Validation of the days alive and out of hospital (DAOH) outcome measure in a retrospective cohort of patients having emergency laparotomy

Background Days alive and out of hospital (DAOH) is a composite, patient-centred outcome measure describing a patient's postoperative recovery, encompassing hospitalisation and mortality. DAOH is the number of days not in hospital over a defined postoperative period. Patients who die have DAOH of zero. The Standardising Endpoints in Perioperative Medicine (StEP) group recommended it as a perioperative outcome. However, DAOH has never been validated in patients undergoing emergency laparotomy (EL). Here, we validate DAOH after EL and establish the optimal duration of observation.

Methods Prospectively collected data of patients having EL in England (1 December 2013 – 30 November 2017) were linked to national hospital admission and mortality records for the year following surgery. We evaluated construct validity by assessing DAOH variation with known perioperative risk factors, and predictive validity for one-year mortality using multivariate Bayesian mixed-effects logistic regression. Optimal postoperative DAOH period (30-days or 90-days) was judged on distributional and pragmatic properties.

Conclusions DAOH is a valid, patient-centred outcome after EL. We recommend its use in clinical trials, quality assurance and quality improvement, measured at 30-days since mortality heavily skews DAOH measured at 90-days and beyond.

Results 78921 records were analysed. Median 30-day DAOH (DAOH30) was 16 days (IQR 0-22), and median DAOH90 75days (46-82). DAOH was shorter in the presence of known perioperative risk factors. For patients surviving the first 30 postoperative days, shorter DAOH30 was associated with higher one-year mortality.

Introduction

Emergency laparotomy (EL) is carried out on acutely unwell patients, many with underlying comorbidities, requiring prolonged periods of complex postoperative care. The National Emergency Laparotomy Audit (NELA) examines outcomes for most patients in England and Wales having such surgery. It aims to improve quality of care and outcomes a

Mortality is a key outcome measure used for quality assurance and research in this cohort. However, for the majority of patients, who survive their surgery, this inadequately describes their postoperative recovery The Standardised Endpoints in Perioperative Medicine (StEP) initiative [1] endeavoured to define a set of patient-centred outcomes in perioperative medicine. This group recommended Days Alive and Out of Hospital at 30 days ($DAOH_{30}$) as a robust outcome. DAOH also describes resource utilisation and quality of care. DAOH is easy to measure at scale using established data linkage methods, unlike questionnaire-based methods or variably defined morbidity outcomes.

The concept of DAOH arose in the context of chronic diseases. [2–5] Its introduction to perioperative medicine has been led by Myles *et al* [6] who validated its use in an Australian cohort of patients enrolled in clinical trials. Several authors have since applied this in broader perioperative settings. Bell *et al* [7] examined DAOH in a Swedish cohort of 636885 patients having a mixture of elective and emergency surgery. In Canada, Jerath *et al* [8] analysed DAOH in 540072 patients having elective surgery. Jørgensen *et al* [9] used this measure in a Danish cohort of 16137 patients having elective hip and knee arthroplasty. All these authors provided strong evidence of the validity and utility of DAOH as an outcome in perioperative settings.

DAOH has never been validated in a cohort exclusively having emergency laparotomy. Those studies applying DAOH to a perioperative cohort [6–9] have validated DAOH at 30 days; this was also recommended by the StEP initiative. [1] In contrast to these studies of elective or mixed elective and emergency surgical populations, the cohort having emergency laparotomy has a higher population mortality rate (approximately 10% 30-day mortality [10]), longer postoperative hospital stays and high rates of readmission. To appropriately weight the outcome of mortality, patients who die within the period are defined to have DAOH of zero days. This definition shifts the mass of the bimodal distribution heavily to zero. In a population of this type, we hypothesised that measurement of DAOH over a 90-day period would better reflect outcomes of this cohort.

We further hypothesised that greater degrees of comorbidity and more severe pathology would be present in patients with shorter DAOH, and that patients with short DAOH would have higher long-term mortality rates.

In this study, we aimed to provide evidence of construct and predictive validity of DAOH in emergency laparotomy and to determine the optimal time period over which to measure DAOH in this setting.

Methods

Study design

This was a retrospective cohort study of patient level records. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [11] were followed and a STROBE checklist included in the supplementary material.

NELA collects data prospectively under a section 251 exemption of the NHS Act 2006. This analysis was approved by the NELA Project Team and the Healthcare Quality Improvement Project (HQIP).

Data sources

Patient level records were collected as part the NELA project in English hospitals, from 1 December 2013 to 30 November 2017. These records were linked with mortality data within one year of surgery held by the Office for National Statistics (ONS) and with Hospital Episode Statistics (HES) data for hospital admissions [12]. HES is a high-quality national database that records all NHS hospital admissions in England. It details dates, duration of stay and admitting hospital. Subsequent postoperative admissions might be to a hospital different from that undertaking the initial laparotomy surgery, this is captured by HES. Data were deterministically linked by NHS Number and demographic data using methods described previously. [13] Records with inconsistency between HES episode dates and NELA recorded date of surgery were excluded.

Patient identifiable data was stored on a secure server at the Royal College of Surgeons, London. Inclusion and exclusion criteria for the NELA project are described elsewhere, [14] broadly adult patients having emergency intra-abdominal surgery of the gastrointestinal tract in NHS hospitals within England and Wales are included. Some surgery, notably appendicectomy and cholecystectomy, are excluded.

Calculation of DAOH

DAOH was defined as in Myles *el al*. [6] Total postoperative duration of initial and any subsequent hospital stays, over the defined period (30, 90, 180 or 365 postoperative days) was subtracted from the total period length to give the number of days spent out of hospital. **[Point 7]** Our data does not account for time spent in a non-hospital care facility. If a patient died within that time period, DAOH was defined as zero days. A longer DAOH is a more favourable outcome.

Descriptive analysis

Descriptive analyses included all patients with available DAOH data. Unadjusted summary statistics were presented as the median (IQR) for continuous variables and number (%) for categorical variables.

Validation

To establish construct validity of DAOH, we looked at variation in DAOH according to factors known to be associated with perioperative risk.

Categorising DAOH into "shorter" (DAOH below 33rd percentile) versus "longer" (all other) cohorts allows comparison of demographic and clinical factors between these groups. The 33rd percentile was used to define the longer and shorter groups, rather than the 10th percentile in Jerath *et al*. [8] This is to avoid the "shorter" DAOH cohort being composed primarily of patients with zero DAOH due to prolonged hospital stay or mortality in the time period.

Similarly to Jerath *et al*, [8] we examined the consistency of DAOH over time points by analysis of the movement between "shorter" and "longer" DAOH groups over time (30 days to 90 days to 180 days to 365 days).

Predictive Validity

Predictive validity is the ability of a measure to predict a future event in a manner consistent with clinical expectation. To determine the predictive validity of DAOH on one-year mortality, a multivariate mixed effects logistic regression model was constructed using Bayesian methodology. Both $DAOH_{30}$ and $DAOH_{90}$ were assessed. In each, the models excluded patients who had died within the 30 or 90 days, respectively.

To avoid over or under adjusting models, we borrowed from causal inference methods. [15–18] All covariates that affect one-year mortality would be expected to influence DAOH, acting as confounders. Therefore, all such variables were included as linear covariates (Supplementary table 9).

A random intercept for each hospital was included to account for within hospital correlation. We used uninformative flat prior distributions for the population effects [19] and scaled Students t-distributions (3 degrees of freedom, location 0, and scale 2.5) for standard deviations of global and hospital level intercepts. [20] Modelling was conducted using the 'brms' package [19,21] in R version 3.6.3 (2020-02-29). [22]

Determining optimal DAOH measurement period

DAOH can be measured over any time interval in the postoperative period. The optimal time-interval was determined through pragmatic considerations and observing the behaviour and composition (length of stay, readmissions and mortality) of DAOH at 30, 90, 180 and 365-day time points.

Results

Data

Patient level NELA records from 1 December 2013 - 30 November 2017 were linked with HES and ONS data (supplementary figure 1). Of the 94573 records, 81666 linked with high degree of certainty, 2745 were excluded due to inconsistency of dates between HES record and date of surgery recorded by NELA. The remaining 78921 patient level records were included for analysis.

Demographic descriptions included all 78921 patients. Regression analysis excluded 2828 records with missing covariates (supplementary figure 1).

Descriptive analysis of DAOH

Table 1: Summary of DAOH measure and constituent parts

DAOH (median, IQR)	Readmission (N (%))	Mortality (N (percent))	Length of stay after index surgery in survivors (median, IQR)
16 (0 to 22)	6223 (7.9)	8657 (11.0)	12 (7 to 21)
75 (46 to 82)	15079 (19.1)	11906 (15.1)	12 (7 to 24)
163 (122 to 171)	22896 (29.0)	14478 (18.3)	13 (7 to 26)
345 (261 to 356)	31507 (39.9)	17748 (22.5)	14 (8 to 29)

DAOH is a composite measure composed of hospital length of stay, additional stays resulting from readmissions and mortality. At 30 days, median (IQR) DAOH was 16 (0 to 22) days, median (IQR) index length of stay was 12 (7 to 21) days. 30-day mortality was 11.0% and 6223 (7.9%) had at least one readmission (table 1).

Over the year following EL, 60% of patients had no further hospital admissions. However, 21.5% had one hospital readmission and 17.5% had two or more readmissions. Stays for subsequent admissions tended to be shorter than for EL (median stay of 5 (IQR 2 to 10) days).

Mortality increases over time, at 11% by 30 days, increasing to 22.5% by 1 year.

Table 2: Pattern of mortality in patients with DAOH of zero days at 30, 90, 180 and 365-day observation points (DAOH = 0 can be the result of hospitalisation for the whole duration or due to mortality)

	Number with DAOH = 0	Number who died	Mortality rate (%)
DAOH 30	20936	8657	41.4
DAOH 90	13763	11906	86.5
DAOH 180	14795	14478	97.9

DAOH 365	17769	17748	99.9

DAOH of zero can result from mortality or hospital stay spanning the observation period. Patient mortality was the reason for DAOH of zero in 41.4% at 30 days, 86.5% at 90 days increasing to 97.9% and 99.9% by 180 and 365 days, respectively. Notably, 15.6% and 2.4% of all surviving patients remained in hospital at 30 and 90 days, respectively (table 2). By 180 and 365 days, the proportion of surviving patients remaining in hospital was 0.4% and <0.1%, respectively.

Table 3: Pattern of DAOH and number of admissions (including index EL admission) in patients who survive to 30, 90, 180 and 365 day observation points (median (IQR))

Period	DAOH (median (IQR))	1 admission	2 admissions	>2 admissions
30 days	18 (7 to 23)	64159 (91.3%)	5696 (8.1%)	409 (0.6%)
90 days	77 (66 to 83)	53286 (79.5%)	10480 (15.6%)	3249 (4.8%)
180 days	167 (155 to 172)	44942 (69.7%)	12961 (20.1%)	6540 (10.1%)
365 days	351 (338 to 357)	35833 (58.6%)	14362 (23.5%)	10978 (17.9%)

For patients who survived (table 3), median (IQR) DAOH was 18 (7 to 23) (7 to 23)- 23)), 77 (66 to 83) (66 to 83)- 83)), 167 (155 to 172) (155 to 172)- 172)), and 351 (338 to 357) (338 to 357)- 357)) days for 30, 90, 180 and 365 day periods, respectively. By 30 days, 8.7% of patients had at least one readmission, increasing to 20.4% at 90 days, 30.2% and 41.4% by 180 and 365 days, respectively.

Table 4: Impact of readmission on DAOH in patients who survive to 30, 90, 180 and 365 day observation points (median (IQR))

Period	DAOH (1 admission)	DAOH (2 admissions)	DAOH (>2 admissions)
30 days	18 (7 to 23)	15 (9 to 20)	14 (10 to 18)
90 days	79 (70 to 83)	71 (56 to 78)	61 (46 to 72)
180 days	170 (162 to 174)	161 (144 to 168)	146 (118 to 160)
365 days	355 (348 to 359)	347 (334 to 354)	330 (299 to 344)

[Point 5] Having one readmission shortens median $DAOH_{30}$ by 3 days and $DAOH_{90}$ by 8 days. Having two or more readmissions shortens $DAOH_{30}$ by 4 days and $DAOH_{90}$ by 18 days (supplementary table 4).

Characteristics of the population

Table 5: DAOH 30 variation according to perioperative risk factors

		DAOH 30	Primary admission LOS >30 days but discharged alive	Readmitted within 30-days	Died within 30-days
Characteristic	**No. of individuals (%)**	Median (IQR)	N = 8,659	N = 6,223	N = 8,657
Total (all)	78921	16 (0 to 22)	8659(11%)	6223(7.9%)	8657(11%)
Age (years)					
18-29	4298 (5.4)	22 (16 to 24.8)	179 (4.2%)	504 (12%)	75 (1.7%)
30-39	4615 (5.8)	21 (15 to 24)	235 (5.1%)	456 (9.9%)	111 (2.4%)
40-49	8044 (10.2)	20 (12 to 24)	499 (6.2%)	850 (11%)	304 (3.8%)
50-59	11442 (14.5)	19 (8 to 23)	919 (8.0%)	1,031 (9.0%)	719 (6.3%)
60-69	16942 (21.5)	16 (0 to 22)	1,825 (11%)	1,353 (8.0%)	1,748 (10%)
70-79	19531 (24.7)	12 (0 to 20)	2,611 (13%)	1,256 (6.4%)	2,905 (15%)
80+	14049 (17.8)	6 (0 to 17)	2,391 (17%)	773 (5.5%)	2,795 (20%)
Sex					
Female	41003 (52.0)	16 (0 to 22)	4,683 (11%)	3,233 (7.9%)	4,464 (11%)
Male	37918 (48.0)	16 (0 to 22)	3,976 (10%)	2,990 (7.9%)	4,193 (11%)
ASA					
1 or 2	35539 (45.0)	21 (15 to 24)	1,764 (5.0%)	3,017 (8.5%)	836 (2.4%)
3	28042 (35.5)	13 (0 to 20)	3,707 (13%)	2,427 (8.7%)	2,736 (9.8%)

4	13791 (17.5)	0 (0 to 12)	2,911 (21%)	758 (5.5%)	4,162 (30%)
5	1549 (2.0)	0 (0 to 0)	277 (18%)	21 (1.4%)	923 (60%)
ECG findings					
Normal	63088 (80.6)	18 (4 to 23)	6,053 (9.6%)	5,264 (8.3%)	5,175 (8.2%)
AF with normal rate	3345 (4.3)	8 (0 to 19)	502 (15%)	264 (7.9%)	608 (18%)
AF abnormal Q-waves, ST segment, T-waves	11884 (15.2)	3 (0 to 17)	2,031 (17%)	649 (5.5%)	2,802 (24%)
Cardiac signs					
No failure	57606 (73.4)	18 (5 to 23)	5,344 (9.3%)	4,764 (8.3%)	4,533 (7.9%)
Mild	19932 (25.4)	8 (0 to 19)	3,072 (15%)	1,370 (6.9%)	3,745 (19%)
Severe	935 (1.2)	0 (0 to 12)	184 (20%)	50 (5.3%)	311 (33%)
Respiratory signs					
No dyspnoea	56809 (72.4)	18 (7 to 23)	4,998 (8.8%)	4,675 (8.2%)	3,990 (7.0%)
Exertional dyspnoea	12738 (16.2)	9 (0 to 19)	1,961 (15%)	946 (7.4%)	2,172 (17%)
Limiting dyspnoea	6365 (8.1)	1 (0 to 16)	1,104 (17%)	432 (6.8%)	1,561 (25%)
Resting dyspnoea	2572 (3.3)	0 (0 to 10)	543 (21%)	132 (5.1%)	864 (34%)
Urgency					
Expedited	13061 (16.6)	18 (7 to 23)	1,130 (8.7%)	1,254 (9.6%)	851 (6.5%)
Urgent	56265 (71.6)	17 (1 to 22)	5,983 (11%)	4,410 (7.8%)	5,300 (9.4%)
Immediate	9251 (11.8)	1 (0 to 18)	1,505 (16%)	529 (5.7%)	2,470 (27%)
Malignancy					
None	60534 (77.0)	16 (0 to 22)	6,758 (11%)	4,672 (7.7%)	6,377 (11%)

Primary	9771 (12.4)	16 (0 to 21)	1,077 (11%)	741 (7.6%)	964 (9.9%)
Nodal metastases	3148 (4.0)	15 (0 to 21)	330 (10%)	258 (8.2%)	387 (12%)
Distant metastases	5186 (6.6)	14 (0 to 21)	456 (8.8%)	531 (10%)	893 (17%)
Laparoscopic	6837 (8.7)	22 (15 to 25)	370 (5.4%)	649 (9.5%)	269 (3.9%)
Open surgery	72084 (91.3)	15 (0 to 22)	8,289 (11%)	5,574 (7.7%)	8,388 (12%)
Ischaemia	9865 (12.5)	6 (0 to 20)	1,459 (15%)	567 (5.7%)	2,319 (24%)
Obstruction	27361 (34.7)	18 (4 to 23)	2,574 (9.4%)	2,231 (8.2%)	2,295 (8.4%)
Bleeding	2515 (3.2)	14 (0 to 22)	352 (14%)	214 (8.5%)	346 (14%)
Sepsis	28481 (36.1)	13 (0 to 21)	4,043 (14%)	1,990 (7.0%)	3,573 (13%)
Other pathology	32349 (41.0)	17 (2 to 22)	3,167 (9.8%)	2,785 (8.6%)	3,191 (9.9%)
NELA predicted 30-day mortality					
<5%	39502 (52.1)	21 (14 to 24)	1,954 (4.9%)	3,671 (9.3%)	607 (1.5%)
5-10%	12148 (16.0)	14 (0 to 20)	1,615 (13%)	985 (8.1%)	933 (7.7%)
10-20%	10818 (14.3)	7 (0 to 17)	1,956 (18%)	805 (7.4%)	1,685 (16%)
20-30%	5365 (7.1)	0 (0 to 13)	1,123 (21%)	262 (4.9%)	1,438 (27%)
30-40%	3251 (4.3)	0 (0 to 8)	702 (22%)	143 (4.4%)	1,137 (35%)
40-50%	2006 (2.6)	0 (0 to 1.8)	454 (23%)	69 (3.4%)	873 (44%)
>50%	2753 (3.6)	0 (0 to 0)	526 (19%)	50 (1.8%)	1,621 (59%)

DAOH at all time points decreases with increasing age, ASA score and more severe cardiorespiratory abnormalities (table 5 and supplementary tables 11-13). It is shorter for cases requiring more urgent surgery and in the presence of malignancy. Patients presenting with bowel ischaemia also have shorter DAOH compared to other categories of pathology. Finally, patients having laparoscopic or laparoscopic assisted surgery have longer DAOH than those having open surgery.

[Point 8] There is a striking relationship between the previously validated NELA Risk Adjustment model [23] predicted 30-day mortality and DAOH. Median $DAOH_{30}$ reduces from 21 for 5% predicted mortality to 0 days for risks ≥ 20%. This relationship persists after excluding patients who died within the time periods (supplementary table 15).

[Point 9] We observe that index length of stay in isolation exhibits a paradoxical behaviour. Shorter stays are found in groups with lower risk and those with more severe comorbidity (supplementary table 14).

Longer versus shorter DAOH groups

Patients surviving the first 30 days were divided into longer and shorter DAOH groups at each time point according to whether DAOH is above or below the 33rd percentile, respectively. The 33rd percentiles were 12 ($DAOH_{30}$), 69 ($DAOH_{90}$), 157 ($DAOH_{180}$) and 336 ($DAOH_{365}$) days.

Table 6: Characteristics of patients in longer versus shorter DAOH at 30 and 90 days in patients remaining alive by those times (percentages by column)

	DAOH 30		**DAOH 90**	
Characteristic	**Longer (>12 days)**	**Shorter (≤ 12 days)**	**Longer (>12 days)**	**Shorter (≤ 12 days)**
	N = 46,236	N = 24,028	N = 46,957	N = 20,058
Age (years)				
18-29	3,529 (7.6%)	694 (2.9%)	3,560 (7.6%)	640 (3.2%)
30-39	3,682 (8.0%)	822 (3.4%)	3,720 (7.9%)	732 (3.6%)
40-49	6,014 (13%)	1,726 (7.2%)	6,066 (13%)	1,524 (7.6%)
50-59	7,864 (17%)	2,859 (12%)	7,884 (17%)	2,465 (12%)
60-69	10,017 (22%)	5,177 (22%)	10,118 (22%)	4,357 (22%)
70-79	9,742 (21%)	6,884 (29%)	9,959 (21%)	5,673 (28%)
80+	5,388 (12%)	5,866 (24%)	5,650 (12%)	4,667 (23%)
Sex				
Female	23,670 (51%)	12,869 (54%)	24,136 (51%)	10,752 (54%)
Male	22,566 (49%)	11,159 (46%)	22,821 (49%)	9,306 (46%)
ASA				
1 or 2	28,172 (61%)	6,531 (27%)	28,629 (61%)	5,505 (27%)
3	14,681 (32%)	10,625 (44%)	14,865 (32%)	8,883 (44%)
4	3,250 (7.0%)	6,379 (27%)	3,315 (7.1%)	5,269 (26%)
5	133 (0.3%)	493 (2.1%)	148 (0.3%)	401 (2.0%)

ECG findings				
Normal	40,210 (88%)	17,703 (74%)	40,720 (87%)	14,883 (75%)
AF normal rate	1,397 (3.0%)	1,340 (5.6%)	1,440 (3.1%)	1,090 (5.5%)
AF abnormal Q-waves, ST segment, T-waves	4,265 (9.3%)	4,817 (20%)	4,436 (9.5%)	3,944 (20%)
Cardiac signs				
No failure	37,425 (81%)	15,648 (66%)	37,899 (81%)	13,116 (66%)
Mild	8,345 (18%)	7,842 (33%)	8,584 (18%)	6,512 (33%)
Severe	232 (0.5%)	392 (1.6%)	230 (0.5%)	321 (1.6%)
Respiratory signs				
No dyspnoea	37,794 (82%)	15,025 (63%)	38,294 (82%)	12,532 (63%)
Exertional dyspnoea	5,542 (12%)	5,024 (21%)	5,672 (12%)	4,232 (21%)
Limiting dyspnoea	2,104 (4.6%)	2,700 (11%)	2,163 (4.6%)	2,235 (11%)
Resting dyspnoea	559 (1.2%)	1,149 (4.8%)	585 (1.3%)	958 (4.8%)
Urgency				
Expedited	8,649 (19%)	3,561 (15%)	8,557 (18%)	2,919 (15%)
Urgent	34,021 (74%)	16,944 (71%)	34,656 (74%)	14,151 (71%)
Immediate	3,371 (7.3%)	3,410 (14%)	3,544 (7.6%)	2,903 (15%)
Malignancy				
None	35,912 (78%)	18,245 (76%)	37,080 (79%)	15,568 (78%)
Primary	5,639 (12%)	3,168 (13%)	5,739 (12%)	2,586 (13%)
Nodal metastases	1,750 (3.8%)	1,011 (4.2%)	1,695 (3.6%)	782 (3.9%)
Distant metastases	2,794 (6.1%)	1,499 (6.3%)	2,294 (4.9%)	1,043 (5.2%)
Laparoscopic	5,400 (12%)	1,168 (4.9%)	5,270 (11%)	1,026 (5.1%)
Open surgery	40,836 (88%)	22,860 (95%)	41,687 (89%)	19,032 (95%)
Ischaemia	4,089 (8.8%)	3,457 (14%)	4,240 (9.0%)	2,946 (15%)
Obstruction	17,422 (38%)	7,644 (32%)	17,763 (38%)	6,463 (32%)
Bleeding	1,319 (2.9%)	850 (3.5%)	1,385 (2.9%)	697 (3.5%)

Sepsis	14,623 (32%)	10,285 (43%)	15,261 (32%)	8,677 (43%)
Other pathology	19,712 (43%)	9,446 (39%)	19,518 (42%)	7,691 (38%)
NELA predicted 30-day mortality				
<5%	31,283 (70%)	7,612 (33%)	31,725 (70%)	6,585 (34%)
5-10%	6,506 (15%)	4,709 (20%)	6,664 (15%)	3,918 (20%)
10-20%	4,148 (9.3%)	4,985 (22%)	4,222 (9.4%)	4,109 (21%)
20-30%	1,406 (3.2%)	2,521 (11%)	1,396 (3.1%)	2,097 (11%)
30-40%	603 (1.4%)	1,511 (6.5%)	617 (1.4%)	1,205 (6.2%)
40-50%	257 (0.6%)	876 (3.8%)	262 (0.6%)	702 (3.6%)
>50%	197 (0.4%)	935 (4.0%)	210 (0.5%)	731 (3.8%)

Looking at characteristics of longer versus shorter $DAOH_{30}$ (table 6), younger patients are substantially more prevalent in the longer group and older patients in the shorter group. ASA scores increase and comorbidities (cardiorespiratory and ECG abnormalities) become more marked in the shorter group. There is no apparent difference in the distribution of malignancy between the groups, but patients with findings of bowel ischaemia or sepsis are more frequently represented in the shorter DAOH group than those with other pathology.

For patients in the shorter $DAOH_{30}$ group (supplementary table 16), 87.1% remain in the shorter group at 90 days, 82.8% at 180 days and 74.1% by 365 days. There is less movement from longer $DAOH_{30}$ to shorter DAOH groups at 90, 180 or 365 days. A similar, though smaller movement is seen when beginning at 90 days.

Table 7: Mortality for patients in longer versus shorter DAOH groups (excludes patients who died by 30 or 90 days)

	Number	90 day mortality (%)	180 day mortality (%)	365 day mortality (%)
DAOH 30				
Longer DAOH30	46236	2.08	4.42	8.09
Shorter DAOH30	24028	9.51	15.71	22.27
DAOH 90				
Longer DAOH90	46957		2.00	5.63
Shorter DAOH90	20058		8.14	15.94

Mortality rates steadily increase over the year in longer and shorter DAOH groups (table 7), but the rate of mortality is considerably higher by one year in the shorter $DAOH_{30}$ group (22.3 %) compared to the longer $DAOH_{30}$ group (8.1 %). The shorter and longer $DAOH_{90}$ groups show a similar pattern of 1 year mortality (15.9 versus 5.6 %).

Predictive validity

[Point 12] $DAOH_{30}$ and $DAOH_{90}$ have an association with subsequent one year mortality. After adjustment for risk factors and excluding patients who died within 30 ($N = 8657$) or 90 days ($N = 11906$) as appropriate. AUC was 0.84 (95% CI…) and odds ratio of 0.94 (95% credible interval 0.937 - 0.943) for $DAOH_{30}$ and AUC = 0.84, OR 0.976 (95% credible interval 0.975 - 0.978)) for $DAOH_{90}$.

Discussion

~~DAOH is a valid patient-centred outcome measure for patients having emergency laparotomy. Previous work has demonstrated its face validity [6–9] and confirm this for EL.~~ We have demonstrated, for the first time, both construct and predictive validity of DAOH after EL in a large cohort of patients. The measure varies as expected according to perioperative risk factors, in particular shorter DAOH in older patients and those with more severe comorbidities (ASA scores and cardiorespiratory impairment). And, in patients surviving the initial 30-days after surgery, DAOH was a good discriminator of one-year survival. It is notable that a substantial proportion of patients remain in hospital for a full 30 days, but the proportion decreases by 90 days and beyond.

The measure provides a single summary measure of perioperative recovery and extends the set of outcome measures for EL surgery beyond mortality **[Point 3+6]** and those reported by NELA. It also captures hospital readmission, which may be to multiple hospitals. For patients included in NELA, DAOH can be calculated at scale from existing linkage with HES and ONS data. The outcome is important for clinicians, service managers and patients alike. DAOH has been recommended as a perioperative outcome by the StEP expert group. [1] It may aid risk prediction, the consent process and lead to a better understanding of resource utilisation compared to simple measures of mortality and length of stay. DAOH is a well-defined measure indirectly reflecting patient comorbidity, risk and perioperative complications. It behaves as expected given patient risk factors. This is in contrast to isolated hospital length of stay (that may be short due to rapid recovery or early mortality).

We recommend use of DAOH at 30 days in the context of emergency laparotomy as an outcome measure for clinical trials and quality improvement. This has the optimal balance of performance and pragmatism in the EL population. Myles *et al* [6] cautioned that DAOH is heavily influenced by mortality if its rate exceeds approximately 10%. Beyond 30 days, mortality following EL rises beyond this rate. Furthermore, beyond 30 days, a DAOH value of zero becomes increasingly and predominantly reflective of mortality rather than prolonged hospital stay. The recommendation of measurement at 30 days is supported by previous investigators [6–9] and the StEP initiative. [1] A pragmatic argument can be made for a shorter duration of observation. The data is more rapidly obtainable and allows more agile responses in practice, without incumbent delays of a long follow up period.

There are several idiosyncrasies of DAOH. In common with other perioperative validation studies of DAOH [6–9] our cohort has a bimodal distribution. Some features are exaggerated in EL. The peak at zero days is more prominent in this setting and the second mode of shorter duration than previously described. The reasons for this divergence lie in the constituent parts of DAOH. The 30-day mortality rate after EL is considerably higher than in other studies. Initial hospital lengths of stay are longer and repeated hospitalisation more common. It is likely that DAOH is applicable to other high-risk emergency surgical populations with a similar pattern of mortality and recovery, such as after hip fracture repair.

Strengths and Limitations

To our knowledge, this is the largest validation of DAOH in an emergency laparotomy cohort. The cohort is drawn from NELA data than includes 181 NHS hospitals in England and Wales who perform EL on a regular basis. This high-quality dataset captures most EL procedures performed in England, [12,24–26] and links to national administrative data through reliable processes. This study is the first to validate DAOH in a cohort with such high average risk. However, DAOH is heavily influenced by mortality, suggesting a need for a conditional modelling approach for DAOH given death or survival. [6] As a clinical trial outcome, DAOH has superior statistical power compared to rare outcomes, such as mortality. In this cohort, mortality is common, nevertheless, DAOH provides a more holistic measure of recovery from surgery with a unique and more granular data point for each patient.

While quality and coverage of the NELA data and linkage to external datasets is good, it relies on local data validation and timely data entry. Some EL cases are missed (due to miscoding, hospital non-participation or inability to link data to HES/ONS). Nonetheless, generalisability of these results is expected to be high.

In the UK, hospital discharge may be delayed due to reasons external to hospital quality or patient recovery, such as delays to establishing home social support. These issues and nuances are not captured in the data. However, the mixed-effects modelling used here accounts, to a degree, for clustered effects. This analysis only used data collected in England. Health and community services differ between countries; therefore, consideration would need to be given to the local setting when using the measure.

Finally, existing data linkage agreements for NELA do not include the ability to determine the discharge destination. Therefore, we cannot identify stays in a rehabilitation or nursing care facility. These are clearly important considerations for a patient discharged from hospital after surgery.

Further work

DAOH is finding favour as an outcome in perioperative studies. [27,28] This should now be extended to emergency laparotomy cohorts. Furthermore, there is an association between shorter DAOH outcomes and socioeconomic deprivation, [29] a similar signal for mortality was identified after emergency laparotomy. [30] Similar analysis of DAOH would be warranted. Patient-focussed research should be conducted to determine how to communicate the concept of DAOH.

Conclusion

$DAOH_{30}$ is a valid outcome measure for patients having emergency laparotomy. Its definition is simple and consistent, allowing easy comparison between studies. DAOH can be derived from existing data sources and has predictive value for longer term mortality. $DAOH_{30}$ is an outcome measure that has received consensus support from the perioperative medicine community [1] and should be used in clinical trials, quality assurance or improvement projects in the emergency laparotomy cohort.

Supplementary Material

STROBE Checklist

Table 8: SUPPLEMENTARY TABLE: STROBE Statement—Checklist of items that should be included in reports of cohort studies

	Item Number	Recommendation	
Title and abstract	1	(a) Indicate the study's design with a commonly used term in the title or the abstract	X
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	X
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	X
Objectives	3	State specific objectives, including any prespecified hypotheses	X
Methods			
Study design	4	Present key elements of study design early in the paper	X
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	X
Participants	6	(a) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	X
		(b) For matched studies, give matching criteria and number of exposed and unexposed	X
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	X
Data sources/measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	X
Bias	9	Describe any efforts to address potential sources of bias	X

Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	X
Statistical methods	12	(a) Describe all statistical methods, including those used to control for confounding	X
		(b) Describe any methods used to examine subgroups and interactions	X
		(c) Explain how missing data were addressed	X
		(d) If applicable, explain how loss to follow-up was addressed	N/A
		(e) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	X
		(b) Give reasons for non-participation at each stage	X
		(c) Consider use of a flow diagram	X
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	X
		(b) Indicate number of participants with missing data for each variable of interest	X
		(c) Summarise follow-up time (eg, average and total amount)	X
Outcome data	15*	Report numbers of outcome events or summary measures over time	X
Main results	16	(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make	X

		clear which confounders were adjusted for and why they were included	
		(b) Report category boundaries when continuous variables were categorised	X
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	X
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	X
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	X
Generalisability	21	Discuss the generalisability (external validity) of the study results	X
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	X

Covariates in model of one-year mortality

Table 9: SUPPLEMENTARY TABLE: Linear covariates included in one-year mortality predictive model

Variable	**Variable**
DAOH	Predicted blood loss
Age	Predictive peritoneal soiling
Sex	Heart rate
White cell count	Systolic blood pressure
Haemoglobin	Emergency laparotomy after elective surgery

Laparoscopic/Open approach	ASA score
Ischaemia	Cardiac pathology
Obstruction	Respiratory pathology
Bleeding	ECG abnormalities
Sepsis	Serum urea
Other pathology	Operating hospital (random effect term)
Malignancy	

Data linkage

Table 10: SUPPLEMENTARY TABLE: NELA-HES linkage quality

Match rank	N
1	72675
2	5188
3	13
4	1
5	4
6	16
Unknown	1024

Data inclusion and exclusion criteria

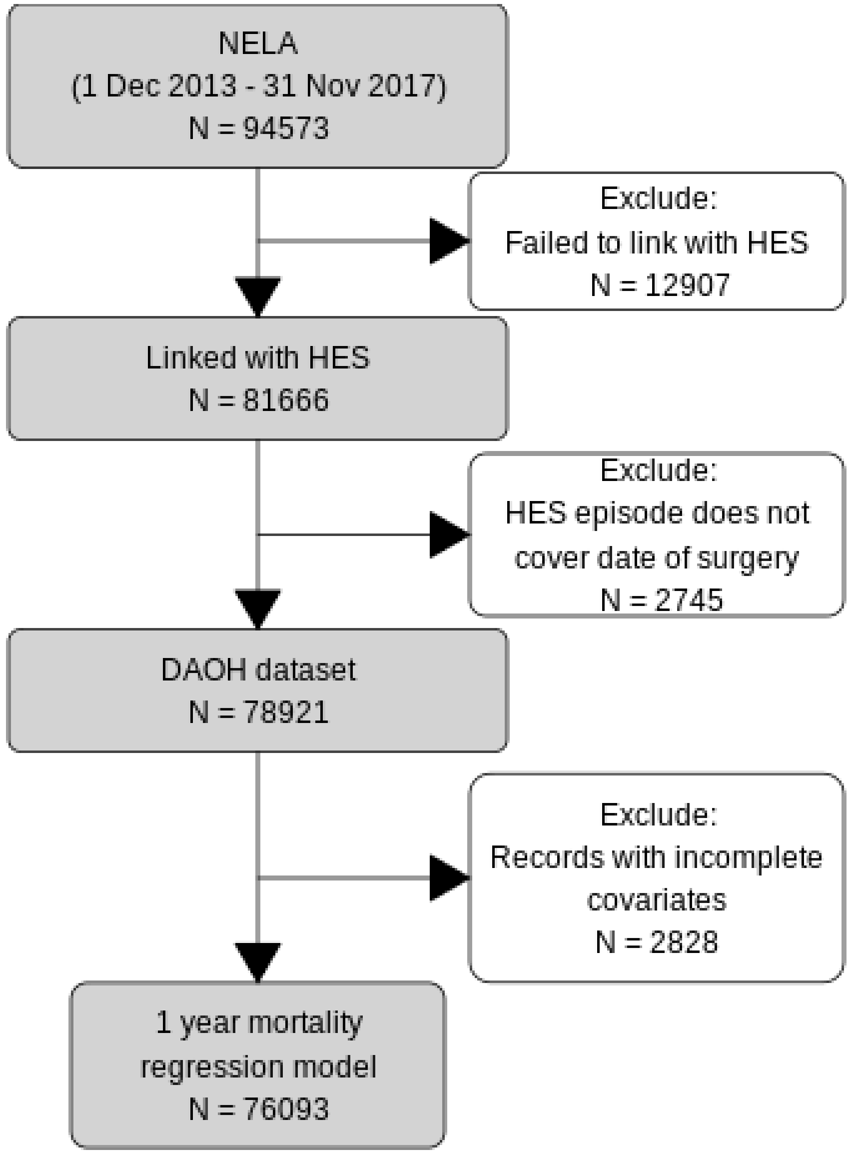

Figure 1: SUPPLEMENTARY FIGURE: DAOH data linkage CONSORT diagram. NELA data was deterministically linked with HES data on hospital admissions. The resulting data (DAOH dataset) was used for further analysis, including a variety of regression models. Records with incomplete covariates were excluded for these models as shown.

Distribution of DAOH at different time points

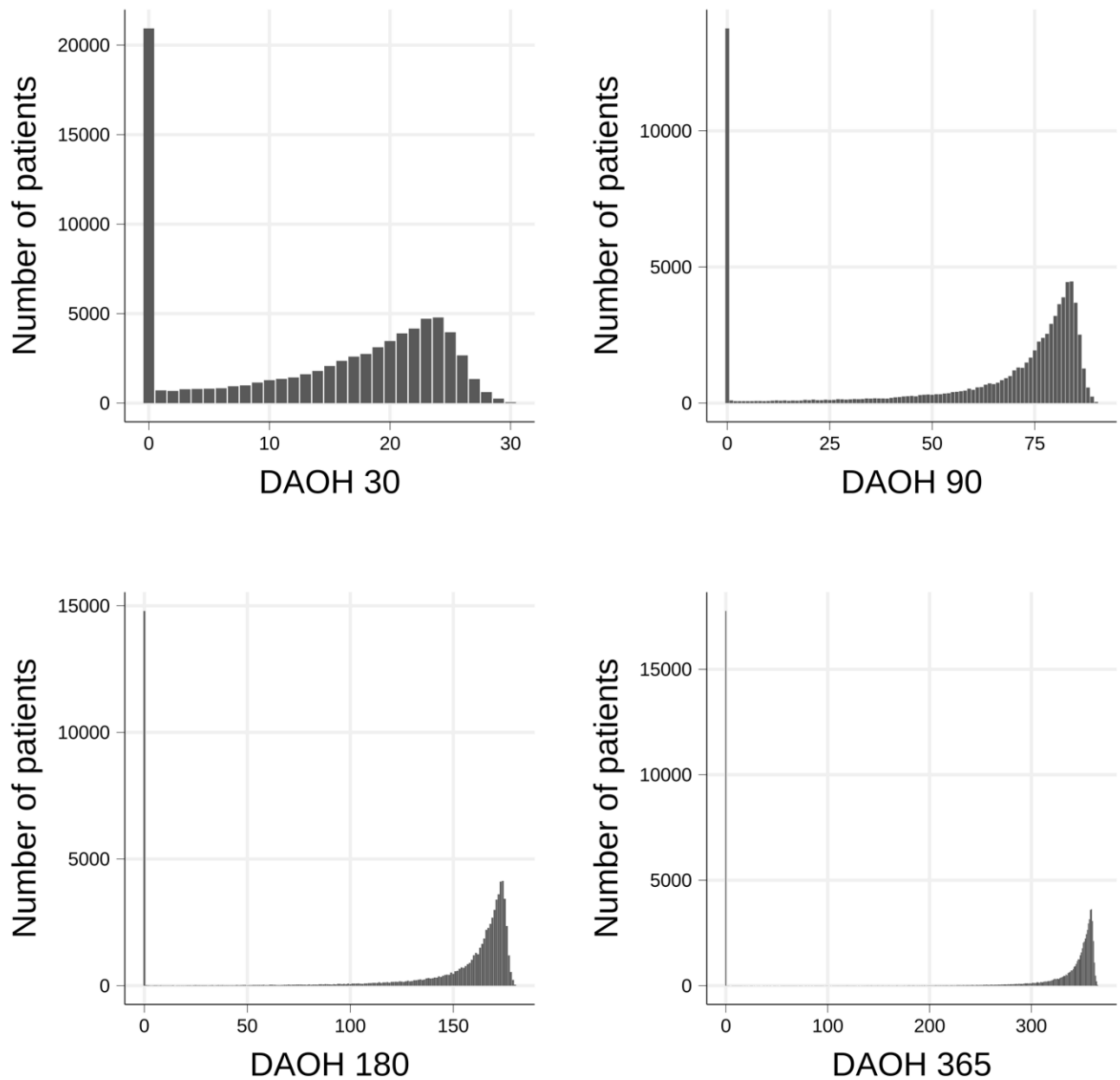

Figure 2: SUPPLEMENTARY FIGURE: Comparison of DAOH at 30, 90, 180 and 365 days after surgery

DAOH at 90, 180 and 365 days

Table 11: SUPPLEMENTARY TABLE: DAOH 90 variation according to perioperative risk factors

		DAOH 90	Primary admission LOS >90 days but	Readmitted within 90-days	Died within 90-days

			discharged alive		
Characteristic	No. of individuals (%)	Median (IQR)	N = 1,321	N = 15,079	N = 11,906
Total (all)	78921	75 (46 to 82)	1321(1.7%)	15079(19.1 %)	11906(15.1 %)
Age (years)					
18-29	4298 (5.4)	82 (75 to 84)	26 (0.6%)	871 (20%)	98 (2.3%)
30-39	4615 (5.8)	81 (74 to 84)	41 (0.9%)	918 (20%)	163 (3.5%)
40-49	8044 (10.2)	80 (70 to 84)	88 (1.1%)	1,649 (20%)	454 (5.6%)
50-59	11442 (14.5)	78 (63 to 83)	146 (1.3%)	2,334 (20%)	1,093 (9.6%)
60-69	16942 (21.5)	75 (46 to 82)	335 (2.0%)	3,400 (20%)	2,467 (15%)
70-79	19531 (24.7)	70 (18 to 80)	402 (2.1%)	3,596 (18%)	3,899 (20%)
80+	14049 (17.8)	61 (0 to 77)	283 (2.0%)	2,311 (16%)	3,732 (27%)
Sex					
Female	41003 (52.0)	74 (46 to 82)	681 (1.7%)	7,853 (19%)	6,115 (15%)
Male	37918 (48.0)	75 (46 to 82)	640 (1.7%)	7,226 (19%)	5,791 (15%)
ASA					
1 or 2	35539 (45.0)	80 (73 to 84)	207 (0.6%)	6,227 (18%)	1,405 (4.0%)
3	28042 (35.5)	71 (41 to 80)	505 (1.8%)	6,245 (22%)	4,294 (15%)
4	13791 (17.5)	28 (0 to 69)	556 (4.0%)	2,486 (18%)	5,207 (38%)
5	1549 (2.0)	0 (0 to 24)	53 (3.4%)	121 (7.8%)	1,000 (65%)
ECG findings					
Normal	63088 (80.6)	77 (57 to 82)	911 (1.4%)	12,232 (19%)	7,485 (12%)

AF normal rate	3345 (4.3)	64 (0 to 78)	70 (2.1%)	682 (20%)	815 (24%)
AF abnormal Q-waves, ST segment, T-waves	11884 (15.2)	56 (0 to 76)	324 (2.7%)	2,037 (17%)	3,504 (29%)
Cardiac signs					
No failure	57606 (73.4)	77 (59 to 83)	784 (1.4%)	11,023 (19%)	6,591 (11%)
Mild	19932 (25.4)	64 (0 to 78)	494 (2.5%)	3,782 (19%)	4,836 (24%)
Severe	935 (1.2)	19 (0 to 69)	29 (3.1%)	173 (19%)	384 (41%)
Respiratory signs					
No dyspnoea	56809 (72.4)	77 (61 to 83)	691 (1.2%)	10,787 (19%)	5,983 (11%)
Exertional dyspnoea	12738 (16.2)	65 (0 to 78)	350 (2.7%)	2,546 (20%)	2,834 (22%)
Limiting dyspnoea	6365 (8.1)	52 (0 to 75)	179 (2.8%)	1,220 (19%)	1,967 (31%)
Resting dyspnoea	2572 (3.3)	21 (0 to 67)	92 (3.6%)	430 (17%)	1,029 (40%)
Urgency					
Expedited	13061 (16.6)	77 (58 to 83)	125 (1.0%)	2,901 (22%)	1,585 (12%)
Urgent	56265 (71.6)	76 (52 to 82)	881 (1.6%)	10,648 (19%)	7,458 (13%)
Immediate	9251 (11.8)	55 (0 to 77)	307 (3.3%)	1,450 (16%)	2,804 (30%)
Malignancy					
None	60534 (77.0)	76 (50 to 82)	1,105 (1.8%)	10,753 (18%)	7,886 (13%)
Primary	9771 (12.4)	74 (48 to 81)	131 (1.3%)	1,927 (20%)	1,446 (15%)
Nodal metastases	3148 (4.0)	71 (25 to 80)	38 (1.2%)	783 (25%)	671 (21%)
Distant metastases	5186 (6.6)	65 (0 to 79)	38 (0.7%)	1,556 (30%)	1,849 (36%)

Laparoscopic	6837 (8.7)	82 (71 to 85)	41 (0.6%)	1,436 (21%)	541 (7.9%)
Open surgery	72084 (91.3)	74 (43 to 81)	1,280 (1.8%)	13,643 (19%)	11,365 (16%)
Ischaemia	9865 (12.5)	61 (0 to 79)	330 (3.3%)	1,625 (16%)	2,679 (27%)
Obstruction	27361 (34.7)	77 (58 to 83)	392 (1.4%)	5,113 (19%)	3,135 (11%)
Bleeding	2515 (3.2)	72 (34 to 81)	54 (2.1%)	454 (18%)	433 (17%)
Sepsis	28481 (36.1)	72 (35 to 81)	662 (2.3%)	5,047 (18%)	4,543 (16%)
Other pathology	32349 (41.0)	75 (48 to 82)	401 (1.2%)	6,988 (22%)	5,140 (16%)
NELA predicted 30-day mortality					
<5%	39502 (52.1)	80 (73 to 84)	251 (0.6%)	7,530 (19%)	1,192 (3.0%)
5-10%	12148 (16.0)	72 (47 to 80)	214 (1.8%)	2,609 (21%)	1,566 (13%)
10-20%	10818 (14.3)	61 (0 to 76)	310 (2.9%)	2,353 (22%)	2,487 (23%)
20-30%	5365 (7.1)	39 (0 to 70)	178 (3.3%)	959 (18%)	1,872 (35%)
30-40%	3251 (4.3)	7 (0 to 63)	123 (3.8%)	547 (17%)	1,429 (44%)
40-50%	2006 (2.6)	0 (0 to 53.8)	99 (4.9%)	275 (14%)	1,042 (52%)
>50%	2753 (3.6)	0 (0 to 20)	95 (3.5%)	226 (8.2%)	1,812 (66%)

Table 12: SUPPLEMENTARY TABLE: DAOH 180 variation according to perioperative risk factors

		DAOH 180	**Primary admission LOS >180 days but discharged alive**	**Readmitted within 180-days**	**Died within 180-days**
Characteristic	No. of individuals (%)	Median (IQR)	N = 243	N = 22,896	N = 14,478

Total (all)	78921	163 (122 to 171)	243(0.3%)	22896(29%)	14478(18.3 %)
Age (years)					
18-29	4298 (5.4)	171 (164 to 174)	11 (0.3%)	1,207 (28%)	124 (2.9%)
30-39	4615 (5.8)	171 (162 to 174)	12 (0.3%)	1,348 (29%)	206 (4.5%)
40-49	8044 (10.2)	169 (157 to 173)	22 (0.3%)	2,365 (29%)	572 (7.1%)
50-59	11442 (14.5)	167 (147 to 173)	36 (0.3%)	3,466 (30%)	1,374 (12%)
60-69	16942 (21.5)	163 (120 to 171)	73 (0.4%)	5,197 (31%)	3,072 (18%)
70-79	19531 (24.7)	157 (25 to 169)	64 (0.3%)	5,649 (29%)	4,730 (24%)
80+	14049 (17.8)	147 (0 to 166)	25 (0.2%)	3,664 (26%)	4,400 (31%)
Sex					
Female	41003 (52.0)	163 (122 to 171)	115 (0.3%)	11,837 (29%)	7,434 (18%)
Male	37918 (48.0)	164 (121 to 172)	128 (0.3%)	11,059 (29%)	7,044 (19%)
ASA					
1 or 2	35539 (45.0)	170 (161 to 174)	33 (<0.1%)	9,212 (26%)	2,016 (5.7%)
3	28042 (35.5)	159 (108 to 169)	88 (0.3%)	9,332 (33%)	5,567 (20%)
4	13791 (17.5)	96 (0 to 156)	107 (0.8%)	4,105 (30%)	5,867 (43%)
5	1549 (2.0)	0 (0 to 104)	15 (1.0%)	247 (16%)	1,028 (66%)
ECG findings					
Normal	63088 (80.6)	165 (139 to 172)	184 (0.3%)	18,305 (29%)	9,392 (15%)
AF normal rate	3345 (4.3)	149 (0 to 167)	12 (0.4%)	1,041 (31%)	971 (29%)
AF abnormal Q-waves, ST	11884 (15.2)	140 (0 to 165)	46 (0.4%)	3,355 (28%)	3,995 (34%)

segment, T-waves					
Cardiac signs					
No failure	57606 (73.4)	166 (142 to 172)	160 (0.3%)	16,495 (29%)	8,304 (14%)
Mild	19932 (25.4)	150 (0 to 167)	76 (0.4%)	5,975 (30%)	5,635 (28%)
Severe	935 (1.2)	74 (0 to 156)	7 (0.7%)	272 (29%)	429 (46%)
Respiratory signs					
No dyspnoea	56809 (72.4)	166 (145 to 172)	132 (0.2%)	16,117 (28%)	7,591 (13%)
Exertional dyspnoea	12738 (16.2)	152 (0 to 167)	54 (0.4%)	3,977 (31%)	3,394 (27%)
Limiting dyspnoea	6365 (8.1)	133 (0 to 163)	32 (0.5%)	1,959 (31%)	2,251 (35%)
Resting dyspnoea	2572 (3.3)	85.5 (0 to 155)	25 (1.0%)	702 (27%)	1,137 (44%)
Urgency					
Expedited	13061 (16.6)	165 (138 to 172)	21 (0.2%)	4,277 (33%)	2,173 (17%)
Urgent	56265 (71.6)	164 (132 to 172)	158 (0.3%)	16,134 (29%)	9,196 (16%)
Immediate	9251 (11.8)	141 (0 to 167)	64 (0.7%)	2,375 (26%)	3,042 (33%)
Malignancy					
None	60534 (77.0)	165 (134 to 172)	219 (0.4%)	16,340 (27%)	9,043 (15%)
Primary	9771 (12.4)	162 (121 to 170)	17 (0.2%)	3,080 (32%)	1,892 (19%)
Nodal metastases	3148 (4.0)	157 (0 to 169)	4 (0.1%)	1,179 (37%)	935 (30%)
Distant metastases	5186 (6.6)	83 (0 to 166)	3 (<0.1%)	2,205 (43%)	2,548 (49%)
Laparoscopic	6837 (8.7)	171 (157 to 175)	7 (0.1%)	2,018 (30%)	759 (11%)

Open surgery	72084 (91.3)	162 (116 to 171)	236 (0.3%)	20,878 (29%)	13,719 (19%)
Ischaemia	9865 (12.5)	148 (0 to 169)	69 (0.7%)	2,656 (27%)	2,937 (30%)
Obstruction	27361 (34.7)	166 (141 to 172)	86 (0.3%)	7,579 (28%)	3,813 (14%)
Bleeding	2515 (3.2)	161 (113 to 171)	11 (0.4%)	689 (27%)	485 (19%)
Sepsis	28481 (36.1)	160 (111 to 170)	108 (0.4%)	7,954 (28%)	5,284 (19%)
Other pathology	32349 (41.0)	163 (113 to 171)	66 (0.2%)	10,475 (32%)	6,714 (21%)
NELA predicted 30-day mortality					
<5%	39502 (52.1)	170 (161 to 173)	51 (0.1%)	11,015 (28%)	1,867 (4.7%)
5-10%	12148 (16.0)	160 (123 to 169)	35 (0.3%)	3,971 (33%)	2,072 (17%)
10-20%	10818 (14.3)	146 (0 to 165)	53 (0.5%)	3,635 (34%)	3,091 (29%)
20-30%	5365 (7.1)	111 (0 to 158)	35 (0.7%)	1,573 (29%)	2,202 (41%)
30-40%	3251 (4.3)	0 (0 to 149)	24 (0.7%)	905 (28%)	1,612 (50%)
40-50%	2006 (2.6)	0 (0 to 137)	23 (1.1%)	464 (23%)	1,145 (57%)
>50%	2753 (3.6)	0 (0 to 94)	15 (0.5%)	465 (17%)	1,897 (69%)

Table 13: SUPPLEMENTARY TABLE: DAOH 365 variation according to perioperative risk factors

		DAOH 365	**Primary admission LOS >365 days but discharged alive**	**Readmitted within 365-days**	**Died within 365-days**
Characteristic	No. of individuals (%)	Median (IQR)	N = 21	N = 31,507	N = 17,748

Total (all)	78921	345 (261 to 356)	21(0%)	31507(39.9 %)	17748(22.5 %)
Age (years)					
18-29	4298 (5.4)	355 (346 to 359)	3 (<0.1%)	1,711 (40%)	152 (3.5%)
30-39	4615 (5.8)	354 (344 to 359)	3 (<0.1%)	1,901 (41%)	278 (6.0%)
40-49	8044 (10.2)	353 (336.8 to 358)	1 (<0.1%)	3,332 (41%)	747 (9.3%)
50-59	11442 (14.5)	350 (319 to 357)	7 (<0.1%)	4,834 (42%)	1,784 (16%)
60-69	16942 (21.5)	345 (253 to 355)	2 (<0.1%)	7,044 (42%)	3,843 (23%)
70-79	19531 (24.7)	337 (0 to 353)	5 (<0.1%)	7,630 (39%)	5,707 (29%)
80+	14049 (17.8)	322 (0 to 349)	0 (0%)	5,055 (36%)	5,237 (37%)
Sex					
Female	41003 (52.0)	345 (266 to 356)	10 (<0.1%)	16,149 (39%)	9,070 (22%)
Male	37918 (48.0)	345 (254 to 356)	11 (<0.1%)	15,358 (41%)	8,678 (23%)
ASA					
1 or 2	35539 (45.0)	354 (342 to 358)	1 (<0.1%)	13,329 (38%)	2,986 (8.4%)
3	28042 (35.5)	339 (0 to 353)	4 (<0.1%)	12,592 (45%)	7,087 (25%)
4	13791 (17.5)	209 (0 to 336)	15 (0.1%)	5,268 (38%)	6,611 (48%)
5	1549 (2.0)	0 (0 to 274)	1 (<0.1%)	318 (21%)	1,064 (69%)
ECG findings					
Normal	63088 (80.6)	348 (305 to 356)	20 (<0.1%)	25,344 (40%)	11,861 (19%)
AF normal rate	3345 (4.3)	324 (0 to 350)	0 (0%)	1,410 (42%)	1,191 (36%)
AF abnormal Q -waves, ST	11884 (15.2)	313 (0 to 348)	1 (<0.1%)	4,487 (38%)	4,551 (38%)

segment, T-waves					
Cardiac signs					
No failure	57606 (73.4)	349 (310 to 357)	13 (<0.1%)	22,963 (40%)	10,468 (18%)
Mild	19932 (25.4)	326 (0 to 351)	6 (<0.1%)	8,006 (40%)	6,671 (33%)
Severe	935 (1.2)	0 (0 to 334)	2 (0.2%)	346 (37%)	480 (51%)
Respiratory signs					
No dyspnoea	56809 (72.4)	349 (317 to 357)	8 (<0.1%)	22,562 (40%)	9,746 (17%)
Exertional dyspnoea	12738 (16.2)	329 (0 to 351)	5 (<0.1%)	5,289 (42%)	4,021 (32%)
Limiting dyspnoea	6365 (8.1)	300 (0 to 345)	4 (<0.1%)	2,578 (41%)	2,608 (41%)
Resting dyspnoea	2572 (3.3)	168 (0 to 334)	4 (0.2%)	897 (35%)	1,251 (49%)
Urgency					
Expedited	13061 (16.6)	347 (278 to 356)	1 (<0.1%)	5,860 (45%)	2,936 (22%)
Urgent	56265 (71.6)	347 (292 to 356)	15 (<0.1%)	22,300 (40%)	11,427 (20%)
Immediate	9251 (11.8)	318 (0 to 350)	5 (<0.1%)	3,197 (35%)	3,294 (36%)
Malignancy					
None	60534 (77.0)	348 (306 to 356)	18 (<0.1%)	22,728 (38%)	10,493 (17%)
Primary	9771 (12.4)	342 (0 to 354)	2 (<0.1%)	4,327 (44%)	2,560 (26%)
Nodal metastases	3148 (4.0)	327.5 (0 to 352)	1 (<0.1%)	1,537 (49%)	1,273 (40%)
Distant metastases	5186 (6.6)	0 (0 to 340)	0 (0%)	2,793 (54%)	3,345 (65%)
Laparoscopic	6837 (8.7)	354 (334 to 360)	1 (<0.1%)	2,719 (40%)	1,025 (15%)
Open surgery	72084 (91.3)	344 (241.8 to 355)	20 (<0.1%)	28,788 (40%)	16,723 (23%)

Ischaemia	9865 (12.5)	326 (0 to 353)	3 (<0.1%)	3,494 (35%)	3,239 (33%)
Obstruction	27361 (34.7)	349 (312 to 357)	4 (<0.1%)	10,318 (38%)	4,720 (17%)
Bleeding	2515 (3.2)	344 (273.5 to 356)	1 (<0.1%)	911 (36%)	546 (22%)
Sepsis	28481 (36.1)	342 (264 to 354)	14 (<0.1%)	11,265 (40%)	6,176 (22%)
Other pathology	32349 (41.0)	344 (0 to 355)	6 (<0.1%)	14,290 (44%)	8,767 (27%)
NELA predicted 30-day mortality					
<5%	39502 (52.1)	353 (342 to 358)	3 (<0.1%)	15,786 (40%)	2,881 (7.3%)
5-10%	12148 (16.0)	340 (247.8 to 353)	2 (<0.1%)	5,380 (44%)	2,791 (23%)
10-20%	10818 (14.3)	318 (0 to 347)	4 (<0.1%)	4,756 (44%)	3,789 (35%)
20-30%	5365 (7.1)	242 (0 to 337)	6 (0.1%)	2,089 (39%)	2,544 (47%)
30-40%	3251 (4.3)	0 (0 to 325.5)	3 (<0.1%)	1,142 (35%)	1,802 (55%)
40-50%	2006 (2.6)	0 (0 to 312)	2 (<0.1%)	584 (29%)	1,240 (62%)
>50%	2753 (3.6)	0 (0 to 233)	1 (<0.1%)	590 (21%)	1,984 (72%)

Table 14: Index admission length of stay variation according to perioperative risk factors

		Index LOS (days)
Characteristic	No. of individuals (%)	Median (IQR)
Age (years)		
18-29	4298 (5.4)	6.9 (4.6 to 11.7)
30-39	4615 (5.8)	7.4 (4.9 to 12.4)
40-49	8044 (10.2)	8.3 (5.2 to 14.4)
50-59	11442 (14.5)	9.2 (5.5 to 16.2)
60-69	16942 (21.5)	10.4 (6.2 to 18.6)
70-79	19531 (24.7)	11.6 (6.5 to 21.3)
80+	14049 (17.8)	13.4 (7.5 to 23.3)

Sex		
Female	41003 (52.0)	10.4 (6.1 to 19.2)
Male	37918 (48.0)	10.1 (5.6 to 18.4)
ASA		
1 or 2	35539 (45.0)	8.1 (5.3 to 13.4)
3	28042 (35.5)	12.5 (7.4 to 21.5)
4	13791 (17.5)	14.6 (7.0 to 28.6)
5	1549 (2.0)	6.6 (0.4 to 25.1)
ECG findings		
Normal	63088 (80.6)	9.6 (5.6 to 17.5)
AF normal rate	3345 (4.3)	13.0 (7.3 to 22.5)
AF abnormal Q-waves, ST segment, T-waves	11884 (15.2)	13.1 (6.5 to 24.5)
Cardiac signs		
No failure	57606 (73.4)	9.5 (5.6 to 17.1)
Mild	19932 (25.4)	12.5 (6.7 to 23.3)
Severe	935 (1.2)	13.4 (5.6 to 26.2)
Respiratory signs		
No dyspnoea	56809 (72.4)	9.4 (5.6 to 16.6)
Exertional dyspnoea	12738 (16.2)	12.6 (7.1 to 23.3)
Limiting dyspnoea	6365 (8.1)	13.5 (7.3 to 25.3)
Resting dyspnoea	2572 (3.3)	14.3 (6.2 to 28.4)
Urgency		
Expedited	13061 (16.6)	9.6 (6.0 to 17.3)
Urgent	56265 (71.6)	10.3 (6.1 to 18.4)
Immediate	9251 (11.8)	11.3 (5.1 to 24.0)
Malignancy		
None	60534 (77.0)	10.0 (5.6 to 18.5)
Primary	9771 (12.4)	11.3 (6.6 to 19.4)
Nodal metastases	3148 (4.0)	11.4 (6.5 to 19.4)
Distant metastases	5186 (6.6)	10.6 (6.4 to 18.4)
Laparoscopic	6837 (8.7)	6.4 (3.6 to 12.1)
Open surgery	72084 (91.3)	10.5 (6.3 to 19.4)

Ischaemia	9865 (12.5)	10.5 (5.2 to 22.0)
Obstruction	27361 (34.7)	9.5 (5.5 to 17.4)
Bleeding	2515 (3.2)	10.5 (6.0 to 21.0)
Sepsis	28481 (36.1)	11.6 (6.5 to 21.9)
Other pathology	32349 (41.0)	10.3 (6.2 to 18.3)
NELA predicted 30-day mortality		
<5%	39502 (52.1)	8.3 (5.4 to 13.5)
5-10%	12148 (16.0)	12.6 (7.6 to 21.5)
10-20%	10818 (14.3)	14.5 (8.4 to 25.4)
20-30%	5365 (7.1)	15.4 (8.2 to 27.9)
30-40%	3251 (4.3)	14.9 (6.6 to 28.5)
40-50%	2006 (2.6)	14.2 (4.0 to 29.3)
>50%	2753 (3.6)	9.0 (0.7 to 25.3)

Relationship between NELA predicted 30-day mortality and DAOH in patients surviving EL

Table 15: DAOH variation in surviving patients according to NELA predicted 30-day mortality

NELA predicted 30-day mortality	DAOH30 (median (IQR)	DAOH90 (median (IQR)	DAOH180 (median (IQR)	DAOH365 (median (IQR)
<5%	21 (15 to 24)	80 (74 to 84)	170 (163 to 174)	354 (346 to 358)
5-10%	15 (4 to 21)	75 (61 to 81)	164 (150 to 170)	347 (332 to 355)
10-20%	11 (0 to 18)	70 (52 to 78)	159 (140 to 168)	342 (321 to 352)
20-30%	6 (0 to 16)	64 (42 to 76)	153 (129 to 165)	336 (311 to 349)
30-40%	2 (0 to 14)	59 (34 to 74)	149 (123 to 163)	332 (302 to 346)
40-50%	0 (0 to 11)	55.5 (28 to 71)	146 (116 to 160)	327 (298 to 345)
>50%	0 (0 to 8)	50 (17 to 67)	139 (104 to 157)	323 (282 to 341)

Movement between longer and shorter DAOH categories

Table 16: SUPPLEMENTARY TABLE: Movement between longer and shorter DAOH categories over time (excludes patients who died by 30 or 90 days)

	Number	Shorter DAOH90 (%)	Shorter DAOH180 (%)	Shorter DAOH365 (%)
Longer DAOH30	46236	5.2	8.8	12.7
Shorter DAOH30	24028	87.1	82.8	74.1
Longer DAOH90	46957		4.6	9.5
Shorter DAOH90	20058		92.4	79.8

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Declaration of interest

LJS - is a NELA Project Team member. CMO – served on the NELA Project Team between 2012 and 2019. SRM - is a NELA Project Team member and Director of the Health Services Research Centre which delivers NELA for the Royal College of Anaesthetists. She is National Clinical Director for Critical and Perioperative Care at NHS England.

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Authors' contributions

LJS - devising research questions, methodology, data analysis, manuscript drafting. CMO - refining research questions, manuscript revisions. SRM - refining research questions, manuscript revisions.

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