BJA

British Journal of Anaesthesia, 116 (1): 54–62 (2016)

doi: 10.1093/bja/aev372
Clinical Practice

CLINICAL PRACTICE

Mortality of emergency general surgical patients and associations with hospital structures and processes

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Abstract

Background: Variations in patient outcomes between providers have been described for emergency admissions, including general surgery. The aim of this study was to investigate whether differences in modifiable hospital structures and processes were associated with variance in mortality, amongst patients admitted for emergency colorectal laparotomy, peptic ulcer surgery, appendicectomy, hernia repair and pancreatitis.

Methods: Adult emergency admissions in the English NHS were extracted from the Hospital Episode Statistics between April 2005 and March 2010. The association between mortality and structure and process measures including medical and nursing staffing levels, critical care and operating theatre availability, radiology utilization, teaching hospital status and weekend admissions were investigated.

Results: There were 294 602 emergency admissions to 156 NHS Trusts (hospital systems) with a 30-day mortality of 4.2%. Trust-level mortality rates for this cohort ranged from 1.6 to 8.0%. The lowest mortality rates were observed in Trusts with higher levels of medical and nursing staffing, and a greater number of operating theatres and critical care beds relative to provider size. Higher mortality rates were seen in patients admitted to hospital at weekends [OR 1.11 (95% CI 1.06–1.17) $P<0.0001$], in Trusts with fewer general surgical doctors [1.07 (1.01–1.13) $P=0.019$] and with lower nursing staff ratios [1.07 (1.01–1.13) $P=0.024$].

Conclusions: Significant differences between Trusts were identified in staffing and other infrastructure resources for patients admitted with an emergency general surgical diagnosis. Associations between these factors and mortality rates suggest that potentially modifiable factors exist that relate to patient outcomes, and warrant further investigation.

Key words: healthcare delivery; health resources; health services research; outcome

Patients undergoing emergency general surgery, especially those undergoing intra-abdominal operations, are at high-risk of poor postoperative outcomes.[1 2] The variability in the quality of care delivered and the outcomes from emergency admissions and operations is of growing concern.[3 4] The Royal College of Surgeons of England (RCS) has highlighted this variability and proposed a care bundle which addresses many of the perceived deficiencies, but also highlights the paucity of high quality data on the care of the higher risk general surgical patient.[5] The Enhanced Peri-Operative Care for High-risk patients (EPOCH) study, currently

Accepted: August 8, 2015

Editor's key points

- Levels of clinician seniority and staffing, and other resources, are likely to impact on outcomes of care, particularly in the emergency setting.
- This study has identified variation in risk-adjusted mortality of emergency general surgical patients associated with modifiable structures and process.
- Evidence-based structured pathways and appropriate resources are needed to improve perioperative surgical care.

underway in the UK, aims to assess the impact of implementation of a modification of this perioperative care pathway, for patients undergoing emergency laparotomy.

There are also national efforts underway in England and Wales to audit general surgical emergency practice and link outcomes to structures and processes of care. Conducted by the National Institute of Academic Anaesthesia's Health Services Research Centre, the National Emergency Laparotomy Audit (NELA) organizational audit, identified inter-institutional variation in structure and process measures including critical care bed provision, availability of imaging and interventional radiology, emergency theatre provision, and patterns of staffing. An individual patient audit of all adults undergoing emergency laparotomy in NHS Hospitals in England and Wales commenced in December 2013 and the first report will be published in the second half of 2015.

Variation in healthcare resource availability and utilization is well established in the UK.[6] In the USA, a number of structure and process factors have been shown to affect patient outcomes, across disparate specialities in individual hospitals.[7] Although our understanding remains incomplete, this observation does suggest that structural and process factors may be relevant at a provider level,[8–10] including 'failure-to-rescue' (FTR).[11] The National Confidential Enquiry into Patient Outcome and Death (NCEPOD) and the RCS have highlighted staff numbers and seniority as particularly important in reducing variations in outcome.

The primary aim of this study was to identify whether modifiable structures and processes within NHS Trusts (hospital systems) in England were associated with mortality in patients undergoing emergency general surgery or admitted with pancreatitis.

Methods

The reporting of this study conforms to the STROBE statement. Ethical approval for studies using Hospital Episode Statistics (HES) database extracts by our unit has previously been sought and we have confirmation that it was not required (Wandsworth Research Ethics Committee).

Emergency general surgery cohort

Patient and outcome data were obtained from the HES database from 1st April 2005 to 31st March 2010. The HES data warehouse is an administrative database that records the details of every patient admission in England and holds patient-level data on patient characteristics, comorbidities, and social deprivation indices.

We extracted relevant data for all emergency admissions to each Trust categorized into a number of predefined clinical groups. These patient groups covered a spectrum of emergency general surgical procedures (appendicectomy, hernia repair, colorectal laparotomy, peptic ulcer surgery) and acute pancreatitis. The outcomes of this cohort have been previously published along with details of patient selection.[10] The groups were analysed as an amalgamated emergency general surgical dataset. Patient selection was based on the primary procedural code (Office of Population, Census and Surveys-Version 4, OPCS-4), with the exception of pancreatitis, where selection was based on primary diagnostic code (International classification of diseases-Tenth Revision, ICD-10) as this condition is the most frequently managed nonoperative surgical condition (Supplementary data Appendix 1).

Outcomes: death

The primary outcome measure was 30-day mortality; 90-day mortality was a secondary outcome measure; both were determined from the Office of National Statistics (ONS) Registry linkage to HES records.

The confounding effect of inter-hospital transfer on mortality rates was accounted for as patients can be tracked between providers within HES. Concurrent admissions were linked and the ultimate outcome was assigned to the index hospital (superspells), which provides the most accurate reflection of death rate. The outcome was attributed to the index hospital Trust, defined as the Trust in which the operation was undertaken for patients who had surgery, with the exception of pancreatitis where the initial hospital of admission was used.

Outcomes: complications and failure to rescue

To aid understanding of the underlying mechanisms by which death rates vary across institutions a *post hoc* analysis of 30-day complication and FTR rates was performed comparing trust mortality categories. Complications were considered binary outcomes. Both surgical complications and medical complications were included using respectively OPCS-4 and ICD-10 codes (Supplementary data Appendix 2). Further details of the methodology used have been published previously.[12] FTR was defined as the number of deaths after a complication divided by the number of patients with a complication.

Structure and process factors

Structure and process data were collated from the Department of Health, Health and Social Care Information Centre (HSCIC) and NHS England databases.[13–15] The variables selected for inclusion in the analysis encompassed aspects of staffing, critical care and operating theatre availability, radiology utilization, and teaching status, including those in the NHS Trust Development Authority accountability framework for NHS Trust boards and the World Health Organization standardized surgical metrics.[16 17] The variables included in the analysis consisted of total doctors, total doctors in general surgery, consultant doctors in general surgery, senior house officers in general surgery, house officers in general surgery, total nurse staffing, total critical care beds, operating theatres, MRI usage, CT usage, total ultrasound, total fluoroscopies, total senior house officers and total house officers, teaching status and weekend *vs* weekday admission.

Where appropriate, numerical factors were scaled as either per hospital bed or annual emergency general surgical admission caseload (general surgical staffing variables), in order that relative differences between Trusts could be ascertained. Numerical variables were further categorized into tertiles for ease of interpretation. Hospitals were classified as teaching hospitals if they had a direct and specific link with a member of the Medical School Council in England. Analysis was performed at NHS

Trust level (i.e. potentially including more than one physical site) and the term 'Trust' is used synonymously with 'hospital'.

Statistical analysis

Analyses were done according to study protocol using methodology detailed in two recent publications.[18 19] The analyses were undertaken with SAS version 9.2 and 9.4 (SAS Institute, USA) and R version 3.0.2 (R Foundation for Statistical Computing, Austria).

The primary outcome measure was death within 30-days of the index operation or admission (for pancreatitis). Death within 90 days was used as a secondary outcome. The risk standardization procedures and hierarchical modelling utilized is detailed previously.[9 10]

Adjustment was made for age, sex, comorbid conditions, social deprivation indices (based on residential address), stratifying by year of discharge and by patient group.[20] For comorbidities, the previously validated Charlson score was used, which requires data from previous hospital admissions. Consequently, HES data from 1st April 2004 were included for risk-adjustment.[21] Patient factors formed first-level predictors and a random hospital effect the second level. The expected mortality for each patient was calculated from the sum of the product of the parameter estimates from the logistic regression models with the relevant covariate value. The parameter estimates used to calculate the expected numbers of deaths at each hospital were obtained, only from the data from other hospitals.

The difference between the expected and observed mortality in each hospital was quantified and tested using standardized funnel plots.[22] A Poisson distribution modelled the expected divergence between observed and expected mortality. A statistically significant divergence was reported when it exceeded the 95% CI of the Poisson distribution.

Table 1 Patient characteristics and crude day 30 and day 90 mortality outcomes for emergency general surgical patients in acute English NHS trusts

Diagnosis/procedure	Acute pancreatitis	Hernia repair	Appendicectomy	Upper gastrointestinal emergency laparotomy	Colorectal emergency surgery
Number of patients/procedures	58 159	42 302	141 538	10 237	42 366
Mean patient age (yr)	56.1 (17–104)	63.2 (17–106)	33.9 (17–101)	59.4 (17–102)	65.5 (17–102)
Male proportion (%)	52.3	57.0	51.7	58.5	47.5
RCS Charlson co-morbidity score (%)					
0	64.7	65.3	88.7	65.7	35.3
1	25.1	24.3	10.3	23.5	42.4
2	7.4	7.5	0.9	7.9	16.1
3	2.8	3.0	0.2	2.9	6.3
Social deprivation quintile (%)					
1	27.0	21.2	20.8	31.3	19.3
2	21.7	20.9	20.7	21.7	19.7
3	19.1	20.8	20.0	17.6	20.6
4	17.3	19.7	19.4	16.2	20.7
5	15.1	17.4	19.2	13.2	19.8
30 day mortality rate (%)	5.2	3.3	0.2	15.1	14.6
90 day mortality rate (%)	7.1	4.9	0.3	18.8	19.9

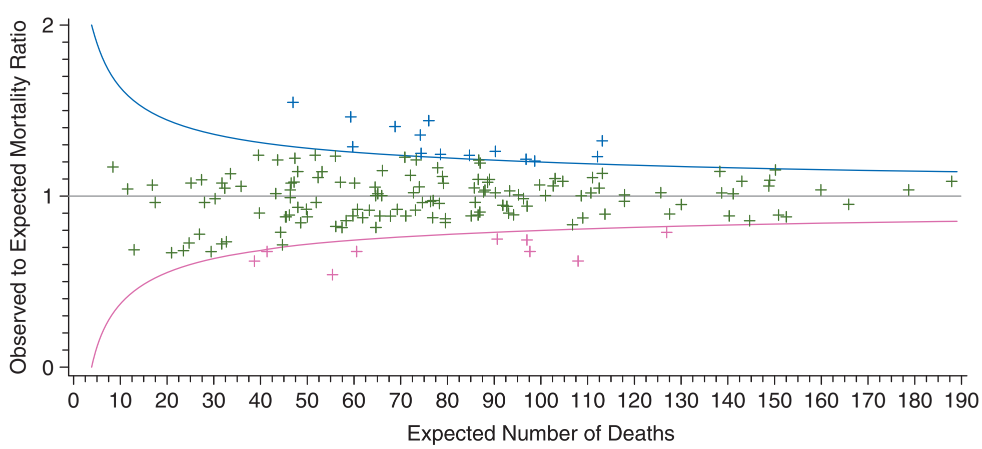

Fig 1 Funnel plot of observed to expected mortality ratio by expected 30 day mortality. Blue and green lines represent the upper and lower approximate 95% confidence limits of the Poisson distribution. Pink cross (low mortality outlier trusts), green cross (expected mortality trusts) and blue cross (high mortality outlier trusts).

NHS Trusts were therefore categorized into low mortality outlier, expected mortality and high mortality outlier categories of risk adjusted 30-day mortality. Differences in the characteristics of high, expected and low mortality trusts were tested using ANOVA and Tukey's Range test. Proportions were compared using the χ^2 test.

Association of structures and processes of care with outcome

The unifactorial association of each structure and process factor with mortality was assessed using a risk adjusted binary logistic regression model. A stepwise selection procedure was done to determine whether inclusion of each individual structure or process covariate, improved goodness-of-fit. Factors with $P<0.2$ in the unifactorial analysis were included in a risk adjusted multifactorial model and tested for significance using a backward selection process using $P<0.05$. Weekend hospital admission, defined as admission on a Saturday or Sunday, was included in the multifactorial model.

Results

The dataset comprised 294 602 patients admitted with general surgical emergencies to 156 English NHS Trusts in the five-year period. Patient characteristics and outcomes are summarized in Table 1. The overall mortality was 4.2% at 30 days and 5.8% at 90 days. NHS Trust mortality rates following eligible procedures ranged from 1.6 to 8.0%.

Variability in structures and processes of care

There was considerable variability in the provision of medical and nurse staffing per bed, critical care bed, standard care bed ratios, operating theatres, and utilization of radiological diagnostic tests between Trusts. Measures of statistical dispersion are summarized in Supplementary data Appendix 3.

Characteristics of low and high mortality outlying trusts

Mortality

There was significant variation in risk-adjusted mortality between acute NHS trusts. At 30 days, 14 trusts were high mortality and 9 trusts were low mortality outliers (Fig. 1). Low mortality outlying trusts at 30 days had significantly greater provision per bed of doctors (0.85 *vs* 0.59 doctors per bed, $P=0.002$), consultant doctors per bed (0.28 *vs* 0.20, $P=0.006$), nursing staff per bed (2.33 *vs* 1.88, $P=0.003$), critical care beds per bed (0.038 *vs* 0.023, $P=0.014$) and operating theatres per bed (0.029 *vs* 0.022, $P=0.002$) than high mortality trusts. Low mortality outlying trusts at 30 days tended to have a greater number of general surgical doctors (0.14 *vs* 0.10 doctors per admission, $P=0.055$) and possibly general surgical house officers (0.040 *vs* 0.029 doctors per admission, $P=0.06$) per emergency admission than high mortality outliers (Table 2).

Complication and failure to rescue

The patients in low mortality trusts had higher comorbidity indices and a correspondingly higher complication rate, however FTR after a complication and overall death rate were lower (Table 2).

Mortality

At 90 days, 12 trusts were high mortality outliers and 6 trusts were low mortality outliers.

Table 2 Differences in Charlson comorbidity category, outcomes and hospital structures between Trust with high, as expected and low 30-day mortality for emergency general surgical admissions. Structural variables were scaled by overall hospital bed number, except general surgical staffing which was scaled by general surgical emergency patients per annum. Values for structural variables are the mean level of each factor with 95% CIs. For structural factors *P*-values indicate differences compared with the low mortality outlier Trusts. For Charlson category and outcome variables statistically significant differences between mortality categories was identified (all $P<0.0001$)

	Outcomes				Structures						
30-day mortality category	Charlson category 2 or 3 (%)	Complication rate (%)	Failure to rescue rate day 30 (%)	Day 30 death (%)	Total doctors per bed	Consultant doctors per bed	Total doctors general surgery per admission	House officers general surgery per admission	Nurses per bed	Operating theatres per bed	Critical Care Beds per bed
High mortality outlier	7.9	15.1	40.2	5.5	0.59 (0.56–0.62) $P=0.002$	0.20 (0.18–0.21) $P=0.006$	0.10 (0.09–0.11) $P=0.055$	0.029 (0.025–0.033) $P=0.060$	1.88 (1.80–1.97) $P=0.003$	0.022 (0.019–0.024) $P=0.002$	0.023 (0.019–0.027) $P=0.014$
Expected	8.5	17.0	33.8	4.6	0.64 (0.61–0.67) $P=0.001$	0.22 (0.21–0.23) $P=0.017$	0.12 (0.11–0.12) $P=0.15$	0.031 (0.029–0.033) $P=0.055$	1.20 (1.91–2.02) $P=0.003$	0.022 (0.021–0.023) $P=0.0003$	0.027 (0.023–0.027) $P=0.005$
Low mortality outlier	10.9	19.2	29.5	3.5	0.85 (0.65–1.05)	0.28 (0.22–0.35)	0.14 (0.11–0.17)	0.040 (0.032–0.048)	2.33 (2.04–2.62)	0.029 (0.022–0.036)	0.038 (0.022–0.055)

Table 3 Hospital resources and association with 30-day mortality. The unifactorial model is a risk adjusted binary logistic regression analysis where each structure and process factor is entered separately. Total ultrasound, total fluoroscopies, total senior house officer and total house officer staffing had statistical significance of *P*>0.2 and are not included in the table. The multifactorial model is a multivariable risk adjusted binary logistic regression analysis, with a variable selection process in which structure or process factors with *P*<0.2 in the unifactorial model were included

Resource and resource level (tertile)	Unifactorial Odds Ratio (95% CI)	Multifactorial Odds Ratio (95% CI)
Total doctor		
Lowest	1.07 (1.00–1.15) *P*=0.045	Goodness of fit not improved by inclusion
Middle	1.08 (1.01–1.15) *P*=0.022	
Highest	1	
Total doctors general surgery		
Lowest	1.07 (1.02–1.13) *P*=0.005	1.067 (1.010–1.126) *P*=0.019
Middle	1.09 (1.04–1.14) *P*=0.0008	1.069 (1.015–1.126) *P*=0.012
Highest	1	1
Consultant doctors general surgery		
Lowest	1.07 (1.02–1.12) *P*=0.009	Goodness of fit not improved by inclusion
Middle	1.04 (0.99–1.09) *P*=0.16	
Highest	1	
Senior house officers general surgery		
Lowest	1.06 (1.01–1.11) *P*=0.029	Goodness of fit not improved by inclusion
Middle	1.03 (0.98–1.08) *P*=0.24	
Highest	1	
House officers general surgery		
Lowest	1.06 (1.00–1.11) *P*=0.035	Goodness of fit not improved by inclusion
Middle	0.99 (0.94–1.04) *P*=0.33	
Highest	1	
Total nurse staffing		
Lowest	1.07 (1.00–1.14) *P*=0.042	1.070 (1.008–1.134) *P*=0.024
Middle	1.09 (1.03–1.15) *P*=0.005	1.086 (1.029–1.148) *P*=0.003
Highest	1	1
Total critical care beds		
Lowest	1.08 (1.00–1.16) *P*=0.036	Goodness of fit not improved by inclusion
Middle	1.09 (1.02–1.16) *P*=0.013	
Highest	1	
Operating theatres		
Lowest	1.04 (0.98–1.11) *P*=0.19	Goodness of fit not improved by inclusion
Middle	1.03 (0.98–1.10) *P*=0.23	
Highest	1	
MRI Usage		
Lowest	1.04 (0.98–1.10) *P*=0.25	Goodness of fit not improved by inclusion
Middle	1.04 (0.98–1.10) *P*=0.19	
Highest	1	
CT Usage		
Lowest	1.04 (0.98–1.10) *P*=0.20	0.998 (0.942–1.058) *P*=0.95
Middle	0.99 (0.94–1.05) *P*=0.74	0.934 (0.884–0.988) *P*=0.016
Highest	1	1
Teaching status		
Non teaching	1.10 (1.01–1.19) *P*=0.023	Goodness of fit not improved by inclusion
Teaching	1	
Admission day		
Weekend	1.12 (1.07–1.18) *P*<0.0001	1.11 (1.06–1.17) *P*<0.0001
Weekday	1	1

Low mortality outlying trusts at 90 days had significantly greater provision per bed of operating theatres per bed (0.028 *vs* 0.023, *P*=0.021) than high mortality trusts. Low mortality outlying trusts at 90 days tended to have a greater number of general surgical senior house officers (0.022 *vs* 0.010 doctors per admission, *P*=0.064) per emergency admission than high mortality outliers. No significant differences were seen for other structures or processes.

Logistic regression models

Mortality

The detailed results for 30-day mortality are shown in Table 3. In the unifactorial analysis, a number of factors were associated with 30-day mortality. These were the number of all doctors, general surgical doctors, consultant general surgeons, senior house officers and house officers in general surgery, and nurses

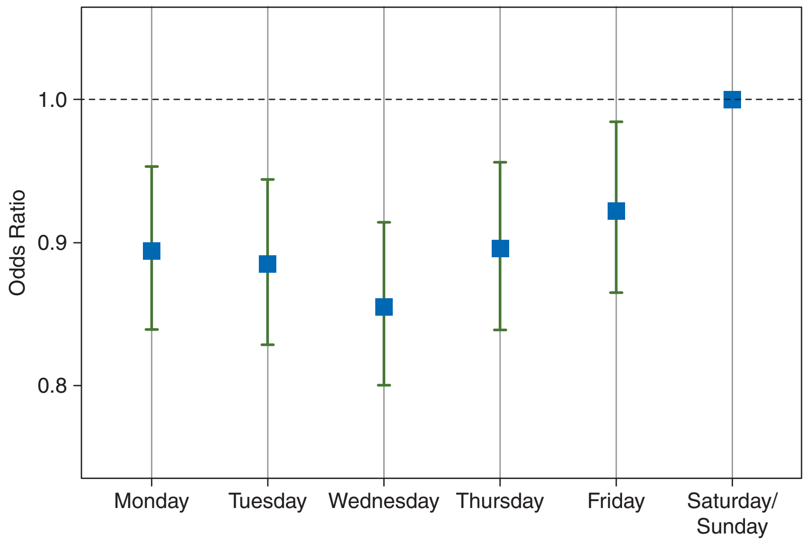

Fig 2 Risk adjusted odds ratio for 30-day mortality by weekday of admission compared with weekend admission. All weekdays had significantly lower mortality than weekend admission. There were no significant differences between weekdays.

per bed, and critical care bed provision, operating theatre provision, and teaching hospital status. Weekend admissions were associated with higher mortality but there was no significant difference between weekdays (Monday to Friday) (Fig. 2). In multifactorial analysis a greater number of general surgical doctors and a greater number of nurses per bed were the only factors that were associated with lower 30-day mortality rates. Weekend admissions were associated with higher 30-day mortality rates.

The results of a subgroup analysis by category of operation/diagnosis is included in Supplementary data Appendix 4–8.

Mortality

The detailed results for 90-day mortality are shown in Table 4. In the unifactorial analysis, a number of factors were associated with 90-day mortality. These were the number of all doctors, general surgical doctors, consultant general surgeons, senior house officers in general surgery, and nurses per bed, and critical care bed provision, CT and fluoroscopy usage, teaching hospital status, and weekend admissions. In multifactorial analysis a greater number of general surgical consultants, fluoroscopy usage, and teaching hospital status were the only factors that were associated with lower 90-day mortality rates. Weekend admissions were associated with higher 90-day mortality rates.

Discussion

The principle finding of this study was that variation in risk-adjusted 30-day and 90-day mortality of emergency general surgical patients was associated with differences in a number of modifiable structures and process. The variation in mortality rates observed appeared to be related to the different ways in which complications were identified and managed. Trusts with the lowest mortality rates recorded higher complication rates but fewer deaths after a complication. Trusts with the lowest mortality were also found to have higher levels of doctor and nurse staffing, and more operating theatres and critical care beds relative to hospital bed number.

Nursing staffing levels have previously been shown to be associate with FTR and mortality in hospitalized patients even after adjusting for hospital size, teaching status and technological proficiency (ability to perform cardiac and transplant operations).[23–25] The findings of our study show that the impact of low nurse staffing ratios persist even after adjustments for a much broader range of variables than previous studies.

Historically, there has been a paucity of research focusing on the impact of medical staffing on mortality outcomes. Although variation in consultant surgical and anaesthetic involvement in emergency laparotomy has been highlighted by the UK Emergency Laparotomy Network, our findings are the first to quantitatively demonstrate the importance of medical staffing and of a multi-disciplinary approach in the contemporary care of patients undergoing emergency general surgical procedures.[26] Consistent with the literature on a wider group of hospitalized patients, general surgical low mortality outliers had relatively more total trust wide doctors, general surgical doctors and consultant general surgical doctors.[27] Total general surgical staffing persisted in the multifactorial model for factors predicting 30-day mortality. The key role of senior clinician involvement has been demonstrated in the care of acute medical patients.[28]

Whilst a higher mortality rate with weekend admission (approximately 12% increased odds when compared with weekdays) is not novel, our findings are noteworthy because the association of weekend admission persisted despite the incorporation of a broad range of structure and process variables.[29]

Unlike the results of Symons and colleagues,[4] but consistent with Almoudaris and colleagues,[30] in our study low 30-day mortality outliers did not have significantly different utilization of imaging modalities. An association between fluoroscopy usage and mortality at 90 days was noted, with a greater use being associated with lower mortality rates.[4 30] This may be a reflection of the growing importance of interventional radiology in the management of general surgical emergencies, and the complications after surgery.

Table 4 Hospital resources and association with 90-day mortality. The unifactorial model is a risk adjusted binary logistic regression analysis where each structure and process factor is entered separately. Total MRI and total senior house officer, total house officer staffing and general surgical house officer staffing had statistical significance of P>0.2 and are not included in the table. The multifactorial model is a multivariable risk adjusted binary logistic regression analysis with a variable selection process in which structure or process factors with P<0.2 in the unifactorial model were included

Resource and resource level (tertile)	Unifactorial Odds Ratio (95% CI)	Multifactorial Odds Ratio (95% CI)
Total doctor		
Lowest	1.06 [1.01–1.11] P=0.015	Goodness of fit not improved by inclusion
Middle	1.07 [1.02–1.12] P=0.009	
Highest	1	
Total doctors general surgery		
Lowest	1.07 [1.02–1.12] P=0.008	
Middle	1.06 [1.01–1.11] P=0.018	Goodness of fit not improved by inclusion
Highest	1	
Consultant doctors general surgery		
Lowest	1.08 [1.03–1.13] P=0.002	1.06 [1.01–1.11] P=0.027
Middle	1.06 [1.02–1.11] P=0.009	1.07 [1.02–1.12] P=0.009
Highest	1	1
Senior house officers general surgery		
Lowest	1.06 [1.01–1.11] P=0.020	Goodness of fit not improved by inclusion
Middle	1.01 [0.97–1.06] P=0.58	
Highest	1	
Total nurse staffing		
Lowest	1.06 [1.01–1.12] P=0.021	
Middle	1.07 [1.02–1.12] P=0.005	Goodness of fit not improved by inclusion
Highest	1	
Total critical care beds		
Lowest	1.04 [0.99–1.09] P=0.14	Goodness of fit not improved by inclusion
Middle	1.06 [1.01–1.11] P=0.012	
Highest	1	
Operating theatres		
Lowest	1.04 [0.99–1.09] P=0.11	Goodness of fit not improved by inclusion
Middle	1.04 [0.99–1.09] P=0.15	
Highest	1	
CT Usage		
Lowest	1.00 [0.96–1.05] P=0.88	0.99 [0.94–1.05] P=0.73
Middle	0.95 [0.90–0.99] P=0.018	0.93 [0.89–0.98] P=0.032
Highest	1	1
Fluoroscopy Usage		
Lowest	1.01 [0.97–1.06] P=0.63	1.00 [0.94–1.05] P=0.87
Middle	1.07 [1.02–1.12] P=0.004	1.06 [1.01–1.12] P=0.022
Highest	1	1
Ultrasound Usage		
Lowest	0.98 [0.94–1.03] P=0.49	
Middle	1.04 [0.99–1.09] P=0.15	Goodness of fit not improved by inclusion
Highest	1	
Teaching status		
Non teaching	1.09 [1.04–1.15] P=0.0002	1.07 [1.02–1.13] P=0.009
Teaching	1	1
Admission day		
Weekend	1.08 [1.03–1.13] P=0.0007	1.08 [1.03–1.13] P=0.001
Weekday		1

The need for structured pathways and access to appropriate resources is emphasized in the RCS and Department of Health Report on the Perioperative Care of the Higher Risk General Surgical Patient.[5] A modified version of this perioperative care pathway is utilized in the EPOCH study, in patients undergoing emergency laparotomy. Amongst other elements, the pathway stipulates consultant delivered decision-making, surgery and anaesthesia. Our analysis suggests that patients with emergency general surgical pathology, particularly those undergoing surgery, are best served by providers that are well staffed by doctors and nurses and have more critical care beds.

The National Emergency Laparotomy Audit aims to improve care of the emergency laparotomy patient through collection of high quality comparative data. Future observational studies, national or international audits should collect data on departmental and hospital wide factors such as staffing levels, junior and senior specialist rotas and out of hour's resource provision, to further understand the associations noted in this study.

Limitations

This study was reliant on a variety of datasets. The structural and process measures were determined from well established, publicly available, data, largely collected for and reported by the Department of Health. Whilst the accuracy of the data collection for these measures is not known, this is the data that the Department of Health utilizes for planning and is considered of sufficient quality for strategic government purposes. We quantified structural and process measures annually to account for changes during the study period.

This study was an observational study utilizing administrative datasets. The linkage of the HES to the ONS Registry provides for accurate mortality outcomes, both in and out of hospital. Whilst the use of mortality rates and administrative data to judge performance has been criticized, systematic reviews have found that coding accuracy is high with HES data, whilst data quality studies demonstrate that HES are fit for purpose, particularly when validated risk adjustment techniques are used.[31 32]

Finally, this study has assessed the effect of the structure and process measures on a defined cohort of emergency general surgical patients in the English NHS. Therefore, the extent to which the results are applicable to elective admissions, different baskets of emergency admissions, or to healthcare systems outside of the United Kingdom is not known. It is likely that the general themes identified as affecting outcome would be applicable, and would be a useful avenue of confirmatory research.

Conclusions

This study highlights the wide variation in structure and process characteristics between acute NHS trusts in England, after adjustment for provider size or workload, and identifies measures that have significant associations with risk adjusted mortality after general surgical emergencies. Each of these factors provides possible insight into understanding variations in quality of care between providers, many of which are modifiable and could provide targets for quality improvement.

Authors' contributions

Study design/planning: B.A.O., S.S., J.D.P., P.J.E.H.
Study conduct: B.A.O., S.S., J.D.P., P.J.E.H.
Data analysis: B.A.O., S.S., A.K., J.D.P., R.M.P., M.P.W.G., M.M.T., P.J.E.H.
Writing paper: B.A.O., S.S., P.J.E.H.
Revising paper: all authors

Supplementary material

Supplementary material is available at *British Journal of Anaesthesia* online.

Declaration of interest

None declared.

Funding

A.K. is a Clinical Lecturer supported by the Circulation Foundation Surgeon Scientist Award. P.J.E.H. is a Clinician Scientist financially supported by the National Institute for Health Research (NIHR-CS-011–008). No other external funding is declared. The NIHR had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

References

1. Pearse RM, Harrison DA, James P, *et al*. Identification and characterisation of the high-risk surgical population in the United Kingdom. *Crit Care* 2006; **10**: R81
2. Pearse RM, Moreno RP, Bauer P, *et al*. Mortality after surgery in Europe: a 7 day cohort study. *Lancet* 2012; **380**: 1059–65
3. Clarke A, Murdoch H, Thomas MJ, Cook TM, Peden CJ. Mortality and postoperative care after emergency laparotomy. *Eur J Anaesthesiol* 2011; **28**: 16–9
4. Symons NRA, Moorthy K, Almoudaris AM, *et al*. Mortality in high-risk emergency general surgical admissions. *Br J Surg* 2013; **100**: 1318–25
5. Anderson I, Eddlestone J, Lees N, *et al*. *The Higher Risk General Surgical Patient - Towards Improved Care for A Forgotten Group*. London: Royal College of Surgeons of England, 2011
6. Right Care. The NHS Atlas of Variation in Healthcare. Available from http://bit.ly/nhsaov2011fhires (accessed 10 February 2014)
7. Elixhauser A, Steiner C, Fraser I. Volume thresholds and hospital characteristics in the USA. *Health Aff (Millwood)* 2003; **22**: 167–77
8. Dimick JB, Staiger DO, Birkmeyer JD. Are mortality rates for different operations related? Implications for measuring the quality of non-cardiac surgery. *Med Care* 2006; **44**: 774–8
9. Sinha S, Karthikesalingam A, Poloniecki JD, Thompson MM, Holt PJ. Inter-Relationship of Procedural Mortality Rates in Vascular Surgery in England Retrospective Analysis of Hospital Episode Statistics From 2005 to 2010. *Circ Cardiovasc Qual Outcomes* 2014; **7**: 131–41
10. Holt PJ, Sinha S, Ozdemir BA, Karthikesalingam A, Poloniecki JD, Thompson MM. Variations and inter-relationship in outcome from emergency admissions in England: a retrospective analysis of Hospital Episode Statistics from 2005–2010. *BMC Health Serv Res* 2014; **14**: 270
11. Silber JH, Williams SV, Krakauer H, Schwartz JS. Hospital and patient characteristics associated with death after surgery. A study of adverse occurrence and failure to rescue. *Med Care* 1992; **30**: 615–29
12. Sinha S, Ata Ozdemir B, Khalid U, *et al*. Failure-to-rescue and interprovider comparisons after elective aortic aneurysm repair. *Br J Surg* 2014; **101**: 1541–50
13. Department of Health. Performance Data and statistics. Available from http://webarchive.nationalarchives.gov.uk/20130107105354/http://www.dh.gov.uk/en/Publicationsandstatistics/Statistics/Performancedataandstatistics/index.htm (accessed 01 July 2013)
14. Health and Social Care Information Centre. Find data. Available from http://www.hscic.gov.uk/searchcatalogue (accessed 01 July 2013)
15. NHS England. Statistical Work Areas. Available from http://www.england.nhs.uk/statistics/statistical-work-areas/ (accessed 01 July 2013)
16. NHS Trust Development Authority. Delivering High Quality Care for Patients: The Accountability Framework. Available from http://www.ntda.nhs.uk/wp-content/uploads/2012/04/framework_050413_web.pdf (accessed 15 June 2013)
17. Weiser TG, Makary MA, Haynes AB, Dziekan G, Berry WR, Gawande AA. Standardised metrics for global surgical surveillance. *The Lancet* 2009; **374**: 1113–7
18. Ozdemir BA, Karthikesalingam A, Sinha S, *et al*. Association of hospital structures with mortality from ruptured abdominal aortic aneurysm. *Br J Surg* 2015; **102**: 516–24

19. Ozdemir BA, Karthikesalingam A, Sinha S, *et al*. Research activity and the association with mortality. *PLoS One* 2015; **10**: e0118253
20. Department for Communities and Local Government. *English Indices of Deprivation 2010*. London: Lad M, 2011
21. Armitage JN, van der Meulen JH. Identifying co-morbidity in surgical patients using administrative data with the Royal College of Surgeons Charlson Score. *Br J Surg* 2010; **97**: 772–81
22. Mayer EK, Bottle A, Rao C, Darzi AW, Athanasiou T. Funnel plots and their emerging application in surgery. *Ann Surg* 2009; **249**: 376–83
23. Aiken LH, Clarke SP, Sloane DM, Sochalski J, Silber JH. Hospital nurse staffing and patient mortality, nurse burnout, and job dissatisfaction. *J Am Med Assoc* 2002; **288**: 1987–93
24. Rafferty AM, Clarke SP, Coles J, *et al*. Outcomes of variation in hospital nurse staffing in English hospitals: Cross-sectional analysis of survey data and discharge records. *Int J Nurs Stud* 2007; **44**: 175–82
25. Needleman J, Buerhaus P, Pankratz VS, Leibson CL, Stevens SR, Harris M. Nurse staffing and inpatient hospital mortality. *N Engl J Med* 2011; **364**: 1037–45
26. Saunders DI, Murray D, Pichel AC, Varley S, Peden CJ, on behalf of the members of the UK Emergency Laparotomy Network. Variations in mortality after emergency laparotomy: the first report of the UK Emergency Laparotomy Network. *Br J Anaesth* 2012; **109**: 368–75
27. Jarman B, Gault S, Alves B, *et al*. Explaining differences in English hospital death rates using routinely collected data. *Br Med J* 1999; **318**: 1515–20
28. Bell D, Lambourne A, Percival F, Laverty AA, Ward DK. Consultant Input in Acute Medical Admissions and Patient Outcomes in Hospitals in England: A Multivariate Analysis. Malaga G, editor. *PLoS ONE* 2013; **8**: e61476
29. Aylin P, Alexandrescu R, Jen MH, Mayer EK, Bottle A. Day of week of procedure and 30 day mortality for elective surgery: retrospective analysis of hospital episode statistics. *Br Med J* 2013; **346**: f2424–f2424
30. Almoudaris AM, Burns EM, Mamidanna R, *et al*. Value of failure to rescue as a marker of the standard of care following reoperation for complications after colorectal resection. *Br J Surg* 2011; **98**: 1775–83
31. Burns EM, Rigby E, Mamidanna R, *et al*. Systematic review of discharge coding accuracy. *J Public Health* 2011; **34**: 138–48
32. Holt PJE, Poloniecki JD, Thompson MM. Multicentre study of the quality of a large administrative data set and implications for comparing death rates. *Br J Surg* 2012; **99**: 58–65

Handling editor: P. S. Myles