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Older Patients Undergoing Emergency Laparotomy – observations from the National Emergency Laparotomy Audit (NELA) Years 1-4

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age and ageing

Revision Sheet

Instructions for authors:

1. In the first column please briefly summarise each point raised by the referee or editor.
2. In the second column, briefly explain how you have responded to each point.
3. In the third column, give the location in the text of the modification – with page and paragraph number reference.
4. Please upload this form to Manuscript Central alongside your revised paper.

Manuscript title:.

Older Patients Undergoing Emergency Laparotomy – observations from the National Emergency Laparotomy Audit (NELA) Years 1-4

Referee 1

Point raised by referee (please summarise)	**Response by author (briefly explain)**	**Location in text: Page and paragraph reference**
No points for revision raised		

Referee 2

Point raised by referee (please summarise)	**Response by author (briefly explain)**	**Location in text: Page and paragraph reference**
Since it is already known that older people have poorer outcomes, the novelty of this paper needs to be enhanced with more historic data if possible and certainly some international data if available.	Thank you. We agree that international comparison would be useful and look forward to future collaboration with the Australian and New Zealand NELA database team. For the purposes of this article, we have referenced historic hip fracture data, a comparable emergency, frail older surgical population.	
Introduction, para 2 is stated "trust level benchmarked performance reports.." So, why not give the reader a flavour of this, eg inter-hospital variation for latest year, and if possible, variation in rates of change over the 4 audits. Demonstrating such variance would be consistent with the suggestion that QI interventions have contributes as these are likely to be have been variable in their implementation nationally.	Analysis and discussion of the inter-hospital variation of NELA outcomes over the first 4 years of data collection is a large, highly interesting topic which could be a stand-alone research question. For the purposes of providing background to this analysis, the annual NELA data reports which provide detailed information regarding inter-hospital quality assurance targets are referenced. Rates of change in mortality over the 4 audits is provided between age groups in Appendix Table 1.	

In the Introduction, para 3 "Multiple factors have contributed to these improvements". The statements in the Abstract and Discussion are more moderate "These improvements are likely to have resulted from.." Suggest - be consistent on this.	Thank you. Introduction paragraph 3 is now modified to 'are likely to have contributed' to maintain consistency.	**(page 2 paragraph 3)**
Methods, the statistical analyses are described clearly enough but hypotheses or a priori questions not clearly stated.	Thank you. The aims of this observational study are described in the final paragraph of the introduction. Due to the broad descriptive aims and word count restriction, hypotheses have not been specifically stated.	
"Simple and multiple regression modelling was conducted. Ok, but what was the approach to determining what remained in the multiple regression modelling and what was in the model (in the Results)?	Selection of covariates used in multiple regression modelling was based on investigator-determined clinical relevance. On discussion with the statistician, this was thought necessary due to the very large NELA patient dataset. Further details are available in the 'variables' section of the Methods. Individual covariates are not listed in the Methods due to word count restrictions but are listed in the Results and Supplementary Data tables.	
"Physiological and biochemical parameters at presentation were removed from the discharge destination regression model." Please state why.	Selection of covariates used in descriptive analysis and regression modelling was based on clinical relevance. Covariates were further condensed in the discharge destination model to exclude presenting physiological and biochemical parameters, again based on clinical relevance and stability of regression modelling.	The corresponding sentence on page 5 has been modified to reflect these reviewer comments. **(page 5 paragraph 2)**
Results: 93,415 NELA patients were eligible for analysis. From how many?	Thank you. There were 97,287 NELA patients exported from the patient dataset between years 1-4. Following exclusion of patients with missing ONS-linked mortality data, 93,415 patients remained (ie. 3872 excluded).	The first sentence of the Results section has been modified to include this. **(page 7 paragraph 1)**
Case ascertainment increased with each year of NELA, reaching 83.0% in year. Briefly explain how this was established and consider inclusion of this important point in the Abstract.	Thank you for raising this issue. Case ascertainment is reported in each NELA annual report (referenced). This is established based on data from Hospital Episode Statistics (HES) for England and the Patient Episode database for Wales (PEDW) to calculate the expected annual number of emergency laparotomies in English and Welsh NHS hospitals. Unfortunately the inclusion of case ascertainment in the abstract is limited by word count.	
In view of its relative importance in the Discussion, I suggest include the raw data from Appx Table 4 on mortality associated with geriatrician input be included in main	Thank you.	This has been added to paragraph 4 of the Results section. **(page 8 paragraph 2)**

report (eg as text)		
Discussion: “Regression analysis of associations with postoperative outcomes in older patients is limited by the effect of unmeasured confounders and clinically driven selection of co-variates” Please expand on this important point.	Thank you. We are limited by the word count but agree this is an important point. The NELA steering group have recognised the need to include variables which may allow further understanding of factors which impact outcomes in older patients. We expect to see more of these collected and reported in future rounds of NELA data collection.	
References: Ref 25 only has one non hip fracture so is probably not relevant. Suggest use the one relevant study from this SR instead.	Thank you for pointing this out. On further review, the relevant study within ref 25 (Hempenius et al, 2016) has neutral long-term outcomes. Ref 25 has been changed to a different study of CGA in older elective surgical patients.	**(page 20 reference 25)**

Associate Editor

Point raised by referee (please summarise)	Response by author (briefly explain)	Location in text: Page and paragraph reference
Please explain what STROBE stands for	Thank you for asking for clarification. STROBE stands for 'Strengthening the reporting of observational studies in Epidemiology'. This a standard format whereby all observational studies are reported in academic literature.	This has been added to the first sentence of the Methods section. **(page 4 paragraph 1)**
p5-why were physiological and biochemical parameters removed from the model?	Thank you for this query. Selection of covariates used in descriptive analysis and regression modelling was based on clinical relevance. Covariates were further condensed in the discharge destination model to exclude presenting physiological and biochemical parameters, again based on clinical relevance and stability of regression modelling.	The corresponding sentence on page 5 has been modified to reflect these reviewer comments. **(page 5 paragraph 2)**
p8-is there change in residence data to include, rather than those discharged to care home?	Thank you. Indeed a change in residence would have been a valuable datapoint to analyse. However, preadmission and discharge residence were only collected as a routine datapoint from NELA year 4 and even within that year there was poor recording of this information. Once further accurate NELA residence data is collected, the results of change in residence analysis will be highly interesting, especially in the setting of growing geriatrician input.	
p11-please explain what P-POSSUM stands for.	Apologies for not being explicit in the manuscript. P-POSSUM stands for 'Portsmouth Physiological and Operative Severity Score for the enUmeration of Mortality'.	This has now been included on page 8 where it is first mentioned. **(page 8 paragraph 3)**
Is there any other data that may explain why geriatrician intervention had an impact eg delirium incidence? if not could this be added to the discussion.	Thank you. It would have been interesting to further examine this, however the data from NELA does not provide sufficient information to be able to postulate why geriatrician intervention had an impact on delirium. Other academic literature in geriatric medicine does address this issue but it is beyond the scope of this article due to the limited word count to provide this detail.	

Abstract

Background: Older patients aged ≥65 years constitute the majority of the National Emergency Laparotomy Audit (NELA) population. To better understand this group and inform future service changes this paper aims to describe patient characteristics, outcomes and process measures across age cohorts and temporally in the four-year period (2014 – 2017) since NELA was established.

Methods: Patient-level data was populated from the NELA dataset years 1-4 and linked with Office of National Statistics mortality data. Descriptive data was compared between groups delineated by age, NELA year and geriatrician review. Primary outcomes were 30-day and 90-day mortality, length of stay and discharge to care home accommodation.

Results: 93,415 NELA patients were included in the analysis. The median age was 67 years. Patients aged ≥65 years had higher 30-day (15.3% vs 4.9%, $p<0.001$) and 90-day mortality (20.4% vs 7.2%, $p<0.001$) rates, longer length of stay (median 15.2 vs 11.3 days, $p<0.001$) and greater likelihood of discharge to care home accommodation compared to younger patients (6.7% vs 1.9%, $p<0.001$). Mortality rate reduction over time was greater in older compared to younger patients. The proportion of older NELA patients seen by a geriatrician postoperatively increased over years 1-4 (8.5% to 16.5%, $p<0.001$). Postoperative geriatrician review was associated with reduced mortality (30-day OR 0.38, CI 0.35-0.42, $p<0.001$, 90-day OR 0.6, CI 0.56-0.65, $p<0.001$).

Conclusions: Older NELA patients have poorer postoperative outcomes. The greatest reduction in mortality rates over time were observed in the oldest cohorts. This may be due to several interventions including increased perioperative geriatrician input.

Introduction

Older patients aged 65 years and above are undergoing emergency surgery with increasing frequency [1]. This cohort is more likely to have age-related physiological impairment and exhibit geriatric syndromes including frailty, sarcopaenia, functional and cognitive impairment [2-4]. These factors, in addition to age-related comorbidities are associated with poorer postoperative outcomes [5, 6]. Unsurprisingly older patients have higher rates of postoperative mortality, morbidity and a prolonged length of hospital stay compared with younger patients [7, 8]. Older people are more likely to experience postoperative functional decline resulting in discharge to supported accommodation [9]. As such, undergoing emergency surgery can be a major life-changing event.

The National Emergency Laparotomy Audit (NELA) was commissioned by the Healthcare Quality Improvement Partnership (HQIP) on behalf of NHS England and the Welsh government. The aims of NELA are to collect perioperative emergency laparotomy data, provide trust level benchmarked performance reports and inform quality improvement programmes [10]. Outcomes after emergency laparotomy have improved in all age groups throughout England and Wales since its inception [10].

Multiple factors ~~have~~ are likely to have contributed to these improvements; a greater awareness of outcomes, hospital-level benchmarking data, publication of standards by professional stakeholders, quality improvement initiatives, and focussed education and training [10, 12-13]. There has been a shift towards identifying high-risk patients with a predicted 30-day mortality risk ≥5% and providing targeted interventions for this cohort, informed through the development of the tailored NELA risk model [11] and the High Risk General Surgical Patient Guideline (HRGSP) [12]. Acknowledging that the majority of patients in the high-risk category are older, this guideline advocates proactive identification of frailty and supports novel collaborative partnerships between general surgery and geriatric medicine alongside traditional clinical stakeholders. Despite these initiatives, consistent challenges in implementation remain, in terms of pathway development, workforce and funding [14-16].

To better understand the older emergency laparotomy population and inform service development, this study aims to report patient demographics, characteristics, clinician-reported outcomes and process measures including geriatrician involvement across age cohorts and temporally in the four-year period (2013 – 2017) since NELA was established. Covariates associated with increased mortality, length of stay and discharge destination to a care-home are described.

Methods

This manuscript adheres to STROBE (Strengthening The Reporting of OBservational studies in Epidemiology) guidelines [17].

Setting & Participants:

The anonymised NELA dataset encompasses 70-80% of adults who have undergone emergency laparotomy across England and Wales in NHS hospitals since 1st December 2013 [10]. Additional details regarding NELA inclusion and exclusion criteria are described elsewhere [10]. Patient-level data were extracted from the NELA dataset on 29th November 2018. Mortality data were populated from the Office for National Statistics (ONS). Patients were eligible for inclusion if enrolled between 1st December 2013 and 30th November 2017 and ONS-linked mortality data were available.

For the purposes of this study, older patients were defined as ≥65 years on presentation to hospital. Descriptive analysis and simple variable regression analysis for each covariate excluded participants with invalid or missing data for that covariate. Multiple variable regression analysis excluded participants with invalid or missing covariate data pertaining to each analysis. Patients were excluded from length of stay descriptive analysis and regression modelling if they had an invalid length of stay <0 hours or exceeding the maximally recorded length of stay in the NELA dataset of 60 days. Patients who had 'unknown' or 'not specified' discharge destination data were excluded from discharge destination regression analysis, thus comparing discharge to a care-home versus discharge home and reduce the confounding effects of patients who had died in hospital.

Ethical Considerations:

NELA is approved under section 251 of the NHS Act 2006 by the Confidentiality Advisory Group (July 2013). Linked ONS data was processed in accordance with NHS Digital Data Sharing Agreement v1.01. This study received approval from the Healthcare Quality Improvement Partnership (HQIP).

Variables:

Thirty and 90-day mortality, length of stay and discharge to care-home accommodation were investigated as primary outcomes. Physiological, biochemical and process measure covariates from the NELA dataset were used for descriptive analysis based on investigator-determined clinical relevance. Continuous covariates were redefined as binary values aligned with current sepsis and HRGSP guidelines to maximise clinical applicability [12, 18]. Based on clinical grounds, covariates used in mortality and length of stay regression modelling were condensed to focus on presentation profile, risk assessment and geriatrician review. Presenting physiological and biochemical parameters ~~at presentation~~ were also removed from the discharge destination regression model on this basis.

Statistical Analysis:

Microsoft IBM-SPSS and Excel software were used to generate descriptive data, graphs and perform statistical analysis. Receiver-operator characteristic curves were produced to identify age inflection points at which mortality and length of stay increase [19]. To calculate the differences between age groups in mortality over time defined by NELA year, logistic regression modelling was performed. Covariates and outcomes were compared between groups delineated by age, NELA year and geriatrician review with descriptive analysis using Chi-Square, Mann-Whitney U and Kruskal-Wallis tests. Subgroup analysis of year 4 data was conducted for both descriptive analysis and regression modelling to investigate new 4th year NELA datapoints.

Simple and multiple regression modelling was conducted in patients ≥65 years to identify covariates associated with postoperative 30 and 90-day mortality, increased length of stay and discharge to care-home accommodation. Logistic regression was used for binary outcomes, mortality and discharge to care-home versus independent living. Although length of stay data was asymmetrically skewed, linear regression was deemed appropriate given continuous length of stay data in the large NELA dataset with correlation of results using sensitivity analysis.

Results

Following the exclusion of 3872 patients with missing mortality data, 93,415 NELA patients were eligible for analysis. Numbers of additional patients excluded from descriptive analysis included 36,418 (missing lactate), 1891 (missing albumin), 1628 (missing C-reactive protein) and 826 patients with an invalid time to theatre recorded. Missing covariate data also led to exclusion of 1289 patients (missing systolic blood pressure), 1200 (missing heart rate), 448 (missing white cell count, WCC) and 320 (missing haemoglobin) from descriptive analysis, mortality and length of stay regression modelling. This equated to 1550 patients excluded from mortality modelling and 2843 patients excluded from length of stay modelling (1550 and 1293 patients excluded due to an invalid length of stay <0 hours or prolonged >60 days).

Case ascertainment increased with each year of NELA, reaching 83.0% in year 4 [10]. However, the total number of NELA patients reduced in year 4 across all age groups, predominantly due to exclusion of 'return to theatre cases' who had undergone non-GI primary procedures. Despite changes in absolute numbers, the NELA age distribution remained stable across the four-year time period in keeping with expected population norms (Appendix Figure 1). No age inflection point was observed in ROC curves between age and mortality, or age and length of stay. For this reason, older patients were defined as 65 years and over in keeping with HRGSP recommendations [12].

The median age of NELA patients over years 1-4 was 67 years with 57% aged 65 years and older. Table 1 outlines characteristics and process measures of NELA patients across age cohorts. Thirty-day mortality rate in patients aged ≥65 years compared <65 years were 15.3% vs 4.9% (p <0.001) and 90-day mortality rate was 20.4% vs 7.2% (p <0.001) with a median length of stay of 15.2 days vs 11.3 days (p <0.001). In NELA year 4, 6.7% of older patients compared to 1.9% (p <0.001) of younger patients were discharged to care-home accommodation. Older patients requiring emergency laparotomy were less likely to mount a tachycardia or WCC response on presentation. Surgery was more likely to entail adhesiolysis or small bowel resection and over one in five (22.8%) operations led to an intraoperative finding of cancer. Older patients had higher ASA grades than younger patients and a higher proportion of the older cohort had predicted 30-day mortality risk ≥5% using different risk prediction tools.

Postoperative geriatrician reviews of older patients increased from 8.5% to 15.7% over NELA years 1-4. Preoperative geriatrician review was recorded in 5.2% of older patients in year 4. Patients aged ≥85 years were more likely to receive geriatrician review; 20% postoperatively and 9.7% preoperatively. Preoperative geriatrician review in patients aged ≥65 years was associated with increased mortality (22.2% vs 13.3%, p<0.001 30-day, 27.9% vs 17.6%, p<0.001 90-day) whereas postoperative review was associated with reduced mortality (9.2% vs 16.1%, p<0.001 30-day, 17.2% vs 20.9% for 90-day). ~~Older patients receiving geriatrician input~~All had a longer median time to theatre (95.9 vs 32.2 hours, p<0.001 for preoperative review, 96.0 vs 37.3 hours, p <0.001 for postoperative review). ~~. There was no~~This subgroup had no observed difference between baseline physiological and biochemical measures ~~in those seen by a geriatrician~~ however ~~this subgroup~~ were more likely to have predicted mortality risk ≥5% using all methods of risk assessment, be ASA grade 4 and have been admitted from a care-home (Appendix Table 4).

Mortality following emergency laparotomy has reduced since the establishment of NELA (Figure 1). Logistic regression analyses found a reduction in 30 and 90-day mortality rate in older age groups over time (defined as NELA year 1 compared to years 2-4). This analysis demonstrated that the mortality rate fell most significantly over years 1-4 in the oldest age group (≥85 years) (30-day mortality OR 0.63, 90-day mortality OR 0.60) (Appendix Table 1). Covariates associated with 30 and 90-day mortality included ASA grade ≥3, NELA risk model or P-POSSUM (Portsmouth Physiological and Operative Severity Score for the enUmeration of Mortality) predicted 30-day mortality risk ≥5% and systolic hypotension ≤90mmHg (Table 2). Preoperative geriatrician review was associated with increased mortality (30-day OR 1.691 and 90-day OR 1.454), whereas postoperative geriatrician review was associated with reduced mortality (30-day OR 0.383 and 90-day OR 0.603) in older NELA patients.

Multiple linear regression analysis (Appendix Table 2) showed that older patients presenting with Hb ≤100g/L had an increased LOS, 6.2 days longer than those with Hb>100g/L. Preoperative and postoperative geriatrician review was associated with increased LOS of 2.4 days and 9.3 days respectively, compared to older patients who did not receive geriatrician review. Covariates associated with discharge to care-home (Appendix Table 3) included admission from care-home (OR 11.113), age ≥85 years (OR 2.481) and postoperative geriatrician review (OR 2.329).

Discussion

This observational analysis of the NELA dataset describes characteristics, process measures and outcomes of older patients undergoing emergency laparotomy over a four-year period. It demonstrates that older patients have poorer postoperative outcomes in terms of 30 and 90-day mortality, longer length of stay and higher rate of discharge to care-home accommodation post emergency laparotomy compared to younger patients. However, improvements in 30 and 90-day mortality across the 2013-2017 period are most apparent in the oldest cohort of NELA patients.

These improvements are likely to have resulted from multiple interventions and changes in clinical practice supported by the development of best practice guidelines [14, 20, 21]. There has been an increase in consultant surgeon and anaesthetist presence in theatre with a reduced reported time to theatre across all age groups over the observed period [22]. Increased assessment and documentation of risk has led to adaptation of perioperative pathways addressing the needs of high-risk patients; this is particularly relevant for older patients and has been hypothesised to prompt geriatrician referral and shared care decision discussions [12]. Despite these improvements, emergency laparotomy in an older patient remains a high risk procedure with long-term mortality data on par with that observed in other high-risk surgical groups such as those undergoing hip fracture repair [23].

Pre and post emergency laparotomy geriatrician input has increased over the first four years of NELA data collection. This may be in response to emerging evidence supporting comprehensive geriatric assessment (CGA) in both elective and emergency older surgical populations [14, 24-26]. Older emergency general surgical patients may benefit from perioperative CGA in terms of reduced mortality [22], length of stay [26] and additional diagnoses and/or interventions made [27]. Despite a recent UK survey reporting appetite for geriatrician-led proactive perioperative services [16], barriers to establishing services include funding, workforce and interspeciality collaboration limiting widespread uptake.

In this study, an association was observed between receipt of geriatrician input and increased time to theatre, prolonged length of stay, and discharge to a care-home facility. Patients referred for geriatrician review were more likely to have a higher ASA grade, predicted mortality risk ≥5% and be admitted from a care-home. Despite this increased patient complexity, postoperative geriatrician intervention was associated with reduced mortality, in keeping with existing evidence describing the impact of CGA on mortality in other populations [26, 28]. In contrast, preoperative geriatrician input was associated with increased mortality. Whilst evaluating the reasons for this observation are beyond the scope of this study, the increased acuity and multimorbidity of patients referred to geriatricians and the resultant complexity in shared decision making with delays to theatre may be relevant.

Frailty tools have been recommended alongside preoperative risk assessment tools to identify high-risk patients who may benefit from geriatrician input [12]. The ELF study showed an association between frailty and 90-day mortality (CFS 5 OR 3.18, 95% CI 1.24-8.14), increased risk of complications and length of hospital stay in older emergency laparotomy patients [29]. Hence, the addition of frailty to the 5th year NELA dataset may be instrumental in better understanding these associations. Both NELA and P-POSSUM risk assessment models were recorded in the NELA dataset (2014-2017), with removal of P-POSSUM from 2019 due to a tendency to overpredict mortality resulting in differences between observed and expected outcomes [30]. The NELA risk model was developed from the NELA database and designed for use in the UK emergency laparotomy population [11]. Interestingly, in this analysis of older patients, the P-POSSUM had a higher association with 30-day mortality, 90-day mortality and length of stay in comparison to the NELA model which had a greater association with discharge to care-home accommodation. These models therefore require further validation within the older population in addition to comparison with frailty scores used to predict risk.

There are acknowledged limitations in this study. Fluctuating case ascertainment, incomplete and ~~inaccurate~~incorrect data entry may introduce inaccuracies. For example, discharge destination has been poorly collected since introduction in year 4. However, the large sample size may mitigate bias. ~~Furthermore, the newly introduced best practice tariff may improve accuracy and completeness of data collection.~~ It is beyond the scope of the current NELA dataset to describe "non-operative emergency laparotomy" patients. This exclusion of a potentially high risk group from operative management may have contributed to the observed reductions in mortality rates in older patients. Additionally, patient-reported postoperative outcomes including quality of life, cognition and function remain unmeasured. Regression analysis of associations with postoperative outcomes in older patients is limited by the effect of unmeasured confounders and clinically driven selection of covariates.

In summary, this study describes improvements in mortality rates in older patients undergoing emergency laparotomy over the first four years of NELA. The value of risk assessment and identification of high-risk patients is crucial to inform perioperative care pathways and shared decision making. The involvement of geriatricians in the care of older patients undergoing emergency laparotomy is increasingly recognised but requires further evaluation to understand causal pathways and implement evidence-based, cost-effective CGA-based services.

Figure 1: 30-day and 90-day mortality: *age and NELA year*

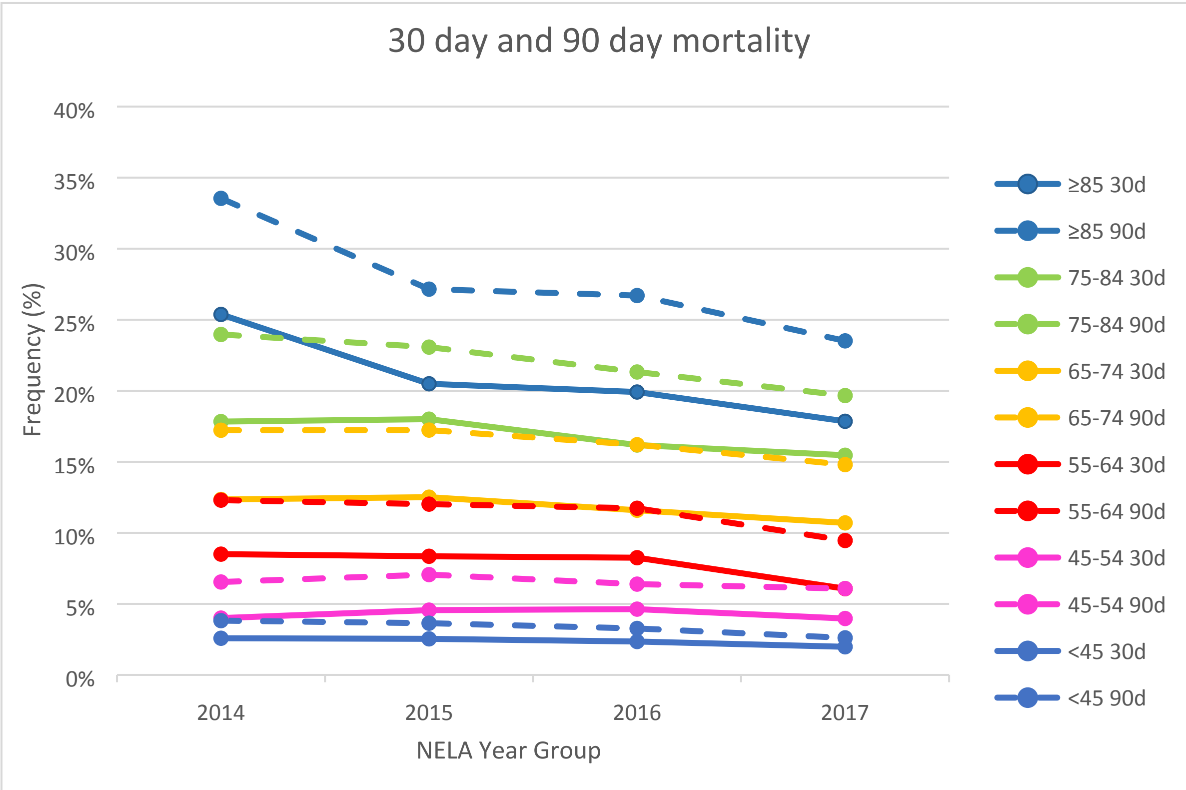

Table 1: Characteristics of NELA subjects 2013-2017: ***comparison of age cohorts (<65 vs ≥65 and <65 vs 65-74, 75-84 and ≥85 years)***

Characteristic	<65 years	All ≥65	P value	65-74	75-84	≥85	P value
Male n,(%)	20683 (51.0%)	24479 (46.3%)	<0.001	11327 (49.7%)	9877 (45.4%)	3275 (39.3%)	<0.001
Pre-admission care home* n,(%)	120 (1.1%)	242 (1.8%)	<0.001	67 (1.1%)	95 (1.8%)	80 (3.8%)	<0.001
SBP 90 and less n ^ ,(%)	2294 (5.7%)	3421 (6.5%)	<0.001	1592 (7.1%)	1417 (6.6%)	412 (5%)	<0.001
HR ≥90 n ^ ,(%)	21272 (53.2%)	25789 (49.3%)	<0.001	11673 (51.8%)	10418 (48.4%)	3698 (44.9%)	<0.001
WCC ≤4 or ≥11 ^ n,(%)	23070 (57.2%)	28664 (54.4%)	<0.001	12471 (55%)	11837 (54.6%)	4356 (52.5%)	0.004
Hb ≤100 g/L ^ n,(%)	6436 (15.9%)	8526 (16.2%)	0.314	3789 (16.7%)	3519 (16.2%)	1218 (14.6%)	<0.001
Lactate ≥2 ^ n,(%)	7819 (33.9%)	12890 (37.9%)	<0.001	5466 (38.9%)	5553 (38.8%)	1871 (34.0%)	<0.001
Albumin 32 and below *^ n,(%)	3564 (37.4%)	5537 (45.3%)	<0.001	2401 (45%)	2274 (45.7%)	862 (45.1%)	<0.001
CRP ≥100 *^ n,(%)	4001 (41.4%)	5063 (40.9%)	<0.001	2357 (43.6%)	2035(40.6%)	671 (34.6%)	<0.001
ASA n,(%)							
1	7868 (19.4%)	1639 (3.1%)	<0.001	1094 (4.8%)	448 (2.1%)	97 (1.2%)	<0.001
2	17235 (42.5%)	15263 (28.9%)	<0.001	7765 (34.1%)	5812 (26.7%)	1686 (20.2%)	<0.001
3	10433 (25.7%)	22714 (42.9%)	<0.001	8929 (39.2%)	9783 (44.9%)	4002 (48.1%)	<0.001
4	4309 (10.6%)	12086 (22.8%)	<0.001	4478 (20%)	5229 (24%)	2379 (28.6%)	<0.001
5	679 (1.7%)	1181 (2.2%)	<0.001	514 (2.3%)	505 (2.3%)	162 (1.9%)	<0.001
NELA model predicted mortality ≥ 5%# n,(%)	1965 (19.5%)	8758 (67.9%)	<0.001	2915 (51.8%)	3935 (75.3%)	1908 (93.7%)	<0.001
P-POSSUM predicted mortality ≥5% n,(%)	17303 (42.9%)	37076 (70%)	<0.001	14522 (63.7%)	16180 (74.3%)	6374 (76.6%)	<0.001
Mortality risk ≥5% by other measure# n,(%)	10872 (42.9%)	27008 (73.2%)	<0.001	10099 (66.1%)	11799 (76.3%)	5110 (83.1%)	<0.001
Risk assessment not documented n,(%)	15156 (37.4%)	15989 (30.2%)	<0.001	7492 (32.9%)	6323 (29%)	2174 (26.1%)	<0.001
Small bowel resection or adhesiolysis n,(%)	11772 (29%)	18698 (35.4%)	<0.001	7310 (32.1%)	7873 (36.1%)	3515 (42.2%)	<0.001
Right hemicolectomy n,(%)	5348 (13.2%)	6672 (12.6%)	0.009	2880 (12.6%)	2764 (12.7%)	1028 (12.3%)	0.058

Hartmann's procedure n,(%)	4438 (10.9%)	7253 (13.7%)	<0.001	3222 (14.1%)	3029 (13.9%)	1002 (12%)	<0.001
Subtotal or panprotoctocolectomy n,(%)	2580 (6.4%)	2396 (4.5%)	<0.001	1179 (5.2%)	979 (4.5%)	238 (2.9%)	<0.001
Peptic ulcer suture or repair of perforation n,(%)	3086 (7.6%)	1982 (3.7%)	<0.001	817 (3.6%)	830 (3.8%)	335(4%)	<0.001
Intra-operative Cancer finding n,(%)	5988 (15%)	11870 (22.8%)	<0.001	5124 (22.8%)	4873 (22.7%)	1873 (22.8%)	<0.001
Pre-op CT n,(%)	32954 (81.3%)	45404 (85.9%)	<0.001	19458 (85.4%)	18743 (86%)	7203 (86.5%)	<0.001
Consultant surgeon in theatre n,(%)	35520 (87.6%)	46422 (87.8%)	0.013	20159 (88.5%)	19080 (87.6%)	7183 (86.3%)	<0.001
Consultant anaesthetist in theatre n,(%)	31324 (77.3%)	43326 (81.9%)	<0.001	18445 (81%)	17986 (82.6%)	6895 (82.8%)	<0.001
Time to surgery (median, IQR) +	33.95 (13-94)	37.8 (15.88-98.2)	<0.001	38.5 (15.33-101.5)	37 (16-97.97)	38.67 (16.83-92.93)	<0.001
Pre-op Geriatrician RV* n,(%)	103 (1%)	681 (5.2%)	<0.001	172 (3%)	306 (5.7%)	203 (9.7%)	<0.001
Post-op Geriatrician RV n,(%)	566 (1.4%)	6060 (11.5%)	<0.001	1521 (6.7%)	2868 (13.2%)	1671 (20%)	<0.001

*variable added in 4th year , ^data missing: 8% albumin missing, 6.8% CRP missing, 39% lactate missing; each analysed with missing data population excluded, +patients with invalid time to theatre excluded (ie. 0 hours or less), #patient excluded from analysis where risk assessment not completed or documented

Table 2: Simple and multiple logistic regression analysis: prediction of 30 and 90-day mortality in NELA patients ≥65 years

Mortality	Variable	OR	P Value	CI	OR	P value	CI
		Simple			Multiple		
30	Age 65-74	1.00	-	-	1.00	-	-
90		1.00	-	-	1.00	-	-
30	Age 75-84	1.51	<0.001	1.36 – 1.601	1.48	<0.001	1.39 – 1.57
90		1.44	<0.001	1.38 – 1.51	1.36	<0.001	1.29 – 1.43
30	Age ≥ 85	1.99	<0.001	1.86 – 2.13	2.03	<0.001	1.89 – 2.19
90		1.97	<0.001	1.85 – 2.09	1.88	<0.001	1.76 – 2.01
30	Male gender	1.05	0.059	1.00 – 1.10	0.97	0.218	0.92 – 1.02
90		1.09	<0.001	1.04 – 1.13	1.01	0.794	0.96 – 1.05
30	SBP ≤ 90mmHg	4.36	<0.001	4.05 – 4.69	2.06	<0.001	1.90 – 2.24
90		3.61	<0.001	3.36 – 3.87	1.85	<0.001	1.71 – 2.00
30	HR ≥ 90	2.30	<0.001	2.19 – 2.42	1.52	<0.001	1.43 – 1.60
90		1.94	<0.001	1.86 – 2.03	1.36	<0.001	1.30 – 1.43
30	WCC ≤4 or ≥11	1.44	<0.001	1.38 – 1.52	1.14	<0.001	1.08 – 1.21
90		1.37	<0.001	1.31 – 1.43	1.15	<0.001	1.09 – 1.20
30	Hb ≤100 g/L	1.54	<0.001	1.45 – 1.63	0.98	0.544	0.92 – 1.05
90		1.70	<0.001	1.62 – 1.80	1.11	0.001	1.05 – 1.18
30	ASA – 1	1.00	-	-	1.00	-	-
90		1.00	-	-	1.00	-	-

30	**ASA – 2**	1.84	<0.001	1.35 – 2.51	1.58	0.004	1.16 – 2.19
90		1.60	<0.001	1.27 – 2.02	1.43	0.003	1.19 – 1.81
30	**ASA – 3**	4.69	<0.001	3.47 – 6.35	3.18	<0.001	2.35 – 4.33
90		4.07	<0.001	3.24 – 5.12	3.00	<0.001	2.38 – 3.79
30	**ASA – 4**	17.27	<0.001	12.76 – 23.35	9.21	<0.001	6.78 – 12.51
90		13.03	<0.001	10.36 – 16.38	8.04	<0.001	6.36 – 10.16
30	**ASA - 5**	58.89	<0.001	42.66 – 81.28	26.84	<0.001	19.32 – 37.29
90		39.34	<0.001	30.42 – 50.88	21.62	<0.001	16.60 – 28.15
30	**P-POSSUM mortality ≥5%**	6.17	<0.001	5.67 – 6.72	2.64	<0.001	2.41 – 2.90
90		5.01	<0.001	4.69 – 5.37	2.29	<0.001	2.12 – 2.46
30	**Cancer at operation**	0.91	.003	0.86 – 0.97	1.27	<0.001	1.19 – 1.35
90		1.34	<0.001	1.28 – 1.41	1.89	<0.001	1.79 – 2.00
30	**Post-op geriatrician RV**	0.53	<0.001	0.48 – 0.58	0.38	<0.001	0.345 – 0.42
90		0.79	<0.001	0.73 – 0.85	0.60	<0.001	0.56 – 0.65
30	**NELA model predicted mortality ≥5% ***	8.23	<0.001	6.82 – 9.93	2.29	<0.001	1.82 – 2.88
90		6.70	<0.001	5.77 – 7.77	2.19	<0.001	1.823 – 2.65
30	**Pre-admission care home***	1.46	0.024	1.05 – 2.03	0.94	0.753	0.66 – 1.35
90		1.93	<0.001	1.46 – 2.55	1.36	0.048	1.00 – 1.86

30	**Pre-op geriatrician RV***	1.88	<0.001	1.56 – 2.27	1.69	<0.001	1.37 – 2.09
90		1.82	<0.001	1.53 – 2.17	1.45	<0.001	1.20 – 1.77

*4th year data points

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Abstract

Background: Older patients aged ≥65 years constitute the majority of the National Emergency Laparotomy Audit (NELA) population. To better understand this group and inform future service changes this paper aims to describe patient characteristics, outcomes and process measures across age cohorts and temporally in the four-year period (2014 – 2017) since NELA was established.

Methods: Patient-level data was populated from the NELA dataset years 1-4 and linked with Office of National Statistics mortality data. Descriptive data was compared between groups delineated by age, NELA year and geriatrician review. Primary outcomes were 30-day and 90-day mortality, length of stay and discharge to care home accommodation.

Results: 93,415 NELA patients were included in the analysis. The median age was 67 years. Patients aged ≥65 years had higher 30-day (15.3% vs 4.9%, $p<0.001$) and 90-day mortality (20.4% vs 7.2%, $p<0.001$) rates, longer length of stay (median 15.2 vs 11.3 days, $p<0.001$) and greater likelihood of discharge to care home accommodation compared to younger patients (6.7% vs 1.9%, $p<0.001$). Mortality rate reduction over time was greater in older compared to younger patients. The proportion of older NELA patients seen by a geriatrician postoperatively increased over years 1-4 (8.5% to 16.5%, $p<0.001$). Postoperative geriatrician review was associated with reduced mortality (30-day OR 0.38, CI 0.35-0.42, $p<0.001$, 90-day OR 0.6, CI 0.56-0.65, $p<0.001$).

Conclusions: Older NELA patients have poorer postoperative outcomes. The greatest reduction in mortality rates over time were observed in the oldest cohorts. This may be due to several interventions including increased perioperative geriatrician input.

Introduction

Older patients aged 65 years and above are undergoing emergency surgery with increasing frequency [1]. This cohort is more likely to have age-related physiological impairment and exhibit geriatric syndromes including frailty, sarcopaenia, functional and cognitive impairment [2-4]. These factors, in addition to age-related comorbidities are associated with poorer postoperative outcomes [5, 6]. Unsurprisingly older patients have higher rates of postoperative mortality, morbidity and a prolonged length of hospital stay compared with younger patients [7, 8]. Older people are more likely to experience postoperative functional decline resulting in discharge to supported accommodation [9]. As such, undergoing emergency surgery can be a major life-changing event.

The National Emergency Laparotomy Audit (NELA) was commissioned by the Healthcare Quality Improvement Partnership (HQIP) on behalf of NHS England and the Welsh government. The aims of NELA are to collect perioperative emergency laparotomy data, provide trust level benchmarked performance reports and inform quality improvement programmes [10]. Outcomes after emergency laparotomy have improved in all age groups throughout England and Wales since its inception [10].

Multiple factors are likely to have contributed to these improvements; a greater awareness of outcomes, hospital-level benchmarking data, publication of standards by professional stakeholders, quality improvement initiatives, and focussed education and training [10, 12-13]. There has been a shift towards identifying high-risk patients with a predicted 30-day mortality risk ≥5% and providing targeted interventions for this cohort, informed through the development of the tailored NELA risk model [11] and the High Risk General Surgical Patient Guideline (HRGSP) [12]. Acknowledging that the majority of patients in the high-risk category are older, this guideline advocates proactive identification of frailty and supports novel collaborative partnerships between general surgery and geriatric medicine alongside traditional clinical stakeholders. Despite these initiatives, consistent challenges in implementation remain, in terms of pathway development, workforce and funding [14-16].

To better understand the older emergency laparotomy population and inform service development, this study aims to report patient demographics, characteristics, clinician-reported outcomes and process measures including geriatrician involvement across age cohorts and temporally in the four-year period (2013 – 2017) since NELA was established. Covariates associated with increased mortality, length of stay and discharge destination to a care-home are described.

Methods

This manuscript adheres to STROBE (Strengthening The Reporting of OBservational studies in Epidemiology) guidelines [17].

Setting & Participants:

The anonymised NELA dataset encompasses 70-80% of adults who have undergone emergency laparotomy across England and Wales in NHS hospitals since 1st December 2013 [10]. Additional details regarding NELA inclusion and exclusion criteria are described elsewhere [10]. Patient-level data were extracted from the NELA dataset on 29th November 2018. Mortality data were populated from the Office for National Statistics (ONS). Patients were eligible for inclusion if enrolled between 1st December 2013 and 30th November 2017 and ONS-linked mortality data were available.

For the purposes of this study, older patients were defined as ≥65 years on presentation to hospital. Descriptive analysis and simple variable regression analysis for each covariate excluded participants with invalid or missing data for that covariate. Multiple variable regression analysis excluded participants with invalid or missing covariate data pertaining to each analysis. Patients were excluded from length of stay descriptive analysis and regression modelling if they had an invalid length of stay <0 hours or exceeding the maximally recorded length of stay in the NELA dataset of 60 days. Patients who had 'unknown' or 'not specified' discharge destination data were excluded from discharge destination regression analysis, thus comparing discharge to a care-home versus discharge home and reduce the confounding effects of patients who had died in hospital.

Ethical Considerations:

NELA is approved under section 251 of the NHS Act 2006 by the Confidentiality Advisory Group (July 2013). Linked ONS data was processed in accordance with NHS Digital Data Sharing Agreement v1.01. This study received approval from the Healthcare Quality Improvement Partnership (HQIP).

Variables:

Thirty and 90-day mortality, length of stay and discharge to care-home accommodation were investigated as primary outcomes. Physiological, biochemical and process measure covariates from the NELA dataset were used for descriptive analysis based on investigator-determined clinical relevance. Continuous covariates were redefined as binary values aligned with current sepsis and HRGSP guidelines to maximise clinical applicability [12, 18]. Based on clinical grounds, covariates used in mortality and length of stay regression modelling were condensed to focus on presentation profile, risk assessment and geriatrician review. Presenting physiological and biochemical parameters were also removed from the discharge destination regression model on this basis.

Statistical Analysis:

Microsoft IBM-SPSS and Excel software were used to generate descriptive data, graphs and perform statistical analysis. Receiver-operator characteristic curves were produced to identify age inflection points at which mortality and length of stay increase [19]. To calculate the differences between age groups in mortality over time defined by NELA year, logistic regression modelling was performed. Covariates and outcomes were compared between groups delineated by age, NELA year and geriatrician review with descriptive analysis using Chi-Square, Mann-Whitney U and Kruskal-Wallis tests. Subgroup analysis of year 4 data was conducted for both descriptive analysis and regression modelling to investigate new 4th year NELA datapoints.

Simple and multiple regression modelling was conducted in patients ≥65 years to identify covariates associated with postoperative 30 and 90-day mortality, increased length of stay and discharge to care-home accommodation. Logistic regression was used for binary outcomes, mortality and discharge to care-home versus independent living. Although length of stay data was asymmetrically skewed, linear regression was deemed appropriate given continuous length of stay data in the large NELA dataset with correlation of results using sensitivity analysis.

Results

Following the exclusion of 3872 patients with missing mortality data, 93,415 NELA patients were eligible for analysis. Numbers of additional patients excluded from descriptive analysis included 36,418 (missing lactate), 1891 (missing albumin), 1628 (missing C-reactive protein) and 826 patients with an invalid time to theatre recorded. Missing covariate data also led to exclusion of 1289 patients (missing systolic blood pressure), 1200 (missing heart rate), 448 (missing white cell count, WCC) and 320 (missing haemoglobin) from descriptive analysis, mortality and length of stay regression modelling. This equated to 1550 patients excluded from mortality modelling and 2843 patients excluded from length of stay modelling (1550 and 1293 patients excluded due to an invalid length of stay <0 hours or prolonged >60 days).

Case ascertainment increased with each year of NELA, reaching 83.0% in year 4 [10]. However, the total number of NELA patients reduced in year 4 across all age groups, predominantly due to exclusion of 'return to theatre cases' who had undergone non-GI primary procedures. Despite changes in absolute numbers, the NELA age distribution remained stable across the four-year time period in keeping with expected population norms (Appendix Figure 1). No age inflection point was observed in ROC curves between age and mortality, or age and length of stay. For this reason, older patients were defined as 65 years and over in keeping with HRGSP recommendations [12].

The median age of NELA patients over years 1-4 was 67 years with 57% aged 65 years and older. Table 1 outlines characteristics and process measures of NELA patients across age cohorts. Thirty-day mortality rate in patients aged ≥65 years compared <65 years were 15.3% vs 4.9% (p <0.001) and 90-day mortality rate was 20.4% vs 7.2% (p <0.001) with a median length of stay of 15.2 days vs 11.3 days (p <0.001). In NELA year 4, 6.7% of older patients compared to 1.9% (p <0.001) of younger patients were discharged to care-home accommodation. Older patients requiring emergency laparotomy were less likely to mount a tachycardia or WCC response on presentation. Surgery was more likely to entail adhesiolysis or small bowel resection and over one in five (22.8%) operations led to an intraoperative finding of cancer. Older patients had higher ASA grades than younger patients and a higher proportion of the older cohort had predicted 30-day mortality risk ≥5% using different risk prediction tools.

Postoperative geriatrician reviews of older patients increased from 8.5% to 15.7% over NELA years 1-4. Preoperative geriatrician review was recorded in 5.2% of older patients in year 4. Patients aged ≥85 years were more likely to receive geriatrician review; 20% postoperatively and 9.7% preoperatively. Preoperative geriatrician review in patients aged ≥65 years was associated with increased mortality (22.2% vs 13.3%, p<0.001 30-day, 27.9% vs 17.6%, p<0.001 90-day) whereas postoperative review was associated with reduced mortality (9.2% vs 16.1%, p<0.001 30-day, 17.2% vs 20.9% for 90-day). All had a longer median time to theatre (95.9 vs 32.2 hours, p<0.001 for preoperative review, 96.0 vs 37.3 hours, p <0.001 for postoperative review). This subgroup had no observed difference between baseline physiological and biochemical measures however were more likely to have predicted mortality risk ≥5% using all methods of risk assessment, be ASA grade 4 and have been admitted from a care-home (Appendix Table 4).

Mortality following emergency laparotomy has reduced since the establishment of NELA (Figure 1). Logistic regression analyses found a reduction in 30 and 90-day mortality rate in older age groups over time (defined as NELA year 1 compared to years 2-4). This analysis demonstrated that the mortality rate fell most significantly over years 1-4 in the oldest age group (≥85 years) (30-day mortality OR 0.63, 90-day mortality OR 0.60) (Appendix Table 1). Covariates associated with 30 and 90-day mortality included ASA grade ≥3, NELA risk model or P-POSSUM (Portsmouth Physiological and Operative Severity Score for the enUmeration of Mortality) predicted 30-day mortality risk ≥5% and systolic hypotension ≤90mmHg

(Table 2). Preoperative geriatrician review was associated with increased mortality (30-day OR 1.691 and 90-day OR 1.454), whereas postoperative geriatrician review was associated with reduced mortality (30-day OR 0.383 and 90-day OR 0.603) in older NELA patients.

Multiple linear regression analysis (Appendix Table 2) showed that older patients presenting with Hb ≤100g/L had an increased LOS, 6.2 days longer than those with Hb>100g/L. Preoperative and postoperative geriatrician review was associated with increased LOS of 2.4 days and 9.3 days respectively, compared to older patients who did not receive geriatrician review. Covariates associated with discharge to care-home (Appendix Table 3) included admission from care-home (OR 11.113), age ≥85 years (OR 2.481) and postoperative geriatrician review (OR 2.329).

Discussion

This observational analysis of the NELA dataset describes characteristics, process measures and outcomes of older patients undergoing emergency laparotomy over a four-year period. It demonstrates that older patients have poorer postoperative outcomes in terms of 30 and 90-day mortality, longer length of stay and higher rate of discharge to care-home accommodation post emergency laparotomy compared to younger patients. However, improvements in 30 and 90-day mortality across the 2013-2017 period are most apparent in the oldest cohort of NELA patients.

These improvements are likely to have resulted from multiple interventions and changes in clinical practice supported by the development of best practice guidelines [14, 20, 21]. There has been an increase in consultant surgeon and anaesthetist presence in theatre with a reduced reported time to theatre across all age groups over the observed period [22]. Increased assessment and documentation of risk has led to adaptation of perioperative pathways addressing the needs of high-risk patients; this is particularly relevant for older patients and has been hypothesised to prompt geriatrician referral and shared care decision discussions [12]. Despite these improvements, emergency laparotomy in an older patient remains a high risk procedure with long-term mortality data on par with that observed in other high-risk surgical groups such as those undergoing hip fracture repair [23].

Pre and post emergency laparotomy geriatrician input has increased over the first four years of NELA data collection. This may be in response to emerging evidence supporting comprehensive geriatric assessment (CGA) in both elective and emergency older surgical populations [14, 24-26]. Older emergency general surgical patients may benefit from perioperative CGA in terms of reduced mortality [22], length of stay [26] and additional diagnoses and/or interventions made [27]. Despite a recent UK survey reporting appetite for geriatrician-led proactive perioperative services [16], barriers to establishing services include funding, workforce and interspeciality collaboration limiting widespread uptake.

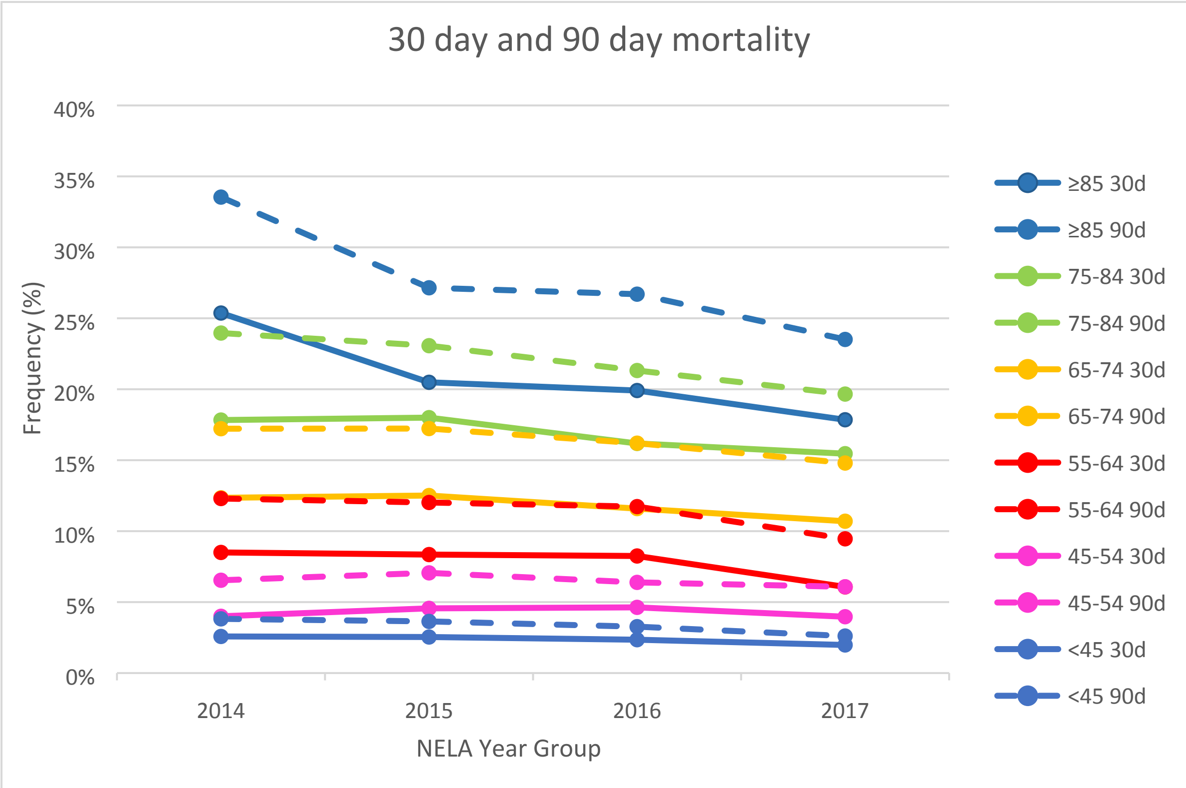
In this study, an association was observed between receipt of geriatrician input and increased time to theatre, prolonged length of stay, and discharge to a care-home facility. Patients referred for geriatrician review were more likely to have a higher ASA grade, predicted mortality risk ≥5% and be admitted from a care-home. Despite this increased patient complexity, postoperative geriatrician intervention was associated with reduced mortality, in keeping with existing evidence describing the impact of CGA on mortality in other populations [26, 28]. In contrast, preoperative geriatrician input was associated with increased mortality. Whilst evaluating the reasons for this observation are beyond the scope of this study, the increased acuity and multimorbidity of patients referred to geriatricians and the resultant complexity in shared decision making with delays to theatre may be relevant.

Frailty tools have been recommended alongside preoperative risk assessment tools to identify high-risk patients who may benefit from geriatrician input [12]. The ELF study showed an association between frailty and 90-day mortality (CFS 5 OR 3.18, 95% CI 1.24-8.14), increased risk of complications and length of hospital stay in older emergency laparotomy patients [29]. Hence, the addition of frailty to the 5th year NELA dataset may be instrumental in better understanding these associations. Both NELA and P-POSSUM risk assessment models were recorded in the NELA dataset (2014-2017), with removal of P-POSSUM from 2019 due to a tendency to overpredict mortality resulting in differences between observed and expected outcomes [30]. The NELA risk model was developed from the NELA database and designed for use in the UK emergency laparotomy population [11]. Interestingly, in this analysis of older patients, the P-POSSUM had a higher association with 30-day mortality, 90-day mortality and length of stay in comparison to the NELA model which had a greater association with discharge to care-home accommodation. These models therefore require further validation within the older population in addition to comparison with frailty scores used to predict risk.

There are acknowledged limitations in this study. Fluctuating case ascertainment, incomplete and incorrect data entry may introduce inaccuracies. For example, discharge destination has been poorly collected since introduction in year 4. However, the large sample size may mitigate bias. It is beyond the scope of the current NELA dataset to describe "non-operative emergency laparotomy" patients. This exclusion of a potentially high risk group from operative management may have contributed to the observed reductions in mortality rates in older patients. Additionally, patient-reported postoperative outcomes including quality of life, cognition and function remain unmeasured. Regression analysis of associations with postoperative outcomes in older patients is limited by the effect of unmeasured confounders and clinically driven selection of covariates.

In summary, this study describes improvements in mortality rates in older patients undergoing emergency laparotomy over the first four years of NELA. The value of risk assessment and identification of high-risk patients is crucial to inform perioperative care pathways and shared decision making. The involvement of geriatricians in the care of older patients undergoing emergency laparotomy is increasingly recognised but requires further evaluation to understand causal pathways and implement evidence-based, cost-effective CGA-based services.

Figure 1: 30-day and 90-day mortality: *age and NELA year*



<u>**Table 1: Characteristics of NELA subjects 2013-2017:** ***comparison of age cohorts (<65 vs ≥65 and <65 vs 65-74, 75-84 and ≥85 years)***</u>

Characteristic	<65 years	All ≥65	P value	65-74	75-84	≥85	P value
Male n,(%)	20683 (51.0%)	24479 (46.3%)	<0.001	11327 (49.7%)	9877 (45.4%)	3275 (39.3%)	<0.001
Pre-admission care home* n,(%)	120 (1.1%)	242 (1.8%)	<0.001	67 (1.1%)	95 (1.8%)	80 (3.8%)	<0.001
SBP 90 and less n ^ ,(%)	2294 (5.7%)	3421 (6.5%)	<0.001	1592 (7.1%)	1417 (6.6%)	412 (5%)	<0.001
HR ≥90 n ^ ,(%)	21272 (53.2%)	25789 (49.3%)	<0.001	11673 (51.8%)	10418 (48.4%)	3698 (44.9%)	<0.001
WCC ≤4 or ≥11 ^ n,(%)	23070 (57.2%)	28664 (54.4%)	<0.001	12471 (55%)	11837 (54.6%)	4356 (52.5%)	0.004
Hb ≤100 g/L ^ n,(%)	6436 (15.9%)	8526 (16.2%)	0.314	3789 (16.7%)	3519 (16.2%)	1218 (14.6%)	<0.001
Lactate ≥2 ^ n,(%)	7819 (33.9%)	12890 (37.9%)	<0.001	5466 (38.9%)	5553 (38.8%)	1871 (34.0%)	<0.001
Albumin 32 and below *^ n,(%)	3564 (37.4%)	5537 (45.3%)	<0.001	2401 (45%)	2274 (45.7%)	862 (45.1%)	<0.001
CRP ≥100 *^ n,(%)	4001 (41.4%)	5063 (40.9%)	<0.001	2357 (43.6%)	2035(40.6%)	671 (34.6%)	<0.001
ASA n,(%)							
1	7868 (19.4%)	1639 (3.1%)	<0.001	1094 (4.8%)	448 (2.1%)	97 (1.2%)	<0.001
2	17235 (42.5%)	15263 (28.9%)	<0.001	7765 (34.1%)	5812 (26.7%)	1686 (20.2%)	<0.001
3	10433 (25.7%)	22714 (42.9%)	<0.001	8929 (39.2%)	9783 (44.9%)	4002 (48.1%)	<0.001
4	4309 (10.6%)	12086 (22.8%)	<0.001	4478 (20%)	5229 (24%)	2379 (28.6%)	<0.001
5	679 (1.7%)	1181 (2.2%)	<0.001	514 (2.3%)	505 (2.3%)	162 (1.9%)	<0.001
NELA model predicted mortality ≥ 5%# n,(%)	1965 (19.5%)	8758 (67.9%)	<0.001	2915 (51.8%)	3935 (75.3%)	1908 (93.7%)	<0.001
P-POSSUM predicted mortality ≥5% n,(%)	17303 (42.9%)	37076 (70%)	<0.001	14522 (63.7%)	16180 (74.3%)	6374 (76.6%)	<0.001
Mortality risk ≥5% by other measure# n,(%)	10872 (42.9%)	27008 (73.2%)	<0.001	10099 (66.1%)	11799 (76.3%)	5110 (83.1%)	<0.001
Risk assessment not documented n,(%)	15156 (37.4%)	15989 (30.2%)	<0.001	7492 (32.9%)	6323 (29%)	2174 (26.1%)	<0.001
Small bowel resection or adhesiolysis n,(%)	11772 (29%)	18698 (35.4%)	<0.001	7310 (32.1%)	7873 (36.1%)	3515 (42.2%)	<0.001
Right hemicolectomy n,(%)	5348 (13.2%)	6672 (12.6%)	0.009	2880 (12.6%)	2764 (12.7%)	1028 (12.3%)	0.058

Hartmann's procedure n,(%)	4438 (10.9%)	7253 (13.7%)	<0.001	3222 (14.1%)	3029 (13.9%)	1002 (12%)	<0.001
Subtotal or panprotoctocolectomy n,(%)	2580 (6.4%)	2396 (4.5%)	<0.001	1179 (5.2%)	979 (4.5%)	238 (2.9%)	<0.001
Peptic ulcer suture or repair of perforation n,(%)	3086 (7.6%)	1982 (3.7%)	<0.001	817 (3.6%)	830 (3.8%)	335(4%)	<0.001
Intra-operative Cancer finding n,(%)	5988 (15%)	11870 (22.8%)	<0.001	5124 (22.8%)	4873 (22.7%)	1873 (22.8%)	<0.001
Pre-op CT n,(%)	32954 (81.3%)	45404 (85.9%)	<0.001	19458 (85.4%)	18743 (86%)	7203 (86.5%)	<0.001
Consultant surgeon in theatre n,(%)	35520 (87.6%)	46422 (87.8%)	0.013	20159 (88.5%)	19080 (87.6%)	7183 (86.3%)	<0.001
Consultant anaesthetist in theatre n,(%)	31324 (77.3%)	43326 (81.9%)	<0.001	18445 (81%)	17986 (82.6%)	6895 (82.8%)	<0.001
Time to surgery (median, IQR) +	33.95 (13-94)	37.8 (15.88-98.2)	<0.001	38.5 (15.33-101.5)	37 (16-97.97)	38.67 (16.83-92.93)	<0.001
Pre-op Geriatrician RV* n,(%)	103 (1%)	681 (5.2%)	<0.001	172 (3%)	306 (5.7%)	203 (9.7%)	<0.001
Post-op Geriatrician RV n,(%)	566 (1.4%)	6060 (11.5%)	<0.001	1521 (6.7%)	2868 (13.2%)	1671 (20%)	<0.001

*variable added in 4^{th} year , ^data missing: 8% albumin missing, 6.8% CRP missing, 39% lactate missing; each analysed with missing data population excluded, +patients with invalid time to theatre excluded (ie. 0 hours or less), #patient excluded from analysis where risk assessment not completed or documented

Table 2: Simple and multiple logistic regression analysis: prediction of 30 and 90-day mortality in NELA patients ≥65 years

Mortality	Variable	OR	P Value	CI	OR	P value	CI
		Simple			Multiple		
30	**Age 65-74**	1.00	-	-	1.00	-	-
90		1.00	-	-	1.00	-	-
30	**Age 75-84**	1.51	<0.001	1.36 – 1.601	1.48	<0.001	1.39 – 1.57
90		1.44	<0.001	1.38 – 1.51	1.36	<0.001	1.29 – 1.43
30	**Age ≥ 85**	1.99	<0.001	1.86 – 2.13	2.03	<0.001	1.89 – 2.19
90		1.97	<0.001	1.85 – 2.09	1.88	<0.001	1.76 – 2.01
30	**Male gender**	1.05	0.059	1.00 – 1.10	0.97	0.218	0.92 – 1.02
90		1.09	<0.001	1.04 – 1.13	1.01	0.794	0.96 – 1.05
30	**SBP ≤ 90mmHg**	4.36	<0.001	4.05 – 4.69	2.06	<0.001	1.90 – 2.24
90		3.61	<0.001	3.36 – 3.87	1.85	<0.001	1.71 – 2.00
30	**HR ≥ 90**	2.30	<0.001	2.19 – 2.42	1.52	<0.001	1.43 – 1.60
90		1.94	<0.001	1.86 – 2.03	1.36	<0.001	1.30 – 1.43
30	**WCC ≤4 or ≥11**	1.44	<0.001	1.38 – 1.52	1.14	<0.001	1.08 – 1.21
90		1.37	<0.001	1.31 – 1.43	1.15	<0.001	1.09 – 1.20
30	**Hb ≤100 g/L**	1.54	<0.001	1.45 – 1.63	0.98	0.544	0.92 – 1.05
90		1.70	<0.001	1.62 – 1.80	1.11	0.001	1.05 – 1.18
30	**ASA – 1**	1.00	-	-	1.00	-	-
90		1.00	-	-	1.00	-	-

30	**ASA – 2**	1.84	<0.001	1.35 – 2.51	1.58	0.004	1.16 – 2.19
90		1.60	<0.001	1.27 – 2.02	1.43	0.003	1.19 – 1.81
30	**ASA – 3**	4.69	<0.001	3.47 – 6.35	3.18	<0.001	2.35 – 4.33
90		4.07	<0.001	3.24 – 5.12	3.00	<0.001	2.38 – 3.79
30	**ASA – 4**	17.27	<0.001	12.76 – 23.35	9.21	<0.001	6.78 – 12.51
90		13.03	<0.001	10.36 – 16.38	8.04	<0.001	6.36 – 10.16
30	**ASA - 5**	58.89	<0.001	42.66 – 81.28	26.84	<0.001	19.32 – 37.29
90		39.34	<0.001	30.42 – 50.88	21.62	<0.001	16.60 – 28.15
30	**P-POSSUM mortality ≥5%**	6.17	<0.001	5.67 – 6.72	2.64	<0.001	2.41 – 2.90
90		5.01	<0.001	4.69 – 5.37	2.29	<0.001	2.12 – 2.46
30	**Cancer at operation**	0.91	.003	0.86 – 0.97	1.27	<0.001	1.19 – 1.35
90		1.34	<0.001	1.28 – 1.41	1.89	<0.001	1.79 – 2.00
30	**Post-op geriatrician RV**	0.53	<0.001	0.48 – 0.58	0.38	<0.001	0.345 – 0.42
90		0.79	<0.001	0.73 – 0.85	0.60	<0.001	0.56 – 0.65
30	**NELA model predicted mortality ≥5% ***	8.23	<0.001	6.82 – 9.93	2.29	<0.001	1.82 – 2.88
90		6.70	<0.001	5.77 – 7.77	2.19	<0.001	1.823 – 2.65
30	**Pre-admission care home***	1.46	0.024	1.05 – 2.03	0.94	0.753	0.66 – 1.35
90		1.93	<0.001	1.46 – 2.55	1.36	0.048	1.00 – 1.86

30	**Pre-op geriatrician RV***	1.88	<0.001	1.56 – 2.27	1.69	<0.001	1.37 – 2.09
90		1.82	<0.001	1.53 – 2.17	1.45	<0.001	1.20 – 1.77

*4th year data points

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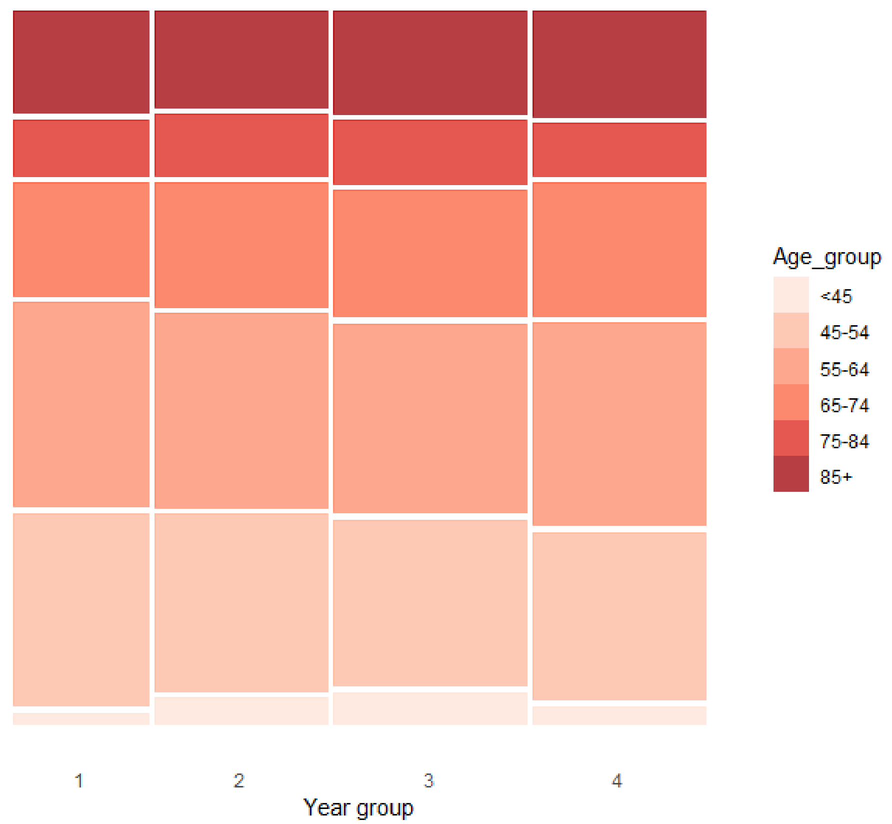
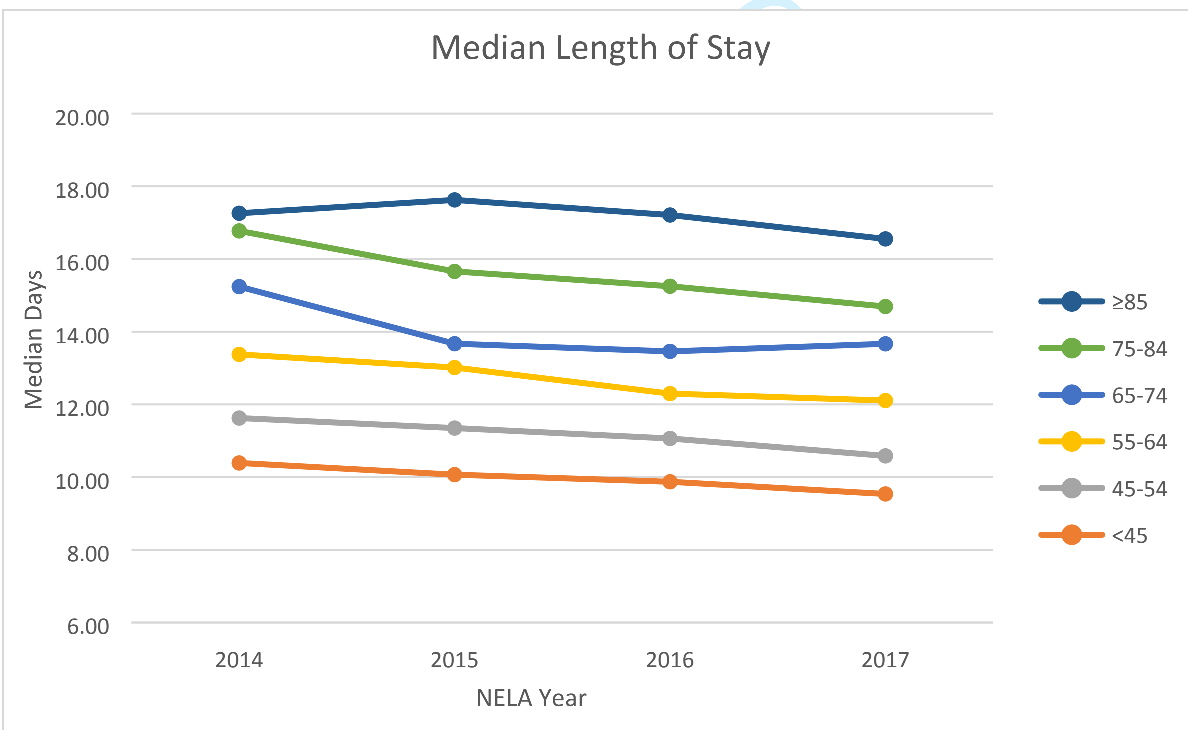
Appendix Figure 1: NELA participant age distribution



Appendix Figure 2: Length of Stay: *age and NELA year*



Appendix Table 1: Simple logistic regression analysis: age-group stratified 30-day and 90-day mortality and NELA year

Mortality	Variable	OR	OR	P Value	CI	OR	P Value	CI	OR	P Value	CI
		Year 1	Year 2			Year 3			Year 4		
30	**Age ≤44**	1.00	1.04	0.820	0.76 – 1.42	0.93	0.66	0.68 – 1.27	0.81	0.21	0.58 – 1.12
90		1.00	0.97	0.80	0.75 – 1.25	0.86	0.24	0.66 – 1.11	0.70	0.01	0.53 – 0.92
30	**Age 45-54**	1.00	1.14	0.34	0.87 – 1.48	1.14	0.32	0.88 – 1.49	0.99	0.98	0.76 – 1.31
90		1.00	1.10	0.39	0.89 – 1.36	0.98	0.82	0.79 – 1.21	0.94	0.57	0.75 – 1.17
30	**Age 55-64**	1.00	0.97	0.76	0.82 – 1.15	0.95	0.57	0.81 – 1.13	0.70	<0.001	0.59 – 0.84
90		1.00	0.97	0.70	0.84 – 1.12	0.94	0.38	0.81 – 1.08	0.76	<0.001	0.65 – 0.88
30	**Age 65-74**	1.00	1.00	0.93	0.90 – 1.03	0.93	0.22	0.83 – 1.05	0.85	0.005	0.75 – 0.95
90		1.00	0.99	0.861	0.90 – 1.10	0.92	0.124	0.84 – 1.02	0.83	<0.001	0.75 – 0.92
30	**Age 75-84**	1.00	1.02	0.73	0.92 – 1.13	0.89	0.03	0.81 – 0.99	0.85	0.003	0.77 – 0.95
90		1.00	0.96	0.36	0.88 – 1.05	0.86	0.002	0.79 – 0.95	0.79	<0.001	0.72 – 0.86
30	**Age ≥85**	1.00	0.75	<0.001	0.65 – 0.87	0.72	<0.001	0.62 – 0.83	0.63	<0.001	0.54 – 0.74
90		1.00	0.73	<0.001	0.64 – 0.84	0.71	<0.001	0.62 – 0.81	0.60	<0.001	0.53 – 0.69

Appendix Table 2: Simple and multiple linear regression analysis: prediction of length of stay in NELA patients ≥65 years

Variable	Beta coefficient	P Value	CI	Beta coefficient	P value	CI
	Simple			Multiple		
Age 65-74	1.00	-	-	1.00	-	-
Age 75-84	1.206	<0.001	0.737 – 1.675	-0.400	0.091	-0.865 – 0.065
Age ≥ 85	1.232	<0.001	0.599 – 1.866	-1.500	<0.001	-2.134 – -0.865
Male gender	0.178	0.419	-0.254 – 0.610	-0.004	0.983	-0.447 – 0.418
SBP ≤ 90mmHg	1.745	<0.001	0.858 – 2.631	-1.656	<0.001	-2.557 – -0.775
HR ≥ 90	2.790	<0.001	2.360 – 3.220	0.901	<0.001	0.458-1.343
WCC ≤4 or ≥11	0.310	0.159	-0.122 – 0.742	-1.023	<0.001	-1.452 – -0.594
Hb ≤100 g/L	8.297	<0.001	7.715 – 8.880	6.220	<0.001	5.638 – 6.812
ASA - 1	1.00	-	-	1.00	-	-
ASA - 2	2.982	<0.001	1.718 – 4.247	2.121	0.001	0.873 – 3.368
ASA - 3	8.923	<0.001	7.679 – 10.168	6.418	<0.001	5.175 – 7.661
ASA - 4	12.699	<0.001	11.417 – 13.981	8.803	<0.001	7.499 – 10.108
ASA - 5	6.823	<0.001	4.935 – 8.711	2.665	0.006	0.754 – 4.577
P-POSSUM mortality ≥5%	7.420	<0.001	6.956 – 7.885	4.030	<0.001	3.505 – 4.556
Cancer at operation	-1.973	<0.001	-2.505 – -1.441	-1.860	<0.001	-2.387 – -1.333
Post-op geriatrician RV	10.182	<0.001	9.507 – 10.856	9.308	<0.001	8.637 – 9.979
NELA model predicted mortality ≥5%*	5.555	<0.001	4.836 – 6.274	0.843	0.102	-0.166 – 1.853

Pre-admission care home*	3.676	0.005	1.116 – 6.236	1.452	0.253	-1.039 – 3.943
Pre-op geriatrician RV*	6.388	<0.001	4.835 – 7.940	2.426	0.002	0.875 – 3.977

*4th year data points

Appendix Table 3: Year 4 Care Home on Discharge (vs Independent – unspecified and unknown excluded) in NELA patients ≥ 65 years

Variable	**OR**	**P Value**	**CI**	**OR**	**P value**	**CI**
	Simple			**Multiple**		
Age 65-74	1.00	-	-	1.00	-	-
Age 75-84	1.982	<0.001	1.671 – 2.351	1.400	<0.001	1.172 – 1.673
Age ≥ 85	4.681	<0.001	3.892 – 5.629	2.481	<0.001	2.034 – 3.028
Male gender	0.726	<0.001	0.63 – 0.836	0.764	<0.001	0.659 – 0.884
Pre-admission care home	24.065	<0.001	17.471 – 33.147	11.113	<0.001	8.4 – 14.704
ASA - 1	1.00	-	-	1.00	-	-
ASA – 2	1.058	0.844	0.604 – 1.852	0.887	0.682	0.501 – 1.572
ASA – 3	2.575	0.001	1.496 – 4.431	1.167	0.593	0.663 – 2.053
ASA – 4	5.825	<0.001	3.367 – 10.078	1.490	0.175	0.838 – 2.649
ASA - 5	7.418	<0.001	3.516 – 15.647	0.885	0.751	0.416 – 1.882
P-POSSUM mortality ≥5%	2.691	<0.001	2.259 – 3.205	1.349	0.003	1.103 – 1.649
NELA model predicted mortality ≥5%	4.656	<0.001	3.822 – 5.671	1.716	<0.001	1.334 – 2.206
Pre-op geriatrician RV	2.519	<0.001	1.968 – 3.224	0.949	0.702	0.726 – 1.241
Post-op geriatrician RV	3.049	<0.001	2.62 – 3.548	2.329	<0.001	1.982 – 2.737

nursing home 639 = 6.2% / residential care 248 = 2.4% / own home or sheltered 9657 = 93.5%

Appendix Table 4: ≥65 year-old patients reviewed by Geriatricians pre-op and post-op characteristics and outcomes

	Pre-op*			Post-op		
	SEEN	**NOT SEEN**	**P value**	**SEEN**	**NOT SEEN**	**P value**
SBP ≤90mmHg ^	38 (5.6%)	738 (5.9%)	0.740	347 (5.8%)	3074 (7.1%)	0.01
HR ≥90 ^	349 (51.6%)	6068 (48.7%)	0.139	3043 (50.6%)	22746 (49.2%)	0.034
WCC ≤4 or ≥11 ^	371 (54.6%)	6797 (54.4%)	0.886	3302 (54.5%)	25362 (54.2%)	0.635
Hb <100 ^	151 (22.2%)	1840 (14.7%)	<0.001	1048 (17.3%)	7478 (16%)	0.01
ASA-1	10 (1.5%)	400 (3.2%)	<0.001	96 (1.6%)	1543 (3.4%)	<0.001
ASA-2	105 (15.4%)	3779 (30.1%)	<0.001	1293 (21.3%)	13970 (29.8%)	<0.001
ASA-3	304 (44.6%)	5527 (44.1%)	<0.001	2864 (47.3%)	19850 (42.4%)	<0.001
ASA-4	245 (36%)	2573 (20.5%)	<0.001	1699 (28%)	10387 (22.2%)	<0.001
ASA-5	17 (2.5%)	259 (2.1%)	<0.001	108 (1.8%)	1073 (2.3%)	<0.001
NELA model predicted mortality ≥ 5% *	571 (83.8%)	8187 (65.3%)	<0.001	1605 (77.6%)	7153 (66.8%)	<0.001
P-POSSUM mortality ≥5%	548 (80.5%)	8582 (68.4%)	<0.001	4688 (77.4%)	32388 (69.2%)	<0.001
Predicted mortality by other measure ≥5% #	470 (84.1%)	6701 (69%)	<0.001	3763 (80.8%)	23245 (72.1%)	<0.001
Pre-admission care home*	36 (5.3%)	206 (1.6%)	<0.001	65 (3.1%)	177 (1.6%)	<0.001
Time to theatre	95.92 (41.75-194)	32.25 (14.54-85.98)	<0.001	95.95 (41.75-194)	37.25 (15.75-97)	<0.001
30-day mortality	151 (22.2%)	1667 (13.3%)	<0.001	560 (9.2%)	7525 (16.1%)	<0.001
90-day mortality	190 (27.9%)	2208 (17.6%)	<0.001	1042 (17.2%)	9765 (20.9%)	<0.001
Length of Stay (median, IQR)	20.24 (11.82-35.15)	14.37 (8.43-24.55)	<0.001	23.09 (13.45-39.47)	14.4 (8.52-25.05)	<0.001
Discharge to care home*	84 (12.3%)	803 (6.4%)	<0.001	291 (14%)	596 (5.3%)	<0.001

*year 4 data only

#risk not documented group excluded