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REVIEW PAPERS

ENDOVASCULAR ANEURYSM REPAIR OR OPEN ANEURYSM REPAIR FOR THE TREATMENT OF ABDOMINAL AORTIC ANEURYSM – THE LATEST UPDATE

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Abdominal aortic aneurysm (AAA) is a segmental dilatation of the abdominal aortic wall with a diameter greater than 3 cm. Approximately 80-85% of cases are located between the renal arteries and the aortic bifurcation (1, 2). AAA is a serious problem in vascular surgery and a lack of proper conduct may lead to the rupture causing fatal bleeding and eventually a very low survival rate of only 10-20% of patients (2, 3, 4). AAA is the 13th leading cause of death in the United States and results in nearly 15,000 deaths each year. Conservative treatment is indicated in the early stages, when the risk of rupture is relatively low. The factors that may reduce the risk of AAA development and its complications include age below 60 years, female sex, smoking cessation, regular blood pressure control, negative family history, loss of weight, the use of beta blockers and statins. However, only properly early diagnosis and appropriate surgical approach significantly improve treatment outcomes (2, 4, 5).

Most cases of AAA are asymptomatic, they are discovered incidentally or diagnosed when rupture occurs. Clinical symptoms, such as abdominal, back, groin, buttock or leg pain are not typical, and bleeding from the ruptured AAA usually leads to hypovolemic shock. In physical examination pulsating tumor of abdomen can be palpable. Abdominal ultrasound is most common diagnostic examination of AAA because of its availability, while more accurate assessment especially when planning surgery provides abdominal computed tomography angiography (2, 6, 7).

The crucial question after the diagnosis of AAA is whether and when to operate. Table 1 shows generally accepted indications for surgery (1, 2, 5, 8, 9, 10).

Over the last several years endovascular aneurysm repair (EVAR) has been frequently used in AAA operations as an alternative to open aneurysm repair (OAR). In Poland, both EVAR and OAR are commonly used to repair AAA because of relatively good outcomes of treatment, but also due to the technical difficulties with videoscopic approach and high cost of robotic system. In the world, 32-74% of pa-

Table 1. Abdominal aortic aneurysm – indications for surgery

Abdominal aortic aneurysm – characteristics
– ruptured
– symptomatic
– diameter over 5–5.5 cm
– widening diameter over 0.5–1 cm per year

tients with AAA repair are undergoing EVAR as it is less invasive and associated with lower rate of complications (11, 12, 13).

Open aneurysm repair (OAR)

Until the introduction of EVAR, OAR was the only method of AAA repair. The operation is carried out under general anesthesia. The transperitoneal approach with a long midline incision is usually done to expose AAA. The intestines are moved to the right and the retroperitoneal space is opened to visualize an aneurysm (fig. 1, 2).

After preparation the common iliac arteries and abdominal aorta, the clamps are placed at the top of and below the aneurysm to temporarily stop the flow of blood. AAA is transected longitudinally on the anterior wall, the mural thrombus is removed and the lumbar arteries, the inferior mesenteric artery are surgically supplied (fig. 3, 4).

A proper sized tubular or bifurcated graft is sutured to the proximal and distal anastomosis by continuous non absorbable monofilament sutures (fig. 5, 6, 7, 8, 9).

The anterior wall of the aneurysm and the retroperitoneal space are shut, the intestines

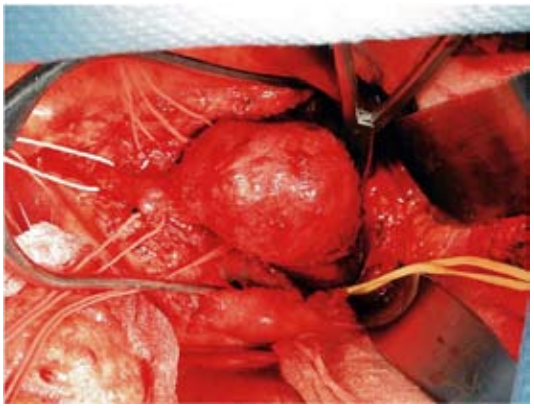

Fig. 1. Abdominal aortic aneurysm – intraoperative view

Fig. 2. Abdominal aortic aneurysm – intraoperative view

Fig. 3. Longitudinally transected abdominal aortic aneurysm on the anterior wall

Fig. 4. Longitudinally transected abdominal aortic aneurysm on the anterior wall

Fig. 5. Graft sutured to the aorta – the proximal anastomosis

Fig. 6. Graft sutured to the aorta – the proximal anastomosis

Fig. 7. Graft sutured to the aorta – the distal anastomosis

Fig. 8. Graft sutured to the aorta – the distal anastomosis

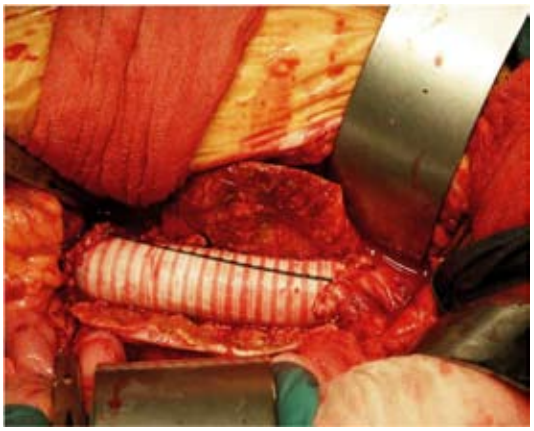

Fig. 9. Graft sutured to the aorta

placed in a natural position, and the abdomen is closed. If OAR is used to repair AAA the patients may develop complications typical for general surgery abdominal operations. OAR is a serious operation which requires postoperative stay in the intensive care unit, however the improvements in patient care, surgical techniques and visceral organ protection have resulted in reduced perioperative risks and improved treatment outcomes. The main systemic complications may include myocardial ischemia, arrhythmia, renal insufficiency, pneumonia, pulmonary embolism, stroke, respiratory failure, sepsis, urinary infection. Most common surgical complications of OAR are wound complications, acute limb ischemia, retroperitoneal bleeding, aortoenteric fistula, intestinal obstruction and ischemia (9, 10, 14).

Endovascular aneurysm repair (EVAR)

Endovascular procedure involves the placement of the stent graft within the lumen of AAA through femoral access. EVAR was first done by Nicholas Volodos in 1987, however the results were first published by Juan Carlos Parodi in 1991. Since then EVAR has been gradually widespread in the world, being less invasive approach to the AAA repair compared to OAR. Endovascular technique is performed under fluoroscopic guidance in an aseptic environment. The procedure may be executed under general, regional or even local anesthesia. Initially two small incisions are usually made in both groin to expose the femoral arteries. Stent graft is introduced into the abdominal aorta through the femoral and iliac arteries using catheters and guidewires. Maneuvers are carried out until positioning it correctly at the top and bottom of the aneurysm. Stent graft is passed through in a long flexible sheath which allows it to be remotely situated within the lumen of AAA. Stent graft comprises a metallic stainless steel or nitinol skeleton covered with an impermeable polytetrafluoroethylene or polyester fabric. The barbs or the other fixing devices of stent graft attach to the artery wall and hold it firmly in place (fig. 10, 11).

Fig. 10. Stentgraft introduced into the abdominal aortic aneurysm – intraoperative angiography

Although EVAR is less invasive surgical technique than OAR, it may caused serious complications.The most common and specific complication is endoleak which is defined as a persistent blood flow outside the lumen of stent graft within the aneurysm sac. Depending on the nature there are five types of endoleak which are presented in tab. 2.

Local wound complications in the groin include bleeding, hematoma, seroma, infection, lymphocele. Pseudoaneurysm, arterial thrombosis and acute limb ischemia can also occur after EVAR. Infection or occlusion of stent-graft, bowel ischemia are rare complications. Iatrogenic rupture is a serious complication but fortunately also rare after EVAR. Renal impairment can be caused by toxic effects of the iodinated contrast media or coverage of a renal artery through the stent graft. In the first case renal function after endovascular procedure usually returns to normal spontaneously. Other systemic complications presented in OAR may be manifested in EVAR as well (15, 16, 17, 18, 19, 20)

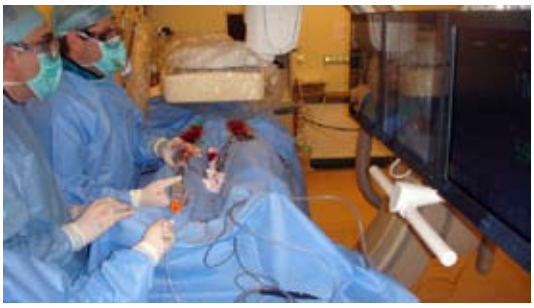

Fig. 11. Endovascular aneurysm repair (EVAR)

Endovascular aneurysm repair (EVAR) versus open aneurysm repair (OAR) – the latest reports

EVAR of AAA is less invasive treatment alternative to OAR which can be performed with avoidance of general anaesthesia. It is less traumatic and causes less perioperative pain. Potential benefits of EVAR cover shorter hospital length of stay, reduced perioperative morbidity and mortality have been reported (19, 20, 21, 22, 23). On the other hand, more frequent re-interventions have been noticed for EVAR and short-term outcomes advantages were lost within long-term observation (19, 20, 21, 24). Perioperative morbidity and mortality are understood in the text as a short-term outcomes within 30 days after operation. The knowledge about both methods of AAA repair was updated during the last years of supervision.

In the United States

Mohan et al. analyzed 42,126 patients with ruptured AAA in the United States from 2001 to 2010. The results of the study demonstrated reduced perioperative mortality (25.9 versus 39.1 %, $p < 0.001$) and shorter hospital

Table 2. Types of endoleak after endovasular aneurysm repair (EVAR)

Type	Definicja / Definition
I	Blood flow into the aneurysm sac is caused by incorrect seal at the proximal or distal end of the stent graft
II	Retrograde flow into the aneurysm sac with side branches of aorta, such as lumbar arteries or the inferior mesenteric artery
III	Blood flow into the aneurysm sac is caused by holes, defects, or separations in the stent graft material
IV	Blood flow into the aneurysm sac due to porosity wall of the stent graft
V	Enlarged diameter of aneurysm sac without identified cause

stay (10.4 versus 13.7 days, $p < 0.001$) after EVAR compared to OAR. Importantly, both parameters have shown steady improvement with time the length of experience in EVAR. Perioperative mortality (41.3 – 25.8%, $p < 0.001$) and mean length of hospital stay (11.8 – 9.7 days, $p < 0.01$) after endovascular procedure reduced steadily over the study period. Regardless of the method of AAA repair, mortality was higher in women compared to men (EVAR 32.2 versus 24.1 %, $p < 0.001$; OAR 46.2 versus 36.9 %, $p < 0.001$) (25). Thomas et al. assessed short-term outcomes of endovascular technique as compared to OAR in both elective and ruptured AAA operations. In the analysis of 37,781 patients significantly lower perioperative mortality and myocardial infarction rates were reported in EVAR. Also, the mean length of hospital stay after both, elective and ruptured AAA repairs was lower in EVAR (12). Dua et al. analyzed 101,978 patients with AAA over the period of 11 years. For both elective and ruptured AAA, EVAR was associated with a lower perioperative mortality rate compared to OAR (4% versus 1% for elective and 41% vs 27% for ruptured, $p < 0.001$ for each) (11). One of the latest study assessed long-term outcomes of EVAR versus OAR in 9-year observation in the patients following AAA repair. Analysis of 23,670 cases revealed improvement of short-term outcomes in endovascular procedure, lower rates of perioperative mortality, readmission, surgical site infection, pneumonia and sepsis. EVAR was independent prognostic factor of better survival in the 3-year observation. However was no significant difference in long-term survival between both methods of AAA repair over the entire study period and after 3 years even EVAR was associated with higher mortality (hazard ratio, 0.99; 95% CI, 0.94 -1.04; $p = 0.64$). Moreover endovascular method was also related to higher rate of re-interventions and AAA late ruptures (26).

In Asia

Although endovascular technique is currently preferable, OAR remains a valid procedure for AAA repair in Japan.Takagi et al. compared EVAR and OAR outcomes in the analysis of short- and long-term survival in 56 826 patients with ruptured AAA. In the study no statistically significant difference were found between both methods in perioperative mortality and long-term survival (27). In other report from Asia comparing a group of 57.1% patients with the ruptured AAA undergoing EVAR and 42.9% treated with OAR, no differences in short-term mortality rate ($p = 0.201$) was noted (28). Hiromatsu et al. evaluated treatment outcomes of OAR in the pre-endovascular time and during the EVAR era for elective AAA repairs. There were two groups of patients, who underwent OAR from January 2004 through November 2006 (pre-EVAR era) and from December 2006 through June 2010 (EVAR era). The results showed similar and relatively low perioperative morbidity and mortality patterns in both groups. The proportion of EVAR in the EVAR era for the elective AAA repair reached 43.4% (29). Morisaki et al. observed significantly lower rate of perioperative cardiac complications (OAR 5.6% versus EVAR 0%, $p < 0.01$) and shorter mean length of hospital stay (OAR 18.6±1.6 days versus EVAR 10.3±0.8 days, $p < 0.05$) after endovascular procedure in the patients over 80 years of age with elective AAA. However there were no differences in the perioperative mortality between endovascular procedure and open repair surgery (EVAR 0% versus OAR 1.1%, $p = 0.43$) for this group of patients. The rate of re-interventions was higher after the endovascular aneurysm repairs (OAR 0% versus EVAR, 5.1%, $p < 0.01$) (30).

In Europe

Randomized controlled trial was performed to evaluate whether EVAR versus open repair diminishes perioperative mortality for the patients with ruptured AAA. In the study, perioperative mortality rate was 36.4% in the endovascular strategy group and 40.6% in the patients who underwent open repair ($p=0.31$). More patients after EVAR than OAR had shorter mean length of hospital stay, respectively 17 days versus 26 days ($p < 0.001$). No significant reduction of perioperative mortality in the patients with ruptured AAA treated with endovascular repair was observed (31). In the follow-up observation of these patients for one year after surgery all-cause mortality

was 41.1% in the endovascular strategy group and 45.1% in the open repair group, odds ratio was 0.85 (95% confidence interval 0.62 to 1.17, p = 0.325) with similar re-intervention rates in each group. Patients surviving rupture had better quality of life in the endovascular strategy versus open repair groups at 3 and 12 months (32). These two trials did not reveal a survival benefit of EVAR for the treatment of the ruptured AAA within 30 days and at 1 year after operation compared to OAR but showed improved quality of live and reduced mean length of hospital stay in the endovascular group (31, 32). In the study of Badger at al. no relevant advantages in short-term outcomes for endovascular repair of the ruptured AAA were revealed and the perioperative mortality was comparable for the both methods, with odds ratio 0.91 (95% confidence interval 0.67 to 1.22, p = 0.52) (33). In the study conducted in the Netherlands, the investigators evaluated the same parameters in the patients with the ruptured AAA but the analysis included also long-term outcomes. According to Van Beck et al., the five years survival rates were similar 36% for EVAR and 38% for OAR (p = 0.83). The rates of freedom from re-intervention were 55% for endovascular procedure and 60% for open repair (p=0.96) but in the patients who survived their hospital stay the re-intervention rate was higher for EVAR than for OAR (p < 0.01) (34). Raats et al. reported that the perioperative mortality was low and without significant difference for both methods, reaching 30% in the EVAR group compared to 26% after OAR (p = 0.64). No difference in mortality was observed between EVAR and OAR over 5 years of follow-up. There were more cardiac complications in the OAR group than in the EVAR group, being 31% versus 9% (p = 0.035), respectively. Re-intervention after discharge was more frequent in the patients following EVAR 35% than after OAR 6% (p < 0.001). Advanced age of the patients was associated with significantly increased mortality in the OAR group (35).

These observations concerning the treatment of ruptured AAA are contrary to the previous reports, where short-term results were better for EVAR. According to them perioperative mortality in emergency OAR remained at nearly 50% and emergency EVAR was related with a lower perioperative mortality rate of about 30% (36, 37, 38). Only one of the recently found reports about management of the ruptured AAA noted still significantly lower short-term mortality in endovascular procedure (EVAR 21.6% versus OAR 29.6%, p < 0.01) (39).

Pol et al. analyzed short-term outcomes after elective EVAR in the group of 926 (77%) patients, aged <80 years, and 274 (23%) ≥ 80 years. They observed that the elderly patients were more frequently operated under general anesthesia (p = 0.028). Procedure duration was longer in this group (p = 0.01) and mean length of hospital stay increased (p < 0.01). Nevertheless endovascular procedure had a high technical rate of success and perioperative morbidity and mortality rates were similar in both groups (p = 0.835 and p = 0.186, respectively). There was no difference in the number of re-interventions at 30 days. However, perioperative quality of life became worse and recovery was slower in the elderly patients (p = 0.003) (40). Saratzis et al. reported on harmful acting of EVAR for renal function in the long-term observation. Endovascular procedure is related with a significant decline in glomerular filtration rate (GFR) after 5 years, which is steeper in the first postoperative year (41). One of the studies conducted in Great Britain searched for the best option of elective AAA repair for the young patients at low perioperative risk. Perioperative mortality and complication rates were relatively low and similar for both methods, respectively 1% and 15% for open repair, 0% and 12% for endovascular procedure. The nature of complications differed between the two groups, endoleak more often associated to EVAR while more serious cardiorespiratory complications were demonstrated in OAR. There was a 14% re-intervention rate after EVAR compared with 7% after OAR (42). Long-term outcomes for young patients in other report from Great Britain were similar in elective AAA repair. The 1-year (98% EVAR, 96% OAR), 5-year (86% EVAR, 88% OAR), and 10-year (54% EVAR, 75% OAR) survival did not differ between EVAR and OAR (p = 0.16). There were also no differences in overall long-term survival (78% EVAR, 85% OAR, p = 0.90) and re-intervention rates (12% EVAR, 16% open repair; p = 0.80) (43). In the prospective randomized controlled trial Paravatsu et al. reported significantly lower short-term mortality following EVAR than OAR for

elective AAA repair, being 1.4% versus 4.2% ($p < 0.0001$), respectively. However, no significant difference was found in mortality at intermediate follow-up (up to four years since randomization), with 15.8% and 17% deaths in the EVAR and OAR groups, respectively ($p = 0.40$). There was also no significant difference in long-term mortality (beyond four years), with 37.3% deaths in the EVAR and 37.8% deaths in the OAR group ($p = 0.78$). The long-term re-intervention rate was significantly higher in the EVAR group than in the OAR group ($p = 0.02$). Perioperative complications rate and quality of life were generally comparable between the EVAR and OAR groups. Nevertheless, there was a slightly higher incidence of pulmonary complications in the OAR group compared with the EVAR group ($p = 0.006$) (44).

The latest comparison of both methods of treatment for the elective AAA from Poland revealed advantages of short-term and mid-term outcomes in the EVAR. Perioperative and 1-year mortality rates in the patients treated in the elective setting were 1.5% and 8.7% for endovascular method, while 4.0% and 15.7% for the open repair, respectively (45).

Laparoscopic approach and robots technique

Although laparoscopy has become an alternative approach to AAA repair, due to the

required advanced videoscopic practice with a long learning curve, the use of the method remains limited. Videoscopic approach is confined to centres with a specific expertise in laparoscopic AAA repair (10, 46, 47). However laparoscopic surgery of AAA is performed in some vascular surgery centers in the world with relatively low perioperative complications and mortality rates comparable with EVAR (46, 47, 48). Robotic systems improve imaging of the operative field and surgeon's skills during videoscopic surgery and therefore simplify the performance of this technique. During the procedure AAA is replaced by graft through a videoscopic retroperitoneal approach using robot system (49). Sedivy et al. compared the routine methods of AAA repair to 64 cases of patients operated by robot-assisted. Perioperative mortality rate in OAR, EVAR and robotic groups were 1.7%, 1.5% and 0.4%, respectively (13) However, robot-assisted techniques for AAA repair require high cost, learning curve and increased operating time, but the outcomes of treatment may be encouraging. In addition to this, the robotic navigation systems have been applied in phantom and animal studies in EVAR. Their benefits, such as improving aortic vessel cannulation, reduce fluoroscopy time, radiation doses and contrast volumes require clinical trials confirming advantages of robotic navigation technologies in endovascular procedure for AAA repair (50).

Conclusions

The article compared recently published results of the studies on the use of EVAR versus OAR in the management AAA. The reports from the United States revealed significantly better short-term outcomes for the patients operated by endovascular technique (11, 12, 25). EVAR should be a preferred method of surgical treatment of both elective and ruptured AAA (11). However, in long-term observation both methods of AAA repair were comparable (26). The latest outcomes reported from Asia have not identified significant difference between the EVAR and OAR (27, 28, 30). Apart from this both methods were used with similar frequency (27, 29). The studies conducted in Europe did not reveal significant difference between EVAR and OAR used for the treatment of ruptured AAA in the short-term outcomes (31, 33, 35). Moreover, for the patients undergoing elective operations of AAA and emergency procedure for the ruptured AAA relatively low rate of perioperative mortality and well long-term survival were reported for both methods of treatment (31, 33, 35, 42, 43, 45). In view of technical difficulties in videoscopic approach with a long learning curve and high cost of robotic system, EVAR or OAR remain routine methods used for AAA repair in the world.

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