OPEN REPAIR OF DESCENDING THORACIC (THORACOABDOMINAL) AORTIC ANEURYSM

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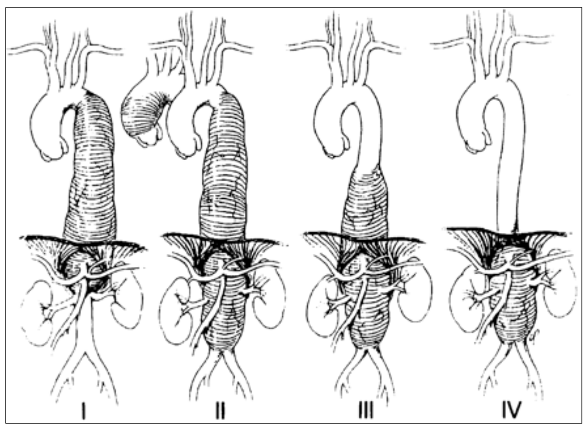
Management of patients undergoing open TAAA repair differs from management of patients for abdominal aortic surgery in three major ways:

1. Single lung ventilation is necessary to improve surgical access and limit potential lung injury.

2. There is often massive blood loss. The dilutional coagulopathy accompanying large transfusion requirements is often a concern.

3. Paraplegia may result as a consequence of prolonged ischemia or resection of the great radicular artery (Artery of Adamkiewicz).

There are three different surgical techniques for thoracoabdominal aneurysm repair. Technique selection is often dictated by the location and extent of the lesion (see Crawford classification, figure at right).



1. "Clamp and sew" – The aorta is clamped proximally and the surgeons perform the anastamoses as rapidly as possible. Back bleeding of the intercostal, mesenteric, renal, and iliac arteries can produce substantial blood loss. Reliant on surgical speed to limit end organ ischemia.

2. Partial bypass/shunts – With the heart beating, blood is partially diverted from either the left atrium or proximal aorta distally into the femoral artery (see figure, page 3). Relies on patient lung function, cardiac function and volume status.

3. Extracorporeal circulation – Distal to the aortic clamp, blood is circulated in the lower body via femoral vein to femoral artery bypass. Relies on external oxygenators for lower body oxygenation. Cases involving the subclavian artery or aortic arch necessitate cardiopulmonary bypass. Hypothermic circulatory arrest may also be required. Of note, blood requirements are typically lessened when bypass or shunt techniques are used.

Each of these techniques aims to limit ischemic time and maximize perfusion to the kidneys, spinal cord, and lower extremities. It is important to know which method the surgeons will employ to coordinate an appropriate anesthetic plan.

PREOPERATIVE CONCERNS

Given the massive insult this operation represents, it is prudent to have an extensive cardiac work-up in these patients. Unfortunately, many of these procedures are performed on a semi-emergent basis, making cardiac preparation unfeasible. All patients should be assumed to have coronary disease.

A chest x-ray or CT scan should be should be examined preoperatively for evidence of left mainstem bronchus compression by the aneurysm. If present, placement of a left sided double lumen tube may be difficult (see Airway Management, below). A hoarse voice may represent aneurysm induced recurrent laryngeal nerve dysfunction.

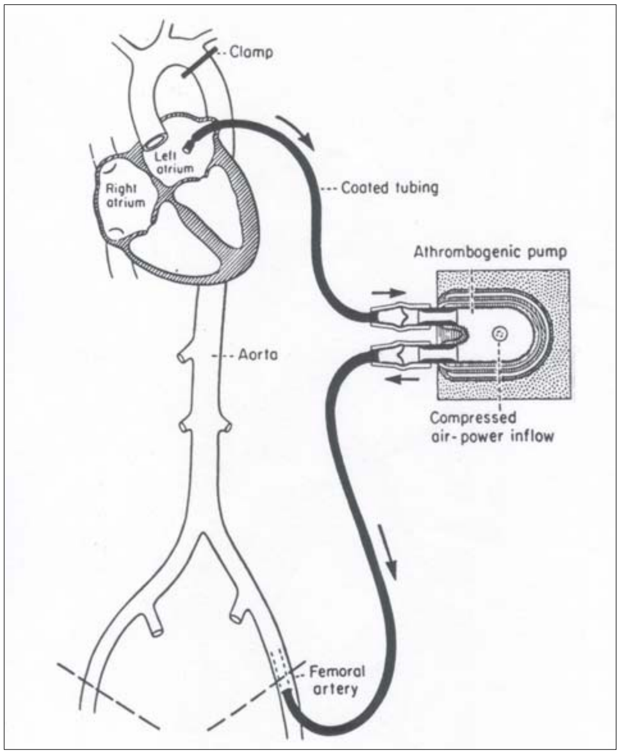
Blood and clotting factors should be available and blood band numbers should be noted. Current recommendations include an initial cross match of ten units of packed red blood cells, ten units of fresh frozen plasma and two to four platelet five packs. O-negative blood may be required in emergency situations. Cell saver – a blood scavenging and recycling system – should be employed.

Newer blood preservation techniques should be considered. Aprotinin, an agent formerly used exclusively for cardiac procedures requiring bypass, preserves platelet function and acts as an anti-inflammatory agent. Improved platelet function decreases blood loss, notably following cross clamp removal. Aprotinin's anti-inflammatory effects may lessen the impact of ischemic mediators released with reperfusion of the lower extremities. Although further studies are needed, use of this agent in TAAA repair appears to decrease the substantial transfusion requirements typical for this surgery.

LINES AND MONITORING

If partial bypass is not used, the primary focus should be on massive blood loss and the ability to rapidly transfuse. Intravenous access is a priority. One or more introducers and several large bore peripheral IVs are often placed. Common introducer sites include the right IJ, left IJ, or femoral veins. "Double stick" techniques – placing two introducers into the same vein – can be employed to avoid the risk incurred by attempting placement of bilateral IJs (carotid puncture and pneumothorax). With the advent of the TEE, Swan-Ganz catheters are often forgone in favor of using an introducer for volume infusion. If needed, a pulmonary artery catheter can be inserted for postoperative management at the conclusion of the procedure.

When partial bypass/shunting is used (see figure, following page), the primary focus is on coordination of upper and lower body blood flows. The surgeons will typically direct the perfusionists to maintain a given distal pressure or flow. As left atrial blood volume must supply both the left ventricle (for upper body perfusion) and the bypass circuit (for lower body perfusion), excessive pump flow may compromise left ventricular filling. The subsequent compromise of proximal pressure and perfusion (e.g. brain and heart) is obviously unacceptable. Effective communication between the anesthesiologist and the perfusionists is essential. A TEE is invaluable in directing bypass flow rates by providing constant evaluation of LV filling status.

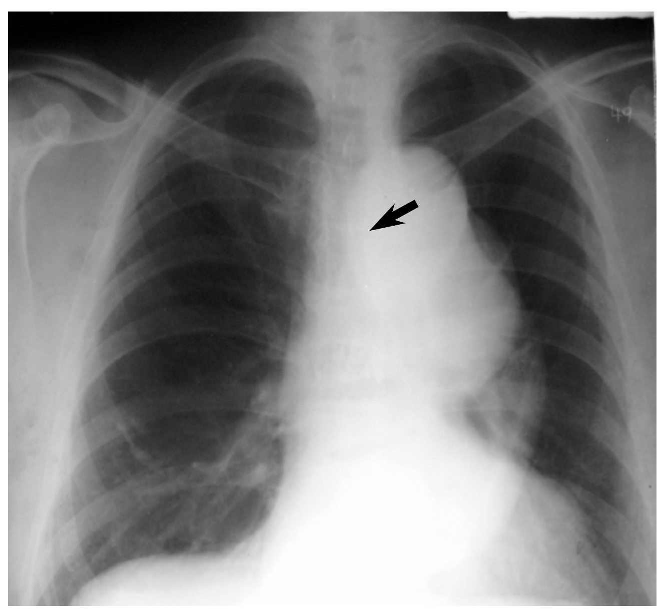


Two to three blood warmers (depending on the number of large bore IVs) should be set up in advance. Because massive transfusion can clot the blood tubing filters, preassembling six transfusion setups with 0.9% saline and blood tubing is prudent – it obviates the need for assembly during periods of intensive volume resuscitation. Pressure bags and a rapid infusion device can be utilized to administer blood products in an expedited fashion.

An arterial line is ideally placed in the right radial artery and consideration should be given to suturing it to the skin. A left radial arterial line is potentially problematic if the aortic clamp will be placed near or proximal to the left subclavian artery. A dorsal pedal or femoral arterial line should be placed if bypass techniques are employed to monitor distal pressures.

AIRWAY MANAGEMENT

Many of these patients will be considered to have full stomachs. In these situations the benefits of a rapid sequence induction must be balanced against the patient's hemodynamic status.



Single lung ventilation is necessary for several reasons:

1. Improvement of surgical exposure.

2. Lessening the postoperative pulmonary dysfunction associated with lung retraction. Retraction of ventilated lung tissue may cause pulmonary contusion, an issue of particular importance if the patient is to be heparinized. Pulmonary hemorrhage may result.

As mentioned above, it is not unusual for an aneurysm to distort the left mainstem bronchus, making left sided double lumen tube placement difficult. If available, a chest x-ray should be examined prior to induction (see image at right). A bronchial blocker and/or right sided double lumen tube should be on hand if left sided tube placement is impractical. Tube or blocker position should be confirmed with a fiberoptic bronchoscope both before and after patient positioning. Like all surgeries requiring single lung ventilation, a poorly placed tube can lead to persistent oxygenation problems. Attentiveness to proper tube placement is strongly recommended.

THE PRE-CLAMP PERIOD

If an acute dissection is present, a large blood volume may be sequestered in the aortic wall; transfusion may be necessary prior to application of the aortic cross clamp. Blood pressure should be well controlled, as hypertension can lead to aneurysm rupture. Before the aortic cross clamp is applied (approximately 30 minutes) mannitol 0.5 - 1.0 g/kg should be administered (see renal protection, below). Low dose heparin is given upon the surgeons' request when they are preparing to apply the aortic clamp; anticoagulation is necessary to prevent thrombosis of the lower extremities. If partial bypass or shunting is used, 'partial' heparinization (100 U/kg) is given. If complete bypass is employed, 'full' heparinization (300 U/kg) is needed.

PREPARATION FOR AORTIC CROSS CLAMPING ***WITHOUT BYPASS***

Nitroprusside, NTG, and/or milrinone should be available for both bolus dosing and infusion to control blood pressure. In the absence of bypass, the systolic blood pressure should be maintained at approximately 180-200 mm Hg after the clamp is applied. Such high pressures are dictated by the drastic reduction in organ perfusion distal to the clamp (spinal cord, kidney, etc.); the use of vasodilators further decreases distal perfusion. Relative hypertension favors perfusion of collaterals to these compromised organs. The needs of the heart (which prefers less afterload) must be balanced against those of the poorly perfused lower body organs.

Aneurysm incision is usually accompanied by significant blood loss requiring transfusion. Cell saver is particularly important at this juncture. Of note, salvaged cells, like packed RBCs, are devoid of platelets and coagulation factors. Platelets and fresh frozen plasma transfusion will be required to avoid the dilutional coagulopathy which may result from large volume RBC (packed or salvaged) transfusion.

Cell saver and packed RBCs have unique concerns worth mentioning. Salvaged blood from a heparinized may contain trace amounts of heparin. A mild secondary heparin effect may develop with cell saver transfusion. Packed RBCs contain a citrate preservative which binds blood calcium. The resulting hypocalcemia may require calcium chloride replacement. Requirements can be directed either by ionized calcium measurements (via ABG) or empirically (one gram for every two or three units of packed cells).

PREPARATION FOR AORTIC CROSS CLAMPING ***WITH BYPASS***

Bypass is slowly initiated before cross clamping, preventing significant effects on blood pressure with clamp placement. Distal flows are titrated to maintain adequate proximal and distal pressures. Proximal pressure drops are usually secondary to excessive LA drainage and subsequently inadequate LV filling. Flow rates must be temporarily decreased and slowly reestablished. Goals usually include distal mean pressures of about 50; proximal mean pressures are ideally equal to the patient's baseline.

COMPLICATIONS OF AORTIC CROSS CLAMP PLACEMENT

Significant stress is placed on both the heart and visceral organs when the aorta is clamped. As expected, the potential for end organ injury is considerable (see table at right – aneurysm 'type' refers to Crawford classification previously described). Two of the most concerning complications of aortic cross clamp placement are renal failure and paraplegia. As a result, preventive measures are taken in an effort to avert these common problems.

Aneurysm Group:	Type I	Type II	Type III	Type IV
Overall: 9%	–	10-25%	–	5%
Paraplegia/spinal cord ischemia	6%	15%	3%	2%
Other neurological complications	6%	12%	2%	1%
Renal insufficiency	–	2-5%	–	–
Respiratory failure	–	10%	–	–
Graft infection	–	1-6%	–	–
MI	–	–	–	–
Graft failure	–	Rare	–	–
Graft thrombosis	–	–	–	–
False aneurysm	–	–	–	–
Embolization	–	–	–	–
Bowel ischemia	–	2-10%	–	–
Impotence	Rare	⇐	⇐	⇐
Ureteral injury	Rare	⇐	⇐	⇐
Hemorrhage	Common	⇐	⇐	⇐

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RENAL PROTECTION

Renal failure is a potentially catastrophic complication of aortic surgery. The incidence of ARF is 3-14%; if subsequent dialysis is required, patient mortality is estimated at 30-60%. Patients at increased risk include those with preexisting renal compromise, older patients, and longer cross clamp times (greater than 30 min.). Hypovolemia and decreased cardiac output significantly increase the likelihood of renal failure. Risk also increases when shunting and bypass techniques are **not** utilized.

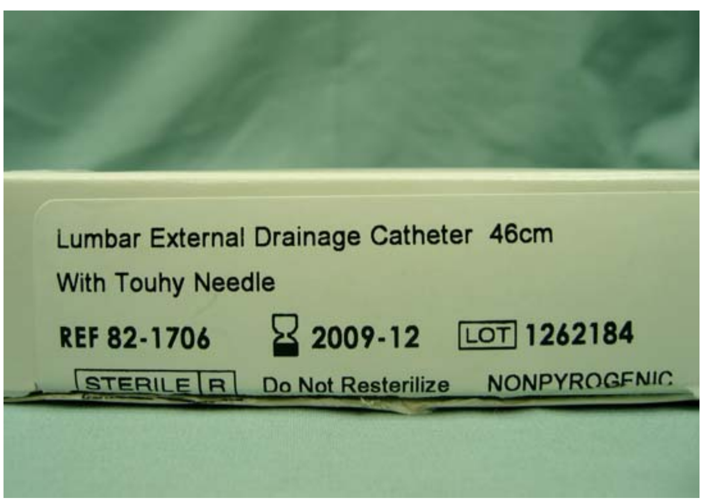
Mannitol, furosemide, dopamine, and fenoldopam (a dopamine-1 and □-2 receptor agonist) are among the many agents used in attempts to preserve renal function. While all augment flow through the renal tubules, only mannitol has proven effective in improving postoperative renal function. Mannitol's effects extend from increased renal perfusion to include free radical scavenging properties. The majority of published sources now recommend administering 0.5-1.0 g/kg of mannitol prior to aortic cross clamping.

SPINAL CORD PROTECTION

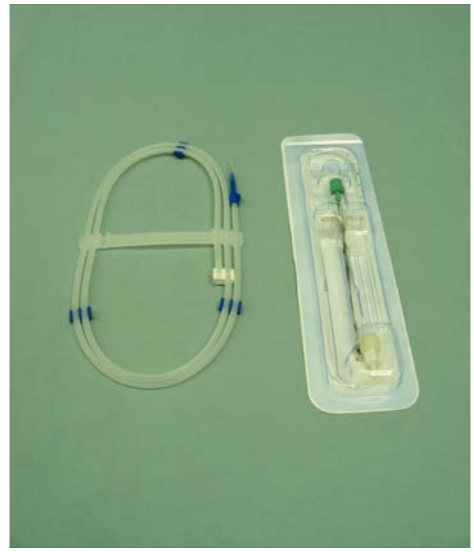
Paraplegia results from prolonged spinal cord ischemia and the disruption or embolization of the radicular blood supply during aneurysm repair. The incidence of paralysis after TAAA repair is disconcertingly high, ranging from 2-20%, depending on aneurysm type. This percentage may double in the presence of a dissection. Prolonged cross clamp time (greater than 30-45 minutes) and perioperative hypotension hold the strongest correlation to postoperative paralysis. The risk of deficits is also higher when the intercostal and radicular arteries are not reimplanted into the aortic graft. Many techniques have been studied in an effort to improve neurologic outcome after TAAA repair. Steroids, magnesium, intrathecal papaverine injection, epidural cooling, systemic hypothermia, and other methods have all been investigated. The most common, however, is CSF drainage through a lumbar catheter.

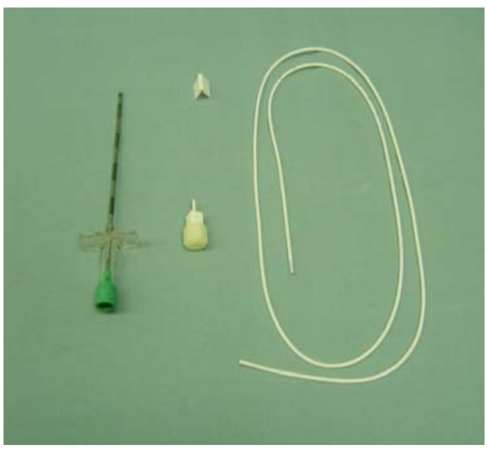
The goal of a lumbar drain is to decrease the CSF pressure. Aortic cross clamp placement decreases distal systemic blood pressure; due to venous engorgement of dural veins, the CSF pressure (CSFP) becomes elevated as well. The lower mean arterial pressure (MAP) limit of spinal cord arterial autoregulation is 60-70 mm Hg; distal MAP after aortic cross clamping can decrease to 30 mm Hg. Because spinal cord perfusion pressure (SCPP) is equal to MAP minus CSFP, a concurrent rise in CSFP from 5 to 20-25 mm Hg can severely compromise spinal cord perfusion. With this in mind, a decrease in CSFP can theoretically improve SCPP. It has become common practice to maintain the subarachnoid pressure at 10 mm Hg using a CSF pressure monitor. This technique can potentially double the perfusion pressure to the spinal cord.

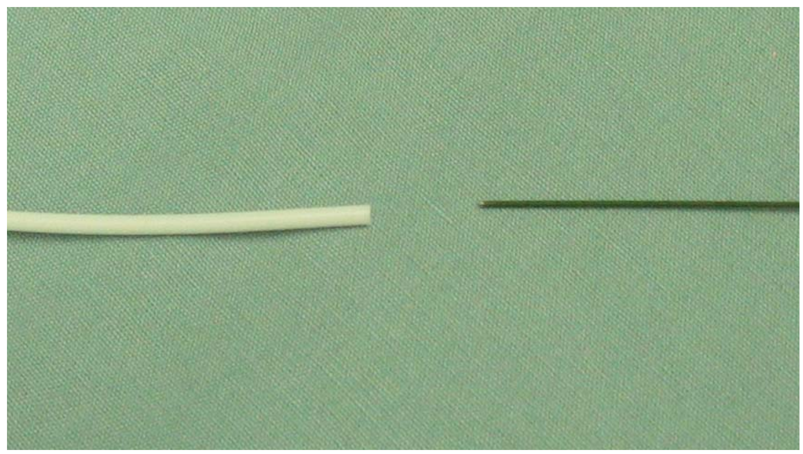
Given their infrequent usage, the lumbar drain kits are briefly reviewed below.



The basic lumbar drain kit is pictured above. Notice that only the insertion needle, catheter, and catheter adaptor are included in the kit. The 14 gauge needle is simply inserted until CSF return is achieved; the catheter is then inserted through the needle. To ensure adequate drainage, five to seven cm of the catheter should be placed in the subarachnoid space.

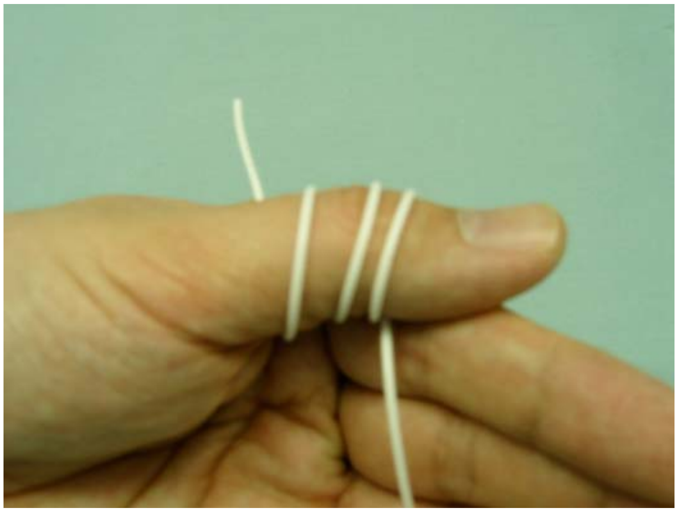






A wire guided kit is also available (above). The wire is designed to function as a catheter 'stylet' to facilitate drain insertion through the included Tuohy needle. **The wire should not be inserted through the needle prior to its insertion into the catheter** (bottom right image, above). The catheter tip is closed, preventing wire induced trauma to the spinal cord and nerve roots. It should be noted that after insertion of the drain, wire removal can be difficult. Slow, steady pressure must be applied when extracting the wire from the placed drain, paying attention to the location of the tubing at the skin. Inadvertent catheter removal can occur.

Finally, a small butterfly suture adapter is included in this kit (bottom left image, above). It can be placed around the tubing and sewn to the skin. Suture is not included and must be obtained separately.

A final word about lumbar drains. Notice how flexible the Silastic catheters are; placement can therefore be quite difficult. The second picture displays the impact of wire insertion into the catheter. It is substantially more difficult to flex the wire guided catheter on the right. This increase in stiffness makes catheter insertion substantially easier.

If a lumbar drain is placed, it usually remains in place for 48-72 hours. A CSF pressure of 10 mm Hg should be maintained via drainage throughout this period. Regardless of drainage time, the catheter should not be removed until normal coagulation status is documented postoperatively.

PREPARATION FOR CROSS CLAMP REMOVAL ***WITHOUT BYPASS***

Given the multiple tasks required, requesting a colleague's assistance at this stage is recommended. All blood products should be in the room and checked. Platelets and FFP are often only administered immediately prior to clamp removal to avoid lower extremity thrombosis. Five to ten minutes before the release of the aortic cross clamp, FFP, platelets, and PRBC should be started to increase preload. In addition to blood products, 50 gm of mannitol, 100 meq of bicarbonate (to balance reperfusion acidosis), and gram of calcium can be given. In order to increase SVR, a low dose infusion of phenylephrine or norepinephrine is frequently initiated five to ten minutes before clamp removal. While epinephrine is also an option, its arrhythmogenic effects are undesirable.

Upon cross clamp removal there is reactive hyperemia, vasodilation, and decreased SVR and preload. Due to the release of thromboxane and acidotic mediators, elevated CVP and pulmonary artery pressures further disrupt hemodynamic status. The surgeon should remove the cross clamp slowly to avoid the profound hypotension which may result from rapid reperfusion. If the hypotension is excessive, the aortic cross clamp can be replaced until volume and hemodynamic status are optimized.

PREPARATION FOR REMOVAL OF THE AORTIC CROSS CLAMP ***WITH BYPASS***

With continuous perfusion of the lower body through partial or full bypass, cross clamp removal is frequently less eventful due to improved acid/base and volume status. The perfusionists gradually reduce the flow rates, allowing proximal pressure to rise as the clamp is gradually released. Volume or pressors may initially be needed, so blood products should be in the room and checked. Maintaining a Hct of 25-30 throughout the case is recommended to maintain blood volume and oxygen carrying capacity. At least two units of PRBC should be pressurized for infusion at cross clamp removal. Of note, hypertension should also be avoided while the surgeons evaluate their anastamoses. High pressures can further disrupt a flawed repair.

LATE OPERATIVE AND POSTOPERATIVE CONSIDERATIONS

It is not uncommon to have a hypovolemic, hypothermic patient with marginal lung function at procedure's end. These patients frequently develop significant facial, scalp, and airway edema (see image, below). As a result, **immediate postoperative extubation or tube exchange can be disastrous if the airway is compromised**. When used, a double lumen tube is frequently left in place overnight with the patient's head elevated. This position allows the airway edema to resolve before extubation or exchange of the endotracheal tube. Deflation of the bronchial cuff is recommended, and consideration should be given to removing the bronchial cuff balloon. The blue bronchial cuff tubing can then be knotted, preventing inadvertent confusion with the tracheal cuff. If single lung ventilation is again required, the knot can be cut and a hypodermic needle inserted for bronchial cuff inflation. Finally, the nurses in the ICU should be provided with several of the long suction catheters supplied with the double lumen tubes; standard suction catheters are of inadequate length.

If a Swan-Ganz catheter is not used during the surgery, it may be inserted via an introducer (preferably in the RIJ) upon completing the procedure or on arrival to the ICU.

TAAA repairs are among the most challenging and enjoyable cases for an anesthesiologist. Attention to detail and communication with surgeons and support staff are critical. With these points in mind, the result is often a successful procedure and a good patient outcome – making these cases among the most rewarding as well.

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