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Original Article

Comparison of In-Hospital Outcomes between Open Aneurysm Repair and Endovascular Aneurysm Repair for Ruptured Abdominal Aortic Aneurysm: A Retrospective Cohort Study Using Japanese Administrative Data

Takeshi Umegaki, MD, PhD,[1] Susumu Kunisawa, MD, PhD,[2] Takahiko Kamibayashi, MD, PhD,[1] Kiyohide Fushimi, MD, PhD,[3] and Yuichi Imanaka, MD, PhD[2]

Objective: To comparatively examine in-hospital mortality between open aneurysm repair (OAR) and endovascular aneurysm repair (EVAR) for ruptured abdominal aortic aneurysm (rAAA) in Japan.
Methods: Using administrative data, this retrospective cohort study analyzed rAAA patients treated at 482 Japanese acute care hospitals between April 1, 2018 and March 31, 2021. Patients were assigned to an OAR group or EVAR group. The propensity score for EVAR was calculated, and logistic regression analysis using inverse probability of treatment weighting was performed with in-hospital mortality as the dependent variable and surgical procedure (EVAR vs OAR) as the main independent variable of interest.
Results: The OAR group and EVAR group comprised 2650 patients from 372 hospitals and 2656 patients from 356 hospitals, respectively. In-hospital mortality was significantly higher (P <0.01) in the OAR group (11.7%) than in the EVAR group (9.4%). The logistic regression analysis calculated the odds ratio for in-hospital mortality to be 0.74 (95% confidence interval: 0.60–0.92; P <0.01) in the EVAR group (reference: OAR group).
Conclusion: EVAR was significantly associated with reduced in-hospital mortality and shorter hospitalizations in patients treated for rAAA in Japan.

Keywords: aortic rupture, abdominal aortic aneurysm, endovascular aneurysm repair, in-hospital mortality

[1]*Department of Anesthesiology, Kansai Medical University, Hirakata, Osaka, Japan*
[2]*Department of Healthcare Economics and Quality Management, Graduate School of Medicine, Kyoto University, Kyoto, Kyoto, Japan*
[3]*Department of Medical and Dental Sciences, Public Health, Health Policy and Informatics, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University, Tokyo, Japan*

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Corresponding author: Yuichi Imanaka, MD, PhD. Department of Healthcare Economics and Quality Management, Graduate School of Medicine, Kyoto University, Yoshida Konoe-cho, Sakyo-ku, Kyoto, Kyoto 606-8501, Japan
Tel: +81-75-753-4454
E-mail: imanaka-y@umin.net

Introduction

A ruptured abdominal aortic aneurysm (rAAA) is a highly fatal condition requiring emergency surgery. The choice of surgical procedure and duration of surgery can be affected by a variety of hospital-level factors, such as the overall availability of operating rooms, as well as the availability of cardiac surgeons, vascular surgeons, and anesthesiologists. In Japan, the mortality rate from rAAA remains unclear. However, the Ministry of Health, Labour and Welfare reported a mortality rate of 15.2 per 100000 population for aortic aneurysms and aortic dissections between January and December 2019, which was comparable to the mortality rates for interstitial lung disease and chronic kidney disease.[1] In other countries, in-hospital mortality rates and 30-day mortality rates for surgical rAAA cases were reported to exceed 25%–50%.[2–5] Furthermore, women tend to have higher mortality rates than men.[2] A portion of rAAA patients die before reaching the operating room, indicating that prompt diagnosis and treatment are crucial for increasing survival rates. A meta-analysis found that octogenarians with rAAA had a 30-day mortality rate of 43%,[3] which emphasizes the need for measures to improve survival in these older patients.

Current surgical interventions for rAAA include open aneurysm repair (OAR) and endovascular aneurysm repair (EVAR). Despite the growing prevalence of endovascular procedures, no large-scale epidemiological studies have examined the difference in prognosis between these surgical techniques in Japan. A multicenter study on the choice between OAR and EVAR for rAAA is currently being jointly conducted by the Japan Surgical Society and the Japanese Committee for Stentgraft Management, but results have yet to be reported. Accordingly, there is a lack of evidence on the clinical outcomes between OAR and EVAR in Japanese hospitals.

Although epidemiological studies on OAR and EVAR can be conducted using prospective methods, large-scale multicenter analyses are constrained by the high labor requirements and costs required for data collection and processing. As an alternative approach, the secondary use of preexisting administrative data can enable large-scale studies to be performed at a relatively low cost. Hospitals produce and submit administrative data to insurers for reimbursements. The majority of Japanese hospitals have adopted the Diagnosis Procedure Combination (DPC) case-mix system to calculate reimbursements for each episode of care. DPC administrative data encompass a wide range of information (e.g., patient characteristics and procedures) produced in a standardized format, thereby facilitating analyses of large samples across multiple hospitals. As a result, DPC data are increasingly used in healthcare research in Japan.

In this study, we used DPC data to conduct a comparative analysis of in-hospital mortality between OAR and EVAR for rAAA cases treated at Japanese acute care hospitals. We also analyzed the differences in the length of stay in the intensive care unit (ICU) and overall hospital stay between these two surgical procedures.

Materials and Methods

Study design and data source

This multicenter retrospective cohort study was conducted using a DPC database comprising clinical and administrative data from Japanese acute care hospitals between April 1, 2018 and March 31, 2021. The data were collected by the DPC Research Group, which is a government-funded initiative aimed at improving healthcare in Japanese hospitals through DPC data research. The DPC database included patient demographics (e.g., sex, height, and weight), primary and secondary diagnoses, comorbidities, emergency admission, clinical tests, prescribed medications, surgeries, treatments, and discharge destination (including mortality). The study was approved by the institutional ethics committee of Kansai Medical University (Approval Number: 2021366).

Patient selection and characteristics

We identified patients with a primary diagnosis of rAAA using the International Classification of Diseases, 10th Revision (ICD-10) codes I713 and I714. Japanese procedural codes were used to identify cases treated with OAR (K5606 and K5607) and EVAR (K5611 and K5612). Emergency admission and discharge dates were determined using the relevant Japanese hospitalization codes. We excluded patients with a planned admission and patients diagnosed with a ruptured thoracoabdominal aortic aneurysm. The remaining patients were categorized into an OAR group or EVAR group for analysis.

For this study, we collected information on the following patient characteristics: age, sex, weight, height, primary diagnosis, Japan Coma Scale (JCS) score at admission and discharge, activities of daily living (ADL) score at admission and discharge, and Charlson comorbidity index. Weight and height were used to calculate body mass index (weight in kg/height in m^2). JCS scores were analyzed using four categories: 0 (alert), 1-digit (awake without stimuli), 2-digit (arousable with some stimuli but reverts to previous status when the stimulus stops), and 3-digit (unarousable by any stimuli). ADL had a maximum score of 20 points, which was calculated using the following 10 items: feeding (0–2 points), transferring (0–3 points), grooming (0–1 point), toileting (0–2 points), bathing (0–1 point), walking on level ground (0–3 points), climbing stairs (0–2 points), dressing (0–2 points), bowel continence (0–2 points), and urinary continence (0–2 points). For this study, we used a modified version of the Charlson comorbidity index (categories: 1, 2, 3, 4, 5, and ≥6 comorbidities) adapted for administrative data.[6,7]

Mechanical ventilation, use of inotropes and vasopressors, renal replacement therapy, and tracheotomy were identified using Japanese procedural codes. Inotropes and vasopressors included dopamine, noradrenalin, adrenalin, and vasopressin.

In addition, we identified the occurrence of the following postoperative complications: reoperation, acute kidney injury (AKI), ischemic heart disease, ischemic bowel disease, paraplegia, cerebral infarction, cerebral hemorrhage, and cerebral hypoxia.

Outcome measures

The primary outcome measure was in-hospital mortality, and the secondary outcome measures were the length (days) of ICU stay and overall hospital stay.

Statistical analysis

First, we conducted a descriptive analysis of the patient characteristics in the OAR and EVAR groups. Continuous variables were calculated as means and standard deviations and compared using Student's t-test. Categorical variables were calculated as percentages, and compared using the Chi-squared test. The incidences of postoperative complications were also compared between the

Table 1 Patient characteristics and use of transfusions in all patients (n = 5306)

Variables	Open group (n = 2650)	EVAR group (n = 2656)	*P* value
Number of hospitals	372	356	
Patient characteristics			
Age (years)	73.4 ± 9.7	77.7 ± 9.3	<0.001
Male (%)	80.0	77.3	0.02
Height (cm)	163.7 ± 9.2	161.8 ± 9.2	<0.001
Weight (kg)	62.5 ± 13.5	59.7 ± 13.0	<0.001
Body mass index (kg m²)	23.3 ± 4.5	22.7 ± 3.9	<0.001
JCS score at admission (%)			
0	76.5	77.1	<0.01
1-digit	12.8	14.6	
2-digit	4.0	3.7	
3-digit	6.8	4.6	
JCS score at discharge (%)			
0	94.0	92.8	0.25
1-digit	4.7	6.0	
2-digit	0.8	0.7	
3-digit	0.5	0.5	
ADL score at admission	7.9 ± 9.1	8.6 ± 9.0	0.01
ADL score at discharge	16.4 ± 6.3	15.4 ± 6.8	<0.001
Charlson comorbidity index (%)			
1	44.6	40.6	<0.01
2	28.1	27.9	
3	16.2	18.3	
4	7.5	8.4	
5	2.7	2.9	
≥6	1.0	1.9	
Transfusion (units)			
Red blood cells	3.0 ± 7.3	2.1±5.7	<0.001
Fresh frozen plasma	1.6 ± 4.4	0.8 ± 3.1	<0.001
Platelet concentrates	4.0 ± 9.6	1.9 ± 6.8	<0.001
Use of intraoperative blood salvage (%)	79.5	2.7	<0.001

Values are presented as mean ± standard deviation for continuous variables and number (percentage) for categorical variables.

EVAR: endovascular aortic repair; JCS: Japan Coma Scale; ADL: activities of daily living

groups. The propensity score for EVAR was calculated using a multiple logistic regression model that accounted for patient age, sex, body mass index, JCS score at admission, ADL score at admission, Charlson comorbidity index, and number of emergency OAR procedures for rAAA at each hospital. Using the inverse probability of treatment weighting, we calculated the odds ratio of EVAR for in-hospital mortality relative to OAR in a logistic regression analysis with a generalized estimating equation approach. In addition, Kaplan–Meier survival curves were plotted to examine the differences in survival between the groups.

P values lower than 0.05 were considered to be statistically significant. Analyses were performed using SPSS Version 28.0 (IBM Japan, Ltd., Tokyo, Japan).

Results

The study sample consisted of 5306 rAAA patients from 482 hospitals. **Table 1** summarizes the patient characteristics. The OAR group and EVAR group comprised 2650 patients from 372 hospitals and 2656 patients from 356 hospitals, respectively. The mean ages of patients in the OAR group and EVAR group were 73.4 years and 77.7 years (P <0.001), respectively. There were significant intergroup differences in sex, weight, height, body mass index, JCS score at admission, ADL score at admission and discharge, and Charlson comorbidity index. In addition, the OAR group had significantly higher use of blood products (red blood cells, fresh frozen plasma, and platelet concentrates) and intraoperative blood salvage (all P <0.001) than the EVAR group.

Table 2 Use of postoperative care in all patients (n = 5306)

Variables	Open group (n = 2650)	EVAR group (n = 2656)	*P* value
Postoperative care			
Mechanical ventilation after surgery (days)	3.7 ± 7.9	2.0 ± 6.4	<0.001
Use of inotropes and vasopressors			
Dopamine (days)	1.3 ± 3.6	0.5 ± 2.1	<0.001
Noradrenalin (days)	1.9 ± 3.9	1.0 ± 2.8	<0.001
Adrenalin (days)	0.1 ± 0.4	0.1 ± 0.3	<0.001
Vasopressin (days)	0.1 ± 0.6	0.1 ± 1.0	0.35
Renal replacement therapy (%)	13.3	7.0	<0.001
Tracheotomy (%)	4.5	2.5	<0.001

Values are presented as mean ± standard deviation for continuous variables and number (percentage) for categorical variables.

EVAR: endovascular aortic repair

Table 3 Patient outcomes in all patients (n = 5306)

Variables	Open group (n = 2650)	EVAR group (n = 2656)	*P* value
Outcomes			
ICU stay (days)	5.0 ± 4.9	3.0 ± 4.1	<0.001
Overall hospital stay (days)	30.5 ± 25.4	24.7 ± 23.8	<0.001
Discharge destination in survivors (%)			
Home	65.4	66.0	
Other hospitals or nursing home	22.9	24.6	0.02
In-hospital mortality (%)	11.7	9.4	

Values are presented as mean ± standard deviation for continuous variables and number (percentage) for categorical variables.

EVAR: endovascular aortic repair; ICU: intensive care unit

Table 4 Complications after surgery in all patients (n = 5306)

Postoperative complications	Open group (n = 2650)	EVAR group (n = 2656)	*P* value
Re-operation (%)	0.9	3.2	<0.001
Acute kidney injury (%)	9.5	5.0	<0.001
Ischemic heart disease (%)	0.2	0.5	0.04
Ischemic bowel disease (%)	2.0	1.2	0.01
Paraplegia (%)	0.6	0.2	0.04
Cerebral infarction (%)	1.4	1.7	0.32
Cerebral hemorrhage (%)	0.1	0.1	0.50
Cerebral hypoxia (%)	0.6	0.2	0.04

EVAR: endovascular aortic repair

The use of postoperative care is presented in **Table 2.** The duration of mechanical ventilation in the OAR group (mean ± standard deviation: 3.7 ± 7.9 days) was significantly longer (P <0.001) than in the EVAR group (2.0 ± 6.4 days). In the use of inotropes and vasopressors, the OAR group had significantly longer use of dopamine, noradrenaline, and adrenalin (all P <0.001) than the EVAR group. Furthermore, the OAR group had significantly higher use of renal replacement therapy and tracheotomy (both P <0.001).

Table 3 shows the differences in unadjusted outcomes between the groups. The length of ICU stay was significantly longer (P <0.001) in the OAR group (5.0 ± 4.9 days) than in the EVAR group (3.0 ± 4.1 days). Similarly, the length of overall hospital stay was significantly longer (P <0.001) in the OAR group (30.5 ± 25.4) than in the EVAR group (24.7 ± 23.8 days). There was no statistically significant difference (adjusted residuals: 1.4) in the proportion of patients discharged home between the OAR group (65.4%) and the EVAR group (66.0%). However, in-hospital mortality was significantly higher (adjusted residuals: 2.7) in the OAR group (11.7%) than in the EVAR group (9.4%).

Table 4 shows the differences in postoperative complications between the groups. The OAR group had

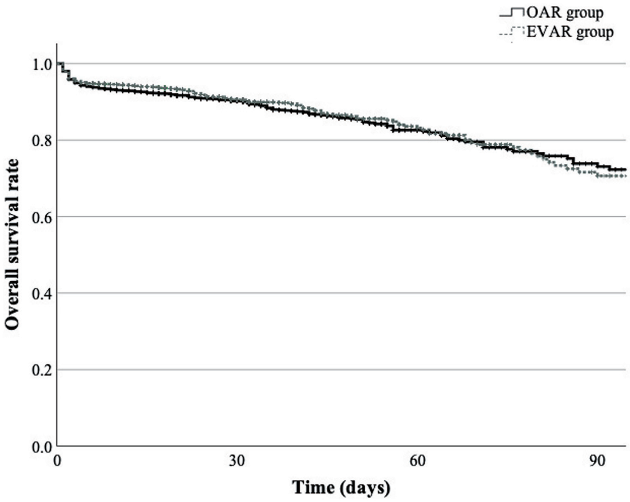

Fig. 1 Kaplan–Meier survival curves of the OAR group and the EVAR group. EVAR: endovascular aneurysm repair; OAR: open aneurysm repair

significantly higher incidences of AKI, ischemic bowel disease, paraplegia, and cerebral hypoxia than the EVAR group. By contrast, the EVAR group had significantly higher incidences of reoperation and ischemic heart disease than the OAR group.

Figure 1 shows the Kaplan–Meier survival curves for both groups. There was no significant difference in survival between the groups (P = 0.35). The results of the multiple logistic regression analysis of in-hospital mortality are presented in the Supplemental Table. The EVAR group had a significantly reduced risk of in-hospital mortality (odds ratio: 0.74; 95% confidence interval: 0.60–0.92; P <0.01) relative to the OAR group.

Discussion

This retrospective cohort study of rAAA patients in 482 Japanese acute care hospitals showed that EVAR was significantly associated with reduced in-hospital mortality when compared with OAR, as well as shorter ICU and hospital stays. These findings differed from those of recent clinical trials conducted in the UK, Canada, the Netherlands, and France, which reported no significant differences in short-term prognosis between OAR and EVAR for the treatment of rAAA.[8–10] In a meta-analysis of three randomized controlled trials comparing OAR and EVAR, Badger et al.[11] noted that 30-day mortality was similar between the two interventions. However, that meta-analysis was conducted using a total of 388 EVAR cases and 373 OAR cases, which represented a much smaller sample size than our present study conducted using DPC data. On the other hand, our results were similar to those of Roosendaal et al., who reported that the relative risk of 30-day mortality for EVAR was significantly lower (0.50; 95% confidence interval: 0.38–0.67) than OAR in a meta-analysis of six observational studies encompassing 7376 octogenarians with rAAA.[3] Similarly, Alsusa et al. reported in a meta-analysis of propensity score-matched data that EVAR generally had a lower perioperative mortality rate than OAR.[12] Although our study employed a retrospective design, the use of inverse probability of treatment weighting contributed to the reliability of our results. Therefore, our findings may be an accurate representation of the relative effectiveness of these surgical approaches in Japanese hospitals. Nevertheless, future prospective studies are needed to confirm or refute our findings.

Several studies have compared the long-term prognosis between OAR and EVAR. The IMPROVE Trial, which was a randomized controlled trial of rAAA patients in 30 UK and Canadian vascular centers, found that EVAR did not have a significantly lower mortality (P = 0.41) than OAR after 7 years.[13] Another randomized controlled trial of patients with asymptomatic abdominal aortic aneurysms in 42 US medical centers did not detect any significant difference (P = 0.65) in survival between OAR and EVAR after 14 years of follow-up.[14] By contrast, an analysis of rAAA patients in the US, Canada, and Singapore using the Society for Vascular Surgery's Vascular Quality Initiative clinical registry found that EVAR had a significantly lower risk of 5-year mortality (hazard ratio: 0.69; 95% confidence interval: 0.60–0.79; P <0.001) than OAR.[15] Accordingly, there remains a lack of consistent evidence on the long-term clinical effectiveness of these surgical procedures.

Our study found that patients in the OAR group generally had a lower ADL score at admission, but a higher ADL score at discharge when compared with those in the EVAR group. This may have been influenced by the fact that ADL scores could not be accurately assessed in the OAR group due to their lower levels of consciousness at admission, as indicated by the JCS scores. Furthermore, the EVAR group generally had higher proportions of patients with more comorbidities than the OAR group. It is therefore possible that the EVAR group actually had lower levels of ADL at both admission and discharge. Although previous studies have not examined the differences in ADL between OAR and EVAR patients, the IMPROVE Trial evaluated cost-effectiveness based on the quality of life (EQ-5D utility scores).[13] That study found that while the EVAR group had a significantly higher quality of life at 3 months and 1 year after surgery, both groups had a similar quality of life at 3 years.[13] Our study may have been affected by difficulties in assessing ADL in acute rAAA patients, and further research is needed to monitor ADL in both OAR and EVAR patients for several months after surgery.

Lederle et al.[14] conducted a randomized controlled trial of 881 patients who received elective repair of abdominal aortic aneurysms and noted that the proportion of patients who underwent a secondary procedure was higher in the EVAR group (26.7%) than in the OAR group (19.8%) for a maximum follow-up of 14 years. In our analysis of patients who received emergency repair of rAAA, we similarly found that the proportion of patients who underwent reoperation was higher in the EVAR group (3.2%) than in the OAR group (0.9%). In this way, the risk of reoperation after EVAR appears to be higher for both elective and emergency procedures. In a previous study of Japanese administrative data, Kimura et al.[16] reported that patients with rAAA had higher proportions of venous thromboembolism, disseminated intravascular coagulation, and kidney failure than those with intact abdominal aortic aneurysms.[16] Our study revealed that incidences of short-term postoperative complications (e.g., reoperation, AKI, ischemic heart disease, ischemic bowel disease, paraplegia, and cerebrovascular accidents) differed between the OAR and EVAR groups. This provides further insight into the relative effectiveness and safety of these surgical procedures for rAAA patients in Japan. A systematic review of AKI after OAR for intact abdominal aortic aneurysms estimated AKI rates to be approximately 20%–26% according to classification methods such as Risk, Injury, Failure, Loss, and End-Stage Renal Disease (RIFLE), Acute Kidney Injury Network (AKIN), Kidney Disease: Improving Global Outcomes (KDIGO), and Aneurysm Renal Injury Score (ARISe).[17] By contrast, EVAR was associated with an AKI rate of only 2%.[18] Moreover, AKI has shown higher rates in patients with rAAA than those with intact abdominal aortic aneurysms[19] and was also the most common complication among our patients. However, our identification of AKI was based on ICD-10 codes, which did not give insight into the classification method (RIFLE, AKIN, KDIGO, and ARISe) used by each hospital. Therefore, there may be hospital-level variations in the criteria used to diagnose AKI in our study sample.

This study has several limitations. First, the DPC database did not include physiological data (e.g., blood pressure, hemoglobin levels, complete blood count, and creatinine levels), duration from rAAA onset to surgery, and aneurysm size. We were unable to obtain information on Fitzgerald classification, proximal neck length, or door-to-intervention time due to the format of the DPC database without these items. To minimize the patient-level variations in these factors, we focused on patients who had an emergency admission for rAAA. Second, the data lacked surgical data, including blood loss, anesthesia time, and operative time. Nevertheless, our analysis was designed to compare OAR and EVAR, and the variable of surgical procedure may incorporate the effects of these intraoperative variables. Third, we did not have access to diagnostic imaging data, such as computed tomography, roentgenography, and echocardiography. Therefore, we could not ascertain if an aneurysm was infrarenal or suprarenal, or whether it was a true aneurysm, pseudoaneurysm, or dissecting aneurysm. In addition, we could not distinguish between fusiform and saccular types of aneurysms. Finally, we did not have data on the number of specialists (e.g., anesthesiologists, cardiac surgeons, and vascular surgeons) and medical treatment systems at each hospital, which may have influenced the decisions regarding surgical procedures.

Conclusion

This large-scale retrospective study provides new evidence that EVAR is associated with lower in-hospital mortality in rAAA patients in Japanese acute care hospitals. Hospitals may benefit from increasing EVAR procedures for the treatment of rAAA where possible, but further research is needed to identify and control the risk factors of reoperation.

Declarations

Ethics approval and consent to participate

This investigation was conducted in accordance with the principles of the Declaration of Helsinki.

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Author contributions

Study conception: TU, SK, and YI
Data collection: SK, KF, and YI
Analysis: TU
Investigation: All authors
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Final approval of the article: all authors
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Disclosure statement

The authors declare no conflicts of interest, financial or otherwise.

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