Eur J Vasc Endovasc Surg (2017) 54, 13–20

Editor's Choice – Assessment of International Outcomes of Intact Abdominal Aortic Aneurysm Repair over 9 Years

J. Budtz-Lilly [a,b,*], M. Venermo [c], S. Debus [d], C.-A. Behrendt [d], M. Altreuther [e], B. Beiles [f], Z. Szeberin [g], N. Eldrup [b], G. Danielsson [h], I. Thomson [i], P. Wigger [j], M. Björck [a], I. Loftus [k], K. Mani [a]

[a] Department of Surgical Sciences, Vascular Surgery, Uppsala University, Uppsala, Sweden
[b] Department of Cardio-Thoracic and Vascular Surgery, Aarhus University Hospital, Aarhus, Denmark
[c] Department of Vascular Surgery, Helsinki University Hospital, Helsinki, Finland
[d] Department of Vascular Medicine, University Heart Centre Hamburg – Eppendorf, Hamburg, Germany
[e] Department of Vascular Surgery, St Olavs Hospital, Trondheim, Norway
[f] Australian and New Zealand Society for Vascular Surgery, Melbourne, Australia
[g] Department of Vascular Surgery, Semmelweis University, Budapest, Hungary
[h] National University Hospital of Iceland, Department of Surgery, Reykjavík, Iceland
[i] Department of Vascular Surgery, Dunedin School of Medicine, Dunedin Hospital, Dunedin, New Zealand
[j] Department of Cardiovascular Surgery, Kantonsspital Winterthur, Switzerland
[k] Department of Vascular Surgery, St George's University of London, London, UK

WHAT THIS PAPER ADDS

This analysis shows that the international results for treatment of intact AAAs are improving, largely because of the increased use of endovascular therapy. This coincides however, with worsening results for open surgical treatment. Fewer patients are undergoing open surgical repair, and the potential technical challenges of these procedures may best be administered by high volume centres. Finally, many patients are still undergoing treatment for small AAAs, and the ostensible risk of treatment is not less than the risk of rupture. This is in contradiction to the recommendations in the Guidelines, and although the impact of this cannot be ascertained from this study, the undertaking is of concern.

Background: Case mix and outcomes of complex surgical procedures vary over time and between regions. This study analyses peri-operative mortality after intact abdominal aortic aneurysm (AAA) repair in 11 countries over 9 years.
Methods: Data on primary AAA repair from vascular surgery registries in 11 countries for the years 2005–2009 and 2010–2013 were analysed. Multivariate adjusted logistic regression analyses were carried out to adjust for variations in case mix.
Results: A total of 83,253 patients were included. Over the two periods, the proportion of patients ≥80 years old increased (18.5% vs. 23.1%; $p < .0001$) as did the proportion of endovascular repair (EVAR) (44.3% vs. 60.6; $p < .0001$). In the latter period, 25.8% of AAAs were less than 5.5 cm. The mean annual volume of open repairs per centre decreased from 12.9 to 10.6 between the two periods ($p < .0001$), and it increased for EVAR from 10.0 to 17.1 ($p < .0001$). Overall, peri-operative mortality fell from 3.0% to 2.4% ($p < .0001$). Mortality for EVAR decreased from 1.5% to 1.1% ($p < .0001$), but the outcome worsened for open repair from 3.9% to 4.4% ($p = .008$). The peri-operative risk was greater for octogenarians (overall, 3.6% vs. 2.1%, $p < .0001$; open, 9.5% vs. 3.6%, $p < .0001$; EVAR, 1.8% vs. 0.7%, $p < .0001$), and women (overall, 3.8% vs. 2.2%, $p < .0001$; open, 6.0% vs. 4.0%, $p < .0001$; EVAR, 1.9% vs. 0.9%, $p < .0001$). Peri-operative mortality after repair of AAAs <5.5 cm was 4.4% with open repair and 1.0% with EVAR, $p < .0001$.
Conclusions: In this large international cohort, total peri-operative mortality continues to fall for the treatment of intact AAAs. The number of EVAR procedures now exceeds open procedures. Mortality after EVAR has decreased, but mortality for open operations has increased. The peri-operative mortality for small AAA treatment, particularly open surgical repair, is still considerable and should be weighed against the risk of rupture.

Article history: Received 21 November 2016, Accepted 2 March 2017, Available online 13 April 2017
Keywords: Abdominal aortic aneurysm, Outcomes, Clinical practice, Vascular registries

* Corresponding author. Department of Surgical Sciences, Vascular Surgery, Uppsala University, 75185 Uppsala, Sweden.
E-mail address: jacoblilly@me.com (J. Budtz-Lilly).

http://dx.doi.org/10.1016/j.ejvs.2017.03.003

INTRODUCTION

Intact abdominal aortic aneurysm (AAA) repair aims to prevent death from rupture. Over the past years, the prevalence of intact AAA repair has increased in many countries.[1–3] This is due to the broad use of endovascular repair (EVAR), enabling treatment of new and elderly patient cohorts previously deemed unfit for open surgery.[4–6] Additionally, the detection rate of small AAAs is increasing, attributable to the introduction of local and national screening programs, as well as the increased use of computed tomography and other types of imaging in medical practice.[7,8] The practice of AAA repair in Europe is guided by the AAA management guidelines of the European Society for Vascular Surgery (ESVS).[9] As the surgical risk of the repair must be balanced against the risk of aneurysm rupture, the ESVS guidelines recommend a threshold diameter of 5.5 cm for intact AAA repair, and suggest that a lowered threshold of $\geq$5.2 cm can be considered for women because of the increased rupture risk in this patient group. With noted increasing surgical activity and screening programs for AAA detection and management, the monitoring of surgical outcome measures is increasingly important. Furthermore, a recent international registry collaboration has demonstrated significant variations between countries in the selection of patients undergoing intact AAA repair, with a high proportion of patients undergoing treatment for an AAA $<$5.5 cm in countries with a fee for service healthcare system.[10] Whether this practice can be justified depends heavily on the peri-operative risks associated with this elective prophylactic procedure.

The Vascunet collaboration is an international network of vascular surgical registries from 11 countries with focus on quality improvement and international benchmarking of vascular surgical activity and outcomes. This large scale registry collaboration allows assessment of real world and up to date surgical practice in different geographical regions.[11,12] An evaluation of AAA repair published in 2008 indicated an excess mortality in the United Kingdom compared with other countries.[13] This finding resulted in the initiation of an intense quality improvement program and reorganisation of vascular surgical services.[11,14]

The current report addresses this and is a continuation of the above mentioned work from the Vascunet collaboration. The objective is to describe trends in contemporary AAA practice in an international context, and to assess the change in peri-operative mortality after repair.

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 multicentre (Germany) databases. The estimated coverage of the participating registries was $>$90% for aortic procedures performed in Denmark, Hungary, Iceland, New Zealand, Sweden, UK, and the Helsinki region in Finland, 80% in Norway, and 62% in Australia. The Swiss database includes patients operated for AAA in public hospitals, and the German data are based on approximately 130 centres participating in the German vascular registry. The current analysis is a continuation of the previous Vascunet report, in which nine countries had amalgamated their data for AAA repair over the 2005–2009 period.[11] As well as updating outcomes of AAA repairs performed from 2010–2013, data were now included for repairs performed in Iceland and New Zealand (2010–2013) and Germany (2005–2013). Data were no longer available from Italy and were therefore excluded.

Study design and participants

Data on primary AAA repairs were collected from vascular registries for the period 2005–2013 from 11 countries. Reoperations were excluded. The data were analysed overall, per country, per treatment (EVAR vs. open surgery), for high and low volume centres, and also between the two time periods (2005–2009 and 2010–2013). When comparing time periods, data from Iceland and New Zealand were excluded, as data were not available from both periods.

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). The covariates included for analysis were age, gender, and AAA diameter (in centimeters). An aneurysm less than 5.5 cm was, by convention, considered a small aneurysm. Although the Vascunet registries include data on risk factors such as smoking, cardiac, pulmonary, and renal disease, these were not included in the present analysis because of differences in the definitions of comorbidity variables. The proportions of missing data for the 83,253 intact AAAs were as follows: age, 2129 (2.6%); gender, 22,578 (27.1%; primarily from the German database, which did not register data regarding gender for 91.6% of their patients); operative technique, 1319 (1.6%); and AAA diameter, 22,211 (26.7%). It should also be noted that AAA diameter was not available for approximately 50% of the patients from 2005–2009 and were therefore excluded from the comparative analysis. For the 2010–2013 period, the proportions of missing data for the 48 878 AAAs were as follows: age, 2111 (4.3%); gender, 10,522 (21.5%); and diameter, 5786 (11.8%) patients.

Data regarding peri-operative mortality after intact AAA repair in the patients treated from 2005–2009 were reported in the previous Vascunet report.[11] The current analyses of peri-operative mortality in patient subgroups and per country, as well as predictors of peri-operative death, were performed in the cohort of patients treated from 2010–2013.

In the UK national vascular surgery database report, the focus of peri-operative outcomes was based on the assessment of elective repair.[15] The mode of admission, elective or acute, was always registered, but the indication for repair, intact or rupture, was missing in 4236 patients. Therefore, outcomes for both elective and intact repair were assessed in the UK cohort.

Statistical analysis

Continuous data are presented with mean values and 95% confidence intervals (CIs), and compared with *t* tests. Rates are presented as percentages with 95% CIs. Missing data were handled by exclusion. Comparison of rates over time was performed using the chi-square test. Logistic regression models were performed to estimate the odds ratios for peri-operative mortality for the studied covariates. When calculating the effect of treatment country on peri-operative mortality, each country was compared with the sum of all other countries in a multivariate regression analysis. The models were tested for goodness of fit and ability to predict outcome (Hosmer—Lemeshow statistic, C-statistic, and Nagelkerkes R^2). A p value $< .05$ was regarded as significant.

High and low volume centres were determined by placing the participating centres into descending order based on the number of procedures performed per year. Four quartiles were formed; the resulting top and bottom groups were designated as either high or low volume centres.

All data analysis was carried out using R Statistical Software Package (R Foundation for Statistical Computing, Vienna, Austria) and SPSS for Mac, Version 23.0 (SPSS Inc., IBM Corp., Armonk, NY, USA).

RESULTS

Included in the analysis were 34,375 patients from 2005—2009 and 48,878 patients from 2010—2013. Characteristics for intact AAA treatment for each country are given in Table 1.

Time trends in patient selection, operative technique, and outcome

The overall proportion of octogenarians and patients treated by EVAR increased from 2005—2009 to 2010—2013, whereas the proportion of female patients decreased (Table 2). The rate of AAAs less than 5.5 cm was 25.8% (95% CI 25.4—26.3) for the 2010—2013 period.

Time trends in peri-operative mortality are given in Fig. 1. Overall, peri-operative mortality decreased between the two periods. Peri-operative mortality after EVAR decreased, while the number of EVAR procedures increased. The peri-operative mortality increased for open surgical repair (Fig. 1). The increase in peri-operative mortality after open repair was statistically significant among low volume centres (bottom quartile of yearly case numbers $\leq$ 10 for 2005—2009, 4.3%; $\leq$10 cases per year for 2010—2013, 5.4%, $p = .03$). There was no statistically significant difference between the two periods among high volume centres (top quartile of yearly case numbers, $\geq$70 cases per year in 2005—2009, 3.4%; >36 cases per year in 2010—2013, 3.4%, $p = .86$). See Table 3 for further analysis. The mean annual volume of open repairs per centre decreased from 12.9 (10.5—15.3) to 10.6 (9.1—12.1) ($p < .0001$), but the mean annual volume of EVAR per centre increased from 10.0 (8.2—11.8) to 17.1 (15.0—19.1) ($p < .0001$).

After correcting for age and gender, logistic regression analysis revealed a reduced peri-operative mortality odds ratio when comparing the latter against the former period (OR = 0.71 [0.64—0.78] $p < .0001$). The adjusted odds ratio for EVAR was also significantly less (OR = 0.59 [0.48—0.73] $p < .0001$), but the adjusted odds ratio for open surgery was increased (OR = 1.17 [1.03—1.30] $p = .01$).

Peri-operative mortality in specific countries and patient subgroups

A detailed analysis of female patients, octogenarians and patients with small AAA is presented in Fig. 2. Mortality was significantly higher in female than males after both open repair and EVAR, although the mean AAA diameter was less in women (mean AAA diameter in female patients 6.0 cm vs. male patients 6.3 cm, $p < .0001$). Although mortality was slightly lower in patients with small AAAs than those with AAA $\geq$5.5 cm, the risk of peri-operative death in the

Table 1. Characteristics of intact AAAs for Vascunet registry participating countries 2005—2013.

	Number of cases (%)	Mean age, years (95% CI)	Women, % (95% CI)	Mean AAA diameter, cm (95% CI)	EVAR, % (95% CI)	AAA < 5.5 cm, % (95% CI)[a]
Total	83,253	72.8 (72.7—72.8)	13.8 (13.6—14.1)	6.1 (6.1—6.1)	53.4 (53.0—53.7)	25.6 (25.2—26.0)
Australia	8120 (8.8)	74.6 (74.4—74.7)	15.5 (14.7—16.3)	5.9 (5.9—6.0)	69.7 (68.7—70.7)	32.1 (31.0—33.2)
Denmark	4739 (5.1)	71.3 (71.1—71.5)	17.4 (16.3—18.5)	n/a	28.6 (27.3—29.8)	n/a
Finland	754 (0.8)	71.9 (71.2—72.5)	12.9 (10.5—15.3)	6.4 (6.3—6.6)	34.0 (30.6—37.3)	17.3 (12.4—22.3)
Germany	24,627 (26.7)	71.9 (71.8—72.0)	14.1 (12.6—15.6)	5.7 (5.7—5.8)	58.7 (58.1—59.3)	46.1 (45.2—47.0)
Hungary	1119 (1.2)	68.8 (68.3—69.3)	14.6 (12.5—16.6)	6.2 (6.1—6.3)	25.3 (22.7—27.8)	26.7 (23.6—29.7)
Iceland[a]	76 (0.1)	72.6 (71.0—74.2)	17.1 (8.4—25.8)	6.4 (6.1—6.7)	54.0 (42.5—65.4)	8.0 (1.7—14.3)
New Zealand[a]	1214 (1.3)	73.8 (73.3—74.3)	18.8 (16.6—21.0)	6.2 (6.1—6.2)	51.7 (48.9—54.5)	21.8 (19.5—24.2)
Norway	4802 (5.2)	n/a	17.0 (15.9—18.0)	6.3 (6.3—6.4)	30.4 (29.1—31.8)	22.4 (20.6—24.2)
Sweden	8027 (8.7)	72.2 (72.1—72.4)	16.7 (15.9—17.5)	6.2 (6.1—6.2)	50.2 (49.1—51.3)	20.5 (19.2—21.7)
Switzerland	3988 (4.3)	70.9 (70.6—71.2)	11.5 (10.5—12.5)	5.9 (5.8—6.0)	44.4 (42.9—46.0)	36.6 (30.9—38.4)
United Kingdom	25,787 (27.9)	74.1 (74.0—74.2)	13.3 (12.9—13.8)	6.6 (6.6—6.6)	57.5 (56.9—58.1)	9.2 (8.7—9.6)

Note. $p < 0.01$ inter-country variation for all variables. AAA = abdominal aortic aneurysm; CI = confidence interval; EVAR = endovascular aneurysm repair; n/a = not available.
[a] Data only available for 2010—2013.

Table 2. Comparison of AAA patient characteristics from the previous (2005–2009) and current (2010–2013) time periods after exclusion of Iceland and New Zealand.

	2005–2009	2010–2013	*p*
Mean age, years (95% CI)	72.1 (72.0–72.2)	73.3 (73.3–73.4)	<.0001
Open repair, % (95% CI)	70.7 (70.5–70.8)	71.0 (70.9–71.1)	<.0001
EVAR, % (95% CI)	73.9 (73.7–74.0)	74.8 (74.8–74.9)	<.0001
Rate EVAR, % (95 %CI)	44.3 (43.7–44.8)	60.6 (60.1–61.0)	<.0001
Rate women, % (95% CI)	15.5 (15.0–15.9)	14.1 (13.8–14.5)	<.0001
Rate octogenarians, % (95% CI)	18.5 (18.1–18.9)	23.1 (22.7–23.5)	<.0001
AAA < 5.5 cm, % (95% CI)	n/a	25.8 (25.4–26.3)	
Women, AAA< 5.5 cm, % (95% CI)	n/a	27.7 (26.4–29.0)	

AAA = abdominal aortic aneurysm; CI = confidence interval; EVAR = endovascular aneurysm repair; n/a = not available.

small AAA cohort was 3.1% after open repair, and 3.4–9.7% in octogenarians undergoing open surgery. In a multivariate logistic regression analysis, patient age, AAA diameter, and female gender were all significant predictors of peri-operative mortality in this cohort (Table 4). These risk factors were greater among patients treated by EVAR than those treated by open surgical repair.

The peri-operative mortality for each participating country from 2010–2013 are given in Fig. 3A–C. There were no peri-operative deaths for the 76 patients from Iceland and they are therefore not included in the figure. Peri-operative mortality after intact AAA repair was significantly lower than the overall mean in Australia, Norway, and Sweden (Fig. 3A). Although there was no significant difference in EVAR mortality between countries (Fig. 3B), open repair mortality was lower than the overall mean in Norway and Sweden, and higher than the overall mean in the UK (Fig. 3C). In the UK, the peri-operative mortality after elective AAA repair as opposed to intact repair, was 3.5% (3.1–4.0%) after open repair and 0.8% (0.6–0.9%) after EVAR. This was similar to mortality rates after intact repair

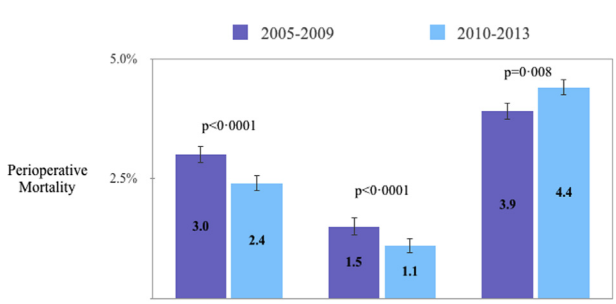

Figure 1. Changes in peri-operative mortality in the Vascunet Registry between the two periods.

Table 3. Peri-operative mortality for high and low volume centres for 2005–2009 and 2010–2013 for open AAA repair and EVAR.

	2005–2009	2010–2013	p
Open Repair			
High Volume	3.4%	3.4%	0.86
Low Volume	4.3%	5.4%	0.03
EVAR			
High Volume	1.8%	1.1%	0.02
Low Volume	1.3%	1.2%	0.56

AAA = abdominal aortic aneurysm; EVAR = Endovascular aneurysm repair.

in other registries. Results from the multivariate logistic analysis, comparing outcome between countries after correction for age, AAA diameter, and patient gender are given in Table 5. The risk adjusted odds ratio for peri-operative mortality after intact AAA repair was <1 in Australia and Norway, and >1 in Hungary and the United Kingdom. The Hosmer–Lemeshow statistic indicated moderate to adequate goodness of fit, and the R^2 indicated a low predictability for the regression model assessing outcome based on country of repair.

DISCUSSION

In this international cohort study, the total peri-operative mortality following treatment for intact AAAs decreased over time. Mortality following treatment by EVAR fell and at the same time, the number of EVAR procedures increased. Mortality after open repair tended to increase, however, and varied significantly between countries. The increase in mortality after open repair is of concern, considering the increased focus on improved auditing and quality of surgical care.[16,17]

The highest level of evidence for medical and surgical treatment is through randomised controlled trials and meta-analyses. Guidelines are often based on these results. Registry based reports are powerful tools for assessing current practices and outcomes in the real world setting, reflecting whether treatments follow current evidence and recommendations.[18] International registry based assessments of surgical care are scarce and moreover, often affected by variations in the definitions of metrics, validity, and case selection. The current report on intact AAA repair focuses on the "hard" outcome of peri-operative mortality and is based on a 10 year experience of international benchmarking of vascular surgical outcome data within the Vascunet collaboration.[11–13] The participating registries in this collaboration have established routines for internal and external validation of data.[19–21] All registries have national, regional, or centre based coverage, which reduces the risk of selective case reporting. With the implementation of AAA screening in several countries, and the increasing prevalence of intact AAA repair, an international assessment of AAA management practices becomes even more important.[22,23]

The overall decrease in peri-operative mortality after intact AAA repair is encouraging. This improvement

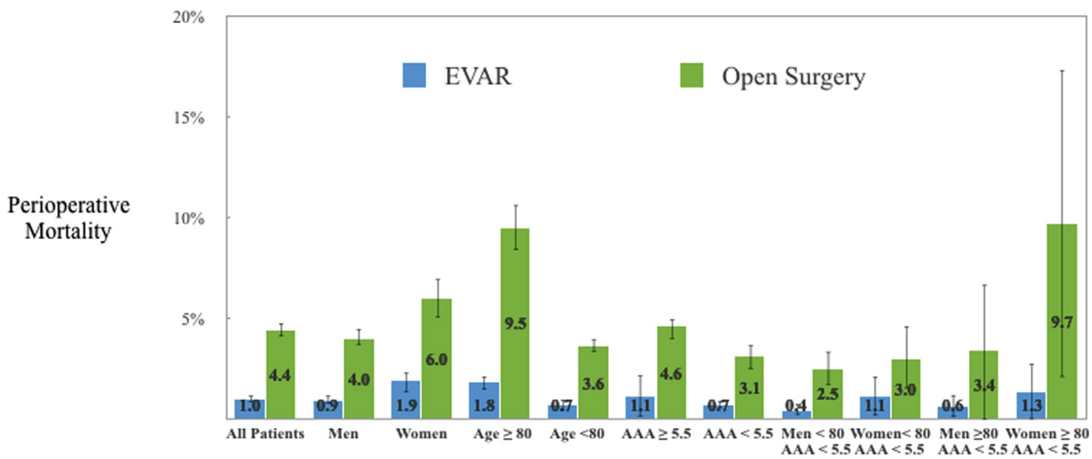

Figure 2. Peri-operative mortality for patient subgroups undergoing treatment for intact abdominal aortic aneurysm (AAA), 2010—13.

occurred despite an increase in patient age. The reasons appear twofold: mortality following EVAR has fallen, and more patients are now offered EVAR, notably true for both women and octogenarians. The improvement in mortality after EVAR could be an effect of increased volumes and surgical proficiency. The impact of improved new generation devices may also play a role. The negative development in outcomes following open AAA repair is more surprising and may result from multiple reasons. A higher rate of anatomically demanding cases which are selected for open repair in the endovascular era may contribute to this development.[24] It is known, for example, that aneurysms with a hostile infrarenal neck have a higher risk of adverse outcome also after open repair.[25,26] The dramatic reduction in the percentage of open repair cases is another important factor. The volume—outcome relationship in complex vascular surgical procedures is well established.[27] The decreasing number of open repairs per centre may have resulted in reduced technical competence. With expanding EVAR activity, a further need for centralisation of open aortic repair may be indicated in several countries. This is also congruent with the ESVS guidelines, recommending AAA repair only in hospitals performing at least 50 elective cases per annum, whether by open repair or EVAR.[9]

The falling peri-operative mortality risk may impact decision making of when to treat, and can be interpreted by some as a motivator for a lowered diameter threshold for intact AAA repair. The recent analysis on international variations in AAA treatment by Beck et al. has indeed shown a tendency to treat small AAAs with EVAR, particularly in countries with fee for service reimbursement.[10] On the other hand, four randomised controlled trials have refuted the clinical benefit of surgical repair of small aneurysms.[28—31] Karthikesalingam et al.[32] have challenged these trials by revealing a significantly reduced rate of rupture in the United States, where more than 40% of AAA repairs were performed on aneurysms with a diameter less than 5.5 cm.

Conclusions from the data presented here suggest that the peri-operative mortality risk for surgical treatment of AAAs <5.5 cm exceeds the risk of rupture in some cohorts. The risk of rupture of aneurysms <5.5 cm was <1% per year in the randomised trials referred to above, similar to the mortality risk of EVAR in patients with AAA <5.5 cm. With increasing numbers of relatively young patients with screening detected small AAAs, it is important to assess whether EVAR is considered in these patients solely based on the merits of a low peri-operative risk. Although EVAR can be performed at a low risk, it is associated with a significant cost and, moreover, may not result in any survival benefit. Durability after EVAR is also inferior compared with open repair; a yearly rupture risk of 1% was reported from the EVAR 1 trial.[33] Risk of open repair was higher, particularly in the elderly and in female patients, questioning the benefit of early repair in these patients. Finally, even with acceptable peri-operative outcomes, the expected 4 year survival of 40—50% in the elderly cohort should be included in considerations of when to treat.[34]

The current analysis underscores the limited evidence regarding best management of AAA among women. Overall,

Table 4. Logistic regression predicting peri-operative mortality based on age, maximum AAA diameter, and patient sex, 2010—2013.

	Odds ratio	p	95% CI Lower	Upper
Overall				
Age, per year	1.05	<.001	1.03	1.06
AAA diameter, per cm	1.31	<.001	1.25	1.36
Female patient	1.91	<.001	1.59	2.29
Open surgery				
Age, per year	1.09	<.001	1.07	1.10
AAA diameter, per cm	1.15	.001	1.09	1.21
Female patient	1.45	<.001	1.17	1.81
EVAR				
Age, per year	1.06	<.001	1.04	1.08
AAA diameter, per cm	1.37	<.001	1.27	1.48
Female patient	2.08	<.001	1.46	2.95

AAA = abdominal aortic aneurysm; CI = Confidence interval; EVAR = endovascular aneurysm repair.

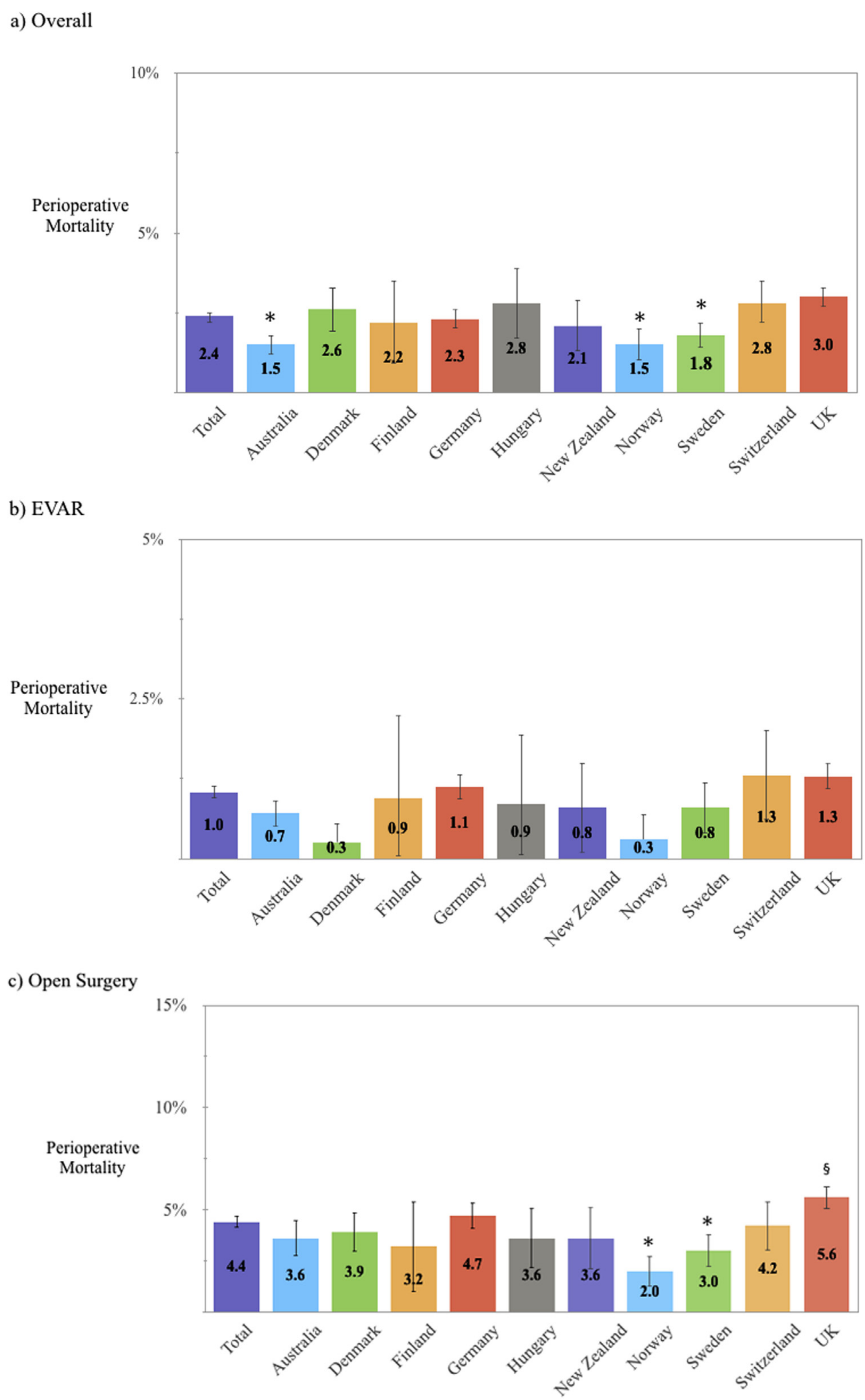

Figure 3. Peri-operative mortality of abdominal aortic aneurysm repair, 2010–2013: (A) overall (B) EVAR (C) open surgery. Note that peri-operative mortality was either in hospital mortality for Australia, Germany, Hungary, New Zealand, Norway, Switzerland, and the United Kingdom, or 30 day mortality for Denmark, Finland, Iceland, and Sweden. * Significantly lower peri-operative mortality than the overall mean. § Significantly higher peri-operative mortality than the overall mean.

Table 5. Multivariate analysis of odds ratio for peri-operative death after intact AAA repair, 2010–2013. Corrected for age, maximum AAA diameter, and patient sex. Each country was compared with the sum of all other countries.

Country	Odds ratio	95% CI	*p*	Hosmer–Lemeshow	R^2
Australia	0.62	0.49–0.77	<.0001	.36	.047
Denmark	1.20	0.92–1.57	.192	.18	.020
Finland	1.22	0.54–2.77	.633	.05	.044
Germany	1.01	0.73–1.40	.968	.06	.044
Hungary	1.60	1.05–2.44	.028	.03	.045
New Zealand	0.96	0.64–1.42	.824	.03	.044
Norway	0.68	0.47–0.98	.038	.22	.033
Sweden	0.83	0.64–1.07	.155	.21	.045
Switzerland	1.35	0.80–2.28	.263	.04	.044
United Kingdom	1.32	1.13–1.54	<.0001	.60	.046

AAA = abdominal aortic aneurysm; CI = confidence interval; EVAR = endovascular aneurysm repair.

almost a third (27.7%) of women were treated for an aneurysm less than 5.5 cm. Although there are indications of increased risk of rupture for women, the mortality associated with repair is also increased, both short and long term.[35,36] Therefore, the recommendation to perform repair at a lower size threshold in female patients could, in fact, be unwarranted.

International variations in peri-operative mortality for intact AAA repair are noted both in the crude and the risk adjusted analysis of peri-operative outcome in this cohort, mainly because of variations in the outcome of open surgery. The mortality after open repair was higher in the UK than in other countries, although the difference is less dramatic after the quality improvement efforts undertaken. On the other hand, intact AAA repair in the UK was almost exclusively performed for large aneurysms, and the mean AAA diameter at time of intact repair was highest in the UK among the countries studied, resulting in a possible net benefit in avoiding ruptures. It should also be reiterated that the data reported are based on the status of the aorta at the time of surgery, namely ruptured or intact. This is important, as it resulted in the exclusion of 17.2% of the patients in the UK registry. This also explains the marked difference between those results reported here and those from the United Kingdom's National Vascular Registry Progress Report, in which results were reported based on the mode of admission, that is, acute or elective.[15] This underscores the need for improved international definitions of variables and outcomes.

Limitations

This study is based on prospectively registered data, vulnerable to both systematic and random missing data. The potential confounding produced by this is mitigated by the otherwise large data set, and by the limitation of analysis on "hard-core" variables such as age, AAA diameter, gender, and mortality. Missing data were treated by exclusion, which limits some of the applicability and interpretation of the analysis. The missing data on patient gender from Germany, for example, limits the contribution of their data to the multivariate analysis given in Table 4. Although the definition of peri-operative mortality was based on in hospital death in some registries and 30 day mortality in others, previous analyses have shown that these outcome measures are reliably comparable.[11] Continuous efforts are made within the Vascunet collaboration to increase the harmonisation of the registered variables in vascular registries.

The method of measurement of AAA size is not provided and could vary, depending on imaging modality.[37] There is also no specification regarding the actual indication for treatment, that is, whether the aneurysm was symptomatic or mycotic, or whether a large iliac aneurysm was also present. It is, however, reasonable to assume that the proportion of variant indications should be fairly constant between the different geographical regions, as well as over time.

CONCLUSION

In this large international cohort of patients, peri-operative mortality following intact AAA repair has continued to fall, mainly due to increased use of EVAR, associated with improved short-term outcomes. For the first time, mortality for open operations has increased, while the volume of open repairs decreased significantly. A quarter of all repairs were performed for AAAs <5.5 cm in size. Although this was a safe procedure when performed with EVAR in the younger male patients, the peri-operative mortality exceeded the estimated annual rupture risk of 1% in those operated on by open repair, as well as female patients and octogenarians. Despite all efforts, differences in mortality remain between countries, especially after open AAA repair. This observation, in combination with the falling number of open repairs per centre can be interpreted as a need to centralise open AAA repair to dedicated centres.

CONFLICT OF INTEREST

None.

FUNDING

None.

REFERENCES

1 Li X, Zhao G, Zhang J, Duan Z, Xin S. Prevalence and trends of the abdominal aortic aneurysms epidemic in general population-a meta-analysis. *PLoS One* 2013;**8**(12):e812060.
2 Schanzer A, Messina L. Two decades of endovascular abdominal aortic aneurysm repair: enormous progress with serious lessons learned. *J Am Heart Assoc* 2012;**1**(3):e000075.
3 Schwarze ML, Shen Y, Hemmerich J, Dale W. Age-related trends in utilization and outcome of open and endovascular repair for abdominal aortic aneurysm in the United States, 2001–2006. *J Vasc Surg* 2009;**50**(4):722–729.e2.
4 Chuter TA, Reilly LM, Faruqi RM, Kerlan RB, Sawhney R, Canto CJ, et al. Endovascular aneurysm repair in high-risk patients. *J Vasc Surg* 2000;**31**(1):122–33.

5 Buth J, Van Marrewijk CJ, Harris PL, Hop WCJ, Riambau V, Laheij RJF. Outcome of endovascular abdominal aortic aneurysm repair in patients with conditions considered unfit for an open procedure: a report on the EUROSTAR experience. *J Vasc Surg* 2002;**35**(2):211—9.

6 Greenhalgh RM. Endovascular aneurysm repair and outcome in patients unfit for open repair of abdominal aortic aneurysm (EVAR trial 2): randomised controlled trial. *Lancet* 2005;**365**(9478):2187—92.

7 Van Walraven C, Wong J, Morant K, Jennings A, Jetty P, Forster AJ. Incidence, follow-up, and outcomes of incidental abdominal aortic aneurysms. *J Vasc Surg* 2010;**52**(2):282—289.e2.

8 Chun KC, Teng KY, Van Spyk EN, Carson JG, Lee ES. Outcomes of an abdominal aortic aneurysm screening program. *J Vasc Surg* 2013;**57**(2):376—81.

9 Moll FL, Powell JT, Fraedrich G, Verzini F, Haulon S, Waltham M, et al. Management of abdominal aortic aneurysms clinical practice guidelines of the European Society for Vascular Surgery. *Eur J Vasc Endovasc Surg* 2011;**41**(S1):S1—58.

10 Beck AW, Sedrakyan A, Mao J, Venermo M, Faizer R, Debus S, et al. Variations in abdominal aortic aneurysm care: a report from the International Consortium of Vascular Registries. *Circulation* 2016;**134**(24):1948—58.

11 Mani K, Lees T, Beiles B, Jensen LP, Venermo M, Simo G, et al. Treatment of abdominal aortic aneurysm in nine countries 2005—2009: a Vascunet report. *Eur J Vasc Endovasc Surg* 2011;**42**(5):598—607.

12 Mani K, Venermo M, Beiles B, Menyhei G, Altreuther M, Loftus I, et al. Regional differences in case mix and perioperative outcome after elective abdominal aortic aneurysm repair in the Vascunet database. *Eur J Vasc Endovasc Surg* 2015;**49**(6):646—52.

13 Gibbons C, Björck M, Jensen LP, Laustsen J, Lees T, Moreno-Carriles R, et al. *The second vascular surgery database report*. Brussels: European Society for Vascular Surgery; 2008.

14 Björck M, Gibbons CP, Jensen LP, Laustsen J, Lees T, Moreno-Carriles R, et al. Vascular registries join to create a common international dataset on AAA surgery. *Eur J Vasc Endovasc Surg* 2007;**34**(3):257—9.

15 Vascular Society of Great Britain and Ireland. National Vascular Registry, 2014 Progress Report. London: Vascular Services Quality Improvement Programme. Retrieved March 15, 2017, from https://www.vsqip.org.uk/reports/nvr-progress-report/.

16 Barshes NR, McPhee J, Ozaki CK, Nguyen LL, Menard MT, Gravereaux E, et al. Increasing complexity in the open surgical repair of abdominal aortic aneurysms. *Ann Vasc Surg* 2012;**26**(1):10—7.

17 Dimick JB, Upchurch GR. Measuring and improving the quality of care for abdominal aortic aneurysm surgery. *Circulation* 2008;**117**(19):2534—41.

18 Malas M, Arhuidese I, Qazi U, Black J, Perler B, Freischlag JA. Perioperative mortality following repair of abdominal aortic aneurysms: application of a randomized clinical trial to real-world practice using a validated nationwide data set. *JAMA Surg* 2014;**149**(12):1260—5.

19 Laustsen J, Jensen L, Hansen A. Accuracy of clinical data in a population based vascular registry. *Eur J Vasc Endovasc Surg* 2004;**27**(2):216—9.

20 Bergqvist D, Bjorck M, Lees T, Menyhei G. Validation of the VASCUNET registry — pilot study. *Vasa* 2014;**43**(2):141—4.

21 Venermo M, Lees T. International Vascunet validation of the Swedvasc registry. *Eur J Vasc Endovasc Surg* 2015;**50**:802—8.

22 Björck M, Bown MJ, Choke E, Earnshaw J, Flørenes T, Glover M, et al. International update on screening for abdominal aortic aneurysms: issues and opportunities. *Eur J Vasc Endovasc Surg* 2015;**49**(2):113—5.

23 Jacomelli J, Summers L, Stevenson A, Lees T, Earnshaw JJ. Impact of the first 5 years of a national abdominal aortic aneurysm screening programme. *Br J Surg* 2016;**103**(9):1125—31.

24 Landry G, Lau I, Liem T, Mitchell E, Moneta G. Open abdominal aortic aneurysm repair in the endovascular era: effect of clamp site on outcomes. *Arch Surg* 2009;**144**(9):811—6.

25 Jordan WD, Ouriel K, Mehta M, Varnagy D, Moore WM, Arko FR, et al. Outcome-based anatomic criteria for defining the hostile aortic neck. *J Vasc Surg* 2015;**61**(6):1383—1390.e1.

26 IMPROVE Trial Investigators. The effect of aortic morphology on peri-operative mortality of ruptured abdominal aortic aneurysm. *Eur Heart J* 2015;**36**(21):1328—34.

27 Holt PJ, Poloniecki JD, Gerrard D, Loftus IM, Thompson MM. Meta-analysis and systematic review of the relationship between volume and outcome in abdominal aortic aneurysm surgery. *Br J Surg* 2007;**94**(4):395—403.

28 United Kingdom Small Aneurysm Trial Participants. Long-term outcomes of immediate repair compared with surveillance of small abdominal aortic aneurysms. *N Engl J Med* 2002;**346**(19):1445—52.

29 Lederle FA, Johnson GR, Wilson SE, Chute EP, Hye RJ, Makaroun MS, et al. The aneurysm detection and management study screening program: validation cohort and final results. *Arch Intern Med* 2000;**160**(10):1425—30.

30 Cao P, De Rango P, Verzini F, Parlani G, Romano L, Cieri E. Comparison of surveillance versus aortic endografting for small aneurysm repair (CAESAR): results from a randomised trial. *Eur J Vasc Endovasc Surg* 2011;**41**(1):13—25.

31 Ouriel K, Clair DG, Kent KC, Zarins CK. Endovascular repair compared with surveillance for patients with small abdominal aortic aneurysms. *J Vasc Surg* 2010;**51**(5):1081—7.

32 Karthikesalingam A, Vidal-Diez A, Holt PJ, Loftus IM, Schermerhorn ML, Soden PA, et al. Thresholds for abdominal aortic aneurysm repair in England and the United States. *N Engl J Med* 2016;**375**(21):2051—9.

33 Greenhalgh RM, Brown LC, Powell JT, Thompson SG, Epstein D, Sculpher MJ. Endovascular versus open repair of abdominal aortic aneurysm. *N Engl J Med* 2010;**362**(20):1863—71.

34 Minor ME, Ellozy S, Carroccio A, Oak J, Chae K, Agarwal G, et al. Endovascular aortic aneurysm repair in the octogenarian: is it worthwhile? *Arch Surg* 2004;**139**(3):308—14.

35 Norman PE, Powell JT. Abdominal aortic aneurysm: the prognosis in women is worse than in men. *Circulation* 2007;**115**(22):2865—9.

36 Vavra AK, Kibbe MR. Part one: for the motion. Evidence supports reducing the threshold diameter to 5 cm for elective interventions in women with abdominal aortic aneurysms. *Eur J Vasc Endovasc Surg* 2014;**48**(6):611—4.

37 Manning BJ, Kristmundsson T, Sonesson B, Resch T. Abdominal aortic aneurysm diameter: a comparison of ultrasound measurements with those from standard and three-dimensional computed tomography reconstruction. *J Vasc Surg* 2009;**50**(2):263—8.