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Editor's Choice – Outcomes Following Intact and Ruptured Aneurysm Repair across Nations: Analysis of International Registry Data from the VASCUNET Collaboration 2014 — 2019

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WHAT THIS PAPER ADDS

This study reports outcomes in over 60 000 patients undergoing intact and ruptured abdominal aortic aneurysm repair from international registries in 10 countries between 2014 and 2019. Variation is seen among countries in the methods of repair, with a slight increase in open repair more recently. The use of endovascular aortic aneurysm repair (EVAR) has increased for ruptured aneurysms and this has been associated with a reduction in mortality.

Objective: To determine the peri-operative mortality rate for intact and ruptured abdominal aortic aneurysm (AAA) repair in 10 countries and to compare practice and outcomes over a six year period by age, sex, and geographic location.

Methods: This VASCUNET study used prospectively collected data from vascular registries in 10 countries on primary repair of intact and ruptured AAAs undertaken between January 2014 and December 2019. The primary outcome was peri-operative death (30 day or in hospital). Logistic regression models were used to estimate the association between peri-operative death, patient characteristics, and type of procedure. Factors associated with the use of endovascular aortic aneurysm repair (EVAR) were also evaluated.

Results: The analysis included 50 642 intact and 9 453 ruptured AAA repairs. The proportion of EVARs for intact repairs increased from 63.4% in 2014 to 67.3% in 2016 before falling to 62.3% in 2019 ($p < .001$), but practice varied between countries. EVAR procedures were more common among older patients ($p < .001$) and men ($p < .001$). Overall peri-operative mortality after intact AAA repair was 1.4% (95% confidence interval [CI] 1.3 — 1.5%) and did not change over time. Mortality rates were stable within countries. Among ruptured AAA repairs, the proportion of EVARs increased from 23.7% in 2014 to 35.2% in 2019 ($p < .001$). The average aortic diameter was 7.8 cm for men and 7.0 cm for women ($p < .001$). The overall peri-operative mortality rate was 31.3% (95% CI 30.4 — 32.2%); the rates were 36.0% (95% CI 34.9 — 37.2%) for open repair and 19.7% (95% CI 18.2 — 21.3%) for EVAR. This difference and shift to EVAR reduced peri-operative mortality from 32.6% (in 2014) to 28.7% (in 2019).

Conclusion: The international practice of intact AAA repair was associated with low mortality rates in registry reported data. There remains variation in the use of EVAR for intact AAAs across countries. Overall peri-operative mortality remains high after ruptured AAA, but an increased use of EVAR has reduced rates over time.

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INTRODUCTION

Over the last two decades, collaborations between national vascular registries have provided valuable insights into the patterns of abdominal aortic aneurysm (AAA) repair within various countries and the patient outcomes achieved. Since its establishment in 1997, the VASCUNET collaboration[1–3] has undertaken a series of studies on both intact and ruptured AAA repairs. The benchmarking information contained in the subsequent publications has supported quality improvement initiatives within the participating countries.[4,5] These studies have illustrated changes in the use of endovascular aortic aneurysm repair (EVAR), variation in the size at which AAAs are treated, the proportion of procedures performed on patients aged $\geq$ 80 years, and improvements in short term post-operative outcomes across countries.[6–9]

The most recent publication on intact aneurysm repair examined practice in 11 countries from 2010 — 2016.[10] The study reported an overall increasing proportion of patients undergoing EVAR, with considerable variation in its use across countries. A further study on ruptured AAA repair between 2010 and 2013 also highlighted variation in patient management.[11]

The aim of this study was to examine how patterns of AAA repair and short term outcomes changed between January 2014 and December 2019 across Europe and Australasia. In particular, data on peri-operative mortality both for intact and ruptured AAAs over the six year period are reported and the extent of variation in patient characteristics, practice, and outcomes by age, sex, and geographic location was explored.

METHODS

The study used extracts of patient data on intact and ruptured AAA repair procedures. De-identified patient level data were provided by the vascular registries from Australia, Denmark, Finland, Hungary, Iceland, New Zealand, Norway, Sweden, Switzerland, and the UK. The registries collect data prospectively. Nine countries provided information of AAA repairs performed by vascular services throughout their country; in most countries these were performed in public hospitals and in some countries in both public and private hospitals. The Finnish registry provided data for the Helsinki area only. The case ascertainment for most of these countries was $\geq$ 90%.[8] The combined dataset was analysed by the UK National Vascular Registry team at the Clinical Effectiveness Unit at the Royal College of Surgeons of England (https://www.vsqip.org.uk/).

Patient cohort

Patients were eligible for the study if they had undergone an open repair or EVAR for AAA between 1 January 2014 and 31 December 2019. Complex procedures on suprarenal AAA and branched and fenestrated endovascular procedures were not within scope. Eight registries provided information on all patients with AAA for the six years. Iceland provided data on patients with intact AAAs for 2014 — 2018 and Switzerland on all procedures for 2017 — 2019. A unified dataset was created for analysis, during which the eligibility of records was checked. Procedures labelled as an exploratory procedure or as complex repairs from any of the datasets were removed.

The unified dataset described the patient at the time of admission in relation to age (years), sex (male, female), aortic status (intact, ruptured), presence of comorbid conditions (diabetes, cardiac disease), maximum AAA diameter at procedure (centimetres), and type of procedure (open repair or EVAR). Age was recorded in years, except in records from Norway that provided it in five year bands. In these cases (approximately 7% of records), patient age was set to the middle of the age band. Unrealistic AAA diameter values were set to missing; diameters entered in millimetres were converted to centimetres. The completeness of variables was high in general, with AAA diameter missing most values (4%), followed by information on diabetes (1%) and cardiac disease (1%). AAA diameter was not available in records from Switzerland.

Outcomes

The primary outcome was peri-operative death, which was either 30 day (Denmark, Sweden, and Finland) or in hospital (other countries).

Statistical analysis

Summary statistics were used to describe patterns of AAA practice and outcomes across the 10 countries. For categorical variables, Pearson's χ^2 or Fisher's exact test were used to assess the statistical significance of differences between groups. For continuous variables, the Mann—Whitney *U* test was applied. The Jonckheere—Terpstra test was used to assess the significance of trends over time. The association between age and other variables was explored using a nearest neighbour smoothing function. This procedure performed less well to examine the proportion of patients who had EVAR by age within countries as estimated values could exceed 1; in this situation, a cubic spline was used to describe the association between use of EVAR and age, and was fitted using logistic regression.

Multivariable logistic regression models were developed to estimate the association between peri-operative death and patient characteristics (age, sex, type of repair, AAA diameter, diabetes, cardiac disease, and year of operation), with men having open repair used as the reference category. Missing patient characteristic data were handled using

multiple imputation via the method of chained equations. The imputation model included peri-operative death, age, sex, type of repair, AAA diameter, diabetes, cardiac disease, and year of operation. Ten imputed datasets were created. The logistic regression model was used to predict the probability of death for each patient. These were then summed for each country to produce the expected number of deaths. The risk adjusted rates for each country were derived using indirect standardisation (observed/expected $\times$ overall rate). Multivariable logistic regression was also used to examine the association between the use of EVAR and patient characteristics.

All statistical tests were two sided, and p values of $<.050$ were considered statistically significant. No correction for multiple hypothesis testing was applied.

All statistical analyses were performed in Stata Statistical Software: Release 17 (StataCorp LLC, College Station, TX, USA).

RESULTS

The study population consisted of 50 642 intact AAA repairs and 9 453 ruptured AAA repairs over the six years between 2014 and 2019. Of the total 60 095 procedures, 59.7% were EVAR. The proportion of EVARs for intact and ruptured AAA repairs was 65.4% and 29.1% respectively.

Repair of intact abdominal aortic aneurysms: patient characteristics and practice

Overall, 13.1% of patients were female and 71.1% were aged $\geq$ 70 years. There was considerable variation in the age distribution across countries (Table 1), with approximately 50% of procedures in Hungary performed on patients aged $<$ 70 years. By contrast, over one quarter of all intact cases were octogenarians for Australia, New Zealand, Finland, and the UK. The proportion of women operated on varied from 10% to 20%. The mean aortic diameter for men exceeded that for women (6.1 cm *vs.* 5.8 cm; $p < .001$), and the difference between men and women was observed across the distribution of ages except the oldest (Supplementary Figure S1). The overall proportion of patients with diabetes and cardiac disease was 15.2% and 42.3%, respectively. The proportion of patients with diabetes was similar for all patient ages, while

Table 1. Characteristics of patients (n = 50 642) who underwent elective repair of intact abdominal aortic aneurysm (AAA) between 2015 and 2019 by country

Characteristic	AUS (n = 9 341)	DK (n = 2 899)	FIN (n = 485)	HUN (n = 1 669)	ICE (n = 103)	NZ (n = 1 811)	NOR (n = 3 891)	SWE (n = 4 317)	SWZ * (n = 1 315)	UK (n = 24 811)
Age										
$<$ 60 years	3.6	4.5	4.1	8.6	6.8	4.1	4.0	2.5	7.0	2.5
60–69 years	21.3	26.0	23.3	41.5	25.2	20.8	27.4	29.2	25.8	25.4
70–79 years	45.2	54.4	45.6	40.7	44.7	48.3	46.5	48.6	44.1	45.9
$\geq$ 80 years	29.8	15.1	27.0	8.8	23.3	26.7	22.2	19.7	23.0	26.0
Missing	0.1	0.0	0.0	0.4	0.0	0.1	0.0	0.0	0.1	0.1
Sex										
Male	85.8	85.5	89.7	84.1	83.5	79.7	82.8	84.1	89.0	89.1
Female	14.2	14.5	10.3	15.9	16.5	20.3	17.2	15.9	10.9	10.9
Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Diabetes										
No	84.2	86.4	78.1	78.8	84.5	86.6	88.1	84.8	61.9	84.7
Yes	15.7	12.7	21.0	21.2	15.5	13.4	11.9	15.1	11.3	15.3
Missing	0.1	0.9	0.8	0.0	0.0	0.0	0.0	0.1	26.8	0.0
Cardiac disease										
No	49.8	62.4	57.1	51.6	46.6	51.9	55.7	59.7	28.4	61.4
Yes	50.2	36.6	41.0	48.4	53.4	48.1	44.3	39.7	43.3	38.5
Missing	0.0	1.0	1.9	0.0	0.0	0.0	0.0	0.6	28.4	0.0
Type of repair										
Open	20.2	57.6	20.0	52.5	39.8	41.6	48.0	37.8	30.3	33.5
EVAR	79.8	42.4	80.0	47.5	60.2	58.4	52.0	62.2	69.7	66.5
AAA diameter										
$<$ 5.5 cm	33.5	11.2	14.8	30.0	17.5	20.7	19.4	19.9	NA	9.6
5.5–6.9 cm	53.4	58.0	59.0	49.9	71.8	58.8	67.1	68.8	NA	74.2
$\geq$ 7.0 cm	12.9	16.7	21.9	20.0	10.7	15.6	12.7	11.2	NA	16.2
Missing	0.1	14.0	4.3	0.1	0.0	4.9	0.9	0.0	NA	0.1
AAA diameter, subgroups †										
Men, AAA $<$ 5.5 cm	32.2	11.1	13.8	28.9	15.1	19.3	15.0	15.9	NA	8.9
Women, AAA $<$ 5.5 cm	41.6	24.3	30.0	36.4	29.4	31.1	41.8	41.6	NA	14.8
Women, AAA $<$ 5.0 cm	12.6	5.2	8.0	17.0	17.6	6.0	6.4	7.7	NA	4.8

Data are presented as %. AUS = Australia; DK = Denmark; Fin = Finland; HUN = Hungary; ICE = Iceland; NZ = New Zealand; NOR = Norway; SWE = Sweden; SWZ = Switzerland; UK = United Kingdom; EVAR = endovascular aortic aneurysm repair; AAA = abdominal aortic aneurysm; NA = not available.

* Time period only 2017 – 2019.

† Excluding missing data.

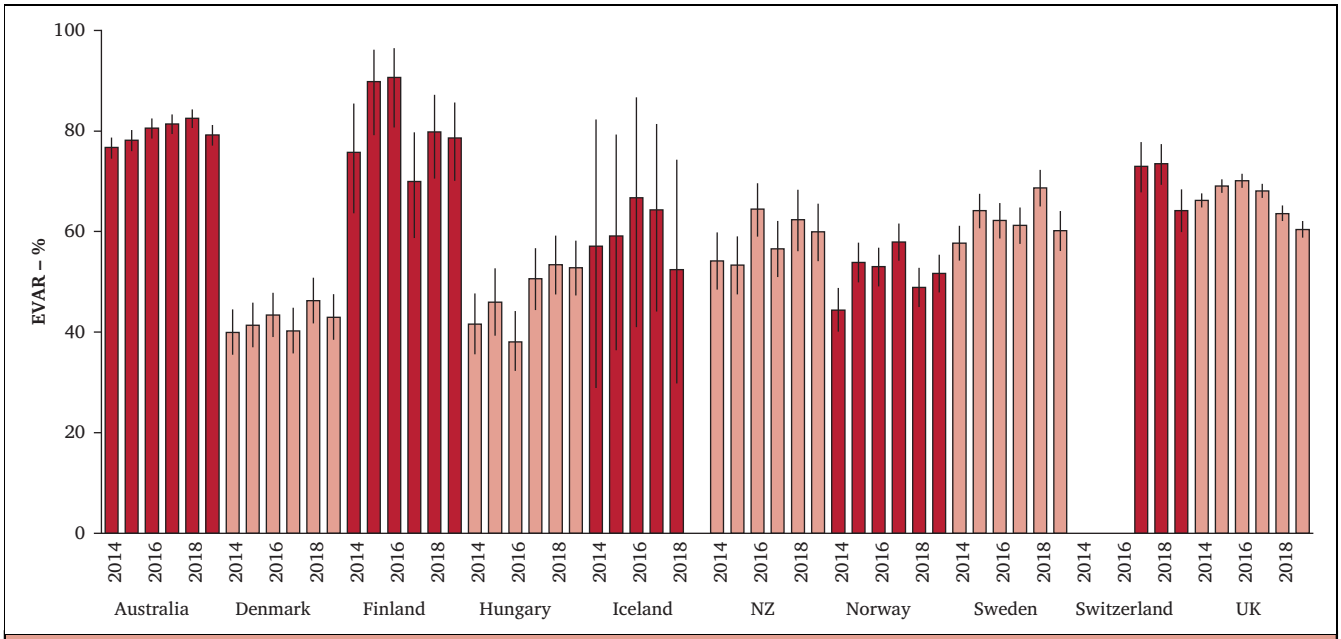

Figure 1. Proportion of intact abdominal aortic aneurysm repairs performed by endovascular aortic aneurysm repair (EVAR) between 2014 and 2019 by country and calendar year. Error bars indicate 95% confidence interval. NZ = New Zealand; UK = United Kingdom.

cardiac disease became more common among older patients (Supplementary Figure S2).

The proportion of procedures performed as EVAR increased from 63.4% in 2014 to 67.3% in 2016 before falling to 62.3% in 2019. Practice within each country by year is shown in Figure 1. Open repair was most common in Denmark, and the proportion of procedures performed using EVAR did not change between 2014 and 2019. Finland and Australia performed the greatest proportion of intact AAA repairs as EVAR. In 2014, Hungary had a similar use of EVAR to Denmark, but its use increased over the subsequent years from 41.6% to 52.8% in 2019 ($p < .001$). Other countries with a statistically significant change over time ($p < .050$) were Australia and the UK (use of EVAR rose and fell), New Zealand (use of EVAR increased), and Switzerland (use of EVAR decreased).

In each country except Iceland, the proportion of patients who had EVAR increased as patients became older (Fig. 2). Among younger patients, the use of EVAR varied across countries for patients aged 50 — 65 years, but this variation had diminished among patients aged > 85 years. Figure 2 also highlights that both Sweden and the UK started from relatively low rates of EVAR among younger patients before EVAR use increased more quickly than in other countries. The use of EVAR was associated with patient sex, AAA diameter, and the presence of diabetes and cardiac disease (Supplementary Table S1). The presence of cardiac disease had a greater influence on the type of procedure for men of different ages than women, with the strongest association for younger men (Supplementary Figure S3).

Short term outcomes after intact abdominal aortic aneurysm repair

Between 2014 and 2019, the overall peri-operative mortality rate for intact AAA was 1.4% (95% confidence interval [CI] 1.3 — 1.5%), with the rates for open repair and EVAR being 2.8% (95% CI 2.6 — 3.1%) and 0.6% (95% CI 0.5 — 0.7%), respectively. There was little change over time (Table 2), and the trend observable for open repair was not statistically significant. The mortality rates for each country were also stable. The largest change was observed in Hungary with the mortality rate decreasing from 3.5% (95% CI 2.4 — 5.1%) in 2014 — 2016 to 2.3% (95% CI 1.4 — 3.5%) in 2017 — 2019, a change that coincided with an increase in the use of EVAR in these two time periods from 41.7% to 52.3%. However, the decrease in mortality was not statistically significant.

Figure 3 shows the observed and risk adjusted mortality rates by country. The risk adjustment model accounted for age, sex, cardiac disease, and procedure type (Supplementary Table S2; Supplementary Figure S4). The risk adjusted rates exhibited less variation between countries than the observed, and most countries had estimated rates that were consistent with the overall peri-operative rate. Hungary had the highest adjusted rate (2.5%; 95% CI 1.8 — 3.3%).

Repair of ruptured abdominal aortic aneurysm: patient characteristics and practice

The characteristics of patients who had a ruptured AAA repair are described in Table 3. Of the 9 453 procedures, 17.6% were female and 77.3% were aged ≥ 70 years. Women were on average older, with 83.8% of women aged ≥ 70 years compared with 76.0% for men ($p < .001$). As before, there was considerable variation in the age distributions across countries (Table 3). The overall proportion of patients with diabetes and cardiac disease was 12.9% and 38.3%, respectively.

The mean aortic diameter for men exceeded that for women (7.8 cm *vs.* 7.0 cm; $p < .001$), and the difference

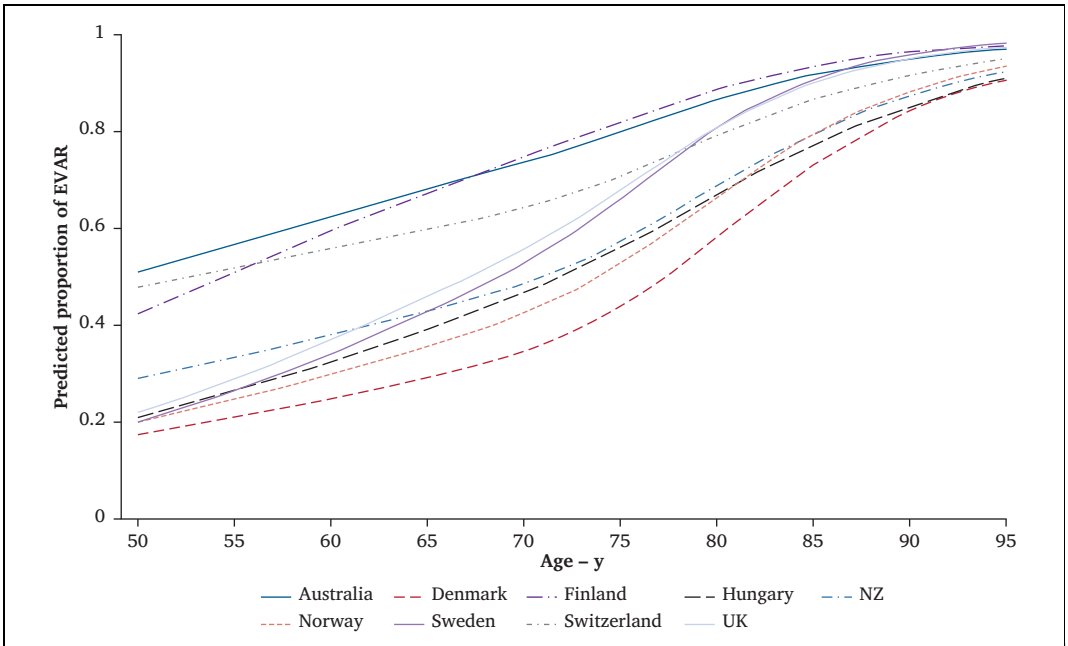

Figure 2. Change in the proportion of intact abdominal aortic aneurysm repairs performed using endovascular aortic aneurysm repair (EVAR) between 2014 and 2019 by patient age, estimated for each country. Data were available for 2017 − 2019. NZ = New Zealand; UK = United Kingdom.

between men and women was observed across the distribution of ages except the oldest patients (Supplementary Figure S5).

The proportion of ruptured AAA repairs performed using EVAR increased from 23.7% in 2014 to 35.2% in 2019 ($p < .001$). The pattern within each country varied (Supplementary Figure S6). There was a statistically significant increase in the use of EVAR from 2014 to 2019 in Australia ($p < .001$), Finland ($p = .010$), Norway ($p = .020$), Sweden ($p < .001$), and the UK ($p < .001$), with the growth in New Zealand being of borderline significance ($p = .060$). Finland performed the greatest proportion of EVARs over the six years at 57.6% (Table 3). As with intact AAA repair, the proportion of patients who had EVAR increased as patients became older. The proportion was fairly stable until patient age reached 75 years, at which point the proportion increased. Each country followed this basic underlying pattern, despite the average level of use differing (Supplementary Figure S7). The use of EVAR was also independently associated with patient sex, AAA diameter, and the presence of diabetes and cardiac disease (Supplementary Table S3). The difference in the unadjusted proportions of EVAR in men (29.3%) and women (27.9%) was not statistically significant ($p = .24$), but after taking account of the other factors the odds ratio of women having EVAR was 0.75 (95% CI 0.66 − 0.85%) compared with men.

Short term outcomes after ruptured abdominal aortic aneurysm repair

Between 2014 and 2019, the overall peri-operative mortality rate for ruptured AAA repair was 31.3% (95% CI 30.4 − 32.2%). The rates were 36.0% (95% CI 34.9 − 37.2%) for open repair and 19.7% (95% CI 18.2 − 21.3%) for EVAR. The overall mortality rate decreased from 32.6% in 2014 to 28.7% in 2019 ($p = .010$), which seemed to reflect the increased use of EVAR (Table 4). The change in mortality rates over time was

Table 2. Peri-operative death after intact abdominal aortic aneurysm repair by year and type of procedure

Year	Death − %*			Procedures − *n*			Proportion EVAR
	Open repair	EVAR	Overall	Total	Open repair	EVAR	
2014	3.0	0.7	1.5	8 611	3 150	5 461	63.4
2015	3.0	0.6	1.4	8 412	2 822	5 590	66.5
2016	2.7	0.7	1.3	8 445	2 764	5 681	67.3
2017	2.6	0.7	1.3	8 783	2 916	5 867	66.8
2018	2.8	0.7	1.4	8 385	2 859	5 526	65.9
2019	2.8	0.4	1.3	8 006	3 022	4 984	62.3
Total	2.8	0.6	1.4	50 642	17 533	33 109	65.4

Data are presented as column percentages or annual number of procedures. EVAR = endovascular aortic aneurysm repair.
* Excluding missing data.

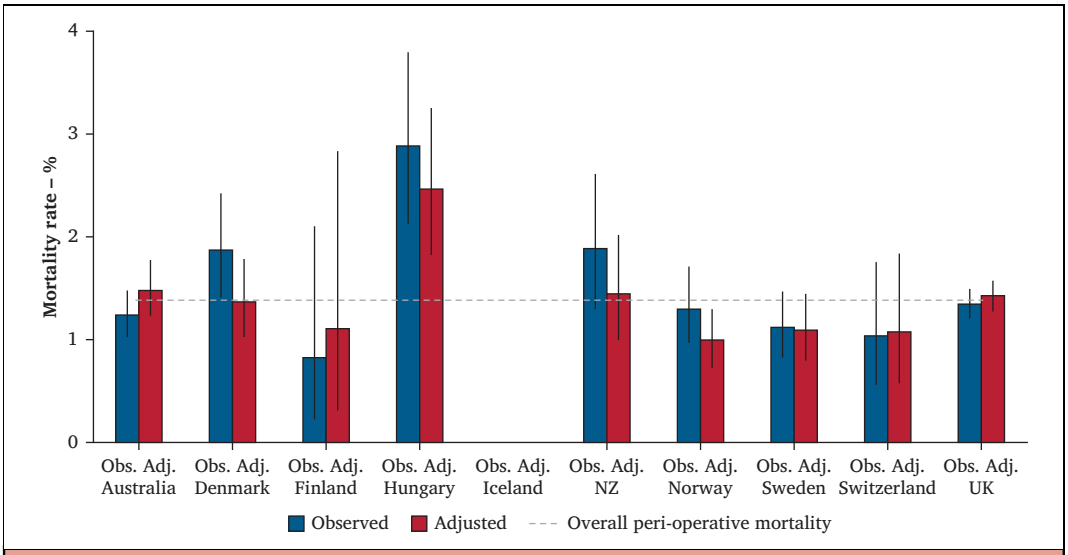

Figure 3. Observed (Obs.) and adjusted (Adj.) peri-operative mortality rates after intact abdominal aortic aneurysm repair between 2014 and 2019 by country. Data were available for 2017 – 2019 for Switzerland. No deaths were observed for Iceland. NZ = New Zealand; UK = United Kingdom.

marginal for EVAR ($p = .040$) and was not statistically significant for open repair ($p = .45$). While several nations showed a decline in overall mortality between 2014 and 2019, these were not statistically significant.

Figure 4 shows the observed and risk adjusted mortality rates after ruptured AAA repair by country. The risk adjustment model accounted for age, sex, cardiac disease, diabetes and procedure type (Supplementary Table S4). Year of procedure was not independently associated with peri-operative mortality. Risk adjustment had a limited effect for most countries, with Finland being the exception, and there was considerable variation across the countries in their adjusted peri-operative mortality rate. The UK had the highest adjusted rate (35.2%; 95% CI 33.6 – 36.8), while the adjusted rates for Australia, Denmark, and Sweden were each below the overall average.

DISCUSSION

This study extends the results in previous VASCUNET/ICVR (International Consortium of Vascular Registries) studies on the use of EVAR and open repair for both intact and ruptured AAAs. All previous studies reported an increase in the rate of EVAR for intact AAA over the time periods studied. For the first time, a reversal of this trend was observed, with a reduction in EVAR use from 2019. There are multiple reasons for this change. The European Society for Vascular Surgery (ESVS) 2019 clinical practice guidelines on the management of abdominal aorto-iliac aneurysms[12] suggested size thresholds for treatment of 5.5 cm for men and 5 cm for women, which have been retained in the recently updated guidelines published in 2024,[13] and an EVAR first strategy for treating intact AAA. In contrast, draft guidelines for the UK published in 2018 by the National Institute for Health and Care Excellence (NICE)[14] discouraged EVAR for intact AAA repair and caused consternation amongst the international vascular community. The final NICE guideline on AAA diagnosis and management published in 2020[15] maintained a threshold for both sexes at 5.5 cm and recommended an open repair first strategy for intact AAA unless contraindicated due to comorbidity or surgical constraints. The differences between the two have been extensively debated.[16]

Coinciding with this debate has been growing concern around the long term durability of EVAR,[17–20] stimulating a re-evaluation in the vascular community on the type of repair offered across a range of patients, from younger fitter patients to the more elderly and frail with adverse anatomy.[21–23] It was observed that younger and fitter patients were more likely to receive open repair for intact AAA in most countries, with a gradual move to greater use of EVAR with increasing patient age. The speed of transition was not consistent across the countries, with Sweden and the UK increasing the use of EVAR for intact AAA among slighter younger patients compared with other countries. For ruptured AAA, the point of change from open repair to EVAR occurred in most countries among patients aged > 75 years.

Previous papers on international practice of AAA repair noted the variation in the age distributions across countries.[6–8,10] The findings in the current study are consistent with this pattern, and around a quarter of all intact cases were octogenarians in some countries. As noted previously,[10] octogenarians were not recruited or were a minority in randomised trials that compared EVAR with open repair and there remains a need to optimise treatments for older patients, particularly women. The present results confirm other study findings that peri-operative mortality is worse among women than men for repair of both intact and ruptured AAA, after accounting for age, type of repair, and comorbid disease.[10,24] For intact AAA, it was also noted that the transition from open repair to EVAR was different for men and women of different age, with and without cardiac disease.

For ruptured AAA, there was a drop of approximately 25% in the number of procedures between 2014 and 2019.

Table 3. Characteristics of patients (n = 9 453) who had ruptured abdominal aortic aneurysm (AAA) repair between 2014 and 2019

Characteristic	AUS (n = 853)	DK (n = 882)	FIN (n = 165)	HUN (n = 338)	NZ (n = 328)	NOR (n = 563)	SWE (n = 976)	SWZ (n = 149) *	UK (n = 5 199)
Age									
< 60 years	4.3	3.1	6.7	11.5	4.6	3.4	3.8	8.7	3.9
60–69 years	23.9	22.0	25.5	37.6	22.0	23.8	15.9	18.1	15.1
70–79 years	44.3	52.5	35.2	33.7	45.7	43.0	44.9	32.2	46.2
≥ 80 years	27.4	22.4	32.7	17.2	27.7	29.8	35.5	40.9	34.7
Missing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Sex									
Male	83.2	85.8	83.0	83.1	81.1	78.5	77.3	85.9	83
Female	16.8	14.2	16.4	16.9	18.9	21.5	22.7	14.1	17
Missing	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Diabetes									
No	84.6	85.0	80.0	82.2	87.2	89.0	84.4	55.7	87.3
Yes	15.4	10.1	14.5	17.8	12.8	11.0	12.0	7.4	12.7
Missing	0.0	4.9	5.5	0.0	0.0	0.0	3.6	36.9	0.0
Cardiac disease									
No	58.6	62.9	59.4	42.9	61.0	62.9	53.0	17.4	63.6
Yes	41.4	32.1	35.2	57.1	39.0	37.1	40.5	26.2	36.3
Missing	0.0	5.0	5.5	0.0	0.0	0.0	6.6	56.4	0.1
Type of repair									
Open	62.5	91.4	42.4	86.4	81.4	74.4	57.5	63.1	70.4
EVAR	37.5	8.6	57.6	13.6	18.6	25.6	42.5	36.9	29.6
AAA diameter									
< 5.5 cm	10.7	7.4	7.3	13.3	9.8	11.0	9.1	NA	7.0
5.5–6.9 cm	24.0	22.0	29.1	24.0	24.7	22.6	22.2	NA	25.6
≥ 7.0 cm	65.3	66.3	50.3	59.2	64.3	61.5	61.9	NA	66.6
Missing	0.0	4.3	13.3	3.6	1.2	5.0	6.8	NA	0.7
AAA diameter, subgroups †									
Men, AAA < 5.5 cm	8.9	7.0	5.9	12.5	6.8	8.5	7.8	NA	6.6
Women, AAA < 5.5 cm	19.6	12.0	20.8	20	23.3	23.0	16.7	NA	9.5
Women, AAA < 5.0 cm	9.8	6.0	8.3	14.5	10.0	8.8	8.8	NA	3.8

Data are presented as column percentages. AUS = Australia; DK = Denmark; Fin = Finland; HUN = Hungary; ICE = Iceland; NZ = New Zealand; NOR = Norway; SWE = Sweden; SWZ = Switzerland; UK = United Kingdom; EVAR = endovascular aortic aneurysm repair; AAA = abdominal aortic aneurysm; NA = not available.
* Time period only 2017 – 2019.
† Excluding missing data.

The gradual decrease in the incidence of ruptured AAA is often attributed to the changing prevalence of smoking and the effect of screening.[25] It was noted that aneurysms in women tended to rupture at smaller diameters than men, confirming the findings in other studies[24] and providing some justification for the lower thresholds for intact AAA repair in women as recommended by the ESVS[12] and the Society for Vascular Surgery (SVS)[26] guidelines. Use of EVAR for ruptured AAA also increased from 23.7% in 2014 to 35.2% in 2019. The unadjusted peri-operative mortality rate for EVAR was nearly half that for open repair, a difference that remained after adjustment for other factors in the regression model. This is in keeping with the results from a previous VASCUNET publication[9] but contrast with the

Table 4. Peri-operative mortality after ruptured abdominal aortic aneurysm repair between 2014 and 2019 by year and type of procedure

Year	Death – %*			Procedures – n			Proportion EVAR
	Open repair	EVAR	Overall	Total	Open repair	EVAR	
2014	36.2	21.1	32.6	1 803	1 376	427	23.7
2015	37.3	20.8	33.0	1 667	1 229	438	26.3
2016	35.2	22.4	31.5	1 640	1 158	482	29.4
2017	36.2	20.3	31.3	1 538	1 070	468	30.4
2018	36.5	15.6	29.9	1 429	979	450	31.5
2019	34.5	18.2	28.7	1 376	892	484	35.2
Total	36.0	19.7	31.3	9 453	6 704	2 749	29.1

Data are presented as column percentages or annual number of procedures. EVAR = endovascular aortic aneurysm repair.
* Excluding missing data.

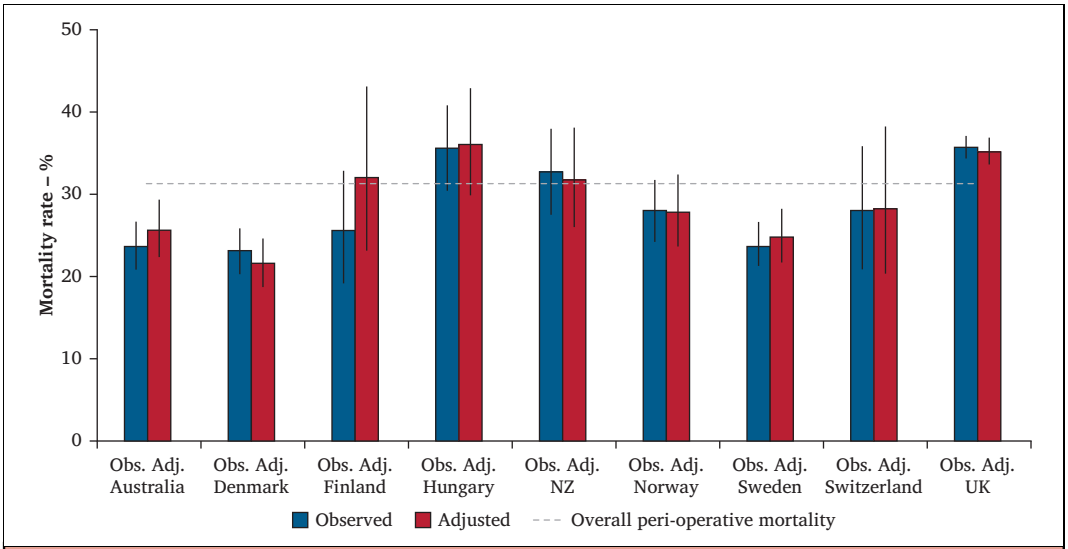

Figure 4. Observed and adjusted peri-operative mortality rates after ruptured abdominal aortic aneurysm repair between 2014 and 2019 by country. Data were available for 2017 – 2019 for Switzerland. Data were unavailable for Iceland. NZ = New Zealand.

IMPROVE trial[27] that reported similar 30 day mortality for both modalities of treatment in a randomised study setting. This study cannot discern whether the differences in mortality are linked to patients with greater anatomical and physiological suitability being offered EVAR for ruptured AAA or to unmeasured patient characteristics. Some of the differences in outcomes between countries could be accounted for by case selection. In Hungary, for example, all patients presenting to hospitals with ruptured AAA undergo treatment, in contrast to a more selective approach in Denmark and Norway.

Strengths and limitations

This study continues the reporting of large datasets from international vascular registries. Strengths of the study include the registries collecting data prospectively and having good case ascertainment rates. The study has several limitations. First, it is possible for there to be selective reporting of AAA repairs and this may result in bias, however external validation by international validators of some registries has demonstrated their data to be accurate.[28–32] Second, while the analysis included adjustment for some confounders, the availability of variables on comorbidity and other patient characteristics was limited, and the results could be affected by residual confounding. Third, the study outcome provided by the registries was either 30 day or in hospital death. While this does not affect the estimates of change within registries, caution is required when comparing the overall mortality rate with estimates of in hospital mortality or 30 day mortality, although there is often a strong agreement between these two measures. In addition, while data completeness was generally good, there were some missing data related to comorbidities and AAA size. Multiple imputation was used to avoid losing records in the regression analysis, the use of which might have introduced bias. Finally, the extent of coverage of registries within nations and their links with national administrative datasets of procedures and deaths were beyond the scope of this paper but are the subject of a scoping review of vascular registries currently being undertaken by the VASCUNET collaboration.

Conclusions

This VASCUNET report on AAA repair in 10 countries demonstrates changing yet safe practices in intact and ruptured AAA repair. There has been some divergence in the use of open repair and EVAR across countries for intact AAA, with a clear reduction in the use of EVAR in the UK over the latter part of the period, which might reflect differences in guideline recommendations issued for intact AAA repair. Whether this trend persists will be evaluated in future data analyses. For ruptured AAA, there is agreement across guidelines on EVAR being the primary treatment strategy. However, there is substantial variation across countries in the proportion of ruptures being treated by EVAR, and examining how patterns of care and outcomes evolve will also be a priority for future studies.

CONFLICTS OF INTEREST

None.

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvs.2024.02.019.

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