Outcomes of emergency endovascular versus open repair for abdominal aortic aneurysm rupture

Suk Jung Choo1,*, Yang-Bin Jeon2,*, Sam-Sae Oh3, Sung Ho Shinn4

1Department of Thoracic and Cardiovascular Surgery, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea
2Department of Traumatology, Gachon University Gil Medical Center, Gachon University College of Medicine, Incheon, Korea
3Department of Thoracic and Cardiovascular Surgery, Kangbuk Samsung Hospital, Sungkyunkwan University College of Medicine, Seoul, Korea
4Department of Thoracic and Cardiovascular Surgery, Cheju Halla General Hospital, Jeju, Korea

INTRODUCTION

Over the last decade, endovascular aneurysm repair (EVAR) has emerged as a less invasive and comparably effective option to open surgical repair (OSR) for the treatment of ruptured abdominal aortic aneurysm (rAAA) [1-3]. However, the question regarding which treatment is better remains controversial. Most studies thus far have been conducted as single-center observational studies with randomized control trials (RCT) being rare due to the practical difficulties of assigning patients to different treatment arms in the emergency setting. The few RCTs that have been reported thus far showed no significant differences between eEVAR and OSR [4-6], while other studies have suggested that eEVAR may be associated with significantly

Purpose: Ruptured abdominal aortic aneurysm (rAAA) is one of the most common aortic emergencies in vascular surgery and is associated with high operative mortality and morbidity rates despite recent treatment advances. We evaluated operative mortality risks for the outcomes of emergency endovascular aneurysm repair (eEVAR) vs. open repair in rAAA.

Methods: Twenty patients underwent eEVAR (n = 12) or open repair (n = 8) for rAAA between 2016 and 2020. We adopted the EVAR first strategy since 2018. Primary endpoints included in-hospital mortality and 1-year survival. The outcome variables were analyzed with Fisher exact, Mann-Whitney test, and linear by linear association. The Kaplan-Meier method was used to estimate survival.

Results: There were 13 males (65.0%) and the median age of the study cohort was 78.0 years (range, 49–88 years). In-hospital mortality occurred in 7 patients (35.0%), 5 (50.0%) in the early period and 2 (20.0%) in the later period of this series. According to the procedure type, 4 (50.0%) and 3 (25.0%) in-hospital mortalities occurred in the open repair and eEVAR patients, respectively. In 6 patients (50.0%), eEVAR was performed on unfavorable anatomy. The 1-year survival of eEVAR vs. open repair group was 75% ± 12.5% and 50% ± 17.7%, respectively. On univariate analysis, preoperative high-risk indices, postoperative acute renal failure requiring dialysis, pulmonary complications, and prolonged mechanical ventilation were associated with higher operative mortality.

Conclusion: The current data showed relatively superior outcomes with eEVAR vs. open repair for rAAA, even in some patients with unfavorable anatomy supporting the feasibility, efficacy, and safety of EVAR first strategy.

Keywords: Emergency endovascular aneurysm repair, Open repair, Ruptured abdominal aortic aneurysm

*Suk Jung Choo and Yang-Bin Jeon contributed equally to this work as co-first authors.

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lower mortality risk [7,8]. The recent 3-year outcomes of the IMPROVE trial suggested that the overall survival, quality of life, and cost-effectiveness may be superior with eEVAR vs. OSR, but the reintervention rates were similar between the 2 modalities [9]. The eEVAR tended to show a lower mortality rate in the early perioperative period with a sustained survival benefit over time extending into the mid-term follow-up period. As a result, there was a steady preferential shift toward eEVAR as the preferred treatment of rAAA with OSR being reserved mostly for patients with unfavorable EVAR anatomy. In light of this current trend, we reviewed our experience to analyze the operative outcomes between the 2 treatment modalities in the treatment of rAAA.

METHODS

Patient data for rAAA was collected retrospectively between 2016 and 2020. The present study was approved by our Institutional Review Board (IRB) of Cheju Halla General Hospital (No. 2020-D03-01) and informed written consent was waived according to the present IRB protocol. All patients in this study had infrarenal AAAs. Preoperative demographic data included hemodynamics and relevant information on the patient status. We used the American Society of Anesthesiologist (ASA) physical status (PS) classification to categorize the preoperative health status [10] while the Hardman index was used to assess the preoperative mortality risk [11].

The suitability assessment of EVAR with regards to the aneurysm morphology was based on meticulous review of the preoperative CT scan. Postoperative complications such as cardiovascular events, renal insufficiency, pulmonary complications, mesenteric ischemia, and infection were carefully documented. Aortic rupture in our center was defined as either free rupture with hematoma in the retroperitoneal/intraabdominal space or contained rupture. The decision to perform EVAR was usually left to the surgeon’s discretion. EVAR was generally preferred in patients with a favorable EVAR anatomy and stable hemodynamics. The treatment strategy of rAAA in our center has changed in favor of the EVAR first strategy to reduce the symptom onset to operation room arrival time as this also better suited the limited manpower situation in our setting. An EVAR first strategy was employed since 2018 for the treatment of rAAA and before this time 2 cases of eEVAR were performed between 2016 and 2017. Permissive hypotension was allowed in the management of rAAA patients to minimize the risk of frank rupture. The availability of EVAR devices at our institution was limited due to the geographically isolated nature of Jeju Island, and since mid-2019 we were able to stock only the most commonly used EVAR devices.

Open repair was usually performed via the transperitoneal approach via abdominal midline incision under general anesthesia. When incising the retroperitoneum via laparotomy, the proximal neck was manually controlled and clamped in an anteroposterior direction usually without taping. We usually administered 3,000 units of heparin. The following procedure was then similar to elective AAA repair. When primary abdominal closure was unsuccessful due to massive hematoma and intestinal edema, temporary abdominal closure was performed to prevent abdominal compartment syndrome. For eEVAR, bilateral femoral arteries were cut-down, after which the remaining procedure was performed similarly in a manner to standard EVAR. We adopted the percutaneous approach without cut-down for EVAR since 2018 due to the unstable nature of the hemodynamics warranting rapid vascular access in these patients.

Hybrid aortic repair defined as aorto-uni-iliac stent-graft insertion combined with femoro-femoral bypass was performed in 2 patients in 2019. Although procedure related type I endoleaks were usually corrected at the time of completion angiography, type II endoleaks were usually left untreated. Abdominal compartment syndrome, defined as sustained intraabdominal pressure (IAP) of >20 mmHg with new organ dysfunction and/or failure [12] was corrected by retroperitoneal or intraabdominal pigtail insertion and/or laparotomy. IAP however, was not routinely checked in the absence of specific symptom/signs of abdominal compartment syndrome. Primary endpoints included in-hospital mortality and 1-year survival. Preoperative, intraoperative, and postoperative outcome variables were analyzed with Fisher exact, Mann-Whitney test, and linear by linear association using IBM SPSS Statistics for Windows, ver. 22.0 (IBM Corp., Armonk, NY, USA). The Kaplan-Meier method was used to estimate survival.

RESULTS

A total of 20 patients underwent either open repair (n = 8) or eEVAR (n = 12) for rAAA between 2016 and 2020. The median patient age was 78.0 years (range, 49–88 years). Eight of 12 patients (66.7%) of the patients in the eEVAR group and 62.5% (5 of 8) in the open repair group had preoperative systolic blood pressure of <90 mmHg at the time of presentation. Four of 12 patients (33.3%) in eEVAR and 2 of 8 patients (25.0%) in open repair group presented with loss of consciousness in the emergency department (ER). On preoperative CT imaging analysis, the mean AAA diameter was 69.3 mm (range, 60–100 mm). Most patients receiving either endovascular vs. open repair group had more than ASA PS grade IV (P > 0.999). The Hardman index (≥3, P = 0.356) was also not significantly different between the 2 groups (Table 1) suggesting a similar intergroup preoperative health status and mortality risks. Demographic data and anatomical characteristics of the aneurysms are summarized in Table 1. The Perclose Proglide
device (Abbott Vascular Devices, Redwood City, CA, USA) was used in 4 patients (4 of 10, 40.0%) since the adaptation of the EVAR first strategy in 2018 for a percutaneous approach. EVAR was also performed in select patients with unfavorable aortic neck anatomy including greater than 60° angulation and/or landing zones less than 1.5 cm (6 of 12, 50.0%). In the OSR group, there were 3 patients (3 of 8, 37.5%) with hostile aortic neck anatomy. The median symptom onset to ER arrival time and symptom onset to operation room arrival time were 180.0 minutes (range, 20–660 minutes) and 385.0 minutes (range, 105–900 minutes), respectively. The mean preoperative hemoglobin level was 9.46 mg/dL (range, 5.0–14.7 mg/dL). With the exception of 2 cases (one by Zenith; Cook Inc, Bloomington, IN, USA and the other by SEAL stent-grafts; S&G BioTech, Yongin, Korea), Endurant IIs (Medtronic Vascular, Santa Rosa, CA, USA) was used for EVAR in the remaining cases (n = 10). Hybrid aortic repair was performed in 2 patients in which, 1 patient with unfavorable aortic neck anatomy had both type Ia and Ib endoleaks. The endoleaks were treated by additional stent grafting and repeat ballooning. The postoperative follow-up CT scan was negative for any further endoleaks (Fig. 1). A case of internal iliac artery embolization along with additional

### Table 1. Demographic data and anatomical characteristics

| Variable                              | eEVAR | Open repair | P-value |
|---------------------------------------|-------|-------------|---------|
| No. of patients                       | 12    | 8           |         |
| Male sex                              | 9 (75.0) | 3 (37.5)    | 0.356   |
| Hypertension                          | 9 (75.0) | 8 (100)     | 0.242   |
| Diabetes mellitus                     | 3 (25.0) | 3 (37.5)    | 0.642   |
| Coronary artery disease               | 2 (16.7) | 2 (25.0)    | >0.999  |
| Cerebrovascular accident              | 3 (25.0) | 1 (12.5)    | 0.619   |
| Chronic kidney disease                | 2 (16.7) | 2 (25.0)    | >0.999  |
| Smoking                               | 6 (50.0) | 3 (37.5)    | 0.670   |
| Low blood pressure, <90 mmHg          | 8 (66.7) | 5 (62.5)    | >0.999  |
| Loss of consciousness                 | 4 (33.3) | 2 (25.0)    | >0.999  |
| ASA PS classification, ≥IV            | 10 (83.3) | 6 (75.0)    | >0.999  |
| Hardman index, ≥3                     | 3 (25.0) | 4 (50.0)    | 0.356   |
| Admission hemoglobin (mg/dL)          | 9.6 (5.0–12.8) | 9.3 (5.3–14.7) | 0.728   |
| Maximal AAA diameter (mm)             | 67.7 (60–78) | 71.5 (60–100) | 0.877   |
| Unfavorable aortic neck anatomy       | 6 (50.0) | 3 (37.5)    | 0.670   |

Values are presented as number only, number (%), or median (range).

eEVAR, emergency endovascular aneurysm repair; ASA, American Society of Anesthesiologist; PS, physical status; AAA, abdominal aortic aneurysm.

**Fig. 1.** (A) Initial angiography demonstrates a ruptured abdominal aortic aneurysm with hostile aortic neck. (B) Aorto-uni-iliac device implantation and crossover femoro-femoral bypass were performed. Additional covered stent graft was inserted to treat persistent type Ia (arrow) and Ib (arrowhead) endoleak on angiography. Repetitive ballooning was performed to treat endoleaks. (C) Follow-up CT reconstruction demonstrates a patent endograft with flow through the femoro-femoral graft into both right internal iliac artery and right lower extremity arterial system without evidence of endoleak.
stent-graft deployment to the external iliac artery was performed as an adjunctive procedure in eEVAR in a patient with ipsilateral common iliac artery aneurysm. Abdominal compartment syndrome which occurred in 1 of each patient in both groups (n = 2) was treated by delayed abdominal wall closure after open repair in one patient.
and by initial retroperitoneal pigtail insertion followed by decompressive laparotomy in the other patient that received EVAR.

In-hospital mortality occurred in 7 patients (35.0%). By surgical period, 5 (50.0%) and 2 deaths (20.0%) occurred in the early (2016–2017) and latter periods (2018–2020), respectively. Median hospital stay of in-hospital mortality is 3 days (range, 2–53 days). According to the type of the procedures, inhospital mortality occurred in 4 open repair (50.0%) and 3 eEVAR patients (25.0%). Early postoperative outcomes and complications are summarized in Table 2.

On univariate analysis, preoperative hemoglobin of <9 mg/dL (P = 0.017), higher ASA PS grade (P = 0.050) and Hardman score (P = 0.011), hypotension (P = 0.044), and preoperative RBC transfusion (P = 0.003) were significant risk factors for mortality (Table 3). Postoperative variables including acute renal failure requiring hemodialysis (P = 0.031), pulmonary complications (P = 0.007), multigang failure (P = 0.007) and the prolonged mechanical ventilation (P = 0.005) were significant risk factors for in-hospital mortality (Table 3). Mesenteric ischemia (P = 0.049) and prolonged mechanical ventilation (P = 0.002) were associated more with open repair than EVAR on univariate analysis. However, mode of repair was not a significant determinant of in-hospital mortality (P = 0.356) (Table 2). The overall 1-year survival rate was 64.3% ± 10.9% and the 1-year survival according to treatment type was 75.0% ± 12.5% and 50.0% ± 17.7% for the eEVAR and open repair group, respectively (Fig. 2).

**DISCUSSION**

Surgery of rAAA is a challenging emergency procedure whose primary objective is to achieve immediate survival and long-term durability. According to current clinical guidelines from the European Society for Vascular Surgery, EVAR is recommended as the first line of treatment for an anatomically suitable rAAA (Recommendation 74, Class I, Level of Evidence B) based on its superior immediate survival benefit [13]. The effectiveness of EVAR for rAAA has been investigated in several RCTs [4-6], but the study implications should be interpreted individually. The ECAR (Endovasculaire ou Chirurgie dans les Anévrysmes aorto-iliaques Rompus) multicenter trial has shown a similar mortality risk between patients with suitable aortic neck anatomy randomized for EVAR or OSR [4]. The relatively small volume AJAX (Amsterdam Acute Aneurysm) multicenter trial (116 patients) showed that EVAR may be performed safely despite a high intraoperative open surgery conversion rate as they reported no significant mortality rate differences [5]. The larger volume IMPROVE (Immediate Management of Patients with Rupture: Open Versus Endovascular repair) multicenter intention-to-treat analysis involving 623 patients also failed to show any significant mortality differences between the 2 treatment modalities [6]. However, a recent study showed a nearly 2-fold increase in adjusted in-hospital mortality and lower perioperative major adverse events along with reintervention rates during the follow-up after EVAR vs. OSR for rAAA, which led to a gradual shift favoring EVAR for rAAA repair over a 15-year period in this group [14]. Other retrospective and observational studies have reported similar lower mortality outcomes with EVAR over open repair [1-3]. Randomized vs. retrospective observational study designs each have uniquely distinct limitations. The need to implement strict inclusion and exclusion criteria may reduce the generalizability of RCT. Furthermore, RCTs may suggest study implications that

![Fig. 2. (A) One-year survival of endovascular or open repair for ruptured abdominal aortic aneurysm. (B) One-year survival of emergency endovascular aneurysm repair (eEVAR) vs. open repair for ruptured abdominal aortic aneurysm.](image-url)
are different from OSR due to their limited sample size. On the other hand, observational studies may be plagued by issues relating to selection and reporting biases which may question the objectivity of the study design.

Studies thus far have generally shown a greater preference for OSR in hemodynamically unstable patients while more stable patients including those with contained rupture were generally considered for EVAR [15]. In this study which included 20 patients, there were no significant differences in the hemodynamic status between the 2 groups. Eight of 12 patients (66.7%) in the eEVAR group and 62.5% (5 of 8) in the open repair group showed systolic blood pressure of <90 mmHg at the time of presentation with 2 of 12 EVAR patients (16.7%) having presented with contained rupture. Therefore, the overall patient severities between the 2 groups were similar.

We adopted the EVAR first strategy for rAAA since 2018. The decision to perform EVAR was left to surgeon discretion. In our study, the median symptom onset to ER arrival time and symptom onset to operation room arrival time were 180.0 minutes (range, 20–660 minutes) and 385.0 minutes (range, 105–900 minutes), respectively showing longer interval of symptom onset to operation room arrival time. Due to logistic issues pertaining to our remote location in Jeju Island, we concentrated on stocking our inventory with the most commonly available EVAR devices since mid-2019 to minimize the symptom onset to treatment by increasing accessibility to existing inventory. The recent study showed good EVAR outcomes for the treatment of rAAA even in select cases with unfavorable anatomy. This study included 13 patients with rAAA undergoing EVAR in which 4 had unfavorable anatomy with 1 case in this subcohort showing minor type 1a endoleak, suggesting high feasibility of achieving satisfactory outcomes by well-trained personnel supported by high-end angiographic technology even in these high-risk patients [16]. Although we were reluctant to do EVAR on unfavorable aortic neck anatomy, we found it did not result in a significantly increased procedure related to major morbidity risk. Although there was 1 case of type 1a and 1b endoleak which required additional stent-graft deployment combined with balloon inflation, no further problems were experienced. This incident also underlined the importance of careful patient selection. With regards to other complications, abdominal compartment syndrome occurred in one of each group (1 in open repair and 1 in eEVAR) with 1 death occurring after open repair suggesting that routine bladder pressure monitoring may be helpful in establishing earlier diagnosis and implementing treatment in a timelier manner. Other risk factors for mortality included preoperative disease severity, hemoglobin level, ASA PS grades, and Hardman scores along with the preoperative RBC transfusions. Postoperatively, acute renal, pulmonary, and multiorgan failure were statistically important univariate mortality risk factors. In our experience, the overall EVAR mortality rate since 2018 in this select high-risk group (2 of 10, 20.0%) of patients was generally encouraging. The 1-year eEVAR and open repair group survival of 75% ± 12.5% and 50% ± 17.7%, respectively were similar to other retrospective reports favoring the EVAR group. Mesenteric ischemia which is a known high-risk factor for mortality in rAAA was observed in 3 patients (2 of 3 died) in the open repair group. Two patients (current smoker) with preoperative cardiovascular and chronic kidney disease presented with hemodynamic instability. One patient underwent suprarenal aortic clamping during the open repair. In all of the patients, mesenteric ischemia occurred in the sigmoid colon. Two patients underwent Hartmann operation. To address the higher mortality risk incurred by prolonged mechanical ventilation (P = 0.005), our policy since 2018 has been to extubate as soon as possible in the angiography room if hemodynamically stable. In our experience, EVAR first strategy in rAAA was helpful in overcoming the greater mortality risk of open repair in a lower volume center [14,17]. Furthermore, the well-trained on hand experienced staff and the greater accessibility to a well-stocked inventory all contributed to the excellent EVAR results at our institution, especially in light of the frequent adverse weather conditions which frequently prohibited helicopter transfer to more specialized care facilities outside of the island.

The limitation of this study is that this is a retrospective short-term study for which multivariate analysis could not be done due to the relatively small sample size. Second, general anesthesia was performed in all patients without local or regional anesthesia support. However, the present results were comparable to higher volume reports in the literature. We expect the anesthesia support to include local and regional anesthesia with increasing experience in the future.

The overall rAAA repair outcomes were relatively superior with eEVAR over OSR and in view of the logistic restrictions posed by the geographical location of our hospital, this has worked well for us. It is especially noteworthy that eEVAR was found to be safe in our experience, even in select patients with unfavorable aortic neck anatomies.

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Conflict of Interest
No potential conflict of interest relevant to this article was reported.

ORCID iD
Suk Jung Choo: https://orcid.org/0000-0003-4291-302X
Yang-Bin Jeon: https://orcid.org/0000-0003-0713-5189
Sam-Sae Oh: https://orcid.org/0000-0003-1381-4700
Sung Ho Shinn: https://orcid.org/0000-0001-9539-7941
AUTHOR CONTRIBUTION

Conceptualization, Formal Analysis: SHS, SJC, YBJ
Investigation: SHS, SJC, SSO

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