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# Socioeconomic deprivation and mortality after emergency laparotomy: an observational epidemiological study

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**Socioeconomic deprivation and mortality after emergency laparotomy: an observational epidemiological study**

Short title: Socioeconomic deprivation and mortality after emergency laparotomy

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**Abstract**

Background

Socioeconomic circumstances can influence access to healthcare, the standard of care provided, and a variety of outcomes. This study aimed to determine the association between crude and risk-adjusted 30-day mortality and socioeconomic group after emergency laparotomy; measure differences in meeting relevant perioperative standards of care; and investigate whether variation in hospital structure or process could explain any difference in mortality between socioeconomic groups.

Methods

Observational study of 58,790 patients, with data prospectively collected for the National Emergency Laparotomy Audit (NELA) in 178 NHS hospitals in England between 1 December 2013 and 31 November 2016, linked with national administrative databases. Socioeconomic group was determined according to the Index of Multiple Deprivation quintile of each patient's usual place of residence.

Results

Overall crude 30-day mortality was 10.3%, with differences between the most deprived (11.2%) and least deprived (9.8%) quintiles ($p < 0.001$). More deprived patients were more likely to have multiple comorbidities, were more acutely unwell at the time of surgery, and required more urgent surgery. After risk-adjustment, patients in the most deprived quintile were at significantly higher risk of death compared to all other quintiles (aOR (95% CI): Q1 (most deprived): Ref, Q2: 0.83 (0.76-0.92), Q3: 0.84 (0.76-0.92), Q4: 0.87 (0.79-0.96), Q5 (least deprived): 0.77 (0.70-0.86)). We found no evidence that differences in hospital-level structure or patient-level performance in standards of care explained this association.

Conclusions

More deprived patients have higher crude and risk-adjusted 30-day mortality after emergency laparotomy, but this is not explained by differences in the standards of care recorded within NELA.

Keywords

Socioeconomic factors

Healthcare disparities

Laparotomy

Perioperative care

Mortality

Short title

Socioeconomic deprivation and mortality after emergency laparotomy

**Introduction**

Emergency laparotomy is one of the most commonly performed high risk emergency surgical procedures, with an estimated annual incidence of 1:1,100 population.[1] While the outcome can vary according to the indication for surgery, the underlying pathology and other risk factors, the overall 30-day mortality rate for this heterogeneous group of patients has been reported to be between 5.4% and 23.9% for the most common indications.[2] When compared to a mortality rate of < 1% for major elective surgery internationally, this represents a population with significant perioperative risk.[3]

It is recognised that socioeconomic circumstances are associated with differences in the prevalence of multimorbidity, variation in health outcomes from a range of diseases, and significant differences in life expectancy.[4-6] However, there are few studies examining the association between socioeconomic deprivation and mortality after emergency laparotomy. In a systematic review of 59 studies in which outcomes after colorectal surgery were reported according to socioeconomic group, only three studies reported outcomes for the subgroup of patients undergoing emergency surgery, with the majority either not distinguishing between patients having elective and emergency operations (35 out of 59), or not reporting the level of surgical urgency (19 out of 59).[7]

The relationships between socioeconomic circumstances and postoperative outcomes are complex. Patients undergo an emergency laparotomy for a variety of indications caused by numerous potential underlying pathologies, each of which may relate to socioeconomic circumstances in aetiology, health service utilisation, and quality of care received. Socioeconomic circumstances can be a factor in variations in access to good quality healthcare, both during an acute illness and throughout the life-course.[8] They can contribute to differences in the manner in which patients engage with healthcare services, for instance due to variation in participation in screening programmes, or other health seeking behaviour.[9, 10] Socioeconomic deprivation can also exacerbate the effect that lifestyle-related risk factors have on poor health and mortality.[11] Insecurity or lack of control over finances, work, or housing, coupled with barriers to maintaining a cohesive social support network, can all have negative effects on health.[12-14] All of these mechanisms could result in differences in the types of pathology with which patients in different socioeconomic groups present, or the age at which certain conditions develop. Socioeconomic circumstances may also result in differences in the overall state of chronic health at the time of presentation, the duration of symptoms or the stage of disease before definitive treatment, and the extent of any physiological derangement at the time of an acute presentation.[15] A hypothesised causal pathway linking socioeconomic circumstances to mortality after emergency laparotomy is summarised in Figure 1.

Given the complex interplay of these mediators there are multiple possible factors that could potentially explain or mitigate outcome differences. However, broadly, if outcomes differ according to socioeconomic circumstances it may be due to three types of reasons: factors that influence a patient's condition at the time of presentation; differences in the care delivered during the perioperative period and subsequent follow up; and lifestyle factors and other social determinants of health that exert an effect both prior to admission and after discharge. Being able to identify a possible explanation for outcome differences based on socioeconomic circumstances would allow interventions to be targeted to address some of the inequality. It is well recognised that the provision of medical resources and the need for medical care are not always well matched, a phenomenon referred to as the inverse care law.[16] If there is evidence to suggest that unwarranted variation in the care delivered during the perioperative period is contributing to differences in outcome between socioeconomic groups, efforts could be made to address this variation and ensure a more equitable allocation of resources.



This study had five interrelated objectives: 1) to document how demographic and risk factors varied by socioeconomic group in this population; 2) to investigate the unadjusted association between socioeconomic group and 30-day mortality risk in patients undergoing emergency laparotomy; 3) to estimate adjusted mortality rates according to socioeconomic group, to determine whether outcomes differed given expected risk; 4) to determine if there were differences between socioeconomic groups in whether standards of care were met in the perioperative period, and if so, whether this could be explained by within- or between-hospital variation; 5) to determine whether any variation in hospital structure or delivery of standards of care could explain or partially explain any of the mortality difference between socioeconomic groups.

## Methods

### Study Design

This was an observational epidemiological study performed through analysis of prospectively collected data from the National Emergency Laparotomy Audit (NELA), linked with national administrative databases.

### Setting

NELA aims to collect data on every emergency laparotomy performed within National Health Service (NHS) hospitals in England and Wales. Data are collected from all hospitals where eligible emergency laparotomies are performed. Based on data obtained from the Hospital Episodes Statistics (HES) database, it is estimated that the NELA dataset includes over 80% of all emergency laparotomies performed in England since data collection began in December 2013.[2, 17-19] This study included patients who were entered into the NELA database after undergoing an eligible emergency laparotomy in England between 1 December 2013 and 31 November 2016. This restriction was applied because the necessary linkage to external databases was not available for patients undergoing surgery from 1 December 2016 onwards at the time work on this analysis began.

### Participants

The full inclusion/exclusion criteria for entry into the NELA database are defined elsewhere.[20] For the purposes of this study patients were also excluded if any of the following applied: treatment in a non-English hospital; treatment in a hospital for which no organisational audit data were available; no available linkage to Office for National Statistics or Hospital Episode Statistics data; unable to link the usual place of residence to a valid Lower Layer Super Output Area (LSOA) in England; an active decision for palliative management at the end of the operation (eg ‘open-close’ laparotomy).

### NELA patient audit and organisational data

The patient data for this analysis were based on an export taken from the NELA database on 2 February 2017. Hospital organisational data was based on the NELA Organisational Audits performed in 2013 and 2016.[19, 21]

Casemix variables used for risk adjustment (online supplement Table S1) and process data pertaining to standards of care (Table S2) were taken directly from the NELA patient audit database, with the exception of comorbidity scores and ethnicity, which were derived from linkage to HES data. Details of the recoding of variables and use of Organisational Audit data describing hospital structure are outlined in the supplementary material.

Data linkage and ethics

Approval from the Health Research Authority Confidentiality Advisory Group under Section 251 of the NHS Act 2006 and Health Service (Control of Patient Information) Regulations 2002 meant individual patient consent was not required to collect, store, and analyse these data. Linkage of the NELA dataset to the Office for National Statistics (ONS) and Hospital Episode Statistics (HES) databases was performed by NHS Digital.

All-cause 30-day mortality

Linked ONS data provided the date of death from any cause based on the national register of deaths. Where data linkage was not available, but the patient was recorded as having died during their index admission within the NELA database, the date of death as recorded on the online case record form was used instead. If no ONS data linkage could be performed and the patient was recorded as being alive at the time of discharge from hospital, they were excluded.

Additional variables derived from HES data

HES data were used to generate additional dummy variables describing ethnicity and comorbidity for the purpose of statistical adjustment.

A patient's ethnicity was based on the modal value entered for the spell covering the emergency laparotomy. Due to some small cell numbers, the available ethnic categories recorded in HES were collapsed into White, Asian, Black, and Other (Table S4).

Comorbidity was estimated based on International Classification of Diseases - 10th Revision (ICD-10) codes recorded within HES, which were used to generate a score based on definitions for the Elixhauser index as defined by Quan et al.[22] Eligible comorbidities were counted if they were included in the discharge coding for any hospital admission whose admission date was within one year prior to the date of the emergency laparotomy, including the admission in which the emergency laparotomy took place. In order to distinguish between pre-existing disease and pathology acquired during the acute illness, chronic lung and kidney disease were only counted when previously coded in an admission beginning within one year prior to the date of the emergency laparotomy, excluding the admission during which the patient underwent their emergency laparotomy.



Patient-level deprivation

Patient-level deprivation was measured in quintiles of the Index of Multiple Deprivation (IMD) score for the patient's usual residence, recorded at the level of Lower Layer Super Output Areas (LSOAs). The IMD score for each LSOA was based on publicly available data from 2015, published by the ONS.[23] Further details of the process by which a patient was linked to a LSOA are provided in the online supplement.

Data Management

Data containing patient identifiable information were stored on a secure server at the Royal College of Surgeons, London. Data cleaning and analysis were performed using Stata versions 13 and 15 (StataCorp, College Station, Texas).

Statistical Analysis

All reported statistical analysis was based on an analysis plan that was developed and approved before we began conducting the analysis. TEP, SRM and PM had worked with the NELA data set (excluding IMD data) for other purposes, so it was not possible for these authors to be completely blind to the entire dataset while drawing up the analysis plan. However, the analysis plan was completed before we conducted the analyses for this paper, and we did not make analytic decisions contingent on seeing the data, thus minimising researcher degrees of freedom.

Differences in categorical demographic and other casemix variables between IMD quintiles were assessed using the chi-square test (objective 1).

Analysis of the crude association between deprivation and 30-day mortality was performed using single-level logistic regression (objective 2). The association between deprivation and risk-adjusted 30-day mortality was performed using mixed effects logistic regression of IMD quintile and casemix variables on 30-day mortality, with a random intercept for hospitals (objective 3). Selection of casemix covariates was based on the previously published NELA risk adjustment model,[24] which was developed and internally validated from a subset of the dataset used in the current study, with continuous patient-level physiological and biochemical parameters transformed where necessary. Additional variables were added to the model to attempt to reduce bias pertinent to this analysis (Table S1).

Investigation of the association between socioeconomic group and hospital structures or processes of care was performed using bivariate logistic regression of IMD quintile on each structure and process variable (objective 4). Regressions of hospital-level structures were weighted according to the numbers of patients treated in each hospital. Since patients are clustered within hospitals, for the patient-level process variables we also calculated adjusted odds ratios from random intercept models, thereby adjusting for the hospital in which the patients were treated.

To address whether hospital structure or processes of care mediated the association between deprivation and 30-day mortality (objective 5), a series of pairs of mixed-effects logistic regression models were compared. The aim was to compare the size of the ‘effect’ of socioeconomic group on risk-adjusted mortality in two models: (1) a ‘reduced’ model that did not control for hospital structure or process of care, and (2) a ‘full’ model that did make this adjustment. A reduction in the ‘effect’ of deprivation in model (2) compared to model (1) would indicate that the structure or process is partly responsible for the differences in adjusted mortality rates between socioeconomic groups. However, coefficients from directly nested logistic regression models are not comparable since coefficients can differ due to the effect of changes to the overall error variance of the model as well as any confounding effect of the control variable.[25] To overcome this each ‘reduced’ model comprised socioeconomic group, casemix adjustment variables, and residuals from a linear regression of the structure or process variable of interest on deprivation.[25] This was then compared with a 'full' model comprising socioeconomic group, casemix adjustment variables and the structure or process variable.

For all multivariate statistical models, multiple imputation was used to account for missing casemix variables. The chained equation method was used to produce 20 imputed sets, with the assumption that data were missing at random.[26] Details of the variables and the prediction models used for the imputation process are included in the online supplement. Missing transformed variables were imputed using a 'transform then impute' approach.[27] Missing outcome variables were not imputed.

The use of imputed data and two-level modelling meant there was no formal test of significance available for the differences in coefficients between pairs of models, therefore these results were assessed through descriptive comparison of the odds ratios and confidence intervals from each pair of full and reduced models.

**Results**

The raw dataset contained a total of 67,372 complete cases. Details of the exclusions during the cleaning and data linking process are outlined in Figure 2. During this process 6,054 patients (9.0%) were excluded due to an inability to link to the ONS and HES databases, which includes an unknown proportion of patients opting out of allowing their personal data to be used in this manner. Following all exclusions, 58,790 patients from 178 hospitals were included in the final analysis.

Differences between socioeconomic groups (objective 1)

Tables 1 and S6 shows the distribution of deprivation and its bivariate associations with variables used in subsequent analyses. The distribution of deprivation within this dataset matches the distribution within the general population. However, there were some significant differences in the demographics between IMD quintiles. Patients in the most deprived quintile were younger on average than those in the least deprived quintile, with a gradient across the socioeconomic spectrum ($p < 0.001$). Nonetheless, patients from the most deprived quintile were more likely to have high ASA scores (4 or 5) and to have more than two comorbidities recorded ($p < 0.001$ for each). The proportion of patients from ethnic minorities increased along the spectrum from the least deprived (2.7%) to the most deprived quintile (10.4%) ($p < 0.001$). There was also a notable difference in the proportion of patients in each IMD quintile in different geographic regions within England. Of all patients in the most deprived quintile, 23.1% lived in the North West, whereas patients in the least deprived quintile were more widely distributed, but predominantly lived in the East and South of England ($p < 0.001$).

More deprived patients were more likely to require the most urgent type of surgery ($p < 0.001$), however they tended to undergo less surgically complex operations ($p = 0.012$). In keeping with the higher degree of surgical urgency, patients in the most deprived quintile were more likely to undergo their emergency laparotomy outside of normal working hours, with the proportion of patients requiring an operation after midnight increasing from least deprived (7.5%) to most deprived (10.0%) ($p < 0.001$).

A higher proportion of more deprived patients underwent surgery for pathologies related to intraabdominal sepsis ($p < 0.001$) and were found to have higher rates of intraabdominal abscess ($p < 0.001$), or perforated or bleeding peptic ulcer ($p < 0.001$ and $p = 0.001$ respectively). More deprived patients were less likely to undergo surgery for intestinal obstruction ($p < 0.001$) and a lower proportion were found to have pathologies such as adhesions, volvulus, or malignancy (both localised and disseminated) ($p < 0.001$ for each). More deprived patients were more likely to have peritoneal free gas or soiling in the form of pus, bile, or gastric or duodenal contents ($p < 0.001$ for each). Additionally, where present, the extent of peritoneal contamination increased with deprivation, with 21.8% of the most deprived patients having generalised contamination, compared to 16.9% in the least deprived quintile ($p < 0.001$).



Socioeconomic groups and 30-day mortality (objectives 2 and 3)

The overall crude 30-day mortality rate was 10.3%, however there were significant differences between IMD quintiles (Q1 (most deprived): 11.2% vs Q5 (least deprived): 9.8%, $p < 0.001$). After adjusting for demographic, physiological, and surgical factors (Table S1) the association between risk-adjusted 30-day mortality and IMD quintile became stronger (Table 2 and Figure 3). While this association was strongest for the most deprived quintile, patients in Q4 were also found to have higher crude and risk adjusted 30-day mortality compared to the least deprived quintile. However, patients in the most deprived quintile (Q1) were at significantly higher risk of death compared to all other quintiles, even after risk adjustment (Figure 3b).

Despite the proportion of patients from ethnic minorities increasing with deprivation, and the unequal distribution of deprivation within the English regions, there was no evidence of an association between either ethnicity or geographical region and mortality after risk adjustment (Table S7).

Socioeconomic groups and hospital structures and processes (objective 4)

Bivariate analysis revealed relationships between patient deprivation and access to structural and organisational factors that lend themselves to the provision of good quality care. The shape and strength of these relationships differed between the various indicators of hospital structure, but generally patients in the most deprived quintile were more likely than the other groups to be treated in a hospital with access to good organisational services (Table S8).

Bivariate analysis also suggested relationships between socioeconomic circumstances and some of the patient-level indicators of adherence to standards of care (Table S9). However, once the variation between hospitals was accounted for, there was generally little difference between the quintiles (Table S9), suggesting that where differences between socioeconomic groups were found in the single-level models, much of the difference could be explained by variation in the delivery of standards of care between hospitals. It may however be the case that patients in different socioeconomic groups vary in their likelihood of being treated in hospitals in which standards are met more consistently.



Mediation of the effect of socioeconomic circumstances on mortality through hospital structures and processes (objective 5)

Finally, descriptive comparison of the nested models examining the association between socioeconomic group and mortality before and after accounting for hospital-level structures and patient-level processes of care showed that controlling for these factors had very little impact on adjusted mortality odds ratios (Figure S1). Thus, there was no evidence that adjusting for any of the hospital-level structural differences or variations in patient-level performance in standards of care contributed to explaining the socioeconomic differences in 30-day mortality after emergency laparotomy.

**Discussion**

We have analysed one of the world's largest and most granular databases describing the structures, processes, and outcomes of patients undergoing emergency laparotomy. Based on the evaluation of patterns related to socioeconomic variation, we can report four key findings. First, socioeconomic deprivation is associated with 30-day mortality after emergency laparotomy, even after applying the best available risk adjustment model. Patients living in the most deprived quintile of areas have a higher postoperative risk of death than patients living in other areas. Second, the demographic and surgical characteristics of patients undergoing an emergency laparotomy in England vary significantly between the five socioeconomic groups. Third, the most deprived patients were slightly more likely than other groups to be treated in a hospital with favourable structures, and we found little difference between the socioeconomic groups in the quality of care received within the same hospital. Finally, neither hospital-level structures nor patient-level indicators of quality of care explained why the most deprived patients have the highest adjusted risk of 30-day mortality.



Due to the comprehensive and national coverage of the English National Health Service (NHS), including the lack of private emergency departments, the population included in this dataset is likely to be a reliable reflection of the full extent of socioeconomic variation within England. This is supported by the fact the quintiles used in this analysis (defined according to national-level deprivation scores rather than limited to those within the study population) are relatively equal in size. Even those patients who would normally opt for private medical cover for elective or non-emergent matters are likely to have been captured within the patient-level data. In spite of this, the differences in the documented urgency of surgery and proportions of patients having surgery 'out of hours' suggest that more deprived patients are more acutely unwell at the time the decision to operate is made. It is unknown if the observed differences in surgical urgency between quintiles were due to later presentation in more deprived patients, since data on the pathological process prior to hospital admission were not available. However, there is evidence suggesting that more deprived patients present later for a range of other conditions, and the finding that more deprived patients were more likely to have more extensive peritoneal contamination (where present) suggests this may also be the case in emergency laparotomy.[15]

While this study has identified an association between deprivation and increased mortality after emergency laparotomy, it is not possible to determine what it is about the state of being deprived that is responsible. However, as Figure 1 demonstrates, there are potential causal pathways for which no data were available. These include the direct effects on postoperative mortality of variations in modifiable lifestyle-related risk factors and inequalities in other social determinants of health, differences in access to appropriate healthcare prior to an acute admission or engagement with services such as the bowel cancer screening programme, as well as differences in follow up and access to healthcare services after discharge. Additionally, the incidence and severity of complications can be a key cause of postoperative mortality, the effect of which may vary between socioeconomic groups due to patient-specific factors, the surgical pathology, the operation performed, and variation in the hospital-specific rates of 'failure to rescue'.[28]

There was generally little difference in the measured standards of care delivered to the most deprived quintile compared to the least deprived (defined by the evidence-based standards included within NELA), and controlling for these processes does not appear to mitigate the association between socioeconomic deprivation and postoperative mortality despite previous analysis finding associations between meeting certain standards and lower mortality.[29] While it is possible that there are other elements of structure and process that were not measured but still exert an influence on outcome differences between socioeconomic groups, the evidence from the health inequalities literature suggests that outcome differences have social and political causes.[30, 31] It is therefore more likely that successful interventions to reduce this socioeconomic inequality would need to address broader social and policy issues rather than focusing solely on care during the perioperative period. While this analysis cannot specify what those interventions should be, epidemiological and perioperative evidence would suggest that efforts to improve health literacy and chronic disease management, plus holistic policies to address lifestyle factors, access to healthcare, housing, childcare, education, employment and working conditions should all be considered.[32-34] While beyond the traditional remit of the biomedical approach to healthcare, these social determinants all combine to influence the standard of living required for maintaining health, which is compromised by the disadvantage accumulated throughout life through inequality in the circumstances in which people are born, grow, live, work, and age.[35]

It is interesting that, in England, more deprived patients were more likely to be treated in hospitals where the structural and organisational factors lend themselves to the provision of good quality care. This is likely to be due to the combination of a universal access healthcare system and the distribution of deprivation as measured by the IMD within England, which is generally more prevalent in cities.[36] For emergency care, patients in the NHS will generally be treated at the nearest suitable hospital, and patients living in cities are more likely to live closer to large teaching hospitals or tertiary referral centres. This contrasts with Australia, which also has a system of universal healthcare, but where deprivation is more associated with remote or rural communities that are far more geographically isolated from major population centres; or the USA, where a patient's payer status may influence the hospital in which they are treated.[37-39] Although the USA does not have a universal healthcare programme, it does have a system of safety net hospitals. However, even after adjusting for differences in patient demographics, these hospitals have been found to have higher postoperative mortality following colectomy, and higher complication rates after emergency general surgery.[40, 41] There is currently no evidence to tell us whether in these countries outcome differences are attributable to variations in the quality of care provided, whereas the data within NELA have helped address this important confounder regarding outcomes in England.



There are a number of limitations to this study. While the NELA annual patient reports have shown case ascertainment rates to be above 80% overall and improving over time, there are variations in case ascertainment between hospitals.[2, 17-19] Additionally, NELA only collects data on patients who undergo surgery. It is therefore not possible to comment on any differences between socioeconomic groups for the subset of patients managed without surgery, or indeed if there are differences in the proportions of patients who were treated conservatively.

The use of administrative databases risks excluding patients where data linkage is not possible. While this was the case in the study, the extent of data linkage was generally good. Additionally, the patient-level information in the Hospital Episode Statistics database is reliant on accurate data collection and entry by clinical coders. Previous analysis of HES suggests that, while there will inevitably be some inaccuracies due to miscoded entries or incomplete clinical record keeping, the data is of sufficient quality for population-level research such as this.[42, 43]

While we attempted to control for comorbidity using the Elixhauser comorbidity score, this does not include any information on variations in disease severity or how well managed a chronic condition may be. Given associations between socioeconomic group and health seeking behaviour and access to healthcare, a simple count of comorbidities is unlikely to fully describe the clinical picture. While it may be true that someone with multiple comorbidities is more likely to be in a poorer state of health compared to someone with none, a single serious or poorly controlled chronic disease may lead to greater functional limitation and perioperative risk than multiple less severe, less limiting, or better controlled diseases. In light of this, access to good quality healthcare for health promotion and chronic disease management over many years preceding the event may influence outcome after an eventual emergency laparotomy, perhaps more so than any variations in care delivered during the acute presentation itself.

This analysis has defined socioeconomic deprivation according to the patient's usual place of residence. Whilst this raises the possibility of the ecological fallacy, whereby an area's relative level of deprivation based on the aggregate data of its population may not reflect the specific circumstances of an individual patient, this tends only to be an issue when measuring over larger areas than those used in this analysis, which is based on the smallest unit of area for which data are available (approximately 1,500 persons per LSOA).[44] However it must be borne in mind that deprivation is widely distributed and even areas of low aggregate deprivation will still include some deprived individuals.

The conclusion that efforts to address adverse outcomes associated with deprivation should focus more on the broader causes of health inequalities than care during an acute episode could likely apply to a range of surgical and medical presentations. Improving the quality of acute care is an important aim for the benefit of the population in general, however this may have little effect on addressing pre-existing disparities between socioeconomic groups. Although the evidence from the health inequalities literature suggests that lifestyle-related factors merely exacerbate mortality differences between socioeconomic groups rather than being a primary cause,[45, 46] further work is required to identify where perioperative risk could be reduced through public health intervention. Additionally, since there exist significant geographical differences in rates of deprivation, future analysis should explore whether the healthcare system in England is equitably resourced in more deprived communities across the country, especially those outside of major cities where the combination of patient demographics and access to appropriate services may prove particularly challenging.

**Other**

Collaborators

NELA collaborators (in alphabetical order): Iain D Anderson, Mike G Bassett, David A Cromwell, Emma Davies, Natalie Eugene, Mike PW. Grocott, Carolyn Johnston, Angela Kuryba, Sonia Lockwood, Jose Lourtie, Dave Murray, C Matt Oliver, Carol Peden, Tom Salih, Kate Walker.

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Author contributions

TEP: Conceptualisation, data curation, formal analysis, investigation, methodology, project administration, software, validation, visualisation, writing (original draft), writing (review and editing).

SRM: Conceptualisation, formal analysis, investigation, methodology, project administration, supervision, validation, writing (review and editing).

RR: Conceptualisation, methodology, supervision, validation, writing (review and editing).

PM: Conceptualisation, formal analysis, investigation, methodology, project administration, supervision, validation, writing (review and editing).

party material where-ever it may be located; and, vi) licence any third party to do any or all of the above.

Competing interests

TEP, SRM, and PM are members of the NELA project team.

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PM's work on this paper was funded by the Royal College of Anaesthetists for his role as statistician for the NIAA Health Services Research Centre.

RR is funded by the National Institute for Health Research (NIHR) Collaboration for Leadership in Applied Health Research and Care North Thames at Bart's Health NHS Trust (NIHR CLAHRC North Thames).

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**Table 1**
**Patient demographics (see Table S6 for further surgical characteristics)**

| | 1 - Most deprived | 2 | 3 | 4 | 5 - Least deprived | Total | P value |
|---|---|---|---|---|---|---|---|
| **Total number** | 11,896 (20.2) | 11,727 (19.9) | 12,305 (20.9) | 11,679 (19.9) | 11,183 (19.0) | 58,790 (100.0) | - |
| **Age category** | | | | | | | |
| 18-39 | 1,689 (14.2) | 1,455 (12.4) | 1,198 (9.7) | 982 (8.4) | 899 (8.0) | 6,223 (10.6) | <0.001 |
| 40-49 | 1,567 (13.2) | 1,295 (11.0) | 1,138 (9.2) | 914 (7.8) | 885 (7.9) | 5,799 (9.9) | |
| 50-59 | 2,030 (17.1) | 1,713 (14.6) | 1,681 (13.7) | 1,484 (12.7) | 1,312 (11.7) | 8,220 (14.0) | |
| 60-69 | 2,422 (20.4) | 2,418 (20.6) | 2,587 (21.0) | 2,446 (20.9) | 2,293 (20.5) | 12,166 (20.7) | |
| 70-79 | 2,461 (20.7) | 2,731 (23.3) | 3,194 (26.0) | 3,177 (27.2) | 3,026 (27.1) | 14,589 (24.8) | |
| 80+ | 1,727 (14.5) | 2,115 (18.0) | 2,507 (20.4) | 2,676 (22.9) | 2,768 (24.8) | 11,793 (20.1) | |
| **Sex** | | | | | | | |
| Male | 5,852 (49.2) | 5,670 (48.3) | 5,887 (47.8) | 5,624 (48.2) | 5,227 (46.7) | 28,260 (48.1) | 0.006 |
| Female | 6,044 (50.8) | 6,057 (51.7) | 6,418 (52.2) | 6,055 (51.8) | 5,956 (53.3) | 30,530 (51.9) | |
| **ASA** | | | | | | | |
| 1 | 1,281 (10.8) | 1,244 (10.6) | 1,250 (10.2) | 1,159 (9.9) | 1,212 (10.8) | 6,146 (10.5) | <0.001 |
| 2 | 3,788 (31.8) | 3,990 (34.0) | 4,356 (35.4) | 4,210 (36.0) | 4,008 (35.8) | 20,352 (34.6) | |
| 3 | 4,280 (36.0) | 4,123 (35.2) | 4,390 (35.7) | 4,131 (35.4) | 3,914 (35.0) | 20,838 (35.4) | |
| 4 | 2,281 (19.2) | 2,139 (18.2) | 2,105 (17.1) | 1,983 (17.0) | 1,848 (16.5) | 10,356 (17.6) | |
| 5 | 266 (2.2) | 231 (2.0) | 204 (1.7) | 196 (1.7) | 201 (1.8) | 1,098 (1.9) | |
| **Urgency of surgery** | | | | | | | |
| <2 hours | 1,665 (14.0) | 1,466 (12.5) | 1,389 (11.3) | 1,358 (11.6) | 1,247 (11.2) | 7,125 (12.1) | <0.001 |
| 2-6 hours | 5,045 (42.4) | 4,936 (42.1) | 4,938 (40.1) | 4,611 (39.5) | 4,447 (39.8) | 23,977 (40.8) | |
| 6-18 hours | 3,437 (28.9) | 3,472 (29.6) | 3,854 (31.3) | 3,698 (31.7) | 3,575 (32.0) | 18,036 (30.7) | |
| 18-24 hours | 1,726 (14.5) | 1,842 (15.7) | 2,111 (17.2) | 1,989 (17.0) | 1,896 (17.0) | 9,564 (16.3) | |
| (Missing) | 23 (0.2) | 11 (0.1) | 13 (0.1) | 23 (0.2) | 18 (0.2) | 88 (0.1) | |
| **Preoperative risk category (NELA model)** | | | | | | | |
| <5% | 6,072 (51.0) | 5,964 (50.9) | 6,152 (50.0) | 5,680 (48.6) | 5,334 (47.7) | 29,202 (49.7) | <0.001 |
| 5-10% | 1,749 (14.7) | 1,763 (15.0) | 1,920 (15.6) | 1,808 (15.5) | 1,840 (16.5) | 9,080 (15.4) | |
| >10-25% | 2,088 (17.6) | 2,034 (17.3) | 2,162 (17.6) | 2,168 (18.6) | 2,027 (18.1) | 10,479 (17.8) | |
| >25-50% | 1,138 (9.6) | 1,109 (9.5) | 1,197 (9.7) | 1,146 (9.8) | 1,103 (9.9) | 5,693 (9.7) | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| >50% | 393 (3.3) | 414 (3.5) | 413 (3.4) | 405 (3.5) | 392 (3.5) | 2,017 (3.4) | |
| (Missing) | 456 (3.8) | 443 (3.8) | 461 (3.7) | 472 (4.0) | 487 (4.4) | 2,319 (3.9) | |
| **Elixhauser comorbidity score** | | | | | | | |
| 0 | 2,038 (17.1) | 2,104 (17.9) | 2,141 (17.4) | 2,025 (17.3) | 1,950 (17.4) | 10,258 (17.4) | <0.001 |
| 1 | 2,225 (18.7) | 2,235 (19.1) | 2,520 (20.5) | 2,368 (20.3) | 2,356 (21.1) | 11,704 (19.9) | |
| 2 | 2,293 (19.3) | 2,319 (19.8) | 2,496 (20.3) | 2,422 (20.7) | 2,270 (20.3) | 11,800 (20.1) | |
| >2 | 5,340 (44.9) | 5,069 (43.2) | 5,148 (41.8) | 4,864 (41.6) | 4,607 (41.2) | 25,028 (42.6) | |
| **Ethnicity** | | | | | | | |
| White | 10,234 (86.0) | 10,329 (88.1) | 11,171 (90.8) | 10,748 (92.0) | 10,369 (92.7) | 52,851 (89.9) | <0.001 |
| Asian | 468 (3.9) | 375 (3.2) | 246 (2.0) | 162 (1.4) | 149 (1.3) | 1,400 (2.4) | |
| Black | 421 (3.5) | 293 (2.5) | 162 (1.3) | 77 (0.7) | 42 (0.4) | 995 (1.7) | |
| Other | 302 (2.5) | 245 (2.1) | 184 (1.5) | 153 (1.3) | 96 (0.9) | 980 (1.7) | |
| (Missing) | 471 (4.0) | 485 (4.1) | 542 (4.4) | 539 (4.6) | 527 (4.7) | 2,564 (4.4) | |
| **Region** | | | | | | | |
| London - North Central | 244 (2.1) | 291 (2.5) | 229 (1.9) | 186 (1.6) | 74 (0.7) | 1,024 (1.7) | <0.001 |
| London - North East | 475 (4.0) | 470 (4.0) | 237 (1.9) | 139 (1.2) | 100 (0.9) | 1,421 (2.4) | |
| London - North West | 134 (1.1) | 265 (2.3) | 252 (2.0) | 170 (1.5) | 124 (1.1) | 945 (1.6) | |
| London - South East | 287 (2.4) | 372 (3.2) | 237 (1.9) | 187 (1.6) | 183 (1.6) | 1,266 (2.2) | |
| London - South West | 134 (1.1) | 281 (2.4) | 312 (2.5) | 306 (2.6) | 427 (3.8) | 1,460 (2.5) | |
| East Midlands | 978 (8.2) | 916 (7.8) | 918 (7.5) | 1,047 (9.0) | 944 (8.4) | 4,803 (8.2) | |
| East of England | 755 (6.3) | 1,290 (11.0) | 1,766 (14.4) | 1,479 (12.7) | 1,471 (13.2) | 6,761 (11.5) | |
| West Midlands | 1,647 (13.8) | 1,133 (9.7) | 1,242 (10.1) | 1,048 (9.0) | 846 (7.6) | 5,916 (10.1) | |
| North East England | 1,283 (10.8) | 899 (7.7) | 663 (5.4) | 569 (4.9) | 542 (4.8) | 3,956 (6.7) | |
| North West England | 2,749 (23.1) | 1,664 (14.2) | 1,469 (11.9) | 1,458 (12.5) | 1,284 (11.5) | 8,624 (14.7) | |
| Yorkshire and Humber | 1,531 (12.9) | 1,100 (9.4) | 1,077 (8.8) | 1,110 (9.5) | 887 (7.9) | 5,705 (9.7) | |
| South Central England | 298 (2.5) | 617 (5.3) | 718 (5.8) | 874 (7.5) | 1,423 (12.7) | 3,930 (6.7) | |
| South East England | 511 (4.3) | 917 (7.8) | 1,173 (9.5) | 1,280 (11.0) | 1,446 (12.9) | 5,327 (9.1) | |
| South West England | 870 (7.3) | 1,512 (12.9) | 2,012 (16.4) | 1,826 (15.6) | 1,432 (12.8) | 7,652 (13.0) | |
| **Time of surgery** | | | | | | | |
| 0800-1159 | 2,752 (23.1) | 2,715 (23.2) | 2,793 (22.7) | 2,714 (23.2) | 2,614 (23.4) | 13,588 (23.1) | <0.001 |
| 1200-1759 | 4,603 (38.7) | 4,733 (40.4) | 5,070 (41.2) | 4,870 (41.7) | 4,603 (41.2) | 23,879 (40.6) | |
| 1800-2359 | 2,881 (24.2) | 2,778 (23.7) | 2,941 (23.9) | 2,775 (23.8) | 2,727 (24.4) | 14,102 (24.0) | |
| 0000-0759 | 1,139 (9.6) | 992 (8.5) | 959 (7.8) | 870 (7.4) | 810 (7.2) | 4,770 (8.1) | |
| (Missing) | 521 (4.4) | 509 (4.3) | 542 (4.4) | 450 (3.9) | 429 (3.8) | 2,451 (4.2) | |

2

**Table 2**
**IMD quintile and 30-day all-cause mortality**

| IMD Quintile | Crude 30-day all-cause mortality (Number (%)) | Unadjusted odds ratios (95% CI) | P value | Adjusted odds ratios* (95% CI) | P value |
|---|---|---|---|---|---|
| 1 - Most deprived | 1,333 (11.2) | 1.16 (1.07 - 1.27) | < 0.001 | 1.29 (1.16 - 1.44) | < 0.001 |
| 2 | 1,175 (10.0) | 1.03 (0.94-1.12) | 0.533 | 1.08 (0.97 - 1.20) | 0.152 |
| 3 | 1,231 (10.0) | 1.03 (0.94-1.12) | 0.555 | 1.08 (0.98 - 1.20) | 0.131 |
| 4 | 1,237 (10.6) | 1.09 (1.00-1.19) | 0.041 | 1.13 (1.02 - 1.25) | 0.020 |
| 5 - Least deprived | 1,093 (9.8) | Ref | - | Ref | - |

** Note: Other covariates not shown, see Table S7 for full model.*

**Figure 1**

**Hypothesised causal pathway between socioeconomic circumstances and 30-day mortality after emergency laparotomy**

Note: The dashed line indicates the causal path under investigation in this analysis. Variables enclosed in boxes indicate those for which data were available and have been included in the risk adjustment model or investigated as mediators. Variables have been colour-coded according to preoperative (dark blue), perioperative (green), and postoperative (light blue).

**Figure 2**
**Patient inclusion diagram**

**Figure 3a**
**IMD quintile and adjusted odds of 30-day mortality (multivariate two-level model, least deprived quintile as reference group)**
*Note: Other covariates not shown, see Table S7 for full model.*

**Figure 3b**
**IMD quintile and adjusted odds of 30-day mortality (multivariate two-level model, most deprived quintile as reference group)**
*Note: Other covariates not shown, see Table S7 for full model.*

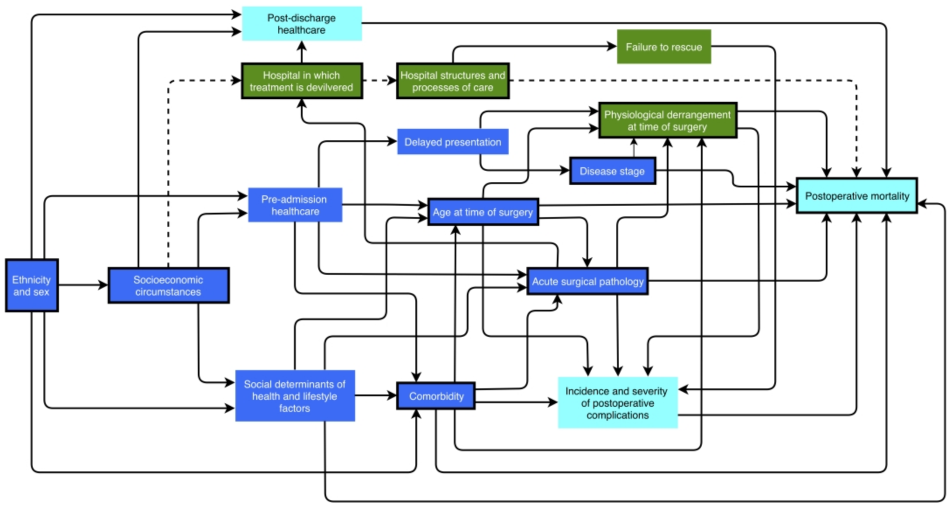


Figure 1: Hypothesised causal pathway between socioeconomic circumstances and 30-day mortality after emergency laparotomy

Note: The dashed line indicates the causal path under investigation in this analysis. Variables enclosed in boxes indicate those for which data were available and have been included in the risk adjustment model or investigated as mediators. Variables have been colour-coded according to preoperative (dark blue), perioperative (green), and postoperative (light blue).

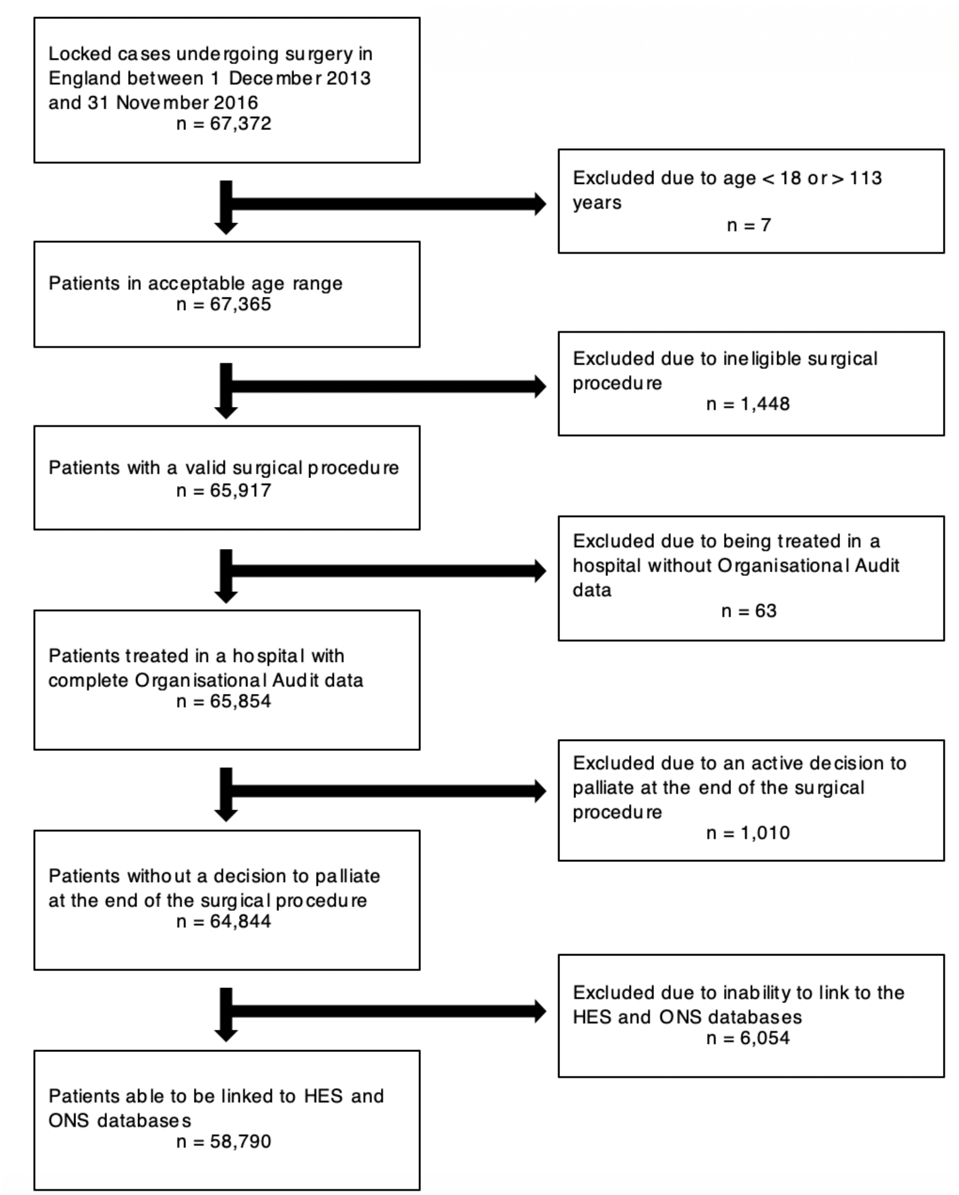


Figure 2: Patient inclusion diagram

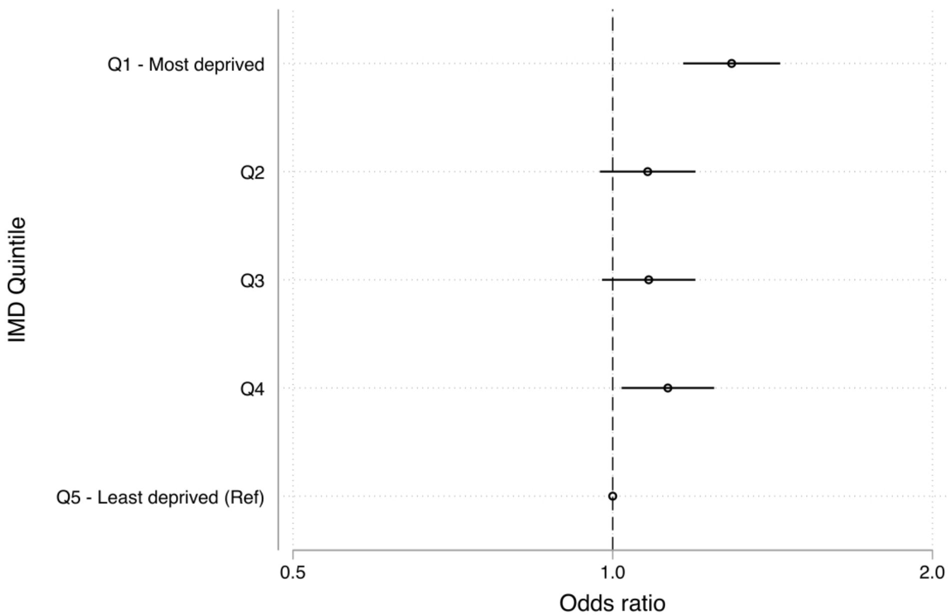


Figure 3a: IMD quintile and adjusted odds of 30-day mortality (multivariate two-level model, least deprived quintile as reference group)
Note: Other covariates not shown, see Table S7 for full model.

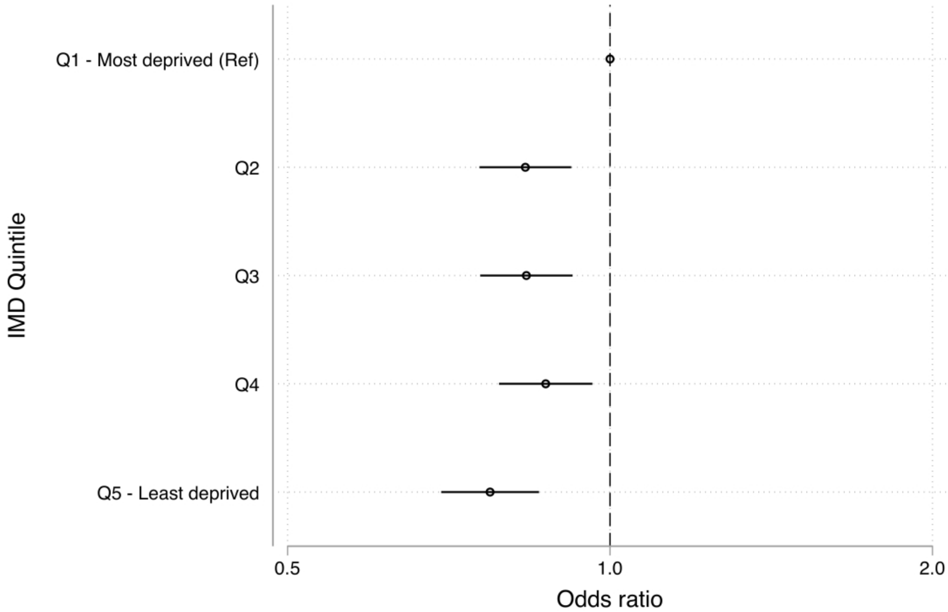


Figure 3b: IMD quintile and adjusted odds of 30-day mortality (multivariate two-level model, most deprived quintile as reference group)
Note: Other covariates not shown, see Table S7 for full model.

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**Socioeconomic deprivation and mortality after emergency laparotomy: an observational epidemiological study**

Short title: Socioeconomic deprivation and mortality after emergency laparotomy

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Keywords

Socioeconomic factors, Healthcare disparities, Perioperative care, Mortality, surgery

Short title

Socioeconomic deprivation and mortality after emergency laparotomy

**Abstract**

Background

Socioeconomic circumstances can influence access to healthcare, the standard of care provided, and a variety of outcomes. This study aimed to determine the association between crude and risk-adjusted 30-day mortality and socioeconomic group after emergency laparotomy; measure differences in meeting relevant perioperative standards of care; and investigate whether variation in hospital structure or process could explain any difference in mortality between socioeconomic groups.

Methods

Observational study of 58,790 patients, with data prospectively collected for the National Emergency Laparotomy Audit in 178 NHS hospitals in England between 1 December 2013 and 31 November 2016, linked with national administrative databases. Socioeconomic group was determined according to the Index of Multiple Deprivation quintile of each patient's usual place of residence.

Results

Overall crude 30-day mortality was 10.3%, with differences between the most deprived (11.2%) and least deprived (9.8%) quintiles ($p < 0.001$). More deprived patients were more likely to have multiple comorbidities, were more acutely unwell at the time of surgery, and required more urgent surgery. After risk-adjustment, patients in the most deprived quintile were at significantly higher risk of death

compared to all other quintiles (adjusted OR (95% CI): Q1 (most deprived): Ref, Q2: 0.83 (0.76-0.92), Q3: 0.84 (0.76-0.92), Q4: 0.87 (0.79-0.96), Q5 (least deprived): 0.77 (0.70-0.86)). We found no evidence that differences in hospital-level structure or patient-level performance in standards of care explained this association.

Conclusions

More deprived patients have higher crude and risk-adjusted 30-day mortality after emergency laparotomy, but this is not explained by differences in the standards of care recorded within the National Emergency Laparotomy Audit.

**Editor's Key Points**

- Socioeconomic deprivation is associated with poor access to education and healthcare, and chronic disease
- This study identified those in the poorest socioeconomic groups were more likely to present to hospital in a more serious condition, with higher rates of sepsis, abscess and bleeding
- Those in the poorest socioeconomic groups were more likely to die after surgery
- These findings could not be explained by hospital or treatment factors

## Introduction

Emergency laparotomy is one of the most commonly performed high risk emergency surgical procedures, with an estimated annual incidence of 1:1,100 population.[1] While the outcome can vary according to the indication for surgery, the underlying pathology and other risk factors, the overall 30-day mortality rate for this heterogeneous group of patients has been reported to be between 5.4% and 23.9% for the most common indications.[2] When compared to a mortality rate of < 1% for major elective surgery internationally, this represents a population with significant perioperative risk.[3]



It is recognised that socioeconomic circumstances are associated with differences in the prevalence of multimorbidity, variation in health outcomes from a range of diseases, and significant differences in life expectancy.[4-6] However, there are few studies examining the association between socioeconomic deprivation and mortality after emergency laparotomy. In a systematic review of 59 studies in which outcomes after colorectal surgery were reported according to socioeconomic group, only three studies reported outcomes for the subgroup of patients undergoing emergency surgery, with the majority either not distinguishing between patients having elective and emergency operations (35 out of 59), or not reporting the level of surgical urgency (19 out of 59).[7]

The relationships between socioeconomic circumstances and postoperative outcomes are complex. Patients undergo an emergency laparotomy for a variety of indications caused by numerous potential underlying pathologies, each of which may relate to socioeconomic circumstances in aetiology, health service utilisation, and quality of care received. Socioeconomic circumstances can be a factor in variations in access to good quality healthcare, both during an acute illness and throughout the life-course.[8] They can contribute to differences in the manner in which patients engage with healthcare services, for instance due to variation in participation in screening programmes, or other health seeking behaviour.[9, 10] Socioeconomic deprivation can also exacerbate the effect that lifestyle-related risk factors have on poor health and mortality.[11] Insecurity or lack of control over finances, work, or housing, coupled with barriers to maintaining a cohesive social support network, can all have negative effects on health.[12-14] All of these mechanisms could result in differences in the types of pathology with which patients in different socioeconomic groups present, or the age at which certain conditions develop. Socioeconomic circumstances may also result in differences in the overall state of chronic health at the time of presentation, the duration of symptoms or the stage of disease before definitive treatment, and the extent of any physiological derangement at the time of an acute presentation.[15] A hypothesised causal pathway linking socioeconomic circumstances to mortality after emergency laparotomy is summarised in Figure 1.

*insert Figure 1 here

Given the complex interplay of these mediators there are multiple possible factors that could potentially explain or mitigate outcome differences. However, broadly, if outcomes differ according to socioeconomic circumstances it may be due to three types of reasons: factors that influence a patient's condition at the time of presentation; differences in the care delivered during the perioperative period and subsequent follow up; and lifestyle factors and other social determinants of health that exert an effect both prior to admission and after discharge. Being able to identify a possible explanation for outcome differences based on socioeconomic circumstances would allow interventions to be targeted to address some of the inequality. It is well recognised that the provision of medical resources and the need for medical care are not always well matched, a phenomenon referred to as the inverse care law.[16] If there is evidence to suggest that unwarranted variation in the care delivered during the perioperative period is contributing to differences in outcome between socioeconomic groups, efforts could be made to address this variation and ensure a more equitable allocation of resources.

This study had five interrelated objectives: 1) to document how demographic and risk factors varied by socioeconomic group in this population; 2) to investigate the unadjusted association between socioeconomic group and 30-day mortality risk in patients undergoing emergency laparotomy; 3) to estimate adjusted mortality rates according to socioeconomic group, to determine whether outcomes differed given expected risk; 4) to determine if there were differences between socioeconomic groups in whether standards of care were met in the perioperative period, and if so, whether this could be explained by within- or between-hospital variation; 5) to determine whether any variation in hospital structure or delivery of standards of care could explain or partially explain any of the mortality difference between socioeconomic groups.

## Methods

### Study Design

This was an observational epidemiological study performed through analysis of prospectively collected data from the National Emergency Laparotomy Audit (NELA), linked with national administrative databases.

### Setting

NELA aims to collect data on every emergency laparotomy performed within National Health Service (NHS) hospitals in England and Wales. Data are collected from all hospitals where eligible emergency laparotomies are performed. Based on data obtained from the Hospital Episodes Statistics (HES) database, it is estimated that the NELA dataset includes over 80% of all emergency laparotomies performed in England since data collection began in December 2013.[2, 17-19] This study included patients who were entered into the NELA database after undergoing an eligible emergency laparotomy in England between 1 December 2013 and 31 November 2016. This restriction was applied because the necessary linkage to external databases was not available for patients undergoing surgery from 1 December 2016 onwards at the time work on this analysis began.

Participants

The full inclusion/exclusion criteria for entry into the NELA database are defined elsewhere.[20] For the purposes of this study patients were also excluded if any of the following applied: treatment in a non-English hospital; treatment in a hospital for which no organisational audit data were available; no available linkage to Office for National Statistics or Hospital Episode Statistics data; unable to link the usual place of residence to a valid Lower Layer Super Output Area (LSOA) in England; an active decision for palliative management at the end of the operation (eg 'open-close' laparotomy).

NELA patient audit and organisational data

The patient data for this analysis were based on an export taken from the NELA database on 2 February 2017. Hospital organisational data was based on the NELA Organisational Audits performed in 2013 and 2016.[19, 21]

Casemix variables used for risk adjustment (online supplement Table S1) and process data pertaining to standards of care (Table S2) were taken directly from the NELA patient audit database, with the exception of comorbidity scores and ethnicity, which were derived from linkage to HES data. Details of the recoding of variables and use of Organisational Audit data describing hospital structure are outlined in the supplementary material.

Data linkage and ethics

Approval from the Health Research Authority Confidentiality Advisory Group under Section 251 of the NHS Act 2006 and Health Service (Control of Patient Information) Regulations 2002 meant individual patient consent was not required to collect, store, and analyse these data. Linkage of the NELA dataset to the Office for National Statistics (ONS) and Hospital Episode Statistics (HES) databases was performed by NHS Digital.



All-cause 30-day mortality

Linked ONS data provided the date of death from any cause based on the national register of deaths. Where data linkage was not available, but the patient was recorded as having died during their index admission within the NELA database, the date of death as recorded on the online case record form was used instead. If no ONS data linkage could be performed and the patient was recorded as being alive at the time of discharge from hospital, they were excluded.

Additional variables derived from HES data

HES data were used to generate additional dummy variables describing ethnicity and comorbidity for the purpose of statistical adjustment.

A patient’s ethnicity was based on the modal value entered for the spell covering the emergency laparotomy. Due to some small cell numbers, the available ethnic categories recorded in HES were collapsed into White, Asian, Black, and Other (Table S4).

Comorbidity was estimated based on International Classification of Diseases - 10th Revision (ICD-10) codes recorded within HES, which were used to generate a score based on definitions for the Elixhauser index as defined by Quan et al.[22] Eligible comorbidities were counted if they were included in the discharge coding for any hospital admission whose admission date was within one year prior to the date of the emergency laparotomy, including the admission in which the emergency laparotomy took place. In order to distinguish between pre-existing disease and pathology acquired during the acute illness, chronic lung and kidney disease were only counted when previously coded in an admission beginning within one year prior to the date of the emergency laparotomy, excluding the admission during which the patient underwent their emergency laparotomy.



Patient-level deprivation

Patient-level deprivation was measured in quintiles of the Index of Multiple Deprivation (IMD) score for the patient's usual residence, recorded at the level of Lower Layer Super Output Areas (LSOAs). The IMD score for each LSOA was based on publicly available data from 2015, published by the ONS.[23] Further details of the process by which a patient was linked to a LSOA are provided in the online supplement.

Data Management

Data containing patient identifiable information were stored on a secure server at the Royal College of Surgeons, London. Data cleaning and analysis were performed using Stata versions 13 and 15 (StataCorp, College Station, Texas).

Statistical Analysis

All reported statistical analysis was based on an analysis plan that was developed and approved before we began conducting the analysis. TEP, SRM and PM had worked with the NELA data set (excluding IMD data) for other purposes, so it was not possible for these authors to be completely blind to the entire dataset while drawing up the analysis plan. However, the analysis plan was completed before we conducted the analyses for this paper, and we did not make analytic decisions contingent on seeing the data, thus minimising researcher degrees of freedom.

Differences in categorical demographic and other casemix variables between IMD quintiles were assessed using the chi-square test (objective 1).

Analysis of the crude association between deprivation and 30-day mortality was performed using single-level logistic regression (objective 2). The association between deprivation and risk-adjusted 30-day mortality was performed using mixed effects logistic regression of IMD quintile and casemix variables on 30-day mortality, with a random intercept for hospitals (objective 3). Selection of casemix covariates was based on the previously published NELA risk adjustment model,[24] which was developed and internally validated from a subset of the dataset used in the current study, with continuous patient-level physiological and biochemical parameters transformed where necessary. Additional variables were added to the model to attempt to reduce bias pertinent to this analysis (Table S1).

Investigation of the association between socioeconomic group and hospital structures or processes of care was performed using bivariate logistic regression of IMD quintile on each structure and process variable (objective 4). Regressions of hospital-level structures were weighted according to the numbers of patients treated in each hospital. Since patients are clustered within hospitals, for the patient-level process variables we also calculated adjusted odds ratios from random intercept models, thereby adjusting for the hospital in which the patients were treated.

To address whether hospital structure or processes of care mediated the association between deprivation and 30-day mortality (objective 5), a series of pairs of mixed-effects logistic regression models were compared. The aim was to compare the size of the 'effect' of socioeconomic group on risk-adjusted mortality in two models: (1) a 'reduced' model that did not control for hospital structure or process of care, and (2) a 'full' model that did make this adjustment. A reduction in the 'effect' of deprivation in model (2) compared to model (1) would indicate that the structure or process is partly responsible for the differences in adjusted mortality rates between socioeconomic groups. However, coefficients from directly nested logistic regression models are not comparable since coefficients can differ due to the effect of changes to the overall error variance of the model as well as any confounding effect of the control variable.[25] To overcome this each 'reduced' model comprised socioeconomic group, casemix adjustment variables, and residuals from a linear regression of the structure or process variable of interest on deprivation.[25] This was then compared with a 'full' model comprising socioeconomic group, casemix adjustment variables and the structure or process variable.

For all multivariate statistical models, multiple imputation was used to account for missing casemix variables. The chained equation method was used to produce 20 imputed sets, with the assumption that data were missing at random.[26] Details of the variables and the prediction models used for the imputation process are included in the online supplement. Missing transformed variables were imputed using a 'transform then impute' approach.[27] Missing outcome variables were not imputed.

The use of imputed data and two-level modelling meant there was no formal test of significance available for the differences in coefficients between pairs of models, therefore these results were assessed through descriptive comparison of the odds ratios and confidence intervals from each pair of full and reduced models.

**Results**

The raw dataset contained a total of 67,372 complete cases. Details of the exclusions during the cleaning and data linking process are outlined in Figure 2. During this process 6,054 patients (9.0%) were excluded due to an inability to link to the ONS and HES databases, which includes an unknown proportion of patients opting out of allowing their personal data to be used in this manner. Following all exclusions, 58,790 patients from 178 hospitals were included in the final analysis.

*insert Figure 2 here



Differences between socioeconomic groups (objective 1)

Tables 1 and S6 shows the distribution of deprivation and its bivariate associations with variables used in subsequent analyses. The distribution of deprivation within this dataset matches the distribution within the general population. However, there were some significant differences in the demographics between IMD quintiles. Patients in the most deprived quintile were younger on average than those in the least deprived quintile, with a gradient across the socioeconomic spectrum ($P < 0.001$). Nonetheless, patients from the most deprived quintile were more likely to have high ASA scores (4 or 5) and to have more than two comorbidities recorded ($P < 0.001$ for each). The proportion of patients from ethnic minorities increased along the spectrum from the least deprived (2.7%) to the most deprived quintile (10.4%) ($P < 0.001$). There was also a notable difference in the proportion of patients in each IMD quintile in different geographic regions within England. Of all patients in the most deprived quintile, 23.1% lived in the North West, whereas patients in the least deprived quintile were more widely distributed, but predominantly lived in the East and South of England (P < 0.001).

*insert Table 1 here

More deprived patients were more likely to require the most urgent type of surgery (P < 0.001), however they tended to undergo less surgically complex operations (P = 0.012). In keeping with the higher degree of surgical urgency, patients in the most deprived quintile were more likely to undergo their emergency laparotomy outside of normal working hours, with the proportion of patients requiring an operation after midnight increasing from least deprived (7.5%) to most deprived (10.0%) (P < 0.001).

A higher proportion of more deprived patients underwent surgery for pathologies related to intraabdominal sepsis (P < 0.001) and were found to have higher rates of intraabdominal abscess (P < 0.001), or perforated or bleeding peptic ulcer (P < 0.001 and P = 0.001 respectively). More deprived patients were less likely to undergo surgery for intestinal obstruction (P < 0.001) and a lower proportion were found to have pathologies such as adhesions, volvulus, or malignancy (both localised and disseminated) (P < 0.001 for each). More deprived patients were more likely to have peritoneal free gas or soiling in the form of pus, bile, or gastric or duodenal contents (P < 0.001 for each). Additionally, where present, the extent of peritoneal contamination increased with deprivation, with

21.8% of the most deprived patients having generalised contamination, compared to 16.9% in the least deprived quintile (P < 0.001).

Socioeconomic groups and 30-day mortality (objectives 2 and 3)

The overall crude 30-day mortality rate was 10.3%, however there were significant differences between IMD quintiles (Q1 (most deprived): 11.2% vs Q5 (least deprived): 9.8%, p < 0.001). After adjusting for demographic, physiological, and surgical factors (Table S1) the association between risk-adjusted 30-day mortality and IMD quintile became stronger (Table 2 and Figure 3). While this association was strongest for the most deprived quintile, patients in Q4 were also found to have higher crude and risk adjusted 30-day mortality compared to the least deprived quintile. However, patients in the most deprived quintile (Q1) were at significantly higher risk of death compared to all other quintiles, even after risk adjustment (Figure 3b).

*insert Table 2 and Figure 3 here

Despite the proportion of patients from ethnic minorities increasing with deprivation, and the unequal distribution of deprivation within the English regions, there was no evidence of an association between either ethnicity or geographical region and mortality after risk adjustment (Table S7).

Socioeconomic groups and hospital structures and processes (objective 4)

Bivariate analysis revealed relationships between patient deprivation and access to structural and organisational factors that lend themselves to the provision of good quality care. The shape and strength of these relationships differed between the various indicators of hospital structure, but generally patients in the most deprived quintile were more likely than the other groups to be treated in a hospital with access to good organisational services (Table S8).

Bivariate analysis also suggested relationships between socioeconomic circumstances and some of the patient-level indicators of adherence to standards of care (Table S9). However, once the variation between hospitals was accounted for, there was generally little difference between the quintiles (Table S9), suggesting that where differences between socioeconomic groups were found in the single-level models, much of the difference could be explained by variation in the delivery of standards of care between hospitals. It may however be the case that patients in different socioeconomic groups vary in their likelihood of being treated in hospitals in which standards are met more consistently.



Mediation of the effect of socioeconomic circumstances on mortality through hospital structures and processes (objective 5)

Finally, descriptive comparison of the nested models examining the association between socioeconomic group and mortality before and after accounting for hospital-level structures and patient-level processes of care showed that controlling for these factors had very little impact on adjusted mortality odds ratios (Figure S1). Thus, there was no evidence that adjusting for any of the hospital-level structural differences or variations in patient-level performance in standards of care contributed to explaining the socioeconomic differences in 30-day mortality after emergency laparotomy.



**Discussion**

We have analysed one of the world's largest and most granular databases describing the structures, processes, and outcomes of patients undergoing emergency laparotomy. Based on the evaluation of patterns related to socioeconomic variation, we can report four key findings. First, socioeconomic deprivation is associated with 30-day mortality after emergency laparotomy, even after applying the best available risk adjustment model. Patients living in the most deprived quintile of areas have a higher postoperative risk of death than patients living in other areas. Second, the demographic and surgical characteristics of patients undergoing an emergency laparotomy in England vary significantly between the five socioeconomic groups. Third, the most deprived patients were slightly more likely than other groups to be treated in a hospital with favourable structures, and we found little difference between the socioeconomic groups in the quality of care received within the same hospital. Finally, neither hospital-level structures nor patient-level indicators of quality of care explained why the most deprived patients have the highest adjusted risk of 30-day mortality.

Due to the comprehensive and national coverage of the English National Health Service (NHS), including the lack of private emergency departments, the population included in this dataset is likely to be a reliable reflection of the full extent of socioeconomic variation within England. This is supported by the fact the quintiles used in this analysis (defined according to national-level deprivation scores rather than limited to those within the study population) are relatively equal in size. Even those patients who would normally opt for private medical cover for elective or non-emergent matters are likely to have been captured within the patient-level data. In spite of this, the differences in the documented urgency of surgery and proportions of patients having surgery ‘out of hours’ suggest that more deprived patients are more acutely unwell at the time the decision to operate is made. It is unknown if the observed differences in surgical urgency between quintiles were due to later presentation in more deprived patients, since data on the pathological process prior to hospital admission were not available. However, there is evidence suggesting that more deprived patients present later for a range of other conditions, and the finding that more deprived patients were more likely to have more extensive peritoneal contamination (where present) suggests this may also be the case in emergency laparotomy.[15]

While this study has identified an association between deprivation and increased mortality after emergency laparotomy, it is not possible to determine what it is about the state of being deprived that is responsible. However, as Figure 1 demonstrates, there are potential causal pathways for which no data were available. These include the direct effects on postoperative mortality of variations in modifiable lifestyle-related risk factors and inequalities in other social determinants of health, differences in access to appropriate healthcare prior to an acute admission or engagement with services such as the bowel cancer screening programme, as well as differences in follow up and access to healthcare services after discharge. Additionally, the incidence and severity of complications can be a key cause of postoperative mortality, the effect of which may vary between socioeconomic groups due to patient-specific factors, the surgical pathology, the operation performed, and variation in the hospital-specific rates of 'failure to rescue'.[28]

There was generally little difference in the measured standards of care delivered to the most deprived quintile compared to the least deprived (defined by the evidence-based standards included within NELA), and controlling for these processes does not appear to mitigate the association between socioeconomic deprivation and postoperative mortality despite previous analysis finding associations between meeting certain standards and lower mortality.[29] While it is possible that there are other elements of structure and process that were not measured but still exert an influence on outcome differences between socioeconomic groups, the evidence from the health inequalities literature suggests that outcome differences have social and political causes.[30, 31] It is therefore more likely that successful interventions to reduce this socioeconomic inequality would need to address broader social and policy issues rather than focusing solely on care during the perioperative period. While this analysis cannot specify what those interventions should be, epidemiological and perioperative evidence would suggest that efforts to improve health literacy and chronic disease management, plus holistic policies to address lifestyle factors, access to healthcare, housing, childcare, education, employment and working conditions should all be considered.[32-34] While beyond the traditional remit of the biomedical approach to healthcare, these social determinants all combine to influence the standard of living required for maintaining health, which is compromised by the disadvantage accumulated throughout life through inequality in the circumstances in which people are born, grow, live, work, and age.[35]



It is interesting that, in England, more deprived patients were more likely to be treated in hospitals where the structural and organisational factors lend themselves to the provision of good quality care. This is likely to be due to the combination of a universal access healthcare system and the distribution of deprivation as measured by the IMD within England, which is generally more prevalent in cities.[36] For emergency care, patients in the NHS will generally be treated at the nearest suitable hospital, and patients living in cities are more likely to live closer to large teaching hospitals or tertiary referral centres. This contrasts with Australia, which also has a system of universal healthcare, but where deprivation is more associated with remote or rural communities that are far more geographically isolated from major population centres; or the USA, where a patient’s payer status may influence the hospital in which they are treated.[37-39] Although the USA does not have a universal healthcare programme, it does have a system of safety net hospitals. However, even after adjusting for differences in patient demographics, these hospitals have been found to have higher postoperative mortality following colectomy, and higher complication rates after emergency general surgery.[40, 41] There is currently no evidence to tell us whether in these countries outcome differences are attributable to variations in the quality of care provided, whereas the data within NELA have helped address this important confounder regarding outcomes in England.

There are a number of limitations to this study. While the NELA annual patient reports have shown case ascertainment rates to be above 80% overall and improving over time, there are variations in case ascertainment between hospitals.[2, 17-19] Additionally, NELA only collects data on patients who undergo surgery. It is therefore not possible to comment on any differences between socioeconomic groups for the subset of patients managed without surgery, or indeed if there are differences in the proportions of patients who were treated conservatively.



The use of administrative databases risks excluding patients where data linkage is not possible. While this was the case in the study, the extent of data linkage was generally good. Additionally, the patient-level information in the Hospital Episode Statistics database is reliant on accurate data collection and entry by clinical coders. Previous analysis of HES suggests that, while there will inevitably be some inaccuracies due to miscoded entries or incomplete clinical record keeping, the data is of sufficient quality for population-level research such as this.[42, 43]

While we attempted to control for comorbidity using the Elixhauser comorbidity score, this does not include any information on variations in disease severity or how well managed a chronic condition may be. Given associations between socioeconomic group and health seeking behaviour and access to healthcare, a simple count of comorbidities is unlikely to fully describe the clinical picture. While it may be true that someone with multiple comorbidities is more likely to be in a poorer state of health compared to someone with none, a single serious or poorly controlled chronic disease may lead to greater functional limitation and perioperative risk than multiple less severe, less limiting, or better controlled diseases. In light of this, access to good quality healthcare for health promotion and chronic disease management over many years preceding the event may influence outcome after an eventual emergency laparotomy, perhaps more so than any variations in care delivered during the acute presentation itself.



This analysis has defined socioeconomic deprivation according to the patient’s usual place of residence. Whilst this raises the possibility of the ecological fallacy, whereby an area’s relative level of deprivation based on the aggregate data of its population may not reflect the specific circumstances of an individual patient, this tends only to be an issue when measuring over larger areas than those used in this analysis, which is based on the smallest unit of area for which data are available (approximately 1,500 persons per LSOA).[44] However it must be borne in mind that deprivation is widely distributed and even areas of low aggregate deprivation will still include some deprived individuals.

The conclusion that efforts to address adverse outcomes associated with deprivation should focus more on the broader causes of health inequalities than care during an acute episode could likely apply to a range of surgical and medical presentations. Improving the quality of acute care is an important aim for the benefit of the population in general, however this may have little effect on addressing pre-existing disparities between socioeconomic groups. Although the evidence from the health inequalities literature suggests that lifestyle-related factors merely exacerbate mortality differences between socioeconomic groups rather than being a primary cause,[45, 46] further work is required to identify where perioperative risk could be reduced through public health intervention. Additionally, since there exist significant geographical differences in rates of deprivation, future analysis should explore whether the healthcare system in England is equitably resourced in more deprived communities across the country, especially those outside of major cities where the combination of patient demographics and access to appropriate services may prove particularly challenging.

**Other**

Collaborators

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Author contributions

TEP: Conceptualisation, data curation, formal analysis, investigation, methodology, project administration, software, validation, visualisation, writing (original draft), writing (review and editing).

SRM: Conceptualisation, formal analysis, investigation, methodology, project administration, supervision, validation, writing (review and editing).

RR: Conceptualisation, methodology, supervision, validation, writing (review and editing).

PM: Conceptualisation, formal analysis, investigation, methodology, project administration, supervision, validation, writing (review and editing).

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Competing interests

TEP, SRM, and PM are members of the NELA project team.

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SRM receives funding from the UCLH Biomedical Research Centre where she is member of the faculty; she also receives funding from the Health Foundation as an Improvement Science fellow,

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RR is funded by the National Institute for Health Research (NIHR) Collaboration for Leadership in Applied Health Research and Care North Thames at Bart's Health NHS Trust (NIHR CLAHRC North Thames).

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Table 1

Patient demographics (see Table S6 for further surgical characteristics)

| | 1 - Most deprived | 2 | 3 | 4 | 5 - Least deprived | Total | P value |
|---|---|---|---|---|---|---|---|
| **Total number** | 11,896 (20.2) | 11,727 (19.9) | 12,305 (20.9) | 11,679 (19.9) | 11,183 (19.0) | 58,790 (100.0) | - |
| **Age category** | | | | | | | |
| 18-39 | 1,689 (14.2) | 1,455 (12.4) | 1,198 (9.7) | 982 (8.4) | 899 (8.0) | 6,223 (10.6) | <0.001 |
| 40-49 | 1,567 (13.2) | 1,295 (11.0) | 1,138 (9.2) | 914 (7.8) | 885 (7.9) | 5,799 (9.9) | |
| 50-59 | 2,030 (17.1) | 1,713 (14.6) | 1,681 (13.7) | 1,484 (12.7) | 1,312 (11.7) | 8,220 (14.0) | |
| 60-69 | 2,422 (20.4) | 2,418 (20.6) | 2,587 (21.0) | 2,446 (20.9) | 2,293 (20.5) | 12,166 (20.7) | |
| 70-79 | 2,461 (20.7) | 2,731 (23.3) | 3,194 (26.0) | 3,177 (27.2) | 3,026 (27.1) | 14,589 (24.8) | |
| 80+ | 1,727 (14.5) | 2,115 (18.0) | 2,507 (20.4) | 2,676 (22.9) | 2,768 (24.8) | 11,793 (20.1) | |
| **Sex** | | | | | | | |
| Male | 5,852 (49.2) | 5,670 (48.3) | 5,887 (47.8) | 5,624 (48.2) | 5,227 (46.7) | 28,260 (48.1) | 0.006 |
| Female | 6,044 (50.8) | 6,057 (51.7) | 6,418 (52.2) | 6,055 (51.8) | 5,956 (53.3) | 30,530 (51.9) | |
| **ASA** | | | | | | | |
| 1 | 1,281 (10.8) | 1,244 (10.6) | 1,250 (10.2) | 1,159 (9.9) | 1,212 (10.8) | 6,146 (10.5) | <0.001 |
| 2 | 3,788 (31.8) | 3,990 (34.0) | 4,356 (35.4) | 4,210 (36.0) | 4,008 (35.8) | 20,352 (34.6) | |
| 3 | 4,280 (36.0) | 4,123 (35.2) | 4,390 (35.7) | 4,131 (35.4) | 3,914 (35.0) | 20,838 (35.4) | |
| 4 | 2,281 (19.2) | 2,139 (18.2) | 2,105 (17.1) | 1,983 (17.0) | 1,848 (16.5) | 10,356 (17.6) | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 5 | 266 (2.2) | 231 (2.0) | 204 (1.7) | 196 (1.7) | 201 (1.8) | 1,098 (1.9) | |
| **Urgency of surgery** | | | | | | | |
| <2 hours | 1,665 (14.0) | 1,466 (12.5) | 1,389 (11.3) | 1,358 (11.6) | 1,247 (11.2) | 7,125 (12.1) | <0.001 |
| 2-6 hours | 5,045 (42.4) | 4,936 (42.1) | 4,938 (40.1) | 4,611 (39.5) | 4,447 (39.8) | 23,977 (40.8) | |
| 6-18 hours | 3,437 (28.9) | 3,472 (29.6) | 3,854 (31.3) | 3,698 (31.7) | 3,575 (32.0) | 18,036 (30.7) | |
| 18-24 hours | 1,726 (14.5) | 1,842 (15.7) | 2,111 (17.2) | 1,989 (17.0) | 1,896 (17.0) | 9,564 (16.3) | |
| (Missing) | 23 (0.2) | 11 (0.1) | 13 (0.1) | 23 (0.2) | 18 (0.2) | 88 (0.1) | |
| **Preoperative risk category (NELA model)** | | | | | | | |
| <5% | 6,072 (51.0) | 5,964 (50.9) | 6,152 (50.0) | 5,680 (48.6) | 5,334 (47.7) | 29,202 (49.7) | <0.001 |
| 5-10% | 1,749 (14.7) | 1,763 (15.0) | 1,920 (15.6) | 1,808 (15.5) | 1,840 (16.5) | 9,080 (15.4) | |
| >10-25% | 2,088 (17.6) | 2,034 (17.3) | 2,162 (17.6) | 2,168 (18.6) | 2,027 (18.1) | 10,479 (17.8) | |
| >25-50% | 1,138 (9.6) | 1,109 (9.5) | 1,197 (9.7) | 1,146 (9.8) | 1,103 (9.9) | 5,693 (9.7) | |
| >50% | 393 (3.3) | 414 (3.5) | 413 (3.4) | 405 (3.5) | 392 (3.5) | 2,017 (3.4) | |
| (Missing) | 456 (3.8) | 443 (3.8) | 461 (3.7) | 472 (4.0) | 487 (4.4) | 2,319 (3.9) | |
| **Elixhauser comorbidity score** | | | | | | | |
| 0 | 2,038 (17.1) | 2,104 (17.9) | 2,141 (17.4) | 2,025 (17.3) | 1,950 (17.4) | 10,258 (17.4) | <0.001 |
| 1 | 2,225 (18.7) | 2,235 (19.1) | 2,520 (20.5) | 2,368 (20.3) | 2,356 (21.1) | 11,704 (19.9) | |
| 2 | 2,293 (19.3) | 2,319 (19.8) | 2,496 (20.3) | 2,422 (20.7) | 2,270 (20.3) | 11,800 (20.1) | |
| >2 | 5,340 (44.9) | 5,069 (43.2) | 5,148 (41.8) | 4,864 (41.6) | 4,607 (41.2) | 25,028 (42.6) | |
| **Ethnicity** | | | | | | | |
| White | 10,234 (86.0) | 10,329 (88.1) | 11,171 (90.8) | 10,748 (92.0) | 10,369 (92.7) | 52,851 (89.9) | <0.001 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Asian | 468 (3.9) | 375 (3.2) | 246 (2.0) | 162 (1.4) | 149 (1.3) | 1,400 (2.4) | |
| Black | 421 (3.5) | 293 (2.5) | 162 (1.3) | 77 (0.7) | 42 (0.4) | 995 (1.7) | |
| Other | 302 (2.5) | 245 (2.1) | 184 (1.5) | 153 (1.3) | 96 (0.9) | 980 (1.7) | |
| (Missing) | 471 (4.0) | 485 (4.1) | 542 (4.4) | 539 (4.6) | 527 (4.7) | 2,564 (4.4) | |
| **Region** | | | | | | | |
| London - North Central | 244 (2.1) | 291 (2.5) | 229 (1.9) | 186 (1.6) | 74 (0.7) | 1,024 (1.7) | <0.001 |
| London - North East | 475 (4.0) | 470 (4.0) | 237 (1.9) | 139 (1.2) | 100 (0.9) | 1,421 (2.4) | |
| London - North West | 134 (1.1) | 265 (2.3) | 252 (2.0) | 170 (1.5) | 124 (1.1) | 945 (1.6) | |
| London - South East | 287 (2.4) | 372 (3.2) | 237 (1.9) | 187 (1.6) | 183 (1.6) | 1,266 (2.2) | |
| London - South West | 134 (1.1) | 281 (2.4) | 312 (2.5) | 306 (2.6) | 427 (3.8) | 1,460 (2.5) | |
| East Midlands | 978 (8.2) | 916 (7.8) | 918 (7.5) | 1,047 (9.0) | 944 (8.4) | 4,803 (8.2) | |
| East of England | 755 (6.3) | 1,290 (11.0) | 1,766 (14.4) | 1,479 (12.7) | 1,471 (13.2) | 6,761 (11.5) | |
| West Midlands | 1,647 (13.8) | 1,133 (9.7) | 1,242 (10.1) | 1,048 (9.0) | 846 (7.6) | 5,916 (10.1) | |
| North East England | 1,283 (10.8) | 899 (7.7) | 663 (5.4) | 569 (4.9) | 542 (4.8) | 3,956 (6.7) | |
| North West England | 2,749 (23.1) | 1,664 (14.2) | 1,469 (11.9) | 1,458 (12.5) | 1,284 (11.5) | 8,624 (14.7) | |
| Yorkshire and Humber | 1,531 (12.9) | 1,100 (9.4) | 1,077 (8.8) | 1,110 (9.5) | 887 (7.9) | 5,705 (9.7) | |
| South Central England | 298 (2.5) | 617 (5.3) | 718 (5.8) | 874 (7.5) | 1,423 (12.7) | 3,930 (6.7) | |
| South East England | 511 (4.3) | 917 (7.8) | 1,173 (9.5) | 1,280 (11.0) | 1,446 (12.9) | 5,327 (9.1) | |
| South West England | 870 (7.3) | 1,512 (12.9) | 2,012 (16.4) | 1,826 (15.6) | 1,432 (12.8) | 7,652 (13.0) | |
| **Time of surgery** | | | | | | | |
| 0800-1159 | 2,752 (23.1) | 2,715 (23.2) | 2,793 (22.7) | 2,714 (23.2) | 2,614 (23.4) | 13,588 (23.1) | <0.001 |
| 1200-1759 | 4,603 (38.7) | 4,733 (40.4) | 5,070 (41.2) | 4,870 (41.7) | 4,603 (41.2) | 23,879 (40.6) | |
| 1800-2359 | 2,881 (24.2) | 2,778 (23.7) | 2,941 (23.9) | 2,775 (23.8) | 2,727 (24.4) | 14,102 (24.0) | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 0000-0759 | 1,139 (9.6) | 992 (8.5) | 959 (7.8) | 870 (7.4) | 810 (7.2) | 4,770 (8.1) |
| (Missing) | 521 (4.4) | 509 (4.3) | 542 (4.4) | 450 (3.9) | 429 (3.8) | 2,451 (4.2) |

**Table 2**

**IMD quintile and 30-day all-cause mortality**

| IMD Quintile | Crude 30-day all-cause mortality (Number (%)) | Unadjusted odds ratios (95% CI) | P value | Adjusted odds ratios* (95% CI) | P value |
|---|---|---|---|---|---|
| 1 - Most deprived | 1,333 (11.2) | 1.16 (1.07 - 1.27) | < 0.001 | 1.29 (1.16 - 1.44) | < 0.001 |
| 2 | 1,175 (10.0) | 1.03 (0.94-1.12) | 0.533 | 1.08 (0.97 - 1.20) | 0.152 |
| 3 | 1,231 (10.0) | 1.03 (0.94-1.12) | 0.555 | 1.08 (0.98 - 1.20) | 0.131 |
| 4 | 1,237 (10.6) | 1.09 (1.00-1.19) | 0.041 | 1.13 (1.02 - 1.25) | 0.020 |
| 5 - Least deprived | 1,093 (9.8) | Ref | - | Ref | - |

** Note: Other covariates not shown, see Table S7 for full model.*

**Figure 1**

**Hypothesised causal pathway between socioeconomic circumstances and 30-day mortality after emergency laparotomy**

Note: The dashed line indicates the causal path under investigation in this analysis. Variables enclosed in boxes indicate those for which data were available and have been included in the risk adjustment model or investigated as mediators. Variables have been colour-coded according to preoperative (dark blue), perioperative (green), and postoperative (light blue).

4

Figure 2

Patient inclusion diagram

**Figure 3a**

**IMD quintile and adjusted odds of 30-day mortality (multivariate two-level model, least deprived quintile as reference group)**

*Note: Other covariates not shown, see Table S7 for full model.*

4.

**Figure 3b**

**IMD quintile and adjusted odds of 30-day mortality (multivariate two-level model, most deprived quintile as reference group)**

*Note: Other covariates not shown, see Table S7 for full model.*