Endovascular versus open repair in patients with abdominal aortic aneurysm: a claims-based data analysis in Japan

Yuki Kimura,1 Hiroshi Ohtsu,1,2,3 Naohiro Yonemoto,4,5 Nobuyoshi Azuma,6 Kazuhiro Sase1,3

ABSTRACT

Objectives Endovascular aortic repair (EVAR) evolved through competition with open aortic repair (OAR) as a safe and effective treatment option for appropriately selected patients with abdominal aortic aneurysm (AAA). Although endoleaks are the most common reason for post-EVAR reintervention, compliance with lifelong regular follow-up imaging remains a challenge.

Design Retrospective data analysis.

Setting The Japan Medical Data Center (JMDC), a claims database with anonymous data linkage across hospitals, consists of corporate employees and their families of ≤75 years of age.

Participants The analysis included participants in the JMDC who underwent EVAR or OAR for intact (iAAA) or ruptured (rAAA) AAA. Patients with less than 6 months of records before the aortic repair were excluded.

Main outcome measures Overall survival and reintervention rates.

Results We identified 986 cases (837 iAAA and 149 rAAA) from JMDC with first aortic repairs between January 2015 and December 2020. The number of patients, median age (years (IQR)), follow-up (months) and post-procedure CT scan (times per year) were as follows: iAAA (OAR: n=593, 62.0 (57.0–67.0), 26.0, 1.6, EVAR: n=244, 65.0 (31.0–69.0), 17.0, 2.2), rAAA (OAR: n=110, 59.0 (53.0–59.0), 16.0, 2.1, EVAR: n=39, 62.0 (31.0–67.0), 18.0, 2.4). Reintervention rate was significantly higher among EVAR than OAR in rAAA (15.4% vs 8.2%, p=0.04). In iAAA, there were no group difference after 5 years (7.8% vs 11.0%, p=0.28), even though EVAR had initial advantage. There were no differences in mortality rate between EVAR and OAR for either rAAA or iAAA.

Conclusions Claims-based analysis in Japan showed no statistically significant difference in 5-year mortality rate of EVAR compared with OAR. However, EVAR had a significantly higher reintervention rate in ruptured AAA, and a long-term upward trend offset the initial benefit in intact cases.

WHAT ARE THE NEW FINDINGS?

⇒ Lifelong regular follow-up with imaging is recommended at 30 days post-EVAR and annually thereafter.

⇒ International collaborations to create real-world surveillance systems are warranted.

WHAT IS ALREADY KNOWN ABOUT THIS SUBJECT?

⇒ Endovascular aortic repair (EVAR) has evolved through competition with open aortic repair (OAR) as a safe and effective treatment option for appropriately selected patients with abdominal aortic aneurysm (AAA).

⇒ Although annual follow-up with imaging is recommended for EVAR, long-term surveillance and data collection remain challenging.

HOW MIGHT THESE RESULTS AFFECT FUTURE RESEARCH OR SURGICAL PRACTICE?

⇒ Standards of care need to be set by the Society for Vascular Surgery (SVS),3 the European Society for Vascular Surgery (ESVS),4 and the Japanese Society for Vascular Surgery (JSVS).5 In addition, collaborations for quality improvement such as VASCUNET, Vascular Quality Initiative (VQI), and International Consortium of Vascular Registries (ICVR) have helped to

INTRODUCTION

Although abdominal aortic aneurysms (AAA) are asymptomatic, they tend to enlarge, and ruptured cases have a high mortality rate.

The exact number of patients with AAA is unknown, but it is estimated to be approximately 1.4% of the population between 50 and 84 and is more common in men and smokers.12 Treatment of AAA includes open aortic repair (OAR) and endovascular aortic repair (EVAR), as updated in the practice guidelines by the Society for Vascular Surgery (SVS),3 the European Society for Vascular Surgery (ESVS),4 and the Japanese Society for Vascular Surgery (JSVS).5 In addition, collaborations for quality improvement such as VASCUNET, Vascular Quality Initiative (VQI), and International Consortium of Vascular Registries (ICVR) have helped to
improve the outcomes of patients with intact (iAAA) and ruptured (rAAA) AAA.⁶

EVAR has evolved as a safe and effective treatment option for appropriately selected AAA patients through competition with OAR.¹⁻³⁵ Although EVAR has an advantage in perioperative outcomes, aneurysm sac failure to regress after EVAR is associated with lower long-term survival.⁷ Endoleaks are the most common reason for aortic reintervention.⁸ Current guidelines recommend follow-up imaging at 30 days post-EVAR and annually thereafter.⁹ However, the imaging follow-up compliance is reported to be only about 40%.¹⁰ Therefore, the US Food and Drug Administration (FDA) recently issued a letter to healthcare providers to recommend lifelong annual follow-up imaging and create a real-world surveillance system.⁹

Real-world evidence (RWE) is a new concept in regulatory science to appraise fit-for-purpose reliability and relevance of real-world data (RWD).¹⁰¹¹ Since there are limitations with registry-based research in vascular medicine,¹² health insurance claims have been used as a promising source of RWD with high external validity because there is no reimbursement without billing the payer.¹³⁻¹⁶ Recently, a patient-level claims database with an anonymous data-linkage system was developed in Japan and used in various areas of medical research.¹⁹⁻²¹ In this study, we aimed to examine the relevance of the claims database and evaluate the long-term outcome of EVAR and OAR for the treatment of AAA.¹³⁻¹⁵¹⁶

**METHODS**

**Study design and data source**

This retrospective cohort study used anonymized patient-level claims data from the Japan Medical Data Center (JMDC, Tokyo).¹⁹ The JMDC is one of the largest databases in Japan, with approximately 9.8 million beneficiaries of ≤75 years of age or 7.8% of the Japanese population registered as of 2021.²⁰ The Japanese universal health insurance system is based on Fee-for-Service (FFS) and Diagnosis Procedure Combination (DPC).²² While the Diagnosis Related Group (DRG) in the USA is a pay-per-case system, the DPC is a pay-per-day system with a blanket portion for basic hospital fees and an FFS portion, including surgical procedures and expensive devices. Therefore, missing data are rare for expensive imaging and surgeries.¹³ The JMDC anonymously links monthly billing receipts routinely collected from DPC hospitals, FFS clinics, and pharmacies to provide a patient-centric database.²⁰ In this study, the codes from the JMDC, based on the International Classification of Diseases, 10th Edition (ICD-10), the Anatomical Therapeutic Chemical Classification (ATC), and specific billing codes for medical devices, are designated by square brackets.

**Patient selection**

We have designed our patient selection flow from the JMDC claims database (figure 1) based on a previously published study from Germany.¹³ Patients with a diagnosis code of rAAA [1713] or iAAA [1714], with their first procedure code for OAR [150245110, 150245210] or EVAR [150301410, 150301510, 150400410] in the analysis. AAA, abdominal aortic aneurysm; EVAR, endovascular aortic repair; JMDC, Japan Medical Data Center; iAAA, intact abdominal aortic aneurysm; ICD-10, International Classification of Diseases, 10th Edition; rAAA, ruptured abdominal aortic aneurysm; OAR, open aortic repair.

**Ethical consideration**

The Research Ethics Committee, Faculty of Medicine, Juntendo University approved the protocol of this study (E21-0163-M01) according to the Ethical Guidelines for Medical Research Involving Human Subjects (Ministry of Health, Labour, and Welfare of Japan) and the World Medical Association (WMA) Declaration of Helsinki. The need for informed consent was waived in this observational study owing to the anonymity of the data.

**Preoperative risk factors**

Preoperative risk factors¹ including hypertension [I10-I15], dyslipidemia [E78], diabetes mellitus [E10-E14], chronic obstructive pulmonary disease (COPD) [J44], cerebrovascular disease [I63], renal failure [N17-N18], atrial fibrillation [I48], heart failure [I50], ischemic heart disease [I20-I25], prescription of antiplatelet agents [B01C], prescription of direct oral anticoagulants [B01F, B01E], warfarin [B01A], and smoking history. The Japanese claims data contain a ‘tentative disease code’ for billing purposes.²²⁻²⁴ Therefore, to increase specificity,
we combined the codes for the diagnosis, prescription, and treatment of hypertension, dyslipidemia, diabetes mellitus, COPD, cerebrovascular disease, renal failure, heart failure, and ischemic heart disease within the same billing month. We have defined smoking before the index date based on the smoking history described in previous studies using the JMDC.

Outcomes
Postoperative outcomes including cerebrovascular disease [I63], thromboembolism [I802, I822], disseminated intravascular coagulation (DIC) [D65], renal failure [N17–N18], CT follow-up rate, reintervention, 30-day mortality, and 5-year mortality were studied. Cerebrovascular disease, thromboembolism, DIC, and renal failure were defined by a combination of diagnosis and prescription or procedure. The death flags in the subscribers and diagnoses tables have been integrated with withdrawals not elsewhere classified within 1 month after the index. We defined reintervention after OAR and EVAR as the first AAA-related procedure code (online supplemental table 1) billed in the month following the primary procedure or later, which is consistent with prior works. The CT follow-up rate was calculated as the number of CT scans performed per year of follow-up after the initial procedure.

Statistical analysis
The data of the patients who withdrew from insurance were considered censored data, and all patients were included in the analyses. Categorical variables were summarized by count (percentage) and were compared using Fisher’s exact test, and continuous variables were summarized by median (IQR) and were compared using the Wilcoxon rank-sum test. Survival curves were evaluated using the Kaplan-Meier method with the log-rank test. Multivariable Cox proportional hazards models were used to estimate HRs and 95% CIs, adjusting for baseline variables. All analyses maintained the standard definition of statistical significance as a two-tailed p value of 0.05 or less. Statistical analyses were conducted using SAS V.9.4 (SAS Institute).

RESULTS
Data source and patient selection
Figure 1 shows the flow chart of patient selection. A total of 17,298 patients with ICD-10 code for aortic aneurysm and dissection [I71] were selected from among those registered in the JMDC database. Between January 2015 and December 2020, 986 patients underwent the first repair for AAA. Of these, 149 patients had an rAAA (39 EVAR and 110 OAR cases), and 837 patients had an iAAA (244 EVAR and 593 OAR cases).

Patient background and risk factors
Baseline demographics, comorbidities, and clinical characteristics of JMDC patients who underwent OAR and EVAR are shown in table 1. In the iAAA group, the most notable differences between OAR and EVAR were

Table 1 Baseline patient characteristics

| Variables                  | iAAA          | rAAA          | P value |
|----------------------------|---------------|---------------|---------|
|                            | OAR n=593     | EVAR n=244    |         |
| Age, median (IQR)          | 62.0 (31.0–69.0) | 65.0 (31.0–69.0) | <0.0001* |
| Female gender, n (%)       | 74 (12.5%)    | 10 (4.1%)     | <0.0001† |
| Hypertension, n (%)        | 377 (63.6%)   | 158 (64.8%)   | 0.81†   |
| Dyslipidemia, n (%)        | 209 (35.2%)   | 96 (39.3%)    | 0.27†   |
| Diabetes, n (%)            | 87 (14.7%)    | 33 (13.5%)    | 0.74†   |
| COPD, n (%)                | 1 (0.2%)      | 2 (0.8%)      | 0.21†   |
| Cerebrovascular accident, n (%) | 38 (6.4%)    | 8 (3.3%)      | 0.09†   |
| Kidney failure, n (%)      | 12 (2.0%)     | 4 (1.6%)      | 1.00†   |
| Atrial fibrillation, n (%) | 78 (13.2%)    | 25 (10.2%)    | 0.30†   |
| Chronic heart failure, n (%) | 167 (28.2%)   | 67 (27.5%)    | 0.87†   |
| Ischemic heart disease, n (%) | 147 (24.8%)   | 59 (24.2%)    | 0.93†   |
| Coronary angiography, n (%) | 192 (32.4%)   | 60 (24.6%)    | 0.03†   |
| Antiplatelet agent, n (%)  | 260 (43.8%)   | 113 (46.3%)   | 0.54†   |
| Oral anticoagulant, n (%)  | 74 (12.5%)    | 34 (13.9%)    | 0.57†   |
| Smoking, n (%)             | 240 (40.5%)   | 105 (43.0%)   | 0.54†   |

Categorical values are reported as total numbers (%) and continuous variables as medians (IQR).
*Wilcoxon rank-sum test.
†Fisher’s exact test.
COPD, Chronic Obstructive Pulmonary Disease; EVAR, endovascular aortic repair; iAAA, intact abdominal aortic aneurysm; OAR, open aortic repair; rAAA, ruptured abdominal aortic aneurysm.
a significantly higher percentage of women (12.5% vs 4.1%, \(p<0.0001\)) and a significantly higher median age (62 years vs 65 years, \(p<0.0001\)) for EVAR. In the rAAA group, there was no statistically significant difference in the proportion of women between OAR and EVAR, although EVAR had a significantly higher median age (59 years vs 62 years, \(p<0.0001\)). There was no statistically significant difference for smoking, one of the prognostic determinants,\(^1\) between OAR and EVAR in either iAAA (40.5% vs 43.0%, \(p=0.54\)) or rAAA (36.4% vs 35.9%, \(p=1.00\)).

### Outcomes

The postoperative outcomes are summarized in table 2. Frequencies of CT follow-up per year (median) were 2.21 (EVAR) and 1.62 (OAR) for iAAA, and 2.40 (EVAR) and 2.10 (OAR) for rAAA.

There were no significant differences in mortality rate and 5-year mortality between OAR and EVAR for either iAAA or rAAA (figure 2).

In rAAA (figure 3B), the reintervention rate was significantly higher in the EVAR group (log-rank \(p=0.04\)). The 5-year reintervention ratios for EVAR and OAR were 15.4% and 8.2%, respectively.

In iAAA (figure 3A), there were no group differences in reintervention rates (log-rank \(p=0.28\)), where EVAR was lower in the early postoperative period, followed by a gradual increase. The 5-year reintervention ratios for EVAR and OAR were 7.8% and 11.0%, respectively.

Table 3 shows that EVAR (HR 3.07; 95% CI 1.08 to 8.73) was an independent predictor of more frequent reintervention in rAAA after adjusting for baseline variables with multivariate analysis using Cox proportional hazards model.

### DISCUSSION

To the best of our knowledge, this is the first RWD study in Japan to evaluate the long-term outcomes of AAA repair using an insurance claims database with anonymous data linkage. Although the 5-year mortality rates of EVAR and OAR were comparable, the higher reintervention rate of EVAR in rAAA suggests that regular follow-up with imaging is critical. International collaborations to create real-world surveillance systems are warranted to overcome minor differences in device use and patient selection with a common goal of improving the quality of care.

The relevance of JMDC, as one of the new sources of RWD, was studied from three different aspects: payment system, anonymous data linkage, and validity of signals. Japanese universal health insurance payment system consists of FFS and DPC.\(^{22}\) While DRG in the USA is a pay-per-case system, the Japanese DPC is a pay-per-day system with a blanket portion for basic hospital fees and an FFS portion. Therefore, missing data are rare for expensive imaging, surgeries, and devices.\(^{13}\) The anonymous data linkage system of JMDC enables the evaluation of risk factors and long-term outcomes across hospitals, increasing the sensitivity for reinterventions and CT scans. The validation of signals from the Japanese claims database has been extensively studied. For example, the specificity of codes for procedures, prescriptions, and devices is high, while code combination is needed to compensate for the ‘tentative diagnosis’ for billing purpose.\(^{23}\) Therefore, we have used our algorithm\(^{21}\) for code combination in JMDC to maximize specificity. We have compared our study design, including patient selection and device use (online supplemental table 2) and the short-term and long-term outcomes (online supplemental table 3) with existing registries in Japan.\(^{26–29}\)
Accordingly, JMDC may have fit-for-purpose quality and relevance to efficiently monitor patients who underwent EVAR, at least for follow-up imaging and reintervention.

Reinterventions to address device or treatment failures are estimated to occur in 20%—30% of EVAR patients. We have adopted the definitions of reintervention from claims-based studies in the USA and mapped them to fit with the JMDC code (online supplemental table 1). Since existing registries in Japan (online supplemental table 2) did not cover the long-term outcomes of EVAR for rAAA, our report is the first to show that the reintervention rate of EVAR (15.4%) is significantly higher than OAR (8.2%) in rAAA (log-rank p=0.284 (figure 3B)). In addition, the Kaplan-Meier curve indicated that a steady increase canceled the early postoperative advantage of EVAR without a plateau in iAAA (7.8% vs 11.0%, log-rank p=0.284 (figure 3A)). Although EVAR may have a lower perioperative adverse event than OAR, the early advantage may not be maintained long-term. In fact, both sac expansion and no reduction in sac size post-EVAR are associated with endoleaks, which are the most common reason for aortic reinterventions. Therefore, we suggest guidelines recommending lifelong annual follow-up for patients who underwent EVAR starting 30 days post-procedure are relevant, at least for those ≤75 years of age, in Japan.

Follow-up imaging to identify and correct device-related or procedure-related complications after EVAR is recommended by multiple guidelines. However, imaging follow-up compliance is reported to be only about 40% despite these important recommendations. Previous reports from Japanese registries did not include information on this critical compliance. Because

Figure 2 Kaplan-Meier curve and log-rank test for rate of mortality. (A) iAAA (n=837): 30-day mortality (OAR: 2.0% (12/593), EVAR: 2.9% (7/244)), 5-year mortality (OAR: 5.7% (34/593), EVAR: 3.7% (9/244)), log-rank p=0.326. (B) rAAA (n=149): 30-day mortality (OAR: 9.1% (10/110), EVAR: 10.3% (4/39)), 5-year mortality (OAR: 12.7% (14/110), EVAR: 12.8% (5/39)), log-rank p=0.987. EVAR, endovascular aortic repair; iAAA, intact abdominal aortic aneurysm; rAAA, ruptured abdominal aortic aneurysm; OAR, open aortic repair.

Figure 3 Kaplan-Meier curve and log-rank test for rate of reintervention. (A) iAAA (n=837): event rate (OAR: 11.0% (65/593), EVAR: 7.8% (19/244)), log-rank p=0.284. (B) rAAA (n=149): event rate (OAR: 8.2% (9/110), EVAR: 15.4% (8/39)), log-rank p=0.041. EVAR, endovascular aortic repair; iAAA, intact abdominal aortic aneurysm; rAAA, ruptured abdominal aortic aneurysm; OAR, open aortic repair.
Japanese hospitals have more CT scanners per capita than other countries,\(^3\) patients may get scanned at a nearby clinic rather than at the tertiary hospital where vascular surgeons belong. The patient-centric nature of JMDC to link procedure codes of follow-up imaging across hospitals has enabled the detection of impressive numbers of CT follow-ups per year (table 2). Therefore, a claims-based database with anonymous linkage can be an example of a relevant and efficient long-term real-world surveillance system to improve care for patients who underwent EVAR.

Mortality is the most critical outcome in long-term follow-up studies. Data from the registry of the JSVS indicated that the 30-day mortality in rAAA (15.7% in OAR and 15.3% in EVAR) was lower than that in Europe (31.6%) and the USA (30.0%).\(^5\)\(^,\)\(^6\) Our 30-day and 5-year mortality data after EVAR or OAR were comparable (online supplemental table 3A, 3B). However, while the external validity of claims-based analyses is high for procedures including reintervention and imaging, the patient selection and device use may affect the mortality when using JMDC as a source for RWD. For patient selection in iAAA, guidelines recommend AAA repair for aneurysm sizes larger than 55 mm in males and 50 mm in females.\(^3\)\(^,\)\(^5\) However, significant variation exists in the management of AAA,\(^3\)\(^,\)\(^5\)\(^,\)\(^9\) and some Japanese hospitals set indications of OAR and EVAR to 50 mm in males and 45 mm in females.\(^5\) Since there is no clinical information available from the JMDC claims database, we have searched the literature and found a detailed analysis from the Japanese Committee for Stent-Graft Management (JACSM).\(^27\) The mean diameter was 51 mm (47–57 mm). Of the 37,224 patients who underwent EVAR for iAAA in the JACSM registry, 13,682 (36.8%) were smaller than 50 mm, 10,567 (28.4%) were between 50 and 55 mm, 5256 (14.1%) were between 55 and 60 mm, and 7719 (20.7%) were larger than 60 mm. Therefore, the indication of EVAR for iAAA in the JMDC may also be smaller than in other countries. Regarding the device used for rAAA, the proportion of EVAR (%EVAR) tended to be lower in younger cohorts (online supplemental table 3B), reflecting concerns about the impact of EVAR longevity on long-term outcomes. However, the JACSM registry, collected under the Pharmaceuticals and Medical Devices Act, excluded rAAA cases because of the off-label use. In other words, most of the resource for a

|                  | iAAA HR | 95% CI    | rAAA HR | 95% CI    |
|------------------|---------|-----------|---------|-----------|
| (A) Five-year mortality |         |           |         |           |
| EVAR (vs OAR)    | 0.63    | 0.29 to 1.34 | 1.35    | 0.45 to 4.10 |
| Age (years)      | 1.04    | 1.00 to 1.08 | 0.98    | 0.93 to 1.04 |
| Hypertension     | 0.63    | 0.30 to 1.32 | 1.43    | 0.50 to 4.12 |
| Dyslipidemia     | 0.39    | 0.18 to 0.85 | 0.82    | 0.27 to 2.51 |
| Diabetes mellitus| 1.36    | 0.62 to 2.98 | 0.80    | 0.17 to 3.79 |
| Chronic heart failure | 1.12  | 0.56 to 2.25 | 3.57    | 1.27 to 10.04 |
| Ischemic heart disease | 0.83  | 0.40 to 1.73 | 0.52    | 0.20 to 1.37 |
| Atrial fibrillation | 1.56  | 0.70 to 3.49 | 1.32    | 0.38 to 4.61 |
| Venous thromboembolism | 1.94  | 1.04 to 3.61 | 0.37    | 0.10 to 1.40 |
| History of smoking | 0.63  | 0.32 to 1.23 | 0.30    | 0.08 to 1.08 |
| (B) Five-year reintervention |         |           |         |           |
| EVAR (vs OAR)    | 0.76    | 0.45 to 1.28 | 3.07    | 1.08 to 8.73 |
| Age (years)      | 1.00    | 0.98 to 1.03 | 1.03    | 0.96 to 1.09 |
| Hypertension     | 0.91    | 0.56 to 1.47 | 0.48    | 0.16 to 1.47 |
| Dyslipidemia     | 1.04    | 0.64 to 1.67 | 0.89    | 0.26 to 3.08 |
| Diabetes mellitus| 0.94    | 0.49 to 1.80 | 0.71    | 0.15 to 3.32 |
| Chronic heart failure | 0.95  | 0.56 to 1.61 | 0.64    | 0.16 to 2.60 |
| Ischemic heart disease | 0.88  | 0.53 to 1.48 | 2.36    | 0.74 to 7.52 |
| Atrial fibrillation | 1.12  | 0.58 to 2.18 | 3.73    | 1.03 to 13.49 |
| Venous thromboembolism | 1.16  | 0.72 to 1.87 | 0.08    | 0.01 to 0.66 |
| History of smoking | 0.84  | 0.54 to 1.31 | 1.20    | 0.37 to 3.88 |

HR and proportional hazard model (multiple variable model) for overall survival (A) and reintervention (B). Significant p values (p<0.05) are marked.

EVAR, endovascular aortic repair; iAAA, intact abdominal aortic aneurysm; OAR, open aortic repair; rAAA, ruptured abdominal aortic aneurysm.
post-marketing surveillance system with the highest sensitivity is not aimed at the highest risk patient population. Therefore, regulators, manufacturers, and academia need to optimize the allocation of resources to create a real-world surveillance system to collect long-term follow-up data for quality improvement.  

There are opportunities for international collaborations to improve the quality of care. Codes and algorithms from previous claims-based studies helped identify an unmet medical need in Japan, that is, the need to create a real-world surveillance system for the long-term follow-up of EVAR in rAAA. Historically, highly coordinated cooperative efforts of vascular surgeons, such as the VASCUNET and the VQI, have helped develop evidence-based guidelines to improve the outcomes of patients with AAA. In addition, the Medical Device Epidemiology Network (MDEpiNet), a public-private partnership supported by the US FDA, has established the ICVR.

Japanese surgeons also contributed to internationally coordinated registry networks. One important lesson from the experiences of international collaborations is to have governing structures for data sharing. In addition to direct data sharing from multiple sources, distributed systems enable more inclusive collaboration for research and surveillance. Global efforts have focused on high priority questions related to device use and patient selection variation. From regulatory and industry perspectives, RWE from RWD can be used for pre-market and post-market purposes. However, various factors, including financial incentives, disincentives, varying skillsets, or access to devices, need to be optimized to maximize patient outcomes. Especially, the long-term follow-up linking multiple sources of RWD becomes more challenging when facing data protection laws in different countries. Therefore, further studies on international collaborations to explore feasible and efficient sources of RWD are warranted.

Limitations
This study has some limitations.

First, we could not fully adjust for unmeasured confounding factors in an observational study. Therefore, randomized controlled trials are the gold standard for the appraisal of causalities.

Second, JMDC, like other receipt databases, does not contain medical information such as laboratory data and images. Therefore, known risk factors for AAA, including aortic diameter, may have been confounded. Further studies are needed to clinically validate the sensitivity and specificity of comorbidities and outcomes.

Third, because codes such as UDI, used to uniquely identify devices, are not implemented in the Japanese insurance system, it was impossible to determine the causal relationship between adverse events and specific devices, procedures, or diseases.

Fourth, we studied only those cases that could undergo intervention with EVAR or OAR. However, many cases of rAAA die before surgery or even before arriving at the hospital. Yamaguchi et al reported that in octogenarians emergency repair was less likely (42.8% vs 68.0%) but in-hospital death regardless of repair was higher (61.8% vs 37.6%) than in younger patients. Therefore, future studies including older patients are warranted to optimally allocate medical resources and improve the population-based outcomes of rAAA.

Fifth, JMDC is known to have a ‘healthy-workers bias’. While the prevalence of AAA is higher in older people, beneficiaries of this claims database JMDC consist of corporate employees and their families aged ≤75 years. Accordingly, age and socioeconomic status may be contributing to lower mortality rates.

Finally, JMDC also has a ‘survivorship bias’ since the system captures in-hospital deaths directly but not out-of-hospital deaths only indirectly. For example, Sakai et al reported that although the sensitivity and specificity of procedures, prescriptions, and in-hospital deaths were high, the sensitivity of outpatient death was limited to about 50%. Therefore, although systematic bias between groups is unlikely, our data regarding long-term mortality need to be interpreted with this in mind.

In conclusion, our analysis of the long-term outcomes using a Japanese insurance claims database with anonymous data linkage revealed a high compliance with the regular annual follow-up imaging and comparable 5-year mortality between EVAR and OAR in patients who underwent AAA repair. However, EVAR had a significantly higher reintervention rate in ruptured AAA (rAAA), and a long-term upward trend offset the initial benefit in intact cases (iAAA). Therefore, patients who underwent EVAR should receive lifelong annual follow-up imaging starting at 30 days post-procedure. Furthermore, international collaborations to create real-world surveillance systems are warranted.

Author affiliations
1Clinical Pharmacology and Regulatory Science, Juntendo University School of Medicine Graduate School of Medicine, Bunkyo-ku, Japan
2Leading Center for the Development and Research of Cancer Medicine, Juntendo University, Bunkyo-ku, Japan
3Institute for Medical Regulatory Science, Organization for University Research Initiatives, Waseda University, Wakamatsu-cho, Shinjuku-ku, Japan
4Department of Public Health, Juntendo University School of Medicine Graduate School of Medicine, Bunkyo-ku, Japan
5National Institute of Mental Health, National Center of Neurology and Psychiatry, Kodaira, Japan
6Department of Vascular Surgery, Asahikawa Medical University, Midorigaoka higashi Asahikawa, Japan

Twitter Kazuhiro Sase @ksase

Acknowledgements We would like to thank Kiyoshi Matsuoka for helping us with biostatistics, Shiro Matsuya for the excellent assistance as a data scientist, and Editage (https://authorservices.bmj.com/) for English language editing.

Contributors YK: Writing—original draft, conceptualization, visualization, formal analysis, and data curation. HD: Formal analysis, data curation, and writing—review and editing. NY: Formal analysis, data curation, and writing—review and editing. NA: Conceptualization, visualization, formal analysis, data curation, writing—review and editing, funding acquisition, and supervision. KS: The guarantor. Formal analysis, data curation, writing—review and editing, funding acquisition, and supervision.

Kimura Y, et al. BMJ Surg Interv Health Technologies 2022;4:e000131. doi:10.1136/bmjsit-2022-000131
Funding KS, HO, and NA were supported by the Ministry of Health, Labour, and Welfare (MHLW KAKENHI grant 20F1A108). KS was supported by JSPS/MEXT (KAKENHI 18K12134 for HO and KS, 20K08427 for HO and KS), MHLW (20K00209 for KS), and AMED (20ck0106633H001 for HO and KS).

Competing interests YK received a fee from the Pharmaceuticals and Medical Devices Agency, HO received a consultant fee from EPS International, outside the submission work. NY is an employee and shareholder of Pfizer. KS has received lecture fees from Dichi Sankyo, Novartis, Pfizer, and Bristol-Myers Squibb, outside the submitted work.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. Data may be obtained from a third party and are not publicly available. Data may be available through the JMDC (www.jmdc.co.jp/en/jmdc-claims-database).

Supplemental material This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/.

ORCID iDs Hiroshi Ohtsu http://orcid.org/0000-0003-3261-8828 Kazuhiro Sase http://orcid.org/0000-0002-2714-304X

REFERENCES
1 Schanzer A, Oderich GS. Management of abdominal aortic aneurysms. N Engl J Med 2021;385:1690–9.
2 Bossone E, Eagle KA. Epidemiology and management of aortic disease: aortic aneurysms and acute aortic syndromes. Nat Rev Cardiol 2021;18:331–41.
3 Chaikof EL, Dalman RL, Eskandari MK, et al. The Society for vascular surgery practice guidelines on the care of patients with an abdominal aortic aneurysm. J Vasc Surg 2018;67:2–77.
4 Wannhainen A, Verzini F, Van Herzeele I, et al. Editor’s Choice – European Society for Vascular Surgery (ESVS) 2018 Clinical Practice Guidelines on the Management of Abdominal Aortic-Ilac Artery Aneurysms. Eur J Vasc Endovasc Surg 2019;57:8–93.
5 Ogino H. JCS/JSCS/JATS/JSVS 2020 guideline on diagnosis and treatment of aortic aneurysm and aortic dissection (in Japanese), 2020. Available: https://www.j-circ.or.jp/cms/wp-content/uploads/2020/07/JCS2020_Ogino.pdf.
6 Behrendt C-A, Vennermo M, Cronenwett JL, et al. Real-World Evidence - What Is It and What Can It Tell Us? N Engl J Med 2016;375:2293–7.
7 Ohtsu H, Shimomura A, Sase K. Real-World evidence in Cardio-Oncology. JACC CardioOncol 2022;4:95–7.
8 Behrendt C-A, Debus ES, Mani K, et al. The strengths and limitations of claims based research in countries with fee for service reimbursement. Eur J Vasc Endovasc Surg 2018;56:615–6.
9 Behrendt C-A, Sedrakyan A, Rieß HC, et al. Short-Term and long-term results of endovascular and open repair of abdominal aortic aneurysms in Germany. J Vasc Surg 2017;66:1704–11.
10 Hoel AW, Faerber AE, Moore KG, et al. A pilot study for long-term outcome assessment after aortic aneurysm repair using Vascular Quality Initiative data matched to Medicare claims. J Vasc Surg 2017;66:751–91.
11 Colombo JA, Sedrakyan A, Mao J, et al. Claims-based surveillance for reintervention after endovascular aneurysm repair among non-Medicare patients. J Vasc Surg 2019;70:741–7.
12 Colombo JA, Kang R, Hoel AW, et al. A comparison of reintervention rates after endovascular aneurysm repair between the vascular quality initiative registry, Medicare claims, and chart review. J Vasc Surg 2019;69:74–9.
13 Colombo JA, Ramkumar N, Martinez-Cambloquent P, et al. Five-Year reintervention after endovascular abdominal aortic aneurysm repair in the vascular quality initiative. J Vasc Surg 2020;71:799–805.
14 Garland SK, Falister MO, Beiles CB, et al. Long term outcomes following elective repair of intact abdominal aortic aneurysms: a comparison between open surgical and endovascular aortic repair using linked administrative and clinical registry data. Ann Surg 2021; doi:10.1097/SLA.0000000000003259. [Epub ahead of print: 20 Oct 2021].
15 Kimura S, Sato T, Ikeda S, et al. Development of a database of health insurance claims: validation of disease classifications and anonymous record linkage. J Epidemiol 2010;20:413–9.
16 Nagai K, Tanaka T, Kodaia N, et al. Data resource profile: JMDC claims database sourced from health insurance societies. J Gen Fam Med 2021;22:118–27.
17 Fujikawa I, Ohtsu H, Yonemoto N, et al. Association between prenatal antepartum exposure to antidepressants and neonatal morbidity: an analysis of real-world data from a nationwide claims database in Japan. J Affect Disord 2022;310:60–7.
18 Nakagawa Y, Takemura T, Yoshihara H, et al. A new accounting system for financial balance based on personnel cost after the introduction of a DPC/DRG system. J Med Syst 2011;35:251–64.
19 Fujihara K, Yamada-Harada M, Matsubayashi Y, et al. Accuracy of Japanese claims data in identifying diabetes-related complications. Pharmacoeconomic Drug Saf 2021;30:594–601.
20 Yamama H, Monwah M, Horiguchi H, et al. Validity of diagnoses, procedures, and laboratory data in Japanese administrative data. J Epidemiol 2017;27:476–82.
21 Fukasawa T, Tanemura N, Kimura S, et al. Utility of a specific health checkup database containing lifestyle behaviors and lifestyle diseases for employee health insurance in Japan. J Epidemiol 2020;30:57–66.
22 Vascular surgery in Japan: 2016 annual report by the Japanese Society for vascular surgery. Ann Vasc Dis 2021;14:419–38.
23 Hoshina K, Iehimaru S, Sasabuchi Y, et al. Outcomes of endovascular repair for abdominal aortic aneurysms: a nationwide survey in Japan. Ann Vasc Surg 2019;269:564–73.
24 Yamaguchi T, Nakai M, Sumita Y, et al. Editor’s Choice - Endovascular Repair Versus Surgical Repair for Japanese Patients With Ruptured Thoracic and Abdominal Aortic Aneurysms: A Nationwide Study. Eur J Vasc Endovasc Surg 2019;57:779–86.
25 Yamaguchi T, Nakai M, Sumita Y, et al. Impact of endovascular repair on the outcomes of octogenarians with ruptured abdominal aortic aneurysms: a nationwide Japanese study. Eur J Vasc Endovasc Surg 2020;59:219–25.
26 Blakesslee-Carter J, Beck A, Spangler E. Occurrence and outcomes of type 3 endoleaks in endovascular aortic repair within the vascular quality initiative database. BMJ Surg Innov Health Technol 2020;2:e000054.
27 Koyama T, Yamori Y, Ohshima A, et al. Patterns of CT use in patients with aortic aneurysms. Eur J Radiol 2021;22:118–27.
28 Hirst A, Philippou Y, Blazebay J, et al. No surgical innovation without improvement. BMJ Innov 2016;134:1959–61.
29 Yamashita S, Shimohara T, Ueta M, et al. Limitations of claims based research in countries with fee for service reimbursement. Eur J Vasc Endovasc Surg 2018;66:751–91.
30 Sherman RE, Anderson SA, Dal Pan GJ, et al. Real-World Evidence - What Is It and What Can It Tell Us? N Engl J Med 2016;375:2293–7.
yielded a high return on investment. *BMJ Surg Interv Health Technol* 2020;2:e000039.

36 Fraser AG. Postmarket surveillance of high-risk medical devices needs transparent, comprehensive and independent registries. *BMJ Surg Interv Health Technol* 2020;2:e000065.

37 Tsougranis G, Eldrup-Jorgensen J, Bertges D, et al. The Vascular Implant Surveillance and Interventional Outcomes (VISION) Coordinated Registry Network: An effort to advance evidence evaluation for vascular devices. *J Vasc Surg* 2020;72:2153–60.

38 Venermo M, Sedrakyan A, Cronenwett J. International Consortium of vascular registries. *Gefässchirurgie* 2019;24:9–12.

39 Sedrakyan A, Cronenwett JL, Venermo M, et al. An international vascular registry infrastructure for medical device evaluation and surveillance. *J Vasc Surg* 2017;65:1220–2.

40 Boyle JR, Mao J, Beck AW, et al. Editor’s Choice - Variation in Intact Abdominal Aortic Aneurysm Repair Outcomes by Country: Analysis of International Consortium of Vascular Registries 2010 - 2016. *Eur J Vasc Endovasc Surg* 2021;62:16–24.

41 Scali ST, Beck A, Sedrakyan A, et al. Editor’s Choice - Optimal Threshold for the Volume-Outcome Relationship After Open AAA Repair in the Endovascular Era: Analysis of the International Consortium of Vascular Registries. *Eur J Vasc Endovasc Surg* 2021;61:747–55.

42 Nakatani T, Sase K, Oshiyama H, et al. Japanese Registry for mechanically assisted circulatory support: first report. *J Heart Lung Transplant* 2017;36:1087–96.

43 Sakai M, Ohtera S, Iwao T, et al. Validation of claims data to identify death among aged persons utilizing enrollment data from health insurance unions. *Environ Health Prev Med* 2019;24:63.