Ruptured Abdominal Aortic Aneurysms: Remote Aortic Occlusion for the General Surgeon

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When Parodi and colleagues [1] implanted the first endograft to treat an infrarenal abdominal aortic aneurysm (AAA) in 1991, they forever changed the treatment of aortic aneurysmal disease. This technology has reduced the mortality risk compared with open repair, and it has eliminated the associated morbidity of an abdominal operation in high-risk patients [2–5]. Similarly, whereas open surgery has remained the primary therapy for ruptured abdominal aortic aneurysms (RAAA), it is nonetheless associated with significant morbidity and mortality ranging from 30% to 80% [6]. Despite technological advances and advances in critical care, the actual surgical approach and resultant mortality has only marginally changed over the last 50 years [7,8].

The success of endovascular aneurysm repair (EVAR) for elective aneurysms has been slow to transition into the treatment of emergent aneurysmal disease. There are several obstacles preventing this from occurring, ranging from institutional limitations, imaging, graft availability, and availability of an endovascular surgeon. Although not all vascular surgeons and general surgeons are capable of performing EVAR, there are basic endovascular techniques that can be useful for standard open repair.

During the Korean War, Lieutenant Colonel Hughes [9] introduced the technique of remote aortic occlusion by placement of transfemoral Foley catheters in three injured soldiers who presented in hemorrhagic shock from penetrating truncal trauma. He used this technique as compassionate

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use and noted all three patients to temporarily experience hemodynamic improvement. A decade later, Hesse and Kletschka [10] used intraluminal aortic occlusion specifically for ruptured abdominal aneurysms in 1961. Their technique involved placing a Foley catheter through the aneurysmal rent in the aorta and guiding it into the thoracic aorta. If the aneurysm was not easily defined, the balloon was placed through an arteriotomy placed in the common iliac artery. Within the past 2 decades, endovascular procedures have become commonplace in the United States, and vascular surgeons are using remote aortic occlusion to manage RAAAs [11–13].

This article addresses the challenges associated with performing endovascular procedures in an after-hours environment, the preoperative preparation of patients who have RAAAs, and the technique of remote aortic occlusion.

**Remote aortic occlusion for ruptured abdominal aortic aneurysms**

*Institutional preparation*

When a patient presents to the emergency room with a presumed RAAA, the institution must have a predetermined algorithm to rapidly assess the patient, prepare the operative suite, obtain axial imaging, and transport the patient to the operative suite. At the authors’ institution, endovascular training is provided on an annual basis to the house officers, surgical staff, and operating room technicians to rehearse the prepared algorithm for RAAAs. Mehta and colleagues [14] found that mock preparation for emergent ruptured aneurysms highlighted the importance of early diagnosis and institutional readiness. Additionally, rehearsing the emergent algorithm with each elective aneurysm prepared the anesthesiologists, operating room staff, and radiographic technicians for emergent cases.

In order to use endovascular techniques, the institution must have an available fluoroscopic C-arm and operative imaging table. In addition, there must be a basic set of endovascular supplies readily available for the surgeon. The scrub technicians and circulating nurses must also have familiarity with access needles, wires, sheaths, and contrast agents. Whereas most general surgeons have had experience with intraoperative cholangiograms, few have used intraoperative vascular imaging in their practice. The majority of general surgeons are extremely comfortable with gaining access in the groin using Seldinger’s technique, however. Having a team with basic endovascular knowledge is imperative for using this technique for emergent cases.

*Preoperative management*

Once the patient is identified as having a RAAA, the patient’s clinical status dictates the urgency of treatment. The ideal perfusion pressure has brought about much debate with regards to resuscitation of patients who have RAAAs. The majority of research in this area has focused on
hypotensive (systolic blood pressure < 90 mmHg) trauma patients suffering from hemorrhagic shock, and a consensus suggests that delayed resuscitation until hemorrhage is controlled improves survival and reduces postoperative morbidity, primarily multisystem organ failure [15,16]. This literature has been applied to RAAAs, and although there are multiple animal studies in this arena, no prospective studies have been performed in patients who have RAAAs [17]. Increasing the patient’s systolic blood pressure could exacerbate ongoing hemorrhage or convert a contained rupture to free rupture. If the patient is mentating, resuscitation (crystalloid and blood products) should be reserved until the aortic occlusion balloon (AOB) is secured.

If a vascular surgeon is available for potential endovascular repair of an RAAA, a preoperative CT scan will be valuable for endograft sizing. Transferring a patient who has an RAAA to the CT scanner contradicts general surgical training principles, and can be viewed as a deplorable decision; however, Lloyd and colleagues [18] performed a time-to-death analysis of patients who presented with RAAAs and were not able to undergo repair secondary to malignancies or secondary to comorbidities that precluded open repair. The median time from onset of symptoms to admission was 2.5 hours, and death occurred in 12.5% within 2 hours of admission (4.5 hours from onset of symptoms); the remainder died after 2 hours. The median time-to-death in this study was 16 hours and 38 minutes [18]. This study illustrates the feasibility of obtaining preoperative axial imaging. Most CT scanners can perform 2 to 3 mm collimation imaging of the aorta in 5 to 10 minutes en route to the operative suite. If the decision is made to defer preoperative axial imaging, intraoperative sizing of the aneurysm can be performed with aortography and intravascular ultrasound should a vascular surgeon be available.

Once the decision is made to repair the aneurysm, the patient should proceed to the operative suite, and it is imperative that the patient be placed on an imaging table. Having the imaging table and C-arm available in the assigned operative suite must be part of the operative personnel’s checklist. Before induction of anesthesia, central access and arterial monitoring should be obtained. Blood products for massive resuscitation should be in the operative suite. A Foley catheter should be placed, and then the patient should be prepared and draped. At this time, the surgical team can place the AOB before induction of general endotracheal anesthesia. If an endovascular approach is going to be attempted, regional anesthesia or even local anesthesia can be used based on the hemodynamic status of the patient. Box 1 lists the basic inventory that should be readily available when placing AOBs.

**Technique**

**Access to the common femoral artery**

With the patient prepped and draped, the operator should use a standard access needle that will accept a 0.035” wire. The authors prefer the groin
because of the straightforward percutaneous approach, and the right side keeps the surgeon on the opposite side of the table as the C-arm. Utilizing Seldinger’s technique, the vessel is accessed, ideally over the medial third of the femoral head. Most of these patients do not have palpable groin pulses; therefore the surgeon must rely on anatomic landmarks, image guidance, or a cut-down procedure. The authors’ standard approach is to place a Kelly clamp inline with the proposed access site, and then check our planned site with fluoroscopic imaging. The tip of the Kelly clamp is then adjusted such that the tip is overlying the common femoral artery just over the medial third of the femoral head. Often the calcifications in the vessel wall can be visualized on fluoroscopic images. Once the vessel is marked, we attempt access.

Another modality that is readily accessible in the operative suite is duplex ultrasound. If access is difficult, an ultrasound probe can be brought onto the field to aid in the identification of the common femoral artery. Once differentiated from the vein by its lateral location and noncompressibility, the common femoral artery can be mapped caudally until identification of the profunda femoris artery, with access obtained just cranial to the profunda takeoff. Access is obtained with the duplex image in an axial view, and the access needle placed at a 45° angle to the ultrasound probe. As the needle is advanced, the path of the needle can be visualized under ultrasound by separation of the tissue planes. Ultrasound-guided access of the femoral vessels has yielded excellent success and deferred the need for cutdown in the authors’ practice. Finally, if all attempts at percutaneous access fail, a femoral cutdown can be performed in less than three minutes under local anesthesia, still avoiding induction of general anesthesia. Patients in profound shock require no local anesthesia for access, be it percutaneous or open.

Once adequate flash is obtained from the access needle, The authors first pass a Bentson wire (Cook Medical, Bloomington, Indiana) into the

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**Box 1. Basic inventory necessary for aortic occlusion balloon placement**

- Fluoroscopic C-arm and imaging table.
- Access needle
- 30 cc aspiration syringe
- 6 Fr sheath and 11 Fr sheath
- 150 cm, 0.035” Bentson wire
- 150 cm, 0.035” Glide wire
- 150 cm, 0.035” Amplatz wire
- 125 cm, 33 mm AOB
- 65 cm Kumpe catheter
- 65 cm, 11 Fr sheath
- Bottle of contrast (Visipaque, GE Healthcare, Waukesha, Wisconsin)
common femoral artery, and if the wire does not easily pass, we then use a hydrophilic glide wire. If this fails, we redirect the access needle and repeat the steps. Once the wire easily passes into the artery, a 6 Fr sheath is placed in the groin, which is just an initial step to serially dilate the vessel to our working sheath, the 11 Fr sheath. After the sheath has been flushed, we then replace the 6 Fr sheath with an 11 Fr sheath. At this point, the operator has a working system from the right groin that can accept a 33 mm AOB.

Selecting the supraceliac aorta

At this point the Bentson wire should be followed under fluoroscopic guidance through the iliac vessels and into the aneurysm sac. Fig. 1 illustrates the proceeding steps. The wire should be advanced under direct fluoroscopic imaging into the supraceliac aorta. If the wire advances easily into the thoracic aorta, it has already bridged the RAAA, but not uncommonly, the wire will coil in the redundant and tortuous aneurysmal sac (see Fig. 1A).

At this point, a selective catheter is required to direct the wire into the supraceliac aorta. The authors' catheter of choice is the Kumpe catheter.

![Fig. 1. Illustration of aortic balloon placement. (A) Placement of the access wire. (B) Using a Kumpe catheter to select the proximal aorta. (C) Positioning the tip of the Kumpe catheter just beyond the proximal aorta. (D) Retracting the catheter, applying torque to the catheter, and advancing the Bentson wire. (E) Purchasing hold in the supraceliac aorta and retracting the Kumpe catheter. (F) Advancing the AOB into position.](image)
(Cook Medical), which has a hockey-stick bend at the tip. This catheter is advanced over the Bentson wired through our working sheath (11 Fr sheath), and then advanced over the tip of the wire (see Fig. 1B). When selecting vessels, the selective catheter and wire should never be pushed into the orifice; instead, the catheter should be advanced beyond the orifice with the floppy tip of the Bentson wire just beyond the end of the Kumpe catheter (see Fig. 1C). From this vantage point, counterclockwise torque is applied to the Kumpe catheter in the right groin while slowly withdrawing the catheter and watching the catheter under fluoroscopic imaging. The wire can then be advanced into the supraceliac aorta (see Fig. 1D). Once the wire is in the thoracic aorta, the redundant loop in the aortic sac will snap into a straight line across the aneurysm (see Fig. 1E).

**Placement of the aortic occlusion balloon**

Once the wire is secured in the thoracic aorta, the Kumpe catheter can be withdrawn over the wire, and the 33 mm AOB can be advanced over the wire into a supraceliac position (see Fig. 1F). With the balloon in position, the authors shoot a hand-injected aortogram through the central channel of the AOB to confirm its position. In addition, we test the balloon by inflation with contrast and saline mixed 50/50. The compliant characteristic of the AOB allows conformation to the wall of the fairly noncompliant aorta. Therefore, the balloon will initially appear spherical, but once it accommodates the endoluminal surface of the aorta, it will expand by elongating along the walls of the aorta (Fig. 2).

The occlusion balloon is injected under fluoroscopy, and once the balloon profiles the aorta, the location of the balloon is secured in the right groin by the assistant. In addition, the volume of contrast required to achieve a change in balloon profile, and hence occlusion is recorded (Fig. 3). At this time, the balloon is deflated, and anesthesia can start resuscitation (crystalloid and blood products) and prepare for induction.

**Perform the open repair**

The AOB is reserved only for periods of hemodynamic instability. With induction of anesthesia or upon opening the abdominal fascia, the patient may require interval inflation of the AOB and continued resuscitation from the anesthesia provider. Having proximal control secured allows the surgeon a relatively bloodless field to dissect the infrarenal neck of the RAAA (Fig. 4). Once the infrarenal neck is isolated, a vascular clamp can replace the AOB; the balloon is simply retracted into the aneurysm sac before clamp application.

Once the balloon has been inflated and deflated, it is more difficult to retract through an 11 Fr sheath; therefore, once the aneurysm sac is opened, the authors cut the balloon tip off the catheter and retract the system through the groin. The standard open repair of an AAA ensues.
Discussion

Although an AOB can be placed in less than 5 minutes in experienced hands, technical difficulties can occur with any of the above steps. Most general surgeons are comfortable with obtaining access in the groin, and depending on their comfort with ultrasound, ultrasound-guided access is an alternative. If percutaneous attempts fail, general surgeons can perform a rapid cutdown at the groin and access the common femoral vessel.

Fig. 2. Test inflation of the AOB. The balloon has opposed the aortic wall and started to elongate with continued inflation. Note the wire inferior to balloon buckling against the cranial to caudal pressure.

Fig. 3. The AOB is secured at the groin. The contrast (large white arrow) has been marked from test occlusion, and the wire (small white arrow) remains in place throughout the procedure. This particular patient had a prior right groin exploration; therefore, the AOB was placed from the left groin.
General surgeons are probably least familiar with selecting the supracaeliac aorta using a directional catheter (ie, the Kumpe). For endovascular surgeons, this is a very common maneuver, and is performed at the beginning of every elective endovascular aneurysm repair. The authors recommend using this opportunity under elective circumstances to gain experience with handling wires in the aneurysm sac and selecting the supracaeliac aorta before attempting this technique in the emergent setting.

Once proximal placement is confirmed, the assistant must secure the AOB at the groin or the patient’s pressure will force the balloon caudally into the aneurysm sac. When the test occlusion is performed under fluoroscopy, the force on the balloon can be felt by the assistant securing the catheter. If the patient’s aortic pressure is greater than the columnar strength of the catheter system, the wire and balloon will start to buckle. This can be seen in Fig. 2 just caudal to the balloon. To increase the columnar support of the system, the Bentzon wire can be replaced with an Amplatz wire (Cook Medical), which is more rigid. If this fails to secure the balloon in place, then the AOB can be removed, and a 65 cm 11 or 12 Fr sheath can be placed over the Amplatz wire into the supracaeliac aorta. The AOB can then be passed through the sheath so that the balloon extends just beyond the tip of the sheath. When the balloon is inflated, the sheath will wedge against the caudal aspect of the balloon and prevent migration. Veith and colleagues [23] have described this modification as an adjunct to EVAR for RAAAs. Typically, an Amplatz wire has enough columnar support to hold the balloon in position; therefore, the authors only place the 65 cm, 11 Fr sheath if it fails to secure the balloon.

Some authors have used a transbrachial approach for placement of the AOB [11,12,20,21]. The primary reported benefit of this approach is lack of balloon migration into the aneurysm sac. The transbrachial approach, initially used when the surgeon planned to repair the RAAA with an endograft, allowed both groins still available for graft insertion. The disadvantage...
of this technique is the required cutdown procedure over the brachial artery near the median nerve and the placement of a very large sheath relative to the normal size of the brachial artery. Additionally, using the right brachial artery places the patient at risk for cerebral embolization as the innominate and left common carotid arteries are crossed. Utilizing the left arm will place the operators in a difficult location between the patient and the C-arm. In addition, the stiffness associated with the AOB and sheaths make them difficult to navigate through the arch into the descending thoracic aorta. Relative risk of ischemic complications to the hand is also a concern.

For these reasons, the authors feel that the femoral approach is superior. Dr. Veith and colleagues [22] have reported the largest experience treating RAAAs with EVAR; their group uses a transfemoral AOB and then places the endograft from the contralateral groin [23]. If a transfemoral AOB is placed as a temporizing measure until the vascular surgeon arrives, it does not hinder the placement of an endograft.

The risks associated with AOB placement include a time delay such that the patient experiences a poor outcome. Those patients that survive through transport to the hospital typically have a contained rupture that is dependent on the retroperitoneal hematoma and tone of the abdominal wall musculature. Based on Lloyd and colleagues’ [18] time-to-death analysis, most patients have 2.5 hours after being admitted to the hospital before free rupture. The authors feel that the benefits of securing the proximal aorta before anesthetic induction and release of the tamponade effect of the abdominal wall far outweigh the risks of a relatively small time delay.

Manipulating wires and catheters within the aneurysm sac could potentially convert a contained rupture to free rupture. The authors have not experienced this complication, nor has it been reported in the literature. Surgeons have used AOBs for penetrating truncal trauma and experienced the balloon exiting the injury site in the aorta [19]. If this were to occur during placement, we feel that it would be recognized by using fluoroscopic guidance.

The most devastating complication of occluding the aorta is spinal cord, visceral, and lower extremity ischemia. The balloon is only inflated if the patient’s hemodynamic status demands proximal control. Based on the patient’s underlying vascular disease, collateral flow, and moribund state, the ischemia time is variable. Intermittent periods of aortic occlusion are better tolerated than prolonged occlusion [19]; therefore, the authors limit periods of occlusion to 10 minutes with variable periods of reperfusion. This complication is inherent in all types of proximal control, and the AOB could theoretically reduce periods of hypotension.

At the authors’ institution, we have adopted the approach of placing a transfemoral AOB before resuscitation, induction of anesthesia, and exclusion of the RAAA. The availability of commercial endografts and surgeons trained in the art of endovascular technique is such that each patient is considered for endovascular repair. The utility of remote aortic
occlusion has served as an invaluable adjunct to our experience of open RAAA repair, and we feel that this is a useful adjunct for the general surgeon faced with an RAAA.

Summary

Although the treatment and mortality for RAAAs has changed very little in the last 50 years, the elective repair of abdominal aortic aneurysms has dramatically changed because of endovascular technology. EVAR for RAAAs has been limited to relatively few centers, but remote endovascular occlusion of the aorta is a technique that can be used by both vascular and general surgeons alike. Preoperative placement of a remote AOB from the groin is a rapid and effective method of obtaining proximal control and has the potential to improve the morbidity and mortality in this moribund population of patients.

References


