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Anesthesiology Clin N Am
22 (2004) 319–332

ANESTHESIOLOGY
CLINICS OF
NORTH AMERICA

Intraoperative management: endovascular stents

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Over the last two decades, the introduction of minimally invasive treatment options for a variety of vascular disease processes has made a dramatic contribution to the change in the practice of vascular surgery and anesthesia. The ability to treat pathology using both intraluminal and extraluminal methods has provided vascular surgeons, interventional radiologists, and cardiologists with unique treatment options that were not available less than a decade ago. Peripheral interventions to treat vascular disease have exploded from 90,000 in 1994 to more than 200,000 in 1997, and endovascular procedures have replaced nearly 50% of the traditional open vascular operations [1].

Intraluminal techniques, including balloon angioplasty, stenting, atherectomy, thrombectomy, and thrombolysis have been used for diagnostic and therapeutic management of a variety of vascular disorders. Endovascular grafts are being implanted in virtually any accessible artery in the body. Carotid artery stenting is becoming commonplace. Angioplasty and stenting are also used to improve blood flow through iliac, popliteal, and renal arteries, and even for transjugular intrahepatic portosystemic shunts. Stents have also been used to exclude dialysis catheter pseudoaneurysms [2], thereby potentially prolonging the functional life of arteriovenous fistulae.

Most peripheral angioplasties and stents involve a low risk of bleeding and minimal hemodynamic stress, which may be treated with small doses of opioids or benzodiazepines. The latter two agents, in conjunction with local anesthesia for the arterial puncture and sheath placement, provide optimal circumstances for performing these procedures, the same anesthetic used daily, thousands of times, in cardiac catheterization suites. Moderate sedation can be given under the supervision of the radiologist, with rarely an anesthesiologist involved. In particular cases, notably carotid and aortic procedures (stenting of aneurysms and dissections), anesthesiologists are involved but for reasons other than to provide analgesia and sedation to the patient.

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doi:10.1016/j.atc.2004.03.002

Treatment alternatives for aortic surgery

Surgical repair of aortic aneurysms

Conventional repair of aortic aneurysms typically involves significant hemodynamic and metabolic stresses, particularly among patients who are usually elderly and have multiple comorbid conditions such as ischemic heart disease, hypertension, chronic obstructive pulmonary disease, diabetes, and renal dysfunction.

With the high risk of aneurysm rupture, the current standard of treatment of an aortic abdominal aneurysm (AAA) is open surgical repair. The natural history of an aortic aneurysm is characterized by continued expansion and rupture of the aneurysm [3]. Open surgical repair involves a major abdominal incision, exposure of the aorta, cross-clamping of the aorta, removal of the aneurysmal aorta, and replacement with a prosthetic graft. Considerable hemodynamic and metabolic stresses are associated with surgical trauma, aortic cross-clamping, and large fluid shifts [4,5]. Open surgical repair is curative because the aneurysm is removed, and treatment requires minimal follow-up, low risk of aortic rupture, and a proven long-term success rate.

Any treatment for an aortic aneurysm must have a lower mortality rate than that associated with the risk of aneurysm rupture. Initially, the mortality rate for the elective surgical repair of nonruptured AAAs was approximately 20%, but mortality now averages 2% in single-center studies, 4% in multicenter studies, and 7% in population-based studies [6–8]. The decrease in mortality is partly the result of improved surgical techniques and material, increased surgical experience, and improvements in anesthetic management and monitoring (use of central venous pressure), and postoperative care. Although mortality has decreased, aortic surgery is still associated with significant morbidity and the potential for a long convalescence. Morbidity from open repair may be caused by myocardial infarction, renal failure, pulmonary dysfunction, hepatic failure, ischemic bowel, or stroke. Furthermore, some patients may not be eligible for the operation because the risks are considered too high. These factors have led to the investigation of alternative methods for the management of AAAs.

Introduction of endovascular stenting of the abdominal aorta

Based on the work of Parodi et al [9], aortic aneurysms can be treated by the endovascular placement of a stented prosthetic graft. Endovascular stenting of vascular disease is a less invasive treatment option than open surgical repair. The first aortic grafts were handmade and consisted of individualized graft systems tailored by surgeons. The rapid advancement has been driven by graft system technology. The basic components of each device include a delivery system, mobile and fixed components of the prosthetic graft, and anchoring or fixation devices. A number of commercially available systems, used worldwide, include the AnueRx (AnueRx, Santa Rosa, California), EVT/Ancure (Guidant, Indianapolis, Indiana), Excluder (Gore Medical Associates, Sunnyvale, California), Stentor (Mintec, Bahamas), Talent (Norid Medical Manufacturing Corporation, Fort Lauderdale, Florida), Vanguard (Boston Scientific/Meditech, Wayne, New Jersey), and Zenith (Zenith, Bloomington, Indiana) devices, among others. Some systems have already been taken off the market because of the failure of certain components. Commercial graft systems are used more in other countries than in the United States. In the United States, the Food and Drug Administration (FDA) initially set strict inclusion and exclusion criteria for the systems used in the first clinical trials. The FDA first approved two devices for commercial use, the Ancure tube (Guidant Endovascular Technologies, Inc., Indianapolis, IN) and the AneuRx bifurcated stent graft system (Medtronic, Minneapolis, MN). [10,11]. The main types of prosthetic aortic grafts available worldwide today are the aorto–aortic tube graft, the bifurcated aorto–bi–iliac graft, and the aorto–uni–iliac grafts. It is important to have an understanding of the devices and the steps of this technically demanding procedure.

Intraoperative device-related complications are common and may affect anesthetic management. As technology continues to improve, device-related complications are decreasing, which may be because of improvements in the devices, delivery systems, and operator use. Device-related complications are dangerous because they may require secondary interventions or conversion to an open procedure, which is associated with increased mortality [12].

The procedures can be performed in an operating room with interventional capabilities or in a specialized radiology suite. Access is through a peripheral artery with a surgical cut down. Large-diameter introduction systems are placed by arteriotomy. Intravenous contrast dye and fluoroscopy are used intermittently during the procedure to define arterial structures and confirm proper placement and function of the graft and its components. Proximal and distal grafts may be self-expanding or balloon-expanded stents, which, when deployed, attach themselves by friction, hooks, compression, or crimps to the intact portion of the vessel wall. This treatment requires a normal segment of aorta to anchor the proximal end of the graft. The goal of treatment is to provide a new conduit of blood flow through the endoluminal graft without removing the aneurysm or disease portion, effectively isolating the aneurysm from the circulation and preventing rupture or stenosis.

Advantages of endovascular stents for the treatment of aortic aneurysms

Initial studies have found that when compared with conventional, open surgical repair, endovascular stenting of the aorta has considerable advantages in, for example, decreased blood loss, use of the intensive care unit, length of hospitalization, and speed of recovery [13,14]. The most significant of these advantages is in recovery; patients with an uncomplicated hospital course return to their normal state of health and activity within days of the surgery. An endovascular approach avoids a major abdominal incision, dissection of the aorta and aortic cross-clamping, and allows for alternatives in anesthetic management, notably the avoidance of general anesthesia.

Less hemodynamic and metabolic stress is incurred with endovascular repair than with open surgical repair [15]. Plasma catecholamine concentrations, changes in cardiovascular variables, and acid–base status are all greater with open surgical repair [16]. The decreased stress response may be because of reduced bowel ischemia, endotoxemia, and cytokine generation [17]. Each technique produces a different biologic response; endovascular repair, for example, induces an inflammatory response, whereas open repair induces responses associated with extensive surgical trauma and reperfusion injury [18].

Other advantages of endovascular stents include improved postoperative pulmonary function and analgesia [19]. Because of the localized nature of the procedure, endovascular repair allows the possibility of regional anesthesia and intravenous sedation as alternatives to general anesthesia.

Preoperative evaluation

Anatomic considerations for endovascular stent placement

The choice of standard surgical repair or a minimally invasive endovascular approach is currently limited by institutional practices, availability of equipment and physician to perform each procedure, and patient-related considerations. In a large center that has experiences with both techniques, the choice can be based on the anatomic features of the aneurysm and the patient's comorbid conditions. With the endovascular approach, unlike open surgical repair, the first decision in selection of patients for treatment is based on strict anatomic criteria. With the first generation of endografts, only a small percentage of patients had aneurysm anatomy that was suitable for endovascular repair. Since the introduction of the bifurcated systems, however, approximately half of the patients with infrarenal AAAs are candidates, based on anatomic criteria [20,21]. Criteria are specific to each system used and may change as the systems continue to evolve. The guidelines are designed to improve patient outcome. The breaching of anatomic criteria has led to a significant increase in the complication rate for endovascular repair [22,23].

Preoperative surgical evaluation must first define the anatomy of the abdominal aorta and branch vessels. The infrarenal aortic neck anatomy is crucial because this is the location for the proximal attachment site of the graft. The length of normal aorta above the aneurysm must have the greatest area of graft in contact with normal aorta for attachment and sealing. Aortic curvature in this area presents both immediate and late concerns. Angulation makes placement more difficult and also increases force on the prosthetic graft, thereby increasing the potential for distal migration of the graft. The presence of an aortic branch vessel may allow continued flow into the aneurysmal sac. Iliac artery tortuosity, aneurysm formation, and diameter are characteristics that are also critical because these vessels hold the larger diameter delivery systems.

When the determination is made that the aneurysm is amenable to treatment by less invasive options, the selection of patients is determined by weighing risks and benefits of invasive or noninvasive repair, based on the patient's comorbidities. The preoperative history, physical examination, and evaluation for each treatment option are almost identical. Preoperative evaluation to determine and quantify cardiac, pulmonary, and renal function, to allow optimization of medical therapies, and to assess risk factors known to increase perioperative morbidity and mortality are essential. A small percentage of patients have prohibitive risk for open surgical repair. The designation of "unfit" for open surgical repair or "unfit" for anesthesia is often not well defined. The American Society of Anesthesiologist classification system is a generalization of overall medical status and is not intended to be used as a measure of perioperative risk stratification. The Society of Vascular Surgery/International Society of Cardiothoracic Surgery-North American Chapter has defined age, cardiac function, pulmonary function, and renal function as predictors of medical risk for elective aortic aneurysm repair [24].

Intraoperative management

Because of the technical aspects of the endovascular graft systems and the procedure, endovascular repair of an aortic aneurysm presents unique challenges for intraoperative management and development of a safe anesthetic plan. The procedure is less invasive, requires minimal anesthesia, and is less likely to induce hemodynamic stress; yet, it may still be associated with many of the same risks and complications of any aortic surgery, such as massive sudden blood loss because of aortic rupture.

The goals of intraoperative management should be to provide hemodynamic stability while preserving cardiac and renal flow and maintaining intravascular volume, adequate oxygenation, and body temperature. In the preoperative holding area, explanation of the intraoperative events in conjunction with small doses of a benzodiazepine can reduce patient anxiety. After the patient is brought to the operating room, appropriate catheters for hemodynamic monitoring and large-bore intravenous catheters should be placed. An arterial catheter is used routinely for continuous blood pressure monitoring and can also be used to collect samples for arterial blood gas analysis, hematocrit, and clotting times, as needed. Because of the systemic nature of arteriosclerosis, before a radial arterial catheter is placed blood pressure should be checked in both arms to detect any differences. Central venous access should be considered to provide central delivery of vasopressors and to determine and maintain intravascular volume. When local anesthesia is used, a central venous catheter may not be necessary. In patients with poor left ventricular function or renal failure, pulmonary artery catheter monitoring or transesophageal echocardiography can provide a more accurate assessment of intravascular volume and cardiac function. A Foley catheter is required as an additional measure of volume status. Temperature should also be closely followed and normothermia maintained because patients are prepared for a full, open procedure, which leaves a large surface area exposed.

The endovascular operation requires close intraoperative fluid management with early replacement of preoperative deficits and maintenance of intravascular volume. The patient is usually given intravenous heparin before arterial incision. With the first generation of endovascular delivery systems, significant blood loss could occur during placement and manipulation of the systems. Advances have improved the hemostatic valves and other components, which have decreased blood loss during the procedure.

Postoperative care

Postoperative recovery after an uncomplicated endovascular surgery does not routinely require the use of an ICU. The patients are typically advanced to a regular diet and are ambulatory on the first postoperative day. Analgesic requirements are minimal and can be managed with nonsteroidal anti-inflammatory medications or small boluses of opioids. Postimplantation syndrome related to a systemic inflammatory response to the graft material may occur, manifesting with fever, leukocytosis, and increased C-reactive protein concentrations [25]. Hyperpyrexia can be associated with tachycardia, which warrants continued hemodynamic monitoring in patients with cardiac disease. The average length of stay in the hospital is usually less than 5 days.

Anesthetic techniques

As reported in 1991 by Parodi et al [9], the first intraluminal grafts were performed under local or limited epidural anesthesia. For the experimental procedure, these investigators selected five high-risk patients with serious comorbidity, such as severe chronic obstructive pulmonary disease, acute stroke, severe asthma, or an ejection fraction less than 20%. The authors suggested that the transfemoral approach allowed the procedure to be performed under local or limited epidural anesthesia without the morbidity of a high regional block or general anesthesia. Various anesthetic techniques for the management of endovascular surgery have since been reported, including general, combined general and regional, combined spinal and epidural, bilateral prevertebral blocks, and local anesthesia with sedation.

Many institutions initially performed endovascular surgery under general anesthesia. For both the surgeons and anesthesiologists, this choice was probably related to the uncertainties inherent in performing a new surgical technique. For example, according to a report of the clinical experience at one institution [26], aortic stent graft procedures were performed under general anesthesia until acceptable operating room times and a low risk of surgical complications could be determined; after the first seven operations, most operations were performed under local anesthesia.

A safe anesthetic can be administered by a vigilant and capable anesthesiologist, using any of the techniques mentioned earlier. The question is whether any particular anesthetic technique is superior in hemodynamic stability, with minimal use of vasopressors, maintaining intravascular volume without excessive volume administration, and preserving cardiac, pulmonary, renal and cerebral function while also providing adequate surgical conditions for the operation.

General anesthesia for endovascular stent repair

For the induction and maintenance of general anesthesia, the choice of medications and means of hemodynamic monitoring are based on the patient's cardiac function. Patients with preserved left ventricular function generally tolerate the depressant effects of intravenous and inhaled anesthetic agents with appropriate compensatory mechanisms. General anesthesia typically consists of a balanced technique with a low-dose inhalational agent and opioids. Neuromuscular blocking agents are typically not necessary. The case can be performed with a laryngeal mask airway if there are no patient contraindications. For patients with compromised left ventricular function, an opioid-based technique provides greater hemodynamic stability. General anesthesia with a laryngeal mask airway or tracheal tube helps maintain the patency of the airway throughout the procedure, allows for hemodynamic manipulation, can accommodate for variations in duration of the operation, reduces the possibility of patient movement, and allows for control of respiratory movement during fluoroscopy. Furthermore, placement of additional intravascular lines or monitors with the patient under general anesthesia is usually a little easier, and any issues of the patient's toleration of the supine positioning on the operating table during long operations are avoided. In the limited, nonrandomized retrospective studies of anesthetic techniques, general anesthesia was associated with more hypotensive episodes, increased fluid requirements, and increased use of inotropic support compared with regional or local anesthesia [26–28].

Comparing cardiopulmonary morbidity and mortality rates in 200 patients for endovascular abdominal aortic repair who had general versus local anesthesia, there was no difference found in overall cardiac and pulmonary morbidity and mortality. The presence of two or more preoperative cardiac risk factors significantly increases the risk of a major postoperative cardiac event [29].

Regional anesthesia for endovascular stent repair

Spinal, epidural, and combined spinal–epidural techniques have been used for endovascular surgery. The sensory level at which anesthetic blockade is needed is below the T10 dermatome, to provide anesthesia for the infrainguinal surgical field and for peritoneal retraction, if needed, for iliac artery exposure. The block can be performed in the low lumbar region. The level of sensory anesthesia required for endovascular surgery has fewer hemodynamic side effects than the high thoracic level needed for open surgical repair.

The advantages of epidural anesthesia over other regional techniques include the ability to titrate the local anesthetic slowly to achieve the appropriate sensory level and to accommodate variations in duration of the procedure. Also, slow titration of an epidural anesthetic allows for compensatory mechanisms to minimize hemodynamic changes.

Some institutions base the choice of anesthetic on the surgical approach for the procedure, with regional anesthesia used for the iliac approach and local anesthesia for the femoral approach [26]. Regional anesthesia has a proven advantage over general anesthesia in postoperative pulmonary function. General anesthesia with mechanical ventilation can cause decreased lung volumes, ventilation–perfusion mismatch, decreased functional residual capacity, atelectasis, and impaired ciliary function with thickened secretions, predisposing to postoperative pulmonary dysfunction and infection [30].

The benefits of regional anesthesia over general anesthesia for patients with compromised myocardial function remain controversial because of difficulty in demonstrating differences in morbidity and mortality. In attempting to identify differences in outcome, many studies have compared general anesthesia with combined general–epidural anesthesia for surgical procedures associated with significantly more surgical trauma or those that require a higher thoracic level of anesthesia than would be required for endovascular surgery. Hemodynamic effects related to increased venous capacitance and decreased preload of a low lumbar epidural titrated slowly are minimal. If blood pressure is maintained, myocardial function should not be significantly affected. Regional anesthesia has been reported in a series of 21 patients with no periods of clinically significant hypotension during the procedure [31]. The use of vasopressors and median fluid balance was lower with the use of regional versus general anesthesia for endovascular repair of aortic aneurysms.

Other benefits of regional anesthesia over general anesthesia include a shorter postoperative hospital stay [32]. Because of the lower level of anesthesia required for the endovascular procedure, the theoretical disadvantages of regional anesthesia are not present, such as the difficulty controlling hemodynamics in a bleeding patient with a high sympathectomy or postoperative fluid overload when the block recedes. Potential disadvantages with regional anesthesia include difficulties in patient comfort while placing intravascular lines, patient tolerance of supine positioning on the operating table during long operations, and the need to convert to general anesthesia if the procedure is converted to an open surgical repair.

Risk of epidural hematoma

In patients undergoing peripheral vascular surgery while receiving intraoperative heparin, regional anesthesia can be safely performed, with a low risk of spinal or epidural hematoma [33]. Theoretical concerns about placement of a catheter in a patient who will undergo intraoperative anticoagulation should not restrict the use of regional anesthesia if results of coagulation tests performed at the time of placement of the block or epidural catheter and before removal of the catheter are normal. Neurologic function should be monitored postoperatively.

Local anesthesia for endovascular stent repair

For the transfemoral approach, local anesthesia is well tolerated and provides greater hemodynamic stability than other anesthetic techniques, demonstrated by decreased use of inotropic agents. Intravenous sedation regimens include titration of benzodiazepines with or without continuous infusions of propofol or opioids. Modifications in surgical technique and catheter technology have simplified parts of the procedure, for example, by decreasing the clamp time, leg ischemia, and pain for patients.

Angioplasty and dilatation may be performed to relieve occlusions in the arterial vasculature during the procedure. During placement of a guidewire and positioning of the balloon under fluoroscopy, the balloon is inflated to dilate the narrowed areas. This may be repeated two or three time and last for 30 to 60 seconds at a time. The patient commonly feels pain during dilatation, which resolves with deflation of the balloon. This pain in fact may serve as a sign of appropriate expansion. The pain is thought to be related to stretching of the adventitial nerve fibers, and the absence of pain may indicate insufficient balloon inflation. Persistent pain after deflation of the balloon may indicate arterial rupture with extravasation and should be investigated [34]. Thus, the patient's ability to sense decreasing pain and localize improvement that accompanies parts of the procedure are significant indicators of successful surgery.

Henretta et al [35] first demonstrated the feasibility of local anesthesia with intravenous sedation as a safe alternative in a clinical series of 47 patients. A retrospective, nonrandomized analysis of 91 patients found local anesthesia superior to both general and epidural anesthesia, with evaluation based on decreased fluid requirements, decreased operating time, decreased use of inotropic agents, and decreased length of hospital stay [26].

As with any surgical procedure with local or regional anesthesia, preparations must be made for conversion to a general anesthesia in the event of conversion to open surgical techniques, or if further access to the iliac arteries is needed, or if the patient is unable to tolerate the supine positioning on the operating table.

Should endovascular surgery lower the threshold for elective aneurysm repair?

With a less invasive treatment option, the question could be considered whether there is any benefit of endovascular repair of smaller aneurysms. Using mathematical models to assess long-term benefits of treatment versus nontreatment, indications for elective aneurysm repair have not changed since the introduction of this technique [36]. The delay of treatment of smaller aneurysms does not change the characteristic of the aneurysm or make the patient unsuitable for endovascular repair. In aneurysms smaller than 7 centimeters, there is no correlation between aneurysm size and suitability for endovascular repair [37].

Complications of endovascular aortic surgery

The development of endoluminal therapies has introduced new treatment options but has also created complex issues regarding patient care. There are many ethical, scientific, and practice issues that must be considered with the introduction of any new surgical procedure. The new treatment should have morbidity and mortality rates lower than current therapies. With small clinical studies having a wide variation in outcome parameters, larger prospective studies are needed. In 1996, the EUROpean collaborators on Stent-graft Techniques for abdominal Aneurysm Repair (EUROSTAR) established a voluntary registry of more than 90 centers for the purpose of combining and studying a large outcome database and now contains information on thousands of patients.

Major perioperative complications have been reported with endovascular surgery, including aneurysm rupture, myocardial infarction, cardiac arrhythmia, pneumonia, respiratory failure, renal failure related to the dye load or acute occlusion, and peripheral embolization including a fatal cerebral embolization. These complications with endovascular repair, however, are infrequent [38,39].

System and graft-related complications

Device-related complications include arterial injury, inability to introduce, advance, or deploy the device, device occlusion, stenosis, migration, and *endoleak* (persistent communication between the normal circulation and the aneurysm sac after placement of the graft). Device-related complications may lead to conversion to an open procedure, which is associated with increased operative mortality [40]. The major disadvantage of endovascular repair is the inability to ensure long-term success of the grafts. Endovascular repair of AAAs requires close surveillance because of the frequent need for secondary interventions.

The durability of the graft material has been investigated. In an analysis of explanted devices from the EUROSTAR registry, the woven polyester sleeves had evidence of yarn shifting, distortion, damage, and filament breakage leading to the formation of holes in the fabric and structural failure of the metallic frame. The conclusion is that the biomaterials within the studied devices required further improvement [41].

The risk of late failure is 3% per year, and the continued presence of the risk of aneurysm rupture is 1% per year [42]. With this treatment, the aneurysm remains present and is isolated from the circulation. Endoleaks are classified by the site of flow into the aneurysmal sac. Type I endoleaks are caused by an inadequate seal at the proximal or distal segments of the endoprosthesis; Type II are branch flow through patent accessory renal, inferior mesenteric, hypogastric, lumbar, or sacral arteries; and Type III are midgraft leaks through a fabric hole or from an inadequate seal between graft components. The potential to increase aneurysm size or intraluminal pressure could lead to aneurysm rupture. The natural history and management of endoleaks is controversial. Types I and III endoleaks are usually considered major complications, representing failure of treatment and correlating with a higher risk of aneurysm rupture and conversion to open procedure. The significance of Type II endoleaks is still under investigation, and they may require secondary intervention if there is an increase in aneurysm size [43,44]. In a study population of 1023 patients, secondary interventions were performed in 18% of patients, with a mean period of 21 months after initial graft placement [45].

What is the role of endovascular repair in patients considered unfit for conventional open repair?

The limited life span of this group of patients makes it difficult to assess long-term outcomes of this procedure. The life expectancy of any patient with significant comorbidity should be greater than 1 year to realize any benefit from the procedure. In a study of 381 patients considered unfit for open repair and anesthesia, patients with significant comorbidity had higher mortality rates from nonaneurysmal-related complications, with cardiac events the most significant [46]. Whether mortality is the result of an effect of treatment or a natural progression of the patient's disease is not known; however, the mortality rate was greater than the mortality rate associated with AAAs greater than 5 centimeters. The presence of symptoms and anatomic ease of endovascular treatment are additional considerations in this population. With increases in both early and late mortality in high-risk patients, individuals with significant comorbidity may benefit from endovascular repair only if the aneurysm size is greater than 6 centimeter [47,48].

Summary

Anesthetic management for major vascular surgery is one of the most complex areas of practice in anesthesiology. Repair of aortic aneurysms involves significant hemodynamic and metabolic stresses, particularly in a population of patients that is usually elderly and has multiple comorbid conditions such as ischemic heart disease, hypertension, chronic pulmonary disease, diabetes mellitus, and renal dysfunction. The introduction of endovascular repair of aortic aneurysms has presented a unique treatment option to approximately half of the patients presenting for AAA repair. The immediate benefits of reducing early morbidity, blood loss, length of stay, and recovery have been proven. The long-term success of the endovascular prosthetic grafts is of concern because of the need for lifelong surveillance, secondary interventions, and continued risk of aneurysmal rupture.

As the technology of this rapidly evolving surgical technique continues to develop, there is hope that material and structural designs will help resolve some of these issues. Indications for endovascular stent graft replacement now extend well beyond elective AAA repair to include repair of ruptured abdominal aneurysms in patients with contained bleeding, thoracoabdominal aneurysms, and aortic injuries caused by blunt trauma [49,50]. Many of these operations are performed under local anesthesia. Even when surgical and anesthetic techniques are less invasive, these patients have a high incidence of severe coexisting diseases and continue to required complex management throughout the perioperative period.

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