Mortality from ruptured abdominal aortic aneurysms: clinical lessons from a comparison of outcomes in England and the USA

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Summary

Background **The outcome of patients with ruptured abdominal aortic aneurysm (rAAA) varies by country. Study of practice differences might allow the formulation of pathways to improve care.**

Methods **We compared data from the Hospital Episode Statistics for England and the Nationwide Inpatient Sample for the USA for patients admitted to hospital with rAAA from 2005 to 2010. Primary outcomes were in-hospital mortality, mortality after intervention, and decision to follow non-corrective treatment. In-hospital mortality and the rate of non-corrective treatment were analysed by binary logistic regression for each health-care system, after adjustment for age, sex, year, and Charlson comorbidity index.**

Findings **The study included 11 799 patients with rAAA in England and 23 838 patients with rAAA in the USA. In-hospital mortality was lower in the USA than in England (53·05% [95% CI 51·26–54·85] *vs* 65·90%; p<0·0001). Intervention (open or endovascular repair) was offered to a greater proportion of cases in the USA than in England (19 174 [80·43%] *vs* 6897 [58·45%]; p<0·0001) and endovascular repair was more common in the USA than in England (4003 [20·88%] *vs* 589 [8·54%]; p<0·0001). Postintervention mortality was similar in both countries (41·77% for England and 41·65% for USA). These observations persisted in age-matched and sex-matched comparisons. In both countries, reduced mortality was associated with increased use of endovascular repair, increased hospital caseload (volume) for rAAA, high hospital bed capacity, hospitals with teaching status, and admission on a weekday.**

Interpretation **In-hospital survival from rAAA, intervention rates, and uptake of endovascular repair are lower in England than in the USA. In England and the USA, the lowest mortality for rAAA was seen in teaching hospitals with larger bed capacities and doing a greater proportion of cases with endovascular repair. These common factors suggest strategies for improving outcomes for patients with rAAA.**

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Introduction

The rupture of an abdominal aortic aneurysm (rAAA) is frequently fatal and accounts for the death of at least 45 individuals per 100 000 population.[1] Surgical intervention is associated with high mortality, and the evidence to suggest improvement in outcome with time is inconsistent.[2–5] In both the USA and England, evidence suggests interhospital variation in the mortality of patients admitted to hospital with rAAA. The outcome of patients with rAAA also varies between countries, with different outcomes published for health-care systems in the USA, the UK, western Europe, and Australia.[6–8]

Modifiable technical, organisational, or hospital-related factors play an important part in patient care, and merit further study to optimise service delivery and improve patient outcomes. A detailed study to compare international outcomes for rAAA would place data from an individual health-care system in a broad context, and might allow the identification of factors that affect survival or the formulation of pathways to improve care.

We present the outcomes of patients with rAAA in England and the USA, with comparison of in-hospital mortality, the proportion of patients managed by non-corrective treatment, and the availability of endovascular surgery.

Methods

Study design

Demographic and in-hospital outcome data were extracted from Hospital Episode Statistics (HES) and the Nationwide Inpatient Sample (NIS) for all patients diagnosed with rAAA between Jan 1, 2005, and Dec 31, 2010. The HES are the administrative dataset for the English National Health Service (NHS) and contain information about every admission of a patient to hospital. The NIS from the Healthcare Cost and Utilisation Project, Agency for Healthcare Research and Quality, is an anonymised, stratified sample of 20% of all discharges from US hospitals, and is the largest all-payer database of hospital admissions for US health care.

The inclusion criteria comprised patients with a diagnosed rAAA, defined by International Classification of Diseases (ICD) 10 codes in HES and ICD9-CM codes in NIS data (appendix). Endovascular repairs for rAAA (rEVAR) and open repairs for rAAA were identified

See **Online** for appendix

according to previously published methods for the HES, and as listed in the appendix for the NIS.[7,9–11]

Outcomes

The primary outcome measures were in-hospital mortality, mortality after intervention (open or endovascular repair), and the decision to follow non-corrective treatment for rAAA. Non-corrective treatment was defined as the patient having a diagnostic code for rAAA but no procedural code for open surgical or endovascular rAAA repair. Secondary outcome measures comprised; the proportion of operated cases managed by rEVAR, length of stay, discharge destination, and the proportion of cases managed in teaching hospitals or hospitals of varying bed capacity.

For more on the **HCUP Nationwide Inpatient Sample (NIS), 2010** see http://www.hcup-us.ahrq.gov/db/nation/nis/NIS_Introduction_2010.jsp

For more on the **NHS bed capacity datasets** see http://www.england.nhs.uk/statistics/statistical-work-areas/bed-availability-and-occupancy/bed-data-overnight/

Data extraction

Patient-level and hospital-level factors were extracted to enable comparable risk adjustment in both the HES and NIS data. These factors included age, sex, hospital, and year of admission. Pre-existing comorbidity was defined separately for the USA and England with techniques validated independently for each country—with the Charlson Index for the NIS and the Royal College of Surgeon's modified Charlson Index for HES.[12,13] Because of systematic differences in coding policies between the USA and England, risk adjustment for comorbidity was used only for within-country analysis rather than for comparative analysis between countries. Hospital factors included bed capacity, teaching status, and institutional annual volume (caseload) for rAAA. Hospital teaching status and bed capacity were defined according to standard NIS documentation. English hospital bed capacity was obtained from publically available NHS datasets. English NHS hospitals were classified as teaching hospitals if they had a direct and specific link with a member of the Medical School Council in England.[14] Institutional volume (caseload) for rAAA was represented as quintiles.

Statistical analysis

Primary and secondary outcomes were modelled separately for the HES and NIS data, with binary logistic regression with risk-adjustment for age, sex, social deprivation, and comorbidity index. Stepwise selection procedures were used with comparison of models by Akaike's information criterion to ascertain whether

	England	USA (95% CI)	p value
Patients (n)	11 799	23 838	..
Patients undergoing intervention (rEVAR or open repair); n, %	6897 (58·45%)	19 174 (80·43%; 78·99–81·88)	<0·0001
Patents undergoing rEVAR (%)	569 (8·54%)	4003 (20·88%; 18·59–23·16)	<0·0001
Open repair (%)	6308 (91·46%)	15 171 (79·12%; 76·84–81·41)	<0·0001
In-hospital mortality (%)	65·90%	53·05% (51·26–54·85)	<0·0001
Post-intervention mortality (rEVAR and open repair, %)	41·77%	41·65% (39·93–43·39)	0·88
rEVAR mortality (%)	31·58%	26·84% (23·72–29·95)	0·0176
Open repair mortality	42·72%	45·57% (43·6–47·54)	0·0001
Length of stay			
Overall	4 (1–14)	4·6 (0·30–12·19)	..
Died in hospital	1 (0–4)	0·44 (0–2·30)	..
Survivors	16 (10–28)	10·6 (6·32–18·80)	..
Discharge destination			
Discharged to usual place of residence (%)	79·99%	33·70% (31·42–35·98)	<0·0001
Discharged to another health-care provider (%)	19·17%	66·14% (63·87–68·42)	<0·0001
Teaching status			
Teaching hospitals (%)	15·14%	17·35% (16·68–18·01)	0·50
rAAA treated in teaching hospital (%)	29·29%	51·53% (48·32–54·76)	<0·0001

95% CIs are provided for the USA because the Nationwide Inpatient Sample (NIS) data are a weighted sample, and therefore provide national estimates with quantifiable precision. The variance in NIS estimates was calculated according to recommended methods of the Healthcare Cost and Utilisation Project.[15] Hospital Episode Statistics data for England are not derived from a sample. They represent 100% of hospital episodes for rAAA during the study period, and therefore no CIs are provided. rEVAR=endovascular repairs for ruptured abdominal aortic aneurysm. rAAA=ruptured abdominal aortic aneurysm.

Table 1: **Primary and secondary outcomes after ruptured abdominal aortic aneurysm in England and the USA**

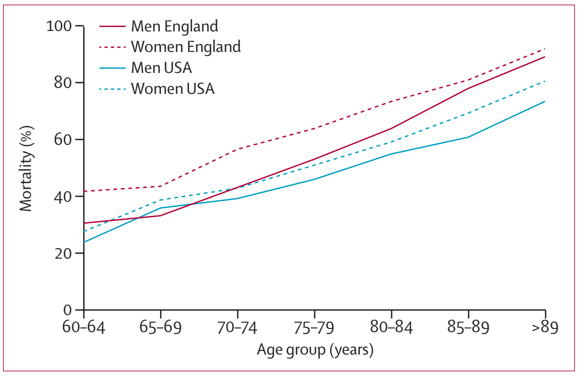

Figure 1: **In-hospital mortality for ruptured abdominal aortic aneurysm after stratified matching for sex and 5-year age grouping**
Comparison was done by logistic regression analysis, incorporating strata as a blocking variable. Odds ratio for adjusted in-hospital mortality in England versus the USA 1·473, 95% CI 1·376–1·576, p<0·0001.

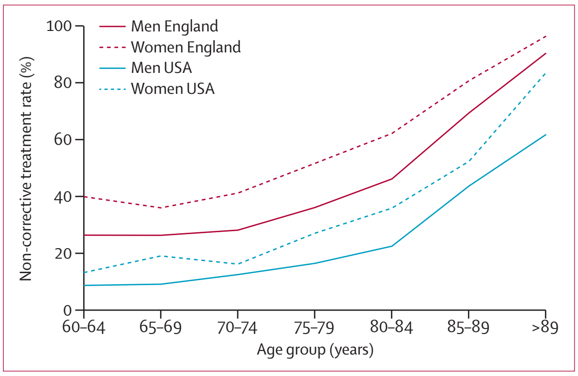

Figure 2: **Non-corrective treatment for ruptured abdominal aortic aneurysm after stratified matching for sex and 5-year age grouping**
Comparison was done by logistic regression analysis, incorporating strata as a blocking variable. Odds ratio for adjusted non-corrective treatment rate in England versus the USA 3·193, 95% CI 2·951–3·455, p<0·0001.

individual covariates improved goodness-of-fit for prediction of in-hospital mortality and non-corrective treatment. The selection process was based on models that included all potential predictor variables without univariate preselection, followed by stepwise selection. Covariates that were integral to the weighting of the NIS were retained in all models, including year of surgery, hospital control, hospital bed size, and region or teaching status. Covariates considered for modelling included age, sex, social deprivation, comorbidity index, hospital procedural volume (caseload), hospital bed capacity and teaching status, geographical region, year of surgery, interhospital transfer status, and admission on a weekend versus a weekday. Inclusion in the model required a significance level of α=0·1, and significant results were reported at α=0·05.

Age-matched and sex-matched analyses were constructed to compare English and US outcomes for in-hospital mortality and the decision to offer non-corrective treatment. HES and NIS datasets were linked with common variables, and strata were created after matching patients for sex and 5-year age groups. A conditional logistic regression analysis was done incorporating the strata as a blocking variable to report the adjusted difference in non-corrective treatment rates or in-hospital mortality between England and the USA. All analyses were done with SAS (version 9.3) and STATA (version 12.0).

Role of the funding source

There was no funding for this study. All authors had access to the study data throughout and were responsible for the decision to submit the manuscript.

Results

11799 patients in England and 23 838 patients in the USA were admitted to hospital with a rAAA during the study period. In England, the mean age was 78·2 years (SD 8·0) and 8694 patients (73·7%) were men. In the USA, the mean age was 76·6 years (SD 9·6) and 17 020 (71·4%) of patients were men. The appendix shows the full demographic details of patient characteristics.

In-hospital mortality was lower in the USA than in England (table 1). Intervention (rEVAR or open surgery) was offered to a greater proportion of cases in the USA than in England and endovascular repair was more common in the USA than in England (table 1). Of patients who underwent intervention, mortality was similar in both countries (table 1). Mortality from endovascular repair was consistently lower than that for open surgery, but comparative mortality after rEVAR was lower in the USA than in England (26·84% *vs* 31·58%; p=0·0176). A comparison of age-matched and sex-matched strata showed that overall in-hospital mortality (odds ratio [OR] 1·473, 95% CI 1·376–1·576, p<0·0001; figure 1) and rate of non-corrective treatment (3·193, 2·951–3·455, p<0·0001; figure 2) were significantly greater in England than in the USA.

The median length of stay of survivors of rAAA was longer in England than in the USA (table 1). English patients were more commonly discharged to their usual place of residence than were US patients (79·99% *vs* 33·70%; p<0·0001), whereas US patients were more commonly discharged to an alternative health-care provider (table 1)—2285 (24·02%) of 9512 patients were discharged to a skilled nursing facility in the USA. The discrepancy in discharge destinations provides important context for this study's comparison of in-hospital mortality.

Although a similar proportion of hospitals were described as teaching institutions in both countries, a greater proportion of rAAA in the USA were treated at teaching institutions than in England (table 1). Compared with non-teaching institutions, mortality, and non-corrective treatment rate was lower at teaching institutions in both countries (table 2), while EVAR was more prevalent in teaching institutions than in non-teaching institutions (table 2). In both countries,

	England			USA		
	Teaching hospitals	Non-teaching hospitals	p value	Teaching hospitals (95% CI)	Non-teaching hospitals (95% CI)	p value
All mortality (intervention and non-corrective treatment; %)	56·04%	69·99%	<0·0001	48·43% (45·89–50·98)	58·05% (55·74– 60·37)	<0·0001
Mortality after intervention (rEVAR or open repair; %)	35·99%	44·8%	<0·0001	39·43% (37·1– 41·77)	44·35% (41·88–46·83)	<0·0001
Interventions done by rEVAR (%)	13·12%	6·14%	<0·0001	25·35% (21·92–28·78)	15·54% (12·96–18·12)	<0·0001
Non-corrective treatment rate (% of all cases that did not undergo intervention)	31·32%	45·63%	<0·0001	14·93% (13·07–16·79)	24·62% (22·55–26·73)	<0·0001
Mortality after rEVAR (%)	28·62%	34·89%	0·11	25·19% (21·53–28·84)	30·54% (24·48–36·6)	<0·0001
Mortality after open repair (%)	37·11%	45·45%	<0·0001	44·27% (41·42–47·12)	46·89% (44·22–49·56)	<0·0001

95% CIs are provided for the USA because the Nationwide Inpatient Sample (NIS) data are a weighted sample, and therefore provide national estimates with quantifiable precision. The variance in NIS estimates was calculated according to recommended methods of the Healthcare Cost and Utilisation Project.[15] Hospital Episode Statistics data for England are not derived from a sample. They represent 100% of hospital episodes for rAAA during the study period, and therefore no CIs are provided. rEVAR=endovascular repairs for ruptured abdominal aortic aneurysm. rAAA=ruptured abdominal aortic aneurysm.

Table 2: **Comparison of outcomes in teaching and non-teaching hospitals in England and the USA**

	England			USA		
	Low bed capacity	Middle bed capacity	High bed capacity	Low bed capacity (95% CI)	Middle bed capacity (95% CI)	High bed capacity (95% CI)
All mortality (intervention and non-corrective treatment; %)	82·56%	68·64%	61·89%	75·86% (73·31– 78·42)	51·33% (48·38– 54·27)	43·82% (41·53– 46·1)
Mortality after intervention (rEVAR or open repair; %)	46·32%	44·65%	40·18%	50·64% (46·25–55·03)	44% (40·96–47·06)	38·32% (36·12–40·53)
Interventions done by rEVAR (%)	9·21%	7·03%	9·12%	16·27%	17·43%	23·73%
Non-corrective treatment rate (% of all cases that did not undergo intervention)	67·52%	43·34%	36·29%	51·29% (48·49–54·09)	13·07% (11·15–15%)	8·91% (7·67–10·14%)
Mortality after rEVAR (%)	25·71%	36·76%	30·38%	34·45% (24·43–44·48)	29·77% (23·09–36·47)	24·49% (20·7–28·28)
Mortality after open repair (%)	48·41%	45·25%	41·16%	53·79% (49·06–58·51)	47·01% (43·69–50·34)	42·63% (39·97–45·29)

95% CIs are provided for the USA because the NIS data are a weighted sample, and therefore provide estimates with quantifiable precision. The variance in NIS national estimates was calculated according to recommended methodology of the Healthcare Cost and Utilisation Project.[15] Hospital Episode Statistics data for England are not derived from a sample. They represent 100% of hospital episodes for rAAA during the study period, and therefore no CIs are provided. rEVAR=endovascular repairs for ruptured abdominal aortic aneurysm. rAAA=ruptured abdominal aortic aneurysm.

Table 3: **Comparison of outcomes in low, middle, and high bed capacity hospitals in England and the USA**

mortality and non-corrective treatment rates were better in hospitals with the highest bed capacity (table 3), in patients who were transferred from the presenting hospital (appendix), and in patients treated on a weekday rather than a weekend (appendix).

After adjustment for age, sex, comorbidity, year, and hospital size or caseload, predictors of mortality in England included admission on a weekend rather than a weekday (OR 1·144, 95% CI 1·037–1·263, p=0·0072), interhospital transfer rather than treatment in the presenting hospital (0·646, 95% CI 0·563–0·739, p<0·0001), and treatment outside a teaching institution (1·462, 95% CI 1·310–1·631, p<0·0001; appendix). In the USA, predictors of mortality included admission on a weekend (OR 1·156, 95% CI 1·005–1·337, p=0·0432) and treatment outside a teaching institution (1·272, 95% CI 1·037–1·560, p=0·0238). After risk adjustment in England, non-corrective treatment was more likely in patients admitted at a weekend than on a weekday (OR 1·274, 95% CI 1·154–1·407, p<0·0001), or treated at non-teaching institutions than teaching institutions (1·459, 1·301–1·636, p<0·0001). Non-corrective treatment was less likely after interhospital transfer in both England (OR 0·431, 95% CI 0·367–0·507, p<0·0001) and the USA (0·637, 0·431–0·943, p=0·0244).

Discussion

The main finding of this study was that the in-hospital mortality of patients with rAAA was significantly lower in the USA than in England. This difference was mainly because US hospitals were less likely to manage rAAA by non-corrective treatment and offered aneurysm repair to a significantly greater proportion of patients. Although operative mortality was similar between countries, patients in the USA were more than twice as likely to be offered rEVAR and were more often managed in a teaching hospital than were patients in England (panel).

The proportion of patients offered intervention (rEVAR or open repair) in the USA greatly differed from that in England, and provides important context for the improvement of English practice.[28,29] Previous studies of Medicare beneficiaries in the USA have reported that 68% of patients with rAAA were offered intervention.[30,31] Although this percentage was lower than the estimate of 80% from our study and other NIS reports, the proportion that was offered intervention in the USA has been consistently reported to be greater than that in England.[6] Postoperative mortality was similar in both countries, suggesting that overall survival from rAAA in England would be improved by offering intervention to a greater proportion of patients, to lower the rate of non-corrective treatment. Published clinical data support this theory, and have shown that an aggressive management strategy with a reduced rate of non-corrective treatment results in decreased overall mortality from rAAA.[32,33]

The data did not allow reporting of 30-day mortality and notably a greater proportion of patients was discharged to a health-care provider in the USA than in England, where most patients were discharged home. The proportion of patients who died after discharge from the primary facility is unknown. Comparisons of in-hospital mortality should therefore be interpreted with caution to acknowledge the risk of confounding by different discharge policies. Further research should also investigate international disparities in 90-day mortality rates, which might mitigate against differences in provision of critical care.[34] However, in view of the stark difference in non-corrective treatment rates, the 13% absolute mortality difference is likely to be entirely explained by deaths in secondary care.

Previous studies have shown that the outcome of rAAA repair is partly determined by patient-level factors including age, sex, and comorbidity.[35–39] Our study adds new insights by showing that common hospital-level factors affected outcomes in both health-care systems. In both countries, in-hospital mortality was more likely in patients treated on a weekend than on a weekday, or in patients treated outside a teaching institution than in a teaching institution.

In both England and the USA, the best outcomes were obtained in hospitals with the highest bed capacity, the greatest annual caseload (volume) of rAAA (appendix), and in hospitals in which the largest proportion of rAAA were managed by rEVAR. These findings add to previous evidence that a volume–outcome relation exists for operative mortality after rAAA in both England and the USA.[40,41] Hospital bed size, teaching status, admission on a weekday, and rAAA caseload might all be regarded as interrelated surrogate markers for the immediacy with which each patient with rAAA had access to the full range of technology and care by a specialist multidisciplinary team.

Previous studies have shown increased mortality associated with weekend admission for a range of emergency conditions in the English NHS.[42,43] The international data presented in this study reinforce these concerns in the English NHS and show that the challenge of provision of high-quality out-of-hours care is widespread and can be demonstrated for rAAA in the USA. The results from our study suggest that service configuration should focus on ensuring that patients with rAAA are treated in a teaching hospital with a high aortic workload, offering both conventional and endovascular repair.

This study shows better outcomes in patients treated by endovascular repair than in those patients treated with open repair in both England and the USA, which is consistent with other studies reporting the outcomes of clinical practice.[33,44] Systematic reviews and previous population studies in both the USA and the UK have also shown that rEVAR was associated with improved outcome compared with open surgery.[7,18,44,45] The strength of population studies is that they report so-called real-world outcomes in non-selected patients. Our data suggest that increasing the proportion of patients with rAAA treated by endovascular methods will improve outcome. In selected patient groups treated under specific protocols for therapy, findings from randomised trials have not shown that rEVAR was associated with improved outcomes in intention-to-treat analyses.[46–48] Nonetheless, the evidence from national outcomes data is in favour of rEVAR, and for many experts the role and interpretation of randomised studies of rEVAR versus open repair remains controversial. Because of the design of our study, the endovascular outcomes could not be adjusted for aortic morphology or haemodynamic status. The use of endovascular repair differed significantly between countries with a three-fold greater use of rEVAR in the USA than in England. About 50% of patients with rAAA are morphologically suitable for rEVAR, yet the use of rEVAR in both countries remained short of this benchmark.[49]

Panel: Research in context

Systematic review

We searched Medline for studies published from Jan 1, 2005, to Dec 23, 2013, which compared mortality or non-corrective treatment for ruptured abdominal aortic aneurysm (rAAA) in the UK or the USA, with unselected administrative data to provide nationally representative information. We used the search terms "ruptured aortic aneurysm", "mortality", and "endovascular" and widened our search to include large international registries. We identified 13 studies with the Medicare dataset and three studies with the Nationwide Inpatient Sample dataset, with mortality rates from 20·0% to 53% after endovascular and open rAAA repair in the USA.[6,16–27] Four studies were reported in the English Hospital Episode Statistics, with mortality from 32·2% to 48·7% after endovascular and open rAAA repair.[7,10,28,29] No studies compared England and the USA. The Vascunet registry reported higher perioperative mortality in the UK (34·2%) than the average of nine western European countries and Australia (31·6%).[5]

Interpretation

As far as we are aware, this study is the first international comparative report of unselected patients with rAAA in England and the USA with use of nationally representative data. Outcomes in England might be improved by reductions in rates of non-corrective treatment and increases in provision of endovascular technology for rAAA. Service configuration should direct rAAA patients to teaching hospitals with a high aortic workload, endovascular capabilities, and proficiency in weekend working.

The limitations of this study relate to the observational nature of the administrative datasets that were analysed. Mortality records in both the HES and NIS datasets have been audited for their accuracy, and this study showed clear evidence that the outcomes of rAAA in England are worse than in the USA.[50,51] In-hospital mortality is higher in England than in the USA, and this difference seems attributable to the lower proportion of patients offered intervention. The uptake of rEVAR is low in England. Common hospital-level factors were associated with mortality from rAAA in both countries and should inform improvements to service configuration.

For the **NIS datasets** see http://www.hcup-us.ahrq.gov/db/nation/nis/nisrelatedreports.jsp

Contributors

AK conceived and designed the study, analysed and interpreted the data, drafted and revised the manuscript, and approved the final version for publication. PJH designed the study, interpreted the data, drafted and revised the manuscript, and approved the final version for publication. AV-D, BAO, JDP, and RJH designed the study, analysed and interpreted the data, revised the manuscript, and approved the final version for publication. MMT conceived and designed the study, analysed and interpreted the data, drafted and revised the manuscript, approved the final version for publication, and was the guarantor of work.

Declaration of interests

We declare that we have no competing interests.

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