Socioeconomic deprivation and long-term outcomes after elective surgery: Analysis of prospective data from two observational studies

Running title: Socioeconomic deprivation and surgical outcomes

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Abstract

Background

Socioeconomic deprivation is associated with health inequalities. We explored relationships between socioeconomic group and outcomes following elective surgery in the UK National Health Service (NHS).

Methods

We combined data from two observational studies in 115 NHS hospitals and determined socioeconomic group using Index of Multiple Deprivation (IMD) quintiles based on place of residence. Post-operative complications and three-year survival were assessed using logistic and Cox regression. Univariate analyses were adjusted for age differences between IMD quintiles. Multivariable analyses were used to account for other baseline risk-factors including sex and comorbid disease. Results are reported as n (%), hazard ratios (HR) or odds ratios (OR) with 95% confidence intervals.

Results

Post-operative complications developed in 971/9,051 patients (10.7%) and 1,597/9,043 patients (17.7%) died within three years. Complication rates increased with deprivation (reference group least-deprived IMD5): IMD1 (OR: 1.44 [1.17-1.78]; p<0.001), IMD2 (OR: 1.38 [1.12-1.70]; p<0.01), IMD3 (OR: 1.09 [0.88-1.35]: p=0.44), IMD4 (OR: 0.89 [0.71-1.11]; p=0.30). More patients from the most-deprived quintile died (IMD1) (n=349, 18.8%) compared to the least-deprived (IMD5) (n=297, 15.9%) with a trend across the socioeconomic spectrum (p=0.01). After age-adjustment, patients in the most-deprived areas experienced reduced three-year survival: IMD1 (HR: 1.43 [1.23-1.67]; p<0.0001), IMD2 (HR: 1.35 [1.15-1.57]; p<0.001), IMD3 (HR: 1.04 [0.89-1.23]; p=0.60), IMD4 (HR: 1.11 [0.95-1.30]; p=0.19). This finding persisted in risk-adjusted analyses. Increased complication rates only partially explained this reduced survival.

Conclusions

Socioeconomic deprivation is associated with worse long-term outcomes after elective surgery. This risk-factor should be considered when planning perioperative care for patients from deprived areas.

Introduction

Surgery is one of the most common treatments offered by the UK National Health Service (NHS) within the UK. One in ten adults undergo a surgical procedure each year, and the annual number of procedures is increasing, particularly in elderly patients.[1] There are 4.6 million hospital admissions that lead to surgery every year in England alone. Perioperative complications present a substantial burden to healthcare cost due to associated morbidity and mortality.[2, 3]

The link between poverty, health inequalities and reduced life expectancy is well established.[4] Differences in socioeconomic status are associated with increased mortality in a range of diseases.[5-7] Inequalities in healthcare exist globally, both within and between countries.[8] Improvements in healthcare provision and outcome in the UK have not been consistent across socioeconomic groups, with persistent limitations in the most deprived areas.[9] The reasons for this are multifactorial and may include: barriers in accessing healthcare due to financial limitations or geographical distance; variations in availability and quality of services in areas of greater deprivation; differences in risk factors such as smoking, alcohol and poor diet; and different patterns of health literacy, health seeking behaviour and patient activation.[10]

The relationship between socioeconomic deprivation and post-operative outcomes remains poorly understood. Previous studies of surgical patients have been small, focused on single disease groups, and did not describe long-term patient outcomes. Associations between worse surgical outcomes and socioeconomic deprivation has been demonstrated with specific types of cancer surgery,[11-15] and increased 30-day mortality following emergency laparotomy.[16] However, these smaller groups may not be representative of the wider surgical population for a variety of reasons.[17] Furthermore, the majority of studies have used income-based metrics of deprivation, which may not reflect the contribution from other domains of social determinants of health.[18] Further work is required to better understand these complex factors and identify ways to reduce perioperative risk. In this study, we investigate associations between socioeconomic deprivation and long-term outcomes after elective surgery. We also identify clinical factors associated with deprivation and assess whether adjustment for these factors modifies the effect of socioeconomic deprivation on outcomes for a range of surgical categories.

Methods

Study cohorts

The International Surgical Outcome Study (ISOS) is an international multi-centre cohort study of perioperative morbidity and mortality in patients undergoing elective surgery (ISRCTN51817007).[3] Data collection occurred during a seven-day period between April and August 2014. All adult patients admitted to participating centres for elective surgery with a planned overnight stay were eligible. The Vascular Events in non-cardiac surgery (VISION) study is a prospective, international cohort study designed to evaluate major complications following non-cardiac surgery.[19] Enrolment into the study took place between August 2007 and January 2011. Patients were eligible if they are 45 years or older and receiving either general or regional anaesthesia, requiring at least an overnight stay in hospital. The research ethics committee/institutional review board at each site approved the protocol prior to patient recruitment for both studies. For this analysis, only patients from England were included from each cohort. Detailed and standardised data are collected before surgery, during the patient's hospital stay until discharge. Patients were followed up for a maximum of 30 days after surgery for complications. Survival data were collected up to one year post-operatively in ISOS and up to three years post-operatively in VISION-UK. Three-year survival data for ISOS was obtained via linkage to NHS Digital held civil registration data (DARS-NIC-68740-X7R2N).

Assessment of socioeconomic deprivation

The UK Office for National Statistics has published data measuring relative deprivation in small areas in England.[6] We used the patient's home address to match to the Office of National Statistics Postcode Directory (ONSPD). A relative measure of socioeconomic deprivation was assessed using the English Indices of Multiple Deprivation 2019 (IMD 2019) using a composite score based on 37 separate indicators.[20] These are grouped into seven distinct domains: income; employment; health and disability; education, skills and training; barriers to housing and other services; crime; and living environment. The contribution of each of these domains to the overall score is weighted differently, with income and employment deprivation weighted the most, to calculate the IMD score. Lower-Layer Super Output Areas (LSOAs) are small areas designed to be of a similar population size, with an average of approximately 1,500 residents or 650 households. There are 32,844 LSOAs in England which have been divided according to their deprivation rank into five equal groups (quintiles). Analyses were carried out by using quintiles of deprivation for LSOAs ranked by IMD in the combined cohort in order to account for potential disproportionate grouping in different IMD quintiles in our dataset.

Outcome measures

The co-primary outcomes were survival assessed at 30 days, one year and three years. The secondary outcomes were in-hospital complications and hospital length of stay. Specific complications included infection (superficial and deep surgical site, body cavity, blood stream), pneumonia, urinary tract infection, cardiac event (myocardial infarction, arrythmia), pulmonary oedema, pulmonary embolism, stroke or transient ischaemic attack, cardiac arrest, gastro-intestinal bleed, acute kidney injury, post-operative bleed or anastomotic leak, and acute respiratory distress syndrome.

Statistical analysis

Analyses were carried out in accordance with a pre-published statistical analysis plan.[21] Descriptive statistics for baseline characteristics for patients across IMD quintiles are presented using means and standard deviations, medians and interquartile ranges, and proportions as appropriate. We compared proportions using Pearson's Chi-square test and continuous variables using two-sample t-test or Wilcoxon rank-sum test as appropriate for the data distribution. Survival rates at 30 days, one year and three years were calculated. Time-to-event analysis was undertaken with follow-up censored at three years. Due to low event rates, a Cox proportional-hazards model was used to assess survival at three years only. We investigated the impact of IMD on survival in univariate analyses adjusted for age. We included the following baseline risk variables in the multivariable model: sex, American Society of Anesthesiologists physical status classification system (ASA), comorbid diseases (coronary artery disease, diabetes mellitus, metastatic cancer, chronic obstructive pulmonary disease (COPD) or asthma, heart failure, liver cirrhosis, cerebral vascular disease), pre-operative haemoglobin, and pre-operative creatinine. The proportional-hazard assumption for included variables was assessed by inspection of scaled Schoenfeld residual plots, non-proportional hazards were investigated by stratification. Univariate and multivariable regression models were developed for the secondary outcomes with the same risk variables as for the primary outcome. Adjusted survival curves and forest plots showing effect sizes were generated. Data are presented as mean (SD), median (IQR) or n (%). Effect measures are presented as hazard ratios (HR) and odds ratios (OR) with 95% confidence intervals (CI). All analyses were performed using R version 3.6.3 (R: A language and environment for statistical computing. R Core Team 2020).

Sensitivity analyses

To evaluate potential differences in quality of care, hospital site was included as a separate variable in models to evaluate both survival and post-operative complications. Due to differences in representation of IMD between the two studies, we summarised descriptive statistics for each study cohort. Due to non-proportionality of age, we assessed three-year survival using a Cox proportional-hazards model stratified by age categorised into quintiles for both the univariate and multivariable models. We assessed the impact of developing a post-operative complication on three-year survival between patients across IMD quintiles by inclusion into the multivariable model. An additional multivariable model was carried out comparing different surgical categories.

Results

A total of 10,096 patients from ISOS and VISION-UK had baseline data available for inclusion in this analysis. We excluded 772 patients not matched to ONSPD and therefore unable to assign IMD. A further 281 patients missing outcome data for survival was excluded leaving 9,034 patients (Figure 1). Patients were recruited from 115 centres across England in ISOS distributed across IMD quintiles (S1 and S2 Tables). Patients in VISION-UK were recruited from 2 centres in London demonstrating a higher representation of more deprived IMD quintiles (S1 and S2 Figures). The majority of surgery was elective (n=8,316, 96.0%), the remaining procedures were made up of urgent (n=273), emergency (n=58), unknown (n=12). Across the combined cohort, the median hospital length of stay was 3.0 days (1.0-6.0). Patients in VISION-UK had longer hospital stays (4.0 days [2.0-8.0]) compared to ISOS (2.0 days [1.0-5.0]) ($p<0.0001$).

Within the combined dataset, association of baseline variables with deprivation is shown in Table 1. There were differences in patient characteristics between IMD quintiles. Patients in the most deprived quintile were significantly younger (median age 58.7 years) than those in the least deprived quintile (median age 65.0 years), with a gradient across the socioeconomic spectrum ($p<0.001$). Patients from more deprived quintiles were more likely to have higher ASA scores (3 or 4) ($p<0.001$), and lower mean baseline haemoglobin (12.9g dL^{-1} in the most deprived to 13.2g dL^{-1} in the least deprived [$p<0.001$]). Distribution of comorbid disease varied between IMD quintiles: there were higher proportions of diabetes mellitus, (15.9% IMD1, 10.2% IMD5) chronic obstructive pulmonary disease (COPD) and asthma (20.7% IMD1, 13.1% IMD5) in the most deprived groups. Conversely, metastatic cancer was more common in the least deprived (1.2% IMD1, 3.4% IMD5) (all $p<0.001$).

Overall death rates were 0.5% at 30 days (n=49), 4.2% at one-year (n=393), and 17.1% at three years (n=1,591). At three years, a larger proportion of patients from the most deprived quintile (IMD1, n=349, 18.8%) died compared to those in the least deprived (IMD5, n=297, 15.9%), there was a trend across the socioeconomic spectrum ($p=0.01$). Patients from the two most deprived quintiles had significantly lower longer-term survival to three years. On average, patients in IMD1 experienced a 40% greater age-adjusted risk of dying over time compared to patients in IMD5 (HR 1.43 [1.23-1.67], p<0.0001) with patients in IMD2 having a 35% greater adjusted-risk (HR 1.35 [1.15-1.57], p<0.001). However, individual hazard ratios for IMD3 and IMD4 did not show a gradient for lower survival with increasing deprivation (Table 2). In a multivariable survival analysis taking into account other baseline risk factors, the association with lower survival persisted in IMD1 patients (adjusted HR 1.29 [1.09-1.51]; p=0.003). In this model, older age, male sex, ASA 2 to 4, metastatic cancer, lower pre-operative haemoglobin, and higher pre-operative creatinine were also statistically associated with risk of death (Table 3). These findings were unchanged when analyses were repeated using a model stratified by age (S4 and S5 Tables). In the multivariable survival model assessing the influence of different surgical categories, patients in the most deprived quintile remained consistently associated with lower survival compared to the least deprived (S7 Table).

Post-operative complications at 30 days occurred in 10.7% of patients (n=971). Rates of post-operative complication increased with increasing deprivation, with 12.3% in the most deprived compared to 9.9% in the least deprived quintile (p=0.001). Compared to patients in the least deprived quintiles, there was a near 30% greater risk of developing a complication in patients in both IMD1 (OR 1.28 [1.04-1.58]; p=0.02) and IMD2 (OR 1.29 [1.05-1.59]; p=0.02). This risk increased when adjusted for differences in age in both IMD1 (OR 1.44 [1.17-1.78]; p<0.001) and IMD2 (OR 1.38 [1.12-1.70]; p<0.01). This finding was driven by infective complications (S11 Table). In the multivariable model, the trend in increased risk for all complications remained but confidence intervals widened to just outside limits of statistical significance in both IMD1 (adjusted OR 1.25 [0.99-1.58]; p=0.06) and IMD2 (adjusted OR 1.25 [0.99-1.57]; p=0.06) (S12 Table). In the multivariable survival model including development of a post-operative complication, patients who had a complication had a reduced three-year survival compared to those who did not (adjusted HR 1.57 [1.38-1.80]; p<0.0001). In this analysis, the most deprived quintile still had a higher risk of death compared to the least deprived (adjusted HR 1.30 [1.10-1.54]; p=0.002) (S8 Table). The impact of a post-operative complication on longer-term survival was relatively higher than the impact of deprivation. Complications were less important (in terms of effect size) than general health and fitness (ASA grade) or age.

The association between increasing deprivation and reduced survival persisted after adjustment for hospital in both IMD1 (HR 1.23 [1.04-1.46]; p=0.01) and IMD2 (HR 1.23 [1.04-1.45]; p=0.01) (S9 Table). The trend of increased risk of complications remained but confidence intervals widened to just outside limits of statistical significance after this adjustment for hospital (S10 Table). Due to the differences in types of surgery and recruitment between the ISOS and VISION-UK study, analysis of association with hospital length of stay was undertaken separately for each cohort. In ISOS, patients who were more deprived has longer hospital stays when adjusted for age although the effect sizes were small: IMD1 (adjusted days 0.69 [0.33-1.04]; p<0.001), IMD2 (adjusted days 0.52 [0.16-0.87]; p=0.004) (S13 Table). There were no differences in the VISION-UK cohort. Effect sizes became non-significant in multivariable analyses (S16 and S17 Tables).

Discussion

The principal finding of this study was that patients living in areas of increased socioeconomic deprivation experienced a greater number of complications following elective surgery and reduced three-year survival. These associations were not fully explained by differences in age, sex or comorbid disease, and persisted across a range of surgical categories. Post-operative complications were independently associated with lower survival and patients from more deprived areas spent more days in hospital.

Our finding that despite younger age, patients from more deprived areas have worse long-term outcomes following surgery is important and consistent with the non-surgical literature.[22, 23] This association was not explained by differences in quality of care between hospitals. Patients living in deprived areas acquire physical and mental health conditions at a younger age as well as higher rates of multi-morbidity.[5, 24, 25] It is well demonstrated that healthcare inequalities increase the prevalence of comorbid diseases strongly associated with lifestyle factors such as diabetes and COPD.[26-28] Poor diet and inadequate nutrition are likely to increase the prevalence of anaemia,[29] and lower pre-operative haemoglobin was consistently associated with reduced post-operative survival and increased morbidity in our analyses. We found that less deprived patients were more likely to have metastatic cancer at the time of surgery. There are multiple potential reasons for this, including lower levels of participation with screening programmes, reduced symptom awareness, and more delayed presentation.[12] Perhaps the most worrying is that access to surgery may be more difficult for deprived patients with advanced cancers, or that they may have a worse overall health status for the same degree of disease severity.[30] Rates of surgery in patients with early-stage lung cancer have been shown to be lower in more deprived patients and presence of comorbidities further reduced receipt of surgery.[15] Cancer surgery may have additional influences and behave differently compared to other surgical categories emphasising the need to further investigate effects within different types of surgery. Greater understanding of differences between This highlights the need for ongoing public health and policy initiatives.

Another key finding is the increase in post-operative complications with increasing deprivation. However, this association weakened after adjustment for baseline comorbid risk factors. Deprived patients may present for elective surgery with more advanced disease and higher burdens of chronic diseases secondary to socioeconomic factors and this may predispose them to post-operative complications.[31-34] It is notable that compared to co-morbid diseases defined as binary categories (i.e. present or absent), all of the pre-operative risk factors associated with adverse outcome were on measured scales of severity (i.e. haemoglobin, creatinine, metastatic cancer status). We could therefore hypothesise that differences in outcome associated with socioeconomic group could be driven in part by differences in baseline disease *severity*, (rather than simply disease status, e.g. hypertensive vs. normotensive). This may provide support for the notion that measures of disease severity (e.g. end-organ damage from diabetes or hypertension, heart failure or angina scores) should be recorded, rather than binary data for these risk factors. Interestingly, although development of a major surgical complication in itself was associated with reduced survival, it did not alter the relationship between deprivation and survival. Differences in survival between socioeconomic groups following surgery follow the same pattern as in the general population. However, surgery also increases the risks of complications particularly in more deprived patients, which in turn reduces long-term survival. This identifies an area in which to target improvements in perioperative care and supports the need to routinely evaluate measures of long-term outcomes. Inclusion of survival and postoperative complications as outcome measures should be considered in future trials examining outcomes of interventions. Aggregating measures of deprivation may also be helpful in pre-operative risk assessment. However, inclusion of this directly into risk scoring may have unintended consequences such as reluctance towards surgery in more deprived patients and increased disparities in quality of care between hospitals perpetuating differences in outcomes, particularly in other healthcare systems. From these findings we can provide two potential directions for future research. The first is to continue existing efforts to identify interventions which would reduce complications for all patients, regardless of socioeconomic group. The second is to consider if patients from more deprived groups might benefit from specific targeted interventions both before and after surgery. Surgery may be used as a window of opportunity where it is possible to implement changes which might specifically seek to address health inequalities, including targeted optimisation of comorbid disease, or targeted post-discharge surveillance and intervention. Particularly, given the impact of poor baseline health status continuing to demonstrate the strongest risk effects. There remain opportunities to improve perioperative services, and some of these may be benefit from being more directed towards high-risk areas with more deprived patients in conjunction with better risk assessment and triage.

Strengths and limitations

We have used a comprehensive dataset from two multicentre studies including a range of surgical categories. Our assessment of socioeconomic deprivation was based on a measure weighted on indicators across multiple domains of inequality. We report long-term survival in an unselected surgical population and were able to evaluate the contribution of baseline health status and comorbid disease using multivariable models. In addition, we followed a statistical analysis plan and performed multiple sensitivity analyses to test the robustness of our findings. There are however some limitations to this study. Firstly, there was a small proportion of patients for whom data linkage was not possible or did not have survival outcome data. The distribution of missingness across our cohort may have affected the ability of detect more marginal differences particularly between the middle deprivation groups. Secondly, we observe small effect sizes and low event rates when assessing survival to three years. Arguably this is too short a period of time to discern differences related to the socioeconomic disparity and other studies have required follow-up to beyond five and even ten years.[35-37] Thirdly, it would have been interesting to see if there were any variations between different surgical specialities through sub-group analysis and whether severity of complications differed with increased deprivation. However, individual surgical categories had small sample sizes and we did not have severity data across the whole cohort. Lastly, there are additional variables for which we did not have data and were unable to assess. These included patient factors such as ethnicity, lifestyle risk factors including smoking, variations in disease severity and chronic disease management in addition to hospital process measures. There may still have been differences in the standards of care delivered to the most-deprived quintile compared to the least-deprived and smaller, low surgical volume centres may have been underrepresented. Furthermore, as is the case for the majority of studies on socioeconomic inequality, we were unable to include direct effects of variations in other social determinants of health, differences in access to appropriate healthcare, in follow up and in access to services after discharge. We have defined deprivation using usual place of residence for each patient and assessed relative level of deprivation for an area based on aggregate population data. Although this is based on the smallest unit of area for which data are available, there remains the possibility that areas of low aggregate deprivation will still include some deprived individuals.

Conclusions

This study has demonstrated variation in patients undergoing surgery in England related to socioeconomic differences and that increased deprivation is associated with worse post-operative outcomes across a range of different surgical categories. Increased surgical risk amongst patients from more deprived areas should be taken into account when planning perioperative care and the influence of deprivation considered in comparative outcome analyses. There is continued need for public health innovation and policy initiatives to address community level socioeconomic factors and broader causes of health inequalities.

Author Contributions

Data collection: ISOS group, VISION-UK group

Study design: YIW, RMP, SRM

Statistical analysis: YIW

Drafting: YIW, RMP, SRM

Critical review and approval of final manuscript: All authors

Declaration of Interests

RP holds research grants and has given lectures and/or performed consultancy work for Glaxo Smithkline, Intersurgical, and Edwards Lifesciences, and is a member of the Associate editorial board of the British Journal of Anaesthesia. SRM is Director of the National Institute of Academic Anaesthesia Health Services Research Centre and the University College London Hospitals Surgical Outcomes Research Centre, and Associate National Clinical Director for elective care at National Health Service England. No other competing interests declared.

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Table 1. Baseline characteristics of study population across Index of Multiple Deprivation (IMD) quintile (1 most deprived to 5 least deprived). Total n=9,324 unless otherwise stated. p-values based on Chi-square (for categorical) or Kruskal-Wallis test (for continuous) comparing proportions across quintiles. ASA: American Society of Anesthesiologists physical status classification system, COPD: chronic obstructive pulmonary disease. Anaemia defined as baseline haemoglobin <13g/dL (male) or <12g/dL (female). Baseline eGFR based on creatinine levels calculated using the CKDepi formula. Chronic kidney disease defined as baseline eGFR <60ml/min/1·72m^2.

	Stratified by IMD quintile					
	IMD1	**IMD2**	**IMD3**	**IMD4**	**IMD5**	P
n	1865	1865	1865	1865	1864	
Age (years) (n=9315]						
Median (IQR)	58.7 (47.0-69.2)	61.0 (49.3-71.0)	62.0 (50.0-71.0)	64.3 (51.0-73.0)	65.0 (51.0-74.0)	<0.001
Female (%) [n=9319]	1037 (55.6)	1027 (55.1)	1012 (54.3)	1022 (54.9)	1016 (54.5)	0.94
ASA (%) [n=9168]						<0.001
1	359 (19.6)	330 (18.1)	394 (21.4)	381 (20.8)	431 (23.5)	
2	952 (52.1)	976 (53.4)	1014 (55.1)	1024 (55.8)	997 (54.3)	
3	488 (26.7)	497 (27.2)	416 (22.6)	412 (22.4)	389 (21.2)	
4	28 (1.5)	25 (1.4)	17 (0.9)	19 (1.0)	19 (1.0)	
Comorbid disease [n=9298]						
Coronary artery disease (%)	226 (12.2)	232 (12.5)	220 (11.8)	219 (11.8)	213 (11.5)	0.90
Diabetes mellitus (%)	295 (15.9)	300 (16.1)	246 (13.2)	250 (13.5)	189 (10.2)	<0.001
Metastatic cancer (%)	23 (1.2)	38 (2.0)	51 (2.7)	49 (2.6)	64 (3.4)	<0.001
COPD or Asthma (%)	384 (20.7)	329 (17.7)	282 (15.1)	233 (12.5)	243 (13.1)	<0.001
Heart failure (%)	51 (2.7)	49 (2.6)	41 (2.2)	51 (2.7)	44 (2.4)	0.78
Cirrhosis (%)	14 (0.8)	10 (0.5)	10 (0.5)	14 (0.8)	10 (0.5)	0.80
Cerebral vascular disease (%)	91 (4.9)	77 (4.1)	64 (3.4)	87 (4.7)	72 (3.9)	0.17
Baseline haemoglobin (g/dL) [n=8106]						
Mean (SD)	12.9 (1.9)	13.1 (1.8)	13.2 (1.8)	13.2 (1.8)	13.2 (1.9)	<0.001
Median (IQR)	13.1 (11.9-14.2)	13.2 (12.0-14.2)	13.4 (12.2-14.4)	13.3 (12.2-14.4)	13.4 (12.3-14.4)	<0.001

Anaemia (%) [n=8106]	527 (32.1)	487 (29.6)	424 (26.2)	428 (26.6)	408 (25.6)	<0.001
Baseline eGFR (ml/min/1·72m^2) [n=7639]						
Median (IQR)	86.3 (67.0-99.0)	84.5 (67.7-97.7)	84.3 (69.4-96.3)	83.8 (66.6-95.8)	82.1 (66.2-94.4)	0.002
Chronic kidney disease (%) [n=7639]	280 (18.0)	271 (17.3)	238 (15.6)	270 (18.0)	266 (17.9)	0.37
Surgical procedure (%) [n=9307]						<0.001
Orthopaedic/Trauma	537 (28.9)	531 (28.5)	534 (28.6)	512 (27.5)	517 (27.8)	
Gastro-intestinal/HPB	310 (16.7)	340 (18.3)	323 (17.3)	285 (15.3)	293 (15.7)	
Obstetrics & Gynaecology	281 (15.1)	203 (10.9)	252 (13.5)	299 (16.1)	307 (16.5)	
Urology/Kidney	206 (11.1)	211 (11.3)	237 (12.7)	256 (13.8)	244 (13.1)	
Cardiothoracic	51 (2.7)	64 (3.4)	79 (4.2)	93 (5.0)	92 (4.9)	
Plastics/Breast	81 (4.4)	95 (5.1)	103 (5.5)	92 (4.9)	108 (5.8)	
Head and neck/Ear, Nose & Throat	152 (8.2)	142 (7.6)	144 (7.7)	148 (8.0)	134 (7.2)	
Vascular	111 (6.0)	109 (5.9)	74 (4.0)	65 (3.5)	65 (3.5)	
Neurosurgical	62 (3.3)	71 (3.8)	40 (2.1)	45 (2.4)	36 (1.9)	
Other	70 (3.8)	94 (5.1)	78 (4.2)	64 (3.4)	67 (3.6)	
Severity of surgery (%) [n=9307]						0.21
Minor	223 (12.0)	184 (9.9)	175 (9.4)	199 (10.7)	192 (10.3)	
Intermediate	680 (36.7)	675 (36.4)	705 (38.0)	649 (35.0)	682 (36.7)	
Severe	951 (51.3)	995 (53.7)	975 (52.6)	1005 (54.2)	985 (53.0)	
Post-operative complications [n=9051]						
Post-op surgical site infection (%)	113 (6.3)	109 (6.1)	88 (4.8)	69 (3.8)	74 (4.0)	<0.001
Post-op pneumonia (%)	41 (2.3)	41 (2.3)	25 (1.4)	31 (1.7)	38 (2.1)	0.20
Post-op urinary tract infection (%)	35 (1.9)	29 (1.6)	29 (1.6)	18 (1.0)	32 (1.7)	0.20
Post-op cardiac event (%)	4 (0.2)	9 (0.5)	10 (0.5)	9 (0.5)	8 (0.4)	0.60
Post-op pulmonary oedema (%)	7 (0.4)	6 (0.3)	3 (0.2)	5 (0.3)	4 (0.2)	0.72
Post-op pulmonary embolism (%)	15 (0.8)	16 (0.9)	5 (0.3)	8 (0.4)	5 (0.3)	0.02
Post-op cerebral vascular accident (%)	4 (0.2)	3 (0.2)	3 (0.2)	6 (0.3)	3 (0.2)	0.78
Post-op cardiac arrest (%)	4 (0.2)	6 (0.3)	6 (0.3)	5 (0.3)	3 (0.2)	0.83
Post-op gastro-intestinal bleed (%)	6 (0.3)	4 (0.2)	6 (0.3)	4 (0.2)	6 (0.3)	0.93

Post-op acute kidney injury (%)	15 (0.8)	21 (1.2)	19 (1.0)	16 (0.9)	18 (1.0)	0.85
Post-op bleed/leak (%)	36 (2.0)	31 (1.7)	42 (2.3)	33 (1.8)	40 (2.2)	0.72
Post-op acute respiratory distress syndrome (%)	0 (0.0)	3 (0.2)	4 (0.2)	3 (0.2)	1 (0.1)	0.30
Post-op all infections (%)	166 (9.2)	170 (9.5)	129 (7.1)	109 (6.0)	130 (7.1)	<0.001
Post-op all non-infections (%)	79 (4.4)	77 (4.3)	77 (4.2)	67 (3.7)	67 (3.7)	0.676
Post-op all complications (%)	222 (12.3)	221 (12.4)	186 (10.2)	161 (8.9)	181 (9.9)	0.001
Hospital length of stay (days) [n=9276]						
Mean (SD)	8.6 (47.1)	7.5 (4258)	6.8 (43.3)	6.2 (32.8)	4.9 (23.2)	0.05
Median (IQR)	3.0 (1.0-6.0)	3.0 (1.0-6.0)	3.0 (1.0-6.0)	3.0 (1.0-5.0)	3.0 (1.0-5.0)	<0.001
Died (%) [n=9043]	351 (19.2)	347 (19.3)	284 (15.8)	317 (17.7)	298 (16.3)	0.01
Death Missing (%)	39 (2.1)	68 (3.6)	63 (3.4)	72 (3.9)	39 (2.1)	0.001

Table 2. Univariate analysis of three-year survival comparing Index of Multiple Deprivation (IMD) quintile (least deprived group Q5 as reference) using Cox proportional-hazards modelling. n=9,306, events=1,591.

	n (%)			Age adjusted	
	30-day	1-year	3-year	Hazard ratio (95% CI)	p-value
Age (25th vs 75th centile)	-	-	-	4.05 (3.69-4.45)	<0.0001
Socioeconomic quintile					
Quintile 1	6 (0.3)	83 (4.5)	351 (19.2)	1.43 (1.23-1.67)	<0.0001
Quintile 2	18 (1.0)	92 (4.9)	347 (19.3)	1.35 (1.15-1.57)	<0.001
Quintile 3	9 (0.5)	61 (3.3)	284 (15.8)	1.04 (0.89-1.23)	0.60
Quintile 4	5 (0.3)	80 (4.3)	317 (17.7)	1.11 (0.95-1.30)	0.19
Quintile 5	11 (0.6)	77 (4.1)	298 (16.3)	Reference	-

Table 3. Multivariable analysis of three-year survival comparing Index of Multiple Deprivation (IMD) quintile (least deprived group Q5 as reference) using Cox proportional-hazards modelling. Model covariates (age, sex, ASA, comorbid disease, pre-operative haemoglobin, pre-operative creatinine), n=7,429, events=1,433. ASA: American Society of Anesthesiologists physical status classification system, COPD: chronic obstructive pulmonary disease.

	Adjusted	
	Hazard ratio (95% CI)	**P value**
Age (25th vs 75th centile)	2.84 (2.55-3.17)	<0.0001
Socioeconomic quintile		
Quintile 1	1.29 (1.09-1.52)	0.003
Quintile 2	1.17 (0.99-1.39)	0.06
Quintile 3	1.01 (0.86-1.21)	0.84
Quintile 4	1.09 (0.92-1.29)	0.33
Quintile 5	Reference	-
Male sex	1.65 (1.47-1.84)	<0.0001
ASA		
1	Reference	-
2	1.90 (1.45-2.50)	<0.0001
3	3.39 (2.56-4.49)	<0.0001
4	5.00 (3.37-7.42)	<0.0001
Comorbid disease		
Coronary Artery Disease	0.91 (0.79-1.04)	0.17
Diabetes mellitus	1.10 (0.97-1.25)	0.16
Metastatic cancer	4.13 (3.41-4.99)	<0.0001
COPD or Asthma	1.02 (0.89-1.18)	0.73
Heart failure	0.86 (0.67-1.11)	0.24
Cirrhosis	1.30 (0.84-2.03)	0.24
Cerebral vascular disease	0.96 (0.78-1.18)	0.70
Baseline haemoglobin (g/dL) (25th vs 75th centile)	0.77 (0.69-0.77)	<0.0001
Baseline creatinine (μmol/L) (25th vs 75th centile)	1.02 (1.00-1.03)	0.03

Figure legends

Figure 1. STROBE flow diagram of study populations.

Figure 2. Survival curve to three years comparing Index of Multiple Deprivation (IMD) quintiles (1 most deprived to 5 least deprived). Cox proportional-hazards analysis, adjusted to median age 62 years.