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Endovascular Aortic Aneurysm Repair: A Review of Anesthesia Concerns and Perioperative Management

Devishree Das[1], Neeti Makhija[1]

[1]Department of Cardiac Anaesthesia and Critical Care, All India Institute of Medical Sciences, New Delhi, India.

***Corresponding author:**
Neeti Makhija,
Department of Cardiac Anaesthesia and Critical Care, All India Institute of Medical Sciences, New Delhi, India.

neetimakhija@hotmail.com

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ABSTRACT

Abdominal aortic aneurysm repair has undergone remarkable improvements from conventional open reconstruction to minimally invasive endovascular techniques since the early 90s to curtail morbidity and mortality. The transcendence of minimal invasiveness led to endovascular aortic aneurysm repair (EVAR) a viable alternative to open surgical technique. However, EVAR is more complex, and requires appropriate patient selection, comprehensive pre-operative assessment, optimization, intraoperative hemodynamic consideration, early detection of postoperative complications, and prompt management. As complexity and versatility increase, it poses an anesthetic challenge as well as requires multidisciplinary intervention. The present article aims to review the perioperative concerns of EVAR with currently available literature.

Keywords: Abdominal aortic aneurysm, Anesthesia concern, Endo-leak, Endovascular repair, Perioperative management, Post implantation syndrome

INTRODUCTION

Endovascular aortic repair (EVAR) was introduced by Parodi *et al.*[1] and Volodos *et al.*[2] The first balloon-expandable endograft was placed by Parodi *et al.* in 1991 for abdominal aortic aneurysms (AAA) in patients who were unfit for open surgical procedures. Since then, tremendous advancements in the endovascular technique have greatly increased its interest, acceptability, and applicability. Associated comorbidity and complexity of procedure pose an immense challenge for both the surgeon and anesthesiologist whether it is a simple infra-renal EVAR, a more compounded supra-renal EVAR, or thoracic endovascular aortic repair (TEVAR). For a successful outcome, patients undergoing EVAR should undergo detailed pre-operative assessment and optimization through a multidisciplinary team approach.

SEARCH STRATEGIES

The non-systematic review was designed after a comprehensive analysis of the literature from textbooks, journals, and internet resources using keywords "abdominal aortic aneurysm," "endovascular repair," "anesthesia concern," "perioperative management," "endo-leak," and "post-implantation syndrome." The filters used were case reports, clinical trials, controlled trials, randomized control trials, observational studies, and text articles. The search engines were Google Scholar, Science Direct, PubMed, EMBASE, Medscape, Medline Scopus, and many others.

AORTIC ANEURYSMS - ITS BUDDING RISK

An aortic aneurysm is permanent dilatation of at least more than 50% of the diameter and constitutes all three layers of the aortic wall.[3-5] AAA constitutes 65% of all aortic aneurysms whereas the majority (95%) include infrarenal aortic aneurysms.[6] Smoking is the greatest risk factor for AAA which accounts for 90% of the patients.[7] Other risk factors include hypertension, hyperlipidemia, atherosclerosis, positive family history, inflammatory vasculitis, and trauma. Etiology for aneurysmal dilatation encompasses Marfan's syndrome (defect in fibrin I) and Type-IV Ehlers-Danlos syndrome (defect in procollagen III).[8] Aneurysm of the thoracoabdominal aorta is classified by Crawford[9] [Figure 1]. It usually complicates with aortic rupture, aortic regurgitation, compression of the esophagus, tracheobronchial tree, vital organ ischemia, and systemic embolization from mural thrombus. As the size of the aneurysm rises, the annual risk of rupture also exponentially increases [Table 1]. Therefore, its intervention is required once the aortic diameter reaches 5.5 cm (or is rapidly increasing i.e., more than 5 mm in 6 months), to limit further complications.[10]

BEGINNING OF INTERVENTIONAL ERA – ITS POTENTIAL ADVANTAGE

The aneurysm of the aortic root, ascending aorta, and aortic arch usually require surgical repair to avoid aneurysmal complications. However, open surgical repair of descending thoracoabdominal aneurysm carries potential adverse effects. Despite technical advances, the major surgical risk remains because of elderly patients with multiple comorbidities. There is a significant risk of major organ ischemia like in the spinal, mesenteric, renal, and lower extremities that may be due to loss of collateral vessels, thromboembolism, temporary interruption of blood supply, or reperfusion injury. Incidence of wound dehiscence and postoperative respiratory failure remain high because of the large incisions, diaphragmatic division, or maybe because of phrenic and recurrent laryngeal nerve injury.[11] The elective surgical repair for AAA constitutes 5% mortality.[12] Thirty-day mortality associated with ruptured AAA is about 80% whereas for those undergoing emergency surgery, it accounts for approximately 40%.

Table 1: Size of aneurysm and its annual risk of rupture.

Aneurysm size (cm)	Annual rupture risk (%)
4–4.9	0.5–5
5–5.9	5–15
6–6.9	10–20
7–7.9	20–40

EVAR was first introduced in 1991. It is a less invasive procedure with potential advantages and certain disadvantages over conventional open surgical repair [Table 2][13] The 30-day mortality following EVAR ranges from 1.7% in patients who were suitable for open surgery,[14] to 9% in those who were unfit for open repair.[15]

With increasing EVAR, there has been increasing literature comparing the outcomes of EVAR and open repair. In the EVAR 1 trial, patients suitable for open repair were randomized to either open repair or EVAR.[14] The short-term mortality and morbidity were found to be 3% lower in the EVAR group but the long-term mortality was similar. However, there is an increased requirement for reintervention (4%) and expenditure in the EVAR group. Complications such as thrombosis, endo-leak, kinking of the graft, and device migration necessitate re-intervention.

The EVAR 2 trial randomized patients who were considered unsuitable for open surgery to either conservative management or EVAR to assess whether EVAR is a potential

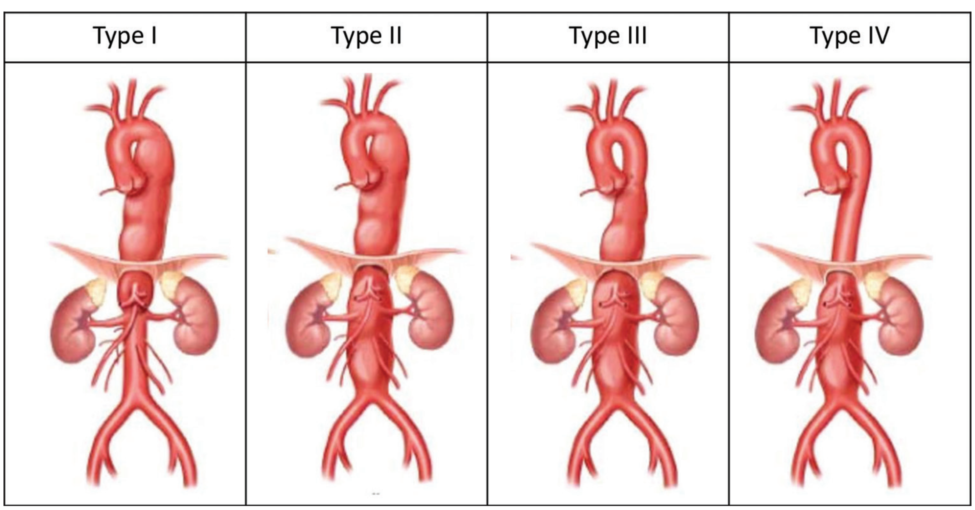

Figure 1: The Crawford classification of thoracoabdominal aortic aneurysm extent.

Table 2: The advantages and disadvantages of EVAR.

Advantages
• Less invasive and avoid large thoracoabdominal incision • Less post-operative pain and decreased requirement of analgesics • Less blood loss and less transfusion requirements • Avoid clamping and unclamping of aorta • Less hemodynamic, metabolic and acid-base alterations • Faster recovery and shorter hospital stay
Disadvantages
• Anatomical obligations • Require contrast administrations • Unique procedure related complications • Require regular follow-up • Long term advantages not defined

alternative to patients considered unfit for open repair. EVAR resulted in considerable 30-day mortality (9%) without significant difference in the long-term survival in both groups.[15] Mortality following the EVAR procedure is comparable with open surgical procedure with respect to a 4-year follow-up in the EVAR 1 trial. A similar outcome was derived from the mid-term quotient of the Dutch randomized endovascular aneurysm management trial (DREAM trial).[13] Nevertheless, the trial concluded that "if the developments in endograft technology and imaging continue to improve, EVAR may become the initial choice for aortic aneurysms."

PATIENT SELECTION – KEY TO SUCCESS

With increasing popularity and practical advancement in EVAR technology, the success rate is shooting up. Out of which, patient selection is the major boosting factor for its expansion. However, there are no appropriate guidelines and selection criteria were defined for patients undergoing EVAR. The surgical risk and life expectancy should be balanced against the risk of aneurysmal rupture.

Intervention should not be recommended for asymptomatic patients having a thoracic aneurysm of <5 cm[16] and asymptomatic abdominal aneurysm of <5.5 cm. Moreover, the Aneurysm Detection and Management in 1998 and the United Kingdom Small Aneurysm Trial revealed early intervention for small abdominal aneurysm, that is, 4–5 cm was not much beneficial.[17,18]

The technical feasibility for endovascular repair of abdominal aneurysm is based on its morphological features mainly evaluated with 3D reconstruction of computed tomography. The principal factors affecting the outcome are the proximal neck (diameter, length, angulation, and existing thrombus), landing zone distally (its diameter and length), caliber, and tortuosity of access vessels.

The proximal aortic neck, also called the landing zone, is the proximal attachment area of the endovascular graft to the non-aneurysmal aorta. A "hostile neck" is defined as an aortic diameter of more than 28 mm, the angulation between the neck and suprarenal part of more than 60°, existing thrombus occupying more than 50% of the circumference of the aorta, higher than 2 mm expansion in the aortic diameter within 10 mm of the proximal landing zone and if the distance between starting of aneurysm sac to the caudal end of the renal artery is <10 mm.[19]

Aneurysms involving the common iliac arteries and extremely calcified iliac arteries may lead to inadequate sealing of graft and graft kinking, respectively. Therefore, a distal landing zone must be chosen with caution. The access arteries should be of adequate caliber to allow the passage of such bulky devices. Tortuous femoral and iliac arteries often straighten with stiff wires for preparation of appropriate access site and focal stenoses should be adequately dilated. However, severe calcification remains challenging as it may rupture while forceful dilatation.

The ultimate decision is made by considering patient factors, including increased risk of rupture in women, smokers, and hypertensive with chronic lung disease.[20]

INTRAOPERATIVE MANAGEMENT – A MULTIDISCIPLINARY APPROACH

The perioperative approach is optimal with a multidisciplinary team consisting of interventional radiologists, surgeons, anesthetists, nursing staff, and imaging specialists. Typically, the procedure is carried out in a hybrid operating room with advanced imaging capabilities.[21]

PRE-OPERATIVE EVALUATION

Patients undergoing EVAR procedures should be evaluated in depth and optimized beforehand like other major vascular procedures. The incidence of diabetes, hypertension, stroke, and major cardiorespiratory disease is higher. The majority of the patients with AAA (70%) also have coronary artery disease that mandates pre-operative assessment and appropriate management preoperatively. According to the American College of Cardiology and American Heart Association [ACC/AHA]) joint guidelines, the infra-renal EVAR is categorized as an intermediate risk procedure whereas complex EVAR is contemplated to be a high-risk technique.[22]

These patients are prone to contrast-induced nephropathy which seek preoperative evaluation of renal function and optimization. The strategies to lessen renal impairment such as continuing adequate pre-operative hydration with normal saline, minimizing contrast load, use of isoosmolar contrast, and avoiding nephrotoxic drugs such as non-steroidal anti-inflammatory and aminoglycosides should be considered.[23] If the glomerular filtration rate (GFR) is <60, intravenous sodium bicarbonate should be administered to alkalinize the urine and when GFR is reduced to 30, the use of N-acetylcysteine may be beneficial.[24] Criado *et al*. found a reliable technique for endograft deployment which includes

catheter-less carbon dioxide angiography through the endograft delivery sheath and it is a safe, non-toxic, and inexpensive technique.[25]

INTRAOPERATIVE MONITORING

All standard monitors such as electrocardiograms, pulse oximeters, noninvasive blood pressure, and temperature monitor are to be attached. Large-bore intravenous access should be secured for rapid transfusion as there is a higher chance of significant blood loss or inadvertent injury to great vessels. Central venous catheterization should be considered in complex procedures, which are accessible for cardiac output monitoring and infusion of essential drugs like inotropes and vasopressors along with rapid volume replacement in crises situation. Broad spectrum antibiotics, with both Gram-positive and Gram-negative microbial coverage, should be administered 1 h before the procedure for appropriate antimicrobial effect. The arterial line should be secured in the upper limb, contralateral side to the surgical access site for the continuous beat to beat monitoring. Hourly urine output should be monitored to surrogate renal function during perioperative period.

ANESTHETIC GOALS

The anesthetic goals for intraoperative management are:

- Provide hemodynamic stability
- Preserve perfusion to vital organs including the heart, brain, spinal cord, kidney, and splanchnic vasculature
- Normothermia
- Avoid myocardial oxygen supply and demand mismatch
- Maintenance of intravascular volume
- Early identification and management of hemorrhage.

General versus regional anesthesia

An anesthetic technique acceptable for EVAR can be general anesthesia, regional anesthesia, or local anesthetic infiltration with monitored anesthesia care. Evidence of the risk and benefit of one technique over other with regards to EVAR is lacking. However, certain factors such as the use of antiplatelet or anticoagulant drugs, duration of surgery, associated comorbidities, and inability to lay flat are favorable toward general anesthesia. Prolonged complex procedures may require sedation or even conversion to general anesthesia. Intraoperative use of heparin is not a contraindication for an epidural, but the timing of catheter insertion and removal should be strictly followed as per guidelines. A short period of breath-hold is required intermittently for good-quality imaging which is either by patient cooperation or conscious sedation.

THE EVAR PROCEDURE

The first and foremost step is to secure the access site, the common femoral arteries either by percutaneous approach or by surgical exploration. Open surgical exposure allows not only direct visualization but also evaluation of the vessel quality, calcification if any, and identification of appropriate arteriotomy site. However, if the percutaneous technique is used, then a large vessel closure device is chosen as a pre-close or a post-close type.

Once the access artery is secured, stiff wires may be inserted into the descending aorta to "straighten out" the aortoiliac system. Then, the aortography was done to localize the level of renal arteries, to confirm the diameters and lengths of the proximal and distal landing zone, aortoiliac bifurcations, and the aneurysmal sac [Figure 2a]. The appropriately sized endografts are selected and systemic anticoagulation is initiated to ensure adequate heparinization by keeping the activated clotting time >250 s.

The main body is inserted and positioned just inferior to the lowest renal artery [Figure 2b]. After confirming the position of the framework, the main body is deployed [Figure 2c]. Subsequently, the interspace from the main body to the iliac bifurcation, and the optimal overlap is measured by contrast injection through the sheath. Then, the graft is deployed from the access site on the contralateral limb. Once the endograft was deployed, a compliant balloon is used to cast the graft at the proximal, distal, and other attachment sites if multiple endografts were deployed in pieces.

On completion, a final aortogram is essential to inspect the correct placement, to exclude the aneurysmal segment, patency of major vessels like renal and hypogastric arteries, and detection of any possible complications [Figure 2d]. All incisions are closed and anticoagulation is reversed. If the hemodynamics were stable and without any inadvertent complications, then the patient can be extubated or brought to a post-operative intensive care unit for optimization before extubating.

TEVAR is a minimally invasive technique that involves endograft placement in the thoracic aorta which is used as an alternative technique to open surgery for an array of pathologies involving the thoracic aorta. Avoidance of sternotomy or thoracoabdominal incision, aortic clamping decamping, huge blood loss, potential end-organ damage, and lower incidence of morbidity make TEVAR a preferred substitute.

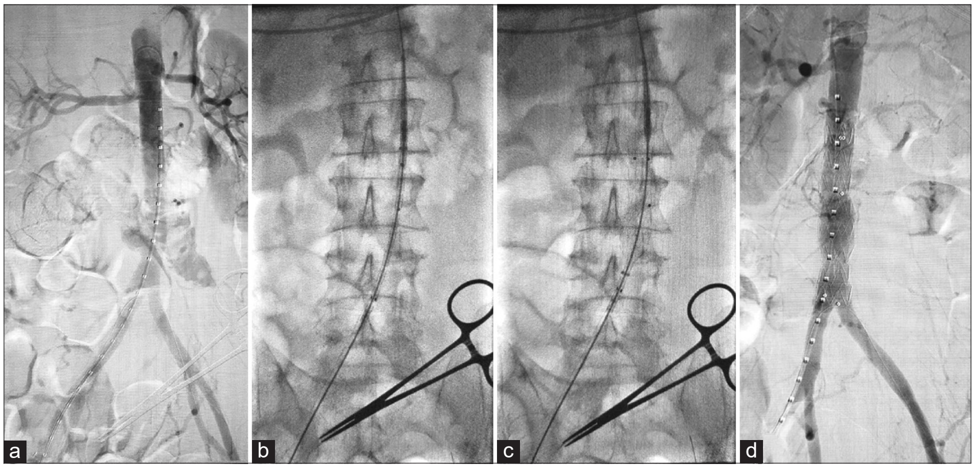

Figure 2: The EVAR procedure (a) initial aortography (b) main body insertion (c) stent deployment (d) final aortogram.

Intraoperative complications

Undoubtedly, EVAR is associated with numerous short-term benefits; however, it is associated with certain unique complications during perioperative settings. It requires a learning curve for the operator as well as need technical advancement to circumvent the intraoperative complication. The following complications may occur.

- Access vessel injury in the form of dissection, even avulsion can occur with the passage of large stiff catheters.[26] Severely calcified, tortuous, and small caliber vessels are the culprit. It may present silently as deterioration of hemodynamics as iliac vessel injury results in retroperitoneal hemorrhage. It is managed either by intraluminal balloon occlusion followed by stent grafting or conversion to open procedure[27]
- Renal artery exclusion occurs in 1% of cases[28] which can be avoided by precise selection and careful deployment of graft
- The aneurysmal sac may be ruptured during excessive manipulation and undue tension because of a large sheath, stiff wire, or the graft delivery device.[29] However, it becomes an emergency with the requirement of massive transfusion, use of vasopressors to maintain hemodynamics, and urgent exploration to check the bleeding
- Embolization may compromise the perfusion of distal vasculature.[30] Distal embolization can occur from an atheromatous plaque, thrombus, intimal flap, or calcified plaque. Therefore, distal pulses need to be recorded preoperatively as well as postoperatively.

POST-OPERATIVE CARE - EARLY DIAGNOSIS AND MANAGEMENT OF COMPLICATIONS

Post-operative care is provided initially in the designated intensive care unit to curtail specific complications associated with EVAR. However, it requires less aggressive care than an open repair.

The distal pulses are regularly checked to determine early occlusion because of thrombus or plaque embolization. The groin access site should be checked to detect hematoma or bleeding. Abdominal girth, tenderness, and bowel sounds are to be assessed at regular intervals to determine organ ischemia, expanding hematoma, or peritonitis. Adequate hydration is to be maintained and hourly urine output is to be measured to assure renal adequacy. Neurological monitoring should be done to rule out spinal cord ischemia and early mobilization should be warranted. Oral intake is to be resumed early after bowel adequacy.

The perioperative complications of the EVAR technique are enumerated in [Table 3]. The major postoperative complications include infection, graft migration, graft kinking, device failure, endoleak, and post-implantation syndrome (PIS).

Infection of the endovascular stent graft is a catastrophic event that is mainly because of intravascular seeding rather than primary graft infection. It is diagnosed by positive blood cultures or CT scan revealing air around the graft.[31] The management protocol should be appropriate antibiotic treatment with complete excision of implanted device and reconstruction with an autologous femoral vein graft, antibiotic-soaked non-autologous graft, or cryopreserved arterial allografts.[32]

The endograft kinking occurs due to the progressive shrinking of aneurysmal sac and aortic remodeling, therefore, requires a redo procedure, however, with the use of newer devices having a longer body and shorter limbs and use of the external supporting system, it can be avoided.[33]

Device failure is a late complication involving earlier-generation grafts and is mainly due to suture breaks, stent fractures, or fabric disintegrations.[34] It is managed by relining the endograft by redoing the endovascular technique but may sometimes rarely require an open surgical technique.

Endoleak is the most common etiology for graft failure in the early postoperative period constituting around 20–30%.[35] It is defined as failure to exclude the aneurysmal sac from the circulation even after the deployment of an endovascular graft. There is a persistent flow of blood into the sac, as a result, it is progressively expanding and prone to rupture. The classification of endoleak is as follows.[5] [Figure 3].

Type I endoleak: (8.2–18%) results from inadequate seal from the proximal (Ia) or distal (Ib) end of the endograft

Type II endoleak: (8–45%) caused by inflow from a visceral vessel

Type III endoleak: (0.7–3.8%) occurs due to a defect in the graft, a disconnection of graft components, or an inadequate seal

Type IV endoleak: (rare) mainly due to the porosity of the graft fabric

Type V endoleak: (5%) Also called endotension, there is an increase in aneurysmal pressure without a demonstrable source of endoleak.

Table 3: The complications of EVAR.

Intraoperative	Post-operative	
	Early onset	**Late onset**
Access vessel injury	Embolization	Endo-leak
Renal artery exclusion	Graft occlusion	Graft migration
Rupture of aneurysmal sac	Ilio-femoral vessel injury	Graft kinking
Embolization	Visceral organ ischemia	Device failure
	Spinal cord ischemia	
	Peritonitis	
	Contrast-induced nephropathy	
	Post-implantation syndrome	

Endoleak can be detected by color Doppler ultrasound surveillance postoperatively as stated by Iscan *et al*.[36] and managed either by the placement of an additional stent graft, embolization of the feeding visceral vessel, or conversion to open repair.

PIS is a systemic inflammatory response occurring in an early phase following the EVAR procedure, mediated mainly by interleukin-6, tumor necrosis factor α, and other cytokines.[37,38] It is mainly because of the material of endograft (polyester or polytetrafluroethylene). The incidence of PIS has been varying widely from 14% to 60%.[39] It can be diagnosed by persistent fever along with elevated leucocyte count without evidence of any infection. Velázquez *et al*. in 1999 first reported PIS as the presence of fever and leukocytosis with a count of more than 11,000/dL.,[40] while Gorich *et al*. described PIS by a white blood cell (WBC) count of more than 10,000/mL.[40] Blum *et al*. denoted the incidence of PIS as 100% in 154 consecutive EVAR techniques with a WBC count of more than 9800/mL and elevated CRP but without fever.[41]

PIS is considered to be a benign condition, although it may prolong hospital length of stay or rehospitalization.[42] As per Gabriel *et al*. extensive use of anti-inflammatory drugs in the acute phase is beneficial,[43] while Morikage *et al*. prefer a conservative approach.[44] A report published recently from Denmark suggested that pre-operative administration of high-dose glucocorticoid reduces the inflammatory response and enhances recovery after EVAR.[45]

CONCLUSION AND FUTURE DIRECTION

EVAR is an evolving technique that is expanding its horizon toward endovascular thoracic aortic aneurysm repair and

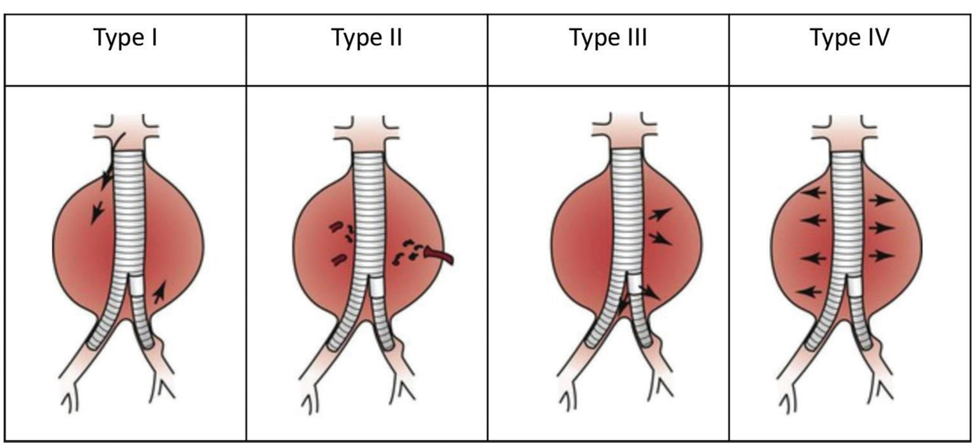

Figure 3: Classification of endo-leak.

even emergency endovascular repair of AAA rupture. Being minimally invasive, the technique is popular in high-risk patients [46] with major comorbidities. EVAR's success rate depends on the active involvement of all team members of a multidisciplinary team. Anesthetic preparedness ranges from the pre-operative phase as patient selection and optimization, intraoperative monitoring, and awareness regarding emergency hemorrhage and conversion to open technique, and postoperatively for early detection of any organ ischemia and immediate resuscitation.[47] Good teamwork and promptness during emergencies play a key role in success.

Declaration of patient consent

Patient's consent not required as patient's identity is not disclosed or compromised.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Parodi JC, Palmaz JC, Barone HD. Transfemoral intraluminal graft implantation for abdominal aortic aneurysms. Ann Vasc Surg 1991;5:491-9.
2. Volodos NL, Karpovich IP, Troyan VI, YuV K, Shekhanin VE, Ternyuk NE, *et al*. Clinical experience of the use of self-fixing synthetic prostheses for remote endoprosthetics of the thoracic and the abdominal aorta and iliac arteries through the femoral artery and as intraoperative endoprosthesis for aorta reconstruction. Vasa Suppl 1991;33:93-5.
3. Hiratzka LF, Bakris GL, Beckman JA, Bersin RM, Carr VF, Casey DE Jr., *et al*. 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with thoracic aortic disease: Executive summary. A report of the American College of Cardiology Foundation, American Heart Association Task Force on Practice Guidelines, American Association for Thoracic Surgery, American College of radiology, American stroke association, society of cardiovascular anaesthesiologist, society of Cardiovascular Angiography and Interventions, and Society for Vascular Medicine. J Am Coll Cardiol 2010;55:1509-44.
4. Svensson LG, Adams DH, Bonow RO, Kouchoukos NT, Miller DC, O'Gara PT, *et al*. Aortic valve and ascending aorta guidelines for management and quality measures. Ann Thorac Surg 2013;95(6 Suppl):S1-66.
5. Erbel R, Aboyans V, Boileau C, Bossone E, Di Bartolomeo R, Eggebrecht H, *et al*. 2014 ESC Guidelines on the diagnosis and treatment of aortic diseases: Document covering acute and chronic aortic diseases of the thoracic and abdominal aorta of the adult. The task force for the diagnosis and treatment of aortic diseases of the European Society of Cardiology (ESC). Eur Heart J 2014;35:2873-926.
6. Singh K, Bønaa KH, Jacobsen BK, Bjørk L, Solberg S. Prevalence of and risk factors for abdominal aortic aneurysms in a population-based study: The Tromsø Study. Am J Epidemiol 2001;154:236-44.
7. Norris EJ. Perioperative management of the patient undergoing aortic vascular surgery. ASA Refresher 2005;16:187-202.
8. Gillum RF. Epidemiology of aortic aneurysm in the United States. J Clin Epidemiol 1995;48:1289-98.
9. Frederick JR, Woo YJ. Thoracoabdominal aortic aneurysm. Ann Cardiothorac Surg 2012;1:277-85.
10. Lederle FA, Johnson GR, Wilson SE, Ballard DJ, Jordan WD Jr., Blebea J, *et al*. Rupture rate of large abdominal aortic aneurysms in patients refusing or unfit for elective repair. JAMA 2002;287:2968-72.
11. LeMaire SA, Price MD, Green SY, Zarda S, Coselli JS. Results of open thoracoabdominal aortic aneurysm repair. Ann Cardiothorac Surg 2012;1:286-92.
12. National Institute for Health and Clinical Excellence (NICE). Endovascular Stent-Grafts for the Treatment of Abdominal Aortic Aneurysms; 2009. Available from: http://www.nice.org.uk /guidance/ta167/ resources/guidance-endovascular-stentgrafts -for-the -treatment-of- abdominal -aortic-aneurysms -pdf [Last accessed on 2015 Apr 13].
13. Prinssen M, Verhoeven EL, Buth J, Cuypers PW, van Sambeek MR, Balm R, *et al*. A randomized trial comparing conventional and endovascular repair of abdominal aortic aneurysms. N Engl J Med 2004;351:1607-18.
14. EVAR Trial Participants. Endovascular aneurysm repair versus open repair in patients with abdominal aortic aneurysm (EVAR trial 1): Randomised controlled trial. Lancet 2005;365:2179-86.
15. EVAR Trial Participants. Endovascular aneurysm repair and outcome in patients unfit for open repair of abdominal aortic aneurysm (EVAR trial 2): Randomised controlled trial. Lancet 2005;365:2187-92.
16. Cambria RA, Gloviczki P, Stanson AW, Cherry KJ Jr., Bower TC, Hallett JW Jr., *et al*. Outcome and expansion rate of 57 thoracoabdominal aortic aneurysms managed nonoperatively. Am J Surg 1995;170:213-7.
17. The United Kingdom Small Aneurysm Trial Participants. Mortality results for randomized controlled trial of early elective surgery or ultrasonographic surveillance for small abdominal aortic aneurysms. Lancet 1998;352:1649-55.
18. Ledele FA, Wilson SE, Johnson GR, Reinke DB, Littooy FN, Acher CW, *et al*. Immediate repair compared with surveillance of small abdominal aortic aneurysms. N Engl J Med 2002;346:1437-44.
19. Choke E, Munneke G, Morgan R, Belli AM, Loftus I, McFarland R, *et al*. Outcomes of endovascular aortic aneurysm repairin patients with hostile neck anatomy. Card Intervent Radiol 2006;29:975-80.
20. Schermerhorn ML. Should usual criteria for intervention in abdominal aortic aneurysms be "downsized", considering reported risk reduction with endovascular repair? Ann NY Acad Sci 2006;1085:47-58.

21. Kaneko T, Davidson MJ. Use of the hybrid operating room in cardiovascular medicine. Circulation 2014;130:910-7.
22. American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery), American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, *et al*. ACC/AHA 2007 Guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery: Executive summary: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Non-cardiac Surgery). Anesth Analg 2008;106:685-712.
23. Wong GT, Irwin MG. Contrast induced nephropathy. Br J Anaesth 2007;99:474-83.
24. Cavusoglu E, Chhabra S, Marmur JD, Kini A, Sharma SK. The prevention of contrast-induced nephropathy in patients undergoing percutaneous coronary intervention. Minerva Cardioangiol 2004;52:419-32.
25. Criado E, Kabbani L, Cho K. Catheter-less angiography for endovascular aortic aneurysm repair: A new application of carbon dioxide as a contrast agent. J Vasc Surg 2008;48:527-34.
26. Cuypers PW, Laheij RJ, Buth J. Which factors increase the risk of conversion to open surgery following endovascular abdominal aortic aneurysm repair? The EUROSTAR collaborators. Eur J Vasc Endovasc Surg 2000;20:183-9.
27. Fairman RM, Velazquez O, Baum R, Carpenter J, Golden MA, Pyeron A, *et al*. Endovascular repair of aortic aneurysms: Critical events and adjunctive procedures. J Vasc Surg 2001;33:1226-32.
28. Gabrielli L, Baudo A, Molinari A, Domanin M. Early complications in endovascular treatment of abdominal aortic aneurysm. Acta Chir Belg 2004;104:519-26.
29. Moskowitz DM, Kahn RA, Marin ML, Hollier LH. Intraoperative rupture of an abdominal aortic aneurysm during an endovascular stent-graft procedure. Can J Anaesth 1999;46:887-90.
30. Maldonado TS, Ranson ME, Rockman CB, Pua B, Cayne NS, Jacobowitz GR, *et al*. Decreased ischemic complications after endovascular aortic aneurysm repair with newer devices. Vasc Endovascular Surg 2007;41:192-9.
31. Leon LR Jr. A diagnostic dilemma: Does peri stent-graft air after thoracic aortic endografting necessarily imply infection? Vasc Endovasc Surg 2007;41:433-9.
32. Zhou W, Lin PH, Bush RL, Terramani TT, Matsuura JH, Cox M, *et al*. *In situ* reconstruction with cryopreserved arterial allografts for management of mycotic aneurysms or aortic prosthetic graft infections: A multi-institutional experience. Tex Heart Inst J 2006;33:14-8.
33. Ouriel K, Clair DG, Greenberg RK, Lyden SP, O'Hara PJ, Sarac TP, *et al*. Endovascular repair of abdominal aortic aneurysms: Device-specific outcome. J Vasc Surg 2003;37:991-8.
34. Najibi S, Steinberg J, Katzen BT, Zemel G, Lin PH, Weiss VJ, *et al*. Detection of isolated hook fractures 36 months after implantation of the Ancure endograft: A cautionary note. J Vasc Surg 2001;34:353-6.
35. White GH, May J, Waugh RC, Chaufour X, Yu W. Type III and Type IV endoleak: Toward a complete definition of blood flow in the sac after endoluminal AAA repair. J Endovasc Surg 1998;5:305-9.
36. Iscan HZ, Unal EU, Akkaya B, Daglı M, Karahan M, Civelek I, *et al*. Color Doppler ultrasound for surveillance following EVAR as the primary tool. J Card Surg 2021;36:111-7.
37. Moulakakis KG, Alepaki M, Sfyroeras GS, Antonopoulos CN, Giannakopoulos TG, Kakisis J, *et al*. The impact of endograft type on inflammatory response after endovascular treatment of abdominal aortic aneurysm. J Vasc Surg 2013;57:668-77.
38. Swartbol P, Norgren L, Parsson H, Truedsson L. Endovascular aortic aneurysm repair induces significant alterations in surface adhesion molecule expression on donor white blood cells exposed to patient plasma. Eur J Vasc Endovasc Surg 1997;14:48-59.
39. Bischoff MS, Hafner S, Able T, Peters AS, Hyhlik-Durr A, Bockler D. Incidence and treatment of post implantation syndrome after endovascular repair of infrarenal aortic aneurisms. Gefasschirurgie 2013;18:381-7.
40. Velázquez OC, Carpenter JP, Baum RA, Barker CF, Golden M, Criado F, *et al*. Perigraft air, fever, and leukocytosis after endovascular repair of abdominal aortic aneurysms. Am J Surg 1999;178:185-9.
41. Blum U, Voshage G, Lammer J, Beyersdorf F, Töllner D, Kretschmer G, *et al*. Endoluminal stentgrafts for infrarenal abdominal aortic aneurysms. N Engl J Med 1997;336: 13-20.
42. Arnaoutoglou E, Kouvelos G, Milionis H, Mavridis A, Kolaitis N, Papa N, *et al*. Post-implantation syndrome following endovascular abdominal aortic aneurysm repair: Preliminary data. Interact Cardiovasc Thorac Surg 2011;12:609-14.
43. Gabriel EA, Locali RF, Romano CC, da Silva Duarte AJ, Palma JH, Buffolo E. Analysis of the inflammatory response in endovascular treatment of aortic aneurysms. Eur J Cardiothorac Surg 2007;31:406-13.
44. Morikage N, Esato K, Zenpo N, Fujioka K, Takenaka H. Is endovascular treatment of abdominal aortic aneurysms less invasive regarding the biological responses? Surg Today 2000;30:142-6.
45. De la Motte L, Kehlet H, Vogt K, Nielsen CH, Groenvall JB, Nielsen HB, *et al*. Preoperative methylprednisolone enhances recovery after endovascular aortic repair: A randomized, double-blind, placebo-controlled clinical trial. Ann Surg 2014;260:540-8; discussion 548-9.
46. Kontopodis N, Galanakis N, Charalambous S, Matsagkas M, Giannoukas AD, Tsetis D, *et al*. Editor's choice-Endovascular aneurysm repair in high risk patients: A systematic review and meta-analysis. Eur J Vasc Endovasc Surg 2022;64:461-74.
47. Bidd H, Lyons O. EVAR: Better off awake? Eur J Vasc Endovasc Surg 2020;59:739.

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