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Editor's Choice — The Impact of Centralisation and Endovascular Aneurysm Repair on Treatment of Ruptured Abdominal Aortic Aneurysms Based on International Registries

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WHAT THIS PAPER ADDS

This international analysis assesses current trends and variations in the treatment of ruptured abdominal aortic aneurysms. The report indicates that outcomes after open repair of ruptured abdominal aortic aneurysms are better at centres with high volumes, while a substantial number of ruptured repairs are carried out at low volume centres. Hospitals that have a primary EVAR strategy for ruptures have an improved peri-operative mortality. This real world evidence could provide benchmarks for vascular surgery centres in their considerations of centralisation and implementation of endovascular aortic repair.

Objectives: Current management of ruptured abdominal aortic aneurysms (RAAA) varies among centres and countries, particularly in the degree of implementation of endovascular aneurysm repair (EVAR) and levels of vascular surgery centralisation. This study assesses these variations and the impact they have on outcomes.
Materials and methods: RAAA repairs from vascular surgical registries in 11 countries, 2010—2013, were investigated. Data were analysed overall, per country, per treatment modality (EVAR or open aortic repair [OAR]), centre volume (quintiles IV), and whether centres were predominantly EVAR (≥50% of RAAA performed with EVAR [EVAR(p)]) or predominantly OAR [OAR(p)]. Primary outcome was peri-operative mortality. Data are presented as either mean values or percentages with 95% CI within parentheses, and compared with chi-square tests, as well as with adjusted OR.
Results: There were 9273 patients included. Mean age was 74.7 (74.5—74.9) years, and 82.7% of patients were men (81.9—83.6). Mean AAA diameter at rupture was 7.6 cm (7.5—7.6). Of these aneurysms, 10.7% (10.0—11.4) were less than 5.5 cm. EVAR was performed in 23.1% (22.3—24.0). There were 6817 procedures performed in OAR(p) centres and 1217 performed in EVAR(p) centres. Overall peri-operative mortality was 28.8% (27.9—29.8). Peri-operative mortality for OAR was 32.1% (31.0—33.2) and for EVAR 17.9% (16.3—19.6), $p < .001$, and the adjusted OR was 0.38 (0.31—0.47), $p < .001$. The peri-operative mortality was 23.0% in EVAR(p) centres (20.6—25.4), 29.7% in OAR(p) centres (28.6—30.8), $p < .001$; adjusted OR = 0.60 (0.46—0.78), $p < .001$. Peri-operative mortality was lower in the highest volume centres (QI > 22 repairs per year), 23.3% (21.2—25.4) than in QII-V, 30.0% (28.9—31.1), $p < .001$. Peri-operative mortality after OAR was lower in high volume centres compared with the other centres, 25.3% (23.0—27.6) and 34.0% (32.7—35.4), respectively, $p < .001$. There was no significant difference in peri-operative mortality after EVAR between centres based on volume.

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Conclusions: Peri-operative mortality is lower in centres with a primary EVAR approach or with high case volume. Most repairs, however, are still performed in low volume centres and in centres with a primary OAR strategy. Reorganisation of acute vascular surgical services may improve outcomes of RAAA repair.

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INTRODUCTION

The mortality following repair of ruptured abdominal aortic aneurysm (RAAA) remains high, despite improvements in 30 day mortality, recently reported at around 30–35%.[1–5] The possible reasons for this improvement over time include better peri-operative and post-operative care, and the technological impact of endovascular aneurysm repair (EVAR).[6–8] It has been documented that the minimal invasiveness of EVAR reduces the morbidity and 30 day mortality of intact AAA treatment, particularly as the procedure can often be performed under local anaesthesia.[9–11] Indeed, EVAR is increasingly being used as the treatment modality of choice for intact AAAs in many countries. The rates for treating RAAA are still lagging, although they have reached as high as 40–50% in the United States and Australia.[12]

Several trials, including the recent Immediate Management of Patients with Ruptured Aneurysm: Open *Versus* Endovascular Repair (IMPROVE) trial, have aimed to assess the superiority of EVAR over open aortic repair (OAR) for ruptures.[4,13,14] As summarised in the meta-analysis by Sweeting et al., there was no difference in survival at 90 days, although women appear to benefit from an endovascular strategy.[15] However, the long-term results from the IMPROVE trial now reveal that an endovascular strategy offers improved survival at 3 years at a lower cost and a better quality of life, with no differences in the number of re-interventions.[16] Whether or not these results reflect general practice can be assessed in multinational vascular surgery databases, as their evaluation can shed light on real world differences in care and outcomes.[17] The objective of the present study is to report the variations in treatment and outcomes for patients with RAAA from 11 countries over 4 years.

MATERIALS AND METHODS

The Vascunet collaboration

Vascunet is an international collaboration of registries, consisting of national (Australia, Denmark, Hungary, Iceland, New Zealand, Norway, Sweden, Switzerland, UK), regional (Finland), and multi-centre (Germany) databases. The completeness of the participating registries was >90% for RAAA procedures performed in Denmark, Hungary, Iceland, Sweden, and Finland, 80% in New Zealand and Norway, and 68% in Australia.[18–21] The ascertainment rate in the UK was estimated at 73% for 2012–2014, but is uncertain for the 2 previous years.[22] The Swiss database includes patients operated for AAA in 129 public hospitals and represents approximately 85% of all open and 70% of all EVAR procedures in the country. The German data are based on approximately 130 certified vascular centres participating in the German Society for Vascular Surgery. A recent report by the same collaboration has documented outcomes following treatment of intact AAAs from the same database.[23]

Study design

Data on ruptured AAA repairs were collected from vascular registries for the 4-year period 2010–2013 from 11 countries. These were analysed overall, per country, per treatment modality (EVAR or OAR), for centre volume (divided into quintiles), and for centres that were either predominantly EVAR (≥50% of RAAA repairs performed with EVAR; EVAR(p)) or predominantly OAR (OAR(p)).

Outcomes and variables

The primary outcome was peri-operative mortality, defined as either in hospital death (registries from Australia, Germany, Hungary, New Zealand, Norway, Switzerland, and United Kingdom) or death within 30 days of surgery (registries from Denmark, Finland, Iceland, and Sweden). Patients were also registered to a single hospital centre identification number. The covariates included for analysis were: age, gender, AAA diameter (cm), and the presence or absence of the following comorbidities: ischaemic heart disease, pulmonary disease, diabetes mellitus, and cerebrovascular disease.

The numbers (proportions) of missing data were as follows: peri-operative mortality, 47 (0.5%); age, 339 (3.6%); gender, 1232 (13.2%); hospital centre identification number, 1266 (13.6%); operative technique, 0 (0%); AAA diameter, 2013 (21.6%); ischaemic heart disease, 252 (2.7%); pulmonary disease, 1927 (20.7%); diabetes mellitus, 1405 (15.1%); cerebrovascular disease, 3313 (35.5%).

Statistical analysis

Continuous data are presented with mean values and 95% CIs, and compared with *t* tests. Rates are presented as percentages with 95% CIs. Missing data were handled by exclusion. Comparison of rates was performed using the chi-square test. Logistic regression models were performed to estimate the OR for peri-operative mortality for the included covariates. To correct for multiple testing, a *p* value of <.01 was regarded as significant. Finally, funnel plots were created using upper and lower CI (95% and 99.8%) from the calculated mean peri-operative mortalities, where values from each centre are displayed in the form of a scatter plot.

Volume per centre was determined by placing the participating centres into descending order, based on the average number of procedures for the 4 year period: Five quintiles (QI, highest volume — QV, lowest volume) were formed.

All data analysis was carried out using R Statistical Software Package (R Foundation for Statistical Computing, Vienna, Austria) and SPSS for Mac, Version 24.0 (SPSS Inc., Armonk, NY, USA: IBM Corp.).

RESULTS

There were 9273 patients with ruptured abdominal aortic aneurysms available for analysis. These represented 16.0% (15.7—16.3) of the total number of AAAs operated on during this period, ranging from 10.3% (9.8—11.8) in Germany to 29.4% (25.9—32.9) in Finland. The overall mean number of patients per treatment centre was 4.9 per year, ranging from 2.3 in Germany to 26.7 in Denmark (Table 1). The mean age was 74.7 years (74.5—74.9), and the majority of patients were men (82.7%, CI 81.9—83.6). EVAR was performed for 23.1% (22.3—24.0) of all RAAA procedures. The mean AAA size at the time of operation was 7.6 cm (7.5—7.6), 7.7 cm (7.7—7.8) for men and 6.9 cm (6.8—7.0) for women. Of these aneurysms, 10.7% (10.0—11.4) were less than 5.5 cm with 8.7% (7.9—9.4) in men, and 17.1% (14.9—19.2) in women.

Comparisons of characteristics and comorbidities between EVAR and OAR patients are given in Table 2. EVAR patients were slightly older (76.5 vs. 74.1 years, $p < .001$) and had greater rates of ischaemic heart and pulmonary disease, while OAR patients had larger aneurysms (7.7 vs. 7.1 cm, $p < .001$) at presentation. Almost all the registries lack data on neck diameter and length, as well as angulation (but those variables have recently been added to most of the registries).

The overall peri-operative mortality was 28.8% (27.9—29.8). For female patients, it was higher: 32.3% (29.9—34.9), compared with male patients, 27.1% (26.1—28.2), $p < .0001$ (Fig. 1). After adjusting for age, AAA diameter, and the above mentioned comorbidities, the peri-operative mortality OR revealed no statistical difference between men and women, OR 1.03 (.86—1.23), $p = .78$.

Peri-operative mortality was 32.1% (31.0—33.2) for OAR and 17.9% (16.3—19.6) for EVAR, $p < .0001$. Data for each country and procedure are given in Table 3. The adjusted peri-operative mortality OR for EVAR against OAR was .38 (0.31—0.47), $p < .001$.

Peri-operative mortality was lower in EVAR(p) centres (23.0%, 95% CI 20.6—25.4) compared with OAR(p) centres (29.7%, 95% CI 28.6—30.8), $p < .001$ (Table 4). A sensitivity analysis was performed, revising the percentage of RAAA patients treated by EVAR for EVAR(p) to $\geq$40%; the peri-operative mortality was 20.2% (16.6—23.9) for EVAR(p)

Table 1. Characteristics of ruptured AAAs for the 11 participating Vascunet countries for 2010—2013.

	Number of cases (%)	RAAAs vs. total AAA repairs, % (95% CI)	Mean number of patients per centre per year	Mean age, years (95% CI)	Mean AAA diameter, cm (95% CI)	EVAR, % (95% CI)
Total	9320	16.0 (15.7—16.3)	4.9	74.7 (74.5—74.9)	7.6 (7.5—7.6)	23.1 (22.2—24.0)
Australia	1444 (15.5)	18.6 (17.8—19.5)	4.2	74.4 (73.9—74.9)	7.2 (7.1—7.2)	39.8 (37.2—42.3)
Denmark	748 (8.0)	25.0 (23.5—26.6)	26.7	72.7 (72.1—73.2)	n/a	5.1 (3.5—6.7)
Finland	192 (2.1)	29.4 (25.9—32.9)	16.0	73.3 (72.0—74.7)	7.8 (7.5—8.0)	9.9 (5.6—14.2)
Germany	1444 (15.5)	10.3 (9.8—10.8)	2.3	74.6 (74.1—75.1)	7.2 (7.0—7.3)	31.2 (28.8—33.6)
Hungary	187 (2.0)	18.0 (15.7—20.4)	2.4	71.3 (69.9—72.6)	7.7 (7.4—8.0)	7.5 (3.7—11.3)
Iceland	21 (0.2)	21.7 (13.3—30.0)	21.0	72.3 (71.0—74·2)	7.8 (7.0—8.6)	19.1 (7.3—37.4)
New Zealand	220 (2.4)	15.3 (13.5—17.2)	n/a	74.5 (73.3—75.7)	7.5 (7.3—7.7)	10.9 (6.8—15.1)
Norway	334 (3.6)	13.8 (12.4—15.1)	n/a	n/a	7.5 (7.3—7.7)	11.7 (8.2—15.1)
Sweden	1038 (11.1)	21.1 (19.9—22.2)	8.4	75.2 (74.8—75.7)	7.6 (7.5—7.8)	29.3 (26.5—32.1)
Switzerland	342 (3.7)	13.6 (12.3—14.9)	5.0	72.5 (71.5—73.5)	7.6 (7.1—8.1)	24.9 (20.3—29.5)
United Kingdom	3350 (35.9)	16.5 (16.0—17.0)	6.7	75.7 (75.4—75.9)	7.9 (7.9—8.0)	18.0 (16.7—19.3)

RAAA = ruptured abdominal aortic aneurysm; AAA = abdominal aortic aneurysm; EVAR = endovascular aneurysm repair; n/a = not available.

Table 2. Comparison of RAAA patient characteristics and comorbidities for EVAR and OAR.

	EVAR	OAR	*p*
Mean age, years (95% CI)	76.5 (76.1—76.9)	74.1 (73.9—74.4)	<.001
Women, % (95% CI)	18.4 (16.6—20.2)	16.9 (16.0—17.9)	.15
Mean AAA diameter, cm (95% CI)	7.1 (7.0—7.2)	7.7 (7.7—7.8)	<.001
Ischaemic heart disease, % (95% CI)	41.6 (39.5—43.8)	28.2 (27.2—29.3)	<.001
Pulmonary disease, % (95% CI)	22.9 (20.7—25.0)	16.6 (15.6—17.5)	<.001
Diabetes mellitus, % (95% CI)	11.9 (10.3—13.4)	11.0 (10.2—11.8)	.30
Cerebrovascular disease, % (95% CI)	6.7 (5.2—8.2)	6.6 (5.9—7.3)	.95

RAAA = ruptured abdominal aortic aneurysm; EVAR = endovascular aneurysm repair; OAR = open aortic repair; AAA = abdominal aortic aneurysm.

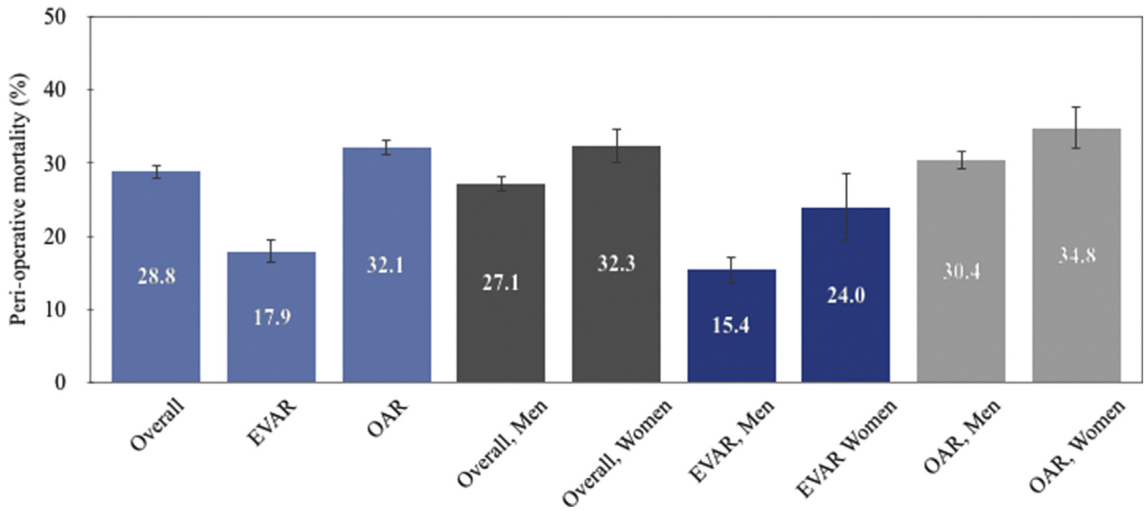

Figure 1. Peri-operative mortality after ruptured AAA repair overall, as well as based on operative technique and gender.

Table 3. Overall and per procedure peri-operative RAAA mortality rates for participating Vascunet countries for 2010–2013.

	Number of EVAR/open repairs (% EVAR)	Overall mortality, % (95% CI)	EVAR mortality, % (95% CI)	OAR mortality, % (95% CI)
Total	2155/7165 (23.1)	28.8 (27.9–29.8)	17.9 (16.3–19.6)	32.1 (31.0–33.2)
Australia	574/870 (39.8)	18.4 (16.4–20.4)	9.2 (6.9–11.6)	24.5 (21.6–27.4)
Denmark	38/710 (5.1)	25.1 (22.0–28.3)	10.5 (0.3–20.8)	25.9 (22.7–29.2)
Finland	19/173 (9.9)	23.7 (17.7–29.8)	[a]	26.3 (19.7–33.0)
Germany	450/994 (31.2)	35.5 (33.1–38.0)	24.2 (20.3–28.3)	40.6 (37.6–43.7)
Hungary	14/173 (7.5)	33.2 (26.4–40.0)	7.1 (0–22.6)	35.3 (28.1–42.5)
Iceland	4/17 (19.0)	19.1 (7.3–37.4)	[a]	23.5 (1.1–46.0)
New Zealand	24/196 (10.9)	28.2 (22.2–34.2)	16.7 (0.6–32.7)	29.6 (23.2–36.0)
Norway	39/295 (11.7)	21.3 (16.9–25.7)	15.4 (3.5–27.2)	22.0 (17.3–26.8)
Sweden	304/734 (29.3)	29.6 (26.8–32.4)	23.4 (18.6–28.1)	32.2 (28.8–35.5)
Switzerland	85/257 (24.9)	22.8 (18.3–27.3)	19.1 (10.5–27.6)	24.0 (18.7–29.3)
United Kingdom	604/2746 (18.0)	32.6 (31.0–34.2)	20.3 (17.0–23.5)	35.3 (33.5–37.1)

RAAA = ruptured abdominal aortic aneurysm; EVAR = endovascular aneurysm repair; OAR = open aortic repair.
[a] There were no deaths in these cohorts, thus limiting the 95% CI.

centres and 34.0% (31.3–36.7) for OAR(p) centres, $p < .001$. For EVAR procedures specifically, there was no significant difference in peri-operative mortality between EVAR(p) (17.9%) and OAR(p) (16.9%), $p = .56$. Nor was there a significant difference among those patients who underwent OAR (EVAR(p), 32.1%, OAR(p), 32.1%, $p = .99$). The OR for peri-operative mortality was significantly lower for EVAR(p) centres, OR 0.60 (0.46–0.78), $p < .001$.The detailed logistic regression is provided as a supplementary table. Of the centres with an EVAR(p) strategy for RAAA repair, 95.4% (90.0–100.0) used a strategy of EVAR(p) for elective AAA repair, whereas only 58.2% (53.2–63.3) of the OAR(p) centres for RAAA repair used an EVAR(p) strategy for elective AAA repair, $p < .001$. More specifically, 82.0% (77.2–86.8) of the EVAR(p) elective patients were treated by EVAR, while 50.7% (47.8–53.6) of the OAR(p) elective patients were treated by EVAR, $p < .001$.[23]

There were 442 participating centres, of which 66 were EVAR(p) treatment centres (Table 5). Of the 13 highest volume centres (QI, >22 repairs per year), none were EVAR(p). The greatest percentage of EVAR (30.6%) was performed in QII. Peri-operative mortality was lower in the highest volume centres, 23.3% (21.2–25.4), $p < .001$. Peri-operative mortality for OAR was significantly lower in the high volume centres compared with the other centres, 25.3% (23.0–27.6) and 34.0% (32.7–35.4), respectively, $p < .001$. Despite the variation in peri-operative mortality in EVAR between quintiles, there was no statistical differences between them, $p = .07$.

The relationship between centre volume and peri-operative mortality is graphically demonstrated in the form of a bubble graft and funnel plots for both EVAR and OAR over 4 years (Figs. 2 and 3) with mean peri-operative mortality as the target value.

DISCUSSION

This large, multinational registry based analysis of RAAA repair activity indicates that although the use of EVAR in treating RAAAs has increased since the previous Vascunet report in 2011,[24] 23.1% vs. 11.7%, significant variations in clinical practice, centralisation, and outcome remain. The study indicates that improved outcome is coupled with a primary EVAR strategy for treatment of ruptures, as well as

Table 4. Comparison of RAAA peri-operative mortalities for primary EVAR and primary OAR centres, 2010—2013.

	Primary EVAR centres	Primary OAR centres	*p*
Number of procedures	1217	6816	
Women, % (95% CI)	18.0 (15.7—20.3)	16.9 (16.0—17.9)	.40
EVAR, % (number EVAR/OAR)	63.8 (777/440)	15.8 (1076/5740)	<.001
Overall peri-operative mortality, % (95% CI)	23.0 (20.6—25.4)	29.7 (28.6—30.8)	<.001
EVAR peri-operative mortality, % (95% CI)	17.9 (15.2—20.6)	16.9 (14.6—19.1)	.56
OAR peri-operative mortality, % (95% CI)	32.1 (27.7—36.5)	32.1 (30.9—33.3)	.99

RAAA = ruptured abdominal aortic aneurysm; EVAR = endovascular aneurysm repair; OAR = open aortic repair.

Table 5. Peri-operative mortalities, overall and per primary strategy, for quintiles of centres, [a]based on mean number of procedures per hospital, 2010—2013.

	Total	QI	QII	QIII	QIV	QV
Number of centres	442	13	25	40	68	296
Number of centres, EVAR as primary treatment	66	0	7	5	11	43
Mean number of procedures per hospital per year	4.5	>22	12—22	8—12	4—8	1—4
EVAR, % (95% CI)	23.1 (22.3—24.0)	14.4 (12.6—16.1)	30.6 (28.4—32.8)	26.0 (23.9—28.2)	21.4 (19.4—23.4)	22.5 (20.5—24.6)
Overall peri-operative mortality (95% CI)	28.8 (27.9—29.8)	23.3 (21.2—25.4)	29.3 (27.1—31.5)	27.9 (25.7—30.1)	30.2 (27.9—32.4)	32.7 (30.4—35.0)
OAR peri-operative mortality (95% CI)	32.1 (31.0—33.2)	25.3 (23.0—27.6)	33.5 (30.8—36.3)	32.0 (29.3—34.7)	33.7 (31.0—36.3)	36.8 (34.1—39.5)
EVAR peri-operative mortality (95% CI)	17.9 (16.3—19.6)	11.2 (7.0—15.3)	19.7 (16.2—23.2)	16.4 (12.8—19.9)	17.3 (13.3—21.3)	18.8 (14.8—22.9)

Q = quintile; EVAR = endovascular aneurysm repair; OAR = open aortic repair.
[a] All centres were placed in descending order, based on the mean number of procedures performed over 4 years. Quintiles were formed based on the number of patients treated per quintile in this rank ordering.

with increased volume of rupture repairs, especially when open surgery is used. These findings may have a bearing on the organisation of acute vascular surgical services.

Patient selection, both in terms of haemodynamic and anatomical stability, has an impact on the choice of treatment and, likewise, on the outcome.[25,26] The patients offered EVAR in this cohort were older and sicker, while no data are available regarding anatomical constraints, including neck length, width, or angulation. It is interesting to note however, that OAR patients had larger AAA diameters, which is known to render aortas less amenable to treatment by EVAR, as well as to poorer outcomes overall.[27—29] Although turn down rate is not assessed in the current database, the fact that patients treated by EVAR are older and bear a greater degree of comorbidities implies that, to some extent, EVAR is used in patients who are otherwise not regarded as optimal open repair candidates.

The implementation and expansion of access to EVAR have led some centres to use EVAR as the treatment of choice for RAAAs. The decision to analyse EVAR(p) against OAR(p) centres was therefore deliberate, as a measure against potential patient selection bias. As seen in Table 4, the peri-operative mortality for EVAR(p) centres was significantly lower than it was for OAR(p) centres, and this remained true in a logistic regression correcting for age, gender, and comorbidities. This is despite the similar peri-operative mortality rates for EVAR and OAR separately in each group. Thus the EVAR(p) centres have better results merely as a result of the greater use of EVAR.

The volume outcome relationship in AAA treatment has been well addressed.[30,31] In their analysis of the Nationwide Inpatient Sample database, for example, McPhee et al. found that the volume of AAA repairs, both intact and ruptured, is predictive of mortality for RAAA treatment. Much of this is explained by the number of open repairs performed. This was similarly shown in a previous Vascunet report on intact repairs, in which worsening mortality for OAR was largely a result of worsening results in low volume centres.[23] The data in Table 5 reflect this as well, where lower peri-operative mortalities for both OAR and EVAR were associated with high volume centres and, more specifically, high OAR volume centres.

Although the relationship between volume and OAR appears strong, the impact of volume on peri-operative outcomes after EVAR is less clear. Zettervall et al. found a strong association between hospital and surgeon volume for open AAA repair and peri-operative mortality but, in contrast no association with EVAR.[32] Indeed, the funnel plots in Fig. 3 illustrate that an increase in volume is associated with improved peri-operative mortality for open repair, whereas this is not true for volumes of EVAR. The differences between quintiles for EVAR patients were not statistically significant (p = .07), and although the number of patients was substantial, a type II statistical error cannot be excluded.

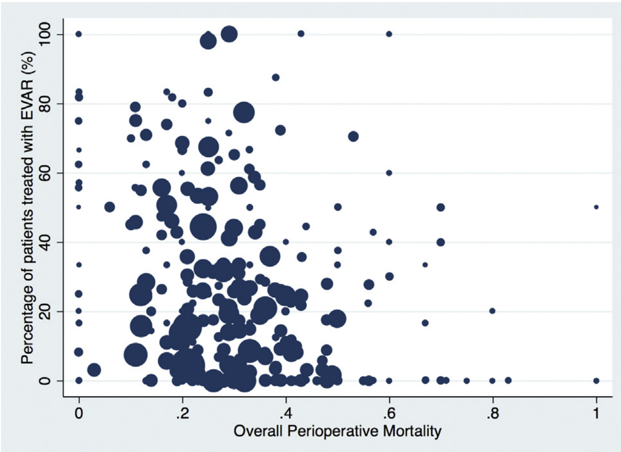

Figure 2. Bubble chart depicting the overall peri-operative mortality and the percentage of EVAR per centre on the x and y axis, respectively, while the size of each bubble represents the relative number of patients treated at each centre for 2010–2013.

It is interesting to note the variation in the care of RAAA patients between countries. The relationship between operation volume, operating technique, and outcome is complex, and it affects country level peri-operative mortality in different ways. Two examples of this are Denmark, which had the highest degree of centralisation (>25 RAAAs per centre, per year), the lowest rates of EVAR (5.1%), and yet the overall peri-operative mortality (25.1%) is in the middle of the group. In contrast, the Australian vascular surgery services are less centralised (<5 RAAAs per centre, per year), and almost 40% of patients were treated by EVAR. Geography, and more specific population densities, may have a major influence on these tendencies. The national variations in peri-operative outcome may also be related to differences in case mix and turn down rate for ruptured AAA repair, which could not be assessed in the current dataset. Other factors such as transfer time, health service funding and the availability of appropriate facilities also play a role.

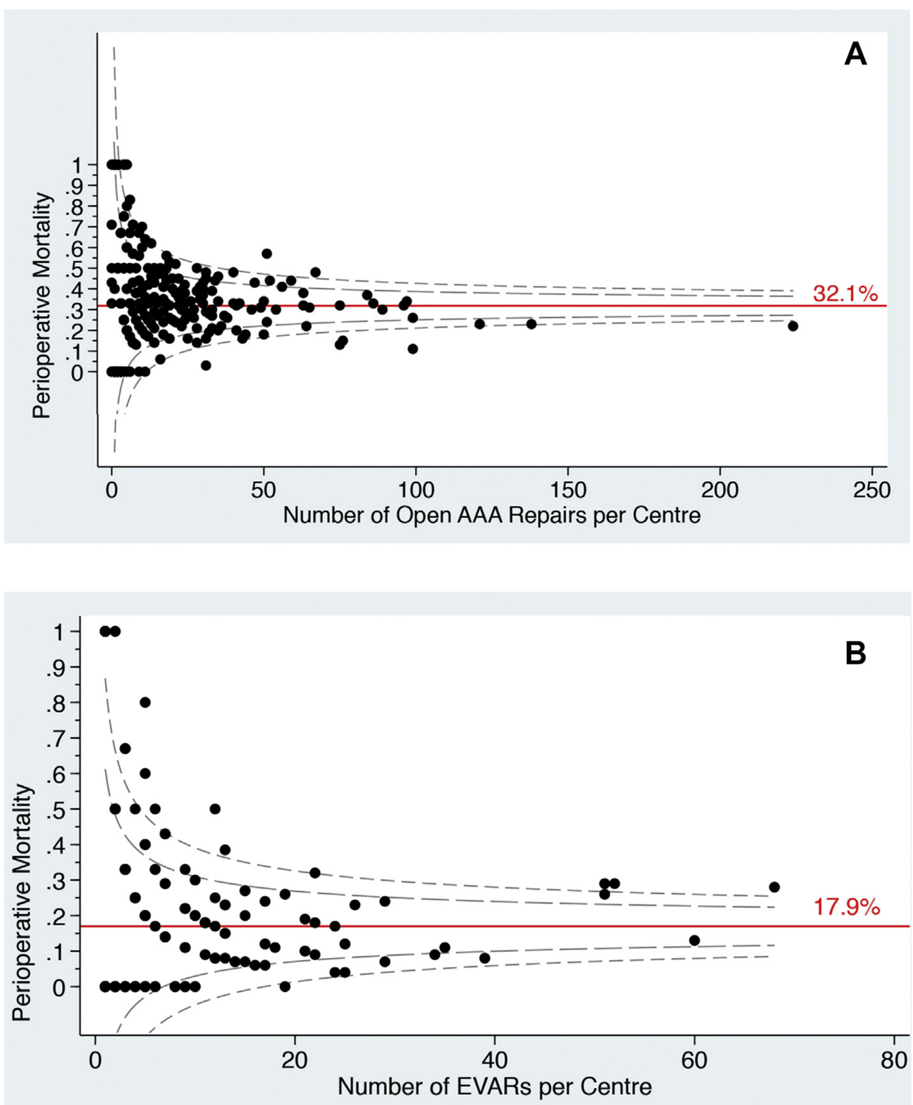

Figure 3. Funnel plot of total volume, 2010–2013, versus peri-operative mortality after ruptured AAA repair with (A) open aortic repair and (B) EVAR. The interrupted lines represent the 95% and 99.8% CI. The target is the mean peri-operative mortality and is shown by the red line.

The guidelines from the European Society of Vascular Surgery state that AAA repair should only be performed in hospitals performing at least 50 elective infrarenal AAA repairs per annum.[33] They also add that the organisational process for implementing appropriate endovascular management of RAAAs is complex and is one of the drawbacks preventing its extensive dissemination. It does appear clear, however, that EVAR(p) centres use EVAR to a greater degree for their intact AAA repair than OAR(p) centres. The fact that the majority of OAR(p) centres (58.2%) primarily treat their elective patients with EVAR perhaps reflects some of the organisational challenges in providing EVAR in the acute setting.

In regards to the positive association of outcomes with centres with high volume, the transfer of a patient to a high volume institution with greater EVAR expertise may seem prudent, yet Mell et al. showed that the gain in expertise was negated by the transfer process itself.[34] The provision of vascular services and referral patterns is also affected by healthcare reimbursement and funding, which varies among the countries included in the current registry collaboration.[12] The landscape of AAA repair is changing however, and more centres are acquiring competency and experience ofEVAR as a primary strategy. The process of vascular surgical service reorganisation is complex, and reports are relatively scarce.[35]

There are, of course, several other important underlying issues coupled with centralisation and access to EVAR. The results presented here do not include patients not treated (who suffer an almost 100% mortality), and how this is related to access to vascular surgery. Furthermore, as seen in Table 1, the percentage of ruptures vs. all AAA repairs, varies significantly among countries. This may be related to screening programmes, as well as to decisions of when to treat patients with an intact AAA. Karthikesalingam et al. touched on this in their recent analysis, suggesting that the reduced rate of ruptures in the United States may be related to a lower diameter threshold when treating intact AAAs.[36] Although the mean AAA rupture size in the present analysis was 7.6 cm, 10.7% were less than 5.5 cm at the time of rupture. Centralisation and EVAR may offer advantages in treating RAAAs, but the prevention of rupture should still be the mainstay of treating AAA.

Limitations

This analysis of prospectively registered data is vulnerable to random and systematic missing data, as well as incorrectly coded data. Aside from random missing data, it should be noted that Norway and New Zealand had no data regarding hospital centre identification number, thus limiting input from their 554 patients included. Not all registries achieved national coverage for ruptured AAA repairs. Generally, centres participating in the registry collaboration include all the cases treated in the unit, reducing the risk of case selection in outcome analysis. As mentioned above, reporting of RAAAs in the UK was not mandatory during the study period, thus exposing the data to selection bias. Some of the participating registries have undergone both external and internal validation,[18–20] and those results showed excellent validity, but not all the participating registries were validated. There is an ongoing process, however, in which all the registries participating in the Vascunet collaboration will undergo independent international validation.

There are other variables not reported, which could have impacted on treatment and outcomes. There are, for example, no data regarding the means of diagnosis at the time of operation. This could certainly have some influence on the percentage of patients reported with an aneurysm less than 5.5 cm. Furthermore, data regarding the haemodynamic stability of the patients are also lacking. This could have impacted decisions as to whether the patient underwent EVAR or open repair and, ultimately, peri-operative mortality. Missing data and the bias of patient selection are incontrovertible limitations of a retrospective analysis, but ones that are hopefully mitigated by such a large and international patient cohort.

CONCLUSION

Despite the growing proportion of EVAR used for intact AAA, OAR still predominates as the treatment used in the majority of RAAA repairs, even in the highest volume centres. Peri-operative mortality is lower in centres that either have high volumes or apply a primary EVAR strategy for treatment of ruptures; however, most patients are operated on at small centres and with open repair. These findings may impact the future organisation of acute vascular surgical services.

CONFLICT OF INTEREST

None.

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APPENDIX A. SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.1016/j.ejvs.2018.01.014.

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