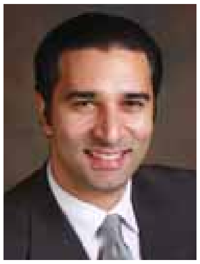

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ENDOVASCULAR REPAIR OF RUPTURED ABDOMINAL AND THORACIC AORTIC ANEURYSMS

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Abstract

Management of acute aortic pathology remains one of the most challenging clinical entities, with a persistently high mortality rate both prior to and upon arrival to a hospital.[1] Responding to the distinct advantages of endovascular approaches to aortic disease, many high-volume cardiovascular centers have focused on endovascular therapies for managing patients with ruptured or leaking aortic aneurysms and other acute aortic syndromes. Nonetheless, similar to outcomes for other surgical emergencies, time and efficiency are critical in managing these conditions. Early diagnosis, transport to an appropriate acute care facility, rapid institution of optimal medical management, availability of cardiovascular anesthesia and intensive care, and appropriate and timely surgical intervention continue to be the keys to success.[2] This article discusses the endovascular approach to ruptured abdominal and thoracic aortic aneurysms.

Endovascular Repair of Ruptured Abdominal Aortic Aneurysms (AAA)

Ruptured AAA

Abdominal aortic aneurysmal disease affects approximately 5% of men and 1% of women over the age of 60 years, and multiple epidemiological studies indicate that the incidence is increasing despite improved medical management of certain risk factors.[3] The mortality rate of a ruptured abdominal aortic aneurysm (rAAA) approaches 90%, and perioperative mortality averages 50% during emergency open repair.[1] Ruptured AAA is the tenth-leading cause of death in the United States, and much of this occurrence is underestimated due to lack of autopsy proof and the default attribution of death to a cardiac event.[1, 3-5]

In the setting of rAAA, patients who survive the initial event and present to an emergency room are often in profound circulatory shock due to hemorrhage and peripheral ischemia-reperfusion injury upon restoration of flow.[6] The subsequent mortality rate of patients who do survive the initial repair approaches 50% due to the “second hit” of systemic inflammatory response syndrome (SIRS), which can later progress to sequential organ failure and multiple organ dysfunction syndrome (MODS).[7-9]

Endovascular Repair for Ruptured AAA

It has been nearly two decades since Parodi and colleagues pioneered the first endovascular aortic aneurysm repair (EVAR) in humans using a Dacron graft introduced retrograde through the femoral artery.[10, 11] Buoyed by device development and refinement of techniques, EVAR has now replaced open aortic repair as the treatment of choice for patients undergoing elective AAA treatment.[12] This evolution stems from large, randomized, controlled trials over the last decade that compared morbidity and mortality rates and favored EVAR over traditional open repair in appropriately selected patients.[13-17]

Several studies have confirmed the feasibility of an endovascular approach to rAAA. Especially when performed under local anesthesia, EVAR provides less of a physiologic challenge compared to traditional open repair.[18, 19] EVAR for rAAA was first reported in 1994 by Marin et al. Since then, worldwide experience from large-volume centers performing emergency EVAR (eEVAR) demonstrates that 30-day mortality rates vary from 7–39%, with an average of 22%.[20] This represents a reduction by nearly half when compared to conventional emergency open repair.[20-23] Variation in these results likely represents the lack of a standard protocol for perioperative care, the steep learning curve for lower-volume centers, and the bias for performing eEVAR in older, sicker patients with pre-existing comorbidities.[24]

To date, there are no large randomized controlled trials comparing the efficacy of eEVAR to traditional open repair, and little long-term outcomes data exists. A recent Cochrane Collaboration review concludes that without randomized controlled trials, the benefit of eEVAR remains undetermined.[6] In response, recruitment is ongoing for three European randomized trials comparing emergency open repair vs. eEVAR for rAAA: Amsterdam’s Acute Endovascular Treatment to Improve Outcome of Ruptured Aortoiliac Aneurysms (AJAX) trial, Paris’s Ruptured Aorta-Iliac Aneurysms: Endo vs. Surgery (ECAR) trial, and the United Kingdom-based Immediate Management of the Patient with Rupture: Open vs. Endovascular Repair (IMPROVE) trial.[25] Some would argue that despite the lack of randomized controlled trials, the adaptation of eEVAR into current practice is appropriate based on evidence collected worldwide from large-volume and teaching institutions.[26] Even when considered independent of volume, in-hospital mortality is significantly reduced when eEVAR for rAAA is performed in teaching institutions with vascular surgery training programs.[27]

Technical Aspects of eEVAR

The endovascular care of patients with suspected rAAA depends on a comprehensive knowledge of endovascular techniques along with the equipment and facilities to perform intraoperative imaging on an emergent basis. A multidisciplinary approach must be implemented that includes emergency and operating-room personnel, imaging technologists, anesthesiologists, and intensive care physicians. An algorithm for the treatment of patients with suspected rAAA must first determine hemodynamic stability. Unstable patients, typically defined as those with a systolic blood pressure (SBP) <90 mmHg, are immediately transported to the operating suite and prepared for either open or endovascular repair. Patients who are hemodynamically stable (i.e., SBP >90 mmHg) swiftly undergo computed tomography angiography (CTA); once rAAA is diagnosed, the anatomic suitability for EVAR is determined. Patients with infrarenal neck length ≥10 mm, aortic diameter ≤32 mm, bilateral iliac artery diameter ≥5 mm, and neck angulation ≤75° are generally suitable for eEVAR. Although this expands the current Food and Drug Administration (FDA) anatomical criteria for elective EVAR,[28] the majority of patients who present with rAAA can be managed effectively with eEVAR based on the above criteria.[29, 30]

All patients must receive adequate, but not excessive, resuscitation while definitive treatment is being initiated. Permissive hypotension, in which SBP is maintained around 70 mmHg (between 50 and 100 mmHg), has proven to be an efficacious therapy, and this gentle physiologic condition can be maintained by the administration of local or loco-regional anesthesia during repair.[23, 31, 32]

After the patient is prepped and draped in the operating room, ipsilateral access is obtained either percutaneously or with femoral artery cutdown, and the floppy guidewire is exchanged for a stiff wire in order to pass a large sheath (12–14 ft x 45 cm in length) for an aortic occlusion balloon. In hemodynamically unstable patients, the balloon is inflated in the supraceliac position, while in stable patients the balloon can be placed in the juxtarenal aorta as a precautionary measure. It is important to ensure that the sheath is advanced fully to stabilize the occlusion balloon in the correct position and prevent downward displacement into the AAA. The stent graft, typically a modular device, is then exchanged under fluoroscopic guidance for the aortic occlusion balloon if the patient remains stable. In cases that necessitate deployment of the occlusion device, the aortogram may be performed through the sheath of the occlusion balloon, and the stent graft may be exchanged from the flush catheter in the contralateral limb for deployment.[30] Alternatively, the aortic occlusion balloon may be placed in the contralateral femoral and an aortogram performed through an ipsilateral pigtail catheter that is then exchanged for the main body of the stent graft (Figure 1). Post-deployment arteriogram is performed to ensure adequate seal and exclusion of the rAAA. If a type I endoleak is discovered, adjunctive procedures such as additional ballooning, aortic cuffs, or Palmaz stent placement are performed. Total percutaneous eEVAR can be achieved in experienced hands and in patients with favorable anatomy.[33]

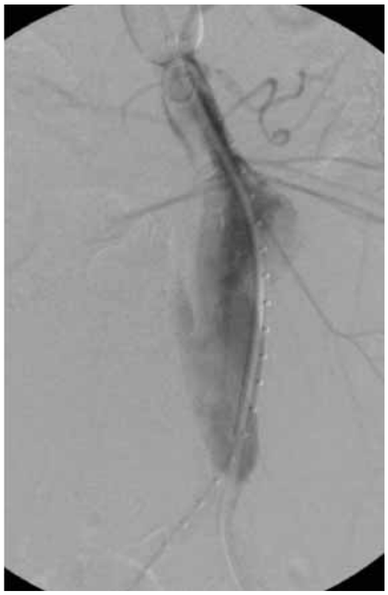

Figure 1. Aortogram performed through an ipsilateral marking pigtail catheter with contralateral aortic occlusion balloon inflated in a hemodynamically unstable patient. The pigtail catheter is replaced with the stent graft for deployment.

Conversion to Open Repair

On occasion, eEVAR fails to provide definitive repair in the setting of rAAA, and open surgical repair is needed. While techniques for open repair will not be discussed here, two important points must be made. First, during conversion to laparotomy, the aortic occlusion balloon and its corresponding sheath are secured in place to maintain aortic occlusion at the appropriate level and prevent dislodgement of the balloon into the rAAA. Additionally, the approach to open repair must be tailored to the type of endograft deployed, including the position of proximal and distal fixation.

Postoperative Care

Postoperative care in the intensive care unit is necessary for continuous hemodynamic monitoring. Vigilant surveillance for signs of abdominal compartment syndrome (ACS) must not be underemphasized as this is a frequent complication. Factors associated with the onset of ACS include hemodynamic instability, massive transfusion requirement, and postoperative coagulopathy.[30] Bladder pressure monitoring and frequent assessment of pulmonary and renal function must not be neglected, and if signs of organ dysfunction ensue, a decompressive laparotomy with temporary abdominal closure is sought.

Complications of eEVAR

Complications of eEVAR are similar to complications from elective EVAR and include endoleak, need for reintervention, stent graft migration, contrast and atheroemboli-induced renal failure, hemorrhage, peripheral ischemia, and local wound complications.[25] Similar to patients after elective EVAR, patients treated with eEVAR undergo postoperative and scheduled surveillance imaging, including contrast-enhanced CT or possibly contrast-enhanced ultrasonography. Long-term outcomes data after eEVAR for rAAA have yet to emerge; however, when compared to open repair, initial trends suggest that the higher secondary intervention rates documented after EVAR[13] could be replicated in patients following eEVAR.[31]

Endovascular Repair of Ruptured Thoracic Aortic Aneurysms

Thoracic aortic aneurysms (TAAs) occur less frequently than AAAs but harbor a 20–54% five-year survival rate due to fatal rupture if left untreated.[34, 35] Elective intervention is generally recommended for TAAs greater than 5.5 cm in diameter due to an annual mortality and rupture risk of 15%.[35-38] Ruptured TAA (rTAA) occurs less frequently than rAAA; however, of the patients who do survive transport to a hospital, overall mortality rates approach 97%.[39, 40]

Open surgical repair of the rTAA, first described in 1951 by Lam and Aram, provides direct inspection of the aneurysm and surrounding branches but requires thoracotomy, aortic cross-clamping, and sometimes cardiopulmonary bypass.[39, 41] First applied in the setting of elective repair, thoracic EVAR (TEVAR) 30-day mortality rates demonstrated an improvement over traditional open repair in several non-randomized trials.[42-44] Emergent thoracic EVAR (eTEVAR) was first attempted for rTAA in 1997 by Semba et al.[45] Since then, eTEVAR has been applied both to rTAA and traumatic thoracic aortic injuries with improvements in perioperative mortality rates.[39, 46-48] In a large, systematic meta-analysis of traditional open repair versus eTEVAR for rTAA, Jonker et al. found a significantly lower 30-day mortality rate (33% vs. 19%, $p = 0.016$) and incidence of myocardial infarction (11.1% vs. 3.5%, $p = 0.047$); however, no significant differences in rates of stroke or paraplegia were observed.[39]

Technical Aspects of eTEVAR

Similar to eEVAR, eTEVAR requires appropriate preoperative evaluation with CTA and the facilities available to assemble the eTEVAR team quickly, including having a hybrid operating room immediately available. In cases where conversion to open repair is necessary, the facility must also have immediate access to resources that include thoracic surgery backup.

Local, spinal, or general anesthesia can be selected depending on the patient's clinical condition, providing that SBP remains less than 100 mmHg. Emergent TEVAR can be performed via standard femoral cutdown; alternatively, a total percutaneous approach can also be achieved.[49] In the contralateral femoral artery, a graduated-marked pigtail catheter is introduced and an aortogram is performed. The stent-graft is advanced over a stiff guidewire to the desired position using fluoroscopy. A proximal landing zone of 2 cm prior to the takeoff of the left subclavian artery is generally required; however, successful intentional occlusion has been recorded.[50] An equivalent distal landing zone length of 2 cm is also required, and if two stent-grafts are deployed, overlap must be greater than 5 cm in order to avoid separation in the case of tortuous anatomy.[51] In the setting of TAA, gentle and swift dilation of the proximal and distal landing zones with balloon angioplasty can secure wall apposition of the stent-graft.[51] Stent-graft size selection is based on the diameters of the proximal and distal landing zones, and an oversize factor of 20–30% is generally allowed to facilitate secure anchoring and seal.[52]

Complications of eTEVAR

Complications of both open and eTEVAR include cardiac events, stroke, paraplegia, multiple organ failure, and infection.[39] Concern over graft durability and a relatively high rate of endoleak (>10%) has led to a requirement by the FDA for continuous surveillance with contrast-enhanced CT after repair.[36, 39] Aneurysm-related death after eTEVAR remains higher than after open repair, and estimated aneurysm-related survival after 3 years remains at 71%.[39] The need for improved device technology greatly outshadows the low overall incidence of ruptured TAA, and industry attention to device advancement is necessary.

Paraplegia caused by the interruption of branch vessels to the spinal cord occurs less frequently after TEVAR than open repair; however, the risk remains between 3–6%.[51] Factors that influence spinal cord ischemia include prior AAA repair, length of thoracic aorta coverage, hypogastric artery interruption, subclavian artery coverage, emergency repair, and hypotension.[51] Strategies proposed to reduce this complication include cerebrospinal fluid drainage, intercostal artery reimplantation, hypothermia, and maintenance of normal SBP, though none of these approaches have consistently proven efficacious.

Case Example of eTEVAR

A 94-year-old Caucasian male who previously had an rAAA treated with eEVAR presented with abdominal pain, hemorrhagic shock, and a left hemothorax. An urgent CT scan of his chest, abdomen, and pelvis demonstrated an aneurysm of the descending thoracic aorta, with blood in the left chest consistent with a ruptured thoracic aneurysm. The Methodist Hospital Acute Aortic Treatment Center protocol was initiated,[2] and he immediately underwent eTEVAR (34 mm x 20 cm TAG) and placement of a left chest tube thoracostomy to evacuate the hemothorax. The patient recovered from this event and was eventually discharged from the hospital. He continues to be asymptomatic at 2-year follow-up with no complications on monitoring CTA (Figure 2).

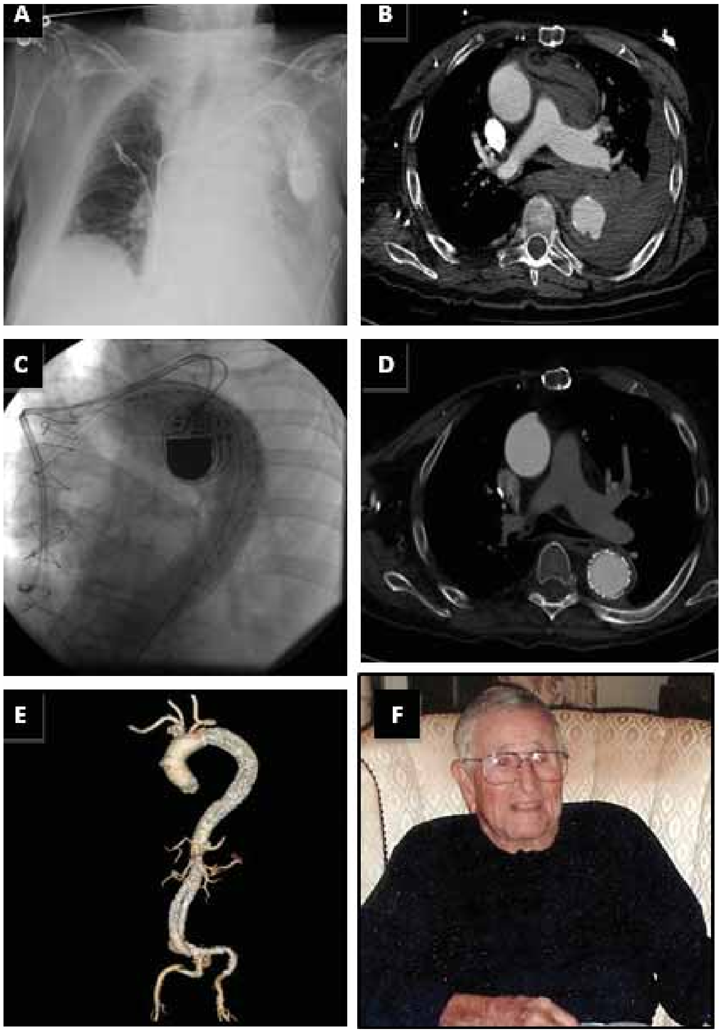

Figure 2. Preoperative, postoperative, and follow-up images of rTAA and rAAA in the same patient. (A) Chest X-ray on presentation demonstrating left hemothorax. (B) CT showing rTAA with hemothorax. (C) Deployment of a TAG® endograft (W.L. Gore & Associates, Inc., Flagstaff, AZ) for repair of ruptured aneurysm. (D) CT at 2 years follow-up. (E) 3D reconstruction of thoracic and abdominal aortic stent graft repair of rTAA and rAAA. (F) Patient with full recovery 2 years after eEVAR of combined rTAA and rAAA.

Conclusion

The evolution of endovascular treatment of AAA and TAA has dramatically changed the approach to these life-threatening diseases. Even in the acute setting of aneurysm rupture, an otherwise fatal condition can now be approached in a minimally invasive manner, providing improved perioperative outcomes and increased options for high-risk patients. Large-volume teaching institutions clearly provide the highest standard of care with this new technology and have consistently demonstrated superior results.[24] In the elective repair of AAA, EVAR is now considered the gold standard in anatomically amenable patients.[12] While long-term outcomes data of eEVAR for rAAA and rTAA remains to be seen, the endovascular approach shows promise in becoming the future standard of care for ruptured aortic aneurysmal disease.

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