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A Comparative Study of Abdominal Aortic Aneurysm: Endovascular Aneurysm Repair versus Open Repair

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Background: Endovascular aneurysm repair (EVAR) has dramatically changed the management of abdominal aortic aneurysms (AAAs) as the number of open aneurysm repairs have declined over time. This report compares AAA-related demographics, operative data, complications, and mortality after treatment by open aneurysm repair or EVAR. **Methods:** We retrospectively reviewed 136 patients with AAAs who were treated over an 8-year time period with open aneurysm repair or EVAR. **Results:** The mean age of the EVAR group was higher than that of the open repair group (p=0.001), and hospital mortality did not differ significantly between groups (p=0.360). However, overall survival was significantly lower in the EVAR group (p=0.033). **Conclusion:** Although EVAR is the primary treatment modality for elderly patients, it would be ideal to set slightly more stringent criteria within the anatomical guidelines contained in the instructions for use of the EVAR device when treating younger patients.

Key words: 1. Aortic aneurysm, abdominal
2. Endovascular procedures
3. Aorta, surgery

Introduction

Since its introduction in the early 1990s, endovascular aneurysm repair (EVAR) has revolutionized the treatment of abdominal aortic aneurysms (AAAs). Each generation of EVAR devices has become more advanced than the last, and the indications for their use have steadily expanded to incorporate more complex anatomical cases [1]. The number of open aneurysm repairs performed over time in both the Medicare database and National Inpatient Sample has significantly declined. As of 2006, 60%–70% of all AAA repairs in these populations were performed using EVAR [2,3]. Additionally, in Korea, the incidence of open aneurysm repair increased 1.2-fold alongside the overall declining trend, while the incidence of endovascular repair increased 15.3-fold. These findings showed that, in Korea, the endovascular repair of AAAs surpassed open repair as the most common technique between 2010 and 2011 [4]. Ultimately, EVAR has become the primary mode of therapy for the majority of patients with AAAs, while open repair remains reserved for those with increasingly complex anatomy or a coexisting disease that prohibits endovascular repair [1].

At our center, we have also performed EVAR for roughly half of all patients with AAAs. This study presents a comparative review of demographics, op-

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erative data, postoperative complications, and the associated outcomes in patients with AAAs who underwent open repair versus those who underwent EVAR. In particular, the short- and long-term mortality rates associated with EVAR and open repair were compared and analyzed. Our goal was to verify whether EVAR could replace open repair as the primary treatment modality for AAAs.

Methods

1) Patients and measurements

The medical records of 136 patients with AAAs who were treated by either open repair techniques or EVAR from January 2007 to December 2014 were retrospectively reviewed. A total of 98 patients were enrolled in the study after 17 were lost to follow-up and 21 were excluded because they had undergone emergency operations of ruptured AAAs. Open repairs were performed by 2 vascular surgeons, and EVARs were performed by a single radiology interventionist.

The treatment modality was primarily determined by anatomical, factors with additional consideration of patient preference and comorbidities.

Patient demographics and clinical data were collected using the computerized patient record system. Demographic variables included age, sex, height, weight, and body mass index. Preoperative health measurements evaluated included smoking status and other comorbidities. Preoperative comorbidities included coronary arterial occlusive disease, hypercholesterolemia, chronic obstructive pulmonary disease, renal insufficiency (serum creatinine level >1.5 mg/dL), diabetes mellitus, cerebrovascular accidents (CVAs), hypertension, and peripheral arterial occlusive disease. Anatomical characteristics of the AAA included aneurysm size, angle, and neck length.

Operative data included the level of aortic cross-clamping (ACC), ACC time, distal anastomosis, sacrifice of the internal iliac artery, blood replacement (packed red blood cells), and intravenous crystalloid replacement.

Postoperative data included length of hospital and intensive care unit (ICU) stay, hospital and 30-day mortality, the fasting period after surgery, re-intubation, and other complications.

2) Operative technique

A standard midline incision was used for all transabdominal approaches. After intra-abdominal examination, the aorta was exposed below the transverse mesocolon, and the bowel was retracted and held in place with a self-retaining retractor.

All retroperitoneal approaches were performed using an incision that began at the tip of the left eleventh rib and moved medially to the lateral borders of the left rectus sheath. The peritoneum was swept anteromedially, and the left kidney was retracted upward.

EVAR was performed under local anesthesia. Bilateral access to the common femoral artery was obtained percutaneously.

3) Analysis

Univariate analyses examined the differences in demographic and clinical covariates between the open repair and EVAR groups. Continuous data were tested with the Student t-test or the Wilcoxon rank sum test. Comparisons among the categorical variables were performed using the Fisher exact test or the chi-square test. Kaplan-Meier analysis was also used. Summary data are reported as mean±standard deviation or percentages. STATA ver. 10.1 (Stata Corp., College Station, TX, USA) was used for data management and analysis. All p-values <0.05 were considered to indicate statistical significance in all tests.

Results

Patient demographics are shown in Table 1. Younger patients preferred open repair techniques. Therefore, there was a statistically significant difference in the age of patients between the open repair group and the EVAR group (p=0.001). The number of patients who had undergone abdominal imaging studies within 5 years in advance of an AAA diagnosis was higher in the EVAR group (p=0.023), and there was a statistically significant difference in sex and the CVA history of patients between the groups. The proportion of men was higher in the EVAR group than in the open repair group (p=0.035) and CVAs were also more common in the EVAR group (p=0.028).

The size, angle, and neck length of the aneurysm in the 2 groups are shown in Table 2. The necks of

Table 1. Demographics of patients

Variable	Total (N=98)	Open repair (N=40)	Endovascular aneurysm repair (N=58)	p-value
Age (yr)	69.6±7.1	66.9±7.5	71.4±6.1	0.001
Male	72 (73.5)	25 (62.5)	47 (81.0)	0.035
Smoking	60 (61.2)	22 (55.0)	38 (65.5)	0.249
Ex-smoker	18 (18.4)	2 (5.0)	16 (27.6)	
Current smoker	42 (42.9)	20 (50.0)	22 (37.9)	
Smoking pack-year	18.0±18.1	15.0±16.6	20.3±18.9	0.164
Coronary artery occlusive disease	20 (20.4)	9 (22.5)	12 (20.7)	0.832
High cholesterol	11 (11.2)	2 (5.0)	9 (15.5)	0.079
Chronic obstructive pulmonary disease	2 (2.0)	1 (2.5)	1 (1.7)	0.792
Renal insufficiency	9 (9.2)	4 (10.0)	5 (8.6)	0.819
Abdominal imaging within 5 years	67 (68.3)	22 (55.0)	45 (77.6)	0.023
Diabetes mellitus	9 (9.2)	5 (12.5)	4 (6.9)	0.350
Cerebrovascular accident	13 (13.3)	2 (5.0)	11 (19.0)	0.028
Hypertension	66 (67.3)	27 (67.5)	40 (69.0)	0.880
Peripheral arterial occlusive disease	1 (1.0)	1 (2.5)	0 (0.0)	0.323
Height (cm)	165.4±7.4	165.6±7.9	165.3±7.1	0.888
Weight (kg)	62.7±9.8	62.7±11.5	62.7±8.6	0.980
Body mass index (kg/m^2)	22.9±3.0	22.8±3.5	22.9±2.7	0.897

Values are presented as mean±standard deviation or number (%).

Table 2. Aneurysm size, angle, and length of neck

Variable	Total	Open repair	Endovascular aneurysm repair	p-value
Aneurysm size (mm)	62.3±14.9	64.4±17.1	60.8±13.0	0.242
Aneurysm angle (°)	54.6±30.2	60.5±36.1	50.2±24.6	0.123
Aneurysm neck (mm)	32.8±19.1	26.0±19.6	37.5±17.3	0.003

Values are presented as mean±standard deviation.

aneurysms were significantly longer in the EVAR group (p=0.003).

The number of cases in which the internal iliac artery had to be sacrificed was 16 in the open repair group (40.0%) and 15 in the EVAR group (25.9%). No statistically significant difference was found between the groups (p=0.210).

Table 3 shows the postoperative results and complications for both groups. The length of hospital stay, ICU stay, and the interval before returning to a normal diet were significantly shorter in the EVAR group. Additionally, the incidence of postoperative pulmonary edema and the incidence of postoperative ileus were lower in the EVAR group.

The open repair group had 2 cases (5%) of in-hospital (30-day) mortality. No late mortality was observed in this group. The causes of death were pneumonia and bowel ischemia. On the contrary, the EVAR group had 1 case of in-hospital mortality and 9 cases of late mortality (15.5%). Five cases of mortality were directly related to post-EVAR complications.

The EVAR-related in-hospital death in our study was caused by right iliac artery acute occlusion (1). Several other complications, such as rhabdomyolysis, acute kidney injury, and myocardial infarction were also linked to deaths following the EVAR procedure. The causes of EVAR-related late mortality were newly occurring type 1 endoleak (2), type II endoleak (1), and type III endoleak (1). Other causes of death were prostate cancer (2), bladder cancer (1), cholangiocarcinoma (1), and pneumonia (1).

No differences were observed between the 2 groups regarding the rate of in-hospital mortality (p=0.360). However, statistically significant differences were observed in the rate of overall mortality (p=0.048). Significant differences were also observed between the two groups in the survival analysis performed using the Kaplan-Meier method (p=0.033) (Fig. 1). The overall survival rate was lower in the EVAR group than in the open repair group.

There were several complications related to the

Table 3. Postoperative complications

Variable	Total (N=98)	Open repair (N=40)	Endovascular aneurysm repair (N=58)	p-value
Length of hospital stay (day)	15.4±12.5	20.1±8.4	12.2±13.8	0.002
Length of intensive care unit stay (day)	2.4±2.3	3.8±2.8	1.4±1.2	0.000
Bleeding	3 (3.1)	2 (5.0)	1 (1.7)	0.360
Wound infection	1 (1.0)	1 (2.5)	0	0.323
Pneumonia	4 (4.1)	2 (5.0)	2 (3.4)	0.706
Pulmonary edema	19 (19.4)	17 (42.5)	2 (3.4)	0.000
Myocardial infarction	2 (2.0)	1 (2.5)	1 (1.7)	0.792
Acute kidney injury	9 (9.2)	5 (12.5)	4 (6.9)	0.350
Dialysis	3 (3.1)	2 (5.0)	1 (1.7)	0.360
Ileus	30 (30.6)	25 (62.5)	5 (8.6)	0.000
Bowel ischemia	1 (1.0)	1 (2.5)	0	0.323
Return to diet (day)	2.2±2.6	4.1±3.0	0.8±1.2	0.000
Reintubation	1 (1.0)	1 (2.5)	0	0.323

Values are presented as mean±standard deviation or number (%).

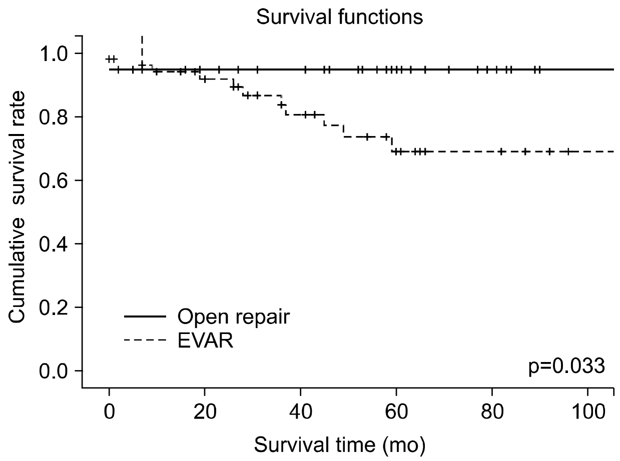

Fig. 1. Kaplan-Meier analysis of open repair and EVAR. EVAR, endovascular aneurysm repair.

EVAR procedures. Eight cases (13.7%) required additional intervention, due to a type I endoleak (2), a type II endoleak through the inferior mesenteric artery (4), or the lumbar artery (2). After close observation of 1 case of a minimal type Ib endoleak and 2 cases of type II endoleaks without additional intervention, the endoleaks were found to be diminished on computed tomography angiography 3 months later. The endoleaks found immediately after intervention were all resolved with or without additional intervention and were not related to late death. There was 1 additional procedure after open repair (2.5%) due to an aortoenteric fistula.

Table 4 shows the comparison of the retroperitoneal approach and the transabdominal approach for open repair. In elective surgery, no differences were observed in the level and time of ACC, the amount of blood replacement, and intravenous crystalloid replacement.

Discussion

Aneurysms are defined as focal dilatations that are at least 50% larger than the expected normal arterial diameter [5]. A practical working definition of an AAA, based on average values for normal individuals, is an aortic transverse diameter of 3 cm. AAAs primarily develop in people who are older than 50 years old, and AAAs are 2–6 times more common in men than in women [6].

The prevalence of AAAs in a population depends on the presence of associated risk factors, such as older age, male sex, white race, positive family history, smoking status, hypertension, hypercholesterolemia, peripheral vascular occlusive disease, and coronary artery disease [7]. Diabetes, deep vein thrombosis, abdominal imaging within 5 years in advance of an AAA diagnosis, black race, and female sex decrease the risk [8]. Recently, genome-wide association studies have revealed a specific association between a genetic variant of low density-lipoprotein receptor-related protein 1 and AAA patients [9].

The choice between observation and prophylactic

Table 4. Comparison with retroperitoneal approach and transabdominal approach

Variable	Retroperitoneal approach (N=35)	Transabdominal approach (N=5)	p-value
ACC level			0.404
Infrarenal	30	5	
Transrenal	2	0	
Suprarenal	2	0	
ACC time (min)	97.6±42.8	87.8±16.8	0.619
Distal anastomosis			0.003
Aorto-biiliac	26	5	
Aorto-bifemoral	5	0	
Aorto-iliac with aorto-femoral	4	0	
Blood replacement (packed red blood cell, unit)	4.8±6.8	4.2±2.6	0.854
Intravenous crystalloid replacement (mL)	3,944.3±1,887.2	3,424.0±916.4	0.551

Values are presented as number or mean±standard deviation.
ACC, aorta cross clamping.

surgical repair of an AAA for an individual patient depends on the risk of AAA rupture, the operative risk associated with repair, and by inference, the modality and location of repair, the patient's life expectancy, and the personal preferences of the patient [6,10].

Randomized trials indicate that, in general, it is safe to wait for the AAA diameter to reach 5 cm or 5.5 cm before performing surgery in selected men who would be compliant with surveillance, even if their operative mortality is predicted to be low [6].

The current outcomes of elective open repair are excellent, with perioperative mortality rates between 1% and 7% depending on center volume and surgeon experience [1]. A recent meta-analysis of randomized trials involving EVAR demonstrated a 30-day mortality rate of 3.3% [11]. In this study, the perioperative mortality associated with elective open repair was 5% and the rate associated with elective EVAR was 1.7%. No statistically significant difference was observed in the perioperative mortality between the 2 modalities.

The results from several trials indicate the need to examine with greater consideration the unique risks associated with each procedure, such as greater physiologic stress and accompanying complications from open surgery compared with continued surveillance, the possible need for future endovascular re-intervention, and a small but persistent risk of rupture with EVAR [12]. The survival analysis from the EVAR-1 trial demonstrated that the initial survival benefit associated with EVAR was lost within 2 years of repair due to the higher death rate associated with cardiovascular causes among patients who had undergone EVAR [13]. A perioperative advantage was also observed in this study. However, no significant survival benefit was observed after EVAR in the Dutch Randomized Endovascular Aneurysm Management trial or the Open Versus Endovascular Repair trial [14,15].

In this study, no significant difference was observed in the perioperative mortality associated with open repair and EVAR. However, a higher long-term survival rate was noted with open repair. Although the higher age in the EVAR group cannot be overlooked, the fact that half of the total deaths were directly associated with post-EVAR complications is sufficiently meaningful.

Data from large registries such as EUROSTAR have estimated a re-intervention rate of 5% per year and a continued rupture rate of 1% per year, despite EVAR [16,17]. In this study, the re-intervention rate was 13.7% (n=8), and the rate of rupture after EVAR was 6.9% (n=4) over the 8-year study period.

In cases of open aneurysm repair, both transabdominal and retroperitoneal approaches may be technically equivalent in many circumstances, as the goal of any approach is to obtain adequate exposure of the affected aortic segment. Under these circumstances, selection of the approach should be determined based on the surgeon's preference and familiarity with each approach [1]. In this study, the outcomes associated with the approach were not significantly different, and selection of the approach was appropriately made according to the patient's anatomy and the surgical situation.

In conclusion, this study reviewed 8 years of surgical treatments for AAAs at a single hospital. Since the introduction of EVAR, the fascinating benefits of the procedure—a short learning curve, low perioperative mortality, and better short- and medium-term outcomes—have promoted its use. Some surgeons perform this challenging procedure even on patients with difficult anatomies. We performed EVAR when the patients were determined to have the appropriate anatomy according to existing guidelines. Thus, EVAR accounted for approximately half of the total operations performed to treat AAAs.

The question of whether EVAR can replace open repair as the primary treatment of AAAs remains, despite the currently growing number of EVAR procedures. Many large-scale trials have not been able to provide a clear answer. With the abundance of scholarly evidence regarding long-term mortality and complications associated with EVAR, as well as 10 years of our own experience, we conclude that EVAR should be used as the primary treatment for older patients with AAAs. However, it would be ideal to set slightly more stringent criteria within the anatomical guidelines contained in the instructions for use of the EVAR device when treating younger patients.

Conflict of interest

No potential conflicts of interest relevant to this article are reported.

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