

Independent Associations of Neighborhood Deprivation and Patient-Level Social Determinants of Health With Textbook Outcomes After Inpatient Surgery

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Objective: Assess associations of social determinants of health (SDoH) using area deprivation index (ADI), race/ethnicity and insurance type with textbook outcomes (TO).

Background: Individual- and contextual-level SDoH affect health outcomes, but only one SDoH level is usually included.

Methods: Three healthcare system cohort study using National Surgical Quality Improvement Program (2013–2019) linked with ADI risk-adjusted for frailty, case status, and operative stress examining TO/TO components (unplanned reoperations, complications, mortality, emergency department/observation stays, and readmissions).

Results: Cohort (34,251 cases) mean age 58.3 [SD = 16.0], 54.8% females, 14.1% Hispanics, 11.6% Non-Hispanic Blacks, 21.6% with ADI >85, and 81.8% TO. Racial and ethnic minorities, non-private insurance, and ADI >85 patients had increased odds of urgent/emergent surgeries (adjusted odds ratios [aORs] range: 1.17–2.83, all $P < 0.001$). Non-Hispanic Black patients, ADI >85 and non-Private insurances had lower TO odds (aORs range: 0.55–0.93, all $P < 0.04$), but ADI >85 lost significance after including case status. Urgent/emergent versus elective had lower TO odds (aOR = 0.51, $P < 0.001$). ADI >85 patients had higher complication and mortality odds. Estimated reduction in TO probability was 9.9% (95% confidence interval [CI] = 7.2%–12.6%) for urgent/emergent cases, 7.0% (95% CI = 4.6%–9.3%) for Medicaid, and 1.6% (95% CI = 0.2%–3.0%) for non-Hispanic Black patients. TO probability difference for lowest-risk (White-Private-ADI <85–elective) to highest-risk (Black-Medicaid-ADI >85–urgent/emergent) was 29.8% for very frail patients.

Conclusion: Multilevel SDoH had independent effects on TO, predominately affecting outcomes through increased rates/odds of urgent/emergent surgeries driving complications and worse outcomes. Lowest-risk versus highest-risk scenarios demonstrated the magnitude of intersecting SDoH variables. Combination of insurance type and ADI should be used to identify high-risk patients to redesign care pathways to improve outcomes. Risk adjustment including contextual neighborhood deprivation and patient-level SDoH could reduce unintended consequences of value-based programs.

Keywords: social risk factors, surgical outcomes, vulnerable populations, safety-net hospitals

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The dataset for this article contains data from the (1) American College of Surgeons National Surgical Quality Improvement Program and (2) electronic health records from multiple institutions cannot be shared without authorization from the American College of Surgeons and the University of Texas Health San Antonio, University Health, University of Pittsburgh Medical Center and University of North Carolina.

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INTRODUCTION

Social determinants of health (SDoH) are the conditions of places in which people live, work, and play.¹ SDoH are a multilevel construct, comprised of both individual- and contextual-level factors as highlighted in the newly released Centers for Medicare and Medicaid Services Framework for Health Equity.¹ Both individual- and contextual-level SDoH contribute to inequitable social conditions,² which directly and indirectly affect health,³ life expectancy, and outcomes.^{4,5} Individual SDoH such as low income may result in poorer living conditions and fewer opportunities to prioritize health and access to health care. Contextual SDoH such as area deprivation may exacerbate or create challenges by limiting access to healthy food options, clean and safe living conditions or physical access to care.⁶ For surgical outcomes specifically, socially determined barriers or delays to care may result in patients preoperatively presenting with more acute conditions,^{7–9} requiring urgent or emergent surgeries,^{7–9} and postoperatively facing more difficulties paying for medications, caring for surgical wounds or obtaining time off from work for recovery. Furthermore, value-based medicine programs have disproportionately affected safety-net hospitals (SNH) serving populations with disadvantaged SDoH,^{10,11} unintentionally exacerbating health disparities. The Hospital Readmission Reduction Program and other pay for performance programs have penalized SNH for worse outcomes,^{10,12,13} further limiting resources to treat disadvantaged populations and potentially shifting resources from higher to lower safety-net burden hospitals.¹⁴

Many studies using large administrative databases classifying hospitals as high or low safety-net burden found that high-burden hospitals have higher complication rates.^{15–17} Administrative databases lack detailed data on patient risk factors and outcomes.^{18–20} Variations in assigning ICD-9/10 codes across institutions further adds to inaccuracies.¹⁹ Area deprivation scores are absent or included at the county or the ZIP code level, which is too large of an area to accurately assess patients at the neighborhood level. For surgical patients, cases are mostly classified as elective or emergent; however, urgent surgeries have worse outcomes than elective cases²¹ and are more prevalent in vulnerable populations.¹⁶ Finally, while administrative database studies are “generalizable,” comparisons between high-burden and low-burden healthcare systems cannot determine whether differences are due to patient risk factors or quality of care leading to speculation that these studies measured differences in patient populations rather than quality of care.⁷

While individual- and contextual-level SDoH affect health outcomes,^{3,22,23} risk adjustment is challenging as few of these factors are collected in Electronic Health Records (EHR).²⁴ Contextual-level SDoH measures include area-level socioeconomic status (SES) variables (eg, median income; percent poverty) or indices such as the area deprivation index (ADI),²⁵ social vulnerability index,²⁶ or the distressed community index.²⁷ Indices using patient ZIP codes or counties showed mixed effects on outcomes^{23,26,28–30} likely due to the lack of granularity.^{22,31} To address these limitations, the National Academy of Medicine suggested using the more granular “Block Group”-level ADI⁴ and Centers for Medicare & Medicaid Services (CMS) are considering adding ADI to risk adjustment.² High

ADI scores signify higher neighborhood deprivation and were associated with increased readmissions for colorectal surgeries.²² Similarly, low ADI for Medicare beneficiaries was associated with improved postoperative outcomes; however, patients identified as White compared to Black disproportionately benefited.³² Other studies found disparities in diagnosis, treatment, and survival for patients with pancreatic cancer^{33,34} and breast cancer³⁵ which were associated with residential racial segregation which is a root cause of disadvantaged SDoH.³⁶ However, because the effect of individual- and contextual-level SDoH on outcomes may vary by outcome type, composite measures such as “Textbook Outcomes” (TO) often provide more comprehensive assessments of surgical outcomes than single variables.^{30,37,38}

We designed this study using high-quality, nurse-abstracted data enriched with EHR/billing data and linked with ADI to examine these associations in a cohort of patients from three academic healthcare systems. To our knowledge, no publications have examined the associations between postoperative TO, block group ADI and patient-level social risk factors (eg, insurance type, race/ethnicity as a social construct³⁹). We hypothesize that ADI, insurance type, and race/ethnicity have independent effects on TO. This study is especially timely as attention to SDoH has increased over the past decade,²⁴ including the introduction of legislature to address health disparities through SDoH.⁴⁰

MATERIALS AND METHODS

Study Population and Data

This study included patients undergoing inpatient procedures in the 2013–2019 American College of Surgeons National Surgical Quality Improvement Program (NSQIP), from three academic healthcare systems following STROBE Reporting Guidelines. NSQIP variables were used for retrospective cohort identification, as well as providing standardized definitions of preoperative risk factors and complications.⁴¹ Working within each site, locally identified NSQIP data were merged with multiple data sources including EHR and the ADI²⁵ at each site. Patient self-reported race and ethnicity were derived from NSQIP variables and EHR. After finalizing the data linkage, local data were deidentified before merging the combined data for analyses. The Institutional Review Boards of the University of Pittsburgh Healthcare System (UPMC) and University of North Carolina agreed to rely on the University of Texas Health San Antonio Institutional Review Board, which approved this study with a waiver of informed consent.

Area Deprivation Index

Area deprivation index (ADI) is a composite measure of 17 education, employment, housing-quality, and poverty measures from the American Community Survey at the block group-level. ADI identifies patients living in disadvantaged neighborhoods,^{25,42} ranking block groups from 1 to 100, with higher values indicating higher levels of socioeconomic deprivation.²⁵ Patients’ home addresses were geocoded to the block group-level using ArcGIS 10.7 desktop version to assign 2018 ADI scores. Post office box addresses were excluded. We defined “Highly deprived” neighborhoods as ADI >85 representing the top 15th percentile of deprivation. Sensitivity analyses examined ADI >75 as the highest-risk quartile of deprivation.

Estimating Patient Frailty/Premorbid Conditions

The risk analysis index (RAI) assesses frailty using variables available in NSQIP. It has been validated previously in multiple datasets^{43–45} and renders a score ranging from 0 to 81 categorized as robust (≤ 20), normal (21–29), frail (30–39), and very frail (≥ 40).⁴³ RAI is used as a single variable estimate of

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patient-level variability that overcomes barriers to model fit encountered by less parsimonious models.^{46–49}

Expanded Operative Stress Score Assignment and Case Status

The operative stress score (OSS) estimates surgical-induced physiologic stress of procedures across surgical specialties based on CPT codes by assigning a score ranging from 1 to 5, with 1 and 5 representing very low and very high physiological stress, respectively. Similar to the RAI, the OSS is a single variable estimate of procedure-level variability, overcoming barriers to model fit encountered with less parsimonious models. We used the expanded OSS⁴⁸ with 2343 CPT codes, providing improved case coverage for nonmajority male populations compared to the original OSS.⁴⁷ We used the 5 levels of the expanded OSS rather than individual CPT codes to alleviate problems with model convergence encountered when a diversity of less common procedures are included to better represent the range of surgeries performed at hospitals. After excluding cases without an expanded OSS assigned to the principal CPT code, OSS was assigned using the highest score for all available procedures within each case.⁴⁸

Case status was determined from NSQIP variables with urgent cases being defined as “no” responses to elective and emergency variables.²¹ Given their unplanned status, urgent and emergent surgeries were combined and compared to elective cases.

Unplanned Reoperations, Clavien-Dindo IV, and Mortality 30-day Complications

We used the NSQIP REOPERATION variable to define unplanned reoperations. Clavien-Dindo classifies complications based on their treatments⁵⁰; Level IV complications were approximated using the NSQIP variables of postoperative septic shock, postoperative dialysis, pulmonary embolus, myocardial infarction, cardiac arrest, prolonged ventilation, reintubation, or stroke, as previously reported.^{48,51} Mortality occurring within 30 days from the date of surgery was determined using NSQIP variables and EHR augmented by state mortality and Social Security Death Master File data.

30-Day Emergency Department Visits/Observation Stays and Readmissions

NSQIP only tracks patients for 30 days after surgery and contains 30-day readmission variables from the date of surgery. We merged NSQIP data with EHR to determine readmissions and emergency department visits/observation stays (EDOS) within 30 days of discharge from the index procedure’s hospitalization, to be consistent with Medicare’s Hospital Readmission Reduction Program definition of 30-day readmissions.

TO Composite Variable

TO is a composite variable, increasingly used as a quality metric, which uses various definitions to define optimal postoperative outcomes as the absence of undesirable outcomes such as complications. Lower odds of TO are associated with worse outcomes while higher odds of TO are associated with better outcomes.^{52,53} Multiple TO definitions have been used in surgical oncology.^{30,37,38} We defined TO as surgeries not having any of the following undesirable events: (1) unplanned reoperations, (2) Clavien-Dindo IV (CDIV), (3) mortality, (4) EDOS, and (5) readmissions. Complications (reoperations, CDIV, and mortality) were tracked for 30 days after the date of surgery, while EDOS and readmissions were tracked for 30 days after the date of hospital discharge.

Insurance Type

Identified, local NSQIP data were merged with local EHR and managerial accounting data to determine insurance type. Insurance type was categorized by encounter billing data supplemented with EHR data and defined as (1) Private including Tricare and Workers’ Compensation, (2) Medicare, (3) Medicaid, and (4) Uninsured including self-pay and county indigent care programs. “Other” insurance type included encounters charged to the Department of Corrections, liability insurance, Veterans Affairs, unknown/missing and other state payor types; these cases were excluded.

Study Outcomes

Our primary outcome was the differential associations of race/ethnicity, ADI, and insurance type with TO for the index surgery adjusted for RAI, OSS, and case status with secondary analyses of the components of TO. Subanalyses assessed preoperative presentation acuity using urgent/emergent cases.

Management of Missing Variables

Cases were excluded due to missing (1) expanded OSS coverage of principal CPT code, (2) ADI assignment secondary to group quarters or low population and housing,²⁵ (3) case status, (4) race/ethnicity, (5) insurance type, and (6) variables used to calculate the RAI. NSQIP stopped collecting cognitive decline variables after 2012. We treated this missing variable as not having any cognitive decline for all patients in the calculation of RAI, as previously reported.⁴⁵ Comparison of RAI models before and after 2012 showed that missing cognitive decline variable, because of its rare occurrences, had minimal effects on model discrimination and calibration.⁴⁵

Statistical Analysis

Categorical data were summarized using counts and percentages and continuous data using mean and standard deviation (SD). Chi-square tests and F-tests were used to test for differences between groups for categorical and continuous variables.

We used nested random intercept logistic regression models to assess the association between race/ethnicity, ADI and insurance type with TO and the 5 components of TO adjusting for RAI, OSS, and case status. The random effect was used to account for clustering within each healthcare system. We calculated marginal effects from these final models (a predicted increase or decrease in the probability of an outcome associated with each predictor variable). To illustrate the magnitude of intersecting risks, we calculated predicted probabilities for TO for lowest- and highest-risk patient scenarios based upon the odds ratios from the final nested TO model for the race/ethnicity, ADI, insurance and case status groups versus the reference group. We additionally performed secondary analyses using random intercept logistic regression models to assess the association between SDoH and case status. We conducted sensitivity analyses using ADI >75 as a cutoff using a broader categorization of deprivation and adding age groups 18–44, 45–64, and ≥65 years as predictor variables. Analyses were performed using R 4.1.1 (R Project for Statistical Computing).

RESULTS

Population Characteristics

The cohort included 34,251 inpatient cases present in the 2013–2019 NSQIP (Fig. 1). Clinical site burden (Supplemental Table 1, <http://links.lww.com/AOSO/A202>) was determined by the percent of uninsured patients at each site as high (35.5%), medium (6.9%) and low (0.7%). Most

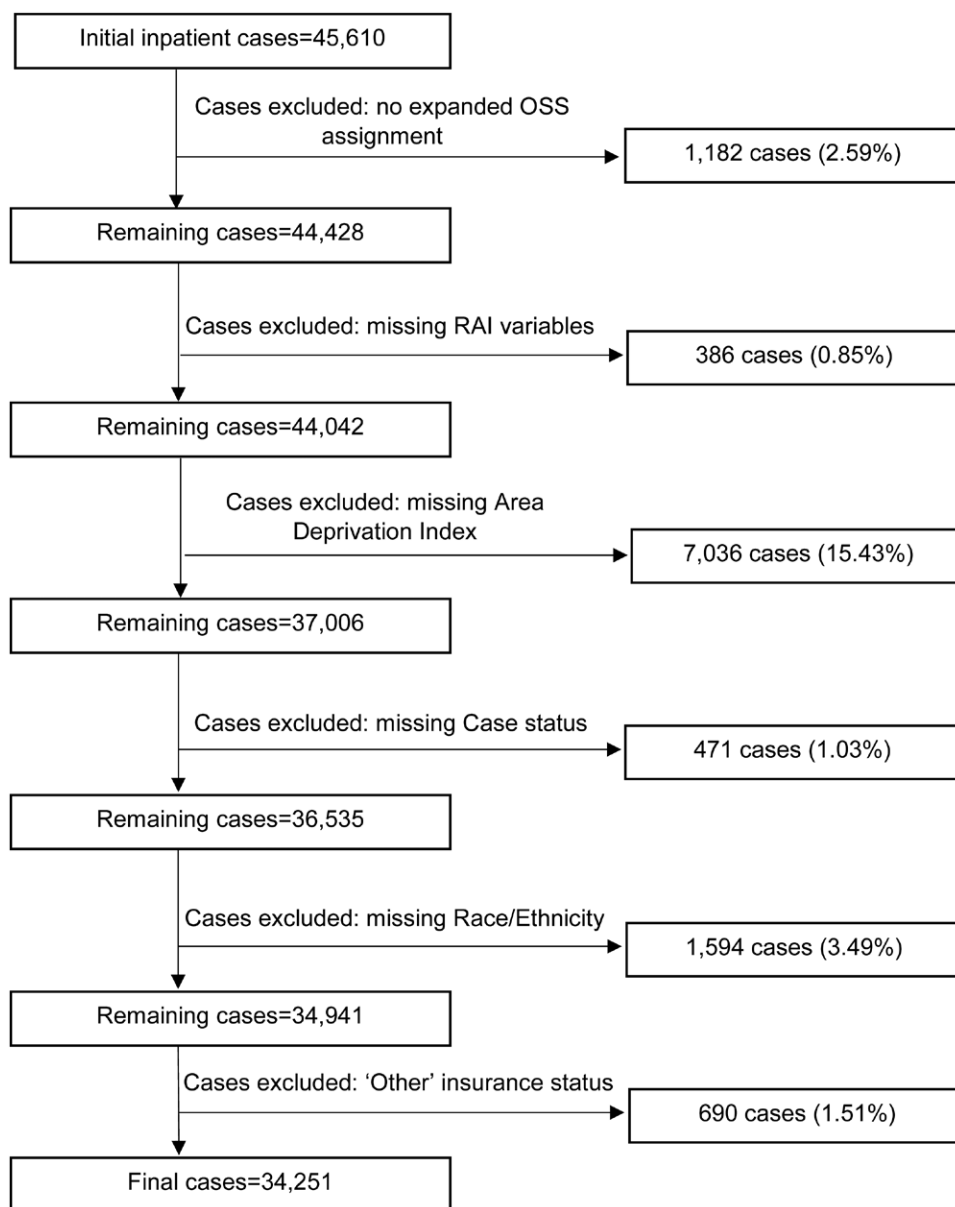


FIGURE 1. Flow diagram of study cohort. National Surgery Quality Improvement Program inpatient cases from 2013 to 2019. Cases were excluded for having no expanded OSS assignment for the principal CPT code, missing variables used to calculate the RAI, missing home address used to assign an ADI/or ADI not assigned to the block group, missing case status, missing race/ethnicity and categorized as “other” insurance type. “Other” insurance status was defined as including encounters charged to the Department of Corrections, liability insurance, Veterans Administration, unknown/missing, and other state payor types. Cases lacking an expanded OSS assignment for the principal CPT code were excluded to avoid erroneously assigning a lower stress OSS based upon additional procedures that were performed. For example, a principal CPT code for a highly stressful procedure not assigned an expanded OSS could be assigned an OSS1 if the additional CPT codes contained any procedure with an expanded OSS rating.

cases (Table 1) were performed on Non-Hispanic White patients (72.6%), followed by Hispanic (14.1%) and Non-Hispanic Black patients (11.6%). Patients had a mean (SD) age of 58.3 (16.0) years, slightly more than half were females (54.8%) and 21.6% of the cohort lived in highly deprived neighborhoods (ADI>85).

Increased Odds of Urgent/Emergent Cases Among Racial and Ethnic Minorities, Non-Private Insurance and ADI >85

Patients from the racial and ethnic minority groups of Black, non-Hispanic (adjusted odds ratio [aOR] = 1.34, 95% CI = 1.23–1.45, $P < 0.001$; Table 2), Hispanic, any race (aOR = 1.36,

95% CI = 1.23–1.50, $P < 0.001$) and Multiracial, non-Hispanic (aOR = 1.33, 95% CI = 1.09–1.62, $P = 0.004$) had higher odds of undergoing urgent/emergent cases versus patients identified as White. Patients living in highly deprived areas (aOR = 1.17, 95% CI = 1.10–1.24, $P < 0.001$) had higher odds of undergoing urgent/emergent versus elective procedures. Medicare (aOR = 1.56, 95% CI = 1.47–1.66, $P < 0.001$), Medicaid (aOR = 2.36, 95% CI = 2.15–2.59, $P < 0.001$), and Uninsured (aOR = 2.83, 95% CI = 2.56–3.12, $P < 0.001$) groups had higher odds of urgent/emergent procedures versus Private. Marginal effects for the probability of undergoing an urgent/emergent procedure were highest for very frail patients (37.1%), Uninsured (21.5%), and Medicaid (17.5%) patients.

TABLE 1.
Patient Characteristics and Clinical Outcomes by Insurance Type

	Overall	Private	Medicare	Medicaid	Uninsured	P
Number (%)*	34,251	13,546 (39.5)	14,907 (43.5)	2826 (8.3)	2972 (8.7)	
Age [mean (SD)]	58.3 (16.0)	50.4 (12.6)	70.0 (11.56) (11.55)	46.7 (13.6)	47.2 (12.4)	<0.001
Sex (Female)	18,760 (54.8)	7991 (59.0)	7677 (51.5)	1577 (55.8)	1515 (51.0)	<0.001
Race/ethnicity						<0.001
Black, non-Hispanic	3982 (11.6)	1429 (10.5)	1654 (11.1)	636 (22.5)	263 (8.8)	
Hispanic, any race	4816 (14.1)	1012 (7.5)	1078 (7.2)	844 (29.9)	1882 (63.3)	
Multiracial, non-Hispanic	573 (1.7)	277 (2.0)	125 (0.8)	97 (3.4)	74 (2.5)	
White, non-Hispanic	24,880 (72.6)	10,828 (79.9)	12,050 (80.8)	1249 (44.2)	753 (25.3)	
RAI						<0.001
Robust (≤20)	18,571 (54.2)	10,509 (77.6)	3369 (22.6)	2182 (77.2)	2511 (84.5)	
Normal (21–29)	11,593 (33.8)	2159 (15.9)	8667 (58.1)	418 (14.8)	349 (11.7)	
Frail (30–39)	3657 (10.7)	842 (6.2)	2533 (17.0)	192 (6.8)	90 (3.0)	
Very frail (≥40)	430 (1.3)	36 (0.3)	338 (2.3)	34 (1.2)	22 (0.7)	
ADI >85 (highly deprived)	7408 (21.6)	2190 (16.2)	3050 (20.5)	1065 (37.7)	1103 (37.1)	<0.001
Clinical sites†						<0.001
High-burden	6225 (18.2)	1446 (10.7)	1603 (10.8)	967 (34.2)	2209 (74.3)	
Medium-burden	8991 (26.3)	3802 (28.1)	3519 (23.6)	1047 (37.0)	623 (21.0)	
Low-burden	19,035 (55.6)	8298 (61.3)	9785 (65.6)	812 (28.7)	140 (4.7)	
Case status						<0.001
Elective	22,871 (66.8)	10,389 (76.7)	9588 (64.3)	1595 (56.4)	1299 (43.7)	
Urgent	7762 (22.7)	2071 (15.3)	3530 (23.7)	871 (30.8)	1290 (43.4)	
Emergent	3618 (10.6)	1086 (8.0)	1789 (12.0)	360 (12.7)	383 (12.9)	
Expanded OSS (surgical-induced physiologic stress)						<0.001
OSS1 (very low)	339 (1.0)	107 (0.8)	107 (0.7)	51 (1.8)	74 (2.5)	
OSS2 (low)	7050 (20.6)	2760 (20.4)	2735 (18.3)	688 (24.3)	867 (29.2)	
OSS3 (moderate)	19,611 (57.3)	7985 (58.9)	8465 (56.8)	1563 (55.3)	1598 (53.8)	
OSS4 (high)	6197 (18.1)	2373 (17.5)	2963 (19.9)	461 (16.3)	400 (13.5)	
OSS5 (very high)	1054 (3.1)	321 (2.4)	637 (4.3)	63 (2.2)	33 (1.1)	
30-day complications‡						<0.001
Reoperation	2090 (6.1)	658 (4.9)	1040 (7.0)	213 (7.5)	179 (6.0)	<0.001
CDIV	1783 (5.2)	372 (2.7)	1105 (7.4)	179 (6.3)	127 (4.3)	<0.001
Mortality	747 (2.2)	125 (0.9)	544 (3.6)	57 (2.0)	21 (0.7)	<0.001
30-day EDOS§	1,914 (5.6)	580 (4.3)	717 (4.8)	269 (9.5)	348 (11.7)	<0.001
30-day readmissions§ Readmissions ^d	1628 (4.8)	406 (3.0)	620 (4.2)	267 (9.4)	335 (11.3)	<0.001
TO	28,015 (81.8)	11,815 (87.2)	11,902 (79.8)	2093 (74.1)	2205 (74.2)	<0.001

Bolded P-values indicate significance at the P < .05 level.

*Percent calculation by row, the rest of the percent calculations were by column.

†Burden level categorized based upon the proportion of uninsured patients at each clinical site.

‡Complications defined as 30 days from date of the index surgery.

§EDOS and Readmissions defined as 30 days from date of hospital discharge of the index surgery; EDOS and Readmissions were evaluated independently; membership in 1 group does not exclude a case from membership in the other.

TABLE 2.
Urgent/Emergent Case Status Adjusted for Race/Ethnicity, Frailty, ADI, and Insurance Type

Predictors	Urgent/Emergent					
	aOR	95% CI	P	aΔU/E (%)	95% CI (%)	P
Race/ethnicity (Ref = White, non-Hispanic)						
Black, non-Hispanic	1.336	1.232–1.450	<0.001	5.8	3.8–7.8	<0.001
Hispanic, any race	1.357	1.227–1.501	<0.001	6.1	3.8–8.5	<0.001
Multiracial, non-Hispanic	1.332	1.094–1.621	0.004	5.7	1.5–9.9	0.007
RAI (Ref = normal 21–29)						
Robust (≤20)	0.903	0.849–0.961	0.001	–2.0	–3.2 to –0.7	0.003
Frail (30–39)	1.597	1.475–1.729	<0.001	9.7	7.5–11.9	<0.001
Very frail (≥40)	5.861	4.652–7.383	<0.001	37.1	32.7–41.5	<0.001
ADI >85 (Ref = ADI ≤85)	1.168	1.100–1.239	<0.001	3.1	1.7–4.4	<0.001
Insurance (Ref = Private)						
Medicare	1.561	1.466–1.661	<0.001	8.6	6.2–11.0	<0.001
Medicaid	2.361	2.150–2.593	<0.001	17.5	13.7–21.3	<0.001
Uninsured	2.829	2.561–3.124	<0.001	21.5	17.5–25.6	<0.001

Bolded P-values indicate significance at the P < .05 level.

aΔU/E indicates adjusted change in the probability of Urgent/Emergent case status; Ref, reference value.

Decreased Odds of TO (Worse Outcomes) Among Black Non-Hispanic Patients, Non-Private Insurance, and ADI >85

Nested models controlling for frailty and operative stress

demonstrated that Black Non-Hispanic, ADI>85 and non-Private insurances were associated with lower odds of TO (Table 3, M1 and M2), but ADI was not significant after adding urgent/emergent cases (Table 3, M3). Odds of TO decreased from

TABLE 3.

TO and Marginal Effects on Textbook Outcomes using 3 Nested Models (M1–M3) Adjusted for Race/Ethnicity, RAI*, OSS†, ADI, Insurance, and Case Status.

Predictors	TO M1			TO M2			TO M3		
	aOR	95% CI	P	aOR	95% CI	P	aOR	95% CI	P
Race/Ethnicity (Ref = White, non-Hispanic)									
Black, non-Hispanic	0.832	0.758–0.914	<0.001	0.872	0.794–0.958	0.004	0.894	0.813–0.982	0.020
Hispanic, any race	0.924	0.829–1.031	0.157	0.974	0.872–1.088	0.637	1.011	0.904–1.131	0.848
Multiracial, non-Hispanic	0.855	0.687–1.063	0.159	0.866	0.695–1.079	0.200	0.887	0.710–1.107	0.290
ADI >85 (Ref = ADI ≤85)	0.888	0.828–0.952	0.001	0.927	0.865–0.995	0.035	0.950	0.885–1.019	0.153
Insurance (Ref = Private)									
Medicare				0.697	0.647–0.752	<0.001	0.738	0.684–0.796	<0.001
Medicaid				0.550	0.495–0.611	<0.001	0.614	0.552–0.683	<0.001
Uninsured				0.756	0.676–0.845	<0.001	0.868	0.775–0.973	0.015
Urgent/emergent (Ref = Elective)							0.511	0.480–0.544	<0.001
Marginal Effects									
Predictors	TO M1			TO M2			TO M3		
	aΔTO (%)	95% CI	P	aΔTO (%)	95% CI	P	aΔTO (%)	95% CI	P
Race/ethnicity (Ref = White, non-Hispanic)									
Black, non-Hispanic	-2.7	-4.3 to -1.1	0.001	-2.0	-3.5 to -0.5	0.010	-1.6	-3.0 to -0.2	0.028
Hispanic, any race	-1.1	-2.7 to 0.5	0.172	-0.4	-1.9 to 1.2	0.640	0.1	-1.4 to 1.7	0.848
Multiracial, non-Hispanic	-2.3	-5.6 to 1.1	0.186	-2.1	-5.4 to 1.3	0.224	-1.7	-5.0 to 1.6	0.308
ADI >85 (Ref = ADI ≤85)	-1.7	-2.8 to -0.6	0.003	-1.1	-2.1 to -0.0	0.046	-0.7	-1.7 to 0.3	0.163
Insurance (Ref = Private)									
Medicare				-4.9	-6.7 to -3.1	<0.001	-4.1	-5.6 to -2.6	<0.001
Medicaid				-8.7	-11.7 to -5.7	<0.001	-7.0	-9.3 to -4.6	<0.001
Uninsured				-3.7	-5.6 to -1.8	<0.001	-1.8	-3.4 to -0.2	0.024
Urgent/emergent (Ref = elective)							-9.9	-12.6 to -7.2	<0.001

Bolded P-values indicate significance at the P < .05 level.

To defines an optimal outcome, lower odds of TO are associated with worse outcomes and higher odds of TO are associated with better outcomes.

*Adjustments for frailty by the RAI not shown.

†Adjustments for operative stress by the expanded OSS not shown.

aΔTO indicates adjusted change in the absolute probability of TO; Ref, reference value.

TABLE 4.

Lowest-Risk Versus Highest-Risk Scenarios on Probability of TO Based Upon Table 3 M3 Stratified by Frailty

Frailty	TO Probability	TO Probability	TO Probability Difference
	Lowest-Risk	Highest-Risk	
	White, non-Hispanic	Black, non-Hispanic	
	Private Insurance	Medicaid	
	ADI ≤ 85	ADI >85	
	Elective surgery	Urgent/emergent surgery	
	OSS3 (moderate)	OSS3 (moderate)	Lowest-Highest Risk
	%	%	%
RAI			
Robust (≤20)	89.6	69.6	20.0
Normal (21–29)	87.7	65.5	22.2
Frail (30–39)	84.4	59.1	25.4
Very frail (≥40)	77.3	47.6	29.8
TO probability difference Robust-Very frail (%)	12.3	22.0	

Bolded P-values indicate significance at the P < .05 level.

Third nested model (M3) from Table 3 used to estimate probabilities using the most common (57.3%) moderate stress surgery group (OSS3). Higher probabilities of TO are associated with better outcomes.

Uninsured (aOR = 0.87, 95% CI = 0.78–0.97, P = 0.015) to Medicare (aOR = 0.74, 95% CI = 0.68–0.80, P < 0.001), and Medicaid (aOR = 0.61, 95% CI = 0.55–0.68, P < 0.001, Table 3 M3) versus Private. Estimated probability differences of TO were -9.9% (95% CI = -12.6% to -7.2%) for urgent/emergent cases, -7.0% (95% CI = -9.3% to -4.6%) for Medicaid, and -1.6% (95% CI = -3.0% to -0.2%) for Black, non-Hispanic patients (Table 3 Marginal Effects M3). Using M3 with

moderate-stress procedures (OSS3), the probabilities of TO were estimated for the lowest-risk and highest-risk groups stratified by frailty (Table 4). As frailty increased, the difference between lowest and highest risk increased. For instance, very frail patients at lowest-risk (White, non-Hispanic, Private, ADI ≤85, elective surgery) versus highest-risk (Black, non-Hispanic, Medicaid, ADI >85, urgent/emergent surgery) had a TO probability of 77.3% and 47.6%, respectively, a difference of 29.8%.

TABLE 5. Complication*, EDOS,† and Readmission‡ Components of TO Adjusted for Race/Ethnicity, RAI‡, OSS§, ADI, Insurance, and Case Status

Predictors	Reoperation			CDIV			Mortality		
	aOR	95% CI	P	aOR	95% CI	P	aOR	95% CI	P
Race/ethnicity (Ref = White, non-Hispanic)									
Black, non-Hispanic	1.137	0.982–1.317	0.085	1.087	0.920–1.285	0.327	0.868	0.671–1.123	0.282
Hispanic, any race	0.902	0.746–1.091	0.289	0.737	0.605–0.897	0.002	0.708	0.542–0.925	0.012
Multiracial, non-Hispanic	0.971	0.666–1.416	0.880	0.739	0.453–1.203	0.224	1.044	0.525–2.073	0.903
ADI >85 (Ref = ADI ≤85)	1.036	0.928–1.158	0.529	1.202	1.068–1.353	0.002	1.285	1.071–1.541	0.007
Insurance (Ref = Private)									
Medicare	1.190	1.058–1.338	0.004	1.685	1.469–1.932	<0.001	1.473	1.183–1.835	0.001
Medicaid	1.395	1.177–1.653	<0.001	1.575	1.292–1.919	<0.001	1.402	0.999–1.966	0.050
Uninsured	1.000	0.823–1.216	0.998	0.829	0.659–1.044	0.111	0.567	0.347–0.927	0.024
Urgent/emergent (Ref = Elective)	1.662	1.509–1.831	<0.001	3.517	3.157–3.919	<0.001	8.711	7.180–10.567	<0.001

Predictors	EDOS			Readmissions		
	aOR	95% CI	P	aOR	95% CI	P
Race/ethnicity (Ref = White, non-Hispanic)						
Black, non-Hispanic	1.155	0.989–1.349	0.069	1.010	0.846–1.207	0.909
Hispanic, any race	1.245	1.055–1.468	0.009	0.971	0.831–1.135	0.711
Multiracial, non-Hispanic	1.147	0.810–1.624	0.439	1.263	0.894–1.783	0.185
ADI >85 (Ref = ADI ≤85)	1.013	0.905–1.135	0.820	0.948	0.837–1.074	0.403
Insurance (Ref = Private)						
Medicare	1.227	1.079–1.395	0.002	1.296	1.120–1.500	0.001
Medicaid	1.691	1.439–1.986	<0.001	1.717	1.444–2.042	<0.001
Uninsured	1.523	1.294–1.792	<0.001	1.249	1.054–1.479	0.010
Urgent/emergent (Ref = Elective)	1.006	0.905–1.119	0.909	1.207	1.074–1.355	0.002

Bolded P-values indicate significance at the P < .05 level.

Ref indicates reference value.

*Defined as 30 days from date of the index surgery.

†Defined as 30 days from date of hospital discharge of the index surgery.

‡Adjustments for frailty by the RAI not shown.

§Adjustments for operative stress by the expanded OSS not shown.

Associations Differ Across TO Components: Increased Odds (Worse Outcomes) of CDIV and Mortality for ADI >85 and EDOS and Readmissions for non-Private Insurance

Urgent/emergent versus elective cases had higher odds of reoperation, CDIV, and mortality (Table 5). Patients from highly deprived areas had higher odds of CDIV complications (aOR = 1.20, 95% CI = 1.07–1.35, P = 0.002) and mortality (aOR = 1.29, 95% CI = 1.07–1.54, P = 0.007). Compared to Private, Medicare patients had higher odds of unplanned reoperations, CDIV and mortality, while Medicaid patients had higher odds of unplanned reoperations and CDIV complications. Uninsured patients were younger, had lower frailty/RAI scores, and underwent lower stress surgeries (Supplemental Table 2, <http://links.lww.com/AOSO/A202>), had lower odds of mortality (aOR = 0.57, 95% CI = 0.35–0.93, P = 0.024) versus Private.

Hispanic patients had higher odds of EDOS versus White, non-Hispanic patients (Table 5). Patients with non-Private insurance had higher odds of EDOS and readmissions. Urgent/emergent versus elective procedures had higher odds of readmissions (aOR = 1.21, 95% CI = 1.07–1.36, P = 0.002). Reoperation and CDIV complications were added as predictor variables for EDOS and readmission (Supplemental Table 3, <http://links.lww.com/AOSO/A202>). Reoperations were associated with higher odds of EDOS (aOR = 1.63, 95% CI = 1.38–1.93, P < 0.001) and readmissions (aOR = 4.63, 95% CI = 4.00–5.36, P < 0.001), while CDIV complications only increased the odds of readmissions (aOR = 1.38, 95% CI = 1.15–1.66, P < 0.001).

Sensitivity Analysis With ADI >75 and Adding Age as a Predictor Variable

We expanded the definition of highly deprived to include patients living in the 25% most deprived block groups (Fig. 2). Regardless of cutoff, patients from highly deprived neighborhoods had higher odds of undergoing urgent/emergent cases. Similarly, patients with ADI >75 and ADI >85 had lower odds of TO after adjusting for race/ethnicity, operative stress, and frailty. ADI >85, but not ADI >75, continued to be significant after adjusting for insurance type (Table 3 M2). For TO components, ADI was a significant predictor of mortality regardless of which cutoff was used.

Although RAI/frailty included age, we added age as a separate predictor (Supplemental Figure 1, <http://links.lww.com/AOSO/A202>). ADI >85 continued to be significantly associated with TO in M1 which included race/ethnicity, but not in M2 which included insurance type. The addition of age did not alter the results for the TO components.

DISCUSSION

This study examined independent associations between TO and (1) contextual-level SDoH measured by ADI and (2) individual-level SDoH using race/ethnicity as a social construct³⁹ and insurance type. ADI, race/ethnicity, and insurance type were each independently associated with worse outcomes as demonstrated by lower odds of TO but the association with ADI lost significance after adjusting for urgent/emergent cases. Associations with the TO components varied by social risk factor but were predominantly associated with urgent/emergent

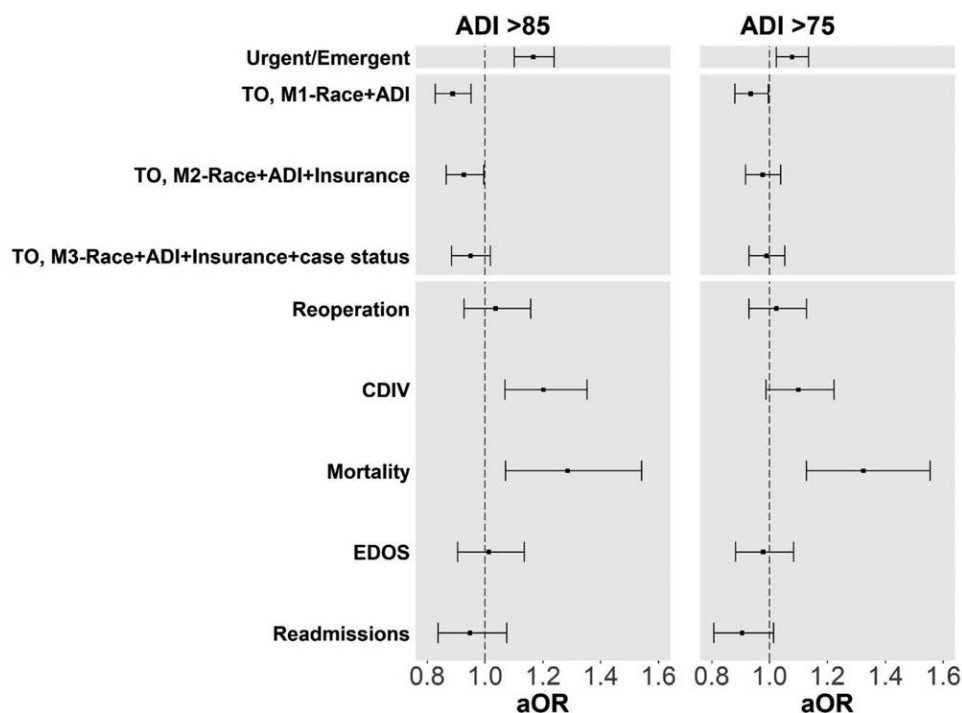


FIGURE 2. Case status, TO and TO components with a sensitivity analysis using ADI >75 as a cutoff point. Forest plot of Tables 2, 3, and 5 (left) with a sensitivity analysis using the ADI >75 as a cutoff point (right). Using different ADI cutoffs resulted in 7408 (21.6%) and 12,340 (36.0%) of the cohort being classified as highly deprived for ADI >85 and ADI >75, respectively. Urgent/emergent cases (Table 2) were adjusted for race/ethnicity RAI/frailty, and insurance type. TO nested models (Table 3) were adjusted for RAI and expanded operative stress score in addition to the variables listed in models 1–3 (M1–M3). TO components (Table 5) were adjusted for RAI, expanded operative stress score, race/ethnicity, insurance type, and urgent/emergent case status (M3 model variables).

cases, suggesting that increased urgent/emergent surgeries among patients from deprived neighborhoods lead to increased complications and lower odds of achieving TO. The current study lays the groundwork for healthcare systems to use their own data to understand their populations. This roadmap can assist healthcare systems explore patterns in outcomes that may identify quality improvement projects tailored to their unique populations.

A strength of this study is the use of high-quality, nurse-abstracted NSQIP data from 3 healthcare systems enriched with EHR data and linked to the granular ADI, as recommended by the National Academy of Medicine.⁴ Using multiple sources provides a more complete dataset for the patients, overcoming many of the known limitations of administrative data. Administrative data uses ICD-9/10 codes, which vary across healthcare systems and often cannot distinguish between preoperative risk factors (eg, preoperative pneumonia or urinary tract infections) from postoperative complications. NSQIP is an audited clinical registry using strict definitions, enabling more accurate identification of preoperative risk factors and complications.^{18,19} Furthermore, we differentiated urgent from elective cases in contrast to many administrative database studies.^{16,54} Although other studies found that outcomes are related to race, income and insurance, this study is the first to combine these factors into a single model, explores their combined impact, and suggests that each SDoH acts independently to thwart positive surgical outcomes.

Prior surgery research studied isolated associations with either insurance type^{54,55} or neighborhood deprivation.^{22,42} This is one of the first studies to simultaneously examine the granular, block group ADI, insurance type, and race/ethnicity on TO, a composite outcome. Although insurance type emerged as a more powerful and consistent factor in TO than ADI, ADI was still associated with CDIV complications and mortality for patients with insurance. Best practices should include both insurance type and ADI in risk adjustment. Future studies should evaluate the changing impact of ADI stratified by insurance type.

The importance of including both granular neighborhood deprivation and individual social risk factors was further illustrated by a study of pediatric asthma patients that showed ADI was associated with increased hospitalizations, modified by insurance type.⁵⁶ Alternatively, chemotherapy completion and mortality among breast cancer patients showed associations with insurance type but not with ZIP code-level neighborhood SES.²³ Area measures only *estimate* individual SES and neighborhood conditions, potentially confounding analyses,³¹ especially when the area/population is large.⁵⁷ Therefore, we used block group ADI to better approximate the patient's neighborhood; this granular measure demonstrated lower odds of TO (Table 3). ADI remained a significant predictor of CDIV complications and mortality, even after controlling for urgent/emergent surgeries (Table 5).

Cutoffs defining deprivation for ADI and other indices vary.^{26,42} ADI >85, but not ADI >75, remained significantly associated with TO after including insurance. However, significant associations between ADI and TO *components* were unaffected by the categorization of deprivation, demonstrating that outcomes can vary with the definition of deprivation used. Neighborhood deprivation and insurance are both independently associated with TO, and both need to be considered in evaluating risk for poor outcomes. However, measuring neighborhood deprivation has nuances that depend on the granularity of the data (block versus ZIP code level) and the cutoff values used. Based on these nuances, the relationship between neighborhood deprivation and TO and its components may be altered. Health systems should establish cutoffs predictive of their populations, to identify patients from deprived neighborhoods and potentially improve their outcomes by providing additional services to improve access to care and postoperative follow up.

We chose TO as our primary outcome because composite measures often provide more comprehensive assessments of surgical outcomes than single variables.^{30,37,38} Our data demonstrate the utility of this approach as Black, non-Hispanic versus White, non-Hispanic patients had lower odds of TO but were similar for all TO components. Thus, identification of healthcare

disparities may be improved by composite variables secondary to the additive effects of each component.

Our data demonstrated increased rates/odds of urgent/emergent surgery among patients that (1) were minorities, (2) were living in highly deprived neighborhoods for both ADI cutoffs, and (3) had non-Private insurance. Urgent/emergent cases were associated with lower/worse odds of TO and higher/worse odds of all TO components except EDOS. ADI >85 was associated with lower odds of TO but was no longer significant after adjusting for urgent/emergent cases, suggesting that the increased rates/odds of urgent/emergent surgeries in patients living in highly deprived neighborhoods was a driving factor in their worse outcomes. Prior studies support our findings; urgent²¹ and emergent surgeries^{54,58} were associated with increased complications. Urgent surgeries generally occur in the context of unplanned hospitalizations and were more prevalent in all 4 insurance types compared to emergency cases. However, urgent procedures were lowest in patients with Private insurance (15.3%) and highest in patients with no insurance (43.4%). Grouping urgent and elective cases together may produce disproportionately high complication rates in patient populations with higher rates of urgent surgeries. Risk adjustment should differentiate urgent from elective cases.

Consistent with the growing literature,^{56,59} contextual-level SDoH (eg, neighborhood deprivation) are distinct from individual-level SDoH (eg, insurance) yet are tightly interrelated. A novel aspect of this study is that we estimated the reduction in TO probability of 9.9% for urgent/emergent cases, 7.0% for Medicaid, and 1.6% for non-Hispanic Black patients. We used these probability differences to show lowest- versus highest-risk differences demonstrating the clinical significance of including multilevel SDoH and the intersection and clustering of these SDoH variables. Specifically, disparities associated with race/ethnicity, insurance type, and neighborhood deprivation are long-term effects of residential racial segregation.^{34,36} We quantified the absolute difference between the lowest- and highest-risk scenarios to illustrate how the risks of race, insurance type, and neighborhood deprivation compound in populations exposed to multiple social risk factors. Very frail patients at lowest-risk (White, non-Hispanic, Private, ADI ≤ 85, elective surgery) versus highest-risk (Black, non-Hispanic, Medicaid, ADI >85, urgent/emergent surgery) had a TO probability of 77.3% and 47.6%, respectively, a difference of 29.8%, showing the magnitude of intersecting risks. Robust, normal and frail lowest- and highest-risk patients had 20.0%, 22.2%, 25.4% differences in TO probability, respectively. These disparities have eluded recognition and precise definition because the risk factors are unavailable in NSQIP without the novel linkage to ADI and insurance type used here. Further research is needed to develop and evaluate strategies for alleviating these disparities. As a first step, we encourage NSQIP to begin collecting more robust preoperative variables assessing individual- and contextual-level SDoH.

Racial and ethnic minorities, uninsured and Medicaid patients as well as patients living in high poverty^{26,32} or segregated areas have worse outcomes.³⁴ However, these factors are not included in risk adjustment placing SNH serving higher proportions of patients from disadvantaged backgrounds at greater risk of being penalized for worse outcomes.^{10,11,60–62} Our findings are in line with these concerns and show the need to include social-risk adjustment in value-based programs. While CMS has assessed the landscape of available contextual SDoH for risk adjustment,² clear actions have not yet been outlined. Continued efforts by policy makers are needed to address this issue.

Limitations

This was a cross-sectional analysis showing associations rather than causal relationships. It is also possible that alternate, unmeasured clinical and social risk factors could confound our findings. The data are derived from three diverse healthcare systems which

may restrict generalizability. However, this study has no equivalent published in the literature, and given that the data are derived from three large academic health centers, the study can affect the national debate regarding SDoH in public policy and risk adjustment. Finally, our NSQIP cohort was a sample of major surgeries performed at 3 healthcare systems; it did not include all procedures during the study period. Our data only included inpatient surgeries, limiting generalizability to outpatient procedures.

CONCLUSION

Neighborhood deprivation and insurance type had independent effects on TO. However, after adjusting for increased urgent/emergent cases, the association with insurance type remained significant, but not neighborhood deprivation. This suggests that neighborhood deprivation may affect outcomes predominately through increased rates/odds of patients undergoing urgent/emergent surgeries further driving complications and worse outcomes. Lowest-risk versus highest-risk scenarios demonstrated the magnitude of intersecting SDoH variables. Our results show that the combination of insurance type and ADI can be useful for identifying high-risk patients, enabling healthcare systems to focus scarce resources on vulnerable populations. Outcomes might be improved by redesigning care pathways that identify and alleviate SDoH. The methods in this study can serve as a roadmap for healthcare systems to use their own data to better understand their unique populations. Better inclusion of multi-level SDoH, including neighborhood deprivation in risk adjustment, could reduce the unintended consequences of value-based medicine programs in decreasing resources to SNH.

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