Thoracoabdominal Aortic Aneurysm – The Branch First Technique

George Matalanis, FRACS, and Stephanie L. Ch'ng, MS

Surgical management of thoracoabdominal aortic aneurysms is complex. In particular, maintaining adequate spinal cord and reno-visceral protection during the operation can be challenging. We describe here a branch-first technique developed at our institution, endeavoring to minimized renal and visceral organ ischemic time, decrease risk of spinal cord injury, and provide a controlled and uncluttered field in which the surgeon can operate.

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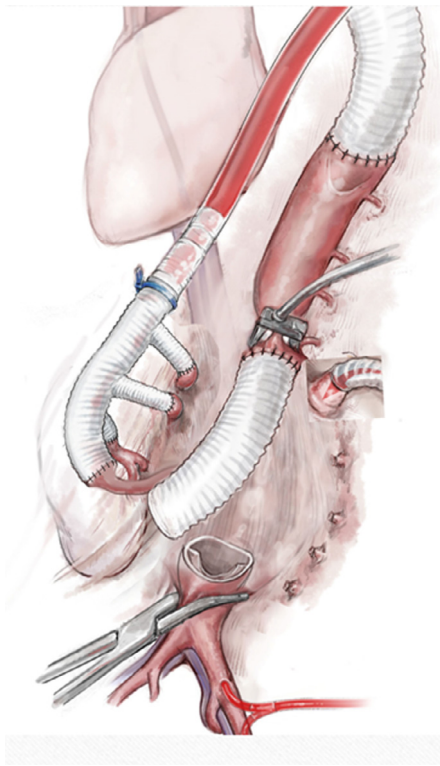

Branch-first TAAA repair technique with near continuous antegrade perfusion.

Central Message

Branch-first technique is an important strategy in reno-visceral protection and hemodynamic stability in thoracoabdominal aortic surgery.

INTRODUCTION

Despite technical advances, use of adjuncts and endovascular stenting, repair of thoracoabdominal aortic aneurysms (TAAA) in particular Crawford type II TAAA, remains a morbid and technically demanding undertaking.

Centers of excellence have reported mortality of 5–13%, spinal cord injury of 3–16%, and renal failure rates of 5–10%.[1,2] However, real-world population series have been unable to replicate these exceptional results, in part due to lower surgeon and hospital volumes.[3]

The challenges of open repair include attaining adequate anatomical access throughout the length of the aorta, spinal cord, and reno-visceral protection, hemostasis, and preservation of hemodynamic stability during the procedure in the face of extreme stressors placed on the system during aortic cross clamping.

Prevention of spinal and reno-visceral injury is a complex and incompletely understood process. Multiple ancillary techniques have been described in the literature with the weight of evidence leaning gently in their favor. These include cerebrospinal fluid drainage (CSF),[4] neuromonitoring,[5] distal perfusion (using left heart bypass),[6] selective reno-visceral crystalloid or blood perfusion,[7,8] and intercostal artery reimplantation.[9] There is also growing observational evidence, adopted from the endovascular rather than open surgical series, that staged repairs of the descending thoracic aorta may further protect against the development of paraplegia/paraparesis.[10]

However, the prevention of reno-visceral ischemia still largely hinges on the reno-visceral exclusion time, traditionally the time to resect and replace the abdominal aorta, in addition to reimplantation either en bloc or individually, of all the reno-visceral arteries into the neoaorta. This time stress is further magnified by the furore of events occurring upon cross clamping and opening the aneurysm, each of which demands attention and expeditious management. Thus, the surgeon must deal with rapid back bleeding from intercostal and visceral arteries, which compounds the risks of coagulopathy, severely imbalances upper vs lower body perfusion and impairs patient temperature control. Difficult decisions regarding which and how many intercostal arteries need to be preserved for reimplantation need to be made. On the other hand, if antegrade catheter perfusion of the renal and visceral arteries is chosen to reduce reno-visceral ischemia, associated

Department of Cardiac Surgery, Austin Health, Heidelberg, Victoria, Australia

Address reprint requests to Stephanie L. Ch'ng, MS, Department of Cardiac Surgery, Austin Health, 145 Studley Road, Heidelberg, VIC 3084, Australia. E-mail: zlt.chng@gmail.com

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difficulties such as arterial injury, catheter dislodgment or "deep throating" with branch exclusion, and athero- or air-embolism need to be pre-empted and managed.

This situation parallels closely that of a total arch replacement, whereby even short interruptions to cerebral blood flow can be poorly tolerated during the reconstruction of the aortic arch and reimplantation of the arch branches. The branch-first total arch replacement technique pioneered at our institution provides a simplified, reliable, and reproducible system which has resulted in improved cerebral outcomes and markedly reduced use of blood products since its inception in 2005.[11] Recent adaptation of the branch-first technique into our thoracoabdominal aortic practice appears to be yielding similar benefits.

The principles of branch-first thoracoabdominal aortic repair (BF-TAAAR) include the minimization of spinal and reno-visceral ischemia, anastomosis in better quality tissue, with acute and long-term benefits, and easy access to all suture lines for hemostasis. Importantly, the previously mentioned perfusion cannula problems with direct ostial cannulation can be avoided. The BF-TAAAR technique further facilitates the maintenance of excellent hemostatic and circulatory control.

We describe here our BF-TAAAR technique which incorporates many of the known beneficial adjuncts such as CSF drainage, distal perfusion, and segment aortic clamping. The advantages include the provision of reliable and near continuous reno-vascular perfusion and the avoidance of rapid blood loss. In addition, wherever possible, Dacron replacement of the lower third of the descending aorta (DTA) bearing the important intercostal branches is avoided, thus reducing the risk for spinal cord injury. Subsequent (staged) thoracic endovascular aortic repair can be easily performed if required, even in patients with genetic aortopathy, as both the proximal and distal landing zones are in Dacron rather than native aorta.

OPERATIVE STRATEGY

Adjuncts, including a CSF drain, neuromonitoring, and moderate hypothermia, are routinely used. Right radial and right femoral arterial lines are used for upper and lower body arterial monitoring and a dual lumen tube for single-lung ventilation.

The patient is positioned on a beanbag in a semi-right lateral decubitus position with the shoulder at 60° and pelvis at 30°. The upper third of the descending aorta is accessed via a high left thoracotomy to the third or fourth intercostal space. This stepped incision approach optimizes the exposure for the entire length of the DTA, minimizing the trauma associated with excessive pulling and retraction of tissues.

The distal arch and proximal half of the DTA are mobilized and about 4—5 levels of intercostal arteries ligated. This facilitates a dry field in which to operate and also avoids steal phenomenon from the spinal cord developing once the aorta is clamped and opened. It also permits circumferential mobilization of the aorta protecting the underlying esophagus from inclusion in subsequent suturing. Access to the visceral aorta is via a low thoracolaparotomy in the sixth to seventh intercostal space and across the costal margin into the upper abdomen, and radial division of the diaphragm to the aortic hiatus.

The left renal, superior mesenteric, and coeliac arteries are mobilized for a distance of 3—4 cm. Again, small-to-medium-sized lumbar arteries are ligated to allow better circumferential exposure of the abdominal aorta and better hemostasis when that part of the aorta is opened. The right renal artery usually remains hidden under the aorta and approach to it must wait until after the aorta is clamped and opened.

The left femoral artery and vein are exposed and mobilized through a short transverse groin incision; the patient is systemically heparinized and placed on partial cardiopulmonary bypass via the left femoral vessels. Single-lung ventilation is supported by the bypass membrane oxygenator, and a sump sucker is utilized to salvage blood back into the reservoir for recirculation. An extra roller pump is added to allow separate reno-visceral perfusion and the "cardioplegia" pump is used for intercostal artery perfusion.

Attention is now turned to replacement of the upper one-third of the DTA. Our intention is to create an adequate landing zone, sufficiently distant form the arch branches, for a subsequent endovascular repair of the remainder of the DTA (if needed). By retaining the lower half of the native DTA, we aim to preserve spinal cord perfusion from the lower intercostals, while allowing the body to develop adequate spinal cord collaterals over time, should the remaining DTA require exclusion by a stent graft in the future.[10]

Proximal control is achieved by clamping the aortic arch, usually between the left common carotid and left subclavian arteries, and a separate clamp is applied to the left subclavian artery. Our preference is to use the Anteflow graft (Terumo Aortic) for replacement of this part of the aorta as the side arm can be used either to reimplant the left subclavian artery or to support the proximal circulation from the bypass circuit if necessary. A septectomy is performed in the distal aorta in chronic dissections to ensure adequate flow to the true and false lumens. Once proximal aortic replacement is complete, aortic clamps are removed and attention is then turned to the visceral aorta.

VISCERAL ARTERY DEBRANCHING AND ANTEGRADE PERFUSION

A trifurcation graft with an additional perfusion limb (TAPP, Terumo Aortic) is prepared with a connector secured to the main limb of the graft for subsequent antegrade perfusion. The left renal, superior mesenteric and coeliac arteries are then sequentially controlled, disconnected from the native aorta and anastomosed to and reperfused via the "perfusion" branch and second and third limbs of the TAPP graft respectively (Fig. 1). It is important to note that aggressive shortening of the limbs of the TAPP graft is required to avoid kinking of the branches. The first limb of the TAPP graft destined for the right renal artery is left clamped. The periods of ischemia to each branch during the anastomosis are brief, usually less than 10 minutes, which together with moderate hypothermia and visceral collateralization is easily tolerated.

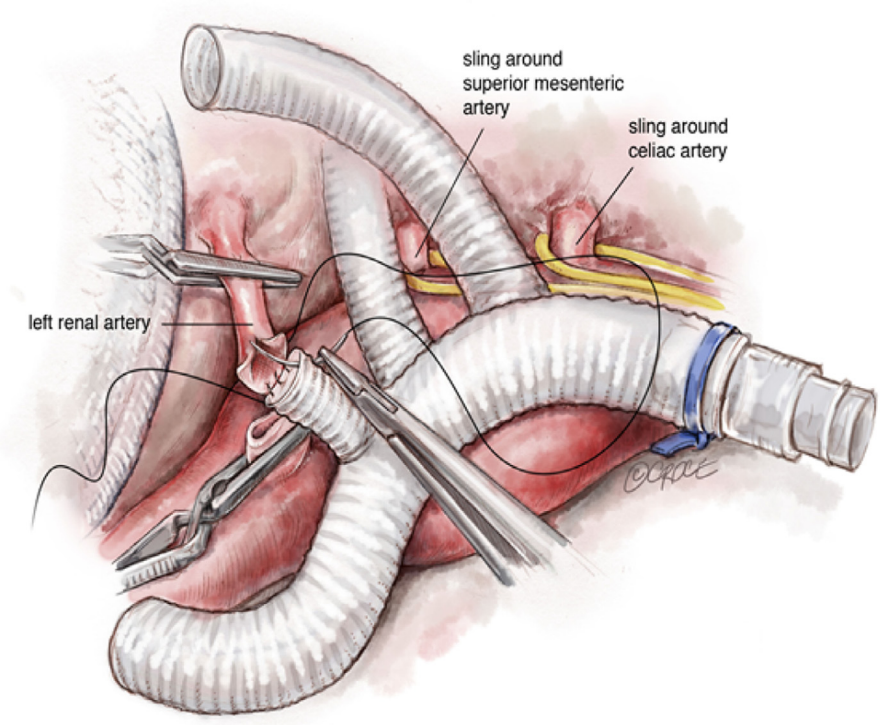

Figure 1. Sequential debranching and perfusion of reno-visceral branches.

The full-perfused graft can be reflected away from the aorta and out of the field, minimizing the clutter away from the abdominal aorta (Fig. 2).

Aortic clamps are then applied, proximally to just above the diaphragm and distally, above the bifurcation. Note, at this stage, there is still ongoing perfusion to the upper body via the heart, to the lower limbs via the arterial cannula, and to the disconnected reno-visceral branches via the TAPP graft. Thus, the right renal artery and the lower intercostal/upper lumbar arteries are the only excluded branches at this stage.

The aorta is then opened, and the right renal and any large intercostal/lumbar arterial buttons are prepared. Perfusion of these branches is our next priority, addressing the aorta only once we have established antegrade flow to these arteries.

The intercostal arterial buttons are anastomosed end-end to a separate 8 mm graft, which is then perfused via the cardioplegia pump. The right renal artery is then anastomosed to the first limb of the TAPP graft and antegrade perfusion restored.

It is now a simple matter to reconstruct the abdominal aorta with a Dacron tube graft.

Finally, both the TAPP and intercostal grafts are anastomosed end-side to the mid-portion of the new abdominal aorta. There will of course be a short period of interruption of antegrade perfusion to the organs during this anastomosis, but again this should be less than 10 minutes. Care is taken to leave a sufficient landing zone, proximal and distal to the TAPP/intercostal reimplantation site for any subsequent thoracic endovascular aortic repair.

Our early experience with BF-TAAAR in 5 elective patients has been encouraging (Table 1). Three patients had chronic dissections and 2 had atherosclerotic disease as the cause of their aneurysms. In this small series, there were no deaths, and 1 patient had transient paraparesis which resolved. There were no cases requiring dialysis or return to theatre for bleeding. There have been no reinterventions on the residual thoracic aorta as yet.

ADVANTAGES AND DISADVANTAGES OF THE BF-TAAAR

The benefits and potential disadvantages of this technique are summarized in Table 2.

Hemostasis can be reassessed readily and without haste after each anastomosis and the viscera and spinal cord are being perfused almost continually.

While full heparinization is required for the full bypass circuit, aiming for an ACT >450 rather than the 200—300 seconds as for left heart bypass, we have not found this to be an adverse factor to achieving hemostasis. On the other hand, it has added the luxury of supporting oxygenation on single-lung ventilation. Furthermore, the inclusion of the reservoir has allowed complete control over blood volume distribution in the split circulation period.

However, the branch-first TAAA technique may not be suitable for all cases, in particular, any situation where the surgeon is unable to dissect free sufficient length of the renal or visceral artery to clamp. This may be due to very short arteries or arteries with early branching patterns, dense peri-aortic adhesions.

Table 1. Early Experience With BF-TAAAR

	1	2	3	4	5
Age	46	54	65	72	35
Gender	M	M	M	M	M
Etiology	Chronic dissection	Chronic dissection	Atherosclerotic aneurysm	Atherosclerotic aneurysm	Chronic dissection
Urgency	Elective	Elective	Elective	Elective	Elective
Connective tissue	Y	N	N	N	N
Pre-op Cr	98	72	72	74	72
Post-op Cr	98	54	62	64	73
Dialysis	N	N	N	N	N
Spinal cord injury	N	N	N	Y [Transient]	N
Tracheostomy	N	N	N	N	N
Return to theater for bleeding	N	N	N	N	N
Cardiac support	N	N	N	N	N

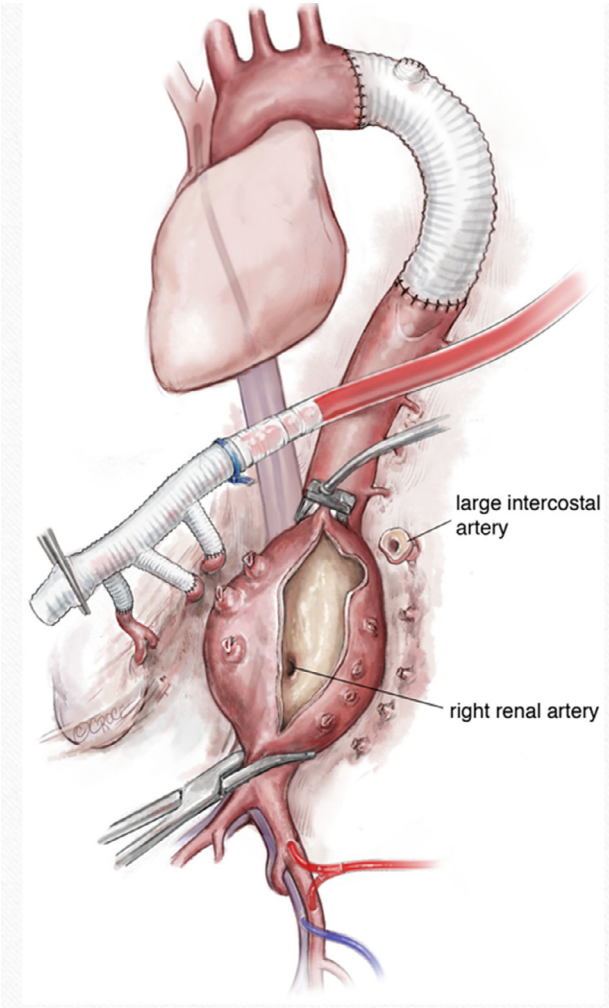

Figure 2. Clutter-free access to the abdominal aorta, with left renal, SMA, Coeliac trunk being perfused by the TAPP graft and smaller lumbar arteries already ligated.

Table 2. Advantages and Disadvantages of BF-TAAAR

Advantages	Hemodynamic stability
	Unrushed anastomoses in good quality tissue
	Minimal spinal and reno-visceral ischemic time
	Clutter-free exposure
	Easy access to anastomoses to check for hemostasis
	Oxygenator support during one lung ventilation
	Retention of important intercostals bearing DTA, but setup for easy endovascular repair at a subsequent interval
Disadvantages	Short renal/visceral artery with early branching
	Dense peri-aortic adhesions, for example, inflammatory aortitis, prior surgery
	Heavily atheromatous aorta at clamp sites with risk of thromboembolism
	Pathology precluding retention of lower DTA for a staged endovascular completion, for example, large aneurysm in that segment
	Full heparinization
	Single inflow graft to all 4 reno-visceral arteries
	Potential for graft limb kinking/twisting

Further limitations of the technique include the potential for graft kinking or twisting and the reliance of all 4 reno-visceral arteries on a single inflow graft. Finally, the technique as described above would not be applicable for patients with pathology not amenable to staged repair and for patients in whom clamping of the aorta may induced unacceptable risks of thromboembolic complications.

Just as the branch-first total arch replacement technique removed the traditionally palpable time pressure of arch reconstruction, allowing the operation to proceed in a logical and

complete fashion,[11] so it brought a similar degree of order and control to the potentially chaotic TAAA surgery. Whether these intraoperative measures will translate to improved clinical outcomes with decreased incidences of spinal cord injury, renovisceral malperfusion syndromes and bleeding complications must wait for further experience. Importantly, it is a safe and reproducible technique to add to the armamentarium of tackling this complex disease.

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