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Organisational factors and mortality after an emergency laparotomy: multilevel analysis of 39 903 National Emergency Laparotomy Audit patients

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Abstract

Background: Studies across healthcare systems have demonstrated between-hospital variation in survival after an emergency laparotomy. We postulate that this variation can be explained by differences in perioperative process delivery, underpinning organisational structures, and associated hospital characteristics.

Methods: We performed this nationwide, registry-based, prospective cohort study using data from the National Emergency Laparotomy Audit organisational and patient audit data sets. Outcome measures were all-cause 30- and 90-day postoperative mortality. We estimated adjusted odds ratios (ORs) for perioperative processes and organisational structures and characteristics by fitting multilevel logistic regression models.

Results: The cohort comprised 39 903 patients undergoing surgery at 185 hospitals. Controlling for case mix and clustering, a substantial proportion of between-hospital mortality variation was explained by differences in processes, infrastructure, and hospital characteristics. Perioperative care pathways [OR: 0.86; 95% confidence interval (CI): 0.76–0.96; and OR: 0.89; 95% CI: 0.81–0.99] and emergency surgical units (OR: 0.89; 95% CI: 0.80–0.99; and OR: 0.89; 95% CI: 0.81–0.98) were associated with reduced 30- and 90-day mortality, respectively. In contrast, infrequent consultant-delivered

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intraoperative care was associated with increased 30- and 90-day mortality (OR: 1.61; 95% CI: 1.01–2.56; and OR: 1.61; 95% CI: 1.08–2.39, respectively). Postoperative geriatric medicine review was associated with substantially lower mortality in older (≥70 yr) patients (OR: 0.35; 95% CI: 0.29–0.42; and OR: 0.64; 95% CI: 0.55–0.73, respectively).

Conclusions: This multicentre study identified low-technology, readily implementable structures and processes that are associated with improved survival after an emergency laparotomy. Key components of pathways, perioperative medicine input, and specialist units require further investigation.

Keywords: health services research; pathological processes; frailty; postoperative mortality; surgical procedures; emergency laparotomy

Editor's key points

- Patients undergoing an emergency laparotomy are at high risk of complications, and so require extra hospital resources.
- Both processes and outcomes of care vary widely across hospital systems.
- This UK-based National Emergency Laparotomy Audit project provides important data for healthcare quality improvement around the world.
- Patients managed with perioperative care pathways and emergency surgical units had better outcomes.

Emergency laparotomies are commonly performed worldwide (incidence: ~1:1100 population)[1] for a spectrum of potentially life-threatening emergency general surgical events in heterogeneous populations. Morbidity complicates the postoperative recovery of a third of patients, and up to 18% die within a month of surgery overall.[2–5] But, across international healthcare systems, the incidence of adverse outcomes varies substantially between hospitals,[2,5–8] suggesting opportunities to improve quality of care and postoperative outcomes.[9,10]

System initiatives target known determinants of unwarranted variation in order to improve quality of care and patient outcomes.[11] Several organisational factors (processes of care, supporting infrastructure, organisational characteristics, and procedure volume) have been shown to be associated with hospital-level variation in patient outcomes in other clinical contexts.[2–5,12–17] But, perioperative care is complex, particularly for patients requiring emergency surgery, and the availability only of generic patient and organisational data items has limited previous analyses of administrative data sets. For emergency laparotomies, the National Emergency Laparotomy Audit (NELA) has used purpose-built patient- and hospital-level data collection platforms since it began in 2013.[18,19]

Hospitals are currently benchmarked against standards informed by expert opinion, because evidence supporting individual management strategies in an emergency laparotomy is limited. The aims of these analyses were therefore to systematically identify the processes of care and underpinning hospital structures and organisational characteristics associated with variation in mortality after an emergency laparotomy, and to quantify the magnitude of these associations within the NELA data sets.

Methods

Patient- and hospital-level data for this study were extracted from the NELA patient data set and NELA 2013 organisational audit, respectively. Submission of these data by NHS hospitals in England and Wales has been described previously.[8,18,19] NELA is approved under section 251 of the NHS Act 2006 by the Confidentiality Advisory Group, and this study received approval from the Healthcare Quality Improvement Partnership.

All-cause postoperative mortality was derived (by the Royal College of Surgeons' Clinical Effectiveness Unit) through linkage of the patient data set with the Office for National Statistics (ONS) death register. Patient records were eligible for inclusion if surgery commenced between December 1, 2013 and November 30, 2015; patient-level explanatory co-variates were completely recorded; ONS-linked mortality outcome was available; and treating hospitals had submitted data to the organisational audit.

Variable definitions, selection, and management

The joint primary endpoints of this study were all-cause 30- and 90-day postoperative mortality.

Physiological and Operative Severity Score for the Enumeration of Mortality and Morbidity (POSSUM)[20] variables comprise the majority of patient risk factors in the NELA data set because the Portsmouth recalibration (P-POSSUM) was the most validated risk model for emergency general surgery.[21] Alongside POSSUM variables, other descriptors beyond the control of the provider, such as admission type and ASA physical status classification (ASA-PS), were entered into multivariable and multilevel models (Table 1). Descriptors were selected for modelling regardless of univariate significance.[22] Day of the week, month, and year of NELA data collection were modelled as explanatory co-variates to model temporal variations in process delivery, competition for structural provisions, and the effects of the audit and contemporaneous quality improvement initiatives.

Perioperative processes were selected from the NELA patient data set if they were recorded for every patient or missing at random, and were applicable either to the entire cohort or, for postoperative geriatric medicine review, a substantial population subgroup (Table 1). The processes were modelled at patient level and at hospital level as quintiles[23] of 'comprehensiveness' of delivery [1 (received by the lowest proportion of patients) to 5 (received by the highest proportion)]. Unplanned admission to critical care and unplanned return to theatre were included as potential markers of postoperative complications.

Hospital structures and characteristics were identified from the 2013 NELA Organisational Audit[19] data set, which was informed by contemporary health services research.[5,14–17,24–28]

Table 1 Candidate variables. ASA-PS, American Society of Anesthesiologists physical status classification; EGS, emergency general surgery; EL, emergency laparotomy; GDFT, goal-directed fluid therapy; GI, gastrointestinal. *Interactions with ASA-PS. †Physiological and Operative Severity Score for the Enumeration of Mortality and Morbidity definitions. ‡Modelled as quintiles

Patient-level variables	Hospital-level variables
Risk factors	Hospital characteristics
Age on entry into theatre*	Hospital size (quartile of beds)
Gender	Tertiary GI surgical referral centre
ASA-PS	Configuration to admit EGS patients
Admission type	Cardiothoracic surgery performed
Reoperation	Aggregate patient-level data
Preoperative	Volume of cases submitted‡
Cardiac co-morbidity score*†	Processes of care‡ (as per aforementioned definitions)
Respiratory co-morbidity score*†	Structural provisions
Procedure number†	Single pathway for EGS patient care
Operative urgency†	Emergency surgical unit
ECG†	Operating theatres per 100 hospital beds‡
Systolic blood pressure	24 h provision of a theatre available for EGS
Heart rate	Critical care beds per 100 hospital beds‡
Glasgow coma score	Routine postoperative geriatric medicine review
Haemoglobin concentration	Regular mortality reviews after EL
White cell count	
Serum urea concentration	
Serum sodium concentration	
Serum potassium concentration	
Serum creatinine concentration	
Serum lactate concentration	
Postoperative	
Operative severity†	
Blood loss score†	
Abdominal soiling score†	
Malignancy score†	
Temporal factors	
Day of week of surgery	
Month of year of surgery	
Year of data collection	
Postoperative events	
Unplanned return to theatre	
Unplanned critical care admission	
Processes of care	
Consultant surgeon review within 14 h of admission	
CT performed before operation	
CT reported before operation by a consultant radiologist	
Risk of death documented before operation	
Timeliness of antibiotic administration	
Preoperative review by consultant surgeon and consultant anaesthetist	
Decision to operate made by consultant surgeon	
Timeliness of arrival in theatre commensurate with operative urgency	
Intraoperative care under direct supervision of consultant surgeon and anaesthetist	
Intraoperative GDFT	
Direct postoperative admission to critical care bed	
Postoperative geriatric medicine review in older patients (≥70 yr)	

Variables were selected for modelling if data were submitted by all participating hospitals (Table 1).[19] Aggregate procedure volumes were modelled as quintiles [1 (fewest) to 5 (most)]. Definitions of hospital structures are provided in the appendices.

Statistical analysis and modelling

Patient-only models were first constructed to identify risk and temporal factors independently associated with postoperative all-cause 30- and 90-day mortality. These predictors were then imported into multilevel models to identify organisational factors (processes, structures, and hospital characteristics) associated with between-hospital variation in 30- and 90-day mortality. Statistical significance was set at $P<0.05$. Analysis and data-set management were performed in Stata® 14 (StataCorp LP, College Station, TX, USA).

Data completeness was assessed and sensitivity analyses were performed. After exclusions, data distributions were assessed and univariate analyses were performed (χ^2 or logistic regression) on 30- and 90-day mortality. Categorical data were regrouped to avoid modelling categories containing few individuals or events. Continuous data were Winsorised (1st and/or 99th centile), and the clinical plausibility of fractional polynomial transformed data (for non-linear relationships) was assessed for 30- and 90-day mortality, using a closed-test approach.[29]

Multiple logistic regression and backward elimination of non-significant ($P \geq 0.05$) variables identified patient risk factors and interaction terms (Table 1) independently associated with all-cause 30- and 90-day postoperative mortality. These analyses are distinct from the development of the NELA risk adjustment model.[42]

Multilevel modelling was performed in three steps[30]: a 'hospital-only' variance component model first quantified the magnitude of between-hospital variation in the study endpoints; secondly, addition of the patient-level risk factors (fixed effects) identified previously generated the multilevel model; and thirdly, organisational factors (Table 1) were modelled as blocks of variables. Model output was reported as odds ratios and median odds ratios (MORs), where larger MOR values indicate greater between-hospital variation.[31]

Post hoc Cox regression demonstrated separation of survival curves immediately after surgery in older patients (≥70 yr) when stratified by postoperative geriatric medicine review. To mitigate against survival bias, postoperative geriatric review and arrangements for routine postoperative review were therefore assessed only in older patients who had survived 48 h after surgery.

Results

The study cohort comprised 39 903 patients undergoing an emergency laparotomy at 185 NHS hospitals in England and Wales (Supplementary Appendix S2). The median age was 68 yr (inter-quartile range: 53–78), and 22 244 (56%) patients had, at a minimum, severe systemic disease (ASA-PS ≥3) (Table 2). Hospitals were markedly heterogeneous with respect to organisational characteristics (Table 3). The patient-level process delivery is reported in Table 4.

Overall, 4501 (11.3%) patients died within 30 days of surgery and 6176 (15.5%) died within 90 days. Of the 18 168 (46%) older patients aged ≥70 yr, 3153 (17.4%) died within 30 days, 4197 (23.1%) died within 90 days, and 840 (4.6%) died within 48 h of surgery. Sensitivity analyses are reported in Supplementary Appendix S2.

Transformations of non-linearly associated continuous variables and patient-only multivariable models are reported in Supplementary materials. Informed by Cox regression stratifying by postoperative geriatric medicine review (Supplementary Appendices), the multilevel analyses of older patients were restricted to those surviving the first 48 h after surgery.

We identified between-hospital variation in postoperative 30- and 90-day survival. Controlling for case-mix variation and hospital characteristics, a substantial proportion of this variation was explained by hospital-level differences in perioperative structural provisions and the comprehensiveness of intraoperative consultant-delivered care (Table 5). Many of the associated organisational factors were common to both 30- and 90-day outcomes.

Modelling patient-level delivery of processes, preoperative risk documentation, and direct critical care admission were associated with increased 30- and 90-day mortality (Table 5). Only postoperative geriatric medicine review of older patients was associated with reduced mortality, at 30 and 90 days (Table 6). At hospital level, infrequent intraoperative consultant-delivered care (surgeon and anaesthetist) was associated with increased 30- and 90-day mortality.

Provision of a perioperative care pathway and emergency surgical unit were associated with decreased 30- and 90-day mortality, independent of hospital characteristics (Table 5). Provision of few operating theatres per 100 hospital beds was associated with increased 30-day mortality.

Case volume, hospital size, and configuration to accept emergency general surgical admissions routinely were not associated with postoperative outcomes. Accounting for these co-variates, 90-day survival was improved at tertiary gastrointestinal referral centres, but both 30- and 90-day mortality was increased at hospitals performing cardiothoracic surgery (Table 5).

Discussion

This study examined the association of organisational factors with postoperative outcomes in, what is to our knowledge, the largest prospectively identified cohort of patients undergoing emergency laparotomies. A substantial amount of the observed between-hospital variation in case-mix adjusted mortality was explained by differences in processes of care, associated structures, and hospital characteristics. Individually, perioperative care pathways and emergency surgical units were associated with reduced 30- and 90-day mortality, whereas infrequent consultant-delivered intraoperative care was associated with reduced survival. In older patients, postoperative geriatric medicine review was associated with substantially improved survival.

Evidence elsewhere of the benefit of individual processes is conflicting, particularly in surgical cohorts,[2,4,5,10,13] but is perhaps more consistent for multidisciplinary care bundles and pathways.[32–34] The associations of intraoperative consultant-delivered care, postoperative geriatric medicine review, perioperative care pathways, emergency surgical units, and tertiary referral centres with improved 30- and 90-day survival in this study underline the importance of consistent delivery of coordinated multidisciplinary care across the perioperative period in these high-risk populations.

The care of older people requires urgent attention; in this and other contemporary emergency laparotomy cohorts, they are numerous and their postoperative outcomes are poor; and in coming decades, the size and clinical complexity of older populations will increase substantially across the globe.[7,35] Whilst the benefits of formalised geriatric medicine input have been demonstrated in orthopaedic populations,[36] input after an emergency laparotomy remains infrequent and is not yet routine.[8] The association between postoperative review and reduced postoperative mortality in this study may, therefore, represent an opportunity to substantially improve postoperative survival in this large, high-risk subgroup.

Benefits of multisystem medicine approaches to perioperative care are not however confined to older individuals,[34,37] and are the focus of ongoing initiatives by anaesthetic professional bodies both in the UK and USA. The results of smaller-scale initiatives, providing perioperative medicine

Table 2 Characteristics and unadjusted all-cause 30- and 90-day mortality of the NELA patient cohort. AF, atrial fibrillation; ASA-PS, American Society of Anesthesiologists physical status classification; NELA, National Emergency Laparotomy Audit. *Merged categories

Risk factor	Frequency (%)	Mortality (%)		Risk factor	Frequency (%)	Mortality (%)	
		30 days	90 days			30 days	90 days
Age (yr)				Gender			
18–39	4122 (10)	2.0	2.8	Male	19 232 (48)	11.4	15.8
40–49	3820 (10)	3.0	5.0	Female	20 671 (52)	11.2	15.2
50–59	5462 (14)	6.1	9.3	ASA-PS			
60–69	8331 (21)	9.8	14.0	1 or 2 (no or mild systemic disease)*	17 659 (44)	2.5	4.1
70–79	10 087 (25)	14.9	19.9	3 (severe disease, not life threatening)	14 169 (36)	9.7	15.5
80–89	7094 (18)	20.1	26.4	4 (severe, life-threatening disease)	7269 (18)	30.6	38.0
≥90	987 (2)	23.1	32.4	5 (moribund)	806 (2)	57.8	62.5
Preoperative							
ECG				Haemoglobin (g L^{-1})			
AF rate 60–90 beats min^{-1} or no abnormality*	33 464 (84)	8.7	12.6	<130 (male)/<115 (female)	16 588 (42)	14.1	20.1
AF rate >90 beats min^{-1} or other arrhythmia	6439 (16)	24.6	30.3	130–180 (male)/115–165 (female)	22 417 (56)	9.1	12.1
Cardiac failure				>180 (male)/>165 (female)	898 (2)	14.1	16.4
No clinical or radiological signs	37 436 (94)	10.1	14.1	White blood cell ($\times 10^9$ L^{-1})			
Clinical/radiological signs/warfarinised*	2467 (6)	29.6	36.1	<3.6	1324 (3)	21.8	27.6
Respiratory symptoms and signs				3.6–11.0	18 479 (47)	9.4	13.6
No dyspnoea	28 801 (72)	7.3	10.8	>11.0	20 100 (50)	12.4	16.5
Dyspnoea on exertion or mild CXR changes	6364 (16)	17.2	22.5	Sodium (mmol L^{-1})			
Dyspnoea limiting exertion or at rest*	4738 (12)	27.8	34.4	<133	6662 (17)	16.2	21.4
Systolic BP (mm Hg)				133–146	32 678 (82)	10.0	14.0
<90	1764 (4)	34.3	38.7	>146	563 (1)	27.2	33.2
90–120	15 688 (40)	13.6	18.1	Potassium (mmol L^{-1})			
>120	22 451 (56)	7.9	11.8	<3.5	4491 (11)	13.3	17.7
				3.5–5.3	33 826 (85)	10.1	14.3
				>5.3	1586 (4)	30.5	35.3
Pulse (beats min^{-1})				Urea (mmol L^{-1})			
<60	877 (2)	6.5	8.6	<2.5	1742 (4)	4.2	7.1
60–100	28 453 (71)	8.7	13.1	2.5–7.8	23 504 (59)	6.4	10.0
>100	10 573 (27)	18.5	22.5	>7.8	14 657 (37)	20.0	25.3
Glasgow coma score							
15	36 682 (92)	9.0	13.1	Creatinine (μmol L^{-1})			
14	1772 (4)	30.2	35.8	<59 (male)/<45 (female)	4248 (10)	9.9	15.1
9–13	670 (2)	46.0	53.6	59–104 (male)/45–84 (female)	23 747 (60)	6.6	10.1

Continued

Table 2 Continued

Risk factor	Frequency (%)	Mortality (%)		Risk factor	Frequency (%)	Mortality (%)	
		30 days	90 days			30 days	90 days
3–8	779 (2)	43.9	48.1	>104 (male)/ >84 (female)	11 908 (30)	21.1	26.3
Number of operations within this admission				Admission type			
1	34 320 (86)	11.1	15.4	Elective	2820 (7)	10.4	14.4
>1*	5583 (14)	12.3	15.9	Emergency	37 083 (93)	11.3	15.6
Surgery							
Primary procedure	35 829 (90)	11.2	15.5				
Surgery for complication	4074 (10)	12.0	15.6				
Intraoperative							
Operative severity				Intraoperative blood loss			
Major	25 256 (63)	9.5	13.5	<100 ml	18 667 (47)	9.5	13.5
Major+	14 647 (37)	14.4	19.0	101–500 ml	17 843 (45)	12.1	16.7
				≥501 ml*	3393 (8)	16.8	20.2
Peritoneal soiling				Severity of malignancy			
None	14 997 (38)	8.0	[illegible]	None or primary only*	35 196 (88)	10.5	13.2
Serous fluid	10 315 (26)	11.6	16.2	Nodal metastases	1714 (4)	11.6	21.2
Localised pus	4300 (11)	7.4	10.8	Distant metastases	2993 (8)	20.2	38.6
Free bowel content, pus, or blood	10 291 (25)	17.3	21.3				
Other							
Year of NELA audit							
Year 1 (December 1, 2013 to November 30, 2014)	18 604 (47)	11.6	16.1				
Year 2 (December 1, 2014 to November 30, 2015)	21 299 (53)	11.0	15.0				
Day of week of surgery				Postoperative complications			
Sunday	4810 (12)	11.5	15.4	Unplanned return to theatre	3878 (10)	17.0	22.9
Monday	5027 (13)	12.6	16.5	No unplanned return to theatre	35 505 (90)	10.3	14.4
Tuesday	6100 (15)	11.4	15.5	Unplanned critical care admission	1553 (4)	19.1	25.3
Wednesday	6321 (16)	11.6	15.8	No unplanned critical care admission	37 745 (95)	10.7	14.8
Thursday	6521 (16)	10.4	14.5	Critical care admission unknown	480 (1)	11.3	15.6
Friday	6076 (15)	10.9	15.8				
Saturday	5048 (13)	10.8	15.0				

Table 3 Hospital characteristics and structural provisions. EGS, emergency general surgery; EL, emergency laparotomy; GI, gastrointestinal; IQR, inter-quartile range

Characteristics and structures	*n* (%) or median (IQR)
Hospital size (number of beds)	450 (353–627)
Configuration to admit EGS patients	171 (92)
Tertiary GI surgical referral centre	67 (36)
Cardiothoracic surgery performed	28 (15)
Case volume	192 (122–281)
Emergency surgical unit	55 (30)
Single pathway for EGS patient care	53 (29)
Regular morbidity and mortality review after EL	148 (80)
Arrangements for postoperative geriatric medicine review	11 (6)
24 h provision of a theatre available for EGS	141 (76)
Operating theatres per 100 hospital beds	2.6 (2.1–3.0)
Critical care beds per 100 hospital beds	2.7 (2.2–3.7)

Table 4 Processes of care and unadjusted all-cause mortality in the National Emergency Laparotomy Audit patient audit cohort

Perioperative process of care	Frequency (%)	Unadjusted mortality (%)	
		30 days	90 days
CT reported before operation by consultant radiologist			
Yes	28 130 (71)	11.2	15.7
No	11 773 (29)	11.4	14.9
Preoperative risk documentation			
Yes	24 174 (61)	13.8	18.5
No	15 729 (39)	7.4	10.9
Intraoperative goal-directed fluid therapy			
Yes	21 212 (53)	13.4	17.8
No	18 691 (47)	8.9	12.8
Intraoperative consultant-delivered care (surgeon and anaesthetist)			
Yes	27 048 (68)	12.5	16.9
No	12 855 (32)	8.6	12.4
Direct postoperative critical care admission			
Yes	24 291 (61)	15.9	20.5
No	15 612 (39)	4.0	7.7
Postoperative review by geriatric medicine physician (if ≥70 yr)			
Yes	1823 (10)	9.0	18.9
No	16 345 (90)	18.3	23.6

ward rounds for emergency laparotomy patients, are eagerly awaited.

In this study, direct postoperative critical care admission was associated with increased 30-day mortality and preoperative risk documentation with increased 30- and 90-day mortality. Nurse:patient ratios, ready access to medical expertise, and early 'rescue' of downstream complications are amongst the proposed benefits of postoperative care in high-dependency environments.[10,38] But, methods to control for case-mix differences may imperfectly describe the risk factors that indicated an increased level of care in the first place. Outcome may, therefore, be seemingly confounded by indication in observational studies,[4,39] and it is likely that alternative study designs are required to evaluate both the clinical effectiveness of the critical care 'intervention' and the individual components that benefit population subgroups.[40] With respect to preoperative documentation of risk, because the frequency of documentation has been shown to increase with likelihood of death,[8] the association with increased mortality is likely also to be confounded by indication.

In contrast with previous data,[14] 30- and 90-day mortality were increased at hospitals performing cardiothoracic surgery, independent of other organisational characteristics. Individuals undergoing cardiac surgery who require an emergency laparotomy at the same institution are likely to carry risk factors inadequately quantified by our case-mix adjustment.

Day of surgery was associated with study endpoints in multivariable modelling (30- and 90-day mortality were statistically 13–15% higher if surgery was started on Monday than on Thursday, the most common day for surgery; Supplementary Appendices). No 'weekend effect' was observed. But, associations with day of surgery were not statistically significant on multilevel modelling (not reported), demonstrating their limited importance relative to hospital-level differences.

The strengths of this study include the prospective identification of a large, multicentre patient cohort; use of a custom-built data set, linked with an externally validated national mortality data registry; data submission by all hospitals performing emergency laparotomies nationally; and robust model building and adjustment for Level 1 and 2 co-variates. Potential weaknesses include the availability of a restricted set of processes, determined in part by the reliability of coding that has been discussed previously[8,18]; self-reporting of organisational variables and case volumes; varying proportion of hospital records excluded from these analyses (0–63%); and potential regional variation in risk factor weighting.[41] Structural associations could be confounded by self-selection of early-adopter hospitals (in 2013), and services may have been reconfigured in the intervening years. Associations in observational research may be suggestive of, but are not equivalent to, demonstrations of causality.

Key elements of effective pathways, multidisciplinary medicine input, and specialist surgical units and referral centres are currently unknown and require identification in subsequent work. System initiatives to ensure consistent delivery of high-quality care should be explored both nationally and at hospital level.

In summary, we found that low-technology structures (perioperative care pathways and emergency surgical units) and processes (consultant-delivered intraoperative care and postoperative geriatric medicine review) were associated with improved survival after an emergency laparotomy. Our findings may represent opportunities to substantially improve survival in these high-risk populations, and should drive the consistent delivery of high-quality, coordinated multidisciplinary care across the perioperative period. The greatest

Table 5 Associations of organisational factors with 30- and 90-day mortality, and the effect of groups of variables on median odds ratios. CCU, critical care unit; CI, confidence interval; EGS, emergency general surgery; GI, gastrointestinal; OR, odds ratio; Q(*n*), quintile; Qu(*n*), quartile. *Median odds ratio

	30-day mortality		90-day mortality	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Hospital-only model	1.23 (1.19–1.29)*	<0.0001	1.20 (1.16–1.24)*	<0.0001
Multilevel model	1.24 (1.19–1.30)*	<0.0001	1.21 (1.17–1.27)*	<0.0001
Patient-level process delivery	1.24 (1.19–1.30)*	<0.0001	1.22 (1.18–1.27)*	<0.0001
Preoperative risk documentation	1.15 (1.06–1.25)	0.001	1.18 (1.10–1.27)	<0.0001
Goal-directed fluid therapy	1.00 (0.93–1.09)	0.94	1.01 (0.94–1.08)	0.85
Consultant intraoperative care	0.93 (0.72–1.19)	0.54	0.85 (0.68–1.05)	0.13
CT reported before operation	1.03 (0.95–1.12)	0.49	1.07 (0.99–1.15)	0.09
Direct postoperative CCU admission	1.28 (1.14–1.42)	<0.0001	1.07 (0.98–1.17)	0.98
Hospital-level processes	1.21 (1.16–1.27)*	<0.0001	1.16 (1.12–1.22)*	<0.0001
Preoperative risk documentation				
Q1 (least)	1.16 (0.97–1.39)	0.10	1.14 (0.98–1.33)	0.08
Q2	1.06 (0.89–1.25)	0.51	1.11 (0.96–1.28)	0.15
Q3	1.02 (0.86–1.21)	0.82	0.96 (0.83–1.11)	0.58
Q4	1.13 (0.96–1.34)	0.13	1.08 (0.94–1.24)	0.30
Q5 (most)	1.00 (reference)		1.00 (reference)	
Consultant intraoperative care				
Q1 (least)	1.61 (1.01–2.56)	0.05	1.61 (1.08–2.39)	0.02
Q2	1.26 (0.87–1.81)	0.22	1.23 (0.89–1.68)	0.21
Q3	1.09 (0.81–1.47)	0.57	1.10 (0.85–1.43)	0.45
Q4	0.95 (0.76–1.18)	0.63	1.00 (0.83–1.21)	1.00
Q5 (most)	1.00 (reference)		1.00 (reference)	
Direct postoperative critical care admission				
Q1 (least)	0.91 (0.76–1.09)	0.30	0.96 (0.83–1.12)	0.64
Q2	0.91 (0.76–1.08)	0.28	1.02 (0.88–1.19)	0.78
Q3	0.98 (0.81–1.17)	0.80	1.02 (0.87–1.19)	0.82
Q4	0.97 (0.81–1.16)	0.74	1.08 (0.92–1.25)	0.35
Q5 (most)	1.00 (reference)		1.00 (reference)	
Characteristics and structures	1.18 (1.13–1.25)*	<0.0001	1.17 (1.13–1.23)*	<0.0001
Case volume				
Q1 (least)	0.95 (0.75–1.19)	0.64	0.87 (0.71–1.07)	0.19
Q2	0.98 (0.82–1.18)	0.87	1.06 (0.90–1.24)	0.52
Q3	1.02 (0.87–1.19)	0.82	1.02 (0.89–1.18)	0.75
Q4	0.91 (0.79–1.05)	0.19	0.93 (0.82–1.06)	0.28
Q5 (most)	1.00 (reference)		1.00 (reference)	
Hospital beds				
Qu1 (fewest)	1.21 (0.98–1.49)	0.08	1.11 (0.92–1.35)	0.27
Qu2	1.16 (0.97–1.40)	0.11	1.14 (0.97–1.35)	0.11
Qu3	1.18 (1.01–1.38)	0.04	1.11 (0.96–1.28)	0.17
Qu4 (most)	1.00 (reference)		1.00 (reference)	
Tertiary GI surgical referral centre	0.89 (0.78–1.01)	0.07	0.88 (0.79–0.99)	0.04
Admits EGS patients	1.13 (0.81–1.59)	0.47	0.97 (0.72–1.32)	0.86
Cardiothoracic surgery performed	1.20 (1.02–1.42)	0.03	1.26 (1.08–1.47)	0.00
24 h fully staffed theatre	0.91 (0.79–1.04)	0.18	0.98 (0.87–1.11)	0.76
Single EGS pathway	0.86 (0.76–0.96)	0.01	0.89 (0.81–0.99)	0.04
Emergency surgical unit	0.89 (0.80–0.99)	0.03	0.89 (0.81–0.98)	0.02
Regular morbidity and mortality meetings	1.04 (0.91–1.19)	0.53	1.02 (0.90–1.14)	0.80
Routine postoperative geriatric medicine review	1.12 (0.84–1.49)	0.45	1.10 (0.85–1.43)	0.47
Operating theatres per 100 hospital beds				
Q1 (least)	1.12 (0.94–1.35)	0.20	1.11 (0.94–1.30)	0.22
Q2	1.22 (1.02–1.45)	0.03	1.12 (0.96–1.32)	0.16
Q3	1.17 (0.98–1.40)	0.08	1.11 (0.95–1.31)	0.19
Q4	1.09 (0.92–1.30)	0.32	1.03 (0.89–1.21)	0.67
Q5 (most)	1.00 (reference)		1.00 (reference)	
Critical care beds per 100 hospital beds				
Q1 (least)	0.92 (0.76–1.12)	0.42	0.95 (0.80–1.13)	0.55
Q2	0.94 (0.79–1.12)	0.49	0.98 (0.83–1.15)	0.81
Q3	1.03 (0.86–1.23)	0.77	1.07 (0.91–1.26)	0.42
Q4	1.01 (0.85–1.19)	0.94	1.05 (0.90–1.22)	0.52
Q5 (most)	1.00 (reference)		1.00 (reference)	

Table 6 Associations of organisational factors with 30- and 90-day mortality, and the effect of groups of variables on median odds ratio in older patients (≥70 yr) surviving 48 h after surgery. CCU, critical care unit; CI, confidence interval; EGS, emergency general surgery; GI, gastrointestinal; OR, odds ratio; Q(*n*), quintile; Qu(*n*), quartile. *Median odds ratio

	30-day mortality		90-day mortality	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Hospital-only model	1.20 (1.15–1.28)*	<0.0001	1.17 (1.12–1.24)*	0.0001
Multilevel model	1.23 (1.17–1.31)*	<0.0001	1.20 (1.15–1.27)*	<0.0001
Patient-level process delivery	1.25 (1.19–1.33)*	<0.0001	1.21 (1.15–1.28)*	<0.0001
Postoperative geriatric review	0.35 (0.29–0.42)	<0.0001	0.64 (0.55–0.73)	0.00
Preoperative risk documentation	1.08 (0.96–1.20)	0.19	1.10 (1.00–1.21)	0.04
Goal-directed fluid therapy	1.03 (0.93–1.15)	0.58	1.04 (0.95–1.13)	0.46
Consultant intraoperative care	1.08 (0.79–1.47)	0.63	0.93 (0.71–1.22)	0.60
CT reported before operation	1.09 (0.97–1.22)	0.14	1.12 (1.02–1.24)	0.02
Direct postoperative CCU admission	1.30 (1.13–1.50)	<0.0001	1.09 (0.97–1.22)	0.14
Characteristics and structures	1.16 (1.09–1.26)*	0.01	1.15 (1.09–1.23)*	0.006
Routine postoperative geriatric review	1.39 (0.98–1.98)	0.07	1.34 (0.98–1.83)	0.06
Case volume				
Q1 (least)	0.86 (0.65–1.14)	0.29	0.78 (0.60–1.00)	0.05
Q2	0.91 (0.73–1.13)	0.40	0.97 (0.80–1.17)	0.72
Q3	0.98 (0.82–1.18)	0.85	1.00 (0.85–1.17)	0.97
Q4	0.93 (0.80–1.09)	0.39	0.94 (0.81–1.08)	0.37
Q5 (most)	1.00 (reference)		1.00 (reference)	
Hospital beds				
Qu1 (fewest)	1.23 (0.96–1.57)	0.10	1.18 (0.95–1.47)	0.14
Qu2	1.21 (0.97–1.50)	0.09	1.22 (1.01–1.48)	0.04
Qu3	1.17 (0.97–1.40)	0.09	1.14 (0.97–1.33)	0.12
Qu4 (most)	1.00 (reference)		1.00 (reference)	
Tertiary GI surgical referral centre	0.93 (0.80–1.08)	0.36	0.91 (0.80–1.04)	0.17
Admits EGS patients	1.21 (0.76–1.90)	0.42	1.09 (0.73–1.62)	0.68
Cardiothoracic surgery performed	1.21 (0.99–1.47)	0.06	1.32 (1.10–1.57)	0.00
24 h fully staffed theatre	0.90 (0.76–1.06)	0.20	1.01 (0.87–1.16)	0.94
Single EGS pathway	0.93 (0.81–1.07)	0.30	0.98 (0.87–1.11)	0.76
Emergency surgical unit	0.92 (0.81–1.04)	0.17	0.93 (0.83–1.03)	0.17
Regular morbidity and mortality meetings	1.15 (0.99–1.35)	0.07	1.13 (0.98–1.29)	0.09
Operating theatres per 100 hospital beds				
Q1 (least)	1.22 (0.99–1.51)	0.07	1.21 (1.00–1.46)	0.05
Q2	1.28 (1.04–1.59)	0.02	1.15 (0.95–1.39)	0.16
Q3	1.21 (0.98–1.50)	0.07	1.13 (0.94–1.36)	0.21
Q4	1.17 (0.95–1.43)	0.14	1.08 (0.90–1.29)	0.42
Q5 (most)	1.00 (reference)		1.00 (reference)	
Critical care beds per 100 hospital beds				
Q1 (least)	0.91 (0.73–1.14)	0.40	0.96 (0.78–1.17)	0.66
Q2	0.91 (0.74–1.12)	0.36	0.98 (0.81–1.18)	0.83
Q3	1.01 (0.82–1.25)	0.91	1.09 (0.90–1.31)	0.37
Q4	1.08 (0.89–1.31)	0.46	1.09 (0.92–1.30)	0.32
Q5 (most)	1.00 (reference)		1.00 (reference)	

benefits will be in the large subgroup of older people, of which a quarter die within 90 days of surgery.

Authors' contributions

Study conception: C.M.O., M.P.G., S.R.M.
Data-set management: C.M.O., M.G.B., T.E.P.
Data-set analyses: C.M.O.
Writing of manuscript: C.M.O., M.P.G., S.R.M.
Critical commentary: M.G.B., T.E.P., I.D.A., D.M.M., M.P.G., S.R.M.

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Declarations of interest

I.D.A. is the Vice President of the Association of Surgeons of Great Britain and Ireland. D.M.M. receives programmed activities as the Chair of the National Emergency Laparotomy Audit (NELA) Project Team. M.P.G. received programmed activities as the Chair of the NELA Project Team, is a medical adviser for Sphere Medical Ltd, and Director of Oxygen Control Systems Ltd, and received an honorarium and travel expenses

from Edwards Lifesciences in 2016. S.R.M. is the Associate National Clinical Director for Elective Care, NHS England.

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Appendix A. Supplementary data

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