ASTR

ORIGINAL ARTICLE
pISSN 2288-6575 • eISSN 2288-6796
https://doi.org/10.4174/astr.2021.100.5.291
Annals of Surgical Treatment and Research

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

Suk Jung Choo[1,*], Yang-Bin Jeon[2,*], Sam-Sae Oh[3], Sung Ho Shinn[4]

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

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.
[Ann Surg Treat Res 2021;100(5):291-297]

Key Words: Emergency endovascular aneurysm repair, Open repair, Ruptured abdominal aortic aneurysm

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

Received August 21, 2020, **Revised** January 19, 2021,
Accepted February 16, 2021

Corresponding Author: Sung Ho Shinn
Department of Thoracic and Cardiovascular Surgery, Cheju Halla General Hospital, 65 Doryeong-ro, Jeju 63127, Korea
Tel: +82-64-740-5039, **Fax:** +82-64-743-3110
E-mail: shinnsungho@gmail.com
ORCID: https://orcid.org/0000-0001-9539-7941

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

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 unfeasible 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

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 stautus; AAA, abdominal aortic aneurysm.

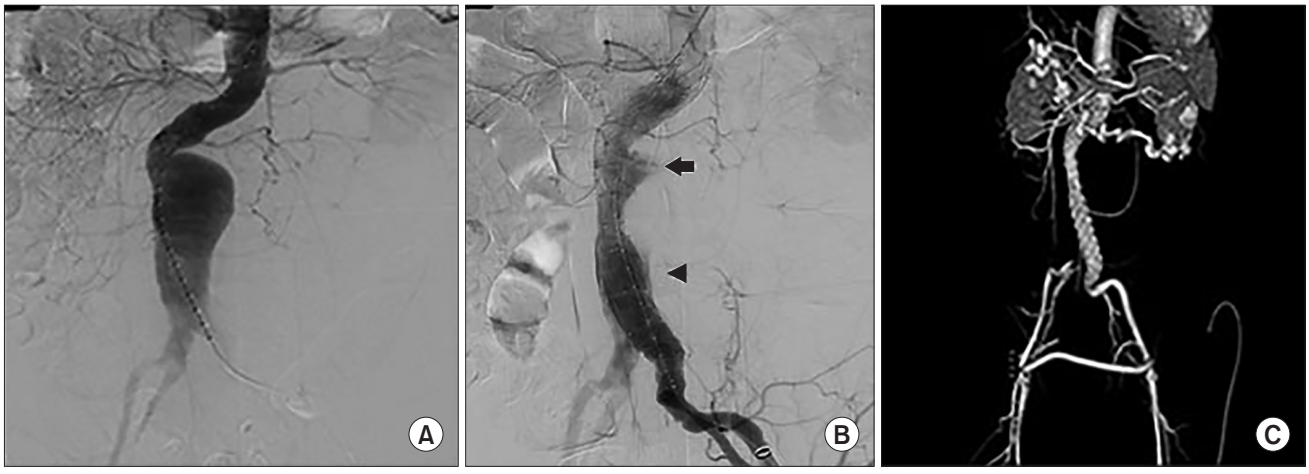

Fig. 1. (A) Initial angiography demonstrates a ruptured abdominal aortic aneurysm with hostile aortic neck. (B) Aorto-uni-iliac device implantation and crossover femoro-femoral bypass were performed. Additional covered stent graft was inserted to treat persistent type Ia (arrow) and Ib (arrowhead) endoleak 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.

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 2. Univariate outcome comparison for eEVAR (n = 12) *vs.* open repair (n = 8)

Variable	eEVAR (n = 12)	Open repair (n = 8)	P-value
Duration of mechanical ventilation (hr)	7 ± 17.2 (0–60)	46.4 ± 51.2 (2–144)	0.002
ICU stay (day)	3.3 ± 2.0 (1–7)	4.9 ± 3.9 (2–14)	NS
Hospital stay (day)	18.3 ± 14.1 (2–49)	21.5 ± 16.3 (2–53)	NS
Endoleak	1 (8.3)	0 (0)	NS
Bleeding	1 (8.3)	1 (12.5)	NS
Limb ischemia	1 (8.3)	1 (12.5)	NS
Mesenteric ischemia	0 (0)	3 (37.5)	0.049
Abdominal compartment syndrome	1 (8.3)	1 (12.5)	NS
Infection	3 (25.0)	1 (12.5)	NS
ARF requiring hemodialysis	3 (25.0)	2 (25.0)	NS
Myocardial infarction	1 (8.3)	0 (0)	NS
Paraparesis	1 (8.3)	1 (12.5)	NS
Pulmonary complications	1 (8.3)	3 (37.5)	NS
Multiorgan failure	2 (16.7)	2 (25.0)	NS
Mortality	3 (25.0)	4 (50.0)	0.356

Values are presented as mean ± standard deviation (range) or number (%).
eEVAR, emergency endovascular aneurysm repair; ICU, intensive care unit; NS, not significant; ARF, acute renal failure.

Table 3. Univariate analysis for in-hospital mortality in ruptured infrarenal abdominal aortic aneurysm

Variable	Survivor (n = 13)	Mortality (n = 7)	P-value
ASA PS classification			
III	4 (30.8)	0 (0)	
IV	9 (69.2)	6 (85.7)	
V	0 (0)	1 (14.3)	0.050
Hardman index			
0	2 (15.4)	0 (0)	
1	9 (69.2)	1 (14.3)	
2	0 (0)	1 (14.3)	
3	1 (7.7)	4 (57.1)	
4	1 (7.7)	0 (0)	
5	0 (0)	1 (14.3)	0.011
Low blood pressure (mmHg)	0 (0)	2 (28.6)	
<70			
70–89	7 (53.8)	4 (57.1)	
≥90	6 (46.2)	1 (14.3)	0.044
Preoperative RBC transfusion (pint)	8 (61.5)	0 (0)	
0			
1	2 (15.4)	1 (14.3)	
2	3 (23.1)	4 (57.1)	
3	0 (0)	2 (28.6)	0.003
Initial Hb (mg/dL)	10.6 ± 2.5 (5.0–14.7)	7.4 ± 1.5 (5.3–9.4)	0.009
Hb, <9 mg/dL	3 (23.1)	6 (85.7)	0.017
ARF requiring hemodialysis	1 (7.7)	4 (57.1)	0.031
Pulmonary complications	0 (0)	4 (57.1)	0.007
Multiorgan failure	0 (0)	4 (57.1)	0.007
Duration of mechanical ventilation (hr)	5.1 ± 8.0 (0–24)	55.6 ± 52.7 (0–144)	0.005

Values are presented as number (%) or mean ± standard deviation (range).
ASA, American Society of Anesthesiologist; PS, physical status; Hb, hemoglobin; ARF, acute renal failure.

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, in-hospital 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), multiorgan 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

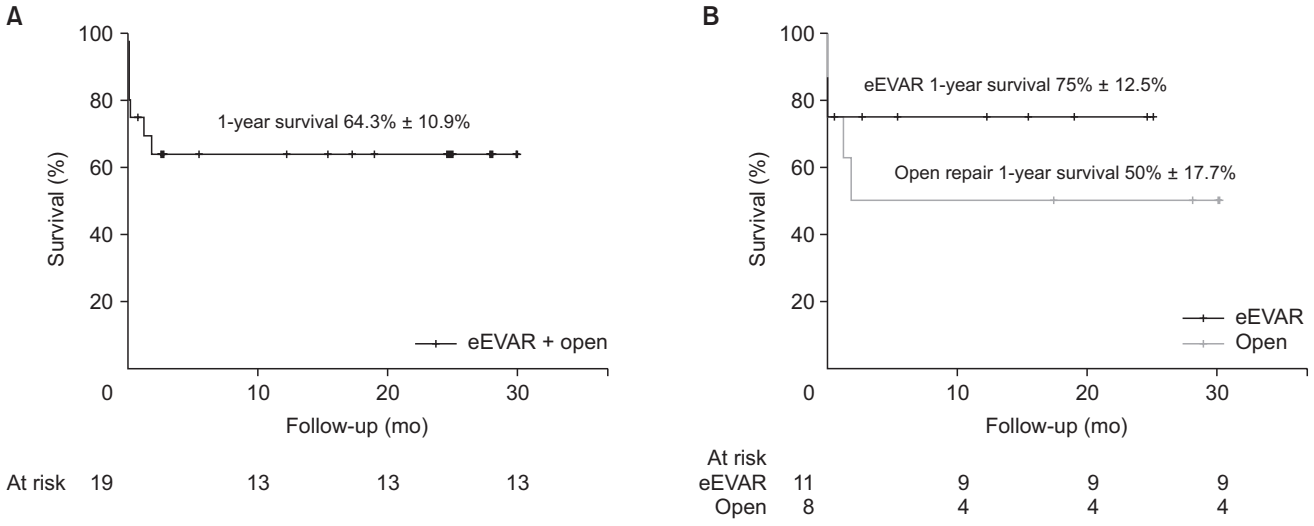

Fig. 2. (A) One-year survival of endovascular or open repair for ruptured abdominal aortic aneurysm. (B) One-year survival of emergency endovascular aneurysm repair (eEVAR) *vs.* open repair for ruptured abdominal aortic aneurysm.

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 Ia and Ib 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.

ACKNOWLEDGEMENTS

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
Methodology: All authors
Project Administration: SHS
Writing – Original Draft: All authors
Writing – Review & Editing: All authors

REFERENCES

1. Jetty P, Husereau D. Trends in the utilization of endovascular therapy for elective and ruptured abdominal aortic aneurysm procedures in Canada. J Vasc Surg 2012;56:1518-26.
2. Nedeau AE, Pomposelli FB, Hamdan AD, Wyers MC, Hsu R, Sachs T, et al. Endovascular vs open repair for ruptured abdominal aortic aneurysm. J Vasc Surg 2012;56:15-20.
3. Antoniou GA, Georgiadis GS, Antoniou SA, Pavlidis P, Maras D, Sfyroeras GS, et al. Endovascular repair for ruptured abdominal aortic aneurysm confers an early survival benefit over open repair. J Vasc Surg 2013;58:1091-105.
4. Reimerink JJ, Hoornweg LL, Vahl AC, Wisselink W, van den Broek TA, Legemate DA, et al. Endovascular repair versus open repair of ruptured abdominal aortic aneurysms: a multicenter randomized controlled trial. Ann Surg 2013;258:248-56.
5. Desgranges P, Kobeiter H, Katsahian S, Bouffi M, Gouny P, Favre JP, et al. Editor's choice: ECAR (Endovasculaire ou Chirurgie dans les Anévrysmes aorto-iliaques Rompus): a French randomized controlled trial of endovascular versus open surgical repair of ruptured aorto-iliac aneurysms. Eur J Vasc Endovasc Surg 2015;50:303-10.
6. IMPROVE Trial Investigators; Powell JT, Sweeting MJ, Thompson MM, Ashleigh R, Bell R, et al. Endovascular or open repair strategy for ruptured abdominal aortic aneurysm: 30 day outcomes from IMPROVE randomised trial. BMJ 2014;348:f7661.
7. Mayer D, Aeschbacher S, Pfammatter T, Veith FJ, Norgren L, Magnuson A, et al. Complete replacement of open repair for ruptured abdominal aortic aneurysms by endovascular aneurysm repair: a two-center 14-year experience. Ann Surg 2012;256:688-96.
8. Mohan PP, Hamblin MH. Comparison of endovascular and open repair of ruptured abdominal aortic aneurysm in the United States in the past decade. Cardiovasc Intervent Radiol 2014;37:337-42.
9. IMPROVE Trial Investigators. Comparative clinical effectiveness 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.
10. Pini R, Gallitto E, Faggioli G, Mascoli C, Vacirca A, Fenelli C, et al. Predictors of perioperative and late survival in octogenarians undergoing elective endovascular abdominal aortic repair. J Vasc Surg 2019;69:1405-11.
11. Acosta S, Ogren M, Bergqvist D, Lindblad B, Dencker M, Zdanowski Z. The Hardman index in patients operated on for ruptured abdominal aortic aneurysm: a systematic review. J Vasc Surg 2006;44:949-54.
12. Kirkpatrick AW, Roberts DJ, De Waele J, Jaeschke R, Malbrain ML, De Keulenaer B, et al. Intra-abdominal hypertension and the abdominal compartment syndrome: updated consensus definitions and clinical practice guidelines from the World Society of the Abdominal Compartment Syndrome. Intensive Care Med 2013;39:1190-206.
13. Wanhainen A, Verzini F, Van Herzeele I, Allaire E, Bown M, Cohnert T, et al. Editor's choice: European Society for Vascular Surgery (ESVS) 2019 clinical practice guidelines on the management of abdominal aorto-iliac artery aneurysms. Eur J Vasc Endovasc Surg 2019;57:8-93.
14. D'Oria M, Hanson KT, Shermerhorn M, Bower TC, Mendes BC, Shuja F, et al. Editor's choice: short term and long term outcomes after endovascular or open repair for ruptured infrarenal abdominal aortic aneurysms in the vascular quality initiative. Eur J Vasc Endovasc Surg 2020;59:703-16.
15. Acher C, Acher CW, Castello Ramirez MC, Wynn M. Operative mortality and morbidity in ruptured abdominal aortic aneurysms in the endovascular age. Ann Vasc Surg 2020;66:70-6.
16. Ko D, Park HS, Kim JY, Kim D, Lee T. Early experiences of endovascular aneurysm repair for ruptured abdominal aortic aneurysms. Ann Surg Treat Res 2019;96:138-45.
17. Budtz-Lilly J, Björck M, Venermo M, Debus S, Behrendt CA, Altreuther M, et al. Editor's choice: the impact of centralisation and endovascular aneurysm repair on treatment of ruptured abdominal aortic aneurysms based on international registries. Eur J Vasc Endovasc Surg 2018;56:181-8.