

## REVIEW

# Open aortic aneurysm repair in the endovascular era

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**Summary**

Open repair (OR) of aortic aneurysms is still relatively mutilating and risky in older and high-risk patients. Since the introduction of EVAR, a significantly lower perioperative mortality has been noted. Apart from advantages, endovascular treatment has some disadvantages as well, due to which OR still has a very important role in the endovascular era.

In a vast majority of the patients younger than 65, with good overall condition, long life expectancy and favorable anatomy, as well as in patients with hostile aneurysm neck anatomy, heritable connective tissue disorders, complete thrombosis of abdominal aortic aneurysm (AAA) and potent accessory renal arteries, OR is the first treatment option in comparison with the endovascular treatment. EVAR is recommended as the first treatment option in patients with inflammatory aneurysms and OR should be considered only in better shaped patients with inflammatory AAA and significant hydronephrosis.

Late open surgical conversion (LOSC) is a noted event after endovascular treatment and is associated with a significantly higher perioperative mortality and other serious perioperative complications compared to primary OR.

Multicenter randomized controlled trials (RCT) did not find a significant difference regarding 30-day mortality between open and endovascular repair of ruptured AAA. However, not all ruptured AAA are suitable for endovascular repair. In a hemodynamically unstable patients, when there is no time for MDCT angiography, EVAR is not possible, and OR is the only option. The incidence of abdominal compartment syndrome after OR is significantly lower in comparison with EVAR thanks to surgical evacuation and drainage of retroperitoneal hematoma.

The improvement of the results of aortic aneurysm treatment largely depends on the volume of yearly aortic operations. Having in mind all the mentioned advantages and disadvantages of OR and endovascular repair, we can conclude that in high volume centers, younger generations of vascular surgeons should be educated in standard and complex open aortic surgery.

**Keywords:** aortic aneurysm, endovascular treatment, EVAR, open repair

## INTRODUCTION

In the first half of the twentieth century, wrapping has been used in the treatment of aortic aneurysms. The aneurysm is wrapped in omentum or cellophane to strengthen the wall and prevent rupture. (1) Nyssen treated Einstein's abdominal aortic aneurysm (AAA) in 1948. The results lasted for seven years when AAA ruptured. However, Einstein refused to undergo a more modern operation. Those were his words exactly: *"I want to go when I want. I have done my share, it is time to go. I will do it elegantly"*. He died on April 12<sup>th</sup>, 1955. (2)

Open repair (OR) of aortic aneurysm that is performed today was introduced about 70 years ago. (3-5) Despite an improvement during the past decades, OR of aortic aneurysms is still relatively mutilating and risky in older and high-risk patients. An approach to aortic aneurysms is mutilating enough. Namely, OR of AAA requires laparotomy, OR of thoracic aneurysms (TAA) requires thoracotomy, while OR of thoracoabdominal aortic aneurysms (TAAA) requires thoraco-phreno-lumbotomy. It is followed by dissection, aortic cross clamping (ACC), and finally with aneurysm replacement using prosthetic graft. In addition, in OR of TAAA, revascularization of the spinal cord and all visceral organs is necessary. However, it requires cerebrospinal fluid drainage, segmental sequential ACC, mechanical circulatory support, moderate hypothermia, and selective retrograde perfusion of visceral organs. (6) It is associated with very high perioperative mortality in older and high-risk patients.

At the beginning of the last decade of the 20<sup>th</sup> century, Volodos and Parodi introduced endovascular aneurysm repair (EVAR). (7, 8) Owing to EVAR laparotomy, thoracotomy, or thoraco-phreno-lumbotomy and ACC are avoided. Instead of that, a stent-graft is placed through the femoral artery in the groin, often under local anesthesia, to the spot of the aortic aneurysm. The final step is stent-graft deployment in the aneurysmal sac. Owing to this, the aneurysm is excluded from circulation. EVAR results in a significantly lower perioperative blood loss, shorter hospitalization, faster recovery, and finally a significantly lower perioperative mortality. (9)

However, apart from the described advantages, EVAR has some disadvantages as well. This is the reason why OR of aortic aneurysms still has a very important role in the endovascular era. In the following part of this paper the main indications for OR of aortic aneurysms will be explained. Those recommendations are based on the literature analysis and on the significant experience of the Clinic for Vascular and Endovascular Surgery of the UCC of Serbia.

## DEGENERATIVE AORTIC ANEURYSMS WITH FAVORABLE ANATOMY

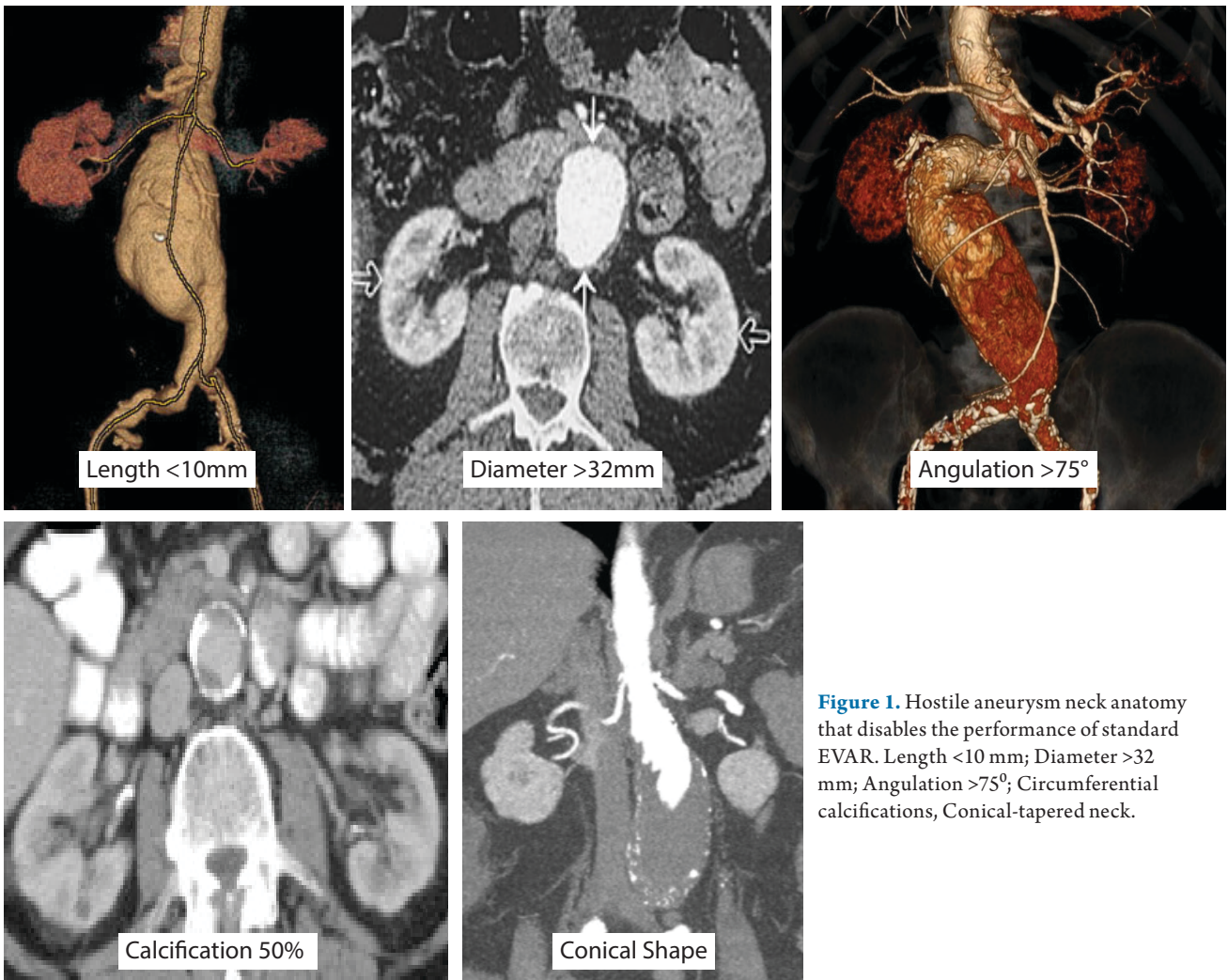
There is no evidence in recent literature to support EVAR as first-line therapy in patients below the age of 65. (10) We disagree that patients' motivation and surgeons' experience should be the main reasons for EVAR in younger, well-conditioned patients with degenerative AAA with suitable anatomy. That is especially supported having in mind long term results. According to EVAR trial 1, endovascular repair of AAA had a significantly higher total and aneurysm-related mortality after 8 years of follow-up in comparison with OR. The increased aneurysm-related mortality in the EVAR group was mainly caused by secondary aneurysmal sac rupture. The incidence of life-threatening re-interventions was also significantly higher in the EVAR group after eight years. (11) To be more precise, the reported single-center late open surgical conversion (LOSC) rates after EVAR ranged from 0.67% to even 22.8%. (12)

Despite advances in the OR of descending thoracic aneurysms during the past few decades, TEVAR is associated with a significantly lower 30-day mortality, as well as with a significantly lower incidence of spinal cord ischemia, respiratory failure and renal insufficiency. However, there is no difference in long-term survival after the second year of the follow-up. (13) At the same time, the incidence of LOSC after TEVAR is higher than previously thought, even in very experienced endovascular centers. (14) Some of the most recently published studies have not found a significant difference regarding early mortality and neurological complications comparing open and total endovascular repair of TAAA. (15) At the same time, OR provides a much lower rate of required re-interventions. (16)

All being said, OR should be considered as first treatment option for degenerative aortic aneurysms with favorable anatomy, in good-risk patients with long life expectancy. (17, 18)

## DEGENERATIVE AORTIC ANEURYSMS WITH UNFAVORABLE ANATOMY

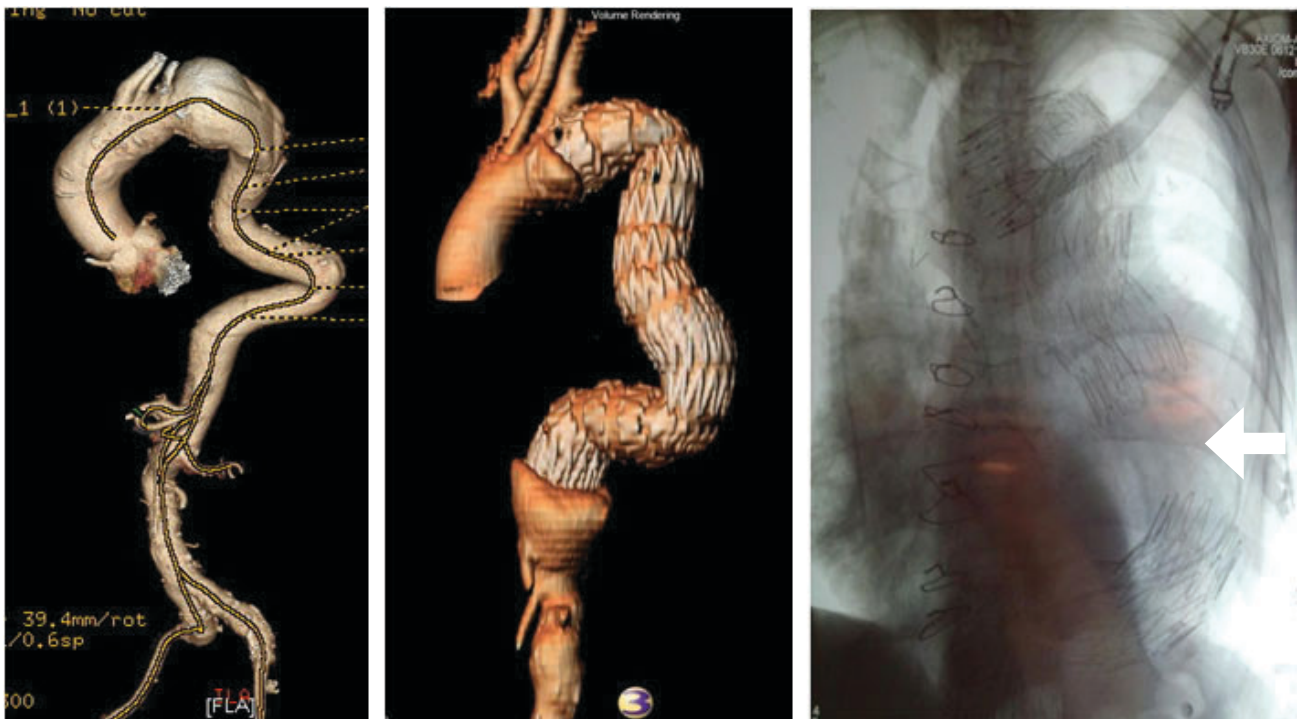
Using these five neck hostility criteria, a Delphi Consensus document identifies patients in whom standard EVAR is feasible; those in whom standard EVAR is not the first choice; those in whom standard EVAR is not advised due to moderate or high risk of failure, and finally, those in whom standard EVAR is not applicable. (19) According to this document, a standard EVAR is not applicable when the neck of the aneurysm is below the length of 10 mm, when the diameter is higher than 32 mm and the angulation is higher than 75°, when circumferential calcification is at least 50%, as well as when its shape is conical. (19) According to a relatively old study, 35% of AAA in male and even 60% in female patients, are not suitable for standard EVAR because of unfavorable aneurysm neck. (20)



**Figure 1.** Hostile aneurysm neck anatomy that disables the performance of standard EVAR. Length <10 mm; Diameter >32 mm; Angulation >75°; Circumferential calcifications, Conical-tapered neck.

New, more flexible generations of thoracic stent-grafts enable their easy implantation in very angulated aneurysms. However, long-term results are not that satisfying.

Namely, a significant angulation is an important cause of long-term stent-graft migration, which was presented in our case. (14)



**Figure 2.** MDCT angiography presents the aneurysm of the descending thoracic aorta with significant angulation (left) before and (middle) after TEVAR (right). Chest radiography presents migration of the distal component of the thoracic stent graft (white arrow).



Severe tortuosity and small diameter of iliac arteries can also be limiting factors for standard EVAR or TEVAR.



**Figure 3.** Severe tortuosity of iliac arteries, which disables standard EVAR.

Because of a short distal landing zone, severe angulation of the thoracic aorta, an occlusion of infrarenal aorta, visceral artery stenosis, as well as tortuosity and small diameter of iliac arteries, between 20 and 40% of TAAA are unsuitable for total endovascular repair. (21, 22)

OR should be considered as first treatment option for degenerative aortic aneurysms with unfavorable anatomy. (17, 18)

### HERITABLE DISORDERS OF CONNECTIVE TISSUE

Endovascular aneurysm repair is not recommended in patients with heritable disorders of connective tissue. Namely, the friability of the aortic wall in these patients seems to be incompatible with the radial force of stent-grafts. At the same time, generalized disease in these patients very frequently causes dilatation of the non-stented aortic segments. Therefore, type 1 endoleak and graft migration can occur. (23) Due to this, endovascular aneurysm repair is recommended in patients with heritable disorders of connective tissue only as a “bridge” to open surgery in emergency cases, including rupture and severe malperfusion. (17, 24) Endovascular aneurysm repair should also be considered if these patients have significant comorbidity. (25) In a vast majority of patients with heritable disorders of connective tissue, OR is the method of choice for the treatment of aortic aneurysms.

### MYCOTIC AORTIC ANEURYSMS

A recommendation from the ESVS guidelines regarding the mycotic AAA is not clearly defined. (17) According to the Swedish national vascular registry, there is no difference in long-term survival and infection-related death outcome between in-situ open and endovascular repair in patients with mycotic AAAs. (26) In our opinion, surgical excision of mycotic AAA followed with an extra-anatomic axillo-bifemoral bypass provides lower early mortality rate and lower long-term re-infection rates in comparison with in-situ open or endovascular repair. Endovascular treatment of mycotic TAA and TAAA, as well as primary aorto-duodenal (ADF), aorto-pulmonary (APF) and aorto-esophageal (AEF) caused by aneurysm rupture, provides an early survival benefit. However, it is associated with a very high re-infection rate. Due to this reason, endovascular repair can be used only as a “bridge” to a definitive open surgery. (27-29)

### INFLAMMATORY AORTIC ANEURYSMS

OR of inflammatory AAAs is associated with a high risk of intraoperative injury of surrounding structures as well as with higher in-hospital mortality. (30) Due to this, EVAR is recommended as first treatment option in patients with inflammatory AAA. (17) OR should be considered only in well-conditioned patients with inflammatory AAA who have significant hydronephrosis. (31)

### COMPLETE THROMBOSIS OF ABDOMINAL AORTIC ANEURYSMS

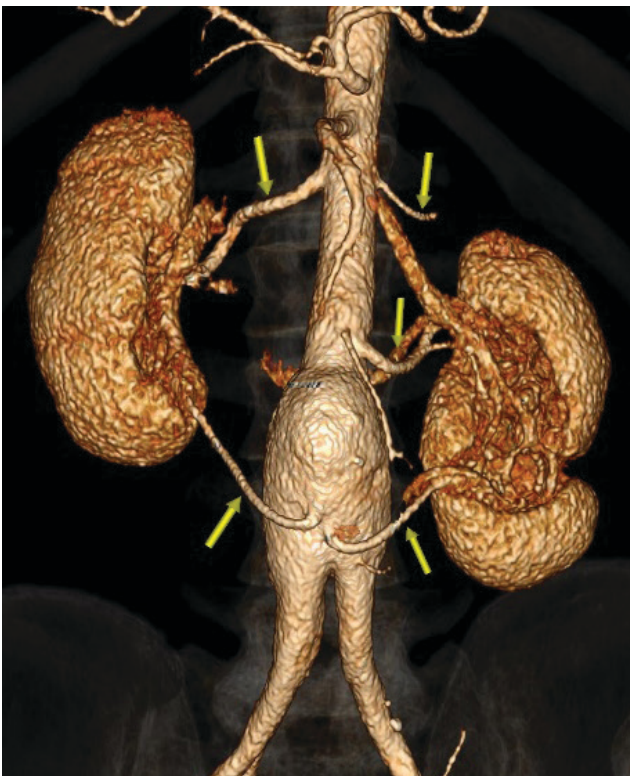
Unlike peripheral aneurysms, complete acute or chronic AAA thrombosis is unusual. However, if AAA thrombosis occurs, EVAR is not feasible. (32) OR is the only option for these patients.

### ABDOMINAL AORTIC ANEURYSMS WITH ASSOCIATED ACCESSORY RENAL ARTERIES

Current guidelines recommend that accessory renal arteries with diameter larger than 3 mm should be preserved during open and endovascular repair of AAA. (17, 33) On the other hand, EVAR very often requires covering of accessory renal arteries to achieve an adequate proximal landing zone. It is always followed by partial renal infarction, which is not accepted and recommended in patients with preexisting renal failure. (34) OR provides an optimal exposition of accessory renal arteries and their preservation (reattachment). Due to this, in a vast majority of cases OR is a method of choice for the treatment of AAA with associated significant accessory renal arteries. (35, 36)



**Figure 4.** Complete thrombosis of the abdominal aortic aneurysm that disables EVAR.



**Figure 5.** MDCT angiography presents the infrarenal aorta with two normal and three accessory renal arteries. Two of them originate from the AAA.

### LATE OPEN SURGICAL CONVERSION AFTER ENDOVASCULAR ANEURYSM REPAIR

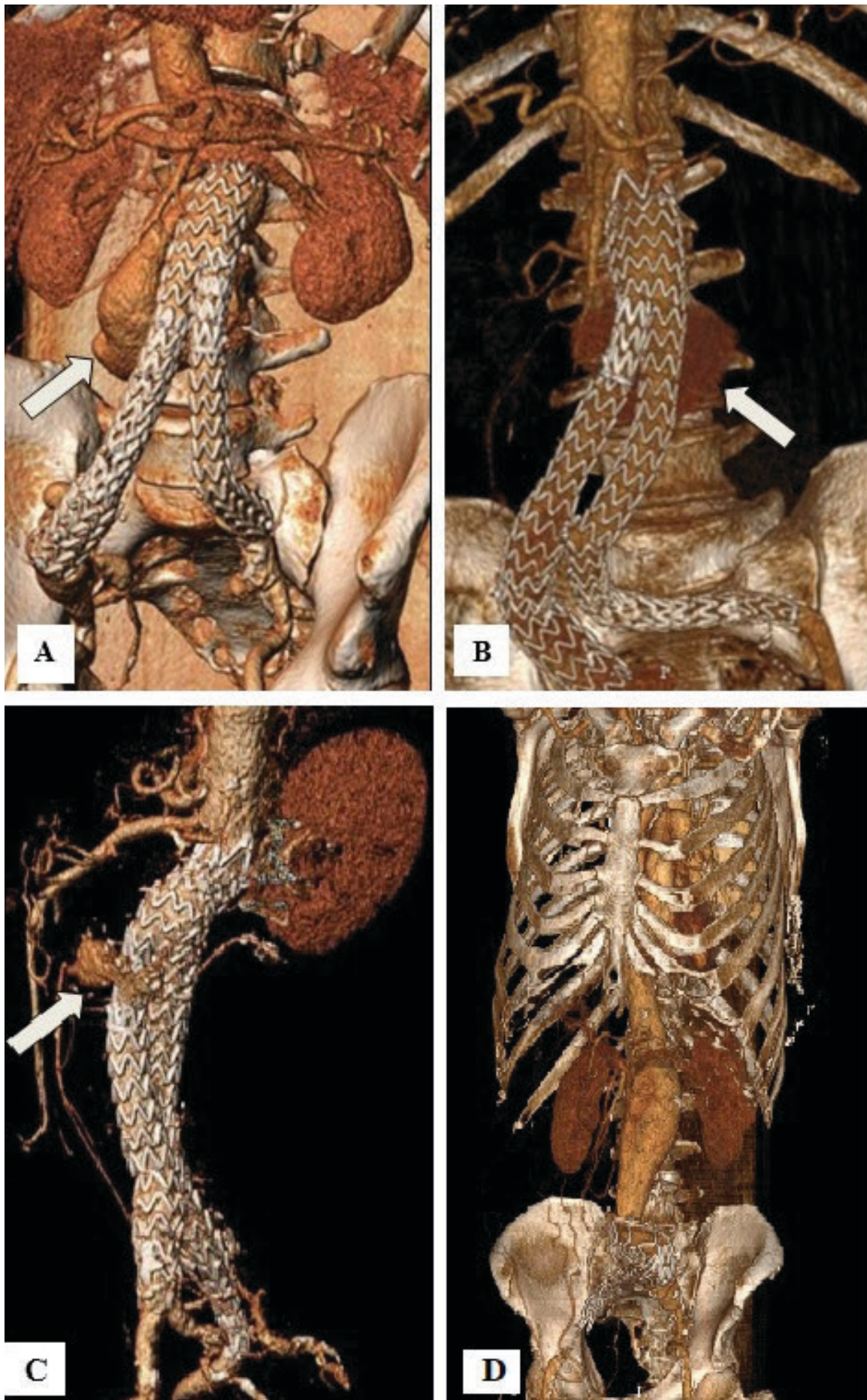
Some long-term complications after previous endovascular aneurysm repair require late open surgical conversion (LOSC). (12) To be more precise, different types of endoleaks, stent-graft collapse, migration and infection, as well as late rupture of the aneurysmal sac are indications for LOSC after EVAR. At the same time, endoleak type I with aneurysm enlargement, aneurysm enlargement without endoleak, collapse, migration and infection of the thoracic stent-graft, distal aneurysm formation and finally secondary AEF and APF, mostly require LOSC after TEVAR. (14)

However, LOSC after both EVAR and TEVAR is associated with significantly higher perioperative mortality and other very serious perioperative complications in comparison with primary OR of TAA and TAAA. (12, 14, 37)

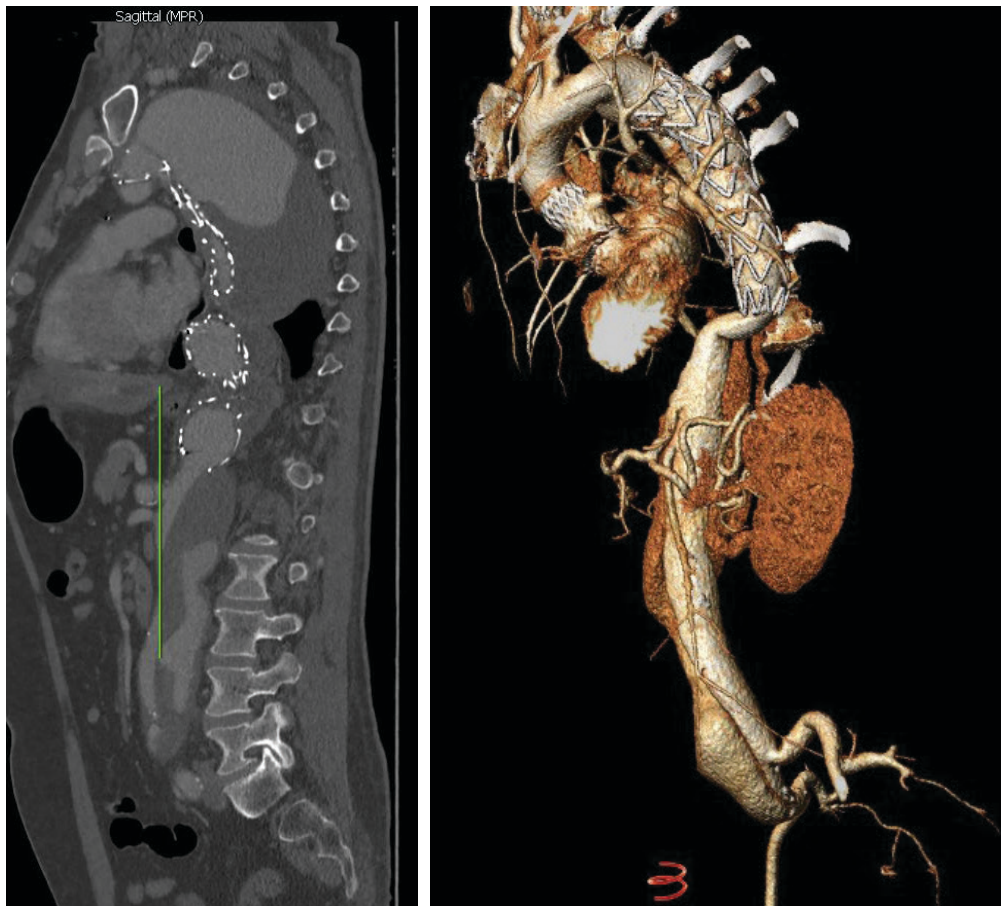
### RUPTURED ABDOMINAL AORTIC ANEURYSMS

Multicenter randomized controlled trials (RCT) did not find a significant difference regarding 30-day mortality between open and endovascular repair of ruptured AAA (AJAX trial: EVAR-21%, OR-25% (38), IMPROVE trial: EVAR-35% (39), OR-37%; ECAR trial: EVAR-18%, OR-24% (40)). This has also been confirmed with the most recently published Japanese national study. (41) Apart





**Figure 6.** MDCT angiography presents (A) endoleak type I; (B) endoleak type II; (C) endoleak type III; (D) stent graft migration after EVAR.



**Figure 7.** MDCT angiography presents (left) the collapse of the thoracic stent graft; (right) distal aneurysm formation after TEVAR.

from that, the majority of vascular surgeons believe that EVAR is the first treatment option for the majority of patients with ruptured AAAs. However, not all ruptured AAAs are suitable for endovascular repair.

A significant number of patients with ruptured AAA is in hemodynamic unstable condition, and if not treated immediately upon admission, more than 80% will die within two hours. (42) In some cases, there is not enough time to perform MDCT angiography, and yet, without it, EVAR is not possible. (43) These patients should be treated after duplex ultrasonography confirmation of ruptured AAA. OR is the only option in such circumstances.

According to IMPROVE trial, 30-day mortality after EVAR in relatively hemodynamic stable patients with good aortic anatomy is 25%, but this group represents only 60% of patients with RAAA. (39) At the same time, long-term mortality and complications after endovascular repair of ruptured AAA are associated with unfavorable anatomy. (44)

Abdominal compartment syndrome after both open and endovascular repair of ruptured AAA is associated with high mortality. (45, 46) Owing to surgical evacuation and drainage of retroperitoneal hematoma, the incidence of abdominal compartment syndrome after OR is significantly lower compared to EVAR. (47)

## CONCLUSION

With all being said about the importance of OR of aortic aneurysms in endovascular era, the question about how to improve the results still remains. First of all, the hospital volume is an independent predictor of an early outcome after OR of aortic aneurysms. (48, 49) Our Clinic is considered a high-volume center for aortic surgery and owing to this fact, a 30-day mortality after elective OR of AAA has been below 1% in the past few years (50) The most recently published studies confirm that a country-based centralization of AAA treatment also reduced perioperative mortality. (51-53) However, what exactly does the high-volume aortic center mean? Recommendations are different. According to SVS guidelines, an elective AAA OR can be performed at centers with the volume of at least 10 procedures each year and with perioperative mortality of 5% or less. (33) In our opinion, it is impossible to guarantee such a low rate of perioperative mortality with such small experience. Due to this, representatives of our Clinic who participated in writing the current ESVS guidelines insisted on the hospital volume higher than 30 procedures per year. (17)

This article has shown that several groups of patients with aortic aneurysms may benefit from the OR. Due to this, younger generations of vascular surgeons should be educated in standard and complex open aortic surgery.



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## Authors' disclosure of conflict of interests

We have no conflict of interests to declare.

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**Final approval of the article:** Lazar Davidovic, David Matejevic, Ognjen Kostic

**Overall responsibility:** Lazar Davidovic

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## OTVORENA REPARACIJA ANEURIZME AORTE U ENDOVASKULARNOJ ERI

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### Sažetak

Otvorena rekonstrukcija (OR) aneurizme aorte je i dalje relativno mutilantna i rizična procedura kod starijih pacijenata i pacijenata sa komorbiditetima. Od uvođenja EVAR-a zabeležen je značajno manji perioperativni mortalitet. Pored prednosti, endovaskularni tretman ima i nedostatke, zbog kojih OR i dalje ima veoma važnu ulogu u endovaskularnoj eri.

Kod velike većine pacijenata mlađih od 65 godina, zadovoljavajućeg opšteg stanja, sa dugim očekivanim životnim vekom i povoljnom anatomijom, kao i kod pacijenata sa hostilnom anatomijom vrata aneurizme, naslednim poremećajima vezivnog tkiva, potpunom trombozom aneurizme abdominalne aorte (AAA) i potentnom akse-sornom bubrežnom arterijom, OR je prva opcija lečenja u odnosu na endovaskularni tretman. EVAR se preporučuje kao prva opcija lečenja kod pacijenata sa inflamatornim aneurizmama, a OR treba uzeti u obzir samo kod pacijenata koji su zadovoljavajućeg opšteg stanja, sa inflamatornom AAA i značajnom hidronefrozom. Kasna otvorena hirurška konverzija (LOSC) je zabeležen događaj nakon endovaskularnog tretmana i povezan je sa

značajno većim perioperativnim mortalitetom i drugim ozbiljnim perioperativnim komplikacijama u poređenju sa primarnim OR. Multicentrična randomizovana kontrolisana ispitivanja (RCT) nisu pronašla značajnu razliku u pogledu 30-dnevnog mortaliteta između otvorene i endovaskularne reparacije rupturane AAA. Međutim, nisu svi pacijenti sa rupturiranom AAA kandidati za endovaskularnu proceduru. Kod hemodinamski nestabilnih pacijenata, kada nema vremena za MDCT angiografiju, EVAR nije moguć i OR je jedina opcija. Incidenca sindroma abdominalnog kompartmenta posle OR je značajno niža u poređenju sa EVAR-om zahvaljujući hirurškoj evakuaciji i drenaži retroperitonealnog hematoma.

Poboljšanje rezultata lečenja aneurizme aorte u velikoj meri zavisi od obima godišnjih operacija aorte. Imajući u vidu sve navedene prednosti i nedostatke OR i endovaskularne rekonstrukcije, možemo zaključiti da bi u centrima velikog obima mlađe generacije vaskularnih hirurga trebalo da se obrazuju iz standardne i složene otvorene hirurgije aorte.

**Ključne reči:** aneurizma aorte, endovaskularni tretman, EVAR, otvorena hirurgija aorte

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