Thoracoabdominal aneurysmectomy: Operative steps for Crawford extent II repair

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Ana Lopez-Marco, PhD, Benjamin Adams, MD, and Aung Ye Oo, MD

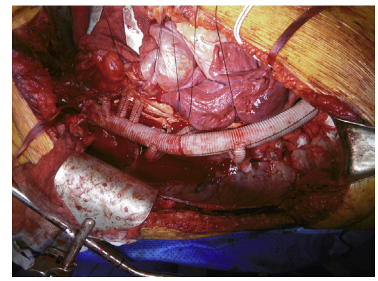
ABSTRACT

Background: Open surgical repair remains the gold standard for treatment of thoracoabdominal aortic aneurysm (TAAA). Surgery aims to replace the whole length of the diseased distal aorta while protecting the spinal cord and the visceral organs to limit ischemia-related complications. The substantial associated surgical risks, including death, paraplegia, renal failure requiring permanent dialysis, and respiratory complications leading to prolonged intensive care unit stay, still outweigh the natural history of TAAA with conservative treatment.

Methods: We describe in detail our current approach to open extent II TAAA repair with a step-by-step illustration of the technique and the surgical adjuncts.

Results: We routinely perform left heart bypass with mild passive hypothermia (34°C), cerebrospinal fluid drainage, sequential aortic cross-clamping, monitoring of motor evoked potentials (MEPs) and cerebral, paraspinal, and lower limb oxygen saturation by near-infrared spectrometry, as well as selective visceral perfusion via the celiac and superior mesenteric arteries and renal protection with intermittent administration of Custodiol HTK (histidine-tryptophan-ketoglutarate) solution via the renal arteries. We advocate for individual branch reimplantation using a branched thoracoabdominal graft when possible, and we selectively reattach 1 or more pairs of the lower thoracic intercostal arteries and/or high lumbar arteries, even in the absence of a significant reduction in the MEPs signal. The distal anastomosis is usually constructed above the aortic bifurcation and occasionally to each iliac separately using a bifurcated graft.

Conclusions: Favorable early outcomes and a durable TAAA repair can be achieved at experienced high-volume centers with standardized preoperative selection and multidisciplinary team–based intraoperative and postoperative management of these patients. (JTCVS Techniques 2020;3:25-36)



Surgical picture of complete repair of Crawford extent II TAAA.

CENTRAL MESSAGE

We describe our extent II TAAA repair technique, including surgical adjuncts: left heart bypass, cerebrospinal fluid drainage, motor evoked potential monitoring, and visceral and renal perfusion.

PERSPECTIVE

Open repair is the gold standard for TAAA treatment. The associated risks (eg, death, paraplegia, renal and respiratory failure) still outweigh TAAA natural history. Favorable outcomes can be achieved at experienced high-volume centers with standardized preoperative selection and multidisciplinary team–based intraoperative and postoperative management, with emphasis on spinal cord and visceral protection.

See Commentaries on pages 37, 39, and 41.

From the Department of Cardiac Surgery, St Bartholomew's Hospital, London, United Kingdom.

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Address for reprints: Ana Lopez-Marco, Department of Cardiac Surgery, Barts Heart Centre, St Bartholomew's Hospital, West Smithfield, EC1A 7BE, London, United Kingdom (E-mail: ana.lopez-marco@nhs.net).

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The first reported thoracoabdominal aortic aneurysm (TAAA) repairs date from the 1950s as described by Etheridge and colleagues[1] and Rob.[2] In the 1960 and 1970s, the surgical technique was refined by and DeBakey and colleagues[3] and then Crawford.[4] Since then, advances in understanding and improving spinal cord and visceral protection contributed by Crawford's protégés Coselli and Safi and coworkers[5-10] have made it possible to reduce mortality and the devastating complications associated with open surgical repair of TAAA.

SURGICAL REPAIR OF TAAA

We describe the technique for repair of a Crawford extent II TAAA, extending from distal to the left subclavian artery

Abbreviations and Acronyms

CT	= computed tomography
ECG	= electrocardiography
LHB	= left heart bypass
LSA	= left subclavian artery
TAAA	= thoracoabdominal aortic aneurysm

(LSA) down to the aortic bifurcation. Individual consent was provided by each participant for the use of their anonymized media files for research purposes.

Patient Selection

The process includes a thorough review of clinical history and physical examination, focusing on age; smoking history and lung disease; previous history of cardiac, neurologic and/or renal disease; and previous aortovascular events fundamental for surgical planning. We routinely assess myocardial and valvular heart function with transthoracic echocardiography and coronary artery status with electrocardiography (ECG)-gated coronary computed tomography (CT) angiography; lung function, with spirometry and transfer factor assessment; and renal function, with blood tests. We conduct a formal anesthetic review at the preliminary visit to assess fitness for surgery, including a functional test (6-minute walk test) for the borderline cases.[11]

The majority of TAAAs can be divided into 2 broad categories: degenerative aneurysms and chronic dissections, either a DeBakey type III or a previously repaired residual DeBakey type I. Patients with degenerative aneurysm usually are at greater risk and experience more complications owing to older age and more associated comorbidities. Patients with connective tissue disease are usually considered lower risk, being younger and having fewer comorbidities.

Preoperative Planning: Tips, Tricks and Pitfalls

A thorough review of the CT images (Figure 1) is paramount for planning the steps of the operation, concentrating on the following aspects.

Identify potential areas for clamping. Extension of the aneurysm toward the aortic arch without an adequate neck or with significant amount of thrombus will preclude or hinder the proximal aortic cross-clamping. We always measure the distance between the left common carotid artery and the LSA. If there is enough space (>0.5 cm), we clamp proximal to the LSA; otherwise, the need to clamp more proximal to the arch mandates the use of cardiopulmonary bypass and antegrade cerebral perfusion, with or without circulatory arrest. The use of cardiopulmonary bypass facilitates hemodynamic control during the operation, but the mandatory use of a full heparin dose increases bleeding, which, combined with the systemic inflammatory response associated with the circuit itself, impacts negatively on the respiratory system.[12] The use of circulatory arrest mandates hypothermia, which is also associated with coagulopathy.

Identify potential areas for aortic cannulation. The inflow cannula is inserted either within the distal aorta

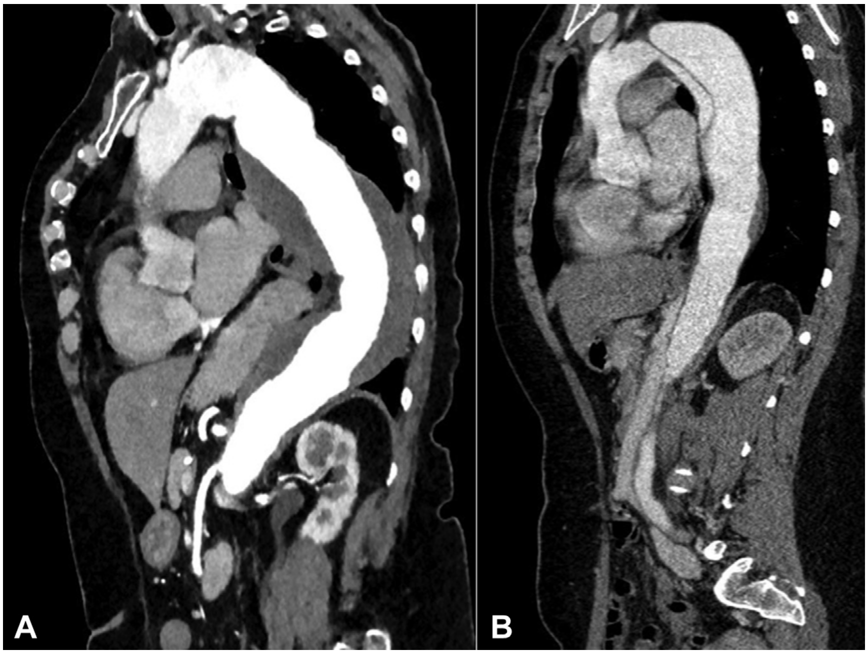

FIGURE 1. Sagittal view of a contrast computed tomography scan showing the whole length of the aorta in a patient with an atherosclerotic aneurysm (A) and in a patient with Marfan syndrome and a DeBakey type III aortic dissection (B).

above the iliac bifurcation or within the left femoral artery. Such as extensive mural thrombus or a large chronic false lumen in the distal abdominal aorta will favor femoral cannulation. We assess for the presence of an intraluminal thrombus intraoperatively with an epiaortic ultrasound in areas of concern. In circumstances when the distal aorta cannot be clamped due to extensive mural thrombus or calcification, we have performed the distal anastomosis without perfusion of the lower body or with perfusion of isothermic blood from the left heart bypass (LHB) using a balloon-tipped cannula in the distal aorta/individual iliac arteries.

Sequence of the operation. Starting the operation at distal and moving to proximal aortic segments has the advantages of reducing manipulation of the left lung and minimizing parenchymal hemorrhage, thereby reducing the risk of respiratory complications. Extensive mural thrombus in the distal aorta mandates inverting the sequence from distal to proximal aortic segments to avoid embolism when starting the LHB.

Anatomy of distal thoracic intercostal/high lumbar spinal arteries. Careful analysis of the preoperative CT scan can help predict the location of the most prominent arteries and their patency status. We use intraoperative motor evoked potential (MEP) monitoring, but tend to implant at least 1 pair of intercostal arteries regardless of any impairment on the MEP signal.[5,13] We prefer to use a separate 12-mm graft that is sutured end-to-side to the back wall of the aorta around the intercostals of interest (T8-L1). By doing this, rather than direct reimplantation in the main graft, we minimize the amount of remaining native aorta, decreasing the risk of developing a patch aneurysm.[14] This technique also facilitates access to the patch anastomosis in the event of bleeding. We maintain continuous perfusion with isothermic blood from the LHB until both ends of the accessory graft are reimplanted onto the main aortic graft, without unnecessarily prolonging the spinal cord ischemic time.

Abnormal anatomy. Cases with an aberrant right subclavian artery origin call for a different strategy for invasive arterial monitoring, as the proximal aorta and arch pressures are lost after application of the proximal cross-clamp in the distal arch. We recommend direct invasive monitoring with a bore needle into the ascending aorta after a small opening in the pericardium. Revascularization of the right subclavian artery also may be planned.

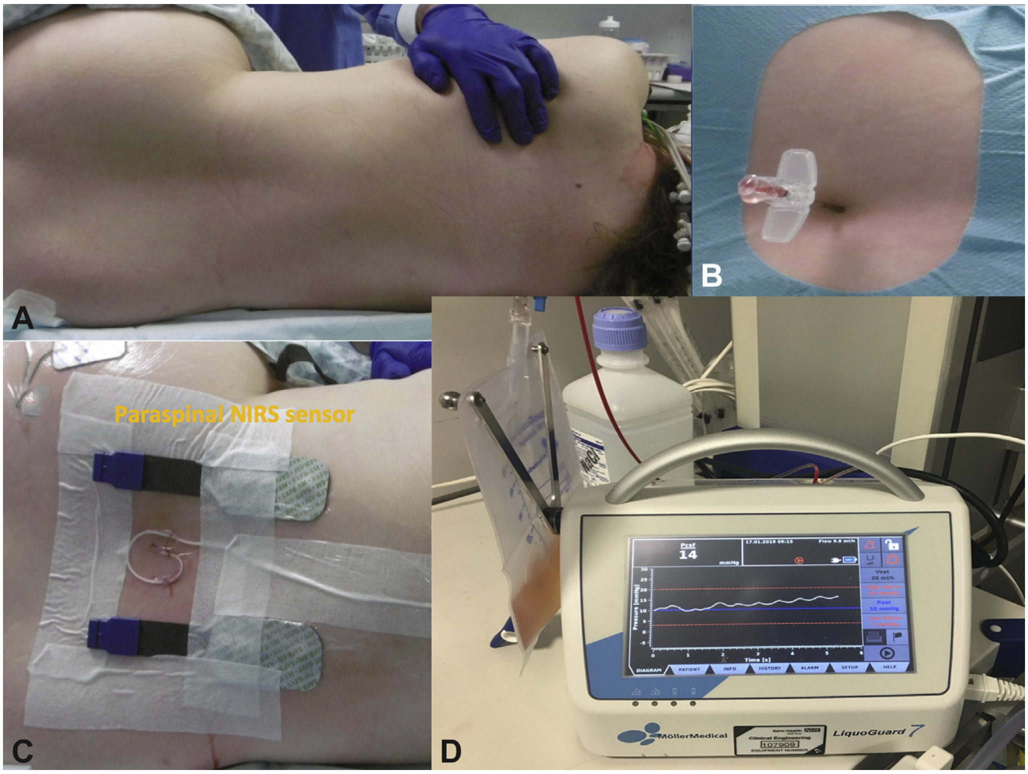

FIGURE 2. Insertion of spinal drain catheter for cerebrospinal fluid (CSF) drainage. A, The patient is placed in the right lateral decubitus position with both hips and knees flexed. B and C, A 5F silicone lumbar catheter is inserted at subarachnoid space at the L3-L4 or L4-L5 level. The catheter is connected to an automated device (LiquoGuard; Möller Medical, Fulda, Germany) that allows for pressure- or volume-controlled CSF drainage. We set the system to a pressure of 10 mm Hg and a volume of 20 mL/h (the system will drain up to 20 mL/h if the CSF pressure is sensed >10 mm Hg).[6,8] D, Near-infrared spectrometer sensors are placed in the paraspinal area to monitor oxygen saturation of the paraspinal muscles.

Operative Technique

Here we describe the technique for repair of a Crawford extent II TAAA, extending distal to the LSA down to the aortic bifurcation. In this particular case, there was sufficient space in the proximal descending thoracic aorta distal to the LSA to allow proximal aortic cross-clamping.

In preparation for surgery, the following monitoring systems and adjuncts are inserted: double-lumen endotracheal tube; right radial and right femoral arterial catheters; central venous line via the right internal jugular vein; ECG leads; nasopharyngeal temperature probe; transesophageal probe; urinary catheter; Vascath via right femoral vein connected to a rapid infusion system; near infra-red spectrometry (NIRS) electrodes located in the forehead, lumbar paraspinal region, and bilateral calves; spinal drain; and MEP pin electrodes in the skull and 4 limbs[13] (Figures 1-3).

The patient is placed on the operating table in a right lateral decubitus position with the hips tilted at 30 degrees, allowing access to the left thorax, abdomen, and left groin. The left arm is placed on top of an elevated arm board and held in 90 degrees flexion at the elbow, which will be elevated above the shoulder plane. A moldable beanbag with suction and vacuum properties is used to maintain the patient's position during the procedure, and a jelly beanbag is positioned underneath the patient at the mid-thoracic level to improve exposure (Figure 3).

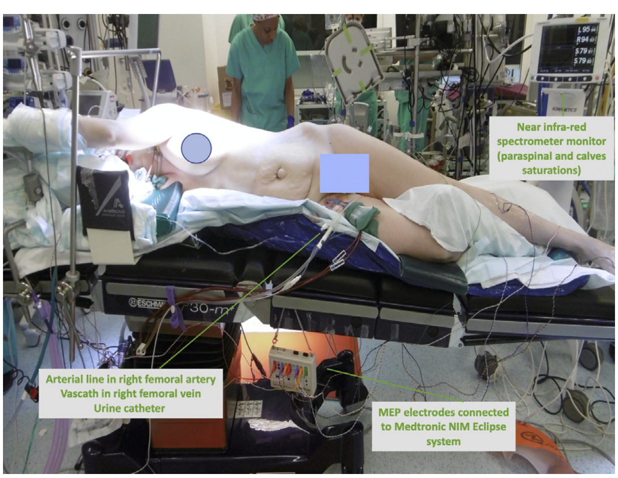

FIGURE 3. Positioning of the patient over the operating table in right lateral decubitus position with the hips tilted at 30 degrees to allow access to the left thorax, abdomen, and left groin. The left arm is placed on top of an elevated arm board and held in a 90-degree flexion at the elbow, which is elevated above the shoulder plane. A moldable beanbag with suction and vacuum properties is used to maintain the patient position during the procedure, and a jelly beanbag is positioned underneath the patient at the mid thoracic level to improve exposure. Monitoring systems and adjuncts required for TAAA repair include a double-lumen endotracheal tube; right radial and right femoral arterial catheters; central venous line via the right internal jugular vein; ECG leads; nasopharyngeal temperature probe; transesophageal probe; urinary catheter; Vascath via the right femoral vein connected to a rapid infusion system; near-infrared spectrometry electrodes located in the forehead, lumbar paraspinal region, and bilateral calves; and motor-evoked potential pin electrodes in the skull and 4 limbs.

The left posterolateral aspect of the thorax, left side of the abdomen, and left groin are prepped and draped. The skin incision is planned from the midpoint between the spinal processes and the tip of the scapula, along the sixth intercostal space, curving along the costal margin and toward the median abdominal line down to the left of the umbilicus (Figure 4, *A*). The latissimus dorsi and serratus anterior are divided before entering the thoracic cavity via a posterolateral thoracotomy, with resection of a portion of the rib above the thoracotomy and a wedge of the costal margin to reduce thoracic trauma and fractures and facilitate exposure and subsequent closure without overlapping during the reapproximation of tissues (Figure 4, *B*). A Richardson retractor is secured to a horizontal bar attached to the surgical table at the shoulder level, to hold the upper ribs open (Figure 4, *C*).

A plane is then created between the abdominal wall and the peritoneum with careful digital blunt dissection until the pre-psoas fatty plane is reached (Figure 5, *A*). At that point, medial visceral rotation is completed and attention is directed toward the diaphragm, which is divided circumferentially, leaving a 3- to 4-cm cuff attached to the chest wall (Figure 5, *B*). The Omni-Tract self-retaining retractor system (Integra Life Sciences, Princeton, NJ) is mounted to hold the laparotomy open (Figure 5, *C*).

The abdominal aorta is then exposed by clearing the retroperitoneal fat, identifying the left renal artery and the ureter as landmarks. Once the whole aorta is exposed, the potential clamping areas and cannulation site(s) are identified, going around the aorta and passing a tape around in each of these locations (Figure 6).

The LHB circuit is used to control hemodynamic disturbances secondary to changes in cardiac afterload after proximal aortic cross-clamping. The LHB reduces proximal hypertension and cardiac afterload and provides distal perfusion. Our preferred setting includes cannulation of the left inferior pulmonary vein with a 28F cannula to drain oxygenated blood that will be reinfused by the centrifugal pump into the distal aorta/left femoral artery via an 18 to 20F cannula. Moderate systemic heparinization (1 mg/kg; activated clotting time target, 250-300 seconds) is used, and the temperature is allowed to drift to 32°C to 34°C. LHB flows should be maintained between 1.5 and 2.5 L/min to keep the distal mean arterial pressure (MAP) at 60 mm Hg or above.[6,7]

The rest of the circuit is completed by 2 or 3 "Y-bifurcated" lines with balloon-tipped perfusion catheters (10 and 13F) on the end for the selective perfusion of the visceral vessels and the intercostal patch with isothermic blood and renal perfusion with cold (4°C) Custodiol solution[9,10] (Figure 7).

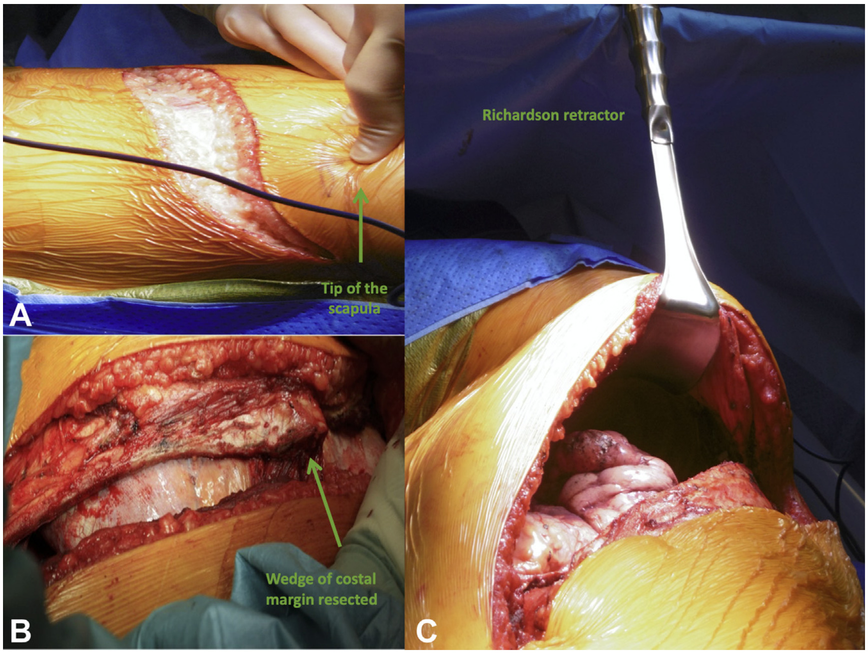

FIGURE 4. A, Left posterolateral thoracotomy incision from the midpoint between the spinal processes and the tip of the scapula, along the sixth intercostal space, curving along the costal margin and towards the median abdominal line down to the left of the umbilicus. B, Resection of a portion of the rib above the thoracotomy and a wedge of the costal margin to reduce thoracic trauma and fractures and facilitate exposure and subsequent closure without overlapping during the reapproximation of tissues. C, A Richardson retractor is secured to a horizontal bar attached to the surgical table at the shoulder level, to hold the upper ribs open.

To establish LHB, the outflow cannula is inserted into the left inferior pulmonary vein, and the inflow cannula can be inserted into various positions, including the left femoral artery, distal abdominal aorta, or the side arm of the branched graft (Figure 8).

The proximal segment of the aorta is clamped, usually just distal to the LSA, and a second clamp is applied at the midpoint of the descending thoracic aorta (Figure 9, *A*). The aorta is then circumferentially transected below the proximal clamp, leaving a cuff of 2 to 3 cm, and the aortic segment between the 2 clamps is opened longitudinally with electrocautery (Figure 9, *B*). The edges of the aorta are retracted laterally with 0 silk sutures. At this point, any high thoracic intercostal arteries with significant backflow are overrun with interrupted 2/0 silk sutures to prevent steal syndrome and facilitate visualization in the surgical field. An appropriate-sized straight Dacron graft is selected and a continuous end-to-end suture with a 3/0 polypropylene suture is performed (Figure 9, *C*), using a second layer of interrupted pledgeted 3/0 polypropylene suture (Figure 9, *D*). The proximal aortic cross-clamp is then moved to the Dacron graft distal to the anastomosis to test the proximal anastomosis. Careful attention to LHB each time that the aortic cross-clamping is modified is paramount, because the flows must be reduced to avoid dramatic drops in the main arterial pressure.

Once the proximal anastomosis is completed and tested, the distal clamp located at the mid descending thoracic aorta is then moved more distally and reapplied above the visceral segments. The aortotomy is extended longitudinally with electrocautery, and 0 silk sutures are placed at the edges of the aorta and retracted laterally to maintain aortic exposure. Attention is directed toward the lower intercostal arteries and/or higher lumbar arteries. Those arteries that are clearly patent around the T8-L1 level are temporarily occluded with 8F umbilical catheters to avoid blood steal phenomenon (Figure 10, *A*). Those arteries that are patent but located away from the T8-L1 level are overrun with interrupted 2/0 silk sutures (Figure 10, *B*).

One or 2 pairs of lower intercostals and/or higher lumbars are selected for reattachment to the aortic graft, either directly, by creating an opening in the aortic graft and using an island technique, or indirectly using an interposition graft. We usually preferred the latter approach, selecting a 10- to 12-mm graft that it is sutured end-to side around the selected intercostals with a continuous 5/0 polypropylene suture (Figure 10, *C*). The graft is continuously perfused with isothermic blood from one of its ends until both ends are reimplanted into the main aortic graft by the end of the procedure (Figure 10, *D*).[5,14]

Intraoperative monitoring of MEP signals guides the reattachment of intercostal arteries, although we tend to routinely reattach 1 or 2 pairs even in the absence of changes in the MEP signal.[5,13]

The aortic clamp is then moved further distally to the infrarenal level, and the aorta is opened longitudinally with electrocautery. Once again, 0 silk sutures are placed along the edges of the aorta to improve exposure. The celiac trunk and superior mesenteric artery are selectively cannulated with two 13F balloon-tipped perfusion catheters, and isothermic blood is administered from the LHB pump at a flow of 200 mL/min. The renal arteries are selectively cannulated with two 10F balloon-tipped perfusion catheters, and Custodiol solution (1 L at 4°C) is administered; subsequent doses of 500 mL can be repeated after 30 minutes if necessary (Figure 11).[9,10]

Any lumbar arteries with significant back bleeding are overrun with 2/0 silk sutures. If the inferior mesenteric artery is back bleeding, it is also overrun with a 4/0 pledgeted polypropylene suture, unless anatomic variations in the aorta identified on the preoperative CT scan mandate its reimplantation to compensate for an obstructed or undeveloped superior mesenteric artery.

The distal aorta is circumferentially transected above the iliac bifurcation. An appropriate-size multibranched graft is selected, and the distal anastomosis is performed with a double-layer buttressed suture using 3/0 polypropylene sutures in the same fashion as the proximal anastomosis (Figure 12, *A*). The aortic clamp is then moved proximally to the anastomosis within the Dacron graft to test the anastomosis (Figure 12, *B*). The 4 branches are clamped with individual hemostat clamps, and the aortic cross-clamp is moved within the aortic graft, proximal to the origin of the branches. This maneuver allows for filling of the graft and its branches to establish the proper orientation of each branch before attempting reimplantation.

The visceral arteries are reimplanted by direct reattachment in each of the corresponding 8/10-mm branches on the aortic graft after careful orientation and trimming. Individual hemostat clamps are placed at the origin of each branch. A 5/0 continuous polypropylene suture is used for each anastomosis, which is performed in an end-to-end fashion. We keep the perfusion catheters in place and the isothermic blood running while constructing the anastomosis, to reduce the ischemic time and control any potential back bleeding. Once the anastomosis is completed, the selective perfusion from the pump is discontinued, the balloon catheter is deflated and removed, and the anastomosis is tightened. Before hemostat clamp removal, the corresponding branch is deaired by creating small holes in the 8/10-mm graft (never in the artery) with a small-gauge needle.

The anastomosis usually starts with the right renal artery in its most posterior position (Figure 13, *A*), but there is no preferred sequence for anastomosing the other branches. However, we advocate for individual reimplantation of visceral branches as opposed to the patch inclusion technique, which leaves a considerable amount of aortic tissue behind and might result in subsequent aneurysmal

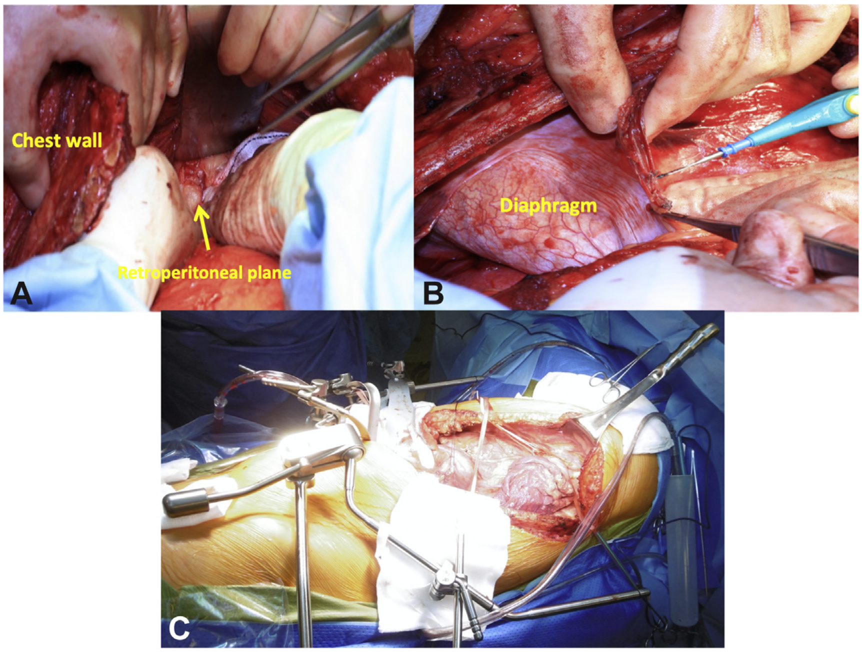

FIGURE 5. A, A plane is created between the abdominal wall and the peritoneum with careful digital blunt dissection until the pre-psoas fatty plane is reached. B, The diaphragm is divided circumferentially, leaving a 3- to 4-cm cuff attached to the chest wall. C, The Omni-Tract self-retaining retractor system is mounted to hold the laparotomy open.

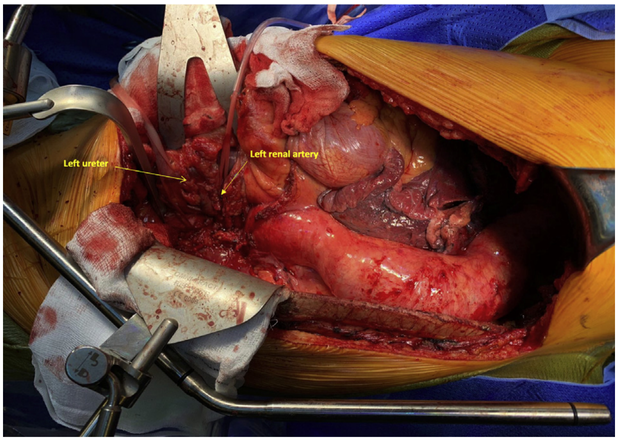

FIGURE 6. The abdominal aorta is then exposed by clearing the retroperitoneal fat, with the left renal artery and the ureter serving as landmarks.

dilatation. Figure 13 shows the following reimplantation sequence: right renal artery (A), superior mesenteric artery (B), celiac trunk (C), and left renal artery (D).

After restoration of flow to the visceral and renal vessels, the 2 separate Dacron grafts used for the proximal and distal aortic segments must be anastomosed together in an end-to-end fashion after ensuring the correct length to avoid kinks. We use a continuous 4/0 polypropylene suture, reinforced with interrupted 4/0 pledgeted polypropylene sutures if necessary (Figure 14, *A*). The graft is then thoroughly deaired by creating small holes with a small-gauge, needle and the 2 remaining clamps are then removed. LHB is usually discontinued at this point.

Finally, the 2 arms of the interposition graft that had been anastomosed end-to-side to the selected intercostal arteries, which are still perfused continuously with isothermic blood, are then anastomosed end-to-side to the main aortic graft with a continuous 4/0 polypropylene suture after guaranteeing the proper orientation to prevent kinks (Figure 14, *B*).

After LHB is discontinued, the arterial and venous cannulas are removed, and cannulation sites are reinforced with a pledgeted 4/0 polypropylene suture. Heparin is reversed with protamine sulfate administration. Hemostasis is secured by thoroughly checking all anastomoses and sutures and reinforcing them as needed. In most cases, administration of blood products (ie, platelet-rich plasma, pooled platelets, Octaplex, or fibrinogen concentrate) is necessary to reverse any coagulopathy, as is the administration of topical hemostatic adjuncts and packing of the extensive thoraco-laparotomy wound with swabs until clots form. We routinely overrun the edges of the residual aneurysm sac wall with a continuous 3/0 polypropylene suture to avoid ooze (Figure 15).

Surgical closure starts with closure of the diaphragm with a 1/0 polypropylene suture until the costal margin area is reached. Then the abdominal fascia is closed using a double-looped PDS suture to the level of the costal cartilage

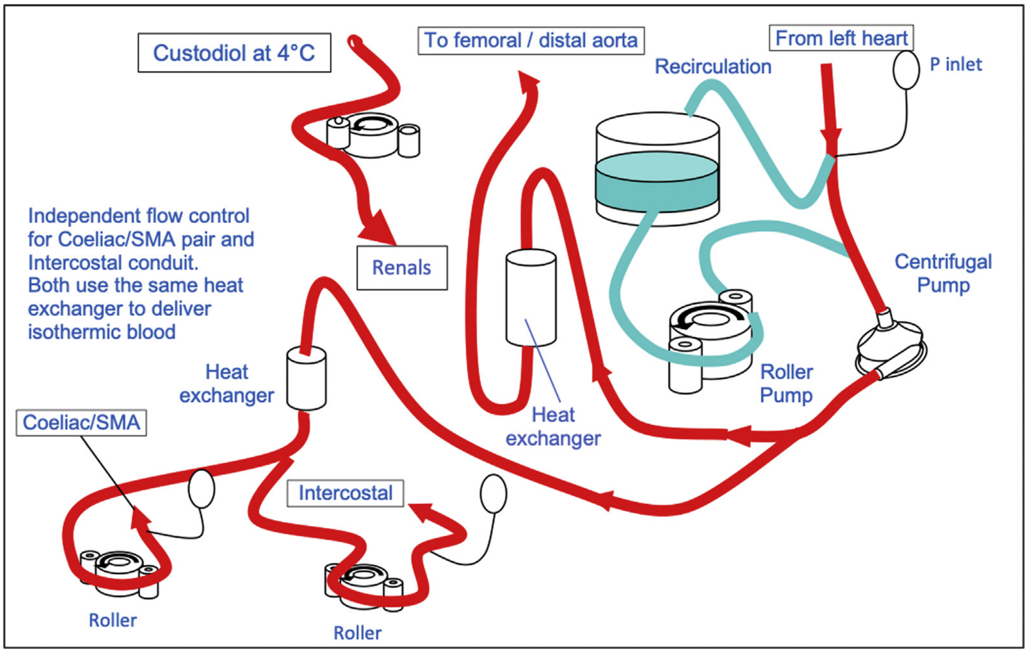

FIGURE 7. The left heart bypass circuit setting includes drainage from the left inferior pulmonary vein and reinfusion by the centrifugal pump into the distal aorta/left femoral artery. The rest of the circuit is completed by 3 "Y-bifurcated" lines with balloon-tipped perfusion catheters (10 and 13 F) on its end for selective perfusion of the visceral vessels and the intercostal patch conduit with isothermic blood and the renal perfusion with cold (4°C) Custodiol solution. A reservoir for rapid blood transfusion is an optional addition. *SMA*, Superior mesenteric artery.

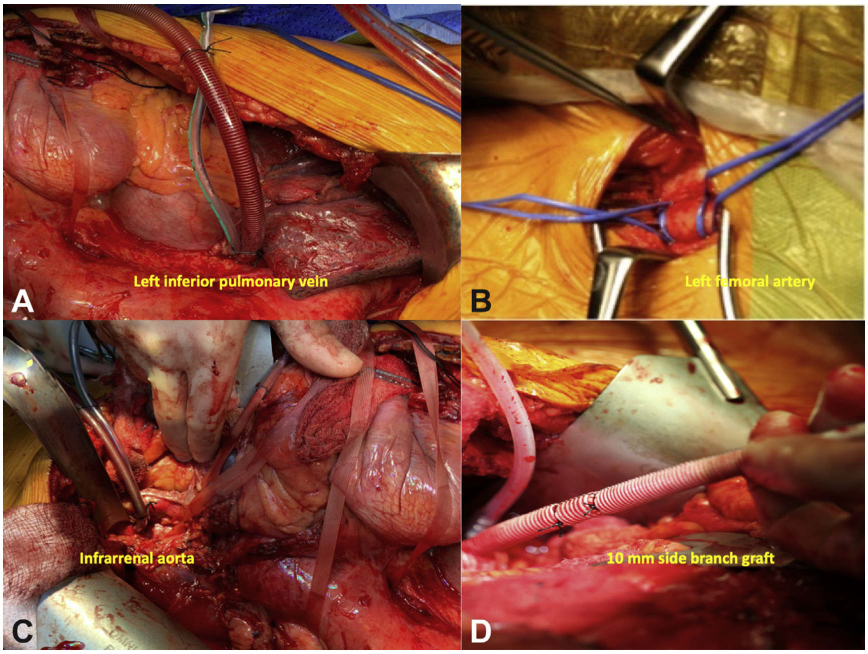

FIGURE 8. Cannulation strategies. A, Outflow cannula in the left inferior pulmonary vein. B-D, The inflow cannula can be inserted into a variety of positions: left femoral artery (B), distal abdominal aorta (C), or the side arm of the branched graft (D).

and tied to the diaphragmatic suture. Two 28F drains are inserted in left pleural cavity in anteroapical and posterobasal positions, and the thoracotomy is then closed with 4 or 5 interrupted 2/0 braided absorbable pericostal sutures placed around the ribs and costal cartilage in a figure-of-eight fashion. Routine closure of the thoracic and abdominal muscular layers is started from both ends of the wound with 1/0 absorbable sutures, followed by 2/0 absorbable

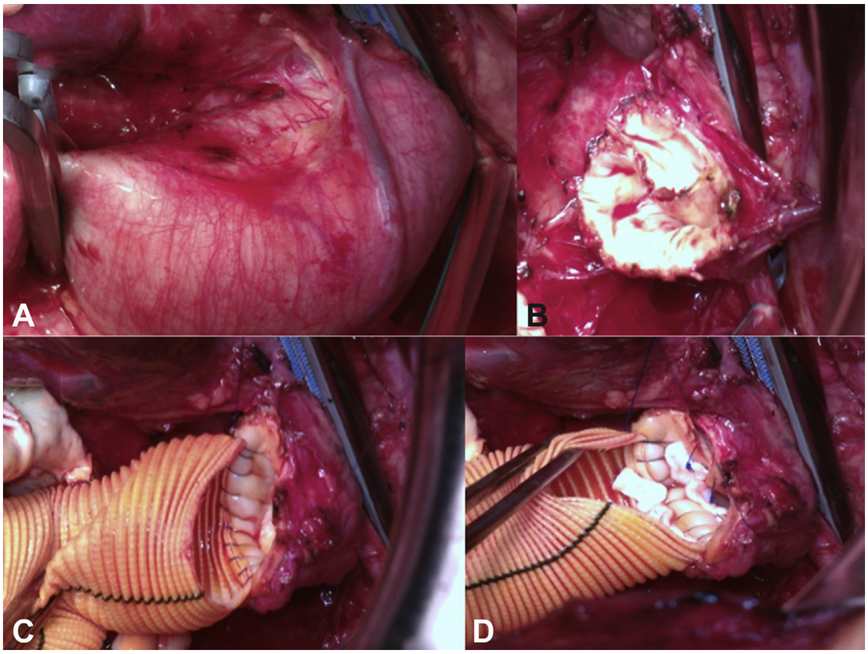

FIGURE 9. A, Clamping of the aorta distal to the left subclavian artery and at the midpoint of the descending thoracic aorta. B, The aorta is circumferentially transected below the proximal clamp, leaving a cuff of 2 to 3 cm. C and D, An appropriately sized straight Dacron graft is selected, and a continuous end-to-end suture with a 3/0 polypropylene suture is performed, using a second layer of interrupted pledgeted 3/0 polypropylene suture.

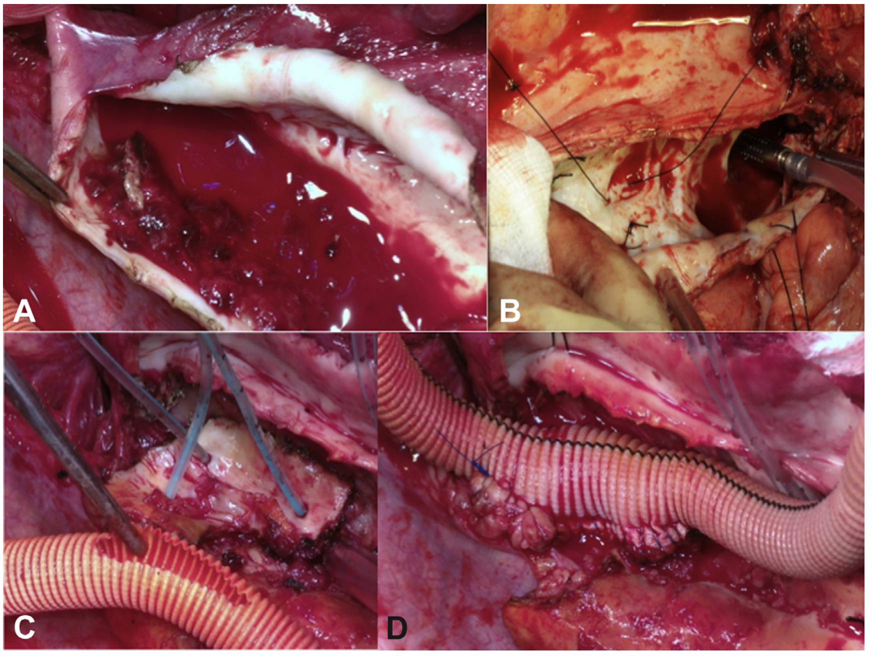

FIGURE 10. A, Exposure of the mid-descending thoracic aorta. B, The patent intercostal arteries away from the T8-L1 level are overrun with interrupted 2/0 silk sutures. C, Arteries patent around the T8-L1 level are temporarily occluded with 8F umbilical catheters to avoid blood steal phenomenon. D, One or 2 pairs are selected to be reattached to the aortic graft using an interposition graft.

sutures for the subcutaneous layer and 3/0 absorbable skin sutures (Figure 16).

Immediate Postoperative Care

The double-lumen tube is exchanged for a single-lumen tube at the earliest opportunity after the operation, unless manipulation of the airway is limited by severe facial edema. The patient is transferred to the intensive care unit with the same intraoperative monitoring systems and adjuncts except for the transesophageal probe.

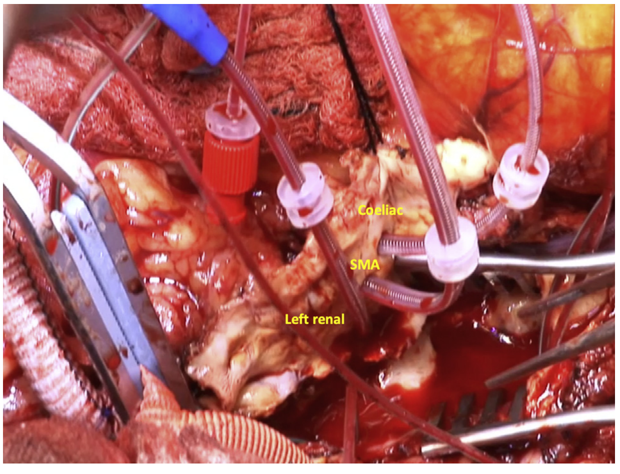

FIGURE 11. Cannulation of the celiac trunk and superior mesenteric and renal arteries with balloon-tipped perfusion catheters for administration of isothermic blood.

Maintaining hemodynamic stability with a desired targeted MAP >85 mm Hg is key for the visceral and spinal protection; thus, the use of vasoconstrictors (noradrenaline and vasopressin) is permissive. We target an MAP of >85 mm Hg for the first week and >75 mm Hg for at least another week to minimize delayed-onset paraplegia.

Cerebrospinal fluid drainage (pressure parameter set at 10 mm Hg and volume removal of 20 mL/h) is continued for at least 3 days, to minimize delayed-onset paraplegia. Other adjuncts for spinal protection include maintaining hemoglobin level >9 mg/dL and oxygen saturation >95% to maximize oxygen delivery.

We routinely hold sedation after 2 to 3 hours if all the above are stable, aiming to assess lower limb mobility. Weaning from the ventilator is desired in the first 12 to 24 hours, which usually necessitates some form of noninvasive ventilation in the first 24 to 48 hours.

Once the patient is extubated, hourly assessment of motor power score, limb sensation, and peripheral perfusion contribute to early detection of spinal injury as well as vascular complications. We maintain the frequency of observations during the first week, reducing it once the patient is fully mobile. A physiotherapist starts fully mobilizing the patient 24 hours after the spinal drain removal.

Intensive daily chest physiotherapy is paramount to facilitate reexpansion of the left lung and minimize the risk of chest infection. Early renal hemofiltration may be used in

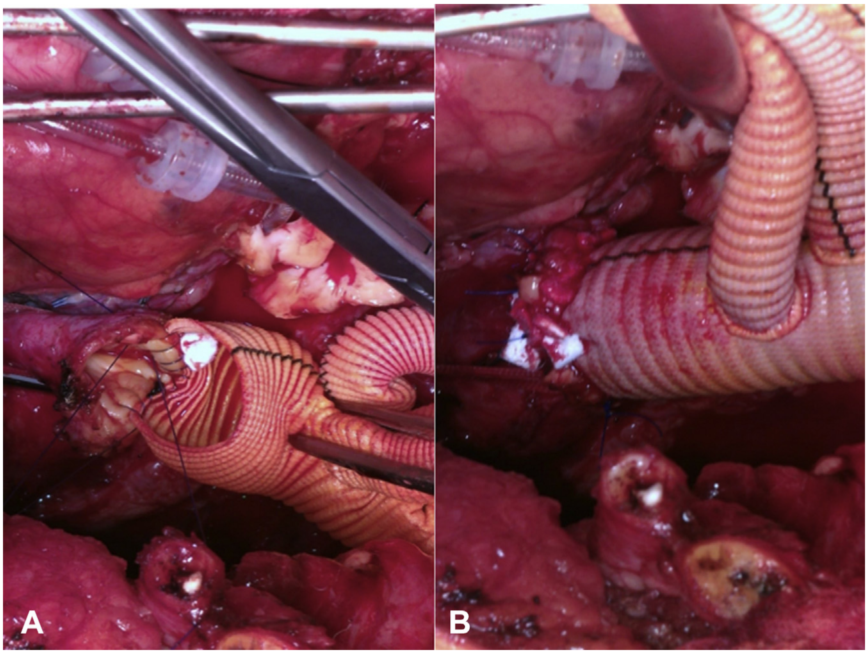

FIGURE 12. A and B, Distal anastomosis to the infrarenal aorta performed with a double-layer buttressed suture using 3/0 Polypropylene sutures.

the event of refractory metabolic acidosis due to reperfusion syndrome, but with the maintenance of a positive fluid balance to contribute to blood pressure maintenance and minimize renal function impairment. Any residual coagulopathy should be corrected in the early postoperative hours guided by the results of thromboelastography.

MEP electrodes are kept until the patient is extubated to provide an objective assessment and monitoring of the spinal cord function while sedated. The chest drains are left in situ for 5 to 7 days until the patient is more mobile to minimize the risk of delayed intrathoracic fluid collections. Nutrition is also important to compensate for the

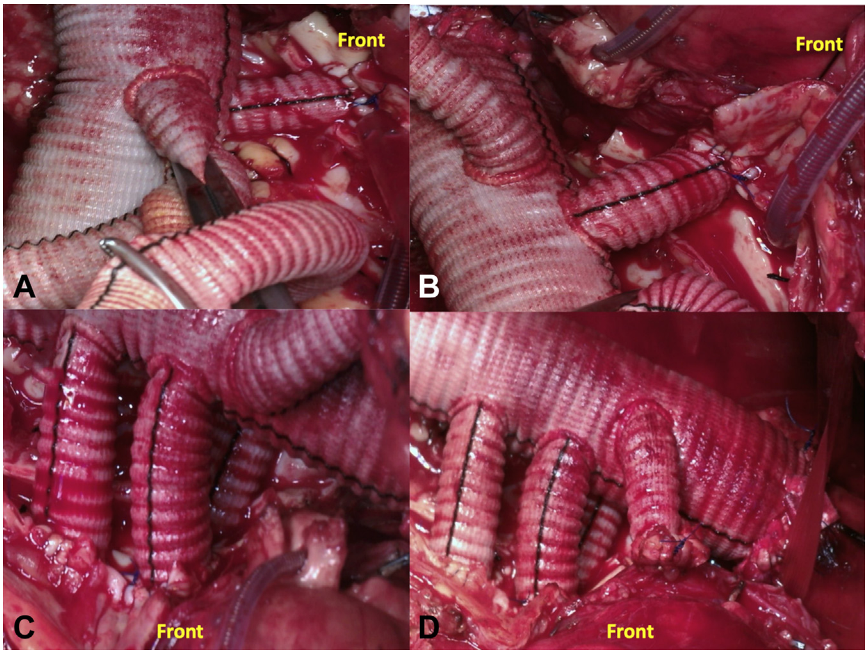

FIGURE 13. Reimplantation of visceral arteries to the corresponding side branch of the graft. A, Right renal artery. B, Superior mesenteric artery. C, Celiac trunk. D, Left renal artery.

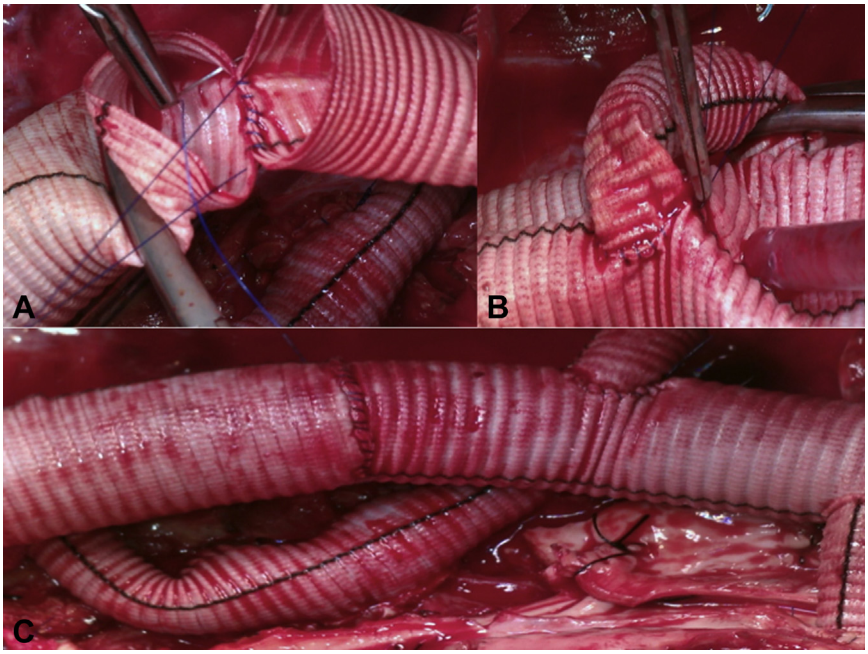

FIGURE 14. Graft-to-graft anastomosis (A), followed by anastomosis of the 2 arms of the graft to the intercostal arteries end-to-side to the main aortic graft (B and C).

catabolic state and minimize the risk of wound healing problems.

In our unit, patients are treated in the intensive care setting until they are extubated and demonstrate stable hemodynamics and respiratory and renal function. Once those targets are met, the patient is transferred to a high-dependence facility and from there to the postoperative ward. Usually these patients remain in the hospital for at least 2 weeks.

Follow-up at Discharge

All patients who undergo TAAA repair are assessed with CT of the aorta before hospital discharge. This CT scan is done to assess the patency of all anastomoses, the presence of intrathoracic and/or intra-abdominal collections, and the state of adjacent aortic segments for future reference (Figure 17).

The routine follow-up after discharge includes clinical visits at 6 weeks, 3 months, 6 months and then annually with repeat CT scans at those visits.

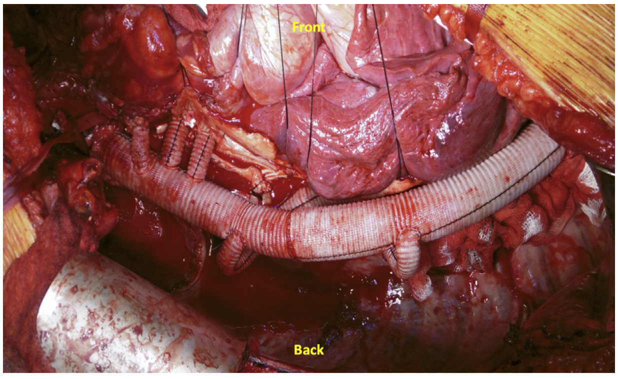

FIGURE 15. Final view after the complete repair.

Conflict of Interest Statement

The authors reported no conflicts of interest.

The *Journal* policy requires editors and reviewers to disclose conflicts of interest and to decline handling or reviewing manuscripts for which they may have a conflict

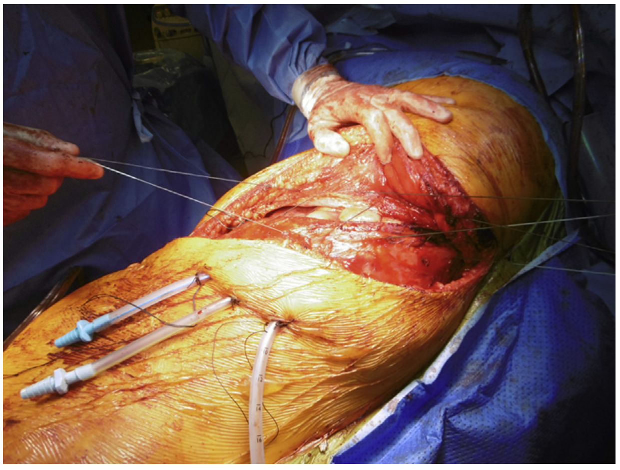

FIGURE 16. Surgical closure of the thoracotomy. Two 28F drains are inserted into the left pleural cavity in anteroapical and posterobasal positions.

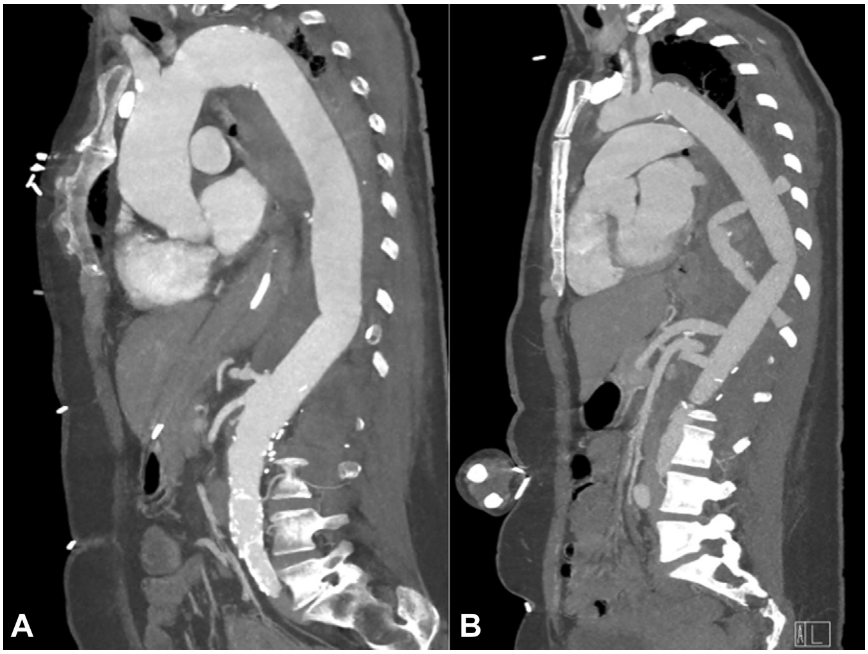

FIGURE 17. Sagittal view of a contrast computed tomography scan showing the whole aorta after the repair of a Crawford extent II thoracoabdominal aneurysm in a patient with an atherosclerotic aneurysm (A) and in a patient with Marfan syndrome and a chronic DeBakey III aortic dissection (B).

of interest. The editors and reviewers of this article have no conflicts of interest.

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Key Words: aortic aneurysm, aortic dissection, thoracoabdominal aorta, spinal cord protection, visceral protection