ANESTHESIOLOGY

Socioeconomic Status and Days Alive and Out of Hospital after Major Elective Noncardiac Surgery

A Population-based Cohort Study

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ABSTRACT

Background: Socioeconomic status is an important but understudied determinant of preoperative health status and postoperative outcomes. Previous work has focused on the impact of socioeconomic status on mortality, hospital stay, or complications. However, individuals with low socioeconomic status are also likely to have fewer supports to facilitate them remaining at home after hospital discharge. Thus, such patients may be less likely to return home over the short and intermediate term after major surgery. The newly validated outcome, days alive and out of hospital, may be highly suited to evaluating the impact of socioeconomic status on this postdischarge period. The study aimed to determine the association of socioeconomic status with short and intermediate term postoperative recovery as measured by days alive and out of hospital.

Methods: The authors evaluated data from 724,459 adult patients who had one of 13 elective major noncardiac surgical procedures between 2006 and 2017. Socioeconomic status was measured by median neighborhood household income (categorized into quintiles). Primary outcome was days alive and out of hospital at 30 days, while secondary outcomes included days alive and out of hospital at 90 and 180 days, and 30-day mortality.

Results: Compared to the highest income quintile, individuals in the lowest quintile had higher unadjusted risks of postoperative complications (6,049 of 121,099 [5%] *vs.* 6,216 of 160,495 [3.9%]) and 30-day mortality (731 of 121,099 [0.6%] *vs.* 701 of 160,495 [0.4%]) and longer mean postoperative length of stay (4.9 *vs.* 4.4 days). From lowest to highest income quintile, the mean adjusted days alive and out of hospital at 30 days after surgery varied between 24.5 to 24.9 days.

Conclusions: Low socioeconomic status is associated with fewer days alive and out of hospital after surgery. Further research is needed to examine the underlying mechanisms and develop posthospital interventions to improve postoperative recovery in patients with fewer socioeconomic resources.

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EDITOR'S PERSPECTIVE

What We Already Know about This Topic

- Low socioeconomic status likely impairs many aspects of health and health care
- Days alive and out of hospital is a new outcome measure that assesses duration of hospitalization and readmission

What This Article Tells Us That Is New

- The investigators evaluated more than 700,000 patients who had 13 types of surgery
- Days alive and out of hospital in the initial postoperative months was about a quarter of a day shorter in the lowest than the highest socioeconomic quintile, adjusted for potential confounding factors
- Confounder-adjusted serious complications were also more common in the lowest quintile (5% *vs.* 3.9%), as was mortality (0.6% *vs.* 0.4%)

Social and economic factors are important yet relatively understudied determinants of perioperative outcomes for adult surgical patients. Previous research has shown that surgical patients from disadvantaged socioeconomic backgrounds have greater burdens of preoperative comorbidity and experience elevated risks of complications, prolonged hospital stay, and death after surgery.[1–3] This socioeconomic gradient in health outcomes is seen in low-, middle-, and high-income countries.[4,5] Importantly, socioeconomic disparities in postoperative outcomes are present both in countries with predominantly private insurer–based healthcare systems (*e.g.*, United States) and countries with largely government-funded systems (*e.g.*, Canada and United Kingdom).[6]

Previous work in postoperative medicine has focused on the impact of socioeconomic status on mortality, length of hospital stay, readmission, or postoperative complications.[2,3,7–9] However, patients with low socioeconomic status

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are also likely to have fewer social and financial supports to help them remain at home after hospital discharge. This aspect of postoperative recovery is captured by a new outcome called days alive and out of hospital, which has been validated by our group. The days alive and out of hospital metric quantifies the combined outcomes of mortality, hospital stay, and readmission after surgical intervention. Hence, the objective of this population-based cohort study was to determine the adjusted association of socioeconomic status with short- and intermediate-term postoperative recovery as measured by days alive and out of hospital.

Materials and Methods

Settings and Data Sources

We conducted a retrospective cohort study using linked population-based administrative healthcare databases in Ontario, Canada. The use of data in this project was authorized under section 45 of Ontario's Personal Health Information Protection Act, which does not require review by a research ethics board. We used the Registered Persons Database, Vital Statistics and Canadian census data to extract demographics, socioeconomic status, and mortality. The Canadian Institute of Health Information Discharge Abstract Database was used to capture all hospital admissions. We used the Ontario Health Insurance Plan database to capture all physician service claims data. Specialized disease-specific registries (Ontario Diabetes Database, Asthma Database, Chronic Obstructive Pulmonary Disease Database, Ontario Hypertension Database) were used to ascertain the presence of specific comorbidities. Data were linked deterministically through unique anonymized patient identifier numbers. Variables and associated codes used in this study have been previously described.[10,11]

Study Cohort

We identified adults (at least 40 yr) who underwent selected elective high- and intermediate-risk elective noncardiac surgical procedures between 2006 and 2017 in acute care hospitals in Ontario, Canada. As the most populous Canadian province, Ontario has over 14 million residents and accounts for about 38% of the overall Canadian population. The study cohort included 12 major noncardiac surgical groups: (1) aortic surgery (open and endovascular abdominal aortic repair); (2) peripheral artery disease procedures (above or below knee amputation, lower limb revascularization); (3) lung resection procedures (open pneumonectomy, open and video assisted thoracoscopic partial lung resection); (4) upper gastrointestinal procedures (partial liver resection, biliary bypass, Whipple's resection, gastrectomy, esophagectomy); (5) lower gastrointestinal procedures (colorectal resection); (6) nephrectomy; (7) hysterectomy; (8) neurosurgery procedures (open craniotomy, posterior fossa surgery); (9) spine surgery; (10) total joint (hip or knee) replacement surgery; (11) shoulder surgery; and (12) prostatectomy.

If a patient underwent multiple eligible surgeries during the study period, only the first procedure was included. We excluded intraoperative deaths, interhospital transfers before surgery, and hospitals undertaking fewer than 50 cases of each surgical procedure during the study period.

Outcomes

The primary outcome was days alive and out of hospital at 30 days after surgery. It was calculated using information on mortality, hospital length of stay, and hospital readmissions between the date of the index surgery and the thirtieth postoperative day using validated sources from the Canadian Institute of Health Information Discharge Abstract Database.[12] Our approach for calculating days alive and out of hospital was consistent with previous work performed by our group and others.[13] In this previously employed approach, patients who died during this 30-day period were assigned a days alive and out of hospital of 0 days. For example, a patient who survived and was discharged 20 days after the indexed surgery had a days alive and out of hospital at 30 days of 10 days. If patients were readmitted to the hospital during this time frame, the number of days spent in hospital were subtracted from the final days alive and out of hospital at 30 days. Thus, a patient discharged on postoperative day 20 who was subsequently readmitted for 2 days on postoperative day 21 had a days alive and out of hospital at 30 days of 8 days. The secondary outcomes were days alive and out of hospital at 90 days and 180 days, and 30-day mortality. Days alive and out of hospital at 90 and 180 days were determined using similar calculations as days alive and out of hospital at 30 days, albeit using different time windows (*i.e.*, 60 and 90 days after surgery). The primary and secondary outcomes were defined *a priori*.

Principal Exposure

Socioeconomic status was characterized using median neighborhood household income from the 2016 Canadian Census data. Patients within the study cohort were linked to the dissemination area of their principal residence using the Statistics Canada Postal Code Conversion File. Dissemination areas, which cover all of Canada, are the smallest standard geographical area where census data are disseminated.[14] The population of a dissemination area is approximately 400 to 700 people. On the basis of the median household income in each dissemination area, neighborhoods are ranked into quintiles. Individuals within quintile 1 reside in neighborhoods with the lowest median household income, whereas those within quintile 5 reside in neighborhoods with the highest median income.[15] This approach to measuring socioeconomic status reflects the resources available in local neighborhoods, such as access to services and infrastructure.[16] This approach has been used by previous medical and surgical studies that assessed the association of socioeconomic status with various health outcomes.[14,17,18] Although neighborhood median household income provides an incomplete *individual* assessment of socioeconomic status, previous studies have shown it to be an acceptable proxy measure.[19]

Covariates

Demographics (age, sex) were identified from the Registered Persons Database. Comorbidities (coronary artery disease, diabetes, hypertension, chronic obstructive pulmonary disease, asthma, stroke, chronic renal insufficiency, Charlson comorbidity index) were extracted from the Canadian Institute of Health Information Discharge Abstract Database (using International Classification of Diseases, Tenth Revision, codes from hospital admissions within 3 yr before the index surgery) and specialized validated Ontario databases.[20–23] Serious postoperative complications (myocardial infarction; heart failure; stroke; pulmonary embolism; acute kidney injury; new requirement for dialysis; respiratory failure; infection; bleeding; wound dehiscence; postoperative biliary, air, or anastomotic leak) within 30 days after surgery were captured from the Canadian Institute of Health Information Discharge Abstract Database. Surgical information extracted included type and duration of the surgical procedure from the Canadian Institute of Health Information Discharge Abstract Database, which shows high accuracy.[12] Preoperative specialty consultations, pulmonary function testing, transthoracic echocardiography, and cardiac stress testing within 6 months before surgery was extracted from the Ontario Health Insurance Plan database. Intraoperative invasive hemodynamic monitoring (arterial and central venous lines), epidural analgesia and postoperative intensive care unit admission was extracted from the Ontario Health Insurance Plan database and the Canadian Institute of Health Information Discharge Abstract Database. Hospital bed numbers and teaching status were obtained from the information about Ontario Healthcare Institutions Database.

Statistical Analysis

Patient characteristics (age, sex, comorbidities, surgery, surgery duration), hospital characteristics (teaching status, total bed number) and postoperative outcomes (days alive and out of hospital at 30, 90, and 180 days, 30-day mortality, length of stay) variables were described within strata defined by quintiles of neighborhood median household income using median (interquartile range) for continuous variables and frequency (percentage) for categorical variables.

Hierarchical multivariable quantile regression models were then used to determine the adjusted association of neighborhood income quintile with days alive and out of hospital at 30, 90, and 180 days. Multivariable quantile regression modeling has been previously used to model days alive and out of hospital because it deals well with its complex distributional properties (highly skewed with a second small peak at 0 days).[11] Quantile regression modeling is also flexible in that it allows for modeling the outcome at different percentiles of its distribution rather than the mean, which is used in conventional regression modeling techniques. Quantile regression modeling was used to predict the median (fiftieth percentile) of the days alive and out of hospital distribution. Our previous work has shown that the distribution of days alive and out of hospital is skewed to the left.[11] Patients residing within the tail of the distribution (percentiles below the median) who have a lower number of days alive and out of hospital are older with higher level of chronic disease burden. To assess whether the impact of socioeconomic status is greater for these patients, quantile regression was also performed at the twenty-fifth and tenth percentile of the days alive and out of hospital distribution. A hierarchical multivariable logistic regression model was used to determine the adjusted association of neighborhood income quintile with 30-day mortality. To explore the impact of comorbidities and surgery on adjusted estimates of association, we developed both a simple model that adjusted only for patient demographics (age, sex) and surgery, and a full model that adjusted for all clinically sensible patient-, surgical-, and hospital-level factors. The covariates in the full model included age, sex, hypertension, coronary artery disease, atrial fibrillation, myocardial infarction, diabetes mellitus, asthma, chronic obstructive airway disease, stroke, chronic kidney disease, chronic liver disease, cancer, Charlson Comorbidity Index score, rural residence, surgical procedure, surgical procedure duration, teaching hospital status, total hospital bed number, year of surgery, and hospital-level surgical volume. The Charlson Comorbidity Index score was categorized as 0 to 1 *versus* 2 or greater. All models incorporated hospital-specific random effects to account for within-hospital clustering.

To test the robustness of our overall findings, we conducted *post hoc* sensitivity analyses restricted to more homogenous groups of surgical procedures. Specifically, the main analyses were repeated within subgroups consisting of patients undergoing joint replacement procedures, as well as patients undergoing upper and lower gastrointestinal resection procedures. These surgeries were selected given that they are common procedures performed by many acute hospitals. Upper and lower gastrointestinal resection were grouped together given they are similar in location of surgical incision location, postoperative morbidity, and perioperative management challenges (*e.g.*, hemodynamic, fluid, and pain management). No statistical power or minimum clinically meaningful difference calculated was conducted before the study. The sample size was based on the available data.

All analyses were conducted using SAS version 9.4 (SAS Institute, USA) and R statistical software (v.0.98.1091 http://www.rstudio.org R Core Team [2014), R: A language and environment for statistical computing; R Foundation for Statistical Computing, the linear quantile mixed models (LQMM) package for Laplace Quantile Regression, Austria; accessed June 2, 2018).[24–27] Strata of deciles were used to compare observed and predicted days alive and out of hospital to evaluate model calibration. Two-sided *P* values less than 0.05 were considered statistically significant.

Results

The cohort included 724,459 patients. The characteristics of patients across strata defined by quintiles of neighborhood median household income are summarized in tables 1 and 2. Median age was similar across quintiles, but the proportion of females was generally higher within lower-income quintiles. In general, the burden of preoperative comorbidity was substantially higher among lower-income quintile groups. This was particularly prominent for diabetes mellitus, chronic obstructive airway disease, asthma, hypertension, and coronary artery disease. The poorer health status of lower-income groups was also reflected by a higher prevalence of preoperative intensive care unit admission, preoperative specialty consultation, preoperative cardiac testing, preoperative pulmonary function testing, and intraoperative invasive monitoring (tables 1 and 2). Surgical and hospital factors such as duration of surgery, surgical volumes, and total number of beds were similar across all neighborhood income quintiles.

Postoperatively, patients within lower income quintiles had higher 30-day mortality risks, longer hospital stays,

Table 1. Unadjusted Patient and Hospital Characteristics of All Elective Surgical Patients across Quintiles of Median Neighborhood Household Income

Variable	Quintile 1 N = 121,099	Quintile 2 N = 141,417	Quintile 3 N = 145,365	Quintile 4 N = 156,083	Quintile 5 N = 160,495	Total N = 724,459	*P* Value
Patient							
Age, yr	65 (55–73)	65 (56–74)	65 (56–73)	65 (56–73)	65 (57–73)	65 (56–73)	< 0.001
Male sex	45,353 (37.5%)	55,449 (39.2%)	58,082 (40.0%)	64,872 (41.6%)	69,111 (43.1%)	292,867 (40.4%)	< 0.001
Atrial fibrillation	3,362 (2.8%)	3,797 (2.7%)	3,789 (2.6%)	4,121 (2.6%)	4,156 (2.6%)	19,225 (2.7%)	0.022
Myocardial infarction	2,363 (2.0%)	2,427 (1.7%)	2,300 (1.6%)	2,325 (1.5%)	2,192 (1.4%)	11,607 (1.6%)	< 0.001
CAD	5,799 (4.8%)	6,041 (4.3%)	5,713 (3.9%)	5,897 (3.8%)	5,743 (3.6%)	29,193 (4.0%)	< 0.001
Hypertension	78,364 (64.7%)	90,303 (63.9%)	90,951 (62.6%)	95,230 (61.0%)	94,786 (59.1%)	449,634 (62.1%)	< 0.001
Diabetes	33,812 (27.9%)	35,864 (25.4%)	34,524 (23.7%)	34,665 (22.2%)	31,002 (19.3%)	169,867 (23.4%)	< 0.001
COPD	29,470 (24.3%)	29,817 (21.1%)	27,287 (18.8%)	27,057 (17.3%)	25,045 (15.6%)	138,676 (19.1%)	< 0.001
Asthma	20,906 (17.3%)	22,860 (16.2%)	22,419 (15.4%)	23,156 (14.8%)	22,348 (13.9%)	111,689 (15.4%)	< 0.001
Stroke	1,466 (1.2%)	1,500 (1.1%)	1,416 (1.0%)	1,471 (0.9%)	1,433 (0.9%)	7,286 (1.0%)	< 0.001
Chronic liver disease	706 (0.6%)	636 (0.4%)	576 (0.4%)	615 (0.4%)	525 (0.3%)	3,058 (0.4%)	< 0.001
Chronic renal disease	1,488 (1.2%)	1,519 (1.1%)	1,406 (1.0%)	1,447 (0.9%)	1,309 (0.8%)	7,169 (1.0%)	< 0.001
Dialysis	559 (0.5%)	533 (0.4%)	488 (0.3%)	470 (0.3%)	430 (0.3%)	2,480 (0.3%)	< 0.001
Primary cancer	6,803 (5.6%)	7,980 (5.6%)	7,691 (5.3%)	8,187 (5.2%)	8,480 (5.3%)	39,141 (5.4%)	< 0.001
Secondary cancer	4,881 (4.0%)	5,696 (4.0%)	5,410 (3.7%)	5,881 (3.8%)	6,142 (3.8%)	28,010 (3.9%)	< 0.001
Charlson Score >2	17,030 (14.1%)	18,396 (13.0%)	17,398 (12.0%)	18,071 (11.6%)	17,640 (11.0%)	88,535 (12.2%)	< 0.001
Preoperative ICU care	1,060 (0.9%)	1,097 (0.8%)	1,040 (0.7%)	1,046 (0.7%)	933 (0.6%)	5,176 (0.7%)	< 0.001
Rural residence	21,146 (17.5%)	23,360 (16.5%)	23,351 (16.1%)	22,880 (14.7%)	22,770 (14.2%)	113,507 (15.7%)	< 0.001
Duration surgery (min)	130 (101–186)	129 (100–184)	129 (100–183)	129 (100–183)	129 (100–182)	129 (100–183)	< 0.001
Surgical Procedure							
Aorta	3,093 (2.6%)	3,426 (2.4%)	3,155 (2.2%)	3,192 (2.0%)	3,027 (1.9%)	15,893 (2.2%)	< 0.001
Hysterectomy	20,907 (17.3%)	24,585 (17.4%)	26,290 (18.1%)	27,969 (17.9%)	26,583 (16.6%)	126,334 (17.4%)	
Joint replacement	57,937 (47.8%)	68,977 (48.8%)	70,733 (48.7%)	76,597 (49.1%)	80,967 (50.4%)	355,211 (49.0%)	
Lower GI	12,308 (10.2%)	14,140 (10.0%)	14,203 (9.8%)	15,207 (9.7%)	14,865 (9.3%)	70,723 (9.8%)	
Nephrectomy	3,016 (2.5%)	3,327 (2.4%)	3,444 (2.4%)	3,543 (2.3%)	3,594 (2.2%)	16,924 (2.3%)	
Upper GI	2,629 (2.2%)	3,169 (2.2%)	3,088 (2.1%)	3,308 (2.1%)	3,483 (2.2%)	15,677 (2.2%)	
Lung resection	4,755 (3.9%)	5,102 (3.6%)	4,859 (3.3%)	5,130 (3.3%)	5,057 (3.2%)	24,903 (3.4%)	
Neurosurgery	1,196 (1.0%)	1,454 (1.0%)	1,503 (1.0%)	1,673 (1.1%)	1,791 (1.1%)	7,617 (1.1%)	
Prostatectomy	3,835 (3.2%)	5,100 (3.6%)	5,807 (4.0%)	6,795 (4.4%)	8,056 (5.0%)	29,593 (4.1%)	
PAD	3,277 (2.7%)	2,866 (2.0%)	2,595 (1.8%)	2,407 (1.5%)	2,208 (1.4%)	13,353 (1.8%)	
Shoulder	3,277 (2.7%)	2,866 (2.0%)	2,595 (1.8%)	2,407 (1.5%)	2,208 (1.4%)	13,353 (1.8%)	
Spine	2,299 (1.9%)	2,642 (1.9%)	2,652 (1.8%)	2,778 (1.8%)	3,098 (1.9%)	13,469 (1.9%)	
Hospital							
Procedure volume	3,090 (1,278–6,209)	3,181 (1,359–6,838)	3,181 (1,318–6,466)	3,305 (1,397–6,838)	3,561 (1,532–7,147)	3,285 (1,372–6,838)	< 0.001
Teaching hospital	45,354 (37.5%)	52,053 (36.8%)	52,062 (35.8%)	56,267 (36.0%)	66,021 (41.1%)	271,757 (37.5%)	< 0.001
Hospital bed number	282 (182–359)	279 (181–359)	277 (172–360)	284 (189–370)	291 (200–418)	284 (192–371)	< 0.001

Continuous and categorical variables are expressed as median (interquartile range) and frequency (percentage), respectively. Quintile 1, lowest median income; quintile 5, highest median income.

CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; GI, gastrointestinal; ICU, intensive care unit; PAD, peripheral arterial disease.

Table 2. Unadjusted Perioperative Care Processes for All Elective Surgical Patients across Quintiles of Median Neighborhood Household Income

Variable	Quintile 1 N = 121,099	Quintile 2 N = 141,417	Quintile 3 N = 145,365	Quintile 4 N = 156,083	Quintile 5 N = 160,495	TOTAL N = 724,459	*P* Value
Preoperative care*							
Cardiology consult	9,374 (7.7%)	10,724 (7.6%)	10,011 (6.9%)	10,166 (6.5%)	10,088 (6.3%)	50,363 (7.0%)	< 0.001
Medical consult	38,839 (32.1%)	44,444 (31.4%)	44,153 (30.4%)	46,077 (29.5%)	46,271 (28.8%)	219,784 (30.3%)	< 0.001
Pulmonary function test	10,508 (8.7%)	11,438 (8.1%)	11,089 (7.6%)	11,586 (7.4%)	11,448 (7.1%)	56,069 (7.7%)	< 0.001
Cardiac stress/echo	24,477 (20.2%)	27,727 (19.6%)	27,432 (18.9%)	29,201 (18.7%)	29,227 (18.2%)	138,064 (19.1%)	< 0.001
Intraoperative care							
Arterial line	28,976 (23.9%)	32,479 (23.0%)	32,564 (22.4%)	34,283 (22.0%)	35,146 (21.9%)	163,448 (22.6%)	< 0.001
Central venous line	6,011 (5.0%)	6,831 (4.8%)	6,534 (4.5%)	6,669 (4.3%)	6,643 (4.1%)	32,688 (4.5%)	< 0.001
Thoracic epidural	11,022 (9.1%)	12,236 (8.7%)	12,581 (8.7%)	13,094 (8.4%)	12,420 (7.7%)	61,353 (8.5%)	< 0.001

Quintile 1, lowest median income; quintile 5, highest median income.

*Preoperative consults and testing performed within 6 months before surgery.

higher risks of complications, and greater need for postoperative intensive care unit care (table 3). The unadjusted median days alive and out of hospital values were qualitatively similar across all income quintiles with median days alive and out of hospital at 30, 90, and 180 days values of 26, 86, and 176 days, respectively (table 3).

The adjusted association of neighborhood median household income quintile, patient and hospital characteristics with days alive and out of hospital is summarized in figure 1 and table 4. Simple models adjusting for only patient age, sex and surgery at the median of the distribution (fiftieth percentile) showed a modest increase in days alive and out of hospital at 30 days with rising neighborhood median income quintile (Model 1, table 4). This gradient was further accentuated with adjustment for comorbidities and hospital factors (Model 2, table 4). This gradient was similar when quantile regression was used to predict the twenty-fifth and tenth percentiles of days alive and out of hospital (table 4, Supplemental Digital Content, table 1, http://links.lww.com/ALN/C162). When days alive and out of hospital was measured over longer postoperative timepoints, higher neighborhood income quintiles remained associated with significantly higher adjusted days alive and out of hospital at 90 and 180 days (fig. 1; Supplemental Digital Content, table 2, http://links.lww.com/ALN/C162). Higher median neighborhood household income quintile was also associated with significantly lower adjusted 30-day mortality risk, although the magnitude of this gradient was less prominent than was the case for days alive and out of hospital (table 4). From lowest to highest income quintile, the mean unadjusted and adjusted days alive and out of hospital at 30 days varied between 24.6 to 25.3 and 24.5 to 24.9 days, respectively (fig. 2).

In sensitivity analyses of patients undergoing upper and lower gastrointestinal resection surgery, joint replacement

Table 3. Unadjusted Postoperative Outcomes for All Elective Surgical Patients across Quintiles of Median Neighborhood Household Income

Variable	Quintile 1 N = 121,099	Quintile 2 N = 141,417	Quintile 3 N = 145,365	Quintile 4 N = 156,083	Quintile 5 N = 160,495	Total N = 724,459	*P* Value
Postoperative complication	6,049 (5.0%)	6,418 (4.5%)	6,326 (4.4%)	6,555 (4.2%)	6,216 (3.9%)	31,564 (4.4%)	< 0.001
Postoperative ICU admission	14,254 (11.8%)	15,489 (11.0%)	14,690 (10.1%)	15,118 (9.7%)	14,746 (9.2%)	74,297 (10.3%)	< 0.001
DAH_{30}	26 (24–27)	26 (24–27)	26 (25–27)	26 (25–27)	26 (25–27)	26 (25–27)	< 0.001
DAH_{90}	86 (84–87)	86 (84–87)	86 (84–87)	86 (84–87)	86 (84–87)	86 (84–87)	< 0.001
DAH_{180}	176 (173–177)	176 (173–177)	176 (173–177)	176 (174–177)	176 (174–177)	176 (173–177)	< 0.001
Postoperative LOS							
Median (IQR)	4 (3–5)	3 (3–5)	3 (3–5)	3 (2–5)	3 (2–5)	3 (3–5)	
Mean ± SD	4.9 ± 7.0	4.7± 6.7	4.6 ± 6.1	4.5 ± 5.7	4.4 ± 5.9	4.6 ± 6.2	< 0.001
30-Day mortality	736 (0.6%)	778 (0.6%)	713 (0.5%)	714 (0.5%)	701 (0.4%)	3,642 (0.5%)	< 0.001

Continuous and categorical variables are expressed as median (interquartile range) and frequency (percentage), respectively. Quintile 1, lowest median income; quintile 5, highest median income.

DAH_{30}, days alive and out of hospital at 30 days; DAH_{90}, days alive and out of hospital at 90 days; DAH_{180}, days alive and out of hospital at 180 days; ICU, intensive care unit; IQR, interquartile range; LOS, length of stay.

surgery, aortic and peripheral arterial disease surgery, quintiles of neighborhood median household income were similarly associated with significantly higher adjusted days alive and out of hospital at 30 days (table 5; Supplemental Digital Content, table 3, http://links.lww.com/ALN/C162). This effect was slightly more prominent among patients having vascular procedures. All models showed good calibration.

Discussion

This large population-based study examined the impact of neighborhood income quintile on postoperative days alive and out of hospital. We found that days alive and out of hospital was influenced by household income in that increasing affluence was associated with slightly higher number of days alive and out of hospital at 30, 90, and 180 days

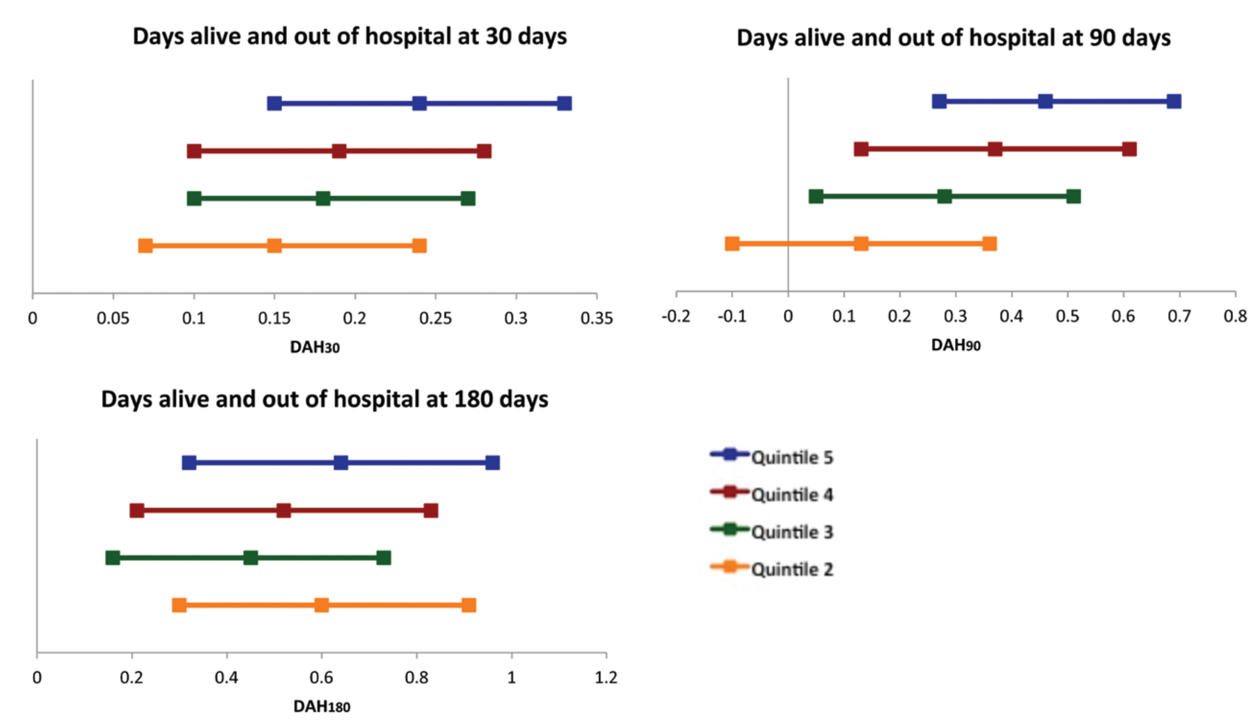

Fig. 1. Forest plots summarizing the adjusted association of quintiles of median neighborhood household income with days alive and out of hospital (DAH) at 30, 90, and 180 days after surgery for all elective surgical patients.

Table 4. Adjusted Association of Quintiles of Median Neighborhood Household Income with 30-Day Mortality Risk and Days Alive and out of Hospital at 30 Days across Different Models

Model No.	1	2	3	4	5
Model Output	**DAH_{30} Parameter (95% CI)**	**DAH_{30} Parameter (95% CI)**	**DAH_{30} Parameter (95% CI)**	**DAH_{30} Parameter (95% CI)**	**30-Day Mortality Odds Ratio (95% CI)**
Predictor variables	Age, sex, income quintile, surgery	Age, sex, income quintile, surgery, comorbidities	Age, sex, income quintile, surgery, comorbidities	Age, sex, income quintile, surgery, comorbidities	Age, sex, income quintile, surgery, comorbidities
*Percentile of outcome distribution predicted	50th percentile	50th percentile	25th percentile	10th percentile	NA
Quintile 1			Reference		
Quintile 2	0.2 (0.1–0.2)	0.2 (0.1–0.3)	0.2 (0.1–0.3)	0.1 (–0.1 to 0.4)	0.9 (0.8–1.0)
Quintile 3	0.2 (0.1–0.3)	0.3 (0.1–0.4)	0.2 (0.1–0.3)	0.2 (0.0–0.5)	0.9 (0.8–1.0)
Quintile 4	0.3 (0.2–0.4)	0.3 (0.2–0.4)	0.3 (0.2–0.4)	0.3 (0.1–0.5)	0.9 (0.8–1.0)
Quintile 5	0.3 (0.2–0.4)	0.4 (0.2–0.5)	0.4 (0.3–0.5)	0.4 (0.2–0.7)	0.8 (0.8–0.9)

*Percentile of DAH_{30} distribution predicted using quantile regression modeling.
DAH_{30}, days alive and out of hospital at 30 days; NA, not applicable.

Table 5. Adjusted Association of Quintiles of Median Neighborhood Household Income with Days Alive and out of Hospital at 30 Days after Surgery among Patients Undergoing Joint Replacement, Upper and Lower Gastrointestinal Resection*

	Days Alive and Out of Hospital at 30 Days, Parameter (95% Confidence Interval)			
	Upper and Lower GI Resection	Joint Replacement	Aortic Surgery	Peripheral Arterial Disease
Quintile 1	Reference			
Quintile 2	0.2 (0.0–0.3)	0.2 (0.1–0.3)	0.5 (0.2–0.7)	0.4 (0.1–0.6)
Quintile 3	0.2 (0.1–0.4)	0.2 (0.1–0.3)	0.5 (0.2–0.9)	0.6 (0.3–0.9)
Quintile 4	0.3 (0.2–0.5)	0.2 (0.1–0.3)	0.5 (0.2–0.8)	0.4 (0.1–0.6)
Quintile 5	0.4 (0.2–0.6)	0.3 (0.2–0.4)	0.5 (0.3–0.8)	0.5 (0.3–0.7)

*Full model results are available in Supplemental Digital Content, table 3 (http://links.lww.com/ALN/C162).
GI, gastrointestinal.

after surgery. The difference in days alive and out of hospital appears clinically small when viewed at a patient level, *i.e.*, patients in the highest neighborhood income quintile had a median additional 0.2 days (mean, 0.4 days) free from hospital in comparison to patients within the lowest-income quintile. However, this difference should also be interpreted at a population level where a difference of 0.2 days is a total gain of 32,099 days free from hospital within our cohort of over 700,000 patients. This translates to a health system cost savings of nearly $36 million given the daily cost of a ward level bed is CAN $1,135 in Canada.[28] Although the effect of higher neighborhood income quintiles on days alive and out of hospital remained significant at days alive and out of hospital at 90 and 180 days, the effect was less pronounced in comparison to the shorter-term timepoint of days alive and out of hospital at 30 days. The weaker association at longer-term follow up could be due to resolution of the social and financial reasons that keep patients in the hospital in the short term, *i.e.*, arrangement of homecare services, placement in rehabilitation or residential care, and financial aid support, which aids keeping patients out of the hospital.

The current paper confirms and builds upon previous studies conducted in general, cardiovascular, lung, and trauma surgery, which also demonstrated the importance of

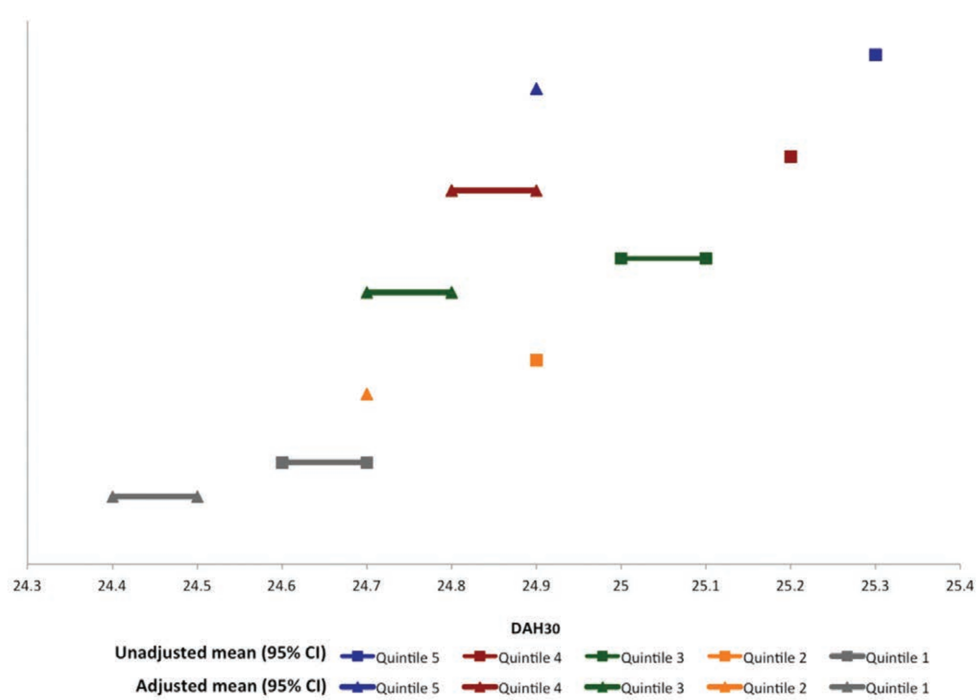

Fig. 2. Unadjusted and adjusted mean days alive and out of hospital (DAH) at 30 days after surgery.

preoperative social and economic factors on postoperative outcomes.[2,3,8,9,29] Our use of days alive and out of hospital has advantages over these previous studies in that the simple quantitative metric combines several important postoperative clinical endpoints (*i.e.*, patient death, hospital stay, and readmission) that are usually analyzed separately. Our study confirms that patients in the lowest socioeconomic strata have a higher burden of preoperative comorbidities, and experience higher risks of postoperative complications and poorer health outcomes. Several complex interrelated reasons likely underpin these findings. Previous research indicates that patients of lower socioeconomic status often have several lifestyle (*i.e.*, poorer diet, higher prevalence of smoking, lower exercise regimens and compliance with medication) factors that increase the risk of chronic disease.[30,31] These lifestyle factors may explain the significant socioeconomic gradient seen in the prevalence of asthma, coronary artery disease, diabetes, and chronic obstructive airway disease. Further, patients of lower socioeconomic status are at greater risk of psychologic distress (anxiety, depression), poor social situations (social isolation, worse housing conditions, need for chronic postdischarge continuing care services) and economic disadvantage (lower earnings and employment opportunities)—all of which affect timely access to health care and life expectancy.[3,32,33] Importantly, the fewer social and economic resources available to patients of lower socioeconomic status are likely to impact timely hospital discharge and their ability to return and remain at home. To help delineate which specific aspects of lower socioeconomic status are prognostically important, further prospective studies are needed to evaluate the association of individual factors—such as educational attainment, occupation, lifestyle differences, social support networks, and individual income—with postoperative outcomes.

Our findings raise important considerations for healthcare providers and policy makers. Compared to wealthier patients, patients of lower socioeconomic status have a higher burden of largely unmodifiable chronic disease that places them at greater risk of morbidity and complex care needs after surgery. These complex care needs may continue after hospital discharge with the need for ongoing support from many different health services including primary care providers, social services, hospital outpatient visits, home nursing or allied health care, local transport services, specialized rehabilitation, and nursing care facilities. However, poorer patients also tend to have greater difficulty accessing community healthcare services that are vital to assist patient recovery.[34,35] This poor access can lead many patients of lower socioeconomic status to prefer returning to the hospital to address any new health issues.[34,36] These differences in the ability to access care are likely even greater in privatized insurer-led healthcare systems than public-funded health systems, where there is often some provision for a safety net of chronic care and primary services after hospital discharge.[37] Hence, improved early understanding and delivery of transitional care needs for vulnerable surgical patients could improve postoperative recovery by enhancing timely hospital discharge after surgery and patients' ability to remain at home.

This study has several limitations that should be considered. First, our results may be influenced by residual confounding since our administrative healthcare data sources did not capture some important patient and hospital characteristics such as physiologic data and lifestyle factors (smoking history, alcohol consumption). Second, while our findings in Canada should be generalizable to other countries with predominantly public-funded healthcare systems (*e.g.*, United Kingdom), this socioeconomic gradient in healthcare outcomes is likely to be greater within economically incentivized private healthcare systems. Notably, while Canada has a universal and publicly funded healthcare system, large socioeconomic disparities in health outcomes still persist.[17,38] Third, we used an area-based approach to ascertain socioeconomic status (*i.e.*, median neighborhood income) rather than an individual-level assessment. This choice was driven by the absence of individual-level lifestyle, family, education, occupation, and economic factors in administrative healthcare databases. We anticipate that measurement of socioeconomic status at an individual level will likely reveal an even larger gradient in days alive and out of hospital across socioeconomic strata. Nonetheless, previous research supports the use of neighborhood median income as a good proxy measure for individual household income.[19,39] An area-based approach also provides a stable reflection of socioeconomic status over time, is subject to fewer missing data, and can provide a geographical assessment of the association between socioeconomic distribution and health outcomes.[16] This latter advantage is particularly useful for policy makers who want to gain deeper understanding of regional differences in postoperative outcomes that might be explained in part by local availability of primary and chronic continuing care services. Fourth, we acknowledge there are several domains of social determinants of health (*i.e.*, social and community factors, level of education, financial stability, neighborhood factors, and access to care) that will influence timely hospital discharge and days at home. Further mixed methods studies are required to evaluate how each of these domains affects days alive and out of hospital, which will ultimately influence how we improve postoperative outcomes. Fifth, given large administrative datasets often demonstrate statistical significance the results, any differences should be interpreted for clinical significance.[40] Sixth, *post hoc* analyses were conducted after review of the descriptive data and thus should be interpreted cautiously and repeated within other study cohorts.

Socioeconomic status has an important impact on outcomes after major surgery. Patients with fewer social supports and limited financial resources are at greater risk of postoperative morbidity, death, and the inability to remain home. Future qualitative studies are needed to gain deeper insights into the posthospital discharge care needs of this complex patient group, which in turn will provide invaluable information to develop targeted interventions to improve their postoperative recovery.

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Competing Interests

The authors declare no competing interests.

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