Surgical Treatment of the Abdominal Aorta

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Alexis R. Powell, Gabriel Crowl, and Vikram S. Kashyap

Abbreviations

AAA Abdominal aortic aneurysm
AIOD Aortoiliac occlusive disease
ePTFE Expanded polytetrafluoroethylene
IMA Inferior mesenteric artery
PFA Profunda femoral artery
rAAA Ruptured abdominal aortic aneurysm
SFA Superficial femoral artery

Aortic Aneurysm

Background

The modern era of surgical treatment of AAA (abdominal aortic aneurysm) began with Dubost's successful repair using homograft in 1951. Since that time, techniques of open repair and perioperative care of the surgical patient have been refined and outcomes today remain excellent. Mortality rates for elective repair approach 1% in experienced hands [1]. The incidence of these lesions is 1.5–3.0% based on autopsy series; however, this figure rises in selected populations. Hypertension, atherosclerotic disease, and known aneurysmal disease of other vessels are risk factors. The natural history of all aneurysms is for progressive increase in size over time; thus, the risk of rupture-specific death rises with age. The intent of repair is to prevent late death related to aneurysm rupture. Although the advent of endovascular treatment options has revolutionized the treatment of AAA, thorough knowledge of the techniques for traditional open surgery remains an essential element of the modern vascular surgeon's armamentarium. Here, we will focus on considerations for open surgical repair.

AAA is a permanent localized dilatation of the intra-abdominal aorta greater than 30 mm in diameter, and this generally accepted definition has been used as the basis for the population-based studies which clarified the natural history of small infrarenal aneurysms [2].

By far, the most common location of abdominal aneurysms is infrarenal. These involve only the segment caudad to the renal arteries, with a portion of normal aorta between the most inferior renal orifice and the abnormal arterial tissue sufficient to allow for open reconstruction while maintaining renal perfusion throughout the repair. Pararenal aneurysms are more proximal lesions in which repair will more directly involve the renal arteries. Juxtarenal aneurysms are pararenal aneurysms with normal tissue at the orifices but inadequate space for an infrarenal aortic clamp. Repair of these lesions requires intraoperative interruption of renal perfusion by cross-clamping proximal to either or both renal arteries; the reconstruction itself remains limited to the infrarenal aorta. Suprarenal aneurysms are those pararenal aneurysms for which both cross-clamp and reconstruction must start superior to the renal arteries, dictating both interruption of renal blood flow and subsequent revascularization during the same procedure. Any aneurysmal involvement of the paravisceral segment of the abdominal aorta is considered a thoracoabdominal aneurysm, requiring a much more complex

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reconstruction with supraceliac clamping and revascularization of the mesenteric circulation.

As the purpose of repair is to prevent rupture-specific death, indications for surgical repair must balance the increasing risk of mortality posed by aneurysm growth with the risks associated with any procedure undertaken for repair. The results of population-based cohort studies on the natural history of AAA suggest an aortic diameter threshold of 5.5 cm for elective repair. This represents a consensus view of the point of equipoise between the risks of intervention and the risks of continued observation [3]. This number should however be considered in the context of each patient individually. Younger patients who otherwise represent a lower surgical risk may be candidates for elective surgery at a diameter of 5.0 cm given that such aneurysms nearly always progress to the 5.5 cm threshold with time. Smaller aneurysms that demonstrate rapid growth of more than 5 mm within a surveillance period of 6 months should also be considered for repair, as these lesions are considered a higher rupture risk. Female patients have long been to known to have higher risk for rupture and death at smaller diameters than their male counterparts. A threshold of 5.0 cm diameter has been proposed for AAA in women; however, high-quality data are lacking [4]. Conversely, patients with a life expectancy of less than 2 years are unlikely to benefit from elective repair. Patients whose comorbidities create prohibitive operative risk require circumspect judgment regarding the timing or feasibility of elective repair, although as the aneurysm becomes larger than 5.5–6.0 cm the risk of rupture-related death usually outweighs perceived operative risk. In the special case of a symptomatic or ruptured aneurysm, the risk of death is so great that very few contraindications exist for surgical intervention so long as such intervention is consistent with the patient's goals of care.

Any decision to perform elective open surgical treatment of AAA must be accompanied by an evaluation of the patient's overall health and any other coexisting health conditions. An assessment of the patient's ability to benefit from the procedure is mandatory. As the objective of AAA repair is to prolong life, risk factors for both perioperative and late morbidity and mortality must be carefully considered against the risk of late rupture of an untreated aneurysm [5]. The most challenging cases are typically those of older, chronically ill patients with large aneurysms. Advanced age, significant cardiopulmonary disease, or dialysis-dependent renal failure all represent increased risk for perioperative complications. These patients are often best served by endovascular treatment. At a minimum, any preoperative assessment should include a thorough review of the patient's medical and surgical history, paying particular attention to any evidence for unreconstructed coronary disease, congestive heart failure, parenchymal lung disease, diabetes mellitus, or chronic renal failure [6]. These conditions should be optimized prior to surgery. The most common cause of death at the time of surgery and following repair is coronary artery disease. A resting 12-lead EKG should be obtained in any patient under consideration for AAA repair as the incidence of coronary artery disease in this population is high [7]. In addition, preoperative cardiac stress testing should be considered for those patients with risk factors for occult coronary disease. Abdominal imaging using computed tomography angiography should almost always be obtained for preoperative planning. Recent research has also suggested that both surgeon and hospital volume play a role in outcomes for elective AAA repair, with higher volumes giving improved results [8].

The first consideration in open operative technique for aneurysm repair is to determine the necessary extent of the reconstruction. As discussed above, the anatomy of the AAA with regard to the renal and mesenteric vessels will dictate the crucial steps of the surgery. The general rule is to exclude all abnormal aortic tissue, replacing it with a graft material, which is sutured to normal aorta in order to restore arterial blood flow distally. In all cases, the surgeon will need to make a determination about the location of the proximal and distal anastomoses; this should be planned prior to the operating room based on the available preoperative imaging. In the case of infrarenal aneurysm, the reconstruction should include the entire infrarenal aorta up to the renal artery orifices in order to prevent recurrent aneurysmal degeneration in any normal-appearing tissue left behind. Pararenal aneurysms will require some period of ischemia to one or both kidneys due to the necessary suprarenal cross-clamp position. Repair of suprarenal AAA will by definition require reimplantation of at least one major aortic branch vessel, and the time necessary for this revascularization lengthens the ischemic period. To prevent postoperative renal insufficiency, this ischemia time must be kept to a minimum. Meticulous intraoperative planning is the key to avoiding this complication; principles of minimizing ischemia time include completion of the proximal anastomosis immediately after clamp placement, followed by repositioning of the clamp onto the graft distal to the renal arteries, thus restoring renal perfusion as the distal portion of the reconstruction proceeds. The position of the cross-clamp must also be considered as a potential cause for embolization of intramural cholesterol crystals or chronic thrombus; preoperative imaging can be very helpful in this regard.

In some cases, the repair can be accomplished with only two anastomoses: proximally as dictated by the extent of disease around the renal arteries and distally at the very furthest portion of the aorta. This is known as a tube graft repair for the shape of the graft used. Otherwise, the distal reconstruction will require a bifurcated graft, with the point of anastomosis on each side determined by the condition of the iliac arteries. These repairs are referred to as aortobiiliac or aortobifemoral depending on the final position of the distal reconstruction (Fig. 19.1).

Graft Material

Synthetic grafts are available in one of two materials: polyester, available as a knitted or woven graft, and expanded polytetrafluoroethylene (ePTFE). Knitted polyester grafts are typically impregnated with collagen or gelatin to reduce porosity. Woven polyester is stronger than the knitted variety,

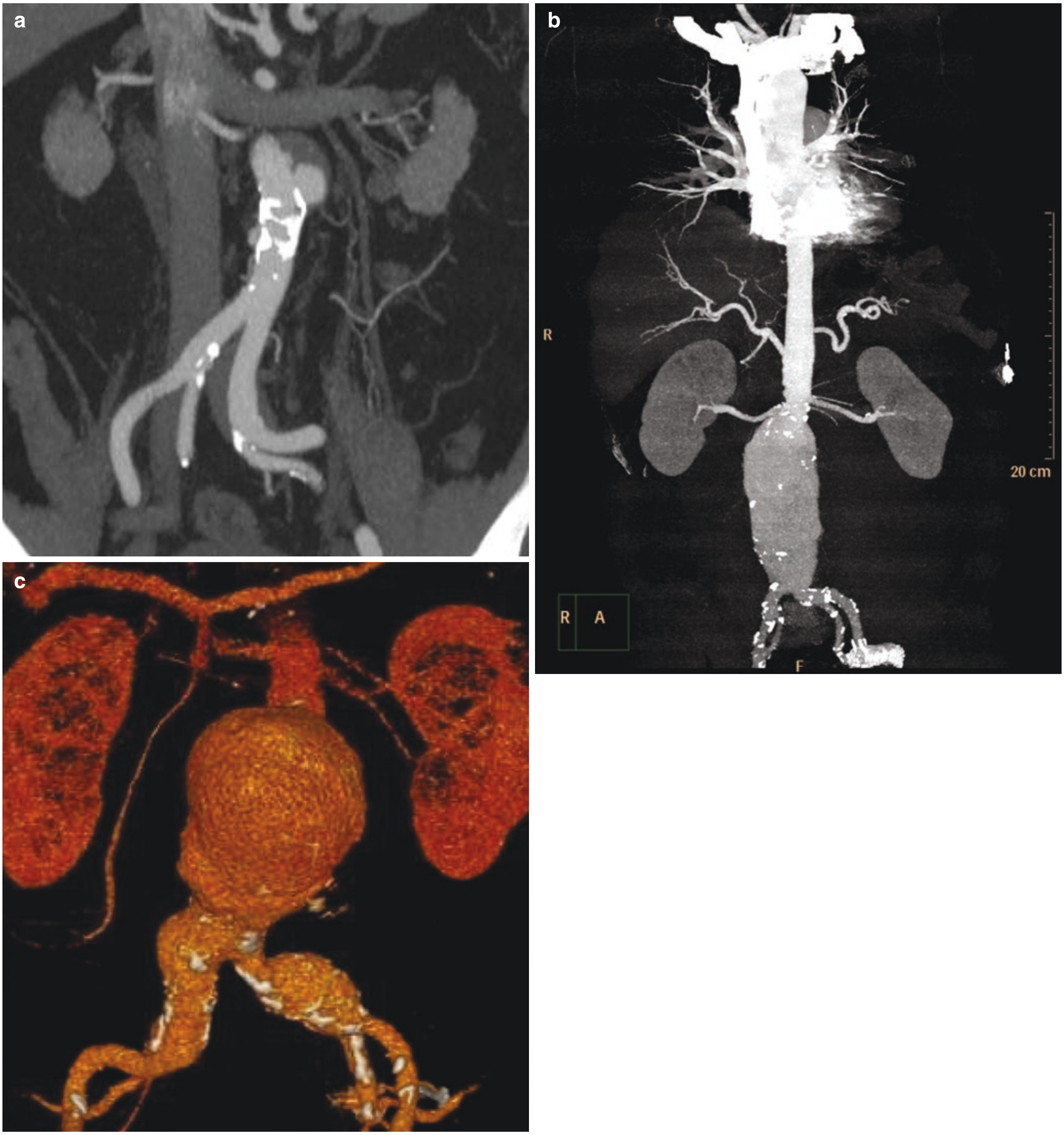

Fig. 19.1 (**a**) Isolated infrarenal aneurysm suitable to tube graft repair. (**b**) Infrarenal aortic aneurysm extending to aortic bifurcation suitable for aortobiiliac repair. (**c**) Infrarenal aortic aneurysm with aneurysmal bilateral iliac arteries suitable for aortobifemoral repair

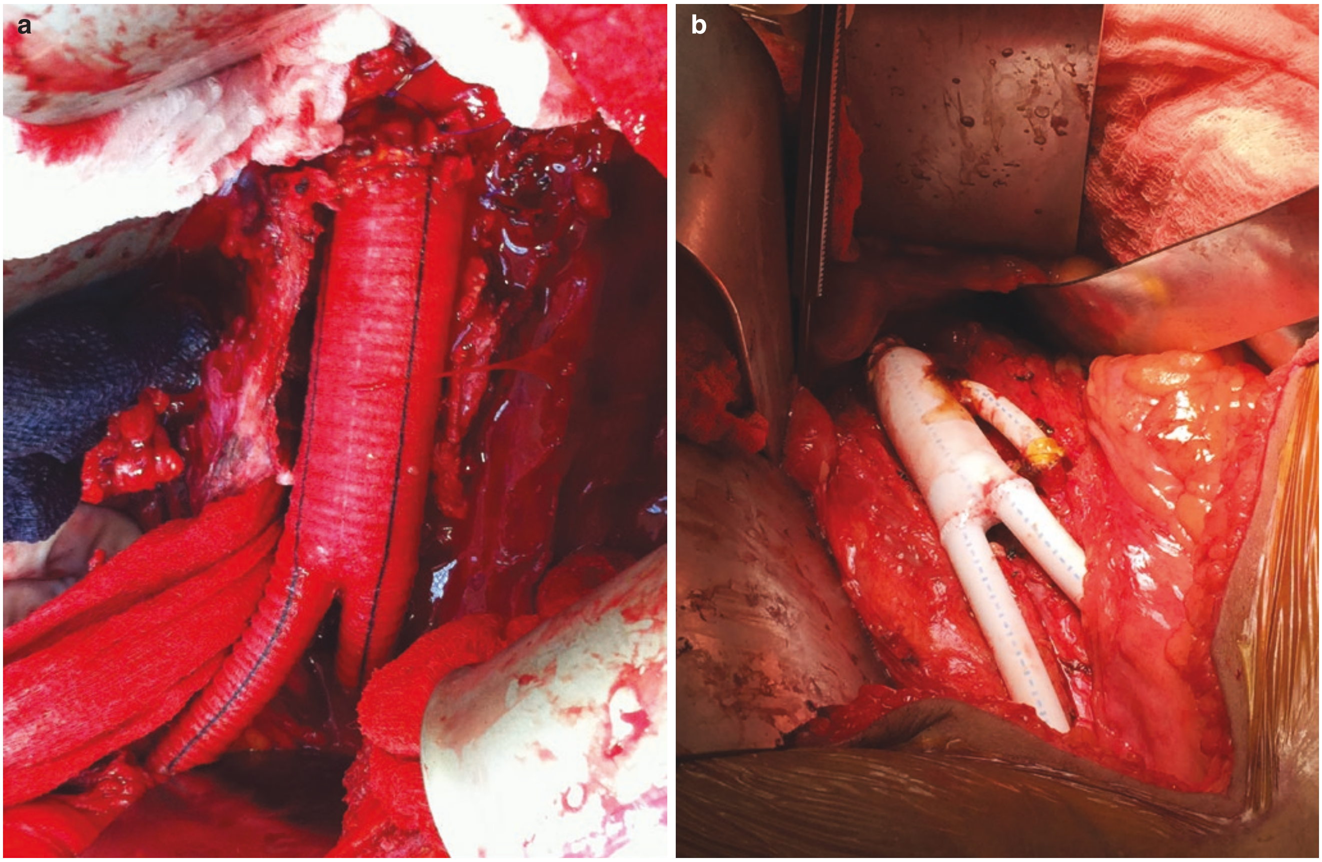

Fig. 19.2 (**a**) Polyester fabric aortic aneurysm repair. (**b**) ePTFE aortic aneurysm repair

but is more difficult to handle. The two materials have been shown to be equivalent for purposes of aortic reconstruction, and the choice is primarily one of surgeon preference based on personal experience and handling characteristics [9] (Fig. 19.2).

Operative Technique

The classic operative exposure for exposing the aneurysmal abdominal aorta is the midline incision. This is made starting from the tip of the xiphoid process and is extended distally to the pubic bone. This allows for transperitoneal exposure of the entire abdominal aortoiliac system if necessary, as well as for comprehensive inspection of the peritoneal contents. A disadvantage of this approach is suboptimal exposure of pararenal aneurysms, depending on the position of the left renal vein. This vessel is usually found immediately anterior to the aorta and can be mobilized or ligated, but with concomitant increased risk of bleeding which can prove difficult to control [10]. Once the abdomen is entered via the midline incision, the transverse colon is mobilized superiorly and the small bowel mobilized to the right side of the abdomen after releasing the ligament of Treitz. These maneuvers provide access to the retroperitoneum. If wider exposure is required to expose the paravisceral aorta, a medial visceral rotation can be performed. This involves mobilization of the descending colon, pancreas, and spleen.

Proximal control of the aorta is established by circumferential dissection of the vessel at the transition point to normal aortic tissue. This may involve some dissection of retroperitoneal lymphatic tissue, which should be ligated to prevent leakage. Control of renal or mesenteric vessels may be required depending upon the extent of the aneurysm; this is accomplished with silastic vessel loops placed under tension. The left renal vein is identified and kept safely out of harm's way. If the left renal vein is divided, its collaterals from the adrenal glands and the pelvis must be preserved. A retroaortic vein should be suspected if none is noted anteriorly; failure to do so can lead to vein injury and dangerous bleeding upon aortic dissection and clamping. Lumbar veins can also sometimes be located immediately behind the aorta, leading to similar bleeding problems if the surgeon does not think to anticipate them (Fig. 19.3).

Distal control is obtained in a similar manner over the iliac vessels, with attention given to identifying and protect-

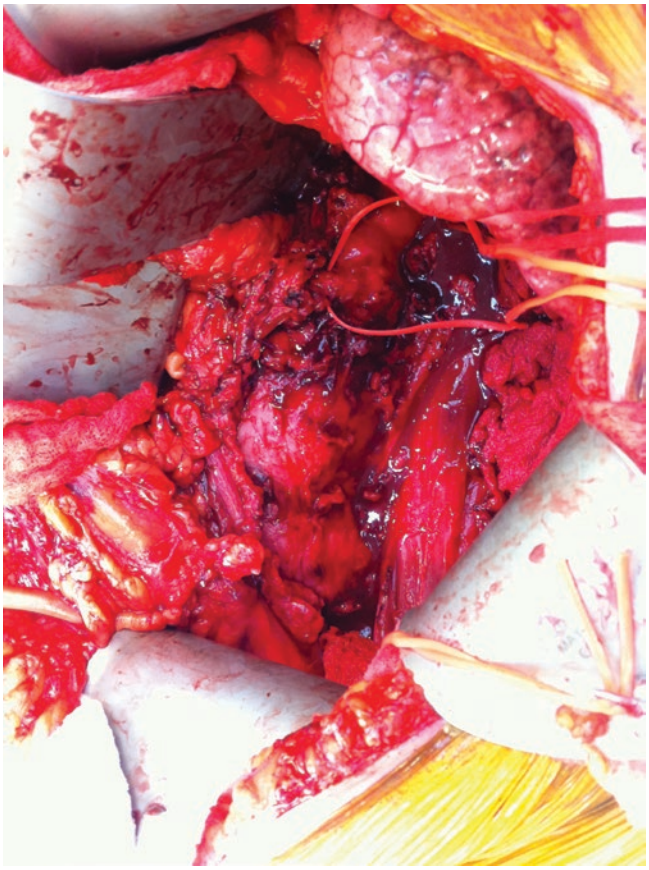

Fig. 19.3 Retroperitoneal exposure of infrarenal AAA with silastic vessel loop around the left renal artery

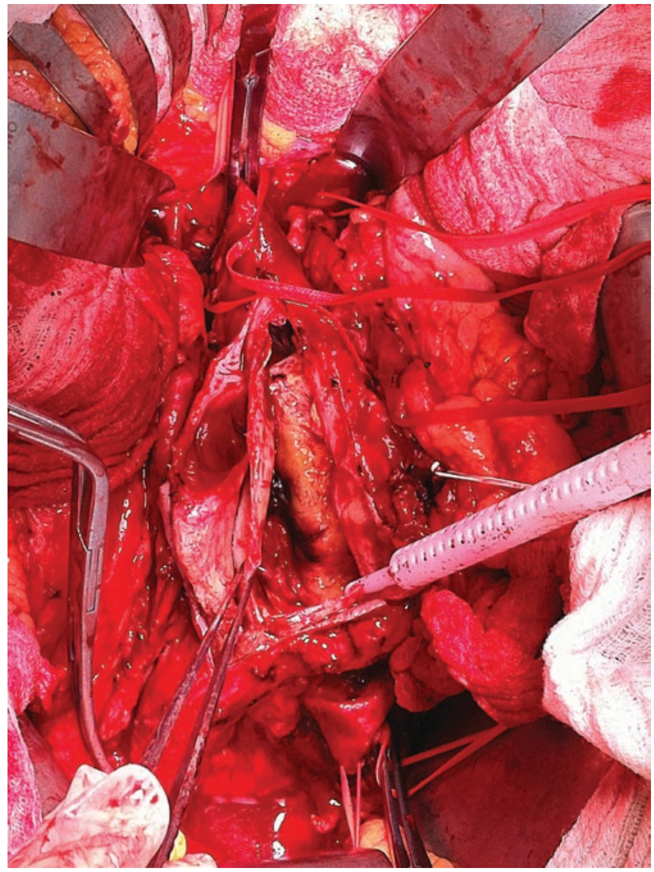

Fig. 19.4 AAA sac is opened and thrombus removed

ing the ureters and iliac veins. Typically, there is no need to pursue dissection on the common iliac arteries much past the aortic bifurcation. The graft anastomosis must be completed using healthy tissue however, and exposure distally should adhere to this concept, as in the case of concomitant aortoiliac aneurysm. When possible, care should be taken in male patients to preserve the autonomic nerve plexus that overlies the left common iliac artery. Sacrificing this structure will not affect the repair but is associated with postoperative sexual dysfunction. With proximal and distal blood flow to the aneurysm sac interrupted by placement of aortic clamps, intravenous heparin is given for prevention of arterial thrombosis. Meticulous attention must be paid to the precise position of the clamps, as a heavily calcified aorta may in fact continue to bleed or be damaged by application of the clamp. This bleeding can be very difficult to control.

The aneurysm sac is entered via longitudinal incision (Fig. 19.4). Intraluminal debris and chronic thrombus are removed, and any back-bleeding lumbar vessels are oversewn. The proximal anastomosis is then completed, followed by the distal anastomoses, using a continuous monofilament polypropylene suture. This is a permanent synthetic suture material with a history of durability in this context. Prior to removing the aortic clamps, the iliac arteries are back-bled and the graft flushed with heparinized saline to prevent distal embolization of thrombus that may have formed during the reconstruction. Unclamping is done in a deliberate manner and in particularly close communication with the anesthesiology team. Profound hemodynamic changes can occur at this time as blood flow is restored. At the conclusion of the reconstruction, the aneurysm sac is closed over the graft with sutures to reduce the likelihood of future aortoenteric fistula. The peritoneal contents are inspected and replaced into the abdomen, and the abdominal wall is closed.

With regard to smaller branches of the aortoiliac system, the inferior mesenteric artery (IMA) and hypogastric arteries deserve special attention. The IMA should be evaluated for the presence of pulsatile back bleeding. If this is the case, then the IMA can be safely ligated. Good flow suggests adequate arterial collateralization to the hindgut. The surgeon should have a low threshold for reimplantation of this vessel if there is concern about this collateral flow, as the consequences of perioperative bowel ischemia can be catastrophic. Similarly, antegrade flow should be preserved to at least one hypogastric artery to limit the likelihood for postoperative pelvic or bowel ischemia, buttock claudication, or sexual dysfunction. If the distal anastomosis is proximal to the iliac bifurcation, anatomic flow is maintained. Otherwise, an end-to-side anastomosis to the external iliac artery should provide retrograde flow to the origin of the ipsilateral hypogastric artery.

Alternative Exposure

The retroperitoneal exposure via an oblique incision is an alternative to the midline transperitoneal approach. The standard incision is made on the patient's left flank from the 10th or 11th intracostal space to the lateral edge of the rectus abdominis muscle in the area of the umbilicus [11]. The incision can be extended caudad for better iliac exposure or cephalad and into the pleural space if control to the visceral or supraceliac aorta is needed. Partial rib resection can also be undertaken to allow more visualization. This approach is preferred by many surgeons for the generous access it provides to aorta for most of its length. The retroperitoneal approach is also said to decrease rates of postoperative ileus and respiratory failure, to reduce resuscitation requirements, and to reduce length of hospital stay. The peritoneal cavity is more difficult to explore from this approach (if necessary); however, this may be a worthwhile trade-off in the case of a reoperative abdomen. No clear advantage has been shown for one approach over the other [12]. The choice of incision should consider individual patient characteristics but typically remains at the discretion of the surgeon.

Special Consideration: The Ruptured AAA

Considerations for repair of ruptured or symptomatic aneurysms (rAAA) differ markedly from those of elective repair. Perioperative management is essentially that of a critically injured trauma patient – one of advanced age and often with multiple chronic illnesses. Preoperative resuscitation should pursue a strategy of permissive hypotension, but should not delay moving the patient to the operating room as the definitive treatment is surgical. Although many rAAA are today treated with endovascular techniques, many centers are not yet equipped to provide this intervention and many patients prove too unstable for transfer. Furthermore, a large proportion of rAAA have anatomy hostile to endovascular therapy (Fig. 19.5).

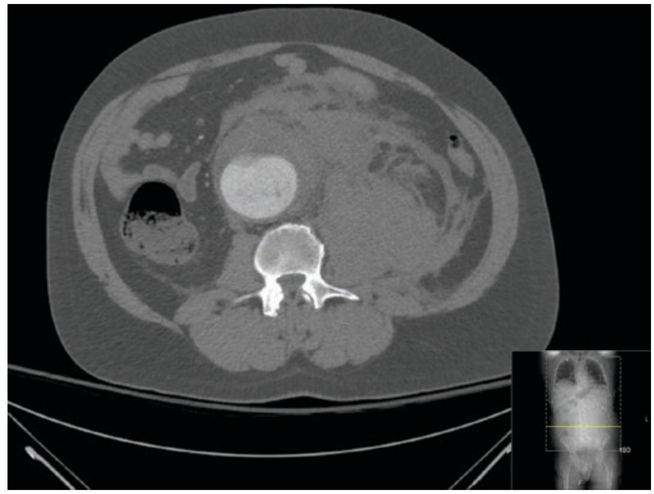

Fig. 19.5 Ruptured infrarenal abdominal aortic aneurysm with retroperitoneal hemorrhage and stranding around aneurysm

Operative Technique

The preferred open approach in most cases of ruptured AAA, particularly infrarenal, is transperitoneal via the midline incision as described above. The initial phase of the operation must focus on control of hemorrhage. This is done by first obtaining supraceliac control with an aortic cross-clamp. Manual aortic compression at the base of the diaphragm can also be utilized if free intraperitoneal hematoma prevents straightforward initial access to the clamp site. Another alternative is the deployment of an endoluminal aortic occlusion balloon. Indeed, some surgeons will place a balloon initially as a temporizing measure, followed by clamp placement once possible. Care must be taken during exploration and clamping not to damage any of the larger veins, as this will worsen hemorrhagic shock and prolong operative time. Once proximal and distal control is obtained, hematoma is removed to facilitate access to the aneurysm sac. The duration of supraceliac clamping should be minimized to shorten ischemia time to the viscera and kidneys. The clamp site should be moved down onto the graft once the proximal anastomosis is complete; however, this is not always possible in the case of pararenal aneurysm. Heparin is not used, as these patients are in shock and all have some degree of coagulopathy. Close coordination with the anesthesia team is necessary to effectively manage the abrupt hemodynamic shifts that occur around the times of clamping and unclamping. Once hemostasis is assured, the patient must be aggressively resuscitated; many will meet the requirements for a massive transfusion protocol [13]. Acidosis, coagulopathy, and hypothermia (the so-called "lethal triad") will contribute to perioperative mortality and morbidity if not recognized and treated rapidly. In spite of these efforts, the mortality rate for rAAA remains stubbornly high. Most patients who tolerate the initial insult relatively well will survive with surgical treatment, but the vast majority of those with persistent hemodynamic instability and end-organ failure will die.

Outcomes

As noted above, the perioperative mortality percentage rate for elective AAA repair lies in the low single digits when performed at centers of excellence. This is most commonly due to acute coronary events; the high prevalence of ischemic heart disease in AAA patients mandates an adequate preoperative cardiac risk assessment. Hypotension during the operation or in the acute postoperative period must raise suspicion for hemorrhage. Venous injuries in particular can be very challenging to manage, emphasizing the importance of a careful approach to dissection. If hypotension is due to bleeding after surgery, a return to the operating room is mandatory. The strategy once there is not unlike the approach to a ruptured aneurysm. Hypotension can also lead to end-organ ischemia, which can affect any organ in the body, most notably the heart, kidneys, bowel, liver, and brain.

Acute postoperative renal insufficiency following AAA repair can be due to ischemia, embolization, or iodinated contrast injury. Chronic kidney disease predisposes patients to worsening kidney function postoperatively. This complication has been linked to a higher incidence of progressive chronic renal failure and late mortality and is an ominous sign in postoperative rAAA patients [14, 15]. While the rate of acute kidney injury is approximately 10% in elective open infrarenal AAA repair, it is higher in those operations requiring renal ischemia time or revascularization [16]. Surgical technique must encompass steps to minimize the possibility for kidney injury in all operations undertaken for AAA repair.

While some degree of ileus is universal following transperitoneal repair, bowel ischemia is a less likely (2%) but far more serious complication [17]. Full-thickness colonic ischemia carries a high mortality rate even when diagnosed early. Diarrhea within the early postoperative phase is always suspicious for this problem and mandates immediate endoscopic investigation. There is no straightforward method to guaranteeing adequate bowel perfusion while in the operating room. However, the techniques mentioned above for IMA reimplantation, antegrade hypogastric flow, and assessment of the bowel prior to closure are crucial to minimizing the chances for a poor outcome. Intraoperative injury to the bowel or ureters can create a range of complications, ranging from prolonged ileus to chronic renal insufficiency, graft infection, or peritonitis. These injuries are best mitigated when recognized and managed at the time of surgery.

While coronary disease remains the leading cause of mortality in the postoperative period, pulmonary complications are the most common. Most patients will be liberated from the ventilator within 48 hours of the completion of surgery; however, postoperative pain and pre-existing lung disease contribute to respiratory failure, reintubation, and pneumonia. Respiratory complications also have a direct negative effect on late survival [18].

The long-term survival of patients undergoing AAA repair is 49–75% at 5 years [19]. This is worse than these patients' age-matched cohorts without AAA, but this is to be expected given this population's higher rates of medical comorbidities. Significant late complications of open AAA repair include incisional hernia, bowel obstruction, graft thrombosis, graft failure, aortoenteric fistula, and graft infection. The combined incidence of these problems is low, but they can prove extremely challenging to manage [20]. Any of these can present years after the index operation, and all providers involved with the patient's care should be vigilant in watching for them.

Hybrid Repair

Background

Although open repair remains the surgical standard of care for pararenal AAA and aneurysmal disease involving the visceral aorta, many patients are considered too high-risk to successfully undergo this physiologically challenging procedure. It was with this consideration in mind that endovascular treatment of aneurysmal disease was first attempted. The indications for fully endovascular repair of these complex lesions continue to expand as the limits of the available technology grow. For some patients, however, the anatomy of the disease is not suitable to treatment with currently available endograft devices and the severity of their comorbidities precludes traditional open repair. When intervention is indicated in these patients, techniques for combined surgical and endovascular repair ("hybrid") can prove very useful. Hybrid procedures combine the most appealing aspects of each method for aneurysm repair: the durability of open revascularization and the improved perioperative survival of endovascular intervention.

Operative Technique

Any endovascular stent-grafting procedure for aneurysmal disease must include adequate landing zones for the proximal and distal ends of the device; this ensures proper apposition of the device to the aortic wall for exclusion of the aneurysm sac. In hybrid repair, these landing zones can be created surgically using aortic reconstruction techniques. If stent-graft coverage of the renal or mesenteric arterial origins is required, the aorta can be debranched by surgical bypass [21]. These vessels should then be surgically ligated or endoluminally coiled proximal to the bypass anastomosis to prevent endoleak.

Fig. 19.6 Thoracoabdominal aneurysm hybrid repair post four-vessel debranching and stent graft placement. Bifurcated grafts off of each common iliac artery supply the bilateral renal arteries, SMA, and hepatic arteries

The inflow for the bypass grafts may come from any normal segment of the aorta or common iliac arteries. Bypasses may also be originated from an infrarenal aortic reconstruction or an existing aortobifemoral bypass graft (Fig. 19.6).

Hybrid repair of abdominal aneurysm is typically undertaken as a staged procedure. Debranching and any necessary open aortic grafting is completed as one stage, followed by aortic stent-grafting at a later date once the patient has had time to recover. This minimizes the physiologic insult of ischemia time and allows recovery of renal function prior to the contrast administration necessary for endovascular intervention. At some centers, both procedures are performed during the same admission to reduce the chance for interval aneurysm rupture [22].

Perioperative care for hybrid procedures is much the same as for each procedure when done individually. The dreaded complication of hybrid repair is neurologic deficit due to spinal cord ischemia following long-segment aortic coverage with stent-grafting. For this reason, the endovascular procedure itself is sometimes staged when possible, and spinal drainage is routinely used [23]. With careful patient selection, near-term results are comparable to traditional open repair [21, 24].

Aortic Dissection

Background

Recent advances in medical and endovascular therapies have rendered open surgical technique for management of descending aortic dissection all but obsolete. Although acute Stanford type B dissection remains a complex condition with a high mortality rate when untreated, most patients can be treated to excellent outcomes without the need for open repair. This preference for alternative modalities is in large part due to the great perils associated with open surgery for this condition. Even modern series report operative mortality exceeding 20%, with higher risk for older patients and those presenting in shock [25]. Postoperative rates of stroke, spinal cord ischemia, and end-stage renal failure are also significant.

Preoperative Management

The first-line treatment for stable type B dissection is medical management with strict blood pressure control in an intensive care setting. Complicated dissection is characterized by the presence of any of the following: aortic rupture, end-organ malperfusion, expansion of the false lumen or the dissection plane, or uncontrolled pain [26]. Complicated dissection suggests futility or failure of medical management and represents an indication for urgent intervention. No high-quality studies have been done to compare open and endovascular techniques in this setting. Nevertheless, the daunting risks associated with open repair favor a first-line endovascular approach. Although relatively little is known about the long-term results of endovascular treatment with stent-grafting or fenestration of complicated type B dissection, it has become the preferred management (Fig. 19.7). Open surgical repair, although it represents the historical standard, has therefore become the option of last resort.

Operative Technique

The objectives of open surgical management mirror those of endovascular treatment. The proximal entry tear is closed, and the aortic wall is reconstructed at the distal anastomosis. This eradicates antegrade flow pressurizing the false lumen, improves flow to the true lumen, and preserves distal perfusion. The exposure is made via left posterolateral thoracotomy; this can be extended distally for retroperitoneal access to the distal aorta if revascularization of important branch vessels is required. No firm recommendation for cardiopulmonary bypass exists, and the decision to use it should be individualized based on the risk posed by expected cross-clamp time and surgeon preference. The portion of aorta reconstructed should be kept to a minimum, as the incidence of devastating neurologic complications due to spinal cord ischemia is directly related to the extent of aortic resection [27]. The most common location for the entry tear is just distal to the origin of the left subclavian artery, often necessitating cross-clamping between the subclavian and left common carotid arteries. The dissected aortic wall is invariably quite friable and should be reinforced with polytetrafluoroethylene

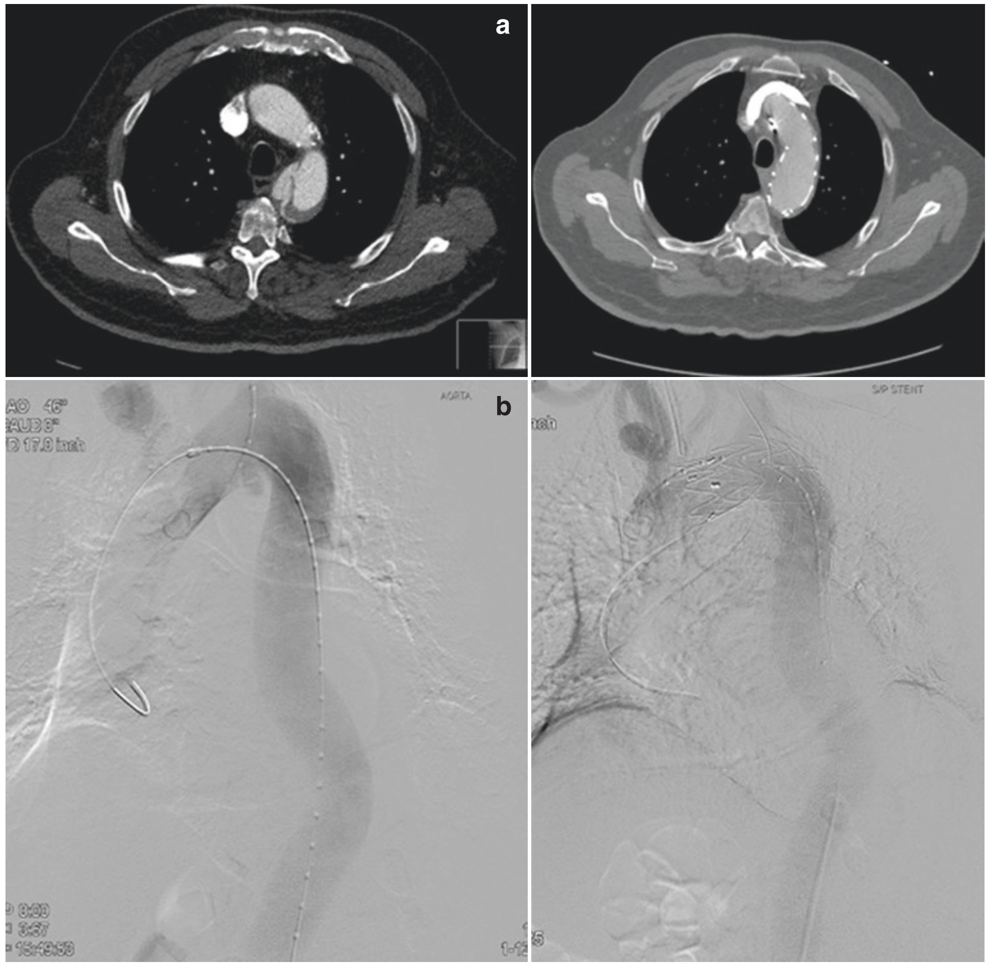

Fig. 19.7 (**a**) Type B dissection with entry tear just distal to left subclavian artery origin before and after stent graft coverage. (**b**) Intraoperative angiogram with stent graft deployment over entry tear

felt or glue aortoplasty prior to reconstruction with a woven polyester graft. The false lumen is closed by reapproximating the aortic wall and incorporating it into the distal anastomosis [28]. If proximal reconstruction does not correct downstream malperfusion, the procedure may include exposure of the distal aorta as described above. The aortic clamp is moved distally to the supraceliac position, and control of the major branches is obtained as in open thoracoabdominal aneurysm repair. The visceral aorta is opened via longitudinal aortotomy, and the intraluminal septum is divided; this fenestrates the dissection plane and usually restores blood flow to aortic branches compromised by the false lumen. However, direct revascularization of the threatened organs and/or distal aortic reconstruction may be necessary.

Aortoiliac Occlusive Disease

Background

Patients with aortoiliac occlusive disease (AIOD) represent a group of patients with peripheral vascular disease whose disease typically concentrates in the infrarenal aorta, iliac arteries, and femoral arteries. There is a trend toward endovascular-first treatments for these patients, as well as a multitude of hybrid repairs (Fig. 19.8). While selecting treatments for AIOD, patient factors such as medical comorbidities, age, life expectancy, previous abdominal surgeries, acute versus chronic presentation, and the patient's preference come into play. The extent of this typical multilevel disease directs the treatment as well. In either case, the operator needs to have expertise in both open and endovascular techniques.

AIOD initially manifests with intermittent claudication, with symptoms involving the thigh, buttock, and calf muscles. Male patients may also complain of erectile dysfunction due to inadequate perfusion of the internal pudendal arteries. Leriche syndrome classically manifests with the triad of claudication of thigh and buttock muscles, impotence, and limb claudication in the absence of femoral pulses [29]. AIOD may progress to rest pain or limb gangrene typically when combined with multilevel disease of the femoropopliteal system. Risk factors for AIOD are the same for general atherosclerosis, including smoking, hypertension, hyperlipidemia, and diabetes [30, 31].

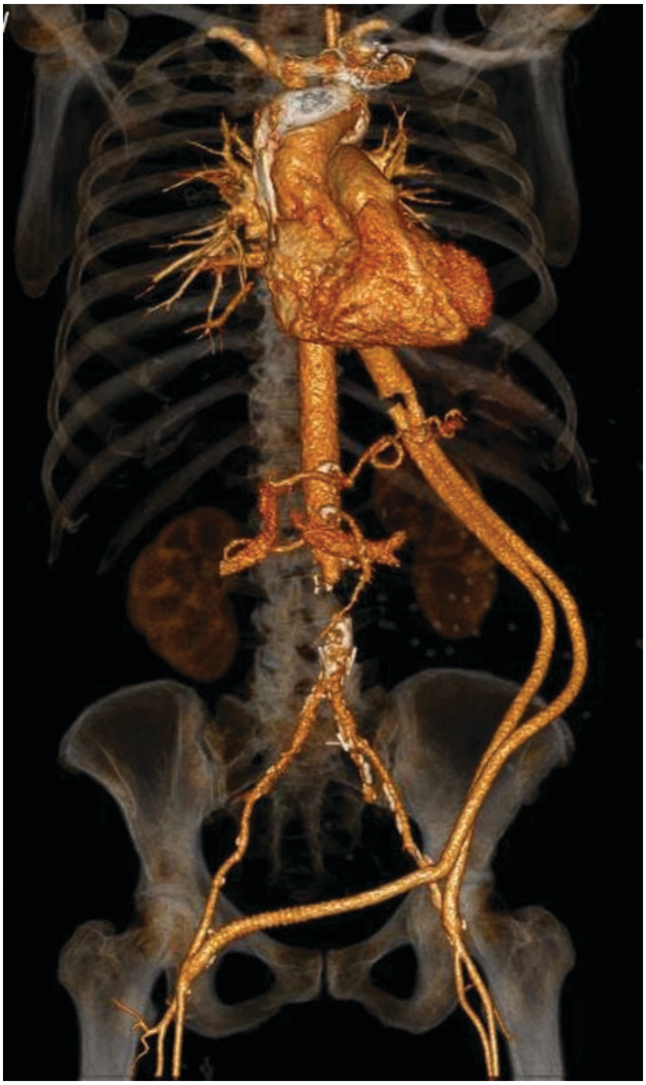

Fig. 19.8 Thoracobifemoral bypass after failure of bilateral iliac artery stents, aortobiiliac bypass for occlusive disease

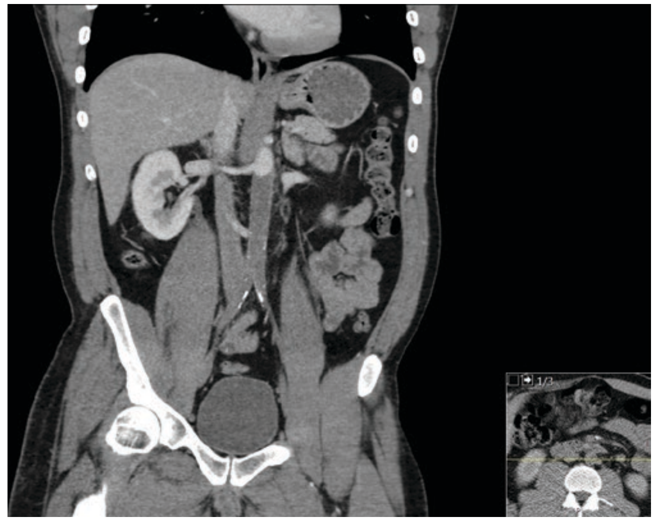

Fig. 19.9 Thrombus flush with renal arteries

The most common location for aortoiliac occlusive disease is at the terminal aorta and proximal common iliac arteries. The lesions typically then progress both proximally and distally over time. Over time, the aortic disease can progress and lead to occlusion of the distal aorta, with thrombus propagation up to the level of the renal arteries (Fig. 19.9). Starrett and Stoney observed in studies that over 30% of patients with aortic occlusion will progress to renal artery thrombosis over a 5- to 10-year period. In contrast, other studies have shown the renal arteries remain patent [32, 33].

Aortobifemoral Bypass Reconstruction

Aortobifemoral bypass grafting is regarded by many as the gold standard for the surgical management of atherosclerotic AIOD confined to infrarenal aorta and extending to the femoral artery bilaterally. This procedure is the choice for most patients who are fairly free of serious comorbidities. The procedure can be done via transabdominal or retroperitoneal approach, similar to aortic reconstruction for aneurysmal disease.

The patient is given broad-spectrum antibiotics intravenously prior to incision. General anesthesia is utilized, and patients should have arterial line for continuous blood pressure monitoring, Foley catheter, and either large-bore IV access or central line access. Operative field extends from the xyphoid process to the bilateral knees.

The infrarenal abdominal aorta is exposed by either transabdominal or retroperitoneal approach. The advantages of both approaches mirror those described previously for abdominal aortic aneurysm repair. The patent pararenal aorta is dissected out and typically Silastic vessel loops placed around the renal artery origins if a suprarenal clamp is to be placed. This is determined by the level of AIOD in the infrarenal aorta. Dissection around the aorta at the planned proximal clamp site is undertaken with sharp and blunt finger dissection to the level of the anterior spine to ensure circumferential dissection. The aorta is also felt at this level to determine the level of calcification to ensure an adequate clamp, as a circumferentially calcified aorta may be impossible to clamp and require intraluminal balloon control or a more proximal clamp. The IMA is identified and encircled with vessel loop for either ligation or reimplantation. The distal clamp site may be either bilateral common iliac arteries or the distal aorta.

Bilateral groin incisions are made to expose the femoral vessels. Incisions can be oblique and 1 cm above the inguinal crease or vertical, depending on the condition and extent of disease of the femoral vessels. Crossing lymphatics and veins are clipped or suture ligated and divided to minimize any possible hematoma or lymphatic leak, which risks a postoperative graft infection. The common femoral artery is circumferentially dissected out at the level of the inguinal ligament, and the inguinal ligament can be partially divided at its posterior attachments to ensure no kinking of the graft in the tunnel. Crossing veins under the inguinal ligament are ligated and divided. Dissection is carried distally to beyond the femoral artery bifurcation, and superficial and deep femoral artery branches are encircled with silastic vessel loops. If preoperative imaging has shown superficial femoral artery (SFA) occlusion or significant profunda femoral artery (PFA) disease, the dissection is carried another 2–3 cm further along the PFA to ensure adequate distal endpoint for the graft. This typically involves ligation of the first branch of the profunda femoral vein to allow for further dissection.

Prior to systemic heparinization, the retroperitoneal tunnels between the aortic and femoral fields are created. The tunnels are made with blunt dissection, and a long instrument can be utilized with care as well. The tunnel should lie in the avascular plane directly anterior to the iliac vessels and posterior to the ureter. Umbilical tape, Foley catheter, or vessel loop is left in the tunnel for later passage of the graft.

The aorta is clamped proximally either above the level of the renal arteries or just below, depending on the extent of thrombus and disease. In the event of pararenal thrombus, the vessel loops around renal arteries are pulled up prior to clamping to avoid thrombus propagation into the renal arteries. Once offending pararenal thrombus is cleaned out, the proximal clamp can be moved to infrarenal location to avoid prolonged renal ischemia time.

Proximally, the bypass can be done in an end-to-side or end-to-end fashion. The end-to-end style is preferred by many surgeons as it has several advantages. There is no competitive flow through the native aortoiliac system, and in theory, it has more superior hemodynamics. Less turbulent flow results in less development of clot or atheroma and eventual graft thrombosis [34]. In addition, an end-to-end anastomosis lies flat in the native vessel configuration, with less impingement on the retroperitoneal covering, reducing the chance of a devastating graft-enteric fistula.

The end-to-side anastomosis does have advantage in certain anatomic configurations, primarily with the interest in maintaining pelvic flow through a large inferior mesenteric artery or maintaining flow to the hypogastric arteries in patients with external iliac artery occlusive disease. In these patients, retrograde flow is impossible through the external iliac arteries, and thus, with an end-to-end configuration, they are more at risk for colonic ischemia, impotence in males, and even neurological compromise [34].

Regardless of the proximal anastomosis type, the proximal aorta is transected (end-to-end) or arteriotomy made (end-to-side) after the proximal aorta is cross-clamped. If the distal aorta is patent or common iliac arteries are patent, distal clamps will be utilized to prevent back bleeding prior to proximal aortic clamping. If a suprarenal clamp is placed and there is pararenal thrombus, the renal arteries are controlled with silastic vessel loops to avoid thrombus propagation with clamping. The aorta is cleaned out and thrombus removed with large forceps and irrigated copiously with heparinized saline. Once clear of thrombus, the clamp can then be moved to infrarenal location. The proximal graft is then beveled to match the transected aorta or arteriotomy and anastomosed in standard fashion. If the quality of the aorta requires extensive endarterectomy, felt pledget cuff may be incorporated. In order to perform the end-to-end anastomosis, a small amount of the diseased aorta is excised to allow room for the new graft to lie. In addition, the distal aorta is typically endarterectomized in a limited fashion to allow for oversewing of this region.

One graft limb is then controlled with vascular clamp and heparinized saline flushed through the other limb to test the anastomosis. Once hemostatic, this limb is clamped as well and proximal aortic clamp released. In an infrarenal clamp location, at this point, there should be little to no change in hemodynamics of the patient. Systolic blood pressure is monitored to avoid hypertension and avoid tension on the fresh anastomosis.

The limbs of the graft are then pulled fully distended through the previously created retroperitoneal tunnels to each groin. One technique commonly utilized is to lift the previously placed umbilical tape and utilize it to guide a long, blunt-tipped aortic clamp to pass the graft through the tunnel, thus minimizing trauma or inadvertent injury to surrounding structures. Care is taken to confirm the graft lies nicely under the inguinal ligament, without any external compression.

The femoral anastomosis location depends on the condition of the outflow vessel branches. In the event of common femoral or profundae disease, local endarterectomy with tacking suture of distal endpoints is crucial. If the superficial femoral artery and profunda are both patent on preoperative imaging, the distal anastomosis can be a standard beveled anastomosis on the common femoral artery. In the event of SFA disease or occlusion, it is recommended to perform profundaplasty with hood of the distal graft onto the PFA to ensure long-term patency. Profundaplasty can be achieved with vein patch angioplasty, or with the hood of the graft itself. After distal anastomoses are completed and hemostasis obtained, the retroperitoneum is closed over the graft and all incisions closed in multilayered fashion (Fig. 19.10).

Excellent early and late term results of aortobifemoral bypasses are noted in several large series. With a carefully chosen patient population for these surgeries, the graft patency at 5 years is estimated at 85–90% and 70–75% at 10 years [35]. Perioperative mortality at tertiary care facilities is single digits at well under 5%. In addition, it should be noted that patients with focal distal aortoiliac atherosclerotic disease are expected to be lower than that of patients with more multilevel disease, thought to be due to concomitant

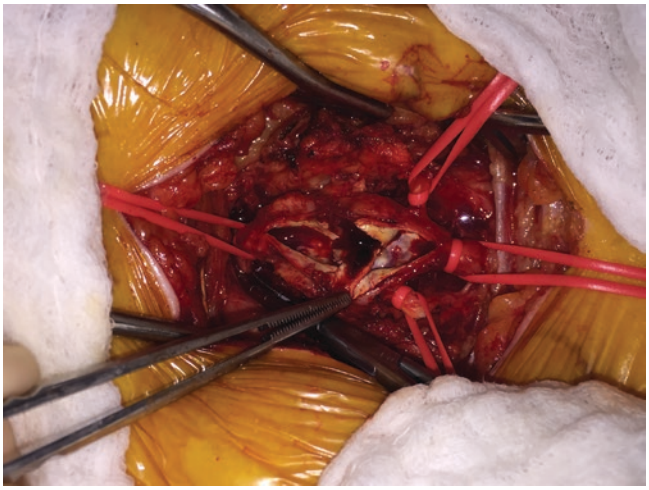

Fig. 19.10 Femoral dissection showing diseased common femoral artery requiring endarterectomy prior to distal anastomosis. The hood of the graft can be used for patch angioplasty

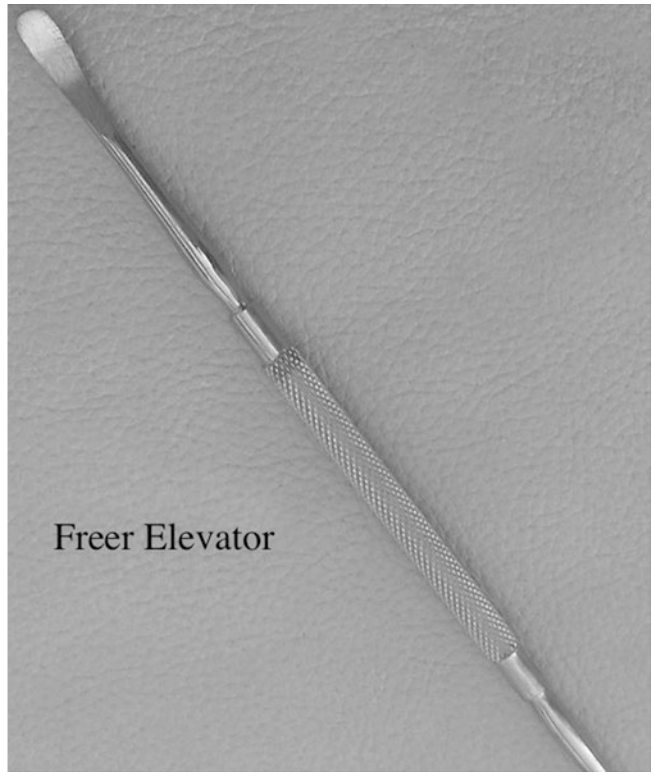

Fig. 19.11 Freer Elevator device utilized for arterial endarterectomy

coronary and visceral occlusive disease. Sadly, graft patency exceeds life expectancy in this population on average, with a mortality rate of 35–40% at 5 years and 50–60% at 10 years postoperatively, the majority thought to be from occlusive coronary disease [35].

Aortoiliac Endarterectomy

Open aortoiliac endarterectomy was historically utilized in patients who now would undergo an aortobifemoral bypass. Wylie performed the first successful procedure in the USA in 1951 [36]. This procedure is still utilized for patients whose disease is confined to the distal abdominal aorta and common iliac vessels. An advantage to this procedure over traditional aortobiiliac or aortobifemoral bypass is that it does not involve synthetic material and thus is not at risk for graft infection. For similar reasons, it is more advantageous in an infected operative field. The procedure should not be utilized in the presence of an aneurysmal aorta.

The patient is supine, and exposure is obtained via the standard midline abdominal incision. Transverse colon is reflected upward and the bowel mobilized to the patient's right. Retroperitoneal space is entered over the aorta and incision carried down along the bilateral iliac arteries. Care is taken to avoid the nerves overlying the left common iliac artery. The infrarenal aorta is carefully dissected out in the avascular plane, as well as lumbar branches and the inferior mesenteric artery origin. The origin of the hypogastric arteries is typically encircled with vessel loop, and external iliac arteries are dissected free for clamping. After heparinization, vascular clamps are placed on the external iliac arteries and infrarenal aorta. The lumbar arteries, IMA, and hypogastric arteries are controlled for back bleeding. The aorta is incised longitudinally down to the level of the aortic bifurcation. Standard endarterectomy is then performed by identifying the disease and deep media plane. Aortic wall is pushed away from disease to further the dissection plane along. Proximally, the diseased intima is transected to endpoint, and tacking sutures may be utilized. More important is the distal endpoint. A small transverse incision is made in bilateral common iliac arteries just proximal to the bifurcation of the iliac artery. The diseased intima is transected, and deep medial plane is extended proximally utilizing Freer elevator or Beaver blade until the specimen is completely mobilized and can be removed (Fig. 19.11). Tacking sutures are utilized to stabilize the distal plaque endpoint to avoid dissection. Disease at the origin of the hypogastric artery can be removed with eversion endarterectomy. The arteriotomies are copiously irrigated to ensure no remaining debris, iliac arteries back bled, and the aorta forward-flushed, and the aortotomy is typically closed with running prolene suture and iliac arteriotomy closed with interrupted sutures. Typically, the hypogastric artery is flushed forward first, so that any clamp debris can be directed toward the pelvis instead of the legs via the external iliac arteries.

The 5-year patency rates after aortoiliac endarterectomy approach 90% in literature [37]. Aneurysmal degeneration of the aorta, although a concern with the deep medial endarter-

Fig. 19.12 3D reconstruction of patient with left axillofemoral bypass

ectomy plane, has not been seen during long-term follow-up, and if recurrent stenosis or occlusion occurs, this can be managed by the other techniques described above.

Axillofemoral Reconstruction

In patients whose comorbidities make them a poor candidate for anatomic reconstruction, extra-anatomic bypass may be the only option. This is typically done by axillofemoral reconstruction, which was first utilized in the 1960s for patients with high cardiopulmonary risk for aortic reconstruction [38, 39]. Preoperatively, blood pressure measurements with demonstration of triphasic Doppler waveform in the brachial artery confirm the absence of disease in the subclavian or axillary artery.

The operation is performed with the patient supine under general anesthesia. The donor arm is typically abducted to some degree. The donor axillary artery is exposed utilizing a transverse incision typically two finger widths below the middle of the clavicle, and the pectoralis major muscles are split and deep fascia divided. Crossing veins and lymphatics are ligated, and care is taken to avoid the adjacent brachial plexus and vein. Control of the axillary artery is obtained. The proximal graft anastomosis is medial to the pectoralis minor muscles, and care is taken to leave enough laxity on the graft with a gentle curve to avoid the dangerous complication of axillary pullout syndrome, which occurs when abduction of the arm results in disruption of the proximal anastomosis. The tunnel between axillary artery and femoral artery should be as close to the fascia as possible and anterior to the anterior superior iliac spine to avoid graft compression. Proximally, the graft can be tunneled anterior to the pectoralis minor or posteriorly. A counter incision can be utilized to assist with tunneling. Typically, a graft of 6–8 mm diameter is utilized, depending on inflow artery size.

The femoral dissection and anastomosis are similar to that for aortofemoral reconstruction. A bifurcated graft can be utilized from the axillary artery to bilateral femoral arteries, or a single axillary artery to ipsilateral femoral artery bypass is performed, with a femoral-femoral bypass then performed with the anastomosis between the distal end of the axillofemoral bypass to the contralateral femoral artery (Fig. 19.12).

Axillobifemoral bypass is associated with approximately 50% 5-year primary patency and 75% secondary patency. 30-day mortality for the procedure in patients with occlusive disease was 10%, significantly higher than aortobifemoral reconstruction. Patency is also significantly lower, with studies showing primary patency at 1, 3, and 5 years was 68%, 53% and 53%, while secondary patency at the same intervals was 83%, 73%, and 73%. Survival at 5 years was 70%, and limb salvage rates approach 96% [40].

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