Am J Cardiovasc Dis 2023;13(3):192-201
www.AJCD.us /ISSN:2160-200X/AJCD0146989

Original Article

Comparative study of the consequences of abdominal aortic aneurysm repair surgery using open and endovascular surgical methods

Seyyed Mostafa Zia Ziabari[1], Hossien Hemmati[1], Emad Khalili Sabet[2], Sheyda Rimaz[3], Mohammad Sadegh Esmaeili Delshad[1], Aryan Rafieezadeh[4], Siamak Rimaz[5], Daniel Rahimi Nejat[3], Zohre Darabipour[6]

[1]Department of General Surgery, Razi Clinical Research Development Unit, Razi Hospital, Guilan University of Medical Sciences, Rasht, Guilan, Iran; [2]Razi Clinical Research Development Unit, Razi Hospital, Guilan University of Medical Sciences, Rasht, Guilan, Iran; [3]Burn and Regenerative Medicine Research Center, Guilan University of Medical Sciences, Rasht, Guilan, Iran; [4]School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran; [5]Anesthesiology Research Center, Department of Anesthesiology, Alzahra Hospital, Guilan University of Medical Sciences, Rasht, Guilan, Iran; [6]Deputy of Research and Technology, Guilan University of Medical Sciences, Rasht, Guilan, Iran

Received October 13, 2022; Accepted June 11, 2023; Epub June 25, 2023; Published June 30, 2023

Abstract: Background: Abdominal aortic aneurysm (AAA) is a life-threatening condition. Open surgery and endovascular repair are the options for treating AAA. This study aimed to compare the frequencies of in-hospital complications and outcomes in two groups of patients who underwent AAA repair surgery using either an open or an endovascular repair method. Methods: This retrospective study was conducted on the records of 60 patients with AAA undergoing elective surgery repair using endovascular approaches or open surgery at Razi Hospital from 2010 to 2019. Patients' related information, including age, sex, changes in blood pressure, respiratory complications, renal complications, myocardial infarction, paraplegia, cloneischemia, lower limb ischemia, duration of hospital stay in intensive care unit and hospital, the dose of packed RBC, the dose of injectable narcotic analgesics, the need for vasopressor medication, duration of surgery, duration of postoperative oral feeding, and death during hospitalization were assessed. Results: A total of 60 patients in two groups were studied. The mean age of patients was 72.4 ± 6.28 years, and most were male (86.7%). The incidence of renal complications (3.3%) and respiratory complications (0%), rate of decrease in arterial blood oxygen saturation, length of stay in ICU (median 2 vs. 4) and hospital (median 4.5 vs. 7), the need for vasopressor injection and the dose of packed RBC (median 0.4 vs. 3.33), the dose of narcotic analgesic injection (53.3%), duration of surgery (median 2.5 vs. 3), duration of postoperative oral feeding (median 23 vs. 54), and the incidence of death were significantly lower in the endoscopic surgery group. Conclusion: Endovascular surgery repairing the rupture of an AAA is associated with fewer postoperative complications and in-hospital death than open surgery.

Keywords: Abdominal aortic aneurysm, endovascular surgery, complication

Introduction

The aortic artery is the largest vessel in the body that carries blood from the heart to the systemic bloodstream. An abdominal aortic aneurysm (AAA) is a condition in which the diameter of the abdominal aortic artery is greater than 30 mm or more than 50% of normal size. Aortic aneurysms are often asymptomatic and characterized by the initial appearance of acute rupture or dissection of the target aneurysm, which is very life-threatening [1-4]. Rupture of the AAA is a medical emergency and is one of the most important causes of death before reaching the hospital [3, 5]; and is associated with a high mortality rate despite immediate surgical intervention.

Open surgery and endovascular repair are the two standard treatment methods for the AAA. Numerous studies have been conducted to select the preferred surgical method; however, they have yet to be confirmed superior to these two methods. Introducing elective surgery to

repair an AAA remains challenging [6]. Reconstructive surgery with an endovascular approach is used in cases with aortic dissection rupture, elective repair of AAA, and traumatic vascular injuries [7]. This procedure is performed on parts of the aorta at moderate risk for open surgery. It is effective in patients needing to clamp the aorta above the renal arteries for surgery. But it is less preferred in patients older than 85 years, patients with aneurysms smaller than 6 cm, and cases with a short-neck aneurysm [8]. Ultimately, the choice of open or endovascular surgical approach depends on the surgeon's diagnosis and the patient's consent. Indications for endovascular AAA repair are expanding to include anatomically challenging and complex aneurysms [9]. Also, endovascular repair is a preferred method with minimal intervention in patients at high risk for surgery due to comorbidities or old age. However, deciding on the open ventricular anatomy is important to repair AAA surgery. To perform this operation endovascularly, the patient's intravascular anatomy and aortoiliac morphology should be considered [10].

The surgeon's criteria for selecting the endovascular AAA repair include the appropriate anatomy according to the specified indications, the patient's underlying diseases, and the patient's ability to pay for this surgery. In cases when the surgeon cannot perform endovascular surgery due to the above factors, if the underlying diseases are not preventable, AAA repair is performed for the patient by open surgery. In such cases, it was evident that the patient must have one of the indications for this type of operation, including asymptomatic AAA more than 5.5 cm in diameter in men and more than 5 cm in diameter in women, AAA rapidly increasing in size (more than 5 mm in 6 months), and symptomatic AAA of any size [10]. Varying results have been reported regarding the difference between the incidence of postoperative complications and the survival rate of patients after AAA repair using endovascular and open surgeries. On the other hand, the need for surgical re-intervention in patients who underwent surgery with an endovascular approach is more than in patients who underwent open surgery. These interventions are mainly due to endocardial displacement or aneurysm rupture [11-13], which are more common in people with a history of vascular disease [14]. On the other hand, no significant difference was found in the frequency of the need for re-intervention or its causes between the two methods [15, 16].

AAA and its rupture is a relatively common and life-threatening condition. Despite extensive advances in surgical treatment approaches, the conflicting results between studies make the selection of the preferred and cost-effective method with minimal complications and consequences challenging. Therefore, this study was designed to identify and compare the complications and outcomes of AAA repair surgery using both open and endovascular methods. The endovascular method is performed at limited vascular surgery centers in Iran, and Razi Educational and Medical Center is the only endovascular surgery center in Guilan province. This study was designed to compare the frequency of in-hospital complications and outcomes of patients undergoing AAA repair using open and endovascular repair and to analyze the results of this comparison for the first time in Iran. By analyzing the outcomes and their frequency in open and endovascular surgical approaches, specialists can choose an efficient and cost-effective method with minor complications to improve patients' quality of life and reduce the costs imposed on hospitals and insurance.

Methods and material

Study design

This retrospective cohort study was done on the records of 60 patients with AAAs undergoing elective surgery repair using endovascular approaches or open surgery at Razi Hospital, Rasht, the only public hospital for vascular and endovascular surgeries from 2010 to 2019, using an available sampling method.

Inclusion and exclusion criteria

The inclusion criterion was the diagnosis of a stable AAA recorded in patients' records. Exclusion criteria were the death of the patient before surgery, incomplete or unreadable information in the record, and patients who underwent emergency abdominal aortic repair due to rupture of the AAA. Indication for endovascular repair (EVAR) is based on the anatomic features of AAA (Suitable diameter & length of neck and landing zone of aneurysm, amount of Thrombosis & Calcification of neck). Based on

previous data, the indications for open surgery or EVAR are abdominal, back or flank pain, evidence of embolization, frank rupture, asymptomatic aneurysm ≥ 5.5 cm in men and > 5.0 cm in women, rapidly expanding AAA, AAA associated with other arterial disease (especially iliac aneurysm), infected AAA, and complications following endovascular repair necessitating early or late conversion to an open AAA repair [15, 16]. The anatomic features of an AAA are assigned with an analysis of computed tomography (CT) scan with intravenous contrast. We should note that EVAR is easier and more suitable to perform than open surgery.

Ethical confirmation and grouping

After obtaining permission from the Ethics Committee of the Guilan University of Medical Sciences and receiving the ethics code (IR.GUMS.REC.1399.143), and establishing the necessary coordination with Razi Medical Training Center, the researcher referred to the center's archive and the records of eligible patients were classified into two groups, open surgery and EVAR. The grouping basis in this study was randomized allocation to each group. Patients' names were entered into SPSS software, and cases were randomly assigned to each group.

Primary and secondary indicators

Using a researcher-made checklist, we collected patient information. The patient's demographic data, including age and gender were collected at the grouping time. The primary indicators and their assessment methods in this study were:

• Blood pressure changes (an increase in blood pressure to more than 140/90 mmHg or a decrease in systolic blood pressure to less than 100 mmHg).

• Arterial hypoxemia (PaO_2 in room air less than 60 mmHg after surgery or arterial oxygen saturation measured by pulse oximeter less than 90%, need for oxygen therapy, re-intubation after extubation, pneumonia, need for mechanical ventilation for more than 48 hours).

• Renal complications (an increase in serum creatinine greater than 0.5 mg/dl from baseline creatinine).

• Myocardial infarction (an increase or a decrease in cardiac enzyme troponin in the presence of clinical signs of myocardial ischemia or electrocardiogram changes during hospitalization).

• Paraplegia (dysfunction of motor or sensory function in the spinal segment in the thoracic, lumbar, or sacral areas in postoperative clinical examination).

• Ischemic clone (evidence of colon ischemia in colonoscopy or reoperation in patients with severe postoperative abdominal pain, early-onset diarrhea, rectorrhagia, unexplained hemodynamic disturbance, unexplained organ failure or clinical diagnosis of intestinal ischemia treated using pharmaceutical therapy).

• Lower limb ischemia (the emergence of pain after severe lower limb surgery at rest, with no improvement exacerbated by raising the organ or skin discoloration Gangrene and tissue necrosis requiring intervention).

The secondary indicators in this study were duration of ICU and hospital stay, amount of packed RBCs injected, the need for vasopressor medications, including norepinephrine, epinephrine, and dopamine, the dose of narcotic analgesics, including morphine and fentanyl, duration of surgery, duration of oral feeding (interval between end of surgery and start of oral feeding) and outcome of surgery (death or survival).

Statistical analysis

The collected data were analyzed by the SPSS version 22 software. Mean and standard deviation (95% confidence interval) was used to describe quantitative variables with a normal distribution, and for quantitative variables with an abnormal distribution, median and interquartile range were used. Qualitative variables were also described using numbers and percentages. The normal distribution of the quantitative variables in the subgroups was measured using the Shapiro-Wilk test. Comparison of quantitative variables in the studied subgroups considering their normal distribution was made using an independent *t*-test or Mann-Whitney nonparametric test (no normal distribution). For qualitative variables, Chi-squared

Table 1. Comparison of the complications of patients undergoing abdominal aortic aneurysm repair using open and endovascular methods

Complications		Endovascular method	Open method	*P*-Value*
Renal Failure	No	29 (96.7)	18 (60)	0/001
	Yes	1 (3.3)	12 (40)	
Respiratory Complication	No	30 (100)	20 (66.7)	0/001
	Yes	0	10 (33.3)	
Blood pressure changes	No	16 (53.3)	12 (40)	0/301
	Yes	14 (46.7)	18 (60)	
Colon Ischemia	No	30 (100)	29 (96.7)	-
	Yes	0	1 (3.3)	
Myocardial Infarction	No	30 (100)	28 (93.3)	-
	Yes	0	2 (6.7)	

*Chi Square Test.

or Fisher's exact test was used. The level of statistical significance was considered at $P < 0.05$.

Results

Study population

In this study, 60 patients diagnosed with AAAs and undergoing elective surgery using either endovascular or open surgery methods were studied. The mean age of patients undergoing AAA surgery was 72.40 ± 6.28 years (mean: 73.00 years and age range 56-85 years). The mean age of patients undergoing open surgery was higher than those undergoing endovascular surgery (73.13 ± 6.40 vs. 71.67 ± 6.19, respectively); however, this difference was not statistically significant ($P = 0.371$) (**Table 1**). Most (86.7%) patients undergoing AAA repair were male. The percentage of male patients in the EVAR and open surgery groups was 90% and 83.3%, respectively; however, this difference was not statistically significant, and a predominance of male patients was observed ($P = 0.706$).

Common complications

Renal failure was found in 13 patients, of which 12 were related to patients undergoing open surgery. The Chi-squared test showed a statistically significant difference between the patients in the two groups in terms of the incidence of renal failure after AAA repair ($P = 0.001$). Also, 50 patients (83.3%) had no respiratory complications after AAA repair, and 10 (33.3%) patients with respiratory complications after AAA repair belonged to the open surgery group. Therefore, there was a statistically significant difference between the two groups in terms of respiratory complications ($P = 0.001$). Changes in blood pressure were seen in 32 patients, of which 14 (46.7%) belonged to the EVAR group, and 18 (60.0%) belonged to the open surgery group. However, the observed difference was not statistically significant ($P = 0.301$). In the present study, paraplegia and lower limb ischemia were not found in patients undergoing AAA repair in both open and endovascular methods. Acute ischemia and acute myocardial infarction were observed in only 1 and 2 patients undergoing open surgery, respectively (**Table 1**).

ICU parameters

The level of O_2 saturation in the intensive care unit (ICU) in patients undergoing endovascular surgery was significantly higher than in patients undergoing open surgery ($P = 0.018$). According to the results, the length of ICU and hospital stay in patients undergoing open surgery was significantly longer than those undergoing endovascular surgery ($P < 0.001$). The amount of blood transfused during hospitalization was significantly higher in patients undergoing open surgery compared to patients undergoing endovascular surgery ($P < 0.001$). The duration of surgery in patients undergoing open surgery was significantly longer compared to patients undergoing endovascular surgery ($P < 0.001$) (**Table 2**).

In total, 15 patients (50%) needed vasopressor medication in the ICU, and all belonged to the open surgery group. Therefore, the need for vasopressor drugs in the ICU was significantly higher in patients undergoing open surgery ($P < 0.001$). No deaths were reported in endovascular patients. Thus, the incidence of death in patients undergoing open surgery was significantly higher (26.7%) ($P = 0.005$).

Pain managements

The use of narcotic analgesics in patients undergoing open surgery was significantly high-

Table 2. Comparison of the level of O_2 saturation, length of ICU and hospital stay, number of transfused blood units, and duration of surgery in the study groups

Variable	Groups	Number	Median (first quarter-third quarter)	Minimum-maximum	*P*-Value*
Oxygen saturation (%)	Endovascular	30	96.5 (95-97)	90-98	0.018
	Open surgery	30	95 (94-96.25)	90-98	
ICU stay (day)	Endovascular	30	2 (1-3)	1-4	0/001 <
	Open surgery	30	4 (3-5)	1-51	
Hospitalization (days)	Endovascular	30	4.5 (4-5)	3-9	0/001 <
	Open surgery	30	7 (6-8)	3-57	
Blood transfusion (unit)	Endovascular	30	0.4	0.00 (0.00-1)	0.00-4
	Open surgery	30	3.33	2 (2-4)	
Duration of surgery (hours)	Endovascular	30	2.5 (2-3)	2-3	0/001 <
	Open surgery	30	3 (3-3.5)	2.50-4	

*Independent T-Test.

Table 3. Comparison of the use of narcotic analgesics in ICU in patients undergoing abdominal aortic aneurysm repair using open and endovascular surgery

Variable		Endovascular	Open surgery	*P*-Value*
Taking painkillers, number (percent)	No	14 (46.7)	4 (13.3)	0.005*
	Yes	16 (53.3)	26 (86.7)	
Type of narcotic analgesics, number (percent)	Morphine	13 (81.3)	8 (30.8)	0.005**
	Fentanyl	0	6 (23.1)	
	Both of them	3 (18.8)	12 (46.2)	
Morphine, number (percent)	No	14 (46.7)	10 (33.3)	0.292*
	Yes	16 (53.3)	20 (66.7)	
Fentanyl, number (percent)	No	27 (90)	12 (40)	0.001* <
	Yes	3 (10)	18 (60)	

*Chi Square Test. **Fisher's Exact Test.

Table 4. Comparison of the dose of morphine and fentanyl in patients undergoing abdominal aortic aneurysm repair using open and endovascular surgery

Variable	Group	Number	Mean	Median (first quarter-third quarter)	Minimum-maximum	*P*-Value*
Morphine (milligram)	Endovascular	16	12.06	9 (6-20)	3-25	0.002
	Open surgery	20	20.35	24 (12-30)	6-50	
Fentanyl (micrograms)	Endovascular	3	5000	5000 (4000-0)	4000-6000	0.221
	Open surgery	18	5800	6000 (6000-6000)	2000-10000	

*Mann Whitney Test.

er than in those undergoing the endovascular method ($P = 0.005$). There was a statistically significant difference in the type of narcotic analgesic used among 42 patients taking these drugs in the ICU ($P = 0.005$). Considering the need for morphine and fentanyl in patients undergoing AAA repair, the observed dose of fentanyl administration was significantly higher in the open surgery group ($P < 0.001$) (**Table 3**). Patients undergoing open surgery received significantly more morphine in ICU than those undergoing endovascular surgery ($P = 0.002$). There was no statistically significant difference in the dose of fentanyl administration in the ICU between patients undergoing open and endovascular surgery ($P = 0.221$) (**Table 4**). The interval between the end of surgery and the start of oral feeding was assessed in 52

patients undergoing AAA repair and was found to be significantly longer in patients undergoing open surgery compared to patients undergoing endovascular surgery (median 54 vs. 23) ($P < 0.001$).

Discussion

The rupture of the AAA is a life-threatening medical emergency and an important cause of death before reaching the hospital [4]. Today, open surgery and endovascular repair are commonly used to treat AAAs. Although several studies have been conducted to find the most suitable surgical method of all methods used worldwide, none of them has been confirmed to be superior to the methods discussed in this study, and the introduction of elective surgery to repair an AAA remains a challenge. Therefore, this study compared the frequency of in-hospital complications and outcomes of two groups of patients undergoing elective AAA repair using open or endovascular methods. The mean age of patients was 72.4 ± 28.6 years (range 56-85 years), and the mean age of patients in the open surgery group was more than the EVAR group. The incidence of AAAs in developed countries is estimated at 2%-8% and is more common in men (4%-8% in men over 50 years of age) than in women (1%-1.3%) [17, 18]. It has been reported that 86.7% of patients were male, and in both groups, a predominance of male patients was observed, which may be due to the higher incidence of the disease in men. However, no significant difference was found in terms of the gender ratio between the two groups.

The prevalence of renal failure was 3.2% in the EVAR group and 40% in the open surgery group, indicating that the incidence of postoperative renal failure after open surgery was significantly higher. This can be due to several factors, including reduced blood flow to the kidneys as due to aortic clamping in open surgery, ischemic injuries, restoration of blood flow after aortic decompression, blood loss during surgery or fluid shifts to the extravascular space, and embolism to the renal arteries [19]. Respiratory complications were found in 33.3% of cases in the open surgery group, while none of the patients operated by the endovascular method had this type of complication; thus, the prevalence of respiratory failure complications in the EVAR group was significantly lower. Also, the percentage of arterial oxygen saturation in patients admitted to the ICU in the EVAR group (95%-97%) was significantly higher than the open surgery group (94%-96.25%) ($P = 0.018$), which may be because of following open aortic aneurysm repair, excessive postoperative pain after surgical incision in the abdomen or sternotomy (following thoracic aortic aneurysm repair) may limit the patient's ability to cough and breathe deeply. As a result, respiratory complications, such as pulmonary atelectasis and pneumonia, following open surgery occur more frequently than endovascular methods [20]. Patients undergoing open AAA repair surgery should be intubated and transferred to the ICU after surgery to manage their ventilation [21]. In the vascular surgery ward of Razi Educational and Medical Center, where our research was conducted, all patients are mechanically ventilated for 24-48 hours after open aortic aneurysm repair surgery and during the transfer to the ICU as routine respiratory support. In this regard, it has been shown that early extubation (removal of the endotracheal tube) in patients whose aortic clamping time is more than 30 minutes during surgery, in patients with below normal basal lung function, or in patients who need a high amount of crystalloid fluid or packed cells during surgery is associated with increased respiratory complications and the risk of death after surgery [20].

In the present study, changes in blood pressure above a diastolic blood pressure of 140.90 mmHg or below a systolic pressure of 100 mmHg were recorded after surgery, which was found to be 46.7% in the EVAR group and 60% in the open surgery group. However, a higher prevalence of postoperative hypertension was observed in patients in the open surgery group. This could be due to a large incision made in this method and more postoperative pain in the patient, which at times is not managed correctly. On the other hand, none of the patients who underwent endovascular aneurysm repair reported hypotension and, consequently, did not receive vasopressor medication, which could be due to myriad factors, such as the absence of excessive bleeding during surgery, among others. In addition, clamping the aorta during open surgery causes a large shift of fluids into the extravascular space, which is an important factor leading to hypotension after the surgery.

This study recorded changes in blood pressure above a diastolic pressure of 140 mmHg or below a systolic pressure lower than 100 mmHg, including postoperative low blood pressure and hypertension. On the other hand, many patients who underwent surgery had a history of hypertension due to chronic comorbidities and old age, which was not adequately managed. Therefore, many patients in both groups had higher-than-normal blood pressures before and even after successful surgery, which were recorded as abnormal blood pressure changes according to our considered criteria. Accordingly, although the incidence of postoperative hypotension and the need for vasopressor following open surgery were significantly higher, the reason for no significant difference in postoperative blood pressure changes between the two groups was a blood pressure higher than normal in patients in the EVAR group after surgery.

Regarding the need for vasopressors, none of the patients in the EVAR group received vasopressors. However, 50% of patients undergoing open surgery received at least one vasopressor drug ($P < 0.001$), which can be due to factors such as the absence of excessive bleeding as this method is less invasive, and there is no need to clamp the artery and hence no associated complications. The average duration of ICU and hospital stay in the EVAR group was about two days (mean and median of 2 days), which was significantly lower than patients undergoing open surgery with an average hospital length of stay of 4 days (according to the median number reported) and an average ICU stay of 2.5 days. Patients who underwent endovascular surgery had an average (median) hospital length of stay of 4.5 days and a mean length of stay of 4.8 days, and the maximum length of hospital stay in this method reached 9 days. However, the median length of hospital stay in patients undergoing open surgery was 7 days with a mean of 8.4 days; in one of the patients, due to ischemic colon, after open surgery and laparotomy and also due to the length of weaning the patient from the mechanical ventilator, this number reached 57 days ($P < 0.001$). Bjork and Ulug in 2017 and Patelis in 2016 also showed that the length of ICU and hospital stay in the EVAR group was significantly shorter than the open surgery [22-24].

In terms of the need for packed cell injection and the injected units during hospitalization, patients in the open surgery group received a significantly higher amount of blood ($P < 0.001$), which can be due to the further reduction of patients' intravascular volume in the open surgery because of the loss of more blood during surgery or the transfer of body fluids to the extravascular space due to aortic clamping. Patelis, in 2016, also showed that the need for packed cell units in patients undergoing endovascular surgery was significantly less than in patients who underwent open AAA repair [23]. Open surgery is more time-consuming than the endovascular procedure because of the large incision and closing of a surgical incision at the end of surgery and the time required for the surgeon to perform vascular anastomoses. The duration of surgery in the EVAR group was significantly shorter than the open surgery group ($P < 0.001$).

In terms of death during hospitalization, none of the patients in the EVAR group died during the study and hospitalization. However, 26.7% of patients in the open surgery group died during this period, which was a statistically significant difference ($P < 0.005$). In this study, the mortality rate of patients who underwent open surgery was higher than in other reports, including that of Rigberg and colleagues [25] in 2006 (mortality after open surgery was 19% vs. 26.7% in our study), and also higher than patients undergoing endovascular surgery (zero percent vs. 26.7%). This may be due to the fact that open or endovascular surgery was not selected randomly before the surgery for AAA repair. Patients were selected according to the following criteria: economic status of patients to pay a high cost of grafts for the endovascular method, the possibility of preparing the graft by the surgeon and its availability during the surgery, and complexity of the aneurysm in terms of its type and anatomical features; many patients underwent open surgery despite initially being considered a good candidate for endovascular surgery.

These factors may have played an essential role in increasing the mortality rate of patients after open surgery in this study. On the other hand, because the Razi center is the only referral center for vascular surgery in the north of Iran, many patients who are referred to this

center and are candidates for AAA repair are those with complex surgical conditions and also at high risk for surgery, which can be another factor for a high mortality rate of patients following open surgery found in our study. It should be noted that the observed difference in the mortality rate of patients undergoing open and endovascular surgery in our study was not only due to the difference in the surgery method but can also be because some patients who underwent open surgery and died following surgery were initially candidates for endovascular surgery, but due to some financial issues related preparing the required grafts, they were subjected to open surgery. In addition, due to the complex anatomy of the AAA, in some patients, the aneurysm repair was not possible by the endovascular method. It was subjected to open surgery and subsequently suffered postoperative complications, including death following surgery.

In this study, the patients were evaluated for the need to take analgesics. The dose of analgesics received in the open surgery group was 81.3% higher than in the EVAR group ($P < 0.005$). Also, 53.3% of patients in the EVAR group received morphine or both morphine and fentanyl analgesics, but none received fentanyl alone. The dose of morphine received (mg) in the ICU ($P < 0.002$) was significantly higher in the open surgery group than in the EVAR group. Also, the need for fentanyl administration ($P < 0.001$) in the EVAR group was significantly lower; however, the dose of fentanyl (μg) received was not significantly different between the two groups, which can be due to the higher levels of pain following incision as well as the large surgical dissection following an open procedure, which makes pain control more challenging for these patients. In this study, the interval to starting oral feeding after surgery in patients of the two groups was also compared. Transient ileus is a relatively common complication following open AAA repair. Accordingly, postoperative care commonly includes the delayed onset of oral feeding in patients until the return of the patient's regular bowel movements [26]. Also, a longer delay in oral feeding was found in the open surgery group compared with the EVAR group ($P < 0.001$), which may be due to the higher prevalence of complications due to early onset of oral feeding after open surgery and the longer duration of postoperative treatment considerations in this method.

One of the limitations of this research was the limited number of available samples. Also, some variables had not been completely recorded in some of the patients' records; thus, those patients were excluded, and the number of samples decreased. It is suggested to repeat the research using a higher sample size and longer follow-up in terms of long-term survival after surgery and study each patient's physiological and anatomical features in managing complications. Also, despite the high cost of endovascular graft, the cost of hospitalization is less for the endovascular method. According to this hypothesis, it is recommended to extract the costs of these two methods accurately from hospital records in a future study and analyze and provide the results to the relevant organizations enabling them to study the feasibility of financial support.

Conclusion

In conclusion, this study showed that AAA repair using the endovascular method is associated with fewer complications and short-term survival in patients. In general, endovascular surgery to repair the rupture of an AAA should be considered by surgeons in light of fewer complications and more satisfactory results for the patient and the treating physician.

Acknowledgements

The authors wish to thank the Deputy for Research of Guilan University of Medical Sciences, Razi Clinical Research Development Unit and all the individuals who helped us during the study.

Disclosure of conflict of interest

None.

Abbreviation

EVAR, Endovascular treatment of abdominal aortic aneurysms.

Address correspondence to: Siamak Rimaz, Anesthesiology Research Center, Department of Anesthesiology, Alzahra Hospital, Guilan University of Medical Sciences, Namjoo Street, Rasht, Guilan,

Iran. Tel: +989111342048; Fax: +981333369024; E-mail: smkrimaz@yahoo.com

References

[1] Golledge J. Abdominal aortic aneurysm: update on pathogenesis and medical treatments. Nat Rev Cardiol 2019; 16: 225-242.

[2] Raffort J, Adam C, Carrier M, Ballaith A, Coscas R, Jean-Baptiste E, Hassen-Khodja R, Chakfé N and Lareyre F. Artificial intelligence in abdominal aortic aneurysm. J Vasc Surg 2020; 72: 321-333, e321.

[3] Keisler B and Carter C. Abdominal aortic aneurysm. Am Fam Physician 2015; 91: 538-543.

[4] Kothandan H, Haw Chieh GL, Khan SA, Karthekeyan RB and Sharad SS. Anesthetic considerations for endovascular abdominal aortic aneurysm repair. Ann Card Anaesth 2016; 19: 132-41.

[5] Anagnostakos J and Lal BK. Abdominal aortic aneurysms. Prog Cardiovasc Dis 2021; 65: 34-43.

[6] Lederle FA, Kyriakides TC, Stroupe KT, Freischlag JA, Padberg FT Jr, Matsumura JS, Huo Z and Johnson GR; OVER Veterans Affairs Cooperative Study Group. Open versus endovascular repair of abdominal aortic aneurysm. N Engl J Med 2019; 380: 2126-2135.

[7] Kumar A, Dmytriw AA, Salem MM, Kuhn AL, Phan K, Bharatha A, Spears J, Thomas A, Puri A and Marotta TR. Reconstructive vs deconstructive endovascular approach to intradural vertebral artery aneurysms: a multicenter cohort study. Neurosurgery 2020; 87: 383-393.

[8] Terlecki P, Terlecki KM, Przywara S, Kęsik JJ and Zubilewicz T. Endovascular treatment of false aneurysm of axillary artery in obese women with epilepsy. 5 years follow up. Acta Angiol 2022; 28: 52-55.

[9] Dubois L, Harlock J, Gill HL, Chen JC, Rheaume P, Jetty P, Boyd AJ, Roche-Nagle G, Hill A and Kopriva D. A Canadian multicenter experience describing outcomes after endovascular abdominal aortic aneurysm repair stent graft explantation. J Vasc Surg 2021; 74: 720-728, e721.

[10] Wanken ZJ, Barnes JA, Trooboff SW, Columbo JA, Jella TK, Kim DJ, Khoshgowari A, Riblet NB and Goodney PP. A systematic review and meta-analysis of long-term reintervention after endovascular abdominal aortic aneurysm repair. J Vasc Surg 2020; 72: 1122-1131.

[11] Ünlü S, Özden Tok Ö, Avcı Demir F, Papadopoulos K and Monaghan MJ. Differential diagnosis of apical hypertrophic cardiomyopathy and apical displacement of the papillary muscles: a multimodality imaging point of view. Echocardiography 2021; 38: 103-113.

[12] Patel R, Sweeting MJ, Powell JT, Greenhalgh RM and Investigators ET. Endovascular versus open repair of abdominal aortic aneurysm in 15-years' follow-up of the UK endovascular aneurysm repair trial 1 (EVAR trial 1): a randomised controlled trial. Lancet 2016; 388: 2366-2374.

[13] van Schaik TG, Yeung KK, Verhagen HJ, de Bruin JL, van Sambeek MR, Balm R, Zeebregts CJ, van Herwaarden JA, Blankensteijn JD and Grobbee D. Long-term survival and secondary procedures after open or endovascular repair of abdominal aortic aneurysms. J Vasc Surg 2017; 66: 1379-1389.

[14] Carnevale ML, Koleilat I, Lipsitz EC, Friedmann P and Indes JE. Extended screening guidelines for the diagnosis of abdominal aortic aneurysm. J Vasc Surg 2020; 72: 1917-1926.

[15] Spanos K, Nana P, Behrendt CA, Kouvelos G, Panuccio G, Heidemann F, Matsagkas M, Debus S, Giannoukas A and Koelbel T. Management of abdominal aortic aneurysm disease: similarities and differences among cardiovascular guidelines and NICE guidance. J Endovasc Ther 2020; 27: 889-901.

[16] Hinchliffe R and Earnshaw J. Endovascular treatment of abdominal aortic aneurysm: a NICE U-turn. Br J Surg 2020; 107: 940-942.

[17] Scott R, Ashton H and Kay D. Abdominal aortic aneurysm in 4237 screened patients: prevalence, development and management over 6 years. Br J Surg 1991; 78: 1122-1125.

[18] Kent KC, Zwolak RM, Egorova NN, Riles TS, Manganaro A, Moskowitz AJ, Gelijns AC and Greco G. Analysis of risk factors for abdominal aortic aneurysm in a cohort of more than 3 million individuals. J Vasc Surg 2010; 52: 539-548.

[19] Schouten O, Kok NF, Boersma E, Bax JJ, Feringa HH, Vidakovic R, Statius van Eps RG, van Sambeek MR and Poldermans D. Effects of statins on renal function after aortic cross clamping during major vascular surgery. Am J Cardiol 2006; 97: 1383-1385.

[20] Jacobs MJ, Elenbaas TW, Schurink GW, Mess WH and Mochtar B. Assessment of spinal cord integrity during thoracoabdominal aortic aneurysm repair. Ann Thorac Surg 2002; 74: S1864-6; discussion S1892-8.

[21] Go AS, Chertow GM, Fan D, McCulloch CE and Hsu CY. Chronic kidney disease and the risks of death, cardiovascular events, and hospitalization. N Engl J Med 2004; 351: 1296-1305.

[22] Rajendran S and May J. Late rupture of abdominal aortic aneurysm after endovascular repair. J Vasc Surg 2017; 65: 52-57.

[23] Sweeting M, Ulug P, Sweeting M, Gomes M, Hinchliffe R, Thompson M, Thompson S, Grieve R and Greenhalgh R. Comparative clinical ef-

fectiveness and cost effectiveness of endovascular strategy *v* open repair for ruptured abdominal aortic aneurysm: three year results of the IMPROVE randomised trial. BMJ 2017; 359: j4859.

[24] Patelis N, Moris D, Karaolanis G and Georgopoulos S. Endovascular vs. open repair for ruptured abdominal aortic aneurysm. Med Sci Monit Basic Res 2016; 22: 34-44.

[25] Rigberg DA, McGory ML, Zingmond DS, Maggard MA, Agustin M, Lawrence PF and Ko CY. Thirty-day mortality statistics underestimate the risk of repair of thoracoabdominal aortic aneurysms: a statewide experience. J Vasc Surg 2006; 43: 217-222.

[26] Ko PJ, Hsieh HC, Liu YH and Liu HP. Experience with early postoperative feeding after abdominal aortic surgery. Chang Gung Med J 2004; 27: 210-216.