



Original Research Article

Social drivers of health and perioperative outcomes: Identifying domains and barriers with significant impact



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ABSTRACT

Objectives: This retrospective cohort of patients undergoing surgery from 2019 to 2023 evaluated the association between individual-level social drivers of health (SDoH) and postoperative outcomes (length of stay, 30-day mortality, 30-day readmission).

Methods: Patients from a multi-site health system who completed a SDoH questionnaire were categorized as high-risk or not high-risk across five SDoH domains (e.g., financial resources) and were stratified into 3 surgical cohorts (elective outpatient, inpatient and emergency surgery). Regression models, adjusted for potential confounders, assessed the association between SDoH and postoperative outcomes.

Results: Among 297,723 patients, 74% completed the SDoH questionnaire. High-risk transportation need was associated with higher unplanned 30-day readmission for all cohorts; for elective surgeries, high-risk transportation was also associated with higher mortality. The other SDoH domains were inconsistently associated with postoperative outcomes.

Conclusions: Individual-level SDoH, particularly transportation needs and financial strain, are linked to adverse postoperative surgical outcomes. Systematic SDoH interventions are crucial to addressing healthcare disparities.

1. Introduction

Social drivers (or determinants) of health (SDoH) are non-medical factors, including socioeconomic status (SES), education, employment, housing, and access to healthcare services, that influence an individual's health status and outcomes.¹ The World Health Organization defines SDoH as *conditions in which people are born, grow, work, live, and age, and the wider set of forces and systems shaping the conditions of daily life*.¹ SDoH likely influences every aspect of clinical care and contributes to perioperative morbidity and mortality.^{2–4} Related are health-related social needs (HRSNs), which are social and economic factors that impact individuals' ability to maintain their health and wellbeing.^{5–7} SDoH and HRSNs are distinct, as SDoH represent the “upstream” population-level conditions that influence health outcomes, whereas HRSNs are the

“downstream” individual needs created by those conditions.⁷ Although SDoH screening is the prevailing terminology in the clinical setting (often implemented through structured questionnaires), the information gathered reflects patients' individual HRSNs rather than broader SDoH.⁷ For the purposes of this study, we will use the term SDoH, with the understanding that questionnaires in the clinical setting are targeted towards HRSNs.

Several recent studies have demonstrated a clear association between HRSNs and adverse surgical outcomes, including higher rates of postoperative complications, readmission, and mortality.^{2,3} Lack of insurance coverage⁴ and socio-geographic considerations, such as the distance between patients and surgical centers, have both been critical for perioperative outcomes.^{8,9} Research shows that patients residing in areas with limited healthcare resources, such as rural or low-income communities, had higher rates of surgical complications and longer

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Glossary

ADI	Area deprivation index
CI	Confidence Interval
EHR	Electronic health record
HR	Hazard Ratio
HRSNs	Health-related social needs
ICU	Intensive care unit
LOS	Length of stay
RR	Relative risk
SDoH	Social Drivers of Health
SES	Socioeconomic status
STROBE	Strengthening Reporting of Observational Studies in Epidemiology
SVI	Social vulnerability index

hospital length of stay (LOS) compared to those in more accessible regions.^{8,9} Similarly, individuals facing housing instability or residing in neighborhoods with higher crime rates (additional SDoH domains) had increased postoperative complications and longer recovery periods.¹⁰ Additional domains of SDoH that have been associated with improved outcomes include social support, quality education, and health literacy.^{11,12} Health and longevity increase with higher levels of educational attainment, and those with low health literacy scores have an increased LOS after abdominal surgery.¹³

The current published research on SDoH needs and perioperative outcomes has focused largely on community-level characteristics, such as the area deprivation index (ADI) and the social vulnerability index (SVI). While community-level characteristics often overlap with SDoH, individual-level SDoH, more specifically, HRSNs may be more significant given their proximity to patients and easier to address as community-level changes generally require policy changes and significant financial investment. Accordingly, this retrospective study examined which individual-level SDoH domains are most associated with adverse perioperative outcomes. Although SDoH often interact and influence each other, by identifying the domains or barriers with the most substantial impact on perioperative outcomes, healthcare providers and policymakers can implement targeted interventions to improve patient outcomes and reduce healthcare disparities.

2. Material and methods

2.1. Overview

This is a retrospective cohort study of patients who completed an institutionally developed and administered SDoH questionnaire and underwent surgery from 2019 to 2023 at four hospital campuses from one large health system. The Mayo Clinic Institutional Review Board (IRB) approved this retrospective study (Mayo Clinic IRB Number 23-005322), and all patients included provided permission to use their medical records for research. Patients were included if they underwent a surgical procedure with general anesthesia. Patients who did not give permission to use their medical records were excluded. This manuscript adheres to the guidelines set forth by the Strengthening Reporting of Observational Studies in Epidemiology (STROBE) protocol. This study was done in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

2.2. Outcomes

The study's primary endpoint was postoperative hospital LOS. The secondary measure was intensive care unit (ICU) LOS, and exploratory measures included 30-day mortality and readmission.

2.3. Predictors

Baseline demographics, comorbidities, intraoperative and postoperative outcome variables were captured. The SDoH Questionnaire was routinely administered once per year to patients seeking care at the Mayo Clinic. Clinically validated assessments for SDoH needs that were available through the electronic health record (EHR) were integrated into the institution's EHR (Supplementary Table 1). This questionnaire allowed screening for individual-level SDoH factors (i.e., HRSNs) using validated questionnaire and scoring processes. The questionnaire was completed either online or via tablet during their in-person visit. The domains assessed by the questionnaire are financial resources, food security, housing stability, interpersonal violence, and transportation needs. For each domain, patients were stratified as either "Not High Risk" or "High Risk" based on self-reporting on the questionnaire.

2.4. Covariates

The following covariates were included: age, race, ethnicity, gender, primary language (English vs other), insurance type (Medicaid, Medicare, or other), Charlson comorbidity index, minimally invasive laparoscopic or robotic procedures, American Society of Anesthesiologists physical status classification, length of the procedure, year of the procedure, and hospital site location.

2.5. Statistical analysis

We stratified analyses by urgency (i.e., emergency, elective) and by inpatient versus outpatient, given potential differences in outcomes between these surgical cohorts. Patient characteristics were summarized for each of the three surgical cohorts among those who did and did not complete SDoH questionnaires, and differences assessed with t-tests for numeric variables, and chi-square tests for categorical variables. Among those who completed SDOH questionnaires, each domain was categorized as high-risk or not high-risk. For the financial resources, food security, and housing stability domains, patients were categorized as high risk if given a score of "high." High risk for the interpersonal violence domain was determined if any of the questions in that domain were answered "yes." Transportation needs were considered high risk if unmet needs were indicated. Patients did not always complete all domains of the SDoH questionnaire, thus sample sizes within each domain differed. If the domain was administered, but not completed, then the patient was given a value of unknown, and included in the not high-risk group.

Differences in postoperative outcomes between high-risk and not high-risk groups were assessed with regression models. Postoperative LOS (in days) and postoperative ICU LOS (in hours) were assessed with negative binomial models; 30-day readmission was assessed with Zhu's modified Poisson regression; and 30-day mortality was assessed with Cox proportional hazards models. All models were adjusted for the covariates described above. Separate models were created for each SDoH domain and within each cohort. For categorical covariates with missing values, an "unknown" category was included in the model. No missing values were observed for numeric covariates. Sensitivity analyses included a subset of patients who had non-government insurance, and a subset of patients who were less than 65 years old. P-values less than 0.05 were considered statistically significant, and there were no adjustments to the p-values. All analyses were conducted using R version 4.2.2.

3. Results

3.1. Descriptive statistics

During the study period, 1,371,646 surgical cases were performed. Exclusions included a lack of 1) research participation authorization

(n = 74,478), 2) SDoH questionnaire completion (n = 545,973), and operations performed after 5/24/2023 (n = 28,992). The overall study sample included 188,593 elective outpatient surgery, 68,058 elective inpatient, and 41,072 emergency surgery patients (total n = 297,723). The SDoH questionnaire was completed by 78%, 82%, and 40% of the elective outpatient, elective inpatient, and emergency surgery cohorts, respectively.

The sample was 91.3% White, 3.5% Black, 2.1% Asian, 1.8% other,

and 1.3% unidentified; ethnicity was assessed separately, with 93.2% non-Hispanic, 4.8% Hispanic, and 1.9% unidentified. Most patients had commercial insurance or were self-pay (n = 159,308; 72.4%), while 26.4% had Medicare, and 1.2% had Medicaid. Comparison of characteristics between those who did and did not complete the SDoH questionnaire and additional descriptive results for other demographic and clinical characteristics are displayed in Table 1.

Most patients were classified as *not high-risk* in each SDoH domain,

Table 1
Comparison of characteristics between those who did and did not complete SDOH.

	Elective Outpatient			Elective Inpatient			Emergent		
	(+) SDoH (n = 147307)	(-) SDoH (n = 41286)	p value	(+) SDoH (n = 56047)	(-) SDoH (n = 12011)	p value	(+) SDoH (n = 16636)	(-) SDoH (n = 24436)	p value
Age, median (IQR)	60.0 (46.0, 69.0)	59.0 (43.0, 70.0)	<0.001	63.0 (51.0, 71.0)	64.0 (51.0, 74.0)	<0.001	63.0 (49.0, 73.0)	62.0 (44.0, 75.0)	<0.001
Race									
White	134558 (91.3%)	36095 (87.4%)	<0.001	51360 (91.6%)	10552 (87.9%)	<0.001	15002 (90.2%)	20871 (85.4%)	<0.001
Black	4999 (3.4%)	2092 (5.1%)		1856 (3.3%)	560 (4.7%)		724 (4.4%)	1268 (5.2%)	
Asian	3165 (2.1%)	922 (2.2%)		1096 (2.0%)	245 (2.0%)		384 (2.3%)	651 (2.7%)	
Pacific Islander	182 (0.1%)	63 (0.2%)		77 (0.1%)	31 (0.3%)		37 (0.2%)	56 (0.2%)	
Native Am	824 (0.6%)	297 (0.7%)		402 (0.7%)	133 (1.1%)		156 (0.9%)	435 (1.8%)	
Other	1497 (1.0%)	785 (1.9%)		654 (1.2%)	266 (2.2%)		215 (1.3%)	561 (2.3%)	
Unknown	2082 (1.4%)	1032 (2.5%)		602 (1.1%)	224 (1.9%)		118 (0.7%)	594 (2.4%)	
Ethnicity									
Hispanic	7119 (4.8%)	2416 (5.9%)	<0.001	2483 (4.4%)	646 (5.4%)	<0.001	1010 (6.1%)	1718 (7.0%)	<0.001
Non-Hispanic	137222 (93.2%)	37565 (91.0%)		52474 (93.6%)	11052 (92.0%)		15426 (92.7%)	21905 (89.6%)	
Unknown	2966 (2.0%)	1305 (3.2%)		1090 (1.9%)	313 (2.6%)		200 (1.2%)	813 (3.3%)	
Gender									
Female	80374 (54.6%)	20579 (49.8%)	<0.001	27813 (49.6%)	5885 (49.0%)	0.084	8218 (49.4%)	11261 (46.1%)	<0.001
Male	66912 (45.4%)	20700 (50.1%)		28232 (50.4%)	6125 (51.0%)		8418 (50.6%)	13174 (53.9%)	
Non-binary	6 (0.0%)	1 (0.0%)		2 (0.0%)	0 (0.0%)		0 (0.0%)	1 (0.0%)	
Unknown	15 (0.0%)	6 (0.0%)		0 (0.0%)	1 (0.0%)				
Language									
English	145611 (98.8%)	39807 (96.4%)	<0.001	55169 (98.4%)	11452 (95.3%)	<0.001	16289 (97.9%)	23112 (94.6%)	<0.001
Other	1693 (1.1%)	1476 (3.6%)		874 (1.6%)	559 (4.7%)		347 (2.1%)	1311 (5.4%)	
Unknown	3 (0.0%)	3 (0.0%)		4 (0.0%)	0 (0.0%)		0 (0.0%)	13 (0.1%)	
Region									
Arizona	34760 (23.6%)	7653 (18.5%)	<0.001	8923 (15.9%)	1438 (12.0%)	<0.001	4056 (24.4%)	5774 (23.6%)	<0.001
Florida	39418 (26.8%)	9630 (23.3%)		10965 (19.6%)	2004 (16.7%)		2856 (17.2%)	3800 (15.6%)	
MCHS NWWI	7716 (5.2%)	3606 (8.7%)		1873 (3.3%)	958 (8.0%)		1648 (9.9%)	2680 (11.0%)	
MCHS SEMN	2810 (1.9%)	2189 (5.3%)		146 (0.3%)	160 (1.3%)		278 (1.7%)	699 (2.9%)	
MCHS SWMN	5164 (3.5%)	3844 (9.3%)		832 (1.5%)	660 (5.5%)		568 (3.4%)	1625 (6.7%)	
MCHS SWWI	4314 (2.9%)	1784 (4.3%)		396 (0.7%)	173 (1.4%)		717 (4.3%)	882 (3.6%)	
Rochester	53125 (36.1%)	12580 (30.5%)		32912 (58.7%)	6618 (55.1%)		6513 (39.2%)	8976 (36.7%)	
Year									
2019	17056 (11.6%)	8034 (19.5%)	<0.001	8980 (16.0%)	2671 (22.2%)	<0.001	1805 (10.8%)	4065 (16.6%)	<0.001
2020	29461 (20.0%)	10750 (26.0%)		12600 (22.5%)	3717 (30.9%)		3785 (22.8%)	5530 (22.6%)	
2021	39017 (26.5%)	9071 (22.0%)		13906 (24.8%)	2488 (20.7%)		4243 (25.5%)	5954 (24.4%)	
2022	42876 (29.1%)	9235 (22.4%)		14319 (25.5%)	2209 (18.4%)		4613 (27.7%)	6217 (25.4%)	
2023	18897 (12.8%)	4196 (10.2%)		6242 (11.1%)	926 (7.7%)		2190 (13.2%)	2670 (10.9%)	
BMI	29.1 (25.2, 34.0)	28.8 (24.9, 33.7)	<0.001	29.2 (25.3, 34.1)	28.9 (25.1, 33.6)	<0.001	29.2 (24.9, 34.6)	28.3 (24.3, 33.5)	<0.001
Insurance									
Medicaid	1677 (1.1%)	824 (2.0%)	<0.001	613 (1.1%)	218 (1.8%)	<0.001	389 (2.3%)	1024 (4.2%)	<0.001
Medicare	34353 (23.3%)	6413 (15.5%)		18438 (32.9%)	2639 (22.0%)		5212 (31.3%)	5018 (20.5%)	
Other	111277 (75.5%)	34049 (82.5%)		36996 (66.0%)	9154 (76.2%)		11035 (66.3%)	18394 (75.3%)	
Current Smoker	45229 (30.7%)	12535 (30.4%)	0.182	19940 (35.6%)	4152 (34.6%)	0.036	6033 (36.3%)	8002 (32.7%)	<0.001
Charlson Score	3.0 (2.0, 5.0)	3.0 (1.0, 5.0)	<0.001	4.0 (2.0, 6.0)	4.0 (2.0, 6.0)	0.017	5.0 (3.0, 8.0)	3.0 (1.0, 5.0)	<0.001
OR ASA Physical Status Classification									
I	12778 (8.7%)	5501 (13.3%)	<0.001	1632 (2.9%)	643 (5.4%)	<0.001	420 (2.5%)	1914 (7.8%)	<0.001
II	75898 (51.5%)	19723 (47.8%)		19124 (34.1%)	3908 (32.5%)		3495 (21.0%)	6439 (26.4%)	
III	56615 (38.4%)	15290 (37.0%)		29492 (52.6%)	5927 (49.3%)		8951 (53.8%)	11275 (46.1%)	
IV	2008 (1.4%)	765 (1.9%)		5766 (10.3%)	1508 (12.6%)		3603 (21.7%)	4380 (17.9%)	
V	0 (0.0%)	3 (0.0%)		32 (0.1%)	24 (0.2%)		159 (1.0%)	370 (1.5%)	
VI	0 (0.0%)	1 (0.0%)		0 (0.0%)	1 (0.0%)		6 (0.0%)	55 (0.2%)	
Not Assessed	8 (0.0%)	3 (0.0%)		1 (0.0%)	0 (0.0%)		2 (0.0%)	3 (0.0%)	
Hours in OR	1.9 (1.1, 2.9)	1.6 (1.0, 2.5)	<0.001	4.5 (3.1, 6.2)	4.0 (2.8, 5.7)	<0.001	2.2 (1.3, 3.7)	1.9 (1.1, 3.0)	<0.001
Laparoscopic or Robotic	21858 (14.8%)	5464 (13.2%)	<0.001	12978 (23.2%)	2484 (20.7%)	<0.001	2892 (17.4%)	4554 (18.6%)	0.001
EBL	16.0 (5.0, 50.0)	10.0 (5.0, 40.0)	<0.001	100.0 (50.0, 350.0)	100.0 (35.0, 300.0)	0.131	50.0 (10.0, 200.0)	30.0 (10.0, 150.0)	<0.001

SDoH = Social determinant of health, IQR = Interquartile range, MCHS = Mayo Clinic Health System, NWWI = Northwest Wisconsin, SEMN = Southeast Minnesota, SWMN = Southwest Minnesota, SWWI = Southwest Wisconsin, BMI = body mass index, OR = operating room, EBL = estimated blood loss.

with 7.4%, 5.4%, 3.4%, 2.5%, and 2.3% in the housing stability, food security, financial resources, interpersonal violence, and transportation need domains identifying as *high-risk*, respectively. Itemized response rates by surgery classification cohorts are displayed in [Table 2](#). Patients undergoing emergency surgery were more likely to report high social risks compared to those undergoing elective procedures, including high-risk in financial resources (5.2%), food security (8.3%), housing (8.9%), interpersonal violence (2.6%), and transportation (4.2%) domains. Across all domains, the emergency surgery cohort also had higher proportions of unknown responses, suggesting lower rates of SDoH screening completion. The most common elective inpatient surgery types were neurological (21.6%), orthopedic (14.1%), and cardiovascular (10.1%). The most common emergent surgery types were general surgery (18.9%), transplant (13.2%), and gastroenterology (13.3%). The most common outpatient surgery types were orthopedic (17.3%), gastroenterology (15.1%), and urology (13.8%; [Supplementary Table 2](#)).

3.2. Regression models

3.2.1. Elective outpatient surgery cohort

In the elective outpatient surgery cohort, patients that identified as high-risk for financial resources or transportation need domains had a higher risk of 30-day readmission (Relative Risk [RR] = 1.23, 95% Confidence Interval [CI]: 1.06-1.43; RR = 1.35, 95% CI: 1.14-1.59, respectively). Housing stability, food security, and interpersonal violence domains were not independently associated with readmission risk ([Table 3](#)). High-risk transportation needs had significantly increased

Table 2

SDoH domain scores across surgery classification cohorts.

	Elective Inpatient (n = 56047)	Elective Outpatient (n = 147307)	Emergent (n = 16636)
SDoH Financial Resources Score			
N	55081	144721	16312
Low (Green)	45294 (82.2)	121183 (83.7)	12617 (77.3)
Medium (Yellow)	5412 (9.8)	12284 (8.5)	1982 (12.2)
High (Red)	2049 (3.7)	4435 (3.1)	841 (5.2)
Unknown (Grey)	2326 (4.2)	6819 (4.7)	872 (5.3)
SDoH Food Security Score			
N	55280	145120	16351
Low (Green)	51031 (92.3)	134251 (92.5)	14555 (89.0)
High (Red)	3040 (5.5)	7404 (5.1)	1356 (8.3)
Unknown (Grey)	1209 (2.2)	3465 (2.4)	440 (2.7)
SDoH Housing Stability Score			
N	29752	86635	8893
Low (Green)	27185 (91.4)	78618 (90.7)	7915 (89.0)
High (Red)	2134 (7.2)	6346 (7.3)	789 (8.9)
Unknown (Grey)	433 (1.5)	1671 (1.9)	189 (2.1)
SDoH Interpersonal Violence Score			
N	25009	82318	9410
No to all questions (Green)	22842 (91.3)	74558 (90.6)	8272 (87.9)
Yes to any questions (Red)	563 (2.3)	2115 (2.6)	241 (2.6)
Unknown (Grey)	1604 (6.4)	5645 (6.9)	897 (9.5)
SDoH Transportation Needs Score			
N	55731	146419	16450
No Needs (Green)	51367 (92.2)	136087 (92.9)	14464 (87.9)
Unmet Needs (Red)	1371 (2.5)	2942 (2.0)	699 (4.2)
Unknown (Grey)	2993 (5.4)	7390 (5.0)	1287 (7.8)

SDoH = social determinants (or drivers) of health.

odds of 30-day mortality (Hazard Ratio [HR] = 2.35, 95% CI: 1.39-3.97).

3.2.2. Elective inpatient surgery cohort

In the elective inpatient surgery cohort, high-risk for financial resources, food security, housing stability, and transportation need were associated with longer hospital LOS (RR = 1.12, 95% CI: 1.08-1.16; RR = 1.10, 95% CI: 1.07-1.13; RR = 1.11, 95% CI: 1.07-1.15; and RR = 1.18, 95% CI: 1.09-1.17 respectively). High-risk for financial resources, food insecurity, and housing stability domains were associated with longer ICU LOS (RR = 1.10, 95% CI: 1.03-1.19; RR = 1.16, 95% CI: 1.09-1.23; and RR = 1.17, 95% CI: 1.08-1.26 respectively). High-risk for financial resources, food security, housing stability, and transportation need domains also had an increased risk of 30-day readmission (RR = 1.39, 95% CI: 1.08-1.16; RR = 1.27, 95% CI: 1.14-1.42; RR = 1.19, 95% CI: 1.03-1.38; and RR = 1.51, 95% CI: 1.31-1.73, respectively). Like the elective outpatient group, only high-risk status in the transportation needs domain was associated with increased risk of 30-day mortality (RR = 1.75, 95% CI: 1.02-3.01) ([Table 4](#)).

3.2.3. Emergency surgery cohort

In the emergency surgery cohort, patients who were high-risk for financial resources, food security, housing stability, and transportation need domains had longer hospital LOS (RR = 1.18, 95% CI: 1.10-1.27; RR = 1.09, 95% CI: 1.03-1.16; RR = 1.15, 95% CI: 1.07-1.25; and RR = 1.27, 95% CI: 1.18-1.37, respectively). No SDoH domains were associated with ICU LOS ([Table 5](#)). Only high-risk transportation needs had increased 30-day readmission risk (RR = 1.36, 95% CI: 1.19-1.55). High-risk in these SDoH domains was not associated with 30-day mortality for emergency surgery patients ([Table 5](#)).

3.3. Sensitivity analyses

3.3.1. Patients without medicare or medicaid

Among elective outpatient surgery patients without Medicare or Medicaid, high-risk for financial resources and transportation need were significantly associated with increased 30-day readmission risk. Food security, housing stability, and transportation needs were associated with 30-day mortality (see [Supplemental eTables 1a-c](#)). Among elective inpatient surgery patients, all domains except interpersonal violence were associated with prolonged hospital LOS, while the financial resources, food security, and housing stability domains were associated with prolonged ICU LOS. High-risk financial resources, food security, and transportation need domains were significantly associated with increased readmission risk. No domain was associated with 30-day mortality (see supplemental data). In the emergency surgery cohort, each domain besides interpersonal violence prolonged hospital LOS, while the housing stability and interpersonal violence domains were associated with prolonged ICU LOS. Only high-risk transportation needs domain was significantly increased 30-day readmission risk. No SDoH domains were associated with 30-day mortality (see supplemental data).

3.4. Sensitivity analyses

3.4.1. Age under 65-years of age

Among the elective outpatient surgery cohort under age 65 years of age, high-risk for financial resources and transportation needs were associated with increased 30-day readmission. High-risk for food security and transportation need increased the risk of 30-day mortality. Among elective inpatient surgery patients, all domains except interpersonal violence were associated with prolonged hospital LOS, while financial resources and food security domains were associated with prolonged ICU LOS. High-risk for financial resources, food security, and transportation need were associated with an increased risk for 30-day readmission. Only transportation needs increased mortality risk. In the emergency surgery cohort, all domains except interpersonal violence

Table 3
Outcomes in elective outpatient surgery cohort.

	Financial Resources		Food Security		Housing Stability		Interpersonal Violence		Transportation Needs		High risk in 2+ Domains	
	Not High-Risk n = 140286	High-Risk n = 4435	Not High-Risk n = 137716	High-Risk n = 7404	Not High-Risk n = 80289	High-Risk n = 6346	Not High-Risk n = 80203	High-Risk n = 2115	Not High-Risk n = 143477	High-Risk n = 2942	Not High-Risk n = 142370	High-Risk n = 4937
30-day Readmission												
N (%)	3895 (2.8)	182 (4.1)	3832 (2.8)	265 (3.6)	2211 (2.8)	202 (3.2)	2117 (2.6)	62 (2.9)	3991 (2.8)	137 (4.7)	3969 (2.8)	193 (3.9)
Adjusted RR [95% CI]	-	1.23 [1.06, 1.43]	-	1.14 [1.00, 1.29]	-	1.14 [0.99, 1.31]	-	1.16 [0.91, 1.49]	-	1.35 [1.14, 1.59]	-	1.23 [1.07, 1.42]
Adjusted p-value	-	0.005	-	0.045	-	0.071	-	0.228	-	<0.001	-	0.005
30-day Mortality												
30-day Survival Probability (95% CI)	0.998 (0.998, 0.999)	0.996 (0.994, 0.998)	0.998 (0.998, 0.998)	0.997 (0.996, 0.998)	0.998 (0.998, 0.999)	0.998 (0.997, 0.999)	0.999 (0.998, 0.999)	0.999 (0.998, 1.000)	0.998 (0.998, 0.998)	0.994 (0.991, 0.997)	0.998 (0.998, 0.998)	0.997 (0.995, 0.998)
Adjusted HR [95% CI]	-	1.61 [0.94, 2.75]	-	1.56 [0.98, 2.49]	-	1.31 [0.71, 2.40]	-	0.81 [0.20, 3.32]	-	2.35 [1.39, 3.97]	-	1.70 [0.99, 2.92]
Adjusted p-value	-	0.080	-	0.061	-	0.382	-	0.772	-	0.001	-	0.053

RR = relative risk, CI = confidence interval, HR = hazard ratio.

were similarly associated with prolonged hospital LOS, while housing stability and interpersonal violence domains were significantly associated with longer ICU LOS. Only transposition needs increased the risk of 30-day readmission (see Supplemental eTable 2a-c).

4. Discussion

This study sought to identify which SDoH domain was most associated with postoperative outcomes. In this large retrospective cohort analysis, we found that patients with transportation needs had the highest risk of 30-day readmission across all surgical cohorts. Other high-risk SDoH domains except interpersonal violence also had a greater likelihood of longer postoperative hospital LOS and 30-day hospital readmission compared to their not high-risk counterparts. These findings were similar across all demographics, including those without Medicare or Medicaid, and those under 65 years of age. The association between transportation insecurity, longer LOS, and higher readmission rates underscores the importance of addressing logistical barriers to healthcare access. Patients who experience transportation insecurity due to transportation challenges or longer travel times may delay seeking surgical treatment or preoperative consultations, leading to more advanced stages at presentation. Those presenting at more advanced stages likely require more extensive care and have a higher risk of readmission.¹⁴⁻¹⁶ Transportation barriers can also lead to fragmented care, where patients experience gaps in their treatment and are less likely to attend follow-up appointments, fill prescriptions or attend other prescribed interventions, missing opportunities for early detection of complications and resulting in readmission as well as poorer outcomes.^{17,18}

High-risk SDoH status was not associated with increased 30-day mortality following either elective or emergency surgery. This suggests that while SDoH needs may influence short-term recovery and readmission rates, the effect on early postoperative survival may be mitigated by the characteristics of the healthcare setting or other contextual factors. Tertiary hospitals provide specialized care, advanced diagnostics, and escalation of care and rescue that could attenuate the potential negative impact of social factors on surgical mortality¹⁹⁻²¹. It is also important to note that while individual-level SDoH certainly influence patient outcomes, the broader neighborhood-level SDoH may play a substantial role in long-term health outcomes (or serve as proxies for other factors).²² Neighborhood-level factors, captured by area deprivation index (ADI) or the social vulnerability index (SVI), may interact with individual-level factors in more complex ways that are not captured in our study's design.^{23,24} Studies have shown that the neighborhood context plays a critical role in shaping health outcomes, particularly for individuals in underserved communities.²⁵ For instance, neighborhoods with limited access to healthy food, safe environments, and healthcare facilities may perpetuate chronic health conditions, which can influence recovery trajectories and postoperative complications.²⁶ Therefore, addressing neighborhood-level SDoH is still crucial for reducing health inequities and improving long-term surgical outcomes.

Our findings are consistent with prior studies exploring the relationship between individual unmet social needs and higher readmission rates and greater postoperative morbidity.^{27,28} While the findings are consistent, there are important differences between the studies. The study by Taylor and colleagues²⁷ utilized data from a national database which improves generalizability of the study findings but lacks granularity in regards to patient comorbidities and differences in hospital practices; the study by Mohanty and colleagues²⁸ was single center, so it included some of the granularity lacking by Taylor and colleagues but was limited to spine surgery and focused mainly on income versus broader SDoH. Another study found that individual-level social risk factors, identified by the presence of Z codes, were more strongly associated with postoperative morbidity than neighborhood-level measures such as the SVI or ADI, indicating the importance of better

Table 4
Outcomes in elective inpatient surgery cohort.

	Financial Resources		Food Security		Housing Stability		Interpersonal Violence		Transportation Needs		High risk in 2+ Domains	
	Not High-Risk n = 53032	High-Risk n = 2049	Not High-Risk n = 52240	High-Risk n = 3040	Not High-Risk n = 27618	High-Risk n = 2134	Not High-Risk n = 24446	High-Risk n = 563	Not High-Risk n = 54360	High-Risk n = 1371	Not High-Risk n = 53982	High Risk n = 2065
Postoperative Length of Stay												
Median (Q1, Q3)	2.9 (1.4, 4.9)	3.0 (1.9, 5.7)	2.9 (1.3, 4.9)	3.0 (1.8, 5.1)	2.9 (1.7, 5.0)	3.0 (1.7, 5.0)	2.9 (1.6, 4.9)	2.9 (1.7, 4.9)	2.9 (1.3, 4.9)	3.0 (1.9, 5.9)	2.9 (1.4, 4.9)	3.0 (1.9, 5.3)
Adjusted RR [95% CI]	–	1.12 [1.08, 1.16]	–	1.10 [1.07, 1.13]	–	1.11 [1.07, 1.15]	–	1.05 [0.99, 1.12]	–	1.18 [1.13, 1.23]	–	1.13 [1.09, 1.17]
Adjusted p-value	–	<0.001	–	<0.001	–	<0.001	–	0.128	–	<0.001	–	<0.001
30-day Readmission												
N	4237 (8.0%)	239 (11.7%)	4166 (8.0%)	326 (10.7%)	2158 (7.8%)	194 (9.1%)	2028 (8.3%)	43 (7.6%)	4354 (8.0%)	175 (12.8%)	4336 (8.0%)	227 (11.0%)
Adjusted RR [95% CI]	–	1.39 [1.23, 1.57]	–	1.27 [1.14, 1.42]	–	1.19 [1.03, 1.38]	–	0.95 [0.71, 1.26]	–	1.51 [1.31, 1.73]	–	1.32 [1.16, 1.50]
Adjusted p-value	–	<0.001	–	<0.001	–	0.016	–	0.708	–	<0.001	–	<0.001
30-day Mortality												
30-day Survival Probability (95% CI)	0.993 (0.993,0.994)	0.992 (0.988,0.996)	0.993 (0.993,0.994)	0.995 (0.993,0.998)	0.994 (0.993,0.995)	0.994 (0.990,0.997)	0.994 (0.993,0.995)	1.000 (1.000,1.000)	0.994 (0.993,0.994)	0.989 (0.984,0.995)	0.993 (0.993,0.994)	0.993 (0.990,0.997)
Adjusted HR [95% CI]	–	1.61 [0.97, 2.67]	–	0.79 [0.45, 1.40]	–	1.54 [0.87, 2.74]	–	0.00 [0.00, Inf]	–	1.75 [1.02, 3.01]	–	1.33 [0.76, 2.35]
Adjusted p-value	–	0.068	–	0.425	–	0.138	–	0.995	–	0.041	–	0.318
Postoperative ICU Length of Stay												
N	11682	452	11502	662	6297	424	5243	103	11954	308	11903	436
Median (Q1, Q3)	26.2 (21.0, 50.2)	27.1 (21.2, 50.4)	26.2 (21.1, 50.0)	26.3 (20.9, 56.2)	27.2 (21.4, 51.9)	28.2 (22.1, 67.8)	28.0 (21.8, 53.1)	27.0 (21.2, 57.7)	26.2 (21.1, 50.2)	24.8 (20.7, 51.2)	26.2 (21.0, 50.1)	26.7 (21.3, 56.1)
Adjusted RR [95% CI]	–	1.10 [1.03, 1.19]	–	1.16 [1.09, 1.23]	–	1.17 [1.08, 1.26]	–	0.92 [0.80, 1.07]	–	1.01 [0.93, 1.11]	–	1.11 [1.03, 1.19]
Adjusted p-value	–	0.007	–	<0.001	–	<0.001	–	0.260	–	0.774	–	0.006

RR = relative risk, CI = confidence interval, HR = hazard ratio, ICU = intensive care unit.

Table 5
Outcomes in emergent surgery cohort.

	Financial Resources		Food Security		Housing Stability		Interpersonal Violence		Transportation Needs		High risk in 2+ Domains	
	Not High-Risk n = 15471	High-Risk n = 841	Not High-Risk n = 14995	High-Risk n = 1356	Not High-Risk n = 8104	High-Risk n = 789	Not High-Risk n = 9169	High-Risk n = 241	Not High-Risk n = 15751	High-Risk n = 699	Not High-Risk n = 15693	High-Risk n = 943
Postoperative Hospital Length of Stay												
Median (Q1, Q3)	3.0 (1.0, 6.1)	3.9 (1.2, 7.5)	3.0 (1.0, 6.1)	3.1 (1.1, 6.9)	3.0 (1.0, 6.1)	3.1 (1.0, 7.0)	2.7 (0.8, 5.9)	1.9 (0.5, 4.8)	3.0 (1.0, 6.1)	4.0 (1.3, 7.7)	3.0 (1.0, 6.1)	3.2 (1.1, 7.4)
Adjusted RR [95% CI]	–	1.18 [1.10, 1.27]	–	1.09 [1.03, 1.16]	–	1.15 [1.07, 1.25]	–	1.14 [0.99, 1.31]	–	1.27 [1.18, 1.37]	–	1.24 [1.16, 1.33]
Adjusted p-value	–	<0.001	–	0.003	–	<0.001	–	0.070	–	<0.001	–	<0.001
30-day Readmission												
N (%)	2617 (16.9%)	181 (21.5%)	2533 (16.9%)	271 (20.0%)	1306 (16.1%)	130 (16.5%)	1373 (15.0%)	33 (13.7%)	2633 (16.7%)	178 (25.5%)	2662 (17.0%)	191 (20.3%)
Adjusted RR [95% CI]	–	1.13 [0.99, 1.30]	–	1.09 [0.97, 1.22]	–	0.98 [0.83, 1.16]	–	0.97 [0.71, 1.33]	–	1.36 [1.19, 1.55]	–	1.11 [0.97, 1.26]
Adjusted p-value	–	0.065	–	0.159	–	0.857	–	0.844	–	<0.001	–	0.136
30-day Mortality												
Survival Prob. (95% CI)	0.944 (0.941,0.948)	0.950 (0.935,0.965)	0.943 (0.939,0.946)	0.964 (0.955,0.974)	0.948 (0.944,0.953)	0.969 (0.956,0.981)	0.952 (0.948,0.957)	0.975 (0.955,0.995)	0.944 (0.941,0.948)	0.950 (0.934,0.967)	0.943 (0.940,0.947)	0.961 (0.948,0.973)
Adjusted HR [95% CI]	–	0.90 [0.65, 1.23]	–	0.69 [0.51, 0.93]	–	0.71 [0.46, 1.08]	–	0.91 [0.40, 2.05]	–	0.75 [0.53, 1.07]	–	0.77 [0.55, 1.08]
Adjusted p-value	–	0.506	–	0.014	–	0.105	–	0.820	–	0.110	–	0.132
Postoperative ICU Length of Stay												
N	2761	163	2692	238	1430	114	1443	36	2835	113	2817	156
Median (Q1, Q3)	44.6 (23.3, 89.8)	43.5 (23.9, 87.6)	44.9 (23.4, 89.8)	41.2 (22.7, 90.3)	45.2 (23.7, 94.2)	40.8 (22.8, 88.3)	44.2 (23.4, 87.7)	46.2 (22.2, 94.9)	44.5 (23.3, 89.6)	57.9 (24.2, 103.6)	44.6 (23.4, 89.8)	47.3 (24.1, 94.6)
Adjusted RR [95% CI]	–	1.08 [0.93, 1.26]	–	1.06 [0.94, 1.21]	–	1.14 [0.95, 1.39]	–	1.37 [1.01, 1.92]	–	0.99 [0.83, 1.19]	–	1.17 [1.00, 1.37]
Adjusted p-value	–	0.340	–	0.350	–	0.161	–	0.053	–	0.878	–	0.056

RR = relative risk, CI = confidence interval, HR = hazard ratio.

understanding these individual factors in the context of surgical risk assessment.²⁹ While these studies were able to demonstrate an association between SDoH risk and outcomes, our study was novel in its approach; seeking to determine the *specific* individual-level SDoH domains that were associated with adverse perioperative outcomes. Understanding that transportation insecurity contributes to longer hospital LOS and higher readmission rates for surgical patients will allow healthcare systems and payers to develop interventions aimed at addressing transportation barriers for high-risk patients. This could include exploring the provision of transportation services and telehealth opportunities, as well as transitional care programs such as home visiting or hospital to home for high-risk surgical patients. This could also include exploring multi-level approach that considers both individual- and neighborhood-level SDoH in efforts to improve surgical outcomes.^{29,30} Future research should consider the interaction between these two levels of social determinants and examine their impact on longer-term health outcomes to inform systemic interventions targeting SDoH in postoperative mortality.

Our findings were discordant with one prior study that evaluated the relationship between HRSNs and hospital readmission rates that found patients with a greater number of high-risk domains were associated with higher odds of hospital readmission at 30 and 90 days, suggesting a dose-response relationship between HRSNs and hospital readmission rates.³¹ Our findings suggest that the relationship between SDoH and surgical outcomes may vary depending on the specific domain of SDoH and the classification of the surgical procedure. For example, transportation insecurity appeared to be a more consistent driver of readmissions across all surgical cohorts, whereas financial strain had a more variable impact. This indicates that the influence of SDoH on postoperative outcomes may not follow a simple linear, dose-response relationship, as has been previously suggested. Instead, our data points to the possibility of domain-specific and procedure-specific interactions, where certain social risks may disproportionately affect outcomes in specific surgical contexts (e.g., elective outpatient vs. emergent surgery). These nuanced relationships warrant further investigation in order to better tailor interventions and resource allocation. More specifically, with limited resources, investigations such as this can help determine which intervention(s) should be prioritized.

The results of this study provide valuable guidance for teams engaged in surgical patient care. Integrating SDoH screening into the preoperative workflow and referring patients at high risk to appropriate resources are critical steps that should be incorporated into the standard protocol for preoperative examinations. In situations where patients have not had access to preoperative planning, it is incumbent upon perioperative teams to identify individuals with SDoH-related needs and address those requirements. Beyond its ethical importance, this approach offers institutions opportunities to reduce healthcare costs and enhance quality of care. Given declining reimbursements nationwide, increased LOS and rising readmission rates may further decrease payments and adversely impact hospital operations. Because of the substantial impact of transportation insecurity on surgical outcomes, institutions should begin by implementing targeted interventions to address these challenges, such as offering rideshare services, providing taxi vouchers, or utilizing care coordinators to connect patients with covered transportation options. Nonetheless, due to the complexity and interrelated nature of SDoH, these basic interventions may be insufficient. For example, while some programs have investigated subsidizing travel assistance initiatives, including rideshare service, their outcomes have been variable.^{32–34} Transportation costs, especially in rural or underserved areas, create significant economic barriers. The financial burden of accessing surgical care extends beyond travel expenses including indirect costs, such as lost income, lodging, childcare, and food may deter patients from seeking timely surgery or essential recovery care.^{35,36} More effective solutions should integrate transportation support with broader interventions aimed at reducing economic barriers to health and/or leverage technology to improve

patient access and monitoring. The financial implications of surgery are multifaceted, and our current survey may not fully capture these broader, hidden patient burdens.

While other studies have shown that individual-level social risk factors are more strongly associated with postoperative outcomes, the strength of our study is in demonstrating which specific individual-level SDoH domains are associated with adverse perioperative outcomes in patients having either elective or emergent surgical procedures. Despite the strength of the retrospective cohort study and our finding of a significant association between transportation insecurity and surgical outcomes, our study is not without limitations. This is a retrospective cohort study of patients from a single healthcare system with inherent biases, for which validity of our study findings is highly dependent on the completeness and accuracy of the data captured within our electronic health records. The SDoH questionnaire completion also varied across the surgical cohorts analyzed, with the lowest completion rate in the emergency surgery cohort. While the lower completion rate in the cohort is understandable, as it may not be feasible for surgical patients who are admitted acutely ill, it may also limit the strength of association noted between individual SDoH domains and surgical outcomes as the analyzed sample may not be representative of the broader population (i.e., there may be a selection bias). Using family members, friends, or relying on neighborhood-level information may be feasible for patients undergoing emergency surgery. Additionally, patients did not always complete all domains of the SDoH questionnaire; thus, sample sizes within each domain differed. If the domain was administered, but not completed, then the patient was given a value of unknown, and included in the not high-risk group which may have resulted in classification errors and overestimation or underestimation of those assigned as high-risk. This highlights the concept of health data disparities, the systematic missingness of data, usually for higher-risk individuals, which limits interventions and strategies to mitigate disparities.³⁷ Additionally, the patient population may not be generalizable to other surgical populations, given the limited variability by sociodemographic characteristics, the population being drawn from a single healthcare system, and the inclusion of patients that completed the SDoH questionnaire. Lastly, SDoH domains may interact in a complex and interconnected way, where a patient who is high-risk in one SDoH domain may have a downstream impact on risk in other domains. For instance, patients who are high-risk for the financial resources' domain have limited resources that may subsequently impact food and transportation access, housing conditions, and educational opportunities, ultimately leading to high-risk status for the food security, housing stability, and transportation need domains (i.e., marginal inequities³⁸) assessed in our study. The inability to assess the potential interaction between SDoH domains remains a limitation of our study.

5. Conclusion

In this large retrospective cohort study, we found that individual-level social drivers of health, particularly transportation needs and financial strain, are linked to adverse postoperative surgical outcomes. Systematic assessment of and intervention on social drivers of health is crucial in the continued efforts to improve the quality of surgical care we provide across different patient cohorts and addressing persistent healthcare disparities.

CRedit authorship contribution statement

Michael A. Edwards: Writing – review & editing, Writing – original draft, Methodology. **Skye Buckner Petty:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation. **Kashmira Chawla:** Writing – original draft, Investigation. **Sreya Pattipati:** Writing – original draft, Methodology. **Ryan May:** Writing – original draft, Methodology. **Erin Westfall:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Mohanad R. Youssef:** Writing –

original draft, Methodology, Investigation, Data curation. **Nathan L. Delafield:** Writing – review & editing, Writing – original draft. **Jaxon K. Quillen:** Writing – original draft, Formal analysis, Data curation. **Adam J. Milam:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Funding acquisition, Data curation, Conceptualization.

Disclosure

Michael A. Edwards, Skye Buckner Petty, Kashmira Chawla, Sreya Pattipati, Ryan May, Erin Westfall, Mohanad R. Youssef, Nathan Delafield, Jaxon K. Quillen, and Adam J. Milam have no conflicts of interests or relevant financial disclosures.

Prior presentation

Abstracts based on this work will be presented at the ACS QS Conference in San Diego, on July 19, 2025.

Data sharing statement

This study is a retrospective analysis of hospital-based data for surgical patients who approved the use of their data for research; data will not be available to access given the protected health information.

Ethics

The Mayo Clinic Institutional Review Board approved this retrospective study (Mayo Clinic IRB Number 23-005322), and all patients included provided permission to use their medical records for research. Patients who did not give permission to use their medical records were excluded. This manuscript adheres to the guidelines set forth by the Strengthening Reporting of Observational Studies in Epidemiology (STROBE) protocol. This study was done in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

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Appendix. ASupplementary data

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