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Critical Care

CRITICAL CARE

Critical care usage after major gastrointestinal and liver surgery: a prospective, multicentre observational study

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Abstract

Background: Patient selection for critical care admission must balance patient safety with optimal resource allocation. This study aimed to determine the relationship between critical care admission, and postoperative mortality after abdominal surgery.

Methods: This prespecified secondary analysis of a multicentre, prospective, observational study included consecutive patients enrolled in the DISCOVER study from UK and Republic of Ireland undergoing major gastrointestinal and liver surgery between October and December 2014. The primary outcome was 30-day mortality. Multivariate logistic regression was used to explore associations between critical care admission (planned and unplanned) and mortality, and inter-centre variation in critical care admission after emergency laparotomy.

Results: Of 4529 patients included, 37.8% (*n*=1713) underwent planned critical care admissions from theatre. Some 3.1% (*n*=86/2816) admitted to ward-level care subsequently underwent unplanned critical care admission. Overall 30-day mortality was 2.9% (*n*=133/4519), and the risk-adjusted association between 30-day mortality and critical care admission was higher in unplanned [odds ratio (OR): 8.65, 95% confidence interval (CI): 3.51–19.97) than planned admissions (OR: 2.32, 95% CI: 1.43–3.85). Some 26.7% of patients (*n*=1210/4529) underwent emergency laparotomies. After adjustment, 49.3% (95% CI: 46.8–51.9%, *P*<0.001) were predicted to have planned critical care admissions, with 7% (*n*=10/145) of centres outside the 95% CI.

Conclusions: After risk adjustment, no 30-day survival benefit was identified for either planned or unplanned postoperative admissions to critical care within this cohort. This likely represents appropriate admission of the highest-risk patients. Planned admissions in selected, intermediate-risk patients may present a strategy to mitigate the risk of unplanned admission. Substantial inter-centre variation exists in planned critical care admissions after emergency laparotomies.

Keywords: critical care; gastrointestinal surgery; intensive care; laparotomy; mortality; risk surgical

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Editor's key points

- High-risk surgical patients should be admitted to critical care after surgery.
- Limited access to critical care sometimes leads to cancellations.
- This study could not identify a surgical benefit from critical care admission but this could be as a result of unaccounted for confounders.

Demand for critical care services is increasing. In 2016, the occupancy rate for critical care beds in the UK was 81.9%, with 4093 urgent operations cancelled because of lack of availability.[1] As technical advances in surgical and perioperative care enable more complex surgical procedures to be performed on higher-risk patient groups, it will be increasingly important to ensure patients are selected appropriately to benefit from planned postoperative critical care admission. Population-level data suggest that 73% of patients that die after surgery across Europe are not routinely admitted to postoperative critical care (Level 2 or 3 beds),[2] with unplanned admission to critical care from ward-level care (Level 0) conveying twice the risk of in-hospital death when compared with planned admission from theatre.

Major gastrointestinal and liver surgery, both elective and emergency, is associated with considerable morbidity and mortality. The development of postoperative complications is associated with an increase in both short- and long-term mortality.[2–4] A single postoperative complication of any type can be associated with reduced long-term survival.[4] Therefore, measures to facilitate early identification of complications through enhanced monitoring and timely 'rescue' through appropriate intervention have been widely implemented.[5] The highest risk patients or patients undergoing high-risk surgery (e.g. emergency laparotomy)[6] are often routinely admitted directly to critical care after surgery as a precautionary and preventative measure. However, previous studies[2,7–10] have not demonstrated a clear benefit to planned critical care admissions on postoperative mortality, even after risk adjustment. This has prompted debate on the added value provided to patients outside those at the highest risk of complications, undergoing emergency surgery, or with significant perioperative events.[11,12] Furthermore, substantial variations in practice between hospitals have been observed,[10,13] with 31–100% (median: 56%) of emergency laparotomy patients being admitted to critical care after operation across England.[13] As such, recent reports by National Confidential Enquiry into Patient Outcomes and Death (NCEPOD) and the King's Fund have highlighted the optimisation of postoperative care, including allocation to appropriate levels of care, as a quality improvement priority.[14,15]

The primary aim of this study was to determine the relationship between direct admission to critical care from theatre after major gastrointestinal and liver surgery, and 30-day postoperative mortality rate. The secondary aim was to explore inter-centre variation in planned admission to critical care after high-risk surgery (using emergency laparotomy as an example).

Methods

This multicentre, prospective, observational study was disseminated through a medical student and surgical trainee collaborative network, with coverage across the UK and Republic of Ireland. Teams of medical students, a junior doctor, and an overseeing consultant surgeon collected data in accordance with a prespecified protocol.[16] This paper represents a pre-specified secondary analysis of the Determining Surgical Complications in the Overweight (DISCOVER) study,[16] and contributing authors are listed in accordance with National Research Collaborative & Association of Surgeons in Training guidelines.[17]

Inclusion and exclusion criteria

This study included all consecutive adult patients (≥18 yr old) undergoing major gastrointestinal or hepatobiliary surgery (major operations being defined according to the surgeon's category of the British United Provident Association schedule of procedures,[18] excluding appendicectomy and cholecystectomy). Emergency and elective procedures were included, with an emergency defined as any surgery on the same admission as diagnosis. Procedures could be performed via laparoscopic or open approaches (inclusive of open, laparoscopic-assisted open, and laparoscopic to open conversion surgeries). Patients undergoing hernia repair (without bowel resection) and procedures performed primarily for a vascular, transplant, urological, or gynaecological indication were not eligible for inclusion in the study. All centres providing acute general surgical care in the UK and Ireland were invited to participate. At each centre, a minimum 2-week window for data collection between October 1, 2014 and November 12, 2014, with 30-day postoperative follow-up using outpatient clinic patient records, electronic patient records, or both. Multiple, distinct 2-week periods were permitted. Data was collected on patient-, disease- and operation-specific risk factors. Anonymised data was uploaded to a secure REDCap server.[19]

Ethics and reporting

Results are reported according to Strengthening the Reporting of Observational Studies in Epidemiology guidelines.[20] A National Research Ethics Service tool was completed, which indicated that full ethical review was not required. Each centre was responsible for registration in line with local clinical governance procedures, and permission for anonymised data upload from the hospital Caldicott guardian.

Data analysis

Data analysis was performed using R (3.3.1, R Foundation for Statistical Computing, AUT, Vienna, Austria). Categorical variables were assessed using the Fisher's test, and continuous variables were assessed using appropriate parametric or non-parametric tests. Statistical significance was set at $P<0.05$.

Critical care was defined according to Intensive Care Society guidance[21] as admission to a high dependency unit (Level 2) or intensive care bed (Level 3), as opposed to standard or enhanced ward level care (Level 0 or 1, respectively). A critical care admission was defined as planned when a decision was made before operation to admit to critical care for postoperative monitoring. In contrast, unplanned admissions were defined as when the decision was made after an intraoperative complication, or complication on the ward. Emergency laparotomy was selected as an index procedure to compare critical care admission rates within centres. It is among the most prevalent of high-risk procedures conducted within general surgical units, and often precedes critical care admission.[22] Thirty-day mortality was determined through follow-up using local electronic records, outpatient letters, or both (censored at 30 days).

Univariable analyses were used to describe associations between patient-, disease- and operative-specific factors and mortality. Multivariate logistic regression models for 30-day postoperative mortality and emergency laparotomy admission to critical care used clinically plausible risk adjustment variables as fixed effects. These included: age; gender; BMI; smoker (current, non-smoker); revised cardiac risk index score; American Society of Anesthesiologists (ASA) physical status; pathology (benign, malignant); approach (open, laparoscopic); and operative risk class [tertiles of operation-specific risk of 30-day mortality derived from 2009 to 2010 Hospital Episode Statistics data, which included low-risk (<1%), moderate-risk (1–9.9%), and high-risk (≥10%) groups, as previously utilised].[23] In addition, the operative centre was modelled as a random-effect in the mixed-effects model exploring inter-centre variation in emergency laparotomy admission to critical care. All effect estimates are presented as odds ratio (OR), alongside the corresponding 95% confidence intervals (CI). The admission rates after indirect standardisation and mixed-effects logistic regression were displayed on funnel plots alongside 95% and 99.9% CI.

Data quality and validation

All investigators were required to complete a mandatory online training module. Some 10% of all included patients were validated by independent investigators for accuracy. Eleven predefined data points were validated for each patient.[23]

Results

Patient characteristics

Of the 4529 patients included across 163 centres in the UK and Ireland, 2816 (62.2%) returned directly to the ward and 1713 (37.8%) were admitted to critical care from theatre (Fig. 1). Of those patients returning to the ward, 86 (3.1%) were later admitted to critical care. The mean age of the cohort was 62 (range: 18–97) yr, half of who were male (50.5%). The most commonly included operations were right hemicolectomy (16%), anterior resection (11%), and small bowel resection (7.3%). Some 35% of patients were ASA physical status 3 and above, 1210 (27%) were operated as an emergency, and 2169 (48%) had a malignant indication for surgery. Across the study data-set, independent validation of 12 096 data points from 1008 patients demonstrated data accuracy of 98.0% and case ascertainment of 92.2%.

The characteristics of the patients not admitted to critical care had significantly different characteristics to those undergoing planned or unplanned critical care admissions (Table 1). Patients who were admitted to critical care were significantly more likely to be older, have a higher ASA physical status and higher operative risk class compared with those who were not admitted. Furthermore, those with planned critical care admission from theatre were more likely to be male, have emergency or open surgery, a malignant operative indication, or higher revised cardiac risk index (RCRI) score. However, it should also be noted that those with unplanned critical care admissions were significantly more likely to be current smokers.

Thirty-day postoperative mortality rate

Across the cohort, the overall 30-day mortality was 2.9% (n=133/4519). The 30-day mortality was 1.2% for elective surgery and 7.6% for emergency surgery (Table 2). The unadjusted 30-day mortality was 5.3% in the planned critical care admission from theatre group, 12.8% in the unplanned critical care admissions from ward care, and 1.2% in patients who remained on the ward. The prevalence of specific postoperative complications in patients with an unplanned critical care admission is provided in Supplementary material (File 1).

In the univariable model, planned admission to critical care from theatre was associated with a five-fold higher risk of 30-day postoperative mortality (OR: 4.83, 95% CI: 3.10–7.78, P<0.001), and unplanned admission to critical care from ward care with a 15 times higher risk of mortality (OR: 14.96, 95% CI: 6.62–31.58, P<0.001), than patients who remained on the ward.

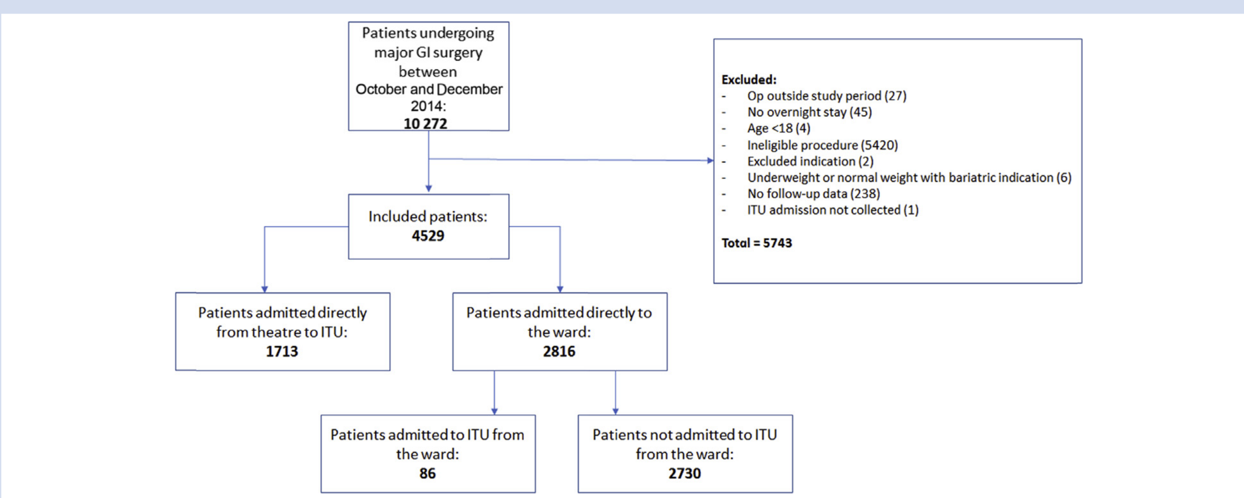

Fig 1. Flow diagram of patient inclusion. GI, gastrointestinal.

Table 1 Patient, disease, and operative specific characteristics by postoperative admission to critical care group. Values in parentheses are percentages unless indicated otherwise. *Values are mean (standard deviation). †Inclusive of open, laparoscopic-assisted open, and laparoscopic to open conversion surgeries. All percentages are calculated without missing data. ‡χ^2 test of 'no admission' to 'admission' group, except ¶two sample *t*-test (two-sided).

	Postoperative admission to critical care (high dependency unit or ICU)				
	No admission to critical care (*n*=2730)	Admission to critical care			
		From theatre (*n*=1713)	P-value‡	From ward (*n*=86)	P-value‡
Age (yr)*	59 (18–94)	65.7 (18–97)	<0.001¶	65.5 (31–94)	0.001¶
BMI (kg m^{-2})			0.002		0.781
Normal weight	832 (33.1)	537 (33.7)		26 (33.8)	
Underweight	92 (3.7)	69 (4.3)		4 (5.2)	
Overweight	765 (30.4)	547 (34.3)		20 (26.0)	
Obese	827 (32.9)	441 (27.7)		27 (35.1)	
Missing data (*n*)	214	119		9	
Sex			<0.001		0.521
Male	1301 (47.7)	943 (55.0)		44 (51.2)	
Female	1429 (52.3)	770 (45.0)		42 (48.8)	
Smoking status			0.483		0.023
Non-smoker	2285 (83.7)	1420 (82.9)		64 (74.4)	
Current smoker	445 (16.3)	293 (17.1)		22 (25.6)	
ASA physical status			<0.001		<0.001
1	425 (15.7)	143 (8.4)		8 (9.3)	
2	1532 (56.7)	741 (43.5)		42 (48.8)	
3	685 (25.4)	647 (37.9)		26 (30.2)	
4	52 (1.9)	149 (8.7)		8 (9.3)	
5	6 (0.2)	25 (1.5)		2 (2.3)	
Missing data (*n*)	30	8		0	
Operative urgency			<0.001		0.208
Elective	2125 (77.8)	1132 (66.1)		62 (72.1)	
Emergency	605 (22.2)	581 (33.9)		24 (27.9)	
Operative pathology			<0.001		0.440
Benign	1543 (56.5)	772 (45.1)		45 (52.3)	
Malignant	1187 (43.5)	941 (54.9)		41 (47.7)	
Operative approach			<0.001		0.002
Laparoscopic	1263 (46.3)	386 (22.5)		25 (29.4)	
Open†	1464 (53.7)	1326 (77.5)		60 (70.6)	
Missing data (*n*)	3	1		1	
Operative risk class			<0.001		0.028
0	312 (11.4)	35 (2.0)		2 (2.3)	
1	1496 (54.8)	1058 (61.8)		50 (58.1)	
≥2	922 (33.8)	620 (36.2)		34 (39.5)	
Revised cardiac risk index			<0.001		0.546
0	2006 (73.5)	1076 (62.9)		59 (68.6)	
1	566 (20.7)	435 (25.4)		22 (25.6)	
2	156 (5.7)	199 (11.6)		5 (5.8)	
Missing data (*n*)	2	3		0	

In the risk adjusted multivariate model (c-statistic: 0.851) the increased risk of 30-day mortality persisted with both planned (OR: 2.32, 95% CI: 1.43–3.85, P<0.001) and unplanned admission to critical care (OR: 8.65, 95% CI: 3.51–19.97, P<0.001). Other factors predictive of 30-day mortality after risk adjustment were underweight BMI, ASA status ≥4, and emergency operation (Table 2 and Fig. 2).

Inter-centre variation in rate of admission to critical care for emergency laparotomy

There were 1210 emergency laparotomies performed at 145 centres over the study period, with a mean of 8.3 patients per centre (median: 7, range: 1–36). Of these patients, 48% had a planned admission to critical care from theatre. At least 80% of patients were admitted in 15% of centres, and fewer than 40% in 39% of centres. The indirectly standardised admission rate of emergency laparotomies to critical care across all centres (Supplementary material, File 2) was 44.3% (95% CI: 40.8–47.8%, *P*<0.001). After adjustment in a mixed-effects model for case-mix at each centre (Table 3), it was estimated that the mean proportion of patients admitted to critical care after their emergency laparotomy (Supplementary material, File 2) was 49.3% (95% CI: 46.8–51.9%, *P*<0.001).

There was substantial inter-centre variation in both the total number of emergency laparotomy patients and the risk-adjusted admission rates to critical care (Supplementary material, File 2). In total, there were 10 centres (7.0%) which were outliers to the risk adjusted rate of planned critical care admission. There were 19 centres at which no emergency laparotomies were admitted to critical care (mean: 2.8 patients, range: 1–12).

Table 2 Univariable and multivariate logistic regression for 30-day postoperative mortality. CI, confidence interval, alpha level =0.05). Values are *n* (%) unless otherwise indicated. *Values are mean (standard deviation). †*n*=371 records excluded because of missing data. ‡χ^2 test, except ¶two sample *t*-test (two-sided).

	30-Day postoperative mortality			Univariable analysis		Multivariable analysis†	
	Dead (*n*=133)	Alive (*n*=4386)	*P*-value‡	Odds ratio (95% CI)	*P*-value	Odds ratio (95% CI)	*P*-value
Critical care admission			<0.001				
None	32 (24.1)	2698 (61.4)	<0.001	1.00 (reference)	–	1.00 (reference)	–
From theatre	90 (67.7)	1623 (36.9)		4.83 (3.10–7.78)	<0.001	2.32 (1.43–3.85)	<0.001
From ward	11 (8.3)	75 (1.7)		14.96 (6.62–31.58)	<0.001	8.65 (3.51–19.97)	<0.001
Age (yr)*	59 (34–96)	61.3 (18–97)	<0.001¶	1.05 (1.04–1.07)	<0.001	1.03 (1.01–1.05)	0.004
Sex			0.786				
Male	67 (50.4)	2174 (49.5)		1.00 (reference)	–	1.00 (reference)	–
Female	66 (49.6)	2222 (50.5)		1.05 (0.72–1.55)	0.786	1.08 (0.71–1.64)	0.731
BMI (kg m^{-2})			<0.001				
Normal weight	40 (36.4)	1355 (33.2)		1.00 (reference)	–	1.00 (reference)	–
Underweight	14 (12.7)	1277 (31.3)		3.16 (1.63–5.81)	<0.001	2.89 (1.38–5.81)	0.004
Overweight	38 (34.5)	1294 (31.7)		0.97 (0.61–1.53)	0.894	0.81 (0.43–1.49)	0.507
Obese	18 (16.4)	151 (3.7)		0.48 (0.27–0.82)	0.010	1.28 (0.78–2.12)	0.335
ASA physical status			<0.001				
1	3 (2.3)	573 (13.1)		1.00 (reference)	–	1.00 (reference)	–
2	31 (23.7)	2284 (52.4)		3.32 (0.99–20.64)	0.102	2.66 (0.78–16.65)	0.186
3	41 (31.3)	1317 (30.2)		7.82 (2.38–48.20)	0.005	3.92 (1.15–24.58)	0.066
4	41 (31.3)	168 (3.9)		55.57 (16.64–345.09)	<0.001	13.37 (3.72–85.91)	<0.001
5	15 (11.5)	18 (0.4)		163.12 (39.19–1120.77)	<0.001	35.01 (7.68–253.35)	<0.001
Smoking status			0.071				
Non-smoker	105 (78.9)	3664 (83.3)		1.00 (reference)	–	1.00 (reference)	–
Current smoker	28 (21.1)	732 (16.7)		1.51 (0.94–2.35)	0.073	1.48 (0.86–2.47)	0.140
Revised cardiac risk index			<0.001				
0	74 (55.6)	3067 (69.8)		1.00 (reference)	–	1.00 (reference)	–
1	39 (29.3)	984 (22.4)		1.67 (1.07–2.57)	0.022	1.15 (0.70–1.87)	0.576
≥2	20 (15.0)	340 (7.7)		3.00 (1.72–5.01)	<0.001	1.30 (0.68–2.38)	0.415
Operative approach			<0.001				
Laparoscopic	22 (20.2)	1542 (38.1)		1.00 (reference)	–	1.00 (reference)	–
Open	87 (79.8)	2507 (61.9)		2.43 (1.55–3.99)	<0.001	1.13 (0.68–1.93)	0.647
Operative urgency			<0.001				
Elective	41 (30.8)	3278 (74.6)		1.00 (reference)	–	1.00 (reference)	–
Emergency	92 (69.2)	1118 (25.4)		6.05 (4.08–9.10)	<0.001	2.78 (1.65–4.72)	<0.001
Operative risk class			<0.001				
0	1 (0.8)	348 (7.9)		1.00 (reference)	–	1.00 (reference)	–
1	60 (45.1)	2544 (57.9)		7.13 (1.56–126.42)	0.052	1.26 (0.23–23.69)	0.831
2	72 (54.1)	1504 (34.2)		14.11 (3.09–249.86)	0.009	1.43 (0.25–27.11)	0.739
Operative pathology			0.030				
Benign	85 (63.9)	2275 (51.8)		1.00 (reference)	–	1.00 (reference)	–
Malignant	48 (36.1)	2121 (48.2)		0.65 (0.44–0.96)	0.031	1.11 (0.68–1.82)	0.677

Discussion

The principal finding was that after risk adjustment for patient, disease and operation-specific factors, planned and unplanned admissions to critical care were associated with higher odds of 30-day postoperative mortality. Converse to common expectations, but consistent with similar studies,[2,7–10] this analysis did not demonstrate a benefit to critical care on 30-day postoperative mortality. This likely represents the presence of unaccounted confounding factors because of appropriate selection bias of patients at higher risk of mortality being admitted. This is difficult to adequately account for in observational research, although this methodology remains best suited to explore this issue, given the ethical and practical difficulties in conducting randomised service-level research regarding critical care admission.[12]

There is ongoing debate on whether planned critical care admissions provide a benefit particularly to 'intermediate-risk' patients (i.e. outside those at the highest risk of complications or emergency surgical patients) and whether it reduces the incidence of so called 'failure to rescue' (i.e. patients who die after a postoperative complication).[11,12] Critical care is a costly and finite resource and many patients with planned admissions directly from theatre do not require traditional critical care interventions (e.g. organ support or invasive monitoring).[11] Thus, the benefit associated with routine critical care admission may actually derive from the enhanced nursing support, early recognition and management of postoperative complications, and increased resources to support enhanced recovery after surgery programmes.[24] Furthermore, critical care is resource-intensive, limited in capacity, and not without the risk of harm (i.e. delirium, delayed mobilisation, or hospital acquired infection).[24,25] Interventions such as implementation of PACUs or '23-hour' recovery, expansion of specialist wards with enhanced nursing input (e.g. Level 1 high dependency units), improved critical care outreach services,

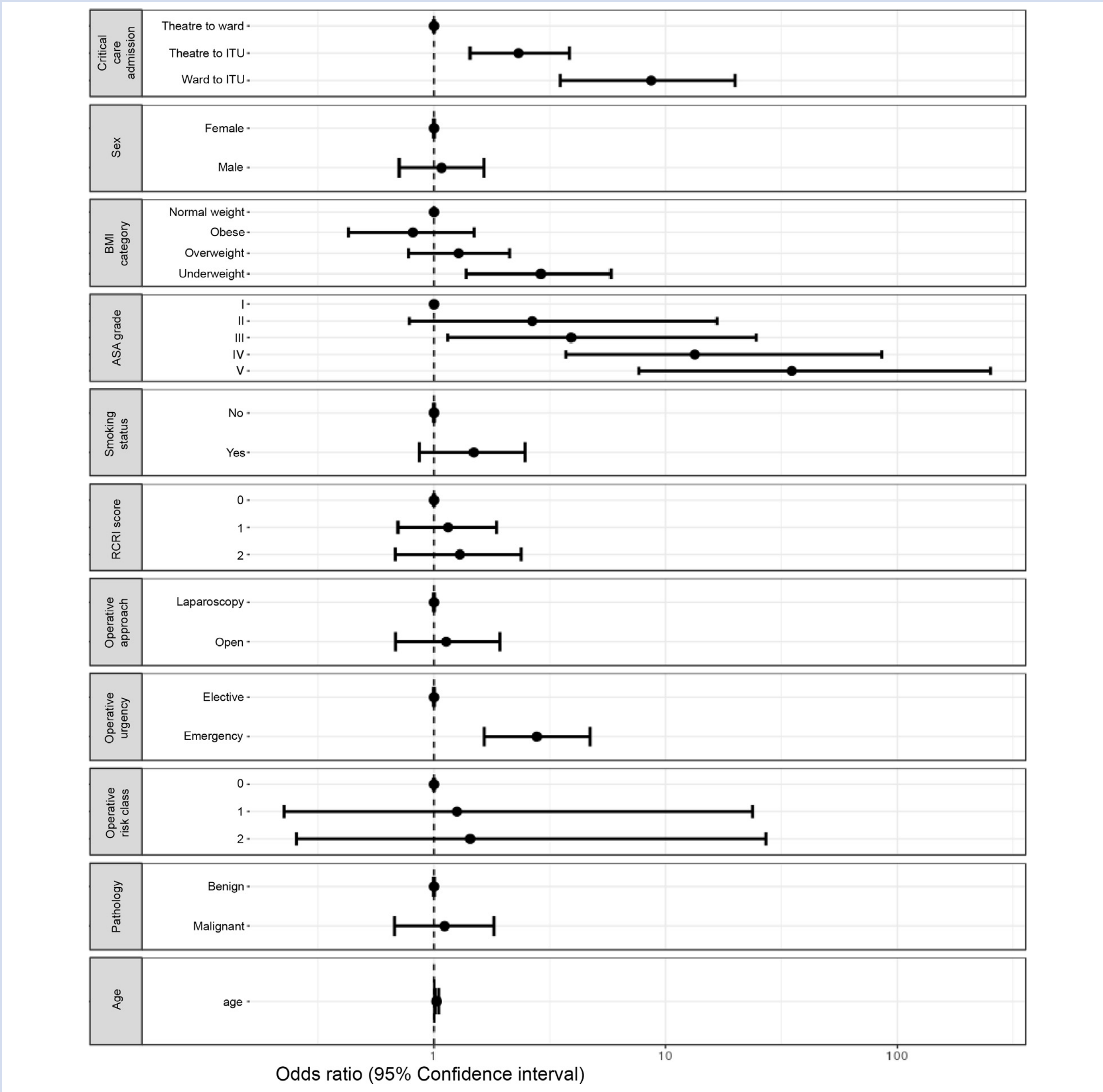

Fig 2. Forest plot of the odds ratio and 95% confidence interval derived from the multivariate logistic regression model for 30-day postoperative mortality. RCRI, revised cardiac risk index.

perioperative medicine teams, and other quality improvement initiatives may reduce the incidence of failure to rescue and have been identified as areas for further investigation.[24,26,27] Strategies for improved triage and risk prediction models to identify who will benefit from planned critical care admission are also essential; this has been highlighted as a major focus for perioperative care research in the future.[27]

Unplanned admissions to critical care represented a small but important minority (*n*=86) and were associated with worse survival outcomes than planned admissions, as previously reported.[7,10,28] The European Surgical Outcomes Study[2] identified that 73% of inpatient deaths were never admitted to critical care after operation, with 43% of those who died having been discharged from critical care; the authors highlighted a systematic failure in allocation of critical care resources. Unplanned admission to critical care can be because of an acute deterioration in an existing clinical condition (potentially preventable), or a serious, unexpected adverse event with a non-modifiable outcome. Unplanned postoperative admissions to critical care demonstrate a wide variation in the proportion of preventable adverse events, between 17.0% and 76.5%.[29] Within our cohort, several complications requiring unplanned admissions were potentially modifiable (Supplementary material, File 1). Moreover, those requiring unplanned admissions had closer preoperative and operative risk profiles to those admitted directly from theatre (than

Table 3 Univariable and mixed-effects logistic regression for planned postoperative location. CI, confidence interval, alpha level =0.05. Variables modelled as fixed-effects are presented in the table, with the operative centre modelled as a random-effect. Values are displayed as *n* (%) unless indicated otherwise. *Values are mean (standard deviation). †*n*=183 records excluded because of missing data. ‡χ^2 test, except ¶two sample *t*-test (two-sided).

	Planned postoperative location			Univariable analysis		Multivariable analysis†	
	Critical care (*n*=505)	Ward (*n*=522)	P-value‡	Odds ratio (95% CI)	P-value	Odds ratio (95% CI)	P-value
Age (yr)*	66.4 (18–97)	60.0 (18–94)	<0.001	1.02 (1.01–1.03)	<0.001	1.01 (1.00–1.02)	0.066
Sex			0.313				
Male	255 (50.5)	280 (53.6)		1.00 (reference)	–	1.00 (reference)	–
Female	250 (49.5)	242 (46.4)		1.13 (0.89–1.45)	0.313	1.18 (0.88–1.58)	0.273
BMI (kg m^{-2})			0.247				
Normal weight	192 (38.0)	225 (43.1)		1.00 (reference)	–	1.00 (reference)	–
Underweight	113 (22.4)	94 (18.0)		1.41 (1.01–1.97)	0.045	1.24 (0.67–2.27)	0.495
Overweight	165 (32.7)	169 (32.4)		1.14 (0.86–1.53)	0.360	1.12 (0.79–1.57)	0.534
Obese	35 (6.9)	34 (6.5)		1.21 (0.72–2.01)	0.471	1.59 (1.06–2.39)	0.024
ASA physical status			<0.001				
1	36 (7.1)	82 (15.7)		1.00 (reference)	–	1.00 (reference)	–
2	149 (29.5)	228 (43.7)		1.49 (0.96–2.34)	0.078	1.41 (0.84–2.37)	0.190
3	200 (39.6)	175 (33.5)		2.60 (1.69–4.08)	<0.001	2.23 (1.30–3.84)	0.004
4	100 (19.8)	35 (6.7)		6.51 (3.80–11.41)	<0.001	5.61 (2.87–10.98)	<0.001
5	20 (4.0)	2 (0.4)		22.78 (6.21–147.50)	<0.001	22.44 (4.53–111.24)	<0.001
Smoking status			0.089				
Non-smoker	399 (79.0)	389 (74.5)		1.00 (reference)	–	1.00 (reference)	–
Current smoker	106 (21.0)	133 (25.5)		0.78 (0.58–1.04)	0.089	0.89 (0.63–1.28)	0.537
Revised cardiac risk index			0.001				
0	314 (62.2)	379 (72.6)		1.00 (reference)	–	1.00 (reference)	–
1	127 (25.1)	106 (20.3)		1.45 (1.07–1.95)	0.015	0.93 (0.64–1.35)	0.698
≥2	64 (12.7)	37 (7.1)		2.09 (1.36–3.24)	<0.001	1.14 (0.66–1.97)	0.638
Operative approach			<0.001				
Laparoscopic	74 (14.7)	156 (29.9)		1.00 (reference)	–	1.00 (reference)	–
Open	431 (85.3)	366 (70.1)		2.48 (1.83–3.40)	<0.001	2.21 (1.54–3.19)	<0.001
Operative risk class			0.252				
0	1 (0.2)	4 (0.8)		1.00 (reference)	–	1.00 (reference)	–
1	203 (40.2)	225 (43.1)		3.61 (0.53–70.91)	0.253	5.04 (0.44–58.27)	0.195
2	301 (59.6)	293 (56.1)		4.11 (0.60–80.64)	0.207	5.47 (0.47–63.06)	0.173
Operative pathology			0.960				
Benign	396 (78.4)	410 (78.5)		1.00 (reference)	–	1.00 (reference)	–
Malignant	109 (21.6)	112 (21.5)		1.01 (0.75–1.36)	0.960	0.99 (0.69–1.42)	0.949

those remaining in ward care). Whilst this implies that some patients may have benefitted from planned critical care admissions, the timing of complications contributing to unplanned admission was not collected. Therefore, a more in-depth understanding of the interaction between early and late complications with failure to rescue was not possible from this dataset.

Our findings suggest variation between hospitals in critical care admission policy and capacity; this could have contributed to the incidence of unplanned ICU admission. Ensuring that appropriate patients are admitted to critical care after surgery has been highlighted as a priority in the UK in recent NCEPOD recommendations,[14] and National Emergency Laparotomy Audit (NELA).[6] Current NELA standards recommend that all emergency laparotomy patients should undergo preoperative risk assessment, and that patients with a predicted mortality >10% are admitted to critical care after operation. In comparison with 2015 NELA data, the standardised (44%) and adjusted rates (49%) of direct postoperative admission to critical care were lower than the 60% previously recorded.[6] Furthermore, as in our study, significant variations in local practice have been previously noted regarding postoperative critical care admissions.[9,30,31] Admission rates between 31% and 100% (median: 56%) of emergency laparotomy patients have been observed across England,[13] and key determinants are likely to be local case-mix, clinical decision-making, and critical care availability. While variation in practice is inevitable based on these considerations,[15] quality improvement should focus on recognising and standardising the aspects of variation that positively impact perioperative care across centres. Data on critical care capacity was not collected in DISCOVER, however it has been previously reported that centres with the lowest bed capacities have significantly higher 30-day mortality after high-risk emergency general surgical procedures.[9] There is also evidence to suggest that access to critical care, rather than the absolute capacity, is more relevant to reducing mortality.[31] Ensuring adequate critical care capacity to care for appropriately risk-stratified patients remains essential. The importance of rationalisation of critical care resources has been highlighted by a number of recent publications. Day of surgery cancellations have become increasing frequent in modern practice, with a substantial negative impact on patients and healthcare providers 32. The availability of critical care beds has been identified as a key contributor to cancellation of surgery. In a 2018 service-wide analysis, operations with planned post-operative critical care admission had 3-fold higher odds of cancellation due to bed capacity issues (OR: 2.92, 95% CI: 2.12 to 4.02, $P < 0.001$) 33.

The current analysis had several advantages over previous studies on this topic, which have been principally retrospective and registry-derived. It is based on a large, prospective, multicentre, cohort study of consecutive patients undergoing major gastrointestinal and liver surgery, and its internal validity is high, with case validation demonstrating a high level of case ascertainment and data accuracy. Data were collected on important patient sociodemographic and operative variables relevant to preoperative decision-making, with high completeness.

Our study also has several potential weaknesses. Although the majority of centres in the UK and Ireland which perform gastrointestinal and liver surgery contributed to DISCOVER,[32,34] a participation bias towards larger-volume centres could have affected the critical care capacity and so admission rates observed. The 'snapshot' methodology utilised in DISCOVER can bias the results if the data collection period is not representative of usual practice—this is a particular concern in lower-volume centres and may have contributed to variation observed (Supplementary material, File 2). The reliability of this study is limited by its observational nature and although associations have been identified, causality cannot be demonstrated. Because of the nature of this paper as a secondary analysis, and being a principally student-led data collection process, granular data on the intraoperative and perioperative management of patients were not feasible to collect. These data may have provided a more complete understanding of the clinical course of these patients, and additional data for adjustment (e.g. delineating Level 2 and 3 beds, preoperative risk scores, or decisions regarding 'do not resuscitate' and treatment restrictions). Finally, the overall 30-day mortality (2.9%, n=133/4519) is on the higher range of reported postoperative mortality in national registries[33,35] and so may reflect the focus on major gastrointestinal and liver surgeries, including emergency cases.

It is essential that limited critical care resources are directed towards the patients who will benefit most. Within this national cohort, planned and unplanned admissions to critical care were associated with higher odds of postoperative death within 30 days. While unaccounted bias and confounding likely contribute, the consistent lack of benefit observed in this and other studies should prompt reflection on the risk-stratification process for critical care admission, and the additional value of routine admissions after major gastrointestinal and liver surgery. Future research efforts should focus on improving preoperative selection for planned critical care admission to minimise the risk and outcome of complications. In addition, more should be done to understand the causes and timing of unplanned critical care admissions in the early postoperative period to better determine whether planned admissions could avert or mitigate these. Overall, ensuring there remains sufficient capacity and appropriate usage of critical care resources for risk-stratified patients remains a key target for quality improvement in perioperative care.

Authors' contributions

Responsible for data interpretation and drafting of the final manuscript: the writing group.
Oversaw project conception and acts as overall guarantor: E.M.
Responsible for statistical analysis and modelling: K.A., J.G., E.M.
Responsible for project level steering, national coordination, and data collection: the steering group.
Responsible for ensuring adherence to hospital-level governance protocols and regional data collection: local leads.
Responsible for patient level data collection and dataset validation: collaborators.
Read and approved the final manuscript, offering critical feedback: all members of the authorship group.

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Declaration of interest

The authors declare that they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.bja.2018.07.029.

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