Open Retroperitoneal Repair for Standard and Complex Abdominal Aortic Aneurysms

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Abstract:

Abdominal Aortic Aneurysm (AAA) management is a critical portion of vascular surgery, with Endovascular Aortic Repair (EVAR) replacing Open Aortic Repair (OAR) as the standard of care due to decreased mortality and morbidity. However, OAR remains essential for cases that are unsuitable for EVAR. The retroperitoneal (RP) approach, introduced in the 1960s, offers unique advantages, particularly extended access to suprarenal segments. Despite comparable outcomes with the transperitoneal (TP) approach, RP's usage is declining. This paper delineates RP technique details, particularly on anatomical considerations, as these are crucial in the complex RP approach. Surgical preparation and outcomes are also highlighted. RP shows promise in complex AAAs, offering lower mortality and complication rates. Sustaining RP's legacy amid evolving endovascular techniques is vital, advocating for comprehensive training in vascular surgery programs.

INTRODUCTION

The management of Abdominal Aortic Aneurysm (AAA) constitutes a significant part of contemporary vascular surgery practice, as it is a relatively common disorder, affecting up to 8% of the population in Western countries[1]. AAA refers to an enlargement of the abdominal aorta more than 1,5 times the diameter of the aorta before the enlargement, and elective treatment is usually considered at a diameter of 5.5cm. Untreated AAAs are likely to increase in size and rupture, eventually causing massive internal bleeding, a severe complication, giving an 80% overall mortality rate. Since the development of endovascular techniques in the 1990s, the standard of care has shifted from Open Aortic Repair (OAR) to Endovascular Aortic Repair (EVAR), mainly due to decreased perioperative mortality and morbidity. However, limitations like anatomic constrictions for EVAR, the need for continuous radiologic surveillance, and the increased risk of reinterventions after endovascular procedures preserve the need for OAR, which, with proven long-term benefits and decreased aneurysm-related mortality[2], remains an essential tool for the treatment of AAAs. Specifically, unfavorable anatomy for EVAR or FEVAR, visceral and iliac vessel variants and occlusive disease, prolonged life expectancy, known connective tissue disorder, open conversion due to endoleak with no endovascular solutions, and inflammatory or infectious AAA are considered indications for OAR, in today's "EVAR era".

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Since the first attempts at aortic repair in the 1950s, two techniques of abdominal aortic approach have developed and been widely used, the transperitoneal (TP) and the retroperitoneal (RP) approach, which Rob first best described in 1963[3]. In 1980, Williams reported an extended RP approach. He claimed that this approach offers better exposure not only of the infrarenal aorta but also of the pararenal and suprarenal aorta[4]. Despite multiple published studies comparing the two techniques, neither has proven to have significantly more advantages, and both have been employed by vascular surgeons with acceptable results. Both approaches are currently used, and the choice between them is based on anatomic criteria and surgeons' experience and preferences. However, there is a tendency indicating that the TP approach is more widely adopted, especially for infrarenal AAAs, as it is considered technically less challenging and more surgeon-friendly, and the number of surgeons using the RP approach is declining[5].

TECHNIQUE

Equipment

In retroperitoneal access to the abdominal aorta, the collaboration of an experienced anesthesiologist and proper surgical preparation plays a crucial role. It is essential for the surgery the use a cell saver machine and continuous arterial blood pressure monitoring. The patient's position on the operating table is secured with a specialized sandbag (surgical bean bag stabilizer). An hourly measuring urinary catheter for accurate urine measurement is necessary for all patients, especially in cases requiring aortic clamping above the kidneys. The use of an abdominal self-retractor like the Omintract™ Retractor, although not obligatory, is found useful most of the times.

CT assessment

Reviewing the patient's CT scan images is vital and should be performed before the operating procedure. We tend to review the aortic CT scan inside the operating theatre before the case, all the members of the surgical team. The morphology of the aneurysm, the relationship of the visceral vessels' origins with it, and the theoretical positions of aortic occlusion are assessed. The position of the lower renal artery's location is crucial in cases of infrarenal occlusion, as well as the position of the inferior mesenteric artery. Also, the position of the left renal vein is noted. On a retroperitoneal approach, the left renal vein, which usually lies anteriorly to the abdominal aorta, will be in a posterior position, making the vessel prone to injury from the aortic clamp on an infrarenal proximal clamping. On the contrary, a retro-aortic left renal vein will be in front of the aorta in the retroperitoneal approach (Figure 3). Preoperative assessment of atherosclerosis and intraluminal thrombus is critical for managing the aorta and clamping areas concerning visceral vessels, renal arteries, and iliac arteries. The general rules for proximal aortic clamping are the following: aortic areas free of thrombus, calcium, or extensive atherosclerosis; absence of any venous structure (i.e., left renal vein) that the aortic clamp could injure; clamping above the aneurysm sac, on the lowest possible level, on healthy aortic tissue. The usual levels of aortic cross-clamping during a retroperitoneal approach are either below the renal veins or above the celiac artery. Clamping above one or two renal arteries is possible. However, the surgeon needs to ensure adequate space from the orifice of the superior mesenteric artery, which usually lies posteriorly and is not visible. Before getting into the patient, a brief review of the procedure plan is done with all the members, including anesthetists and scrub nurses.

Position of patient

The position involves placing the patient on the surgical table above the surgical bean bag stabilizer. The patient lies supine on the bean bag, and peripheral venous lines, a central venous line, and an arterial line are placed. The anesthesiologist proceeds with anesthesia, intubation, and urinary catheter placement. The patient is then moved on the table so that the lumbar region of the spinal column aligns with the potential bending point of the surgical table. The patient is rotated with the right side of the torso towards the ground and the left side away, tilting the upper part of the body to approach 70-90 degrees while the pelvis approaches 30-45 degrees. The right leg is bent at the knee and placed under the straight left leg, with a pillow between them. The extended and externally rotated left upper extremity is placed on a specialized support in front of the patient's head. The operating table is then extended onto the flank area, with the patient in a reverse jack-knife position to increase the exposure on the proximal aorta (Figure 1). Connecting the bean bag stabilizer to the suction machine removes air, stabilizing the patient in the right position. The exposed body areas include the thorax from the midline of the scapula to the anterior thoracic wall and the entire abdomen. In this position, access to the right common iliac is limited, so the pelvic position is sometimes modified for better access to the right inguinal crease.

Patient preparation

The antisepsis is performed after placing the patient in a lateral position and completing patient care and shaving. We typically use a povidone-iodine solution for three washing layers and then repeat the process with chlorhexidine solution for the last layer. Antisepsis covers the entire exposed thorax, abdomen, femoral folds, and the thigh down to the lower third.

Surgeons' positions

The primary surgeon usually stands posteriorly to the patient, on the patient's left side, with one or two assistant surgeons anterior, on the patient's right. By standing on the patient's left side, the surgeon has a better position towards the aorta, especially regarding its proximal or subdiaphragmatic portion. The self-retained abdominal retractor (Omnitract™ Retractor) is anchored securely on the operating table on the right-hand side of the surgeon, leaving minimal space for a fourth assistant.

Incision and approach to the retroperitoneal space

The skin incision begins from the posterior axillary line between the 11th and the 12th ribs (11th intercostal space). An incision between the 10th and the 11th ribs (10th intercostal space) can be used for a higher exposure of the proximal aor-

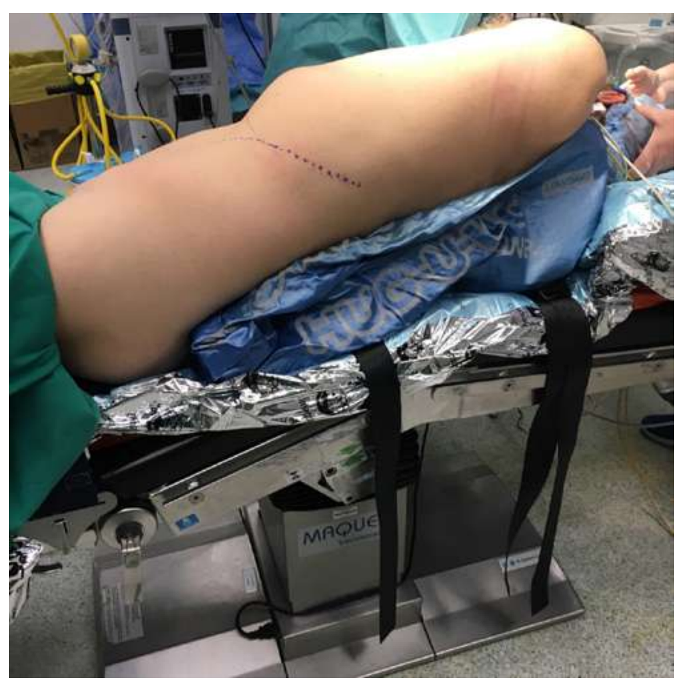

Figure 1: The patient is in the lateral position, and the operating table has been extended so that the patient is in a reverse jack-knife position. The bean bag (blue color) has been sucked around the patient's torso keeping the body stable in the desired position.

Figure 2: The incision is performed from the posterior axillary line of the eleventh intercostal space to the lateral border of the rectus abdominis muscle at the level of the umbilicus or a little lower.

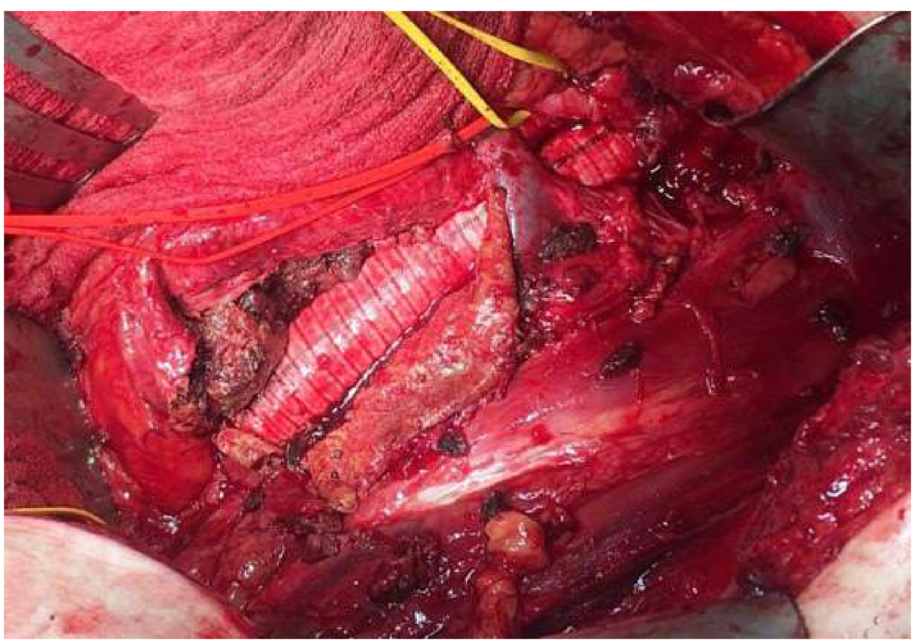

Figure 3: A retro-aortic left renal vein on a posterior repair for a juxtarenal abdominal aortic aneurysm. The graft was positioned underneath the left renal vein after adequately mobilizing.

ta. The skin incision is extended anteriorly up to the sheath of the left rectus abdominis muscle at about the umbilicus level or a bit inferiorly (Figure 2). If an extended exposure on the right-side iliac vessels is anticipated, an almost vertical incision along the lateral border of this sheath is followed. The incision's posterior extension depends on the aneurysm's proximal extension and the anticipated level of proximal aortic clamping. As a general rule, the higher on the aorta, the more posterior on the skin incision.

The subcutaneous tissue is divided using the diathermy, and the external abdominal oblique muscle is identified. The aponeurosis and muscle fibers are divided with diathermy. Similarly, the internal abdominal oblique and transverse abdominal muscles underneath are divided using the diathermy. Care should be taken to avoid opening the peritoneum and entering into the peritoneal cavity, which is more likely to happen on the anterior part of the incision. To avoid this, a good habit is to divide the muscle fibers after the assistant raises some of them using a pair of forceps. The transverse aponeurosis lies underneath the transverse abdominis muscle but is usually challenging to recognize and separate.

Entering the retroperitoneal space is safer and easier in the posterior part of the incision. A fat pad is usually found there after all the muscles have been divided. This fat is a part of the perirenal fat, and this indicates that the retroperitoneal space is there. The surgeon can use his/her fingers to enter this space safely and then to make some space anteriorly towards the anterior part of the incision. The peritoneum can safely be pushed anteriorly away from the retroperitoneal space with careful blunt dissection. If the peritoneum is accidentally torn, it should be sutured and closed using an absorbable suture. Left untreated, the small intestine usually enters the retroperitoneal space, making the whole procedure more difficult. Special care should be taken when pushing the peritoneal cavity anteriorly on the area of the spleen. Although the closed peritoneal cavity protects the spleen, it may be traumatized by applying forced pressure on its surface with either surgeons' hands or instruments. Finally, at this stage, it is essential to free the anterior part of the incised aponeurosis from the underlying peritoneum as much as possible to facilitate the wound closure at the end of the procedure. This is done by blunt finger dissection by the surgeon or the assistant.

During the incision, especially in the 10^{th} intercostal space, there may be a possibility of entering the left pleural cavity due to traction, which should be addressed at the end of the surgery. Sometimes, during the placement of a retractor in the incision, a fracture of the tip of the eleventh rib may occur.

Exposure of the aorta and its branches

After entering the retroperitoneal space, the dissection plane is anterior to the left psoas muscle and posterior to the left kidney (Figure 5). Using the palm, the surgeon rotates the left kidney to the right side, where the assistant controls it. The left ureter is not usually a problem as it comes away from the aorta when the left kidney has been rotated to the right. Nevertheless, it is essential to recognize it to avoid incidental trauma, either during the dissection or when placing the retractors and iliac clamps.

In the case of an infrarenal aortic aneurysm, one can stay below the left kidney. In this situation, the kidney does not need to be rotated to the patient's right side and remains in its position. Similarly, the ureter remains in its position on the left side of the aorta. Nevertheless, this is rarely the case in a retroperitoneal approach, as moving posteriorly to the kidney gives access to all the suprarenal aorta up to the diaphragm.

After the left kidney has been rotated to the patient's right, the surgeon can see and touch the abdominal aorta up to the diaphragm. Of course, it is still covered by adipose tissue and muscle fibers of the diaphragm crus, structures that need to be divided to obtain a clear view of the vessel. At this stage, the surgeon's first step is identifying the left renal artery. This is a necessary part of the procedure. A structure that can assist is the lumbar branch of the left renal vein (ascending lumbar vein), which runs to the left of the aorta and crosses it at about the level of the left renal artery (Figure 4). The left renal vein's lumbar branch is considered the gateway to the aorta when retroperitoneally, and it needs to be ligated and divided to obtain free access to the aorta.

The left renal artery moves upward towards the anteriorly retracted left kidney (Figure 6). After it is found, it should be freed by the surrounding adipose tissue and controlled with a silastic loop. Controlling the artery may be useful for instant identification of the artery if needed and for clamping it easily and quickly if necessary. In cases where an infrarenal aortic clamping is not an option, as in juxta-renal and pararenal aneurysms, the target of the aortic dissection is usually the supraceliac aorta. The aorta can be palpated below the diaphragm where the left and right crus of the diaphragm cover it. These muscles need to be divided to reveal the aorta. We prefer to use a simple pair of Metzenbaum scissors and selectively coagulate any bleeding points with the diathermy. Alternatively, using diathermy to cut the muscle fibers piece-by-piece is an option, but we think this carries a higher risk of burn injury on the aorta itself. After the crus has been divided, the white glossy surface of the supraceliac aorta is seen. With the index finger, the surgeon can bluntly create space around the aorta to be ready to accept the proximal aortic clamp. After the proximal aorta has been achieved, the preparation of

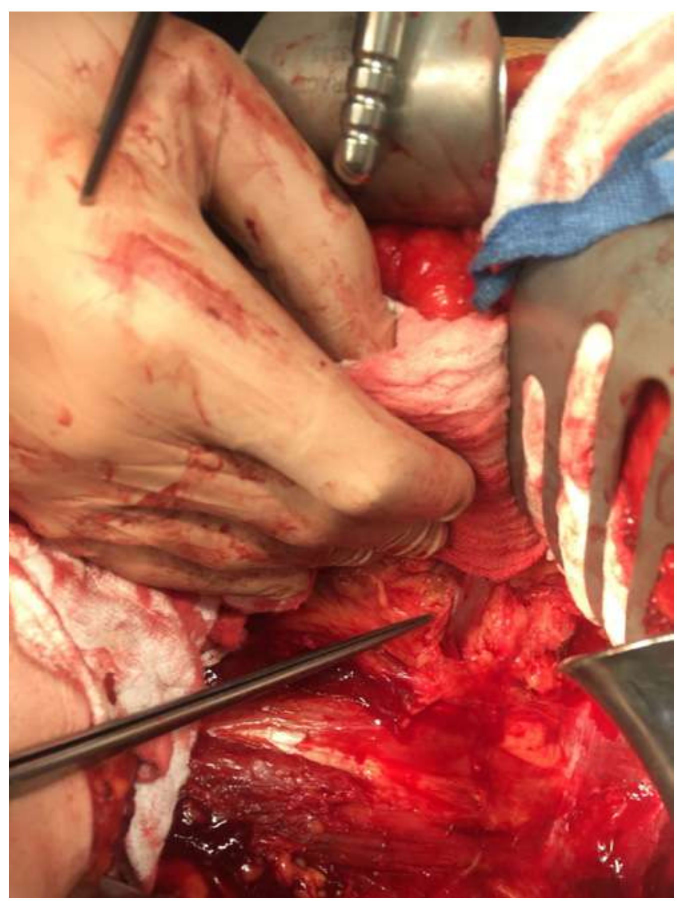

Figure 4: After entering the retroperitoneal space, the ascending lumbar vein is recognized in front of the aorta. The vein must be divided to expose the aorta.

Figure 5: The psoas muscle is the guiding landing mark of the aorta. The aorta lies just medially (on the right side) to the psoas muscle.

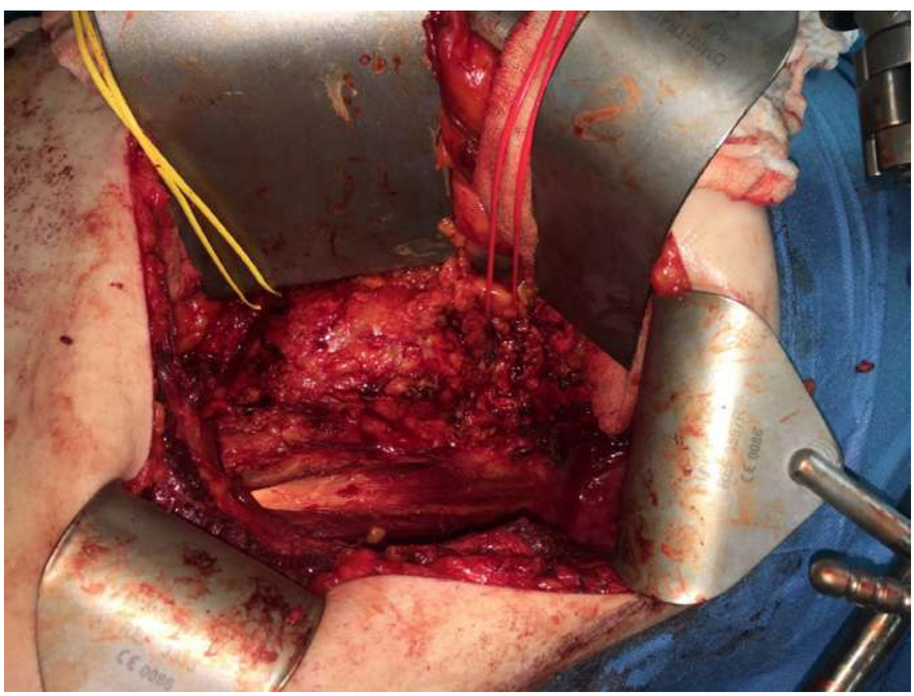

Figure 6: The left renal artery needs to be recognized and controlled with an elastic sling (red color)

the aorta continues distally towards the common iliac arteries in cases of tube graft or distally the iliac arteries bifurcations in the case of a bifurcated graft.

It is essential to understand that the right renal artery is not visible from this exposure as it lies on the posterior side of the aorta. The superior mesenteric artery and the celiac axis are also not always easily visible. Nevertheless, these two vessels can be found if it is considered necessary. It is important to note that the initial part of both vessels is surrounded by thick neural plexus fibers of the sympathetic chain that are sometimes difficult to dissect. If it is challenging to dissect around them using the standard way of sharp dissection with forceps and scissors, a laparoscopic dissection hook with diathermy can be used.

Next, the distal aortic neck must be identified. Sometimes, this can be a part of the infrarenal aorta if this part is disease-free, but most of the times, it is the two common iliac arteries. The left external and common iliac artery are easily found as the patient lies on his right. On the contrary, finding the right common iliac artery is complex and requires manual traction of the aneurysm towards the patient's left. This aneurysm rotation to the left can sometimes be facilitated by dividing the inferior mesenteric artery on the anterior part of the abdominal aorta. However, we prefer to avoid it unless necessary.

Aortic repair

Once satisfied with the preparation of the clamping areas, we proceed with heparinization, aiming for an activated clotting time (ACT) of 200-300 seconds. A dosage of heparin 80 IU/kg is usually enough. It is crucial to remember that the heparin half-life time is about 2 hours, meaning that if the aorta occlusion time extends more than 2-3 hours, an extra administration of about half the initial dose of heparin is necessary to avoid thrombotic events.

The aorta is clamped proximally at the desired level, either infrarenal or supraceliac, depending on the anatomy of the aorta, the proximal extension of the aortic aneurysm, and the condition of the proximal neck. Similarly, either the distal aorta (if it is of average diameter) or, more commonly, the iliac arteries are cross-clamped. In cases where there is severe calcification or thrombus in the common iliac arteries, a Folley urine catheter can be used for intraluminal temporary occlusion of the common iliac arteries after opening the aorta to minimize the risk of plaque rupture or distal embolization. Inflation of the urinary catheter balloon with 2-3 ml of normal saline is usually adequate to stop the back bleeding from the iliac arteries.

Next, the aorta is opened, and its repair is done accordingly. It is essential to highlight that as long as the left renal artery is now anteriorly, due to the left retroperitoneal approach, the aortotomy is performed posteriorly to the left renal artery. Thus, an extension of the aortic incision of the aorta on a suprarenal level is feasible. In cases of suprarenal occlusion, the time of splanchnic ischemia is crucial. For this reason, we must be well-prepared and have all the materials and tools ready to avoid wasting precious time. Initially, we ensure the best possible circulation occlusion, then quickly suture the lumbar arteries and proceed to the central anastomosis. In a juxtarenal aneurysm, the graft is sewn just under the renal arteries. However, in pararenal or suprarenal aneurysms, the aortotomy is extended above the level of renal arteries, often up to the level of the celiac axis, and a beveled anastomosis, usually involving the right renal artery, the upper mesenteric artery, and the celiac artery, is done on an end-to-end fashion. Then, after transferring the aortic clamp at an infrarenal level thus allowing blood flow to the liver, small bowel, and the left kidney, we anastomose the left renal artery to graft using the Carel Patch technique. Occasionally, when direct implantation of the left renal artery to the graft is not possible, a PTFE 6 mm graft can connect the aortic graft to the left renal artery, usually on a lazy-C configuration. In this situation, it is necessary to complete the left renal artery anastomosis as quickly as possible to reduce the left kidney's acute renal tubular necrosis. An overall warm ischemia time of approximately 30 minutes is well tolerated, whereas more extended periods of renal ischemia may lead to some degree of postoperative renal dysfunction. Intra-arterial infusion of various cold solutions into the left kidney has been proposed in the literature. However, there is always the risk of dissecting the fragile endothelium of the left renal artery with the inserting catheter, thus leading to acute renal artery occlusion. Generally, in our practice, we tend not to infuse any solution into the left renal artery and try to complete the anastomoses as quickly as possible.

The distal anastomosis can be done either at the aortic bifurcation using a tube graft, or at the iliac bifurcations or even at the femoral arteries using a bifurcated graft. In case of a bifurcated graft, we tend to perform first the right iliac axis anastomosis as this is the most technically demanding. Using a parachute technique has been found to be helpful in these cases. The anastomosis on the left iliac axis is the easiest, as the left iliac arteries lie quite superficially due to the right position of the patient on the operating table.

Completion of the procedure and wound closure

Hemostasis in the retroperitoneal incision is crucial because the retroperitoneal cavity is a dead space that can accumulate significant blood in case of multiple micro-bleedings. Ligation of bleeding branches and coagulation of the retroperitoneal wall should be performed in case of minor bleeding, always avoiding damage to the left ureter.

The closure of the abdominal wall involves two layers of suturing. The transverse and internal oblique abdominal muscles are sutured in the first layer, involving the reattachment of the internal oblique muscle fascia with a synthetic monofilament loop No 1 suture. The external oblique muscle reattachment in the second layer is performed similarly with the same suture. An important detail is to suture the diaphragm in case of an inadvertent entry into the pleural cavity during the incision opening or by the self-retaining retractor. During closure, it greatly helps to prevent tissue tearing if the extended operating table on a reverse jack-knife position is returned to its neutral leveled position or better tilted the upper part of the operating table anteriorly at an approximately 30-degree angle.

Depending on their hemodynamic status, patientst can be transferred to the Intensive Care Unit or the ward after a 3-4 hour stay in the recovery room.

Retroperitoneal approach in modern practice

Retroperitoneal exposure of the abdominal aorta, although initially an uncommon and unfamiliar approach for most vascular surgeons, once mastered, does provide benefits for both anatomic and postoperative physiologic reasons.

Anatomic considerations

The retroperitoneal approach allows extended access to the suprarenal and supraceliac aortic segment, as the abdominal aorta can be exposed from the diaphragmatic hiatus down to its bifurcation without breaching the peritoneal cavity. It is considered the best option for cases of hostile abdomen due to prior abdominal surgery, obese patients, patients suffering from COPD, inflammatory aneurysms, or aneurysms associated with a horseshoe kidney. In addition, a retro-aortic left renal vein may be handled better when approaching the aorta retroperitoneally. However, access to the right renal artery, beyond its orifice, and to the right iliac vessels, is usually limited. Also, it is more time-consuming and requires a more involved positioning process; therefore, it is not preferable for emergency cases[6]. Aortic repair with a bifurcated aortobifemoral graft, for e.g. concomitant iliac aneurismal or occlusive disease, is considered challenging, as access to the right femoral artery may be blocked due to the patient's position. However, it can be technically feasible when proceeding with care and attention. From a functional point of view, as long as the peritoneal cavity is not entered, the duration of postoperative paralytic ileus is less than with a transperitoneal approach.

Postoperative results

Few Randomized Control Trials (RCTs) have been conducted to assess the effectiveness and safety of the retroperitoneal versus transperitoneal approach for elective open abdominal aortic aneurysm repair on mortality, complications, hospital stay, and blood loss. A review published in 2021, including 5 RCTs and 152 patients, concluded that the obtained results are considered low-certainty evidence[7]. Other studies have extracted data from large registries and databases comparing the outcomes of the two techniques, with mixed results.

No difference in mortality has been established between the two techniques[7]. Studies have suggested various physiological benefits following an RP approach and better short-term results. The TP approach usually involves intestinal manipulation, mesenteric traction, and blood contamination of the peritoneal cavity - all of which may lead to impaired intestinal motility[8]. Thus, the RP technique is associated with lower rates of postoperative ileus or small bowel obstruction, shorter postoperative nasogastric tube decompression times, quicker return to preoperative diet, decreased hospital stay and overall cost[7-16]. RP has also been associated with significantly lower rates of respiratory complications[10,12] and pneumonia[16], as well as decreased intubation time and intensive-care-unit stay, lower incidence of cardiac events and renal dysfunction[7,12,16-18], despite the supra-visceral aortic clamp and the need for greater fluid and vasopressor usage[19]. However, other studies have shown no difference between the two methods[10,15,20], or higher rates of pneumonia, transfusion, and reintubation for the RP group[21]. Ureteric complications are relatively uncommon (<2%) and are mostly attributed to renal tract traction injury rather than ischaemic devascularization. For the TP approach, high-risk areas for ureteric complications would be where the structure proceeds medially into the pelvis superior to the iliac artery, whereas in the RP approach, injury usually occurs in the upper third of the renal tract[22].

Mid-term to long-term results of the two techniques and statistically significant differences have not been established in the bibliography either. Small bowel obstruction is considered a relatively common mid-term complication, and a study has shown it to be of higher incidence in the TP approach[23], although other studies have shown no significant difference[24]. The RP approach through an oblique incision can result in two different complications. It could result in a true hernia and a bulge, a myofascial laxity without defects, from iatrogenic lateral abdominal wall muscle denervation. The incidence of an abdominal bulge has been reported at 10%. Therefore, no effective surgical treatment is available, and this complication is underestimated because the patients will not undergo surgery. On the contrary, transperitoneal approach hernias are more common[23,24] and more likely to demand surgical repair, causing higher rates of late reintervention and readmission when compared to RP approach[25].

Complex AAAs

Extensive literature has been reported considering the treatment of infrarenal AAAs, concluding that EVAR is the approach of choice in the majority of patients. However, juxtarenal aneurysms unsuitable for standard EVAR, and pararenal aneurysms make up 15% of all abdominal aortic aneurysms needing treatment[26]. Endovascular solutions for those complex AAAs (cAAA) include fenestrated EVAR (FEVAR), branched EVAR, or chimney-EVAR (ChEVAR). Increased usage of these techniques has led to lower perioperative morbidity and mortality[27]. However, in certain patients with anatomically complex aneurysms, open repair remains the preferred treatment choice as it may be beneficial for younger patients, patients unable to comply with long-term surveillance, or with highly unfavorable anatomy. Both RP and TP approaches have been used to treat cAAAs, and recent retrospective studies have favored the RP approach in terms of early results. RP has been the approach of choice for more advanced aneurismal disease on preoperative CT, with a larger maximum aortic diameter and more proximal aneurysm extent. However, the outcomes are comparable to those of the TP cases utilizing more distal clamping[28]. Complex AAA has been associated with higher mortality rates compared to infrarenal AAA, which might explain the demonstration of survival benefits for the RP approach. This discrepancy may reflect the relative advantages of each surgical approach concerning their exposure and the need for temporary splanchnic ischemia, which is needed in cAAAs. Keeping the proximal aortic clamp as distal as possible has been shown to benefit[29]. This might suggest that the benefit of an RP approach could be more explicit for cAAAs.

CONCLUSION

It is crucial to highlight the importance of the retroperitoneal approach as an essential and invaluable tool in the armory of vascular surgeons. Both transperitoneal and retroperitoneal techniques have been performed and evolved for decades, but modern endovascular techniques have narrowed their practice, and their indications are limited. The issue of whether either approach confers any advantage has been discussed for decades without a definite resolution. A concern is that an ever-decreasing number of enthusiasts will use the retroperitoneal approach in the future. We consider the preservation of this technique of utmost importance and emphasize the need for quality training of the younger generations in established, high-volume departments to properly navigate future challenges in the contemporary endovascular-driven era.

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