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

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Running title: Perioperative care and mortality after emergency laparotomy

Abstract

Background: Studies across healthcare systems have demonstrated between-hospital variation in survival after 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 datasets. Outcome measures were all-cause 30-day and 90-day postoperative mortality. We estimated adjusted odds ratios 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 casemix and clustering, a substantial proportion of between-hospital mortality variation was explained by differences in processes, infrastructure and hospital characteristics. Perioperative care pathways (odds ratio (OR) 0.86, 95%CI 0.76-0.96; OR 0.89, 95%CI 0.81-0.99) and Emergency Surgical Units (OR 0.89, 95%CI 0.80-0.99; OR 0.89, 95%CI 0.81-0.98) were associated with reduced 30-day and 90-day mortality respectively. In contrast, infrequent consultant-delivered intraoperative care was associated with increased 30-day and 90-day mortality (OR 1.61, 95%CI 1.01-2.56; OR 1.61, 95%CI 1.08-2.39 respectively). Postoperative geriatric medicine review was associated with substantially lower mortality in older (≥70 years) patients (OR 0.35, 95%CI 0.29-0.42; 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 emergency laparotomy. Key components of pathways, perioperative medicine input and specialist units require further investigation.

Keywords: surgical procedures, emergency laparotomy; health planning, health services research; postoperative mortality; pathologic processes, frailty

Editor's Key Points

- Patients undergoing 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 NELA project provides important data for healthcare quality improvement around the world
- Patients managed with perioperative care pathways and emergency surgical units had better outcomes

Introduction

Emergency laparotomies are performed commonly worldwide (incidence ~1:1,100 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]

Systems 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 datasets. 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 emergency laparotomy is limited. The aims of these analyses are therefore to systematically identify the processes of care and underpinning hospital structures and organisational characteristics associated with variation in mortality after emergency laparotomy, and to quantify the magnitude of these associations within the NELA datasets.

Methods

Patient- and hospital-level data for this study were extracted from the National Emergency Laparotomy Audit (NELA) patient dataset and NELA 2013 organisational audit respectively. Submission of these data by NHS hospitals in England and Wales have 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 dataset with the Office for National Statistics (ONS) death register. Patient records were eligible for inclusion if: surgery was commenced between 1st December 2013 and 30th November 2015; patient-level explanatory covariates were completely recorded; ONS-linked mortality outcome was available; and treating hospitals had submitted data to the organisational audit.

Variable definitions, selection and management

Joint primary endpoints of this study were all-cause 30-day 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 dataset 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 American society of Anesthesiologists 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 covariates 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 dataset 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). 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 - 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] dataset, which was informed by contemporary health services research.[5,14-17,24-28] 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 - 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-day 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-day and 90-day mortality. Statistical significance was set at $p<0.05$. Analysis and dataset management was performed in Stata®14 (StataCorp LP, College Station, Texas, USA).

Data completeness was assessed and sensitivity analyses performed. Following exclusions, data distributions were assessed and univariate analyses performed (χ^2 or logistic regression) on 30-day and 90-day mortality. Categorical data were re-grouped to avoid modelling categories containing few individuals or events. Continuous data were Winsorised (1st and/or 99th centiles) and the clinical plausibility of fractional polynomial transformed data (for non-linear relationships) assessed for 30-day 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-day and 90-day postoperative mortality. These analyses are distinct from the development of the NELA risk adjustment model. **[Editor's note: apply BJA reference here]**

**Insert table 1 here*

Multi-level modelling was performed in three steps:[30] a 'hospital-only' variance component model (VCM) first quantified the magnitude of between-hospital variation in the study endpoints; second, addition of the patient-level risk factors (fixed-effects) identified above 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 (MOR), 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 years) 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 hours after surgery.

Results

The study cohort comprised 39,903 patients undergoing emergency laparotomy at 185 NHS hospitals in England and Wales (Appendix 2). Median age was 68 years (IQR 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). Patient-level process delivery is reported in

Table **4**.

**Insert tables 2-4 here*

Overall 4,501 (11.3%) patients died within 30-days of surgery and 6,176 (15.5%) died within 90 days. Of the 18,168 (46%) older patients aged ≥70 years, 3,153 (17.4%) died within 30-days, 4,197 (23.1%) died within 90-days and 840 (4.6%) died within 48 hours of surgery. Sensitivity analyses are reported in Appendix 2.

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 (Appendices), multilevel analyses of older patients were restricted to those surviving the first 48 hours after surgery.

We identified between-hospital variation in postoperative 30-day and 90-day survival. Controlling for casemix 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-day and 90-day outcomes.

**Insert table 5 here*

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

**Insert table 6 here*

Provision of a perioperative care pathway and emergency surgical unit were associated with decreased 30-day 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 routinely accept emergency general surgical admissions were not associated with postoperative outcomes. Accounting for these covariates, 90-day survival was improved at tertiary GI referral centres, but both 30-day and 90-day mortality was increased at hospitals performing cardiothoracic surgery (Table 5).

Discussion

This study examines 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 casemix 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-day 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-day and 90-day survival in this study underline the importance of consistent delivery of co-ordinated multidisciplinary care across the perioperative period in these high-risk populations.

The care of older people requires urgent attention; in this and other contemporary cohorts they are numerous and their postoperative outcomes poor; and in coming decades the size and clinical complexity of older populations will increase substantially across the globe.[7,35] While the benefits of formalised geriatric medicine input has been demonstrated in orthopaedic populations,[36] input after 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 confined to older individuals,[34,37] and are the focus of ongoing initiatives by anaesthetic professional bodies both in the UK and US. The results of smaller-scale initiatives, providing perioperative medicine 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-day and 90-day mortality. Nurse: patient ratios, ready access to medical expertise and early 'rescue' of downstream complications are among the proposed benefits of postoperative care in high dependency environments.[10,38] But methods to control for casemix differences may imperfectly describe the risk factors that indicated an increased level of care in the first place. Outcome may therefore seemingly be 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 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-day 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 casemix adjustment.

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

Strengths of this study include the prospective identification of a large, multicentre patient cohort; use of a custom-built dataset, 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 level 2 covariates. 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 hospitals' 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. Systems initiatives to ensure consistent delivery of high-quality care should be explored both nationally and at hospital-level.

Conclusions

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 emergency laparotomy. Our findings may represent opportunities to substantially improve survival in this high-risk population and should drive the consistent delivery of high-quality, co-ordinated multidisciplinary care across the perioperative period. The greatest benefits will be in the large subgroup of older people, of whom a quarter die within 90-days of surgery.

Contributors

CMO devised the study, performed dataset management and analyses and wrote the manuscript. MGB & TEP performed dataset management and provided critical commentary. IDA & DMM provided critical commentary. MPG & SRM devised the study, wrote the manuscript and provided critical commentary.

Declarations of interest

IDA is the Vice-President of the Association of surgeons of Great Britain and Ireland. DM receives PAs as the chair of the NELA Project Team. MG received PAs 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. SRM is the Associate National Clinical Director for elective care, NHS England.

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The NELA Project Team during the period of data collection *also* comprised: Mr Martin Cripps, Mr Paul Cripps, Professor David Cromwell, Ms Sharon Drake, Dr Mike Galsworthy, Mr James Goodwin, Dr Carolyn Johnston, Mr Jose Lourtie, Mr Dimitri Papadimitriou, Dr Carol Peden, Dr Kate Walker

NHS staff across England and Wales have submitted data to the Audit since 2013

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Table 1 Candidate variables (ECG: electrocardiograph, GCS: Glasgow coma score, CT: computed tomography, GDFT: goal directed fluid therapy, ASA-PS: American Society of Anesthesiologists-physical status classification, † POSSUM definitions, *: interactions with ASA-PS, GI: gastrointestinal, EGS: emergency general surgery, EL: emergency laparotomy, **: modelled as quintiles).

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

Table 2 Characteristics and unadjusted all-cause 30-day and 90-day mortality of the NELA patient cohort. (*: merged categories)

Risk factor	Frequency (%)	Mortality (%)		Risk factor	Frequency (%)	Mortality (%)	
		30-day	90-day			30-day	90-day
Age (years)				Gender			
18-39	4,122 (10)	2.0	2.8	Male	19,232 (48)	11.4	15.8
40-49	3,820 (10)	3.0	5.0	Female	20,671 (52)	11.2	15.2
50-59	5,462 (14)	6.1	9.3	ASA-PS			
60-69	8,331 (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	7,094 (18)	20.1	26.4	4 (Severe, life-threatening disease)	7,269 (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)			
AF rate 60-90bpm or no abnormality*	33,464 (84)	8.7	12.6	<130 (male) / <115 (female)	16,588 (42)	14.1	20.1
AF rate >90bpm or other arrhythmia	6,439 (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 ($x10^9$/l)			
Clinical/ radiological signs/ warfarinised*	2,467 (6)	29.6	36.1	<3.6	1,324 (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	6,364 (16)	17.2	22.5	Sodium (mmol/l)			
Dyspnoea limiting exertion or at rest*	4,738 (12)	27.8	34.4	<133	6,662 (17)	16.2	21.4
Systolic BP (mmHg)				133-146	32,678 (82)	10.0	14.0
<90	1,764 (4)	34.3	38.7	>146	563 (1)	27.2	33.2
90-120	15,688 (40)	13.6	18.1	Potassium (mmol/l)			
>120	22,451 (56)	7.9	11.8	<3.5	4,491 (11)	13.3	17.7
				3.5-5.3	33,826 (85)	10.1	14.3
				>5.3	1,586 (4)	30.5	35.3
Pulse (bpm)				Urea (mmol/l)			

Risk factor	Frequency (%)	Mortality (%) 30-day	Mortality (%) 90-day	Risk factor	Frequency (%)	Mortality (%) 30-day	Mortality (%) 90-day
<60	877 (2)	6.5	8.6	<2.5	1,742 (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 (umol/l)			
14	1,772 (4)	30.2	35.8	<59 (male)/ <45 (female)	4,248 (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
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	2,820 (7)	10.4	14.4
>1*	5,583 (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	4,074 (10)	12.0	15.6				
Intraoperative							
Operative severity				Intra-operative 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*	3,393 (8)	16.8	20.2
Peritoneal Soiling				Severity of malignancy			
None	14,997 (38)	8.0	12.3	None or primary only*	35,196 (88)	10.5	13.2
Serous fluid	10,315 (26)	11.6	16.2	Nodal metastases	1,714 (4)	11.6	21.2
Localised pus	4,300 (11)	7.4	10.8	Distant metastases	2,993 (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 (1/12/13 - 30/11/14)	18,604 (47)	11.6	16.1				

Risk factor	Frequency (%)	Mortality (%)		Risk factor	Frequency (%)	Mortality (%)	
		30-day	90-day			30-day	90-day
Year 2 (1/12/14 - 30/11/15)	21,299 (53)	11.0	15.0				
Day of week of surgery				Postoperative complications			
Sunday	4,810 (12)	11.5	15.4	Unplanned return to theatre	3,878 (10)	17.0	22.9
Monday	5,027 (13)	12.6	16.5	No unplanned return to theatre	35,505 (90)	10.3	14.4
Tuesday	6,100 (15)	11.4	15.5	Unplanned critical care admission	1,553 (4)	19.1	25.3
Wednesday	6,321 (16)	11.6	15.8	No unplanned critical care admission	37,745 (95)	10.7	14.8
Thursday	6,521 (16)	10.4	14.5	Critical care admission unknown	480 (1)	11.3	15.6
Friday	6,076 (15)	10.9	15.8				
Saturday	5,048 (13)	10.8	15.0				

Table 3 Hospital characteristics and structural provisions

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 following EL	148 (80%)
Arrangements for postoperative geriatric medicine review	11 (6%)
24-hour 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 NELA Patient Audit cohort

Perioperative process of care	Frequency (%)	Unadjusted mortality (%)	
		30-day	90-day
CT reported preoperatively 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 & 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 years)			
Yes	1,823 (10)	9.0	18.9
No	16,345 (90)	18.3	23.6

Table 5 Associations of organisational factors with 30-day and 90-day mortality and the effect of groups of variables on median odds ratios (†: Median odds ratio, Q*(n)*: quintile, Qu*(n)*: quartile, CT: computed tomography, CCU: critical care unit GI: gastrointestinal, EGS: emergency general surgery)

	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 preoperatively	1.03 (0.95-1.12)	0.49	1.07 (0.99-1.15)	0.09
Direct postop 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)	- Ref -		- Ref -	
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)	- Ref -		- Ref -	
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)	- Ref -		- Ref -	
Characteristics& 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)	- Ref -		- Ref -	
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)	- Ref -		- Ref -	
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-hour 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)	- Ref -		- Ref -	
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)	- Ref -		- Ref -	

Table 6 Associations of organisational factors with 30-day and 90-day mortality and the effect of groups of variables on median odds ratio in older patients (≥70years) surviving 48 hours after surgery ([†]: Median odds ratio, Q*(n)*: quintile, Qu*(n)*: quartile, CT: computed tomography, CCU: critical care unit, GI: gastrointestinal, EGS: emergency general surgery)

	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 preoperatively	1.09 (0.97-1.22)	0.14	1.12 (1.02-1.24)	0.02
Direct postop CCU admission	1.30 (1.13-1.50)	<0.0001	1.09 (0.97-1.22)	0.14
Characteristics& structures	*1.16 (1.09-1.26)* [†]	*0.01*	*1.15 (1.09-1.23)* [†]	*0.006*
Routine postop 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)	- Ref -		- Ref -	
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)	- Ref -		- Ref -	
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-hour 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)	- Ref -		- Ref -	
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)	- Ref -		- Ref -	