Emergent Aortic Endovascular Stent Grafts for Ruptured Aortoiliac Aneurysms

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ABSTRACT

A ruptured abdominal aortic aneurysm is an emergency anywhere in the world. Physician expertise and clinical status of the patient drive the treatment modalities in the majority of cases. Independent of treatment choice, the goal of therapy is to stabilize the patient as quickly as possible in a manner that establishes maximum survival and minimum morbidity and provides a long-lasting, durable result. Endovascular aortic repair has become an acceptable alternative to open surgical repair in a subset of patients presenting with ruptured aortoiliac aneurysms. Patient selection, physician preference, institutional experience, and availability of appropriate equipment make up a majority of factors influencing treatment choices. Once the decision has been made to treat the patient via endovascular techniques, then experience, planning, and the ability to improvise solutions “on the fly” become vital components to the success of the procedure. Two separate cases, requiring intraprocedural improvisation, are presented followed by a review of the literature.

KEYWORDS: Ruptured aneurysm, emergent stent graft, EVAR

Objectives: Upon completion of this article, the reader should be able to identify the indications for placing emergent endovascular abdominal aortic stent grafts and state the current endovascular and open surgical mortality for ruptured aortic aneurysms.

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Abdominal aortic aneurysms (AAAs) are frequently described as “time bombs” because of the uncertain timing and the high mortality rate associated with the most feared complication: aneurysm rupture. Elective repair of stable AAA has incorporated both open surgical and endovascular techniques. The clinically stable patient allows the luxury of an organized, well-thought out treatment plan, frequently with second and third alternative treatment options. When doubts or

questions arise, there is time to review literature as well as consult other experts in the field. Unfortunately, once an AAA ruptures, these luxuries disappear and urgent decisions are required. The choice between surgical and endovascular techniques involves careful, deliberate consideration of many factors including surgical risks of a major abdominal surgery, availability of an appropriate endovascular device to match the individual anatomy, and physician and institutional experience in both open

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surgical and endovascular procedures.¹⁻⁴ Ruptured AAAs require a more expeditious evaluation and implementation of a specific treatment plan.^{5,6}

INITIAL PRESENTATIONS

Case 1

The first patient, an 88-year-old man, presented to the emergency room with acute-onset right flank pain. The pain had migrated from the right to the left flank, then to the midback in ~24 hours. He had a past medical history of peripheral vascular disease, diabetes, hypertension, diverticulitis, hypothyroidism, and coronary artery disease. He had recently been seen by a vascular surgeon to discuss open versus endovascular options to repair an existing 6.3-cm AAA. Due to a moderately elevated serum creatinine, no cross-sectional imaging was obtained at the time of the clinic evaluation. Physical exam at presentation in the emergency room included a heart rate of 75 beats per minute, blood pressure of 198/94 mm Hg, and 2+ palpable carotid, radial, dorsalis pedis, and posterior tibial pulses bilaterally. Limited abdominal ultrasound demonstrated a 7.8-cm AAA (enlarged from previous measurements). He was also found to have a newly elevated troponin. Fig. 1 is a representative cross-sectional image from a noncontrast computed tomography (CT) scan obtained at presentation, which demonstrates high-attenuation fluid in and around the AAA, indicating new blood and an evolving AAA rupture.

Case 2

The second patient, an 82-year-old man, presented to the emergency department after a syncopal episode and loss of consciousness earlier the same day. He described diffuse abdominal pain that was most pronounced with

Figure 1 Cross-sectional image of the first patient's ruptured abdominal aortic aneurysm. Note the high-attenuation fluid and stranding in the retroperitoneal fat.

Figure 2 Cross-sectional image of the second patient's ruptured internal iliac arterial aneurysm. There is similar high-attenuation fluid adjacent to the dilated internal iliac artery.

movement or palpation. He was initially hypotensive, and volume resuscitation was started. Physical exam after 6 L resuscitation included a heart rate of 82 beats per minute, a blood pressure of 113/60 mm Hg, and "good" femoral, dorsalis pedis, and posterior tibial pulses bilaterally. Contrast-enhanced CT scan demonstrated a 7-cm AAA as well as a 5-cm left internal iliac artery aneurysm (Fig. 2). (Note that an elective common iliac artery repair is frequently performed at a diameter of 3.5 cm or larger.⁷) High-density fluid was present in the pelvis, around the left internal iliac arterial aneurysm and extending up the paracolic gutters bilaterally. He had a past medical history of a four-vessel cardiac bypass, congestive heart failure, and atrial fibrillation. The patient was on warfarin. He was unaware of his AAA or his left internal iliac arterial aneurysm.

PATIENT EVALUATION

Step 1: Make Sure the AAA Is Really Ruptured

In today's medicolegal climate, presentation to an emergency department with abdominal pain and any clinical suggestion of an AAA will frequently result in a CT. In patients with ruptured blood vessels, cross-sectional imaging studies frequently demonstrate high-attenuation, complex fluid. If the abnormal fluid is adjacent to a dilated blood vessel, it is assumed to be a ruptured aneurysm/blood vessel. This high-attenuation fluid may represent a periaortic, retroperitoneal, or psoas hematoma. However, in more subtle ruptures, "stranding" of the retroperitoneal fat and loss of the para-aortic fat plane are also commonly seen. Additional findings that suggest a rupture include a "crescent sign" (C-shaped region of high attenuation within the

mural thrombus/abdominal aortic wall) and “draping” of the posterior wall of the abdominal aorta along the vertebral bodies. The lateral aspects of the aorta fall onto the vertebral body rather than being pulled up and around the aortic circumference.^{8,9} To confirm the diagnosis of a retroperitoneal hemorrhage, a noncontrast CT scan is all that is required. However, a contrast-enhanced, arterial-phase CT scan is recommended when feasible in all cases being considered for an endovascular repair of the ruptured AAA. The contrast-enhanced study allows the evaluation of the lumen diameter and distances between vessel origins. These measurements are vital in selecting the appropriate endograft.

Step 2: Open versus Endovascular Approach

Because of the high mortality rate for ruptured AAA, the decision between an endovascular approach and an open surgical approach should be made expeditiously. Several protocols have been put forth in determining the patient status and evaluation routine. Fig. 3 represents two different approaches to the decision process with a primary deciding factor being (A) patient clinical stability or (B) open operative candidacy based upon preexisting comorbidities. Option A asks whether there is time to evaluate the patient for a potential endovascular approach, and selection bias distributes a “healthier” patient to the endovascular group. Option B asks if the patient would survive a major operation in an elective setting, reversing the selection bias distribution. A third approach involves placing an occlusion balloon within the vasculature to stabilize the patient and allow time for a more complete evaluation. Unfortunately, all approaches introduce bias into any comparative or cohort studies. Therefore, the institutional treatment algorithm becomes a key component in the evaluation of the published literature surrounding endovascular repair of ruptured AAAs. In many clinical settings, any combi-

nation of the approaches outlined above may be utilized when determining if a patient can be evaluated for placement of an endovascular device. Unless specific algorithms are designed and followed, the decision between open and endovascular approach may boil down to interpersonal relationships or bias introduced from the last successful or unsuccessful case.

Step 3: Endovascular Anatomy

After the decision has been made to evaluate the patient for an abdominal aortic stent graft, the vascular anatomy must be critically (and efficiently) analyzed. Most studies and device manufacturers recommend an arterial-phase, contrast-enhanced CT arteriogram (CTA) to assist in evaluating the key vasculature and choosing an appropriate device. However, in some cases, magnetic resonance angiography or catheter arteriography may provide enough information to select an appropriate device. Key components to evaluate in the vascular anatomy include the diameter, angulation, calcification, and location of both proximal and distal landing zones; length of devices required; diameter at aortic bifurcation; as well as the pathway to deliver the devices. The ability to rapidly perform three-dimensional reconstructions greatly assists in defining true diameters of vessels as well as determining craniocaudal lengths required in selecting an appropriate endograft device. Previous experience frequently assists in making quick, efficacious evaluations and decisions at these times. Once these measurements have been made, one must select the most compatible device from available equipment. Another key component to a successful endograft program is the routine development of a primary plan as well as a quality backup plan. The backup plan requires one to contemplate alternative approaches to the same case, should a “surprise” develop during the procedure.

Figure 3 Algorithm (A) initiates the evaluation of the patient with a ruptured abdominal aortic aneurysm by asking if the patient is clinically stable enough to undergo evaluation for an endograft. Algorithm (B) asks if the patient is an operative candidate. These initial choices in the decision tree impart opposite biases into the survival curves for endograft and open surgical operation. AAA, abdominal aortic aneurysm; OR, open/operative repair.

In general, vascular diameters do not change significantly from cross-sectional imaging measurements if appropriate three-dimensional reformats have been made. On the other hand, the length of devices required is occasionally modified due to tortuosity of the vessel and stiffness of guide wires. Rarely, one may be required to reverse the approach (main body of the endograft delivered from the right or the left) depending upon access vessel diameter. When it comes to safe choices in device selection, one must remember that infolding from a generous graft diameter can frequently be treated in vivo with repeat angioplasty and/or stenting. Too small of a graft diameter relative to the vessel can only be treated by additional stent grafts and modifying the intended "landing zone." This change may result in covering renal or visceral vessels proximally and internal iliac arteries distally. Similarly, endografts that are too short in length can always be extended with additional devices. There is almost no way to shorten a device percutaneously after deployment.

PROCEDURE DETAILS AND FOLLOW UP

Case 1

The first patient's age, elevated troponin, and decreased renal function essentially excluded an emergent open surgical repair of his ruptured AAA. Risks and benefits of attempting endovascular repair versus conservative management (including renal failure and dialysis) were discussed with the patient and his family. The decision was made to proceed with the endovascular repair. The noncontrast CT was used to identify and measure proximal and distal landing zones and the appropriate devices were available for use immediately. A contrast-enhanced CTA was not obtained due to the decreased renal function with a plan of identifying appropriate final measurements via intraoperative arteriograms. The diameter of the aorta at the level of the renal arteries as well as both common and external iliac arteries were determined from the noncontrast CT scan. Limited three-dimensional reconstructions were used to estimate appropriate lengths of devices required for the case. Lumen diameter and mural thrombus were unknown components at the time the patient was brought to the operating room.

Bilateral open surgical cutdown exposure to both common femoral arteries was obtained with the assistance of the vascular surgery team. Access from the right common femoral artery was uneventful. On the left, the guide wire would not advance into the left external iliac artery despite adequate arterial flow with an 18-gauge access needle. A pelvic arteriogram was then performed to evaluate the left external iliac artery as well as to assess the landing zones of both iliac limbs of the endograft. Fig. 4 (A and B) demonstrates a chronic occlusion of

the left external iliac artery, the diameter of the bilateral common iliac arteries, and the location of the iliac bifurcations. The left lower-extremity runoff was supplied primarily from collaterals from the left internal iliac artery. Conversion to an aorto-uni-iliac procedure followed by a surgical right-to-left common femoral bypass procedure was considered. In that situation, the left common iliac and internal iliac arterial supply and the corresponding pelvic perfusion would be sacrificed. Therefore, the decision was made to attempt placement of a bifurcated endograft by recanalization of the external iliac artery. Initial attempts from the left common femoral artery were unsuccessful. A wire and catheter were positioned over the aortic bifurcation from the right common femoral arterial access into the left common iliac artery, and antegrade recanalization was attempted. In the blind stump of the proximal left external iliac artery, a hydrophilic wire was advanced into the subintimal space. The wire and catheter were gently advanced to the level of the recanalized left distal external iliac artery. Attempts to reenter the lumen were made, which eventually resulted in complete vessel perforation. The hydrophilic wire was identified within the open cutdown site adjacent to the left common femoral artery. The options were reconsidered (abort the attempted endovascular repair completely, convert to an aorto-unifemoral device, or proceed as planned). Given that the subintimal tract was safely away from the origin of the left internal iliac artery in the external iliac arterial stump, the decision was made to expand the subintimal and extravascular tract enough to successfully allow placement of the contralateral limb of the device. After exchange for a stable working wire, a sheath was advanced through the tract and into the lumen of the left external and common iliac arteries. The main body of the device was deployed uneventfully from the right common femoral arterial approach. The short limb of the main body was successfully cannulated from the complex left common femoral approach. The contralateral limb was deployed without incident, landing in the left common iliac artery above the origin of the internal iliac artery. All landing zones were secured with balloon angioplasty, and digital subtraction arteriography confirmed exclusion of the aneurysm with no residual leak into the left subintimal/extravascular space. Fig. 4C demonstrates the arterial flow through the endograft and into the left internal iliac artery after endovascular aortic repair (EVAR). As an unexpected surprise, the "arteriotomy" on the left did not require suture-mediated closure. Examination of the left lower extremity confirmed adequate distal perfusion without need for a femoral-to-femoral bypass. The patient was discharged on postprocedural day 9 in stable condition primarily due to contrast-induced nephropathy and cardiac evaluation for his non-ST-segment elevation myocardial infarction. One-month follow-up (noncontrast CT, due to elevated creatinine) demonstrated interval

Figure 4 Pelvic arteriogram demonstrating the left external iliac arterial occlusion. The aortogram (A) demonstrates the patent left common and internal iliac arteries. Selective injection from a left common femoral approach (B) demonstrates the distal aspect of the external iliac artery occlusion (as well as a left hip arthroplasty). An aorto-uni-iliac device in this patient would have likely resulted in significant buttock claudication. Extravascular and subintimal techniques were used in the region of the left external iliac artery, allowing the placement of a bifurcated abdominal aortic endografts device and preserving arterial flow into the left hemipelvis. Aortogram after repair (C) demonstrates continued perfusion through to the left internal iliac as well as contrast within the sheath in the subintimal space along the left external iliac artery.

resolution of the retroperitoneal hematoma and decreasing size of the aneurysm sac.

Case 2

The second patient, on the other hand, was clinically stable immediately after the initial resuscitation bolus, allowing for the contrast-enhanced CTA to be obtained. The CTA demonstrated the AAA as well as the very large internal iliac artery aneurysm. No active extravasation was identified; however, there had been an interval increase in the amount of blood in the pelvis. He was clinically stable enough to allow adequate planning of an

endograft procedure both with and without left internal iliac artery coil embolization. Given these results, plans were made to extend the AAA endograft in a manner that would exclude the internal iliac artery aneurysm. The decision to coil embolize the outflow branches of the internal iliac artery aneurysm would be based upon the patient's intraoperative clinical stability. Open surgical exposure of the common femoral arteries were obtained bilaterally with the assistance of the vascular surgery team, and stable access was obtained with bilateral 7-French vascular sheaths. Given the patient's hemodynamic stability at this time, the decision was made to select both anterior and posterior divisions of

Figure 5 Arteriogram of the second patient's repaired aortoiliac aneurysm, demonstrating flow through the endograft and occlusive coils in the anterior and posterior divisions of the left internal iliac artery.

the left internal iliac artery and occlude potential aneurysm sac inflow in hopes of reducing risk of a type II endoleak. After multiple coils in both anterior and posterior divisions, no significant outflow from the aneurysm sac was identified and attention was turned to the AAA. The main body was uneventfully deployed from a right common femoral access. The left limb was extended into the left external iliac artery (excluding the left internal iliac artery aneurysm). Fig. 5 depicts the postplacement arteriogram and isolation of the left internal iliac artery aneurysm with the endograft extension and multiple coils in the anterior and posterior divisions of the internal iliac artery. The patient was discharged on postprocedural day 4 in stable condition. One-month follow-up imaging demonstrated interval resolution of the retroperitoneal blood, with stable to slight interval decrease in both AAA sac and internal iliac arterial aneurysm sac size. Unfortunately, a small type II endoleak remains from a small internal iliac artery branch that was not evident during the embolization procedure. The endoleak and aneurysms are currently being followed for stability.

DISCUSSION

Both cases demonstrate situations that required a flexible approach in treating ruptured aortoiliac aneurysms. The first patient may have just as easily been converted to an unilateral repair and exclusion of the vasculature to the left pelvis. The risk of the subintimal/extravascular

delivery of the contralateral limb seemed low compared with the high probability of a prolonged procedure with femoral-to-femoral bypass and left buttock claudication with the alternative procedure. Therefore, the attempted recanalization was performed. Similarly, in the second patient's case, the coil embolization of the internal iliac branches likely would have been skipped if he had become hemodynamically unstable during the procedure. Also important to note is the cooperation between vascular surgery and interventional radiology teams. Two teams working together in the best interest of the patient can save lives.

LITERATURE

Several studies have been published evaluating the safety and efficacy of an endovascular approach in the treatment of ruptured AAA. A series of 37 patients with ruptured AAA presenting at a European academic institution were evaluated for both endovascular and open surgical repair. Seventeen of these patients were suitable for endovascular management, and 20 were deemed inappropriate for EVAR (hemodynamically unstable, anatomic contraindications, or the appropriate device was not available). The 30-day mortality for the EVAR group was 23.5% and in the open surgical group was 50%. The study also reported a significant decrease in blood loss, operative time, and intensive care unit stay in the EVAR group relative to the open surgical group.¹⁰ A systematic review of the medical literature was completed and published in 2007. The study evaluated all published reports concerning endovascular approaches to ruptured AAAs through November 2006. The study evaluated one randomized controlled trial and 33 non-randomized case series (24 retrospective, nine prospective). The initial review failed to establish a statistically significant decreased mortality with endovascular techniques but demonstrated trends toward decreased blood loss, shorter intensive care unit and hospital stays, decreased complications, and decreased mortality.¹¹ Peppelenbosch et al reported the outcomes of a prospective, intent-to-treat study evaluating open surgical and endovascular repair of ruptured or symptomatic aortic aneurysms in 68 patients.¹² They concluded that an endovascular repair would be feasible in ~80% of patients. The remaining 20% were excluded due to unsuitable arterial anatomy or hemodynamic instability. Blood loss and transfusion requirements were significantly lower in the endovascular group. The perioperative mortality in the endovascular group was significantly lower than the conventional surgical repair group (20% versus 43% respectively, $p < 0.05$).

Vaddineni et al reviewed the University of Alabama experience with 757 AAA repairs between 1999 and 2004.¹³ Three percent ($n = 24$) of the cases were confirmed as ruptured AAAs. In the ruptured

group, 15 were treated with open surgical procedures and nine were treated with endovascular techniques. The authors reported a significantly decreased transfusion requirement in the endovascular group. Although no significant difference in morbidity and mortality was identified in the study, the authors supported the feasibility and short-term viability of the endovascular procedure. The impact of an endovascular treatment option in the early outcomes of patients with ruptured AAAs at a single institution was reviewed by Brant et al.¹⁴ Of the 39 patients reviewed, 46 to 54% were appropriate endovascular candidates. The aneurysm neck and/or the distal landing zones prevented endovascular repair in the majority of non-EVAR cases. Thirty-day mortality rates of 8% and 53% for the endovascular and open surgical groups, respectively, were reported. Similarly, the amount of time in an intensive care unit as well as the hospital were significantly lower in the endovascular group. Mehta and colleagues reviewed the translation of skills from an elective endovascular repair of AAA program to an emergent program for ruptured aneurysms.⁶ After defining hemodynamic stability (with specific heart rates and blood pressures) and establishing a standardized protocol to evaluate patients with an urgent CTA in the emergency room, a mortality of 18% was achieved in the treatment of ruptured AAAs with endovascular techniques. They also reported that a “synchrony of disciplines” must work well together to initiate and support a successful endovascular program for the treatment of ruptured AAAs. The teams involved included diagnostic radiology, interventional radiology, vascular surgery, cardiothoracic surgery, anesthesia, as well as the emergency department. Hinchliffe et al describe a randomized controlled trial of patients with ruptured AAAs who were also considered “fit for open repair.”⁵ This collection of patients was randomized into endovascular or open surgical groups. Of the 103 patients evaluated, 32 were recruited and randomized into the study. The authors reported no significant difference in 30-day mortality (53% for both groups) or hospital stay (10 versus 12 days, respectively). The study did report the median time between diagnosis and the operation was 75 minutes and 100 minutes for the endovascular and open surgical groups, respectively.

The U.S. national trends regarding endovascular repair of ruptured AAAs were reviewed by Lesperance et al.¹⁵ Of the 28,000 patients admitted into hospitals with a diagnosis of ruptured AAA between 2001 and 2004, the percentage of endovascular repairs increased from 6% in 2001 to 11% in 2004. The mortality associated with the endovascular procedures declined from 43% to 29% over the same period. The open repair mortality was reported at 40 to 43%. The team also reported the mortality for endovascular repair was significantly different between teaching hospitals and non-teaching hospitals (21% versus 55%, respectively).

Although there was a shorter hospital stay and lower mortality rate for the endovascular group, there was no significant difference in hospital charges.

A large systematic review and meta-analysis of the current literature has also recently been published.¹⁶ The pooled mortality rate from 31 studies involving 982 patients was ~24%. Similarly, a recent review of the open surgical repair of ruptured AAAs presented a mortality of 41%.² The study also reported that the increased costs associated with the advanced technology devices are somewhat offset by a shorter hospital stay. Alsac and associates also reviewed the literature for endovascular repair of ruptured AAAs with similar results.¹⁷ They described a postoperative mortality of 24% (ranging from 9 to 45%) and concluded that an endovascular approach is an important therapeutic option in ruptured AAAs.

Although many cohort and case-controlled studies suggest that emergent repair of AAAs with endovascular techniques improves mortality, level 1 evidence is lacking.¹⁸ Therefore, a randomized, controlled, multicenter trial would be of great value. Similarly, the percentage of patients with ruptured AAAs with suitable vascular anatomy for an endovascular approach is unclear. There is emerging evidence that patients with vascular anatomy suitable for endovascular repair actually have lower rupture rates than similar-size aneurysms with unfavorable anatomy.¹⁹

CONCLUSIONS

Both patients presented in this article illustrate the need to be “flexible” and willing to improvise when it comes to emergent aortic endograft procedures. A diverse experience with multiple devices and procedures provides enough confidence to improvise in clinically unstable situations. Case reports provide technical insights into unique clinical situations and may provide solutions in future procedures. In reviewing the literature, there are significant data supporting the use of abdominal aortic endografts in the acute/ruptured AAA setting. Comparing the greater than 40% mortality after open surgical repair of ruptured AAAs to the pooled mortality of ~25% (ranging 10 to 40%) after endovascular repair, emergent aortic stent grafts may become standard of care in patients with appropriate vascular anatomy.

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