieved by infusion of iced (4°C) saline solution into epidural space to reach 25 to 28°C during cross clamping. However, this is hard to achieve quickly and may complicate the procedure unnecessarily as CSF needs to be drained simultaneously. The same effect can be achieved by permissive hypothermia of the patient to 33°C during cross clamping [11].

For endovascular repair of TAAAs, the major limitation is that the proximal sealing zone must be in a segment of normal aorta. Open repair of thoracoabdominal aneurysm was performed in this case instead of endovascular stenting due to the large caliber of thoracic aorta. In order to increase the sealing zone, different techniques have been employed. Branched stent grafts have been developed and the midterm results for treating TAAAs are excellent [10,14-20]. Extensive aortic and visceral vessel surgical exposure can be avoided, and visceral perfusion can be maintained during the repair. However, this method requires appropriate patient selection, proper device design, high resolution imaging, technical expertise with endovascular grafting and visceral vessel cannulation and stenting, and meticulous postoperative follow-up. Larger series are still needed to further delineate the safety and efficacy of these devices for the long term results. It is important to reconstruct as anatomic as possible, in order not to compromise the durability of the repair. Branches should come off at smooth angles from the endograft, and bridging stents to the aortic branches should follow the direction of the native artery. Overlap between aortic endograft and branch stents needs to be maximized to reduce the risk of component separation, type III endoleaks and protrusion of branch stents into the main stent graft. The snorkel/chimney/sandwich technique is a valid alternative to branched grafts. The advantages are that they are suitable for tortuous vessels, less expensive, and do not need to be pre-manufactured which may take up to eight weeks. In 2011, Kolvenbach reported their multi-institutional experience of nine TAAAs repaired with the "sandwich technique" [21]. Three of these TAAAs were type IV. This treatment option is technically feasible, but there are no reported data on long-term results, making its use in the elective setting questionable. There is also a large difference in complexity of repair between juxtarenal aneurysms and TAAAs, and that a parallel graft repair of a type IV TAAA may require placement of covered stents into all four visceral vessels. The issue of endoleaks associated with these parallel grafts and the durability of the branches remains unresolved.

In conclusion, this case demonstrated a typical way of open repair of TAAAs, which may soon become a lost art in this endovascular era. Useful adjuncts including left heart bypass and spinal cord protection, adequate preoperative planning and multidisciplinary approach have made this operation successful.

Competing interests

The authors declare that they have no competing interests.

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