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Sex differences in national rates of repair of emergency abdominal aortic aneurysm

A. Aber[1], T. S. Tong[1], J. Chilcott[1], P. Thokala[1], R. Maheswaran[1], S. M. Thomas[2], S. Nawaz[2], S. Walters[1] and J. Michaels[1]

[1]School of Health and Related Research, University of Sheffield, and [2]Sheffield Vascular Institute, Sheffield Teaching Hospitals, Sheffield, UK

Correspondence to: Mr A. Aber, School of Health and Related Research, University of Sheffield, Regent Court, 30 Regent Street, Sheffield, S1 4DA UK (e-mail: a.aber@sheffield.ac.uk)

Background: The aim of this study was to assess the sex differences in both the rate and type of repair for emergency abdominal aortic aneurysm (AAA) in England.

Methods: Hospital Episode Statistics (HES) data sets from April 2002 to February 2015 were obtained. Clinical and administrative codes were used to identify patients who underwent primary emergency definitive repair of ruptured or intact AAA, and patients with a diagnosis of AAA who died in hospital without repair. These three groups included all patients with a primary AAA who presented as an emergency. Sex differences between repair rates and type of surgery (endovascular aneurysm repair (EVAR) *versus* open repair) over time were examined.

Results: In total, 15 717 patients (83.3 per cent men) received emergency surgical intervention for ruptured AAA and 10 276 (81.2 per cent men) for intact AAA; 12 767 (62.0 per cent men) died in hospital without attempted repair. The unadjusted odds ratio for no repair in women *versus* men was 2.88 (95 per cent c.i. 2.75 to 3.02). Women undergoing repair of ruptured AAA were older and had a higher in-hospital mortality rate (50.0 *versus* 41.0 per cent for open repair; 30.9 *versus* 23.5 per cent for EVAR). After adjustment for age, deprivation and co-morbidities, the odds ratio for no repair in women *versus* men was 1.34 (1.28 to 1.40). The in-hospital mortality rate after emergency repair of an intact AAA was also higher among women.

Conclusion: Women who present as an emergency with an AAA are less likely to undergo repair than men. Although some of this can be explained by differences in age and co-morbidities, the differences persist after case-mix adjustment.

+A: Introduction

Abdominal aortic aneurysm (AAA) causes more than 166 000 deaths per year globally[1]. AAA is usually asymptomatic and most deaths are due to emergency symptomatic presentations including life-threatening aneurysm rupture, which is associated with mortality

rates of up to 80 per cent[2–4]. Several developed countries initiated AAA screening programmes for men aged 65 years or over[5–7]. This was because the prevalence of AAA is higher in men[8], and the randomized controlled studies that investigated screening for AAA either did not include women[3,9,10] or were underpowered to examine the benefit of screening in women[11]. Evidence from observational studies[12–17] has demonstrated that, when an AAA is found incidentally, the turn-down rate for elective surgery is significantly higher in woman.

A recent study[18] using the English National Health Service (NHS) administrative data set and UK National Vascular Registry data demonstrated that in-hospital mortality following elective as well as ruptured AAA is worse in women; this confirmed the findings of previous studies[19–22] that used national databases and registries, and demonstrated higher mortality rates following repair of AAA among women. A recent economic evaluation supported by clinical outcome data from an administrative data set and national registry reported that screening women for AAA is not cost-effective under various scenarios, including starting screening at an older age[23].

Considering that women are excluded from screening programmes and face a higher turn-down rate for elective AAA repair, they continue to constitute nearly one-third of patients presenting with ruptured AAA[24,25] and this figure may increase in future.

To investigate the difference in outcomes after emergency presentation with an AAA between men and women it is important to examine beyond repair outcomes, because the first step in the care pathway is assessment by an emergency physician then referral to vascular specialists. The next steps include the decision to offer repair or palliative care, and deciding the type of repair if appropriate.

To determine whether women, compared with men, are being offered comparable management of emergency AAA, both intact and ruptured, in England, the inpatient administrative data set of NHS England was investigated to determine the proportion of each sex not offered repair. Also examined were the differences after emergency repair of an AAA with regard to in-hospital death, duration of hospital stay and critical care stay, and readmission.

+A: Methods

NHS England Hospital Episode Statistics (HES) data were used to identify all patients who had emergency repair of an AAA or died in hospital without repair. HES data for patients with AAA were acquired from April 2002 to February 2015[26]. Inpatient episodes were extracted, sorted chronologically and grouped into admission-level data (Continuous Inpatient Stay)[27] and patient level data (by unique anonymous patient identifier number). The

index admissions were defined as the first AAA repair for emergency intact or ruptured AAA, or the only admission with AAA in which the patient died in hospital with no evidence of repair.

Patients who presented as an emergency with an AAA were divided into three case-mix groups: patients undergoing primary repair for ruptured AAA, or emergency repair for intact AAA, and patients who died in hospital without repair despite presenting with an AAA. These cases were identified by developing algorithms that used a combination of procedure, diagnosis and admission type codes. These algorithms were developed with input from clinicians and data scientists (*Appendix S1* and *Tables S1–S8*, supporting information).

Patients who had repair of a ruptured AAA were identified using a combination of ruptured AAA diagnosis codes (ICD-10)[28] and evidence that they had a definitive repair (OPCS procedure codes)[29]. Patients undergoing emergency repair of an intact infrarenal AAA were identified when the records of the index admission had an emergency admission code[30] and within the same admission had evidence of an infrarenal AAA repair code. The patients who had an emergency AAA presentation and died in hospital with no repair were identified using a combination of AAA diagnosis code and discharge code indicating that the patient died during the admission[31], as well as lack of AAA repair procedure codes within the index or previous admissions. Details of methods used to clean HES data and develop these three case-mix groups were discussed in a previous publication[32].

The primary outcomes of this study were the non-intervention rate for men and women presenting as an emergency with an AAA, and differences between men and women in the type of emergency repair received for intact or ruptured AAA. Secondary outcomes included in-hospital mortality, duration of hospital stay and critical care stay, and 30-day readmission rate after emergency repair of an intact or ruptured AAA by operation type (endovascular aneurysm repair (EVAR) *versus* open repair). This study is reported in compliance with the RECORD statement[33].

+B: Statistical analysis

The yearly trends in non-intervention for emergency AAA and intervention by type of repair (EVAR *versus* open) for ruptured and intact AAA were calculated for each sex. The unadjusted and adjusted odds ratios (ORs) for no intervention for emergency AAA, and for in-hospital death after emergency repair of ruptured and intact AAA, among women *versus* men were calculated. For the adjusted OR, variables that might have confounded the differences between sexes were accounted for, including age, year of presentation, deprivation and co-morbidities using a modified version of Charlson co-morbidity categories

(*Appendix S1* and *Tables S91–S11*, supporting information). These variables were included based on the data available in HES and recommendations by a consensus group of clinicians.

Outcomes such as in-hospital mortality, duration of hospital stay and critical care stay, reoperation during the index admission, and 30-day readmission rate were calculated for each sex and type of procedure (EVAR *versus* open) and indication (emergency repair of ruptured *versus* intact AAA). Mann–Whitney–Wilcoxon and χ^2 tests were used to test for significance in differences between the sexes; $P < 0.050$ was considered significant. R version 3.4.1 (R Foundation for Statistical Computing, Vienna, Austria) was used for statistical analyses.

+A: Results

A total of 38 760 patients were admitted as an emergency with an AAA between April 2002 and February 2015. The mean age of these patients was 76.42 years and women represented 24.3 per cent of the total. Some 12 767 patients (32.9 per cent of all emergency presentations) died in hospital without repair; the mean age was 82.11 years and women represented 38.0 per cent of the patients who died with no repair for emergency AAA.

In total, 25 993 patients underwent emergency repair of an acute AAA and women constituted 17.5 per cent; during the study interval, 15 717 had repair of a ruptured AAA and 10 276 underwent emergency repair of an intact AAA; 9.8 per cent of the patients with a ruptured AAA received EVAR compared with 24.1 per cent of those with an intact AAA. Trends over time in EVAR and open emergency repair of intact and ruptured AAA are shown in *Figs S1* and *S2* (supporting information). The mean age of patients treated with EVAR was higher than that of patients who had open repair (*Fig. 1*).

+B: Sex differences in the rates of no repair

Some 51.5 per cent of women compared with 27.0 per cent of men died in hospital without repair (*Fig. 2*). Despite a trend towards an overall reduction of in-hospital deaths with no repair over time, the sex differences persisted (*Fig. 3*).

In total, 4849 women (mean(s.d.) age 80.08(9.05) years) and 7918 men (aged 75.25(9.26) years) died in hospital and had no repair for an emergency AAA. The odds of no intervention and subsequent death was 1.06 in women and 0.37 for men. The unadjusted OR for no intervention in women *versus* men was 2.88. After adjusting for age, year of presentation, deprivation level and 15 medical co-morbidities, the OR was 1.34 (95 per cent c.i. 1.28 to 1.40) (*Table 1*).

+B: Sex differences in outcomes after repair of ruptured aneurysm

During the study interval, 130 89 men and 2628 women underwent repair of a ruptured AAA (*Fig. 1*); the proportion who had EVAR for ruptured AAA was 9.9 per cent among men and

9.5 per cent in women. Repair rates for ruptured AAA declined from 2002 to 2015 in men, whereas the trends remained almost unchanged for women (*Fig. 4a*). In-hospital mortality rates after repair of ruptured AAA remained higher among women compared with men (*Fig. 4b*).

Among the 14 174 patients who underwent open repair of a ruptured AAA, women were older (mean age 77.05 *versus* 73.63 years), and also had a significantly higher in-hospital mortality rate (50.0 *versus* 41.0 per cent) and shorter hospital stay (median 11 (i.q.r. 2–26) *versus* 12 (4–25) days). Women had a shorter stay in critical care and higher 30-day readmission rate, but the difference was not statistically significant.

A total of 1543 patients had EVAR for ruptured AAA; the women were older and had a significantly higher in-hospital mortality rate (30.9 *versus* 23.5 per cent). Women also had a longer hospital stay (median 10 (5–22) *versus* 8 (4–19) days), and similar critical care stay and 30-day readmission rates, compared with men; however, none of these was statistically significant (*Table 2*).

+B: Sex differences in outcomes after emergency repair of intact aneurysm

Among 10 276 patients who underwent emergency repair of an intact AAA between 2002 and 2015 (*Fig. 1*), most were men. However, the in-hospital mortality rate was higher among women over the same interval. Overall, 7799 patients underwent open repair; women who had this type of repair were significantly older (mean age 73.22 *versus* 70.97 years), had a longer hospital stay (median 13 (8–24) *versus* 11(7–19) days) and higher in-hospital mortality rate (18.1 *versus* 15.4 per cent). The median duration of critical care stay was also shorter for women (*Table 2*).

In total, 2477 patients had emergency EVAR of an intact AAA; the mean age of the women at the time of EVAR was slightly higher than that of men (76.37 *versus* 75.15 years). The median hospital stay was 7 (4–16) days for women *versus* 6 (3–11) days for men. Furthermore, the mean critical care stay was longer among women (2.49 *versus* 1.57 days). The in-hospital mortality rate was higher (7.8 *versus* 5.8 per cent) and the 30-day readmission rate was also significantly higher (29.6 *versus* 22.4 per cent) among women (*Table 2*).

+A: Discussion

In this nationwide evaluation of the sex differences in outcomes among patients presenting as an emergency with an AAA, more than half of the women died in hospital with no repair. To explain the significant difference in rate of no repair between men and women, a case-mix adjusted (logistic regression) model was used to adjust for age, year of presentation, 15 different medical co-morbidities and deprivation level. The higher no-repair rate among

women persisted even after adjusting for these factors. This is an important finding that warrants further investigation to improve outcomes in women with an acute AAA to provide equity in outcomes between the sexes.

The contemporary real-world data on outcomes following emergency EVAR and open repair of ruptured and intact AAA in this study support existing evidence[4,18,19,24,25,34] that EVAR is associated with reduced in-hospital mortality. However, it should be noted that women even had higher rates of postoperative in-hospital mortality following EVAR compared with men. Unlike previous studies[4,24,25,34–36], the present report examines outcomes beyond in-hospital mortality such as hospital and critical care stay, and 30-day readmission rates among patients surviving the operation. Women who survived the index operation had a longer hospital stay except after open repair of ruptured AAA, partly owing to higher mortality compared with men surviving the same type of operation. Thirty-day readmission rates were higher following emergency EVAR of intact AAA. Women had a shorter critical care stay after repair, except for emergency EVAR of intact AAA.

Previous studies[35,36] from over a decade ago examined sex differences in outcomes of emergency AAA, including no repair, using regional data sets or samples of national data. Dueck and colleagues[35] reported that between 1992 and 2001 in Ontario, 80 per cent of men underwent repair for ruptured AAA compared with 58 per cent of women, and that sex had a greater effect on the likelihood of repair than age. McPhee and co-workers[36] reported a similar trend between 2001 and 2004 in the USA, where only 59 per cent of women underwent repair compared with 70 per cent of men presenting with a ruptured AAA. These historical studies from two different countries confirm the high no-repair rates among women and that this problem is not specific to England. The present study attempted to explain the high rates by adjusting for age, year of presentation, deprivation and co-morbidities; yet despite the adjustment, the turn-down rates remained high in women presenting as an emergency with an AAA.

This study included patients who presented as an emergency with an AAA and died in hospital without a procedure. This was important to provide a comprehensive evaluation of sex differences. The results do depend on the accuracy of diagnosis, referral to a hospital with a vascular unit, as well as the decision to offer repair.

Potential limitations of this study are the accuracy and depth of detail of coded data available in HES, and that there may be some relevant case-mix factors that were not available for correction. The UK National Vascular Registry can provide a richer source of clinical data for such investigations, but currently does not collect data on patients who are

turned down for AAA surgery. Another limitation of any large administrative data set is lack of imaging or autopsy evidence; this could not be corrected for owing to the nature of the data used.

It is difficult to suggest specific reasons for lower repair rates in women; further studies are needed to explore this issue. Evidence from studies that examined non-intervention decisions for elective AAA suggest that women not offered elective repair either had unfavourable anatomy for EVAR or suffered from severe co-morbidities that increased their risk of death after open repair[12–17]. In the same interval, vascular services underwent a quality improvement programme in the UK with a focus on improving elective AAA outcomes and reducing the in-hospital mortality rate to less than 3 per cent[37]. Women are currently not excluded in screening programmes, so it seems likely that they will represent an increasing proportion of patients presenting with symptomatic or ruptured AAA. Future AAA service improvements should aim to improve outcomes for women, particularly when they present as an emergency.

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Disclosure: The authors declare no conflict of interest.

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Supporting information
Additional supporting information can be found online in the Supporting Information section at the end of the article.

Typesetter: please refer to marked-up figures

Fig. 1 Outcome of patients presenting as an emergency with an abdominal aortic aneurysm (AAA). Mean(s.d.) age is shown. EVAR, endovascular aneurysm repair

Fig. 2 Repair rates for emergency abdominal aortic aneurysm in **a** women and **b** men admitted as an emergency, 2002–2015

Fig. 3 Sex-specific trends over time for in-hospital death after emergency admission with an abdominal aortic aneurysm (AAA) where patients had no repair. Values are percentage of all emergency AAA admissions

Fig. 4 Trends over time by sex: **a** emergency repair of intact abdominal aortic aneurysm (AAA), **b** in-hospital mortality after emergency repair of intact AAA, **c** incidence of ruptured AAA repair and **d** in-hospital mortality after repair of ruptured AAA

Table 1 Unadjusted and adjusted odds ratios for non-intervention after emergency admission with an abdominal aortic aneurysm

	No intervention and subsequent death	Operation*	Odds	Unadjusted odd ratio	Adjusted odds†	Adjusted odds radio†
Women	4849	4558	1.06	2.88 (2.75, 3.02)	0.60	1.34 (1.28, 1.40)
Men	7918	21 435	0.37	1.00 (reference)	0.45	1.00 (reference)

Values in parentheses are 95 per cent confidence intervals. *Patients undergoing either repair of ruptured abdominal aortic aneurysm (AAA) or emergency repair of intact AAA. †??

Table 2 Characteristics and outcomes of open and endovascular repair of ruptured abdominal aortic aneursym (AAA) and emergency repair of intact AAA

	Open repair of ruptured AAA		EVAR of ruptured AAA		Emergency open repair of intact AAA		Emergency EVAR of intact AAA	
	Women (n = 2379)	Men (n = 11 795)	Women (n = 249)	Men (n = 1294)	Women (n = 1531)	Men (n = 6268)	Women (n = 399)	Men (n = 2078)
Age (years)*	77.05(6.90)	73.63(7.76)	79.18(7.54)	76.37(7.86)	73.22(10.73)	70.97(9.88)	76.37(9.92)	75.1(8.81)
P§	< 0.001		< 0.001		< 0.001		< 0.001	
Duration of hospital stay (days)†	11 (2–26)	12 (4–25)	10 (5–22)	8 (4–19)	13 (8–24)	11 (7–19)	7 (4–16)	6 (3–11)
P§	0.002		0.060		0.010		< 0.001	
In-hospital death (%)	50.0	41.0	30.9	23.5	18.1	15.4	7.8	5.8
P¶	< 0.001		0.013		0.010		0.127	
Readmission within 30 days (% of survivors)	15.0	13.8	22.1	22.3	16.3	16.0	29.6	22.4
P¶	0.290		0.9475		0.784		0.003	
Duration of critical care stay (days)†‡	3 (0–7)	2 (0–7)	2 (2–4)	2 (0–4)	2 (0–5)	2 (0–5)	0 (0–2)	0 (0–2)
n	1113	5262	219	1143	568	2528	345	1792
P§	0.967		0.764		0.041		0.573	

Values are *mean(s.d.) and †median (i.q.r.). ‡Data available only from 2008–2009. EVAR, endovascular aneurysm repair. §Mann–Whitney–Wilcoxon test; ¶χ^2 test.