Original article

Mortality in high-risk emergency general surgical admissions

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Background: There is increasing evidence of variable standards of care for patients undergoing emergency general surgery in the National Health Service (NHS). The aim of this study was to quantify and explore variability in mortality amongst high-risk emergency general surgery admissions to English NHS hospital Trusts.

Methods: The Hospital Episode Statistics (HES) database was used to identify high-risk emergency general surgery diagnoses (greater than 5 per cent national 30-day mortality rate). Adults admitted to English NHS Trusts with these diagnoses between 2000 and 2009 were included in the study. Thirty-day in-hospital mortality was adjusted for patient and hospital factors. Trusts were grouped into high- and low-mortality outliers, and resource availability was compared between high- and low-mortality outlier institutions.

Results: Some 367 796 patients admitted to 145 hospital Trusts were included in the study; the 30-day mortality rate was 15·6 per cent (institutional range 9·2–18·2 per cent). Fourteen and 24 hospital Trusts were identified as high- and low-mortality outlier institutions respectively. Intensive care and high-dependency bed resources, as well as greater institutional use of computed tomography (CT), were independent predictors of reduced mortality ($P < 0·001$). Low-mortality outlying Trusts had significantly more intensive care beds per 1000 hospital beds (20·8 *versus* 14·0; $P = 0·017$) and made significantly greater use of CT (24·6 *versus* 17·2 scans per bed per year; $P < 0·001$) and ultrasonography (42·5 *versus* 30·2 scans per bed per year; $P < 0·001$).

Conclusion: There is significant variability in mortality risk between hospital Trusts treating high-risk emergency general surgery patients. Equitable access to essential hospital resources may reduce variability in outcomes.

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Introduction

Emergencies make up more than one-third of all general surgical admissions to hospitals in the National Health Service (NHS) in England. In total, emergency general surgery accounted for more than 600 000 admissions in 2011[1]. Mortality in this group of patients is high – approximately eight times that associated with elective surgical admission[2]. Numerous publications, including consensus statements[3–5], National Confidential Enquiry into Patient Outcomes and Deaths (NCEPOD) reports[6,7] and small empirical studies[8–10], have described variable standards of care for emergency general surgery. There is emerging literature on the variability in mortality between institutions in the UK for emergency general surgery[11].

There are some indications that emergency surgical care in the UK could be improved. Recent research has demonstrated that the mortality rate for emergency patients admitted to English NHS hospitals at weekends is approximately 10 per cent higher than that for patients admitted during the week[12], suggesting that improvements in the process of care can be made. In addition, comparison of risk-adjusted outcomes from major general surgery has demonstrated significantly higher mortality in the UK compared with North America[13].

The magnitude of the variability in mortality after emergency general surgery between NHS hospital Trusts and the underlying causes are unclear. Variability in outcome cannot easily be corrected unless the underlying causes are understood. Inconsistency in outcome may be caused by differences in resources between NHS hospital Trusts or by differences in the way these resources are used to treat patients[14].

The aims of this study were to develop a basket of high-risk emergency general surgery diagnoses that could be used to quantify the variation in mortality for high-risk emergency general surgery admissions in England using administrative data, and to explore the organizational differences between high- and low-performing hospitals.

Methods

This research was approved under Section 251 (formerly Section 60) granted by the National Information Governance Board for Health and Social Care (formerly the Patient Information Advisory Group), and approved by the South East London Research Ethics Committee.

High-risk emergency general surgery admissions were identified from the Hospital Episode Statistics (HES) database. The use of HES in emergency surgery has been described previously[15] but, in brief, it comprises an administrative data set of all admissions to NHS hospitals in England. Patient-level data include information on patient characteristics, diagnostic and procedural codes, as well as mortality and length of stay.

Selection of a basket of high-risk emergency general surgery diagnoses

Adult patients with a non-elective admission to hospital, discharged between 1 April 2000 and 31 March 2010, were included in the study. Patients were further selected using the International Classification of Diseases, tenth revision (ICD-10) code assigned to the first diagnostic field of the first episode of each admission. General surgical diagnostic codes were considered to be those codes in the gastrointestinal section of ICD-10 for which the proportion of emergency admissions in the study period treated primarily by a general surgeon exceeded 35 per cent. High-risk diagnoses were defined as those that had a crude mortality rate greater than 5 per cent during the study[16]. Four-digit ICD-10 codes were divided into logical groups and considered as single diagnoses for the purposes of analysis, for example gastric, peptic and duodenal ulcer perforation (*Table S1*, supporting information). Patients admitted to NHS hospital Trusts with fewer than 500 high-risk emergency general surgery admissions over the total study interval were excluded. Office of Population, Censuses and Surveys classification of surgical operations and procedures, fourth revision (OPCS-4) codes were used to identify patients who had one or more intra-abdominal operations during any episode of their hospital stay.

Provider structural data

Detailed information on NHS hospital Trusts' organizational characteristics was obtained from the Department of Health's Performance Data and Statistics website[17]. Annual data were collated and averaged over the study interval for each NHS Trust[18]. Where NHS Trusts merged during the study, the HES data set lists them under the final, merged NHS Trust code. To match this coding, organizational data were summed, or averaged across hospitals where appropriate, in years before the merger. Structural variables were adjusted for NHS Trust size on an annual basis, using Department of Health statistics for acute and general hospital beds. Structural data from this source are publically available only at the NHS Trust level and therefore are representative only of the type of environment in which emergency general surgery patients were treated. At Trusts with multiple hospitals, structural data can reflect only the overall resources available, rather than those used specifically in the management of the emergency general surgery patient. Maternity, learning disability and mental health beds were excluded from this analysis, as were operating theatres used exclusively for day-case surgery.

Statistical analysis

Patient-level data used for risk adjustment were age, sex, diagnostic category, year of admission, co-morbidity, and social deprivation indices. Age was considered in four groups (less than 60, 60–69, 70–79 and 80 or more years). The Charlson co-morbidity index[19], based on secondary diagnosis codes, was used to divide the study population into two groups: patients with a score of 0–2 and those scoring 3 or more. Social deprivation based on postcode was assessed using the Carstairs index[20] and converted into population-weighted quintiles. Both of these indices have been used widely in administrative data sets of this type[21,22].

NHS Trusts were categorized into terciles for each structural predictor, for example number of beds or number of computed tomography (CT) scans performed per bed per year. Patients were categorized according to the tercile their treating hospital fell into, and these tercile values were used as potential predictors of mortality.

Predictors of 30-day in-hospital mortality with a significance of $P \leq 0{\cdot}100$ on unadjusted analysis were applied to a multiple logistic regression model[23]. Comparison of means was conducted using independent-samples t tests.

All statistical analyses were performed using IBM SPSS® version 19 (IBM, Armonk, New York, USA). Probabilities of $P < 0.050$ were considered significant, and NHS hospital Trusts with risk-adjusted mortality greater than two standard deviations from the mean were considered to be outliers for the comparison of organizational variables.

Funnel plots were created using tools available from http://www.erpho.org.uk/topics/tools/funnel.aspx using a normal approximation to the Poisson distribution for control limits. Funnel plots are a graphical method of representing performance data in healthcare[24]. Structural characteristics of high- and low-mortality outlying NHS hospital Trusts (those exceeding, and falling below, the second standard deviation confidence limits) were compared to identify differences that might account for any variability in risk-adjusted mortality.

Results

A total of 367 796 patients from 145 NHS hospital Trusts were included in the study population. Eight groups of diagnoses were considered high risk (*Table 1*) and 30-day in-hospital mortality ranged from 7·4 to 47·4 per cent. The mean age for women was 68·6 years, which was significantly older than that for men (65·2 years; $P < 0.001$) (*Table 1*). Some 37·4 per cent of patients had abdominal operative interventions, and the median duration of hospital stay for survivors was 8 days. The median time to death for patients who died in hospital was 5 days.

Variability in risk-adjusted mortality between NHS hospital Trusts

A logistic regression model was used to identify high- and low-mortality outlying NHS Trusts and to assess the independent contribution of patient-specific variables (regression model 1, *Table 2*). Age and diagnosis were predictors of mortality, and the presence of a Charlson score greater than 2 was significantly associated with increased risk of death (odds ratio (OR) 2·61, 95 per cent confidence interval (c.i.) 2·56 to 2·67; $P < 0.001$). There was an increased risk of death among women (OR 1·22, 1·20 to 1·25; $P < 0.001$) and among patients from areas of social deprivation. There was also a significant reduction in mortality risk between the start and end of the study (*Table 2*).

Risk-adjusted mortality ranged from 9·2 to 18·2 per cent between the best and worst performing NHS hospital Trusts (*Fig. 1*). There were 14 of 145 outlying NHS hospital Trusts with risk-adjusted mortality more than two standard deviations above the mean (high-mortality outliers), and 24 of 145 Trusts with mortality rates greater than two standard deviations below the mean (low-mortality outliers).

Effect of hospital structure on risk-adjusted mortality

Seven organizational variables demonstrated significance of $P \leq 0.100$ on unadjusted regression analyses and were included in a second, extended, risk adjustment model for 30-day in-hospital mortality, in addition to the patient-specific variables used in the initial logistic regression (regression model 2, *Table 2*). Admission to a Trust in the highest tercile for institutional intensive care (OR 0·84, 95 per cent c.i. 0·81 to 0·87; $P < 0.001$) and high-dependency (OR 0·96, 0·93 to 0·99; $P = 0.006$) bed facilities, as well as the highest tercile for CT (OR 0·86, 0·83 to 0·89; $P < 0.001$) were all associated with significantly reduced mortality (*Table 2*). There was also a reduced risk of mortality at NHS Trusts in the tercile with the most high-risk emergency general surgery admissions per institutional bed (OR 0·96, 0·93 to 0·99; $P = 0.016$). Conversely, treatment at NHS Trusts in the highest tercile for bed occupancy

Table 1 ICD-10 diagnostic code groups, demographics and unadjusted outcomes

Diagnostic group	No. of patients	Proportion of men (%)	30-day in-hospital mortality (%)	Length of stay (days)*	28-day readmission (%)	Surgical treatment (%)
Bowel obstruction	158 652	46·1	9·8	6 (3–13)	16·3	26·8
Liver and biliary conditions	49 611	49·7	7·4	8 (5–14)	14·8	5·1
Hernias with obstruction or gangrene	31 156	34·1	8·2	6 (3–12)	10·7	83·1
Peritonitis	28 218	48·8	27·3	9 (4–16)	18·2	25·7
Miscellaneous diagnoses	27 843	46·7	28·0	11 (5–21)	16·3	39·9
Gastrointestinal ulcers	26 050	54·8	21·5	9 (6–17)	8·5	80·9
Perforated diverticulitis	25 500	40·6	18·6	13 (8–23)	13·0	63·4
Bowel ischaemia	20 766	38·8	47·4	13 (7–23)	14·2	52·5
Total	367 796	45·6	15·6	8 (4–15)	14·9	37·4

*Values are median (interquartile range).

Table 2 Risk-adjusted multiple logistic regression models for 30-day in-hospital mortality

		Unadjusted *P*	Regression model 1		Regression model 2	
			Odds ratio	*P*	Odds ratio	*P*
Age (years)	< 60	< 0·001	1·00		1·00	
	60–69		2·91 (2·78, 3·04)	< 0·001	2·89 (2·76, 3·02)	< 0·001
	70–79		5·92 (5·69, 6·16)	< 0·001	5·86 (5·63, 6·09)	< 0·001
	≥ 80		14·77 (14·21, 15·34)	< 0·001	14·60 (14·06, 15·17)	< 0·001
Diagnosis	Liver and biliary conditions	< 0·001	1·00		1·00	
	Hernia with obstruction or gangrene		1·06 (1·00, 1·12)	0·037	1·05 (1·00, 1·11)	0·076
	Bowel obstruction		1·49 (1·43, 1·55)	< 0·001	1·49 (1·43, 1·55)	< 0·001
	Perforated diverticulitis		3·58 (3·41, 3·77)	< 0·001	3·57 (3·40, 3·75)	< 0·001
	Gastrointestinal ulcers		4·87 (4·64, 5·12)	< 0·001	4·87 (4·63, 5·11)	< 0·001
	Miscellaneous diagnoses		6·04 (5·77, 6·32)	< 0·001	6·06 (5·79, 6·35)	< 0·001
	Peritonitis		6·90 (6·59, 7·23)	< 0·001	6·99 (6·67, 7·33)	< 0·001
	Ischaemic bowel		12·44 (11·87, 13·03)	< 0·001	12·50 (11·93, 13·11)	< 0·001
Co-morbidities	Charlson score ≤ 2	< 0·001	1·00		1·00	
	Charlson score > 2		2·61 (2·56, 2·67)	< 0·001	2·61 (2·56, 2·67)	< 0·001
Year of discharge	2009	< 0·001	1·00		1·00	
	2008		1·12 (1·07, 1·17)	< 0·001	1·12 (1·08, 1·18)	< 0·001
	2007		1·19 (1·14, 1·24)	< 0·001	1·19 (1·14, 1·24)	< 0·001
	2006		1·34 (1·28, 1·40)	< 0·001	1·34 (1·29, 1·41)	< 0·001
	2005		1·41 (1·35, 1·47)	< 0·001	1·40 (1·34, 1·47)	< 0·001
	2004		1·54 (1·48, 1·61)	< 0·001	1·54 (1·48, 1·61)	< 0·001
	2003		1·60 (1·53, 1·67)	< 0·001	1·60 (1·53, 1·67)	< 0·001
	2002		1·64 (1·57, 1·71)	< 0·001	1·64 (1·56, 1·71)	< 0·001
	2001		1·68 (1·61, 1·76)	< 0·001	1·68 (1·61, 1·76)	< 0·001
	2000		1·65 (1·58, 1·73)	< 0·001	1·65 (1·58, 1·73)	< 0·001
Social deprivation	Carstairs score 1 (least deprived)	< 0·001	1·00		1·00	
	Carstairs score 2		1·07 (1·03, 1·10)	< 0·001	1·06 (1·03, 1·10)	0·001
	Carstairs score 3		1·12 (1·08, 1·16)	< 0·001	1·12 (1·08, 1·15)	< 0·001
	Carstairs score 4		1·20 (1·16, 1·24)	< 0·001	1·19 (1·15, 1·23)	< 0·001
	Carstairs score 5 (most deprived)		1·22 (1·18, 1·27)	< 0·001	1·23 (1·19, 1·28)	< 0·001
	Carstairs score unassigned		1·52 (1·09, 2·13)	0·018	1·50 (1·07, 2·11)	0·018
Sex	M	< 0·001	1·00		1·00	
	F		1·22 (1·20, 1·25)	< 0·001	1·22 (1·19, 1·25)	< 0·001
Admissions per hospital bed	Lowest tercile (1·7–3·0)	< 0·001			1·00	
	Middle tercile				0·97 (0·94, 1·00)	0·022
	Highest tercile (3·7–5·8)				0·96 (0·93, 0·99)	0·016
Bed occupancy	Lowest tercile (76·9–84·8%)	< 0·001			1·00	
	Middle tercile				0·98 (0·95, 1·01)	0·145
	Highest tercile (88·4–94·8%)				1·06 (1·03, 1·09)	< 0·001
Theatres per 1000 hospital beds	Lowest tercile (8·3–15·7)	< 0·001			1·00	
	Middle tercile				1·01 (0·99, 1·04)	0·344
	Highest tercile (20·5–29·8)				1·10 (1·06, 1·13)	< 0·001
ICU beds per 1000 hospital beds	Lowest tercile (4·9–10·6)	< 0·001			1·00	
	Middle tercile				1·03 (1·00, 1·05)	0·065
	Highest tercile (14·4–53·7)				0·84 (0·81, 0·87)	< 0·001
HDU beds per 1000 hospital beds	Lowest tercile (1·2–8·0)	< 0·001			1·00	
	Middle tercile				0·93 (0·90, 0·95)	< 0·001
	Highest tercile (11·9–32·7)				0·96 (0·93, 0·99)	0·006
CT scans per bed per year	Lowest tercile (8·7–17·6)	< 0·001			1·00	
	Middle tercile				0·98 (0·95, 1·01)	0·185
	Highest tercile (22·4–37·6)				0·86 (0·83, 0·89)	< 0·001
Ultrasound scans per bed per year	Lowest tercile (18·4–31·9)	< 0·001			1·00	
	Middle tercile				1·05 (1·02, 1·08)	< 0·001
	Highest tercile (39·2–67·8)				1·02 (0·99, 1·05)	0·178

Values in parentheses are 95 per cent confidence intervals. Regression model 1 uses patient factors alone and was employed to derive risk-adjusted 30-day in-hospital mortality for National Health Service hospital Trusts as well as identifying high- and low-mortality outlying Trusts. Regression model 2 adds structural data to regression model 1; this model was used to assess the contribution of these structural factors to mortality. ICU, intensive care unit; HDU, high-dependency unit; CT, computed tomography.

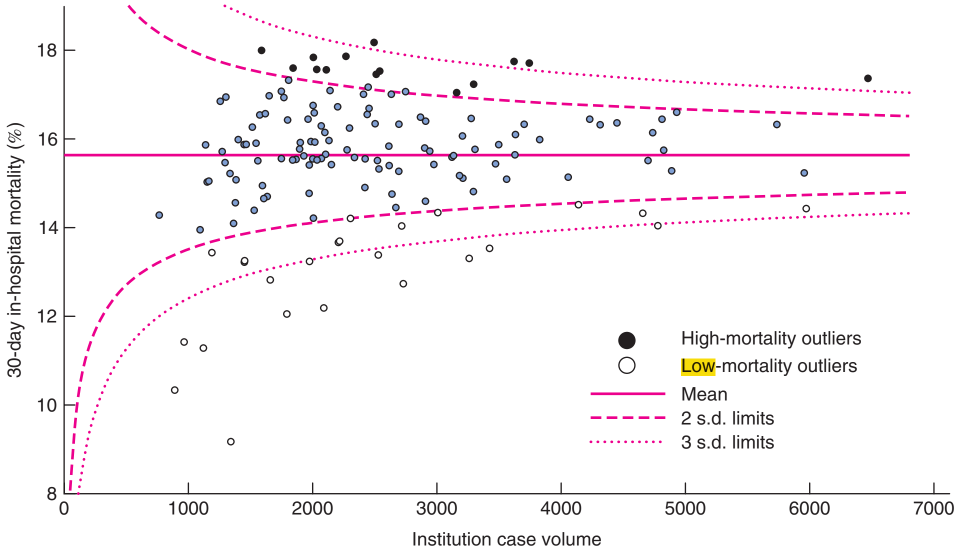

Fig. 1 Funnel plot showing all-cause risk-adjusted in-hospital 30-day mortality for English National Health Service hospital Trusts. Institutions above and below the upper and lower two standard deviation (s.d.) limits represent the respective high- and low-mortality outlying Trusts

Table 3 Organizational differences between high- and low-mortality outlying National Health Service hospital Trusts

	Low-mortality outliers*	High-mortality outliers*	*t*	Mean difference†	*P*‡
Emergency general surgery admissions per Trust bed	3·0(0·2)	3·0(0·2)	−0·33	−0·08 (−0·59, 0·43)	0·745
Bed occupancy (%)	87·1(0·8)	85·9(1·2)	0·85	1·18 (1·63, 3·99)	0·400
Operating theatres per 1000 beds	20·2(1·0)	18·4(1·0)	1·15	1·79 (1·37, 4·95)	0·258
Intensive care beds per 1000 beds	20·8(2·3)	14·0(1·4)	2·51	6·76 (1·30, 12·23)	0·017
High-dependency beds per 1000 beds	13·2(1·8)	13·1(1·8)	0·05	0·13 (−5·36, 5·61)	0·963
CT scans per bed per year	24·6(1·2)	17·2(1·0)	4·26	7·38 (3·87, 10·90)	< 0·001
Ultrasound scans per bed per year	42·5(2·5)	30·2(1·6)	4·16	12·33 (6·31, 18·34)	< 0·001

*Values are mean(s.e.m.); †values in parentheses are 95 per cent confidence intervals. CT, computed tomography. ‡Independent-samples *t* test.

(OR 1·06, 1·03 to 1·09; $P < 0{\cdot}001$) or operating theatres per 1000 hospital beds (OR 1·10, 1·06 to 1·13; $P < 0{\cdot}001$) were independent predictors of mortality (*Table 2*).

Infrastructure differences between high- and low-mortality outlying Trusts

Structural differences between high- and low-mortality outlying Trusts were assessed to investigate the potential underlying causes of the observed variability in risk-adjusted mortality. There was no significant difference in the institutional number of admissions per bed, bed occupancy, number of operating theatres or high-dependency bed resources between high- and low-mortality outlying Trusts (*Table 3*). Low-mortality outlying Trusts had a significantly greater number of intensive care beds per 1000 Trust beds (*Table 3*, *Fig. 2*). In addition, low-mortality outlying Trusts made significantly greater use of CT and ultrasound imaging than high-mortality outlying Trusts (*Table 3*, *Fig. 3*).

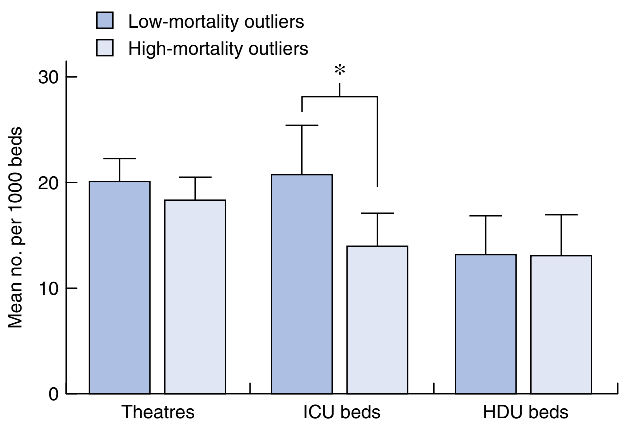

Fig. 2 Hospital operating theatre and critical care provision for high- and low-mortality outlying National Health Service hospital Trusts. Values are mean with 95 per cent confidence intervals. ICU, intensive care unit; HDU, high-dependency unit. $^*P = 0{\cdot}017$ (independent-samples *t* test)

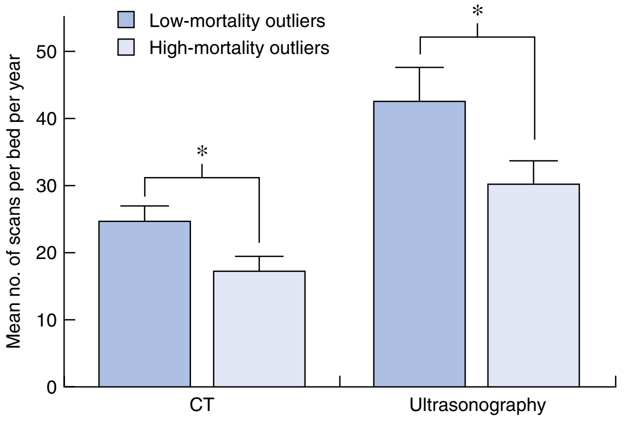

Fig. 3 Use of imaging in high- and low-mortality outlying National Health Service hospital Trusts. Values are mean with 95 per cent confidence intervals. CT, computed tomography. $*P < 0{\cdot}001$ (independent-samples *t* test)

Discussion

This study examined outcome amongst 367 796 high-risk emergency general surgical admissions in England between 2000 and 2009. Risk-adjusted mortality in the worst performing hospital Trust was twice that of the best performer. A significant reduction in mortality risk was observed for Trusts with the most critical care beds and CT usage. Patients treated in NHS Trusts lying within the highest tercile for number of operating theatres and bed occupancy had worse outcomes than those treated in the remaining Trusts. Significant organizational and resource differences exist between high-mortality and low-mortality outlier hospitals.

The study confirms the wide variation in risk-adjusted mortality that exists between English NHS hospital Trusts with emergency general surgery admissions, corroborating previous reports of variability in care[3,5,25]. The significant contribution of structural variables to the risk of death suggests that essential resources, such as critical care and radiology services, may contribute towards standards of emergency surgical care provision. These findings support a plausible hypothesis that better resourced NHS hospital Trusts provide higher quality of care for high-risk emergency general surgery patients.

It is not clear, however, that the total Trust resources available are necessarily reflective of those used to treat emergency general surgery admissions. The data analysed in this study could not report on the availability of dedicated emergency surgical operating theatres. Neither could they distinguish the potential competing resources for critical care beds within Trusts, or identify the proportion of scans performed specifically for emergency general surgery. Caution must be exercised when using overall Trust resource availability as a surrogate for resource availability for high-risk emergency surgical admissions. In addition, other potential quality metrics such as delay before assessment or operation, and surgeon competence were not examined as they are outside the scope of a study using administrative data.

A more detailed investigation of the structure of high- and low-mortality outlying institutions may provide further insights into the causes of the observed variability in outcome. Variability in mortality at individual Trusts before and after changes in infrastructure provision might also shed further light on the way that this affects outcome.

As an administrative data set, HES has the advantage of including all admissions and therefore avoiding issues of selection bias inherent in clinical registries[26]. In addition, selection by diagnosis, rather than limiting the study to patients who undergo an operation, has allowed this study to provide a comprehensive picture of the mortality for all emergency general surgery admissions.

Research using administrative data sets such as HES is reliant on the accuracy of the information that these databases contain. HES has been shown to be reliable for primary diagnostic and procedure codes[27] as well as for 30-day in-hospital mortality[28]. In particular, mortality coding has been shown to be more than 99 per cent accurate[28].

Justification of the diagnostic codes included within this study is merited. A mortality rate higher than 5 per cent has been proposed as a cut-off in previous publications[5,16]. The bundle of diagnostic codes used in this study reflects high-risk emergency general surgery admissions that are likely to include many of the sickest patients admitted to NHS hospitals. These patients require rapid, high-quality care and, as such, provide a suitable population for the investigation of outcomes. Notable exceptions to the diagnostic bundle include acute pancreatitis (mortality rate 4·4 per cent) and acute appendicitis (mortality rate 0·5 per cent), based on HES data for the same years.

There was a significant decrease in mortality over the course of this study, which is not satisfactorily explained by the data. The proportion of patients undergoing intra-abdominal operations fell over the decade, and this may reflect better and wider use of imaging to prevent unnecessary surgery. In addition, there were significant improvements in perioperative care. The number of admissions in the study cohort increased year by year, which may have resulted in less unwell patients being included in later years of the study cohort.

A number of NHS hospital Trusts underwent reconfiguration or merger during the study and this may have resulted in varying outcomes after these changes.

Structural variables such as critical care provision and use of imaging were calculated annually and averaged over the study interval to account for organizational change, but this data set cannot account for changes in the process of care as a result of reconfiguration.

Structural data for NHS Trusts are available only per Trust. Although the overall resources in a hospital are likely to reflect the facilities available, there is no way to differentiate between, for example, acute and elective hospital sites within the same NHS Trust. As an administrative database, HES does not contain information about patient physiology or severity of disease on presentation, and this potentially makes risk adjustment insensitive.

Provision of high-quality care in emergency general surgery services involves ensuring adequate access to hospital resources that are required in the management of critically unwell patients. The high mortality rate and inconsistency in the quality of care should make emergency general surgery an attractive target for quality improvement because the potential gains are far greater than those in many other areas of healthcare. Improving national standards in emergency general surgery demands that essential hospital resources are optimized at institutions offering these services.

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Supporting information

Additional supporting information may be found in the online version of this article:

Table S1 Included diagnostic codes and inclusion criteria (Word document)

Editor's commentary

These authors and their colleagues have produced a number of recent articles using administrative data to expose variations in outcomes across English hospitals. They have shown previously that mortality from elective procedures increases towards the end of the week; their work is used as evidence to move the National Health Service towards 7-day working. The present study compares variations in outcomes with hospital facilities. Their data were anonymized, but in the same week that individual surgeon outcomes data are reported openly in the UK, it could be argued for the sake of transparency, that in future, similar information should be made available and used to improve standards in English hospitals.

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Editor, BJS