

Socio-economic deprivation and short-term mortality after surgery; a nationwide observational cohort study

Statistical analysis plan

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Version 1.0

1. Introduction

Background and rationale

Health inequities are avoidable, unjust differences between groups or populations [1]. Socio-economic deprivation is an important driver of health inequity. Causes include a lack of financial resources and social determinants of health [2] which are mediated by environmental exposures, health behaviours and the ability to access health services effectively [3]. Associations between socio-economic status and factors of potential relevance in the perioperative pathway are recognised, e.g. reduced engagement with screening programmes [4] [5] [6] [7] and a greater risk of emergency hospital admission [8, 9] for people in the most deprived groups. Higher rates of smoking and poorer access to a good diet and exercise have also been shown [10]. The link between these lifestyle factors and the risk of development of diseases including COPD and diabetes is well established. Greater deprivation is also associated with greater mortality from cardiovascular and cerebrovascular diseases [10, 11] suggesting that not only the presence but the severity and management of disease worsens with poorer socio-economic status.

Over 5.1 million NHS surgical procedures take place each year in the United Kingdom (UK) [12]. Although the overall risk of 30-day mortality is low (1%), a smaller, high-risk population accounts for 80% of postoperative deaths [13]. In this population, the association of socio-economic status with post-operative outcomes is under-investigated. In mixed cohorts of patients undergoing elective and emergency vascular surgery [14] and cystectomy [15], deprivation was not associated with poorer short-term outcomes. Larger, multi-centre studies of patients undergoing elective (cardiac [16], general [17], colorectal cancer surgery [18]) and emergency surgery (orthopaedic [19] and abdominal [20, 21]) reported greater 30-day mortality in the most deprived groups, persisting after adjustment for co-morbidities. Deprivation may also influence access to surgery even in a universal healthcare

system. The most deprived group underwent fewer elective operations in studies of colorectal [18] and lung cancer surgery [22] and inequities in access to hip arthroplasty [23], cholecystectomy [24] and cardiac surgery [25] are also reported.

No studies of national data exploring the association of socio-economic deprivation with short-term outcomes in adults, access to surgery or the extent of socio-economic deprivation in the adult surgical population have been undertaken. This study may also indicate points in the peri-operative pathway where there is the potential to intervene to reduce perioperative risk.

2. Hypotheses and objectives

Hypotheses

1. 90-day mortality after surgery increases with increasing socio-economic deprivation
2. The number and age of patients undergoing elective and non-elective surgery varies with socio-economic deprivation
3. Patients in the most deprived groups have an increased length of stay
Deprivation in the peri-operative population varies with hospital location
4. Access to surgery during the COVID-19 pandemic was more limited with increasing socio-economic deprivation

Objectives

Primary objective

1. To describe 90-day mortality after surgery stratified by English Indices of Multiple Deprivation (IMD) deciles [26]

Secondary objectives

1. To describe the number and age of patients undergoing elective and non-elective surgery stratified by IMD
2. To describe length of stay after surgery stratified by IMD
3. To describe people undergoing surgery in England, stratified by IMD and geographical location
4. To describe access to surgery during the COVID-19 pandemic stratified by IMD

3. Methods

Data source

The study will be conducted in England because the data available is confined to this geographical area. Data regarding the number of surgeries taking place will be sourced from hospital episode statistics admitted patient care (HES-APC). This database gathers information on all patient hospital admissions including private hospital care funded by NHS England. This includes data on clinical information regarding diagnoses and operations, patient demographic information and dates of admission and discharge [27]. This will be accessed through NHS Digital approval [DARS-NIC-400985-V3D1C-v1.1]. Office for National Statistics (ONS) data will be used to define the population aged ≥ 18 in each Lower Layer Super Output Area (LSOA) [26].

Study design and setting

This is a nationwide observational cohort study using routinely collected health systems data. The cohort includes patients undergoing a pre-defined list of surgical procedures in the NHS in England between 2015 and 2025. Data prior to and during the COVID-19 pandemic will be analysed, with the pandemic period defined as January 2020 to January 2023. Only routinely collected data will be used to answer our objectives. There is no patient or clinician contact.

Participants and data collection

All patients aged 18 and over undergoing surgery in England between 2015 and 2025 will be included. Admission method codes will be used to define the cohort. Surgery will be defined using assigned Office of Population Census and Surveys Version 4 (OPCS-4) codes [28] for hospital procedures, and surgical procedures will be identified by using a predetermined list of OPCS-4 codes, as previously described [12]. These will be categorised according to anatomical location of the procedure. We will include as covariates age, sex, ethnicity, co-morbidities, surgical specialty and urgency of surgery. Co-morbidities will be recorded at index admission and may be recorded at previous outpatient appointments. International Classification of Disease (10th revision) (ICD-10) codes [29] will be used for diagnostic coding, including primary and secondary coding. Secondary diagnosis codes will be used where possible to create the RCS Charlson Score [30]. Ethnicity data can

be poorly reported in hospital episode statistics and if there is insufficient data, this will not be presented in the final manuscript.

Derivation of variables

Age will be determined as the age of the patient on the date they were admitted. Date of the operative procedure will be the date of the first surgical procedure. Classification of the urgency of surgery will be defined using admission method codes. The type of admission will be classified using admission method codes to elective or non-elective (including emergency and inter-hospital transfers). Each spell will be classified as in-patient or day-case, as previously described [31]. Specialty of surgical procedure will be based on the first operative code. Where multiple operative codes are associated with surgery on a single day, the highest ranked code will be considered the principal surgical procedure. Length of stay will be derived by constructing continuous inpatient spells to calculate the number of days in hospital. Socioeconomic deprivation is derived from LSOAs using the English IMD 2019 (IMD 2019) and reported as deciles. Both LSOA and IMD are provided in Hospital Episodes Statistics (HES) data. To define the COVID-19 pandemic cohort, the following date constraints will be used; pre- pandemic = before Jan 2020, pandemic = Jan 2020 to Jan 2023, and post-pandemic = after Jan 2023.

Exposure variable

The exposure variable is socio-economic deprivation, defined using the IMD. We will use national deciles (rather than deciles within the cohort) to enable us to investigate surgical rates. This is a categorical variable with ten categories (deciles). The reference category is the least deprived decile. The comparison categories are the nine more deprived groups.

Outcome measures

Primary outcome

1. Mortality within 90 days after surgery

Secondary outcomes

2. The number and age of patients undergoing elective and non-elective surgical procedures per IMD decile in the study cohort

3. Length of primary hospital admission within 90 days after surgery
4. The geographical distribution of deprivation with hospital site
5. The number of patients undergoing surgery per IMD decile during the COVID-19 pandemic

Covariate selection

Covariates will be selected based on their known effects on post-operative outcomes, and data availability. These will be: age, sex, comorbidities, ethnicity, type and urgency of surgery. Age will be determined as the age of the patient on the date they were admitted. International Classification of Disease (10th revision) (ICD-10) codes [29] will be used for diagnostic coding, including primary and secondary coding. Secondary diagnosis codes will be used where possible to create the RCS Charlson Score [30]. Ethnicity categories reported in HES data are White, Mixed, Asian, Black or other. Ethnicity data can be poorly reported in hospital episode statistics and if there is insufficient data, this will not be presented. The type of surgery is based on specialty and anatomical location (e.g. bone, breast, cardiac, cerebrovascular, ear, endocrine etc.). Urgency of surgery will be classified using admission method codes to elective or non-elective. This will include emergency and inter-hospital transfers.

4. Statistical analysis

Descriptive analysis

The following characteristics will be presented, stratified by IMD:

1. Number undergoing surgery in study timeframe and during COVID-19 pandemic (sub-group analysis restricted to the pandemic period)
2. Age, mean (SD) and median (IQR)
3. Sex, n (%)
4. Surgical procedure category (elective or non-elective surgery, and surgical specialty)
5. Co-morbid disorder, n (%)
6. Ethnicity, n (%)

We will report the total number of patients undergoing surgery, as defined using OPCS-4 codes, in the time frame assessed. This data will be categorised by IMD decile, by five-year age bands and ethnicity. Count data will be presented as frequencies with percentages, and continuous data will be presented as mean with standard deviation or median with interquartile range. The overall volume

of surgical procedures will be calculated with a 95% confidence interval. If poorly reported, ethnicity data will not be presented in the final manuscript.

Inferential analysis

Univariable and multivariable logistic regression analyses will be used to test the association between socioeconomic deprivation categorised by IMD deciles and mortality at 90 days. To test the association between socioeconomic deprivation categorised by IMD deciles and length of stay, a negative binomial/ Poisson regression or linear model will be used. Length of stay will be analysed as number of completed days.

The reference category is the least deprived decile, with the nine more deprived groups as the comparison categories. For mortality in the ten IMD categories (deciles) it may be most appropriate to use a deviation contrast and compare this to the grand mean. The following additional variables will be entered into the multivariable model: age, sex, presence of comorbidity (using RCS Charlson score), ethnicity, surgical procedure category (surgical specialty and anatomical location) and type of surgery (elective or non-elective surgery, as previously described [31]). Results will be presented as odds ratios with 95% confidence intervals.

To investigate frequency of surgery, patient LSOA will be compared to ONS LSOA data, aggregated for number of residents aged ≥ 18 .

To investigate survival, displayed as a Kaplan-Meier survival curve, the reference group will be IMD 1, the most deprived decile.

Geographic analysis

This will be undertaken to represent the number of patients undergoing surgery at each hospital and the proportion who are in the most deprived quintile, i.e. IMD 1&2. A bubble map could be used, with the size of the circle (at each hospital location on a map of England) representing the number undergoing surgery at that site, and the colour of the circle representing the proportion of patients in the most deprived quintile.

Sample size calculation

We will ensure that there are at least ten indices of outcome per degree of freedom per variable.

Subgroup analyses

To provide additional context, we will undertake planned sub-group analyses for pre-specified sentinel procedures, defined using OPSC-4 codes [28]. These will be undertaken for the following frequently performed surgical procedures [12]; elective hernia repair, appendicectomy, cataract removal, primary hip arthroplasty, cholecystectomy and coronary artery bypass graft.

Sensitivity analysis

A sensitivity analysis will be undertaken for patients remaining inpatient for ≥ 1 night to investigate the population undergoing major surgery and/or have been considered unsuitable for day-case surgery.

Secondary analysis

Separate secondary analyses will be undertaken for elective and non-elective procedures.

Handling of missing data

In the case of missing data for IMD, these patients will be placed into a “missing IMD” category. For missing sex, age and ethnicity data, cases with missing parameters will be excluded from the model. These numbers, characteristics and outcomes will be reported where possible. Ethnicity data can be poorly reported in hospital episode statistics and if there is insufficient data, this will not be presented in the final manuscript. If there are no ICD-10 codes present relating to a chronic disease (e.g. RCS Charlson or similar), it will be assumed the patient does not have chronic diseases.

5. Approvals

Research ethics approval

This analysis of routinely collected, pseudonymised data was approved by the Health Research Authority (20/HRA/3121). Access to NHS England data was approved by the NHS Digital Independent Group Advising on the Release of Data.

6. References

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7. Appendix: Provisional tables

Table 1

Baseline characteristics. Descriptive data stratified by national IMD decile, presented as frequencies with percentages (%), mean (SD) or median (IQR).

Characteristic	National IMD decile										
	Whole cohort	IMD 1	IMD 2	IMD 3	IMD 4	IMD 5	IMD 6	IMD 7	IMD 8	IMD 9	IMD 10
Number of patients, n											
Age											
[y; mean (SD)]											
[median; (IQR)]											
Sex											
Male [n, (%)]											
Female [n (%)]											
Ethnicity [n, %]											
White											
Mixed											
Asian											
Black											
Other											
Not stated											
Co-morbid disorder (RCS Charlson Comorbidity) [n, (%)]											
Myocardial Infarction											
Congestive Heart Failure											
Peripheral Vascular disease											
Stroke or transient ischaemic attack											
Dementia											
Chronic pulmonary disease											
Rheumatological disease											
Liver disease											
Diabetes Mellitus											
Hemiplegia or paraplegia											
Renal disease											
Malignancy											
Metastatic solid tumour											
RCS Charlson Score (n comorbidities)											
Surgical procedure category [n, (%)]											
Elective											
Non-elective											
Inpatient (inpatient for ≥ 1 night)											
Sentinel procedures [n, (%)]											
Elective hernia repair											
Appendicectomy											
Cataract removal											
Primary hip arthroplasty											
Cholecystectomy											
Coronary artery bypass graft											

Table 2

Outcomes; 90-day post-operative mortality for each IMD decile. The reference group is IMD 10 (least deprived).

	90-day mortality				
	n, %	Crude OR	Adjusted OR	95% CI	p-value
Whole cohort					
Age, y; mean (SD)]					
18-64 y					
≥ 65 y					
Sex, Female [n (%)]					
Ethnicity					
White					
Mixed					
Asian					
Black					
Other					
Not stated					
RCS Charlson Score (n comorbidities)					
IMD 1					
IMD 2					
IMD 3					
IMD 4					
IMD 5					
IMD 6					
IMD 7					
IMD 8					
IMD 9					
IMD 10					

Table 3:

Length of stay for each IMD decile. The reference group is IMD 10 (least deprived).

	Length of stay (number of completed days)		
	Median	IQR	p-value
Whole cohort			
18-64 y			
≥ 65 y			
Sex, Female [n (%)]			
White			
Mixed			
Asian			
Black			
Other			
Not stated			
RCS Charlson Score (n comorbidities)			
IMD 1			
IMD 2			
IMD 3			
IMD 4			
IMD 5			
IMD 6			
IMD 7			
IMD 8			
IMD 9			
IMD 10			

Figure 1

Patient flow diagram showing the number of patients included/ excluded from analysis

Figure 2

Graph of IMD deciles (x axis) and number undergoing elective and non-elective surgery (y axis)
(stacked bar)

Figure 3

Graph of IMD deciles (x-axis) and proportion undergoing surgery in 5-year age bands (y-axis)

Figure 4/ Supplementary material

Graph of IMD deciles (x axis) and rate of combined elective and non-elective surgery per e.g.100,000 in each IMD decile of the general population (y axis)

Figure 5/ Supplementary material

Graph of IMD deciles (x axis) and rates of inpatient (LOS ≥ 1 day) surgery (y axis)

Figure 6/ Supplementary material

Graph of IMD deciles (x axis) and overall rates of surgery (y axis) during the COVID-19 pandemic

Figure 7

Forest plots to show odds ratios for mortality by each IMD decile with 95% confidence intervals. Panels for overall cohort, elective surgery only, inpatient elective surgery cohort, non-elective surgery, COVID-19 cohort.

Figure 8/ Supplementary material

Forest plots of prevalence ratios for covariates (age, sex, comorbidities, ethnicity, surgical specialty, urgency of surgery) with mortality.

Figure 9

Kaplan Meier survival curve at 90 days (with most deprived group (IMD 1) as reference group).

Figure 10.

Geographical representation of the number of patients undergoing surgery at each hospital, with the proportion who are in IMD 1&2 (most deprived quintile). This could be represented using a bubble map. The size of the circle ('bubble') at each geographical location corresponds to the number of patients undergoing surgery in that hospital, and the circle appears on the map at the location of the hospital. The colour of the circle represents the proportion of people at that site who are in IMD 1 or 2 (most deprived quintile). A red bubble would correspond to e.g. $\geq 40\%$ people having surgery at

that site who are in the most deprived quintile, an orange bubble $\geq 30\%$, a yellow bubble $\geq 20\%$ etc. The percentage cut-offs will be selected after analysis.

Figure 11/ Supplementary.

Age at presentation (y axis), IMD deciles (x axis) for the sentinel procedures.

8. Appendix: Supplementary Material

S1. Logistic regression outputs for co-variables

	90-day mortality					Length of stay (number of completed days)		
	n, %	Crude OR	Adjusted OR	95% CI	P-value	Median	IQR	p-value
Myocardial Infarction								
Congestive Heart Failure								
Peripheral Vascular disease								
Stroke or transient ischaemic attack								
Dementia								
Chronic pulmonary disease								
Rheumatological disease								
Liver disease								
Diabetes Mellitus								
Hemiplegia or paraplegia								
Renal disease								
Malignancy								
Metastatic solid tumour								

S2. Table of numbers undergoing surgery and in English population stratified by IMD

	Number (%) in surgical cohort	Number (%) in population
IMD 1		
IMD 2		
IMD 3		
IMD 4		
IMD 5		
IMD 6		
IMD 7		
IMD 8		
IMD 9		

IMD 10		
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S3.

Graph of IMD deciles (x axis) and rates of elective surgery (y axis)

S4.

Graph of IMD deciles (x axis) and rates of inpatient (LOS $\geq$ 1 day) surgery (y axis)

S5.

Graph of IMD deciles (x axis) and rates of non-elective surgery (y axis)

S6.

Graph of IMD deciles (x axis) and overall rates of surgery (y axis) during the COVID-19 pandemic

S7.

Table to show 90-day mortality outcomes stratified by elective surgery, inpatient surgery (LOS $\geq$ 1 day), non-elective surgery, surgery during COVID-19 pandemic and the sentinel procedure cohorts (sub-group and sensitivity groups). Reference group is least deprived group.

	90-day mortality			Length of stay (number of completed days)	
	n, %	Crude OR	p-value	Median	IQR
IMD 1					
Elective surgery					
Inpatient surgery (LOS $\geq$ 1 day)					
Non-elective surgery					
COVID-19 cohort					
Elective hernia repair					
Appendicectomy					
Cataract removal					

Primary hip arthroplasty					
Cholecystectomy					
Coronary artery bypass graft					
IMD 2 etc.					