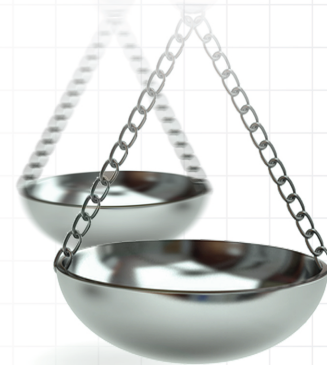




Social determinants of health and their impact on postcolectomy surgery readmissions: a multistate analysis, 2009–2014

Hyun S Park¹ , Robert S White¹, Xiaoyue Ma², Briana Lui¹ & Kane O Pryor^{*,1}

¹Weill Cornell Medicine/New York Presbyterian Hospital, Department of Anesthesiology, 525 East 68th Street, Box 124, New York, NY 10065, USA

²Weill Cornell Medicine, Division of Biostatistics & Epidemiology, Department of Healthcare Policy & Research, 402 East 67th Street, Box 74, New York, NY 10065, USA

*Author for correspondence: Tel.: +1 212 746 2969; Fax: +1 646 962 1920; kap9009@med.cornell.edu

Aim: To examine the effect of race/ethnicity, insurance status and median household income on postoperative readmissions following colectomy. **Patients & methods:** Multivariate analysis of hospital discharge data from California, Florida, Maryland and New York from 2009 to 2014. Primary outcomes included adjusted odds of 30- and 90-day readmissions following colectomy by race, insurance status and median income quartile. **Results:** Total 330,840 discharges included. All 30-day readmissions were higher for black patients (adjusted odds ratio [aOR]: 1.07). Both 30- and 90-day readmissions were higher for Medicaid (aOR: 1.30 and 1.26) and Medicare (aOR: 1.30 and 1.29). The 30- and 90-day readmissions were lower in the highest income quartiles. **Conclusion:** Race, insurance status and median household income are all independent predictors of disparity in readmissions following colectomy.

First draft submitted: 5 August 2019; Accepted for publication: 4 October 2019; Published online: 4 December 2019

Keywords: colectomy • healthcare disparity • insurance status • outcomes research • racial disparity • readmissions

The Hospital Readmission Reduction Program (HRRP), under the Affordable Care Act, mandated that hospitals are penalized financially for higher than expected 30-day readmission rates. This has resulted in a significant reduction in readmissions in both HRRP-targeted and nontargeted procedures [1–3]. However, the HRRP and its financial penalty guidelines fail to account for social risk factors such as race/ethnicity, insurance type and median income, which have been demonstrated to impact readmission rates [4–6]. Safety-net hospitals, which are mandated to care for all patients regardless of the ability to pay, are more likely to treat patients with risk factors related to social determinants of health, and this translates to increased likelihood of readmissions and financial penalties under the current HRRP [7].

Colectomy is one of the most common surgical procedures performed in the USA, with costs associated with each procedure estimated between US\$12,000 and US\$25,000; when complications occur, these costs can increase to approximately US\$50,000 [8,9]. Median cost for readmission care alone is approximately US\$10,000 [10]. Within general surgery, colectomies are associated with the highest rates of complications and readmissions [11,12]. The enhanced recovery after surgery society have started developing protocols to address such complications following colectomy to improve outcomes [13–16]. Studies have identified health disparities for postcolectomy surgical outcomes by insurance payer, socioeconomic status (SES) and race/ethnicity [17–30]. However, the existing literature examining readmissions and social determinants of health in colectomy patients is limited and outdated (Table 1) [10,19–21,25,28–30].

The purpose of this study was to perform a multistate, multivariate analysis of social determinants of health and their impact on colectomy readmissions. This analysis will help to elucidate the social risk factors associated with readmissions and to examine the potential negative impact that nonsocial risk factor adjusted readmission penalization programs, like the HRRP, can have on minority-serving or high safety-net burden hospitals [31,32].

Table 1. Literature review of disparities in colectomy patients by race, insurance payer status and other socioeconomic factors.

Study, (year)	Data (years)	Sample size	Reported outcomes	Study limitations	[Ref.]
Lapar <i>et al.</i> , (2013)	NIS (2003–2007)	893,658	Mortality, length of stay, costs, in-hospital complications	No data on racial disparity, no data on income disparity, outdated	[16]
Hendren <i>et al.</i> , (2011)	MEDPAR (2003–2008)	477,461	30-day readmissions, length of stay	Only Medicaid population, no data on insurance disparity, no data on income disparity, outdated	[15]
Lidor <i>et al.</i> , (2008)	NIS (1999–2003)	45,528	Type of treatment, in-hospital mortality	Limited measured outcomes, no data on income disparity, outdated	[18]
Birkmeyer <i>et al.</i> , (2008)	MEDPAR (1999–2003)	1,028,717	Operative mortality	Only Medicare population, no postoperative outcomes	[11]
Lassiter <i>et al.</i> , (2017)	NIS (2009–2013)	53,054	Laparoscopic vs open	No postoperative outcomes, limited to diverticulitis	[17]
Damle <i>et al.</i> , (2016)	University Health System Consortium (2008–2011)	82,474	Laparoscopic vs open, complications, readmissions, mortality	Limited to racial disparities, no data on insurance disparity, no data on income disparity	[12]
Sadler <i>et al.</i> , (2014)	NIS (1993–2008)	10,111	Postoperative mortality	Limited measured outcomes, outdated, analysis limited to payer status	[21]
Girotti <i>et al.</i> , (2014)	CMS (2006–2008)	254,382	30-day readmissions	Limited to Medicare population, no data on insurance disparity, no data on income disparity	[14]
Tsai <i>et al.</i> , (2014)	MEDPAR (2007–2010)	1,508,402	30-day readmissions	Limited measured outcome, limited to Medicare population, no data on insurance disparity, no data on income disparity	[24]
Nguyen <i>et al.</i> , (2006)	NIS (1998–2003)	23,389	Colectomy rate, length of stay, mortality during admission	Limited postoperative measures, limited data on insurance disparity, outdated	[20]
Mulhern <i>et al.</i> , (2017)	ACS-NSQIP (2011–2014)	28,283	30-day mortality, length of stay, 30-day readmission	No data on insurance disparity, no data on income disparity	[19]
Fry <i>et al.</i> , (2018)	Medicare Limited Dataset (2012–2014)	86,624	Inpatient deaths, length of stay, 90-day mortality, 90-day readmissions	Limited to regional (income) disparity, no data for racial or insurance disparity	[13]
Schneider <i>et al.</i> , (2013)	SEER-Medicare (1986–2005)	125,676	In-hospital mortality, 30-day readmissions	Outdated, limited to racial disparity; no data on insurance disparity, limited to colorectal cancer patients	[23]
Sastow <i>et al.</i> , (2019)	SID, HCUP	444,877	Open vs laparoscopic vs robotic, length of stay, 30- & 90-day readmission rates, cost, complications	Limited to insurance disparity	[22]
Bliss <i>et al.</i> , (2015)	SID, HCUP (2007–2011)	93,913	Readmissions and cost of readmission	Outdated, no data on income disparity	[10]

ACS-NSQIP: American College of Surgeons-National Surgical Quality Improvement Program; CMS: Centers for Medicare & Medicaid; MEDPAR: Medicare Provider Analysis and Review; NIS: National Inpatient Sample; SEER-Medicare: Surveillance, Epidemiology and End Results-Medicare.

Our hypothesis was that social determinants of health impact 30- and 90- day readmissions after colectomy and we predicted that blacks and Hispanics, as compared with white patients; Medicaid and uninsured, as compared with private insurance patients; and patients of poorer median income, as compared with those of richer median income, would have higher unadjusted rates and adjusted odds ratios (aOR) of 30- and 90-day readmission.

Patients & methods

Study database & population

We performed a retrospective, cross-sectional study using data from the State Inpatient Databases (SID), Healthcare Cost and Utilization Project from California (2009–2011), Florida, New York and Maryland for years 2009–2014. SID is an administrative database that includes hospitalization, discharge and inpatient insurance data from nonfederal, nonpsychiatric hospitals. SID's data is recorded so that each record represents one hospital discharge and not an individual patient. The database includes data for each discharge including patient demographics (age, race/ethnicity, sex, primary insurance type and median income by patient's zip code), patient present-on-admission (POA) prehospitalization comorbid medical conditions, including those from the Elixhauser Comorbidity Index [33], hospital-specific data (state, year and hospital surgical volume), and surgery-specific data (surgical subtype). Primary

Table 2. International classification of diseases v.9 procedure codes for population selection.

Colectomy surgical subtype	ICD-9 procedure codes
Open colectomy	45.72 open and other cecectomy 45.73 open and other right hemicolectomy 45.75 open and other left hemicolectomy 45.76 open and other sigmoidectomy
Laparoscopic colectomy	17.32 laparoscopic cecectomy 17.33 laparoscopic right hemicolectomy 17.35 laparoscopic left hemicolectomy 17.36 laparoscopic sigmoidectomy
Robotic colectomy	17.39 robotic, laparoscopic partial excision of large intestine 17.42 laparoscopic robotic assisted procedure 17.49 robotic, unspecified robotic assisted procedure

insurance is classified as Medicaid, Medicare, uninsured, other and private; race/ethnicity is classified as black, Hispanic, white and other; and median income levels were classified by dividing the study population into quartiles with the first quartile corresponding to the lowest median income and the fourth quartile corresponding to the highest median income [34]. SID also uses VisitLink data, which links different hospitalizations for the same patient, to track readmissions for each record and allows for tracking postdischarge days to readmission. International Classification of Diseases, Ninth Revision, Clinical Modification codes were used to identify eligible patients from 2009 to 2014, who underwent colectomy (Table 2). We included all patients older than 18 years old who underwent colectomy and who did not meet the following exclusion criteria: missing demographics data, death during hospitalization, missing sufficient follow-up after initial hospitalization and missing VisitLink data. We cohorted our study population into tertiles based upon visual inspection of the van Walraven score, a modification to the Elixhauser Comorbidity measures that summarizes a patient's comorbid conditions [35].

Study outcomes

The primary outcomes of our study included the unadjusted rates and adjusted odds of 30- and 90-day readmissions following colectomy separately by race/ethnicity, insurance payer status and quartile of median income level.

Statistical analysis

For all patients who underwent colectomy, demographic characteristics and POA comorbidities were compared through bivariate analysis at 30- and 90-day readmission time points by readmission status. For categorical variables, we utilized the Pearson's chi-squared test or Fisher exact test, and for continuous variables we utilized the analysis of variance or Kruskal–Wallis tests for non-normally distributed variables. We developed marginal logistic regression models to fit to the data using generalized estimating equations with exchangeable correlation – respective aOR with 95% CI were calculated and reported. Generalized estimating equations consider the clustering effect when individual hospitals report the same observations overtime, accounting for intrahospital practice patterns. Multivariate models were developed for 30- and 90-day readmissions separately and included *a priori* all variables of interest (race/ethnicity, insurance payer and median income) and possible confounding patient- (demographic or POA comorbidity variables), hospital- and surgical-level variables with bivariate results <0.05. Because readmission rates have been shown to differ by colectomy surgical subtypes [36,37], as a secondary analysis we stratified the population into three independent procedure-type groups – open, laparoscopic and robotic – to explore whether disparities also exist in colectomy patients by surgical subtype. Due to possible limitations in sample size and statistical power for this subgroup analysis, this secondary analysis was intended to serve as a collaborative trend analysis to supplement the main findings. In addition, interaction models were generated for each combination of the three variables of interest – race/ethnicity, insurance and median income – to highlight any associations between the variables and their effect on the outcome. At last, because readmissions differ by hospital safety net burden and surgery type (emergent vs elective) [31,38–41], we included the following variables – hospital safety net burden and surgery type (emergent vs elective) – to the main model as a sensitivity analysis to identify any causal pathways between all variables of interest and readmissions. Hospital safety net burden was based on the percentage of cases billed to Medicaid or uninsured, categorized in tertiles based on the distribution in our sample [31]. All statistical tests and analyses were performed using SAS version 9.4 (SAS Institute Inc., NC, USA).

Results

Patient demographics by readmission status

From 2009 to 2014, a 6-year study period, data from a total of 330,840 discharges after colectomy were included for patients greater than 18 years old from four states – California, Florida, Maryland and New York (Table 3). The mean age of study population was 61.3 years old (standard deviation: 14.8). About 52.3% of patients were women. Procedures included a total of 125,176 (37.8%) open procedures, 72,729 (22.0%) laparoscopic procedures and 132,935 (40.2%) robotic procedures. The population included 6.85% Medicaid, 43.6% Medicare, 2.34% other, 2.67% self-pay and 44.5% private; 9.98% black, 11.8% Hispanic, 1.51% missing, 6.81% other and 69.9% the white race; 21% first income quartile (lowest income), 24.5% second quartile, 26.5% third quartile and 27.9% fourth quartile (highest income).

Unadjusted rates of race/ethnicity, insurance & median income by 30- & 90-day readmissions

Compared with the overall colectomy patient population, in the 30- and 90-day readmissions populations (Table 3), there was an increased rate of Medicaid (30-day rate 9.13% and 90-day rate 8.88%) and Medicare (30-day rate 54.5% and 90-day rate 54.3%); increased rate of black (30-day rate 11.5% and 90-day rate 10.9%) and Hispanic (30-day rate 12.1% and 90-day rate 11.9%); and increased rate of the two lower income quartiles (30-day first quartile rate 24.1% and 90-day first quartile rate 23.8%, 30-day second quartile rate 25.6% and 90-day second quartile rate 25.5%).

Unadjusted readmissions rates

Unadjusted rates for 30- and 90-day readmissions by social determinants of health are shown in Table 4. The 30-day readmissions were significantly higher for black (12.5%) and Hispanic (11.1%) compared with white (10.8%). The 90-day readmissions were significantly higher for the black race (19.1%) compared with the white race (17.6%). Both 30- and 90-day readmissions were lower for patients with race data classified as missing and other compared with the white race. Both 30- and 90-day readmissions were significantly higher for all other insurances (Medicaid, Medicare, self-pay and other) compared with private insurance. At last, both 30- and 90-day readmissions were higher for the two lowest income quartiles compared with the two highest income quartiles.

Unadjusted rates of surgical subtype, surgery type, hospital volume & hospital safety net burden

Unadjusted rates for surgical subtype (robotic/laparoscopic/open), surgery type (elective/emergent/unknown), hospital volume and safety net burden by race/ethnicity, insurance and median household income are also shown in Supplementary Table 1. Black patients were less likely to receive laparoscopic procedure compared with white patients. Nonprivate insurance holders (Medicare, Medicaid, self-pay and other) had higher rates of open colectomy as compared with private insurance, with corresponding lower rates of laparoscopic and robotic colectomy. Further, with increasing income quartile, the rate of open colectomy decreased, while the rates of laparoscopic and robotic colectomies increased. In terms of surgery type, black patients were likely to get more elective and less emergent surgeries; Medicare and Medicaid patients were more likely to get emergent surgeries compared with private insurance patients; and patients from higher income quartiles were more likely to receive elective surgeries and less likely emergent. In terms of hospital volume, Hispanics were more likely to be admitted to smaller hospitals by volume compared with white patients; Medicare holders were more likely to be admitted to smaller hospitals compared with private insurance holders; and with increasing median income, rate of those admitted to higher hospital volume increased. In terms of safety net burden, black and Hispanic patients were more likely to get admitted to high safety net burden hospitals compared with white patients; Medicare patients were more likely to get admitted to high safety burden hospitals compared with private insurance holders; and people in the poorer income quartiles were more likely to be admitted to high safety net burden hospitals.

Overall adjusted multivariate outcomes

Results for adjusted multivariate outcomes for 30- and 90-day readmissions for all patients undergoing colectomy are shown in Table 5. All 30-day readmission rates were significantly higher for the black race (aOR: 1.07; 95% CI: 1.02–1.11) and significantly lower for patients classified as missing (aOR: 0.67; 95% CI: 0.60–0.76) or other race (aOR: 0.94; 95% CI: 0.90–0.99), when compared with the white race. All 90-day readmission rates were significantly lower for patients classified as missing (aOR: 0.71; 95% CI: 0.64–0.79) or other race (aOR: 0.88; 95% CI: 0.84–0.92), when compared with the white race. Both 30- and 90-day readmission rates were significantly

Table 3. Demographics, median income quartiles, primary payer status, and medical characteristics by 30- and 90-day readmissions.

Characteristic	Total population, n = 330,840	30-day readmission, n = 36,006	No 30-day readmission, n = 294,834	p-value	90-day readmission, n = 57,903	No 90-day readmission, n = 27,2937	p-value
Age (years)	61.3 ± 14.8	64.0 ± 15.7	61.0 ± 14.7	<0.001	64.0 ± 15.6	60.7 ± 14.6	0.000
Gender				<0.001			<0.001
– Male	157,753 (47.7%)	16,604 (46.1%)	141,149 (47.9%)		26,561 (45.9%)	131,192 (48.1%)	
– Female	173,087 (52.3%)	19,402 (53.9%)	153,685 (52.1%)		31,342 (54.1%)	141,745 (51.9%)	
Year				<0.001			<0.001
– 2009	60,511 (18.3%)	6980 (19.4%)	53,531 (18.2%)		11,323 (19.6%)	49,188 (18.0%)	
– 2010	65,197 (19.7%)	7276 (20.2%)	57,921 (19.6%)		11,625 (20.1%)	53,572 (19.6%)	
– 2011	64,558 (19.5%)	6931 (19.2%)	57,627 (19.5%)		11,101 (19.2%)	53,457 (19.6%)	
– 2012	48,093 (14.5%)	5086 (14.1%)	43,007 (14.6%)		8158 (14.1%)	39,935 (14.6%)	
– 2013	53,497 (16.2%)	5736 (15.9%)	47,761 (16.2%)		9170 (15.8%)	44,327 (16.2%)	
– 2014	38,984 (11.8%)	3997 (11.1%)	34,987 (11.9%)		6526 (11.3%)	32,458 (11.9%)	
Surgical subtype				0.000			0.000
– Laparoscopic	72,729 (22.0%)	6870 (19.1%)	65859 (22.3%)		10,959 (18.9%)	61,770 (22.6%)	
– Open	125,176 (37.8%)	21035 (58.4%)	104141 (35.3%)		34,777 (60.1%)	90,399 (33.1%)	
– Robotic	132,935 (40.2%)	8101 (22.5%)	124834 (42.3%)		12,167 (21.0%)	120,768 (44.2%)	
Hospital state				<0.001			<0.001
– California	63,439 (19.2%)	6754 (18.8%)	56685 (19.2%)		10,796 (18.6%)	52,643 (19.3%)	
– Florida	137,911 (41.7%)	15598 (43.3%)	122313 (41.5%)		25,164 (43.5%)	112,747 (41.3%)	
– Maryland	12,451 (3.76%)	1291 (3.59%)	11160 (3.79%)		2002 (3.46%)	10,449 (3.83%)	
– New York	117,039 (35.4%)	12363 (34.3%)	104676 (35.5%)		19,941 (34.4%)	97,098 (35.6%)	
Length of stay	4.00 (2.00–8.00)	8.00 (5.00–15.0)	4.00 (2.00–8.00)	0.000	8.00 (5.00–15.0)	4.00 (2.00–7.00)	0.000
Insurance payer status				0.000			0.000
– Medicaid	22,667 (6.85%)	3289 (9.13%)	19 378 (6.57%)		5140 (8.88%)	17,527 (6.42%)	
– Medicare	144,380 (43.6%)	19 625 (54.5%)	124,755 (42.3%)		31,460 (54.3%)	112,920 (41.4%)	
– Other	7758 (2.34%)	817 (2.27%)	6941 (2.35%)		1272 (2.20%)	6486 (2.38%)	
– Private insurance	147,204 (44.5%)	11,283 (31.3%)	135 921 (46.1%)		18,416 (31.8%)	128,788 (47.2%)	
– Self-pay/No charge	8831 (2.67%)	992 (2.76%)	7839 (2.66%)		1615 (2.79%)	7216 (2.64%)	
Race/ethnicity				<0.001			<0.001
– Black	33,009 (9.98%)	4138 (11.5%)	28 871 (9.79%)		6309 (10.9%)	26,700 (9.78%)	
– Hispanic	39,082 (11.8%)	4341 (12.1%)	34 741 (11.8%)		6874 (11.9%)	32,208 (11.8%)	
– Missing	4985 (1.51%)	350 (0.97%)	4635 (1.57%)		615 (1.06%)	4370 (1.60%)	
– Other	22,530 (6.81%)	2162 (6.00%)	20,368 (6.91%)		3343 (5.77%)	19,187 (7.03%)	
– White	231,234 (69.9%)	25015 (69.5%)	206,219 (69.9%)		40,762 (70.4%)	190,472 (69.8%)	
Household income quartile				<0.001			<0.001
– 1	69,628 (21.0%)	8678 (24.1%)	60,950 (20.7%)		13,769 (23.8%)	55,859 (20.5%)	
– 2	81,187 (24.5%)	9206 (25.6%)	71,981 (24.4%)		14,784 (25.5%)	66,403 (24.3%)	
– 3	87,816 (26.5%)	9117 (25.3%)	78,699 (26.7%)		14,789 (25.5%)	73,027 (26.8%)	
– 4	92,209 (27.9%)	9005 (25.0%)	83,204 (28.2%)		14,561 (25.1%)	77,648 (28.4%)	
Surgical type				0.000			0.000
– Elective	178,291 (53.9%)	14,798 (41.1%)	163,493 (55.5%)		22,593 (39.0%)	155,698 (57.0%)	
– Emergency	88,857 (26.9%)	14,432 (40.1%)	74,425 (25.2%)		24,473 (42.3%)	64,384 (23.6%)	
– Unknown	63,692 (19.3%)	6776 (18.8%)	56,916 (19.3%)		10,837 (18.7%)	52,855 (19.4%)	
Hospital volume				<0.001			<0.001
– First quartile	3736 (1.13%)	598 (1.66%)	3138 (1.06%)		940 (1.62%)	2796 (1.02%)	
– 2	22,015 (6.65%)	3088 (8.58%)	18,927 (6.42%)		5162 (8.91%)	16,853 (6.17%)	
– 3	58,670 (17.7%)	7342 (20.4%)	51,328 (17.4%)		12,180 (21.0%)	46,490 (17.0%)	

Table 3. Demographics, median income quartiles, primary payer status, and medical characteristics by 30- and 90-day readmissions (cont.).

Characteristic	Total population, n = 330,840	30-day readmission, n = 36,006	No 30-day readmission, n = 294,834	p-value	90-day readmission, n = 57,903	No 90-day readmission, n = 27,2937	p-value
– 4	246,419 (74.5%)	24,978 (69.4%)	221,441 (75.1%)		39,621 (68.4%)	206,798 (75.8%)	
Hospital safety net burden				<0.001			<0.001
– Low	85,286 (25.8%)	8849 (24.6%)	76,437 (25.9%)		14,366 (24.8%)	70,920 (26.0%)	
– Medium	169,959 (51.4%)	18,030 (50.1%)	15,1929 (51.5%)		29,143 (50.3%)	140,816 (51.6%)	
– High	75,595 (22.8%)	9127 (25.3%)	66,468 (22.5%)		14,394 (24.9%)	61,201 (22.4%)	
Elixhauser comorbidities							
– Congestive heart failure	11,937 (3.61%)	2867 (7.96%)	9070 (3.08%)	0.000	4449 (7.68%)	7488 (2.74%)	0.000
– Valvular disease	11,299 (3.42%)	1715 (4.76%)	9584 (3.25%)	<0.001	2749 (4.75%)	8550 (3.13%)	<0.001
– Pulmonary/circulatory disorder	3419 (1.03%)	715 (1.99%)	2704 (0.92%)	<0.001	1145 (1.98%)	2274 (0.83%)	<0.001
– Peripheral vascular disorder	12,473 (3.77%)	2607 (7.24%)	9866 (3.35%)	<0.001	4085 (7.05%)	8388 (3.07%)	0.000
– Hypertension, uncomplicated	147,340 (44.5%)	16,550 (46.0%)	130,790 (44.4%)	<0.001	26,591 (45.9%)	120,749 (44.2%)	<0.001
– Hypertension, complicated	18,431 (5.57%)	3865 (10.7%)	14,566 (4.94%)	0.000	6097 (10.5%)	12,334 (4.52%)	0.000
– Paralysis	1388 (0.42%)	338 (0.94%)	1050 (0.36%)	<0.001	554 (0.96%)	834 (0.31%)	<0.001
– Other neurological disease	8894 (2.69%)	1555 (4.32%)	7339 (2.49%)	<0.001	2518 (4.35%)	6376 (2.34%)	<0.001
– Chronic pulmonary disease	45,143 (13.6%)	6709 (18.6%)	38,434 (13.0%)	<0.001	10,859 (18.8%)	34,284 (12.6%)	0.000
– Diabetes, uncomplicated	50,722 (15.3%)	6866 (19.1%)	43,856 (14.9%)	<0.001	10,888 (18.8%)	39,834 (14.6%)	<0.001
– Diabetes, complicated	4459 (1.35%)	950 (2.64%)	3509 (1.19%)	<0.001	1457 (2.52%)	3002 (1.10%)	<0.001
– Hypothyroidism	32,950 (9.96%)	4098 (11.4%)	28,852 (9.79%)	<0.001	6566 (11.3%)	26,384 (9.67%)	<0.001
– Renal failure	17,731 (5.36%)	3851 (10.7%)	13,880 (4.71%)	0.000	6008 (10.4%)	11,723 (4.30%)	0.000
– Liver disease	5898 (1.78%)	947 (2.63%)	4951 (1.68%)	<0.001	1508 (2.60%)	4390 (1.61%)	<0.001
– Peptic ulcer disease	144 (0.04%)	28 (0.08%)	116 (0.04%)	0.002	43 (0.07%)	101 (0.04%)	<0.001
– HIV	312 (0.09%)	80 (0.22%)	232 (0.08%)	<0.001	123 (0.21%)	189 (0.07%)	<0.001
– Lymphoma	2293 (0.69%)	504 (1.40%)	1789 (0.61%)	<0.001	778 (1.34%)	1515 (0.56%)	<0.001
– Metastatic cancer	32,370 (9.78%)	5243 (14.6%)	27,127 (9.20%)	<0.001	8938 (15.4%)	23,432 (8.59%)	0.000
– Solid tumor without metastasis	146,736 (44.4%)	14,749 (41.0%)	131,987 (44.8%)	<0.001	23,639 (40.8%)	123,097 (45.1%)	<0.001
– Rheumatoid arthritis	6848 (2.07%)	1103 (3.06%)	5745 (1.95%)	<0.001	1785 (3.08%)	5063 (1.86%)	<0.001
– Coagulopathy	5554 (1.68%)	1138 (3.16%)	4416 (1.50%)	<0.001	1830 (3.16%)	3724 (1.36%)	<0.001
– Obesity	42,111 (12.7%)	4803 (13.3%)	37,308 (12.7%)	<0.001	7678 (13.3%)	34,433 (12.6%)	<0.001
– Weight loss	13,478 (4.07%)	2873 (7.98%)	10,605 (3.60%)	0.000	4665 (8.06%)	8813 (3.23%)	0.000
– Fluid and electrolyte disorder	29,489 (8.91%)	5696 (15.8%)	23,793 (8.07%)	0.000	9385 (16.2%)	20,104 (7.37%)	0.000
– Blood loss	7031 (2.13%)	1094 (3.04%)	5937 (2.01%)	<0.001	1742 (3.01%)	5289 (1.94%)	<0.001
– Deficiency anemia	42,586 (12.9%)	6939 (19.3%)	35,647 (12.1%)	<0.001	11,258 (19.4%)	31,328 (11.5%)	0.000
– Alcohol abuse	5861 (1.77%)	883 (2.45%)	4978 (1.69%)	<0.001	1548 (2.67%)	4313 (1.58%)	<0.001
– Drug abuse	3058 (0.92%)	565 (1.57%)	2493 (0.85%)	<0.001	920 (1.59%)	2138 (0.78%)	<0.001
– Psychosis	5889 (1.78%)	1040 (2.89%)	4849 (1.64%)	<0.001	1742 (3.01%)	4147 (1.52%)	<0.001
– Depression	24,918 (7.53%)	3359 (9.33%)	21,559 (7.31%)	<0.001	5337 (9.22%)	19,581 (7.17%)	<0.001

Table 4. Unadjusted rates for 30- and 90-day readmissions by race/ethnicity, insurance and median income.

Characteristic	30-day readmission rate (%) n = 36,006	90-day readmission rate (%) n = 57,903
Race/ethnicity		
– White (n = 231,234)	25,015 (10.8%)	40,762 (17.6%)
– Black (n = 33,009)	4138 (12.5%)	6309 (19.1%)
– Hispanic (n = 39,082)	4341 (11.1%)	6874 (17.6%)
– Missing (n = 4985)	350 (7.02%)	615 (12.3%)
– Other (n = 22,530)	2162 (9.60%)	3343 (14.8%)
Insurance		
– Private (n = 147,204)	11,283 (7.66%)	18,416 (12.5%)
– Medicare (n = 144,380)	19,625 (13.6%)	31,460 (21.8%)
– Medicaid (n = 22,667)	3289 (14.5%)	5140 (22.7%)
– Self-pay (n = 8831)	992 (11.2%)	1615 (18.3%)
– Other (n = 7758)	817 (10.5%)	1272 (16.4%)
Median household income		
– First quartile (n = 69,628)	8678 (12.5%)	13,769 (19.8%)
– Second quartile (n = 81,187)	9206 (11.3%)	14,784 (18.2%)
– Third quartile (n = 87,816)	9117 (10.4%)	14,789 (16.8%)
– Fourth quartile (n = 92,209)	9005 (9.77%)	14,561 (15.8%)

All statistics have p-values of <0.05.

Table 5. Adjusted odds for 30- and 90-day readmission rates among patients undergoing colectomy by race/ethnicity, insurance and median income.

Characteristic	30-day readmission aOR (95% CI)	90-day readmission aOR (95% CI)
Race/ethnicity		
– White (reference)	1.00	1.00
– Black	1.07 (1.02–1.11) [†]	0.99 (0.96–1.03)
– Hispanic	1.02 (0.98–1.07)	0.99 (0.96–1.03)
– Missing	0.67 (0.60–0.76) [†]	0.71 (0.64–0.79) [†]
– Other	0.94 (0.90–0.99) [†]	0.88 (0.84–0.92) [†]
Insurance		
– Private (reference)	1.00	1.00
– Medicare	1.29 (1.24–1.35) [†]	1.28 (1.24–1.33) [†]
– Medicaid	1.31 (1.24–1.38) [†]	1.26 (1.20–1.33) [†]
– Self-pay	0.97 (0.90–1.05)	0.92 (0.87–0.98) [†]
– Other	1.09 (1.01–1.18) [†]	1.02 (0.95–1.09)
Median household income		
– First quartile (reference)	1.00	1.00
– Second quartile	0.99 (0.95–1.02)	0.99 (0.96–1.02)
– Third quartile	0.94 (0.91–0.98) [†]	0.96 (0.94–0.99) [†]
– Fourth quartile	0.93 (0.90–0.97) [†]	0.95 (0.92–0.99) [†]

Generalized estimating equation models were generated and were adjusted for the following: age, sex, race, insurance payer status, median income level, Elixhauser Comorbidity Index, year of surgery, state of surgery, hospital volume and type of surgery (open, laparoscopic and robotic). Table only depicts the variables of interest: race, insurance payer status and median income level.

[†]p ≤ 0.05.

aOR: Adjusted odds ratio.

higher for Medicaid (30-day aOR: 1.31; 95% CI: 1.24–1.38; 90-day aOR 1.26; 95% CI: 1.20–1.33) and Medicare insurance (30-day aOR: 1.29; 95% CI: 1.24–1.35; 90-day aOR: 1.28; 95% CI: 1.24–1.33) compared with private insurance. All 90-day readmission rates were significantly lower for self-pay (aOR: 0.92; 95% CI: 0.87–0.98) compared with private insurance. Both 30- and 90-day readmission rates were significantly lower for patients in the two highest income quartiles compared with those in the lowest income quartile (fourth quartile 30-day aOR:

0.93; 95% CI: 0.90–0.97; third quartile 30-day aOR: 0.94; 95% CI: 0.91–0.98; fourth quartile 90-day aOR: 0.95; 95% CI: 0.92–0.99; third quartile 90-day aOR: 0.96; 95% CI: 0.94–0.99).

Exploratory outcomes: stratified subgroup analysis of open, laparoscopic & robotic colectomy

Results for adjusted multivariate readmission outcomes for patients stratified by open, laparoscopic and robotic colectomy are shown in Table 6. As stated previously, due to possible limitations in statistical power for this subgroup analysis, these models were intended only to serve as a collaborative trend analysis to supplement the main findings. For open colectomy patients, we found that 30-day readmissions were significantly higher for black versus the white race; significantly lower for missing and other versus the white race; significantly higher for Medicare and Medicaid versus private insurance; and no association was seen for median household income level and readmissions. In laparoscopic colectomy patients, 30-day readmission rates were not affected by black and Hispanic race/ethnicity; significantly higher for Medicare and Medicaid insurance versus private insurance; and significantly lower for patients in the two highest income quartiles compared with those in the lowest income quartile. For robotic colectomy patients, 30-day readmission rates were not affected by black and Hispanic race/ethnicity; significantly higher for Medicare and Medicaid insurance versus private insurance; and significantly lower in the highest income quartile compared with those in the lowest income quartile. Similar trends were seen for 90-day readmissions for all surgical technique subgroups.

Interaction models: race/ethnicity & insurance payer status; insurance payer status & median income; & race/ethnicity & median income

Models including interaction terms of race and primary insurance provided a better fit than the main models for 30- and 90-day readmissions (Table 7). In contrast, models based on the interaction of race/ethnicity and median household income and on the interaction of insurance and median household income were not a better fit than the main models for 30- and 90-day readmissions.

Sensitivity analysis

To further support our findings, we ran our main model with additional variables, hospital safety net burden and surgery type (emergent vs elective). Results for adjusted multivariate outcomes for 30-day and 90-day readmissions are shown in Supplementary Table 2. We noted that for 30-day and 90-day readmissions, same trends were noted with respect to race/ethnicity, insurance and median household income as compared with our initial results without additional variables. For hospital volume, we found that with increasing volume, the likelihood of readmissions decreased; statistical significance was noted for second and third quartile versus reference first quartile. Although trends of increasing readmissions were noted with increasing safety net burden, no statistical significance was achieved. For surgical subtype, laparoscopic and robotic procedures both had significantly less odds of readmissions compared with open procedures (30-day aOR: 0.79; 95% CI: 0.86–0.82; 30-day aOR: 0.84; 95% CI: 0.80–0.89). At last, for surgery type, it was noted that 90-day readmissions were increased when comparing emergency versus elective surgery.

Discussion

This study demonstrates that a statistically significant increase in adjusted odds for hospital readmission at 30- and 90-days exists for patients of low SES after colectomy. The results showed that each patient-level factor studied – race/ethnicity, insurance status and median income level – represents an independent risk factor for hospital readmission. After adjustment for possible confounders, we found that the odds of readmission within 30 days of discharge were increased for patients of the black race compared with the white race; for patients under Medicare, Medicaid and other nonprivate insurances compared with those under private insurance; and for patients with lower income levels compared with those with higher income levels. At 90 days, similar findings were seen with the exception that the black race no longer increased the odds of readmission. Trends were also noted in the subgroup analysis which further supports the consistency and robustness of the findings. At last, our interaction study showed that there is a significant interaction between race/ethnicity and insurance status – specifically, being black or Hispanic and having Medicaid or Medicare increased the odds of both 30- and 90-day readmissions compared with being white with private insurance. This study provides a current and comprehensive multivariate analysis of colectomy outcomes in relation to social determinants of health.

Table 6. Adjusted odds for 30- and 90-day readmission rates among patients undergoing colectomy by race/ethnicity, insurance and median income – stratified by surgical subtype.

	30-day readmission aOR (95% CI)	90-day readmission aOR (95% CI)
Surgical subtype: open (n = 125,176)		
Race/ethnicity		
– White race (reference)	1.00	1.00
– Black	1.09 (1.04–1.15) [†]	1.01 (0.96–1.06)
– Hispanic	1.04 (0.99–1.09)	0.99 (0.95–1.04)
– Missing	0.72 (0.62–0.84) [†]	0.74 (0.64–0.85) [†]
– Other	0.94 (0.88–1.00) [†]	0.87 (0.82–0.93) [†]
Insurance		
– Private insurance (reference)	1.00	1.00
– Medicare	1.28 (1.21–1.34) [†]	1.17 (1.12–1.22) [†]
– Medicaid	1.28 (1.21–1.36) [†]	1.14 (1.08–1.20) [†]
– Self-pay	0.98 (0.90–1.07)	0.85 (0.79–0.92) [†]
– Other	1.06 (0.96–1.17)	0.92 (0.84–1.02)
Median household income		
– First quartile (reference)	1.00	1.00
– Second quartile	1.01 (0.96–1.06)	1.02 (0.98–1.06)
– Third quartile	0.96 (0.91–1.00)	0.99 (0.95–1.03)
– Fourth quartile	0.96 (0.91–1.01)	1.00 (0.96–1.04)
Surgical subtype: laparoscopic (n = 72,729)		
Race/ethnicity		
– White race (reference)	1.00	1.00
– Black	1.06 (0.95–1.18)	1.00 (0.92–1.09)
– Hispanic	1.03 (0.94–1.12)	1.01 (0.94–1.09)
– Missing	0.60 (0.46–0.79) [†]	0.70 (0.56–0.86) [†]
– Other	0.96 (0.86–1.07)	0.90 (0.82–0.98) [†]
Insurance		
– Private (reference)	1.00	1.00
– Medicare	1.28 (1.19–1.38) [†]	1.27 (1.18–1.36) [†]
– Medicaid	1.27 (1.12–1.44) [†]	1.32 (1.17–1.48) [†]
– Self-pay	1.06 (0.86–1.30)	1.11 (0.94–1.32)
– Other	1.35 (1.10–1.67) [†]	1.23 (1.02–1.49) [†]
Median household income		
– First quartile (reference)	1.00	1.00
– Second quartile	0.96 (0.89–1.04)	0.96 (0.90–1.03)
– Third quartile	0.90 (0.82–0.98) [†]	0.93 (0.86–0.99) [†]
– Fourth quartile	0.90 (0.82–0.98) [†]	0.91 (0.85–0.98) [†]
Surgical subtype: robotic (n = 132,935)		
Race/ethnicity		
– White (reference)	1.00	1.00
– Black	1.03 (0.95–1.13)	0.97 (0.90–1.04)
– Hispanic	0.94 (0.87–1.02)	0.94 (0.87–1.01)
– Missing	0.59 (0.45–0.77) [†]	0.64 (0.54–0.77) [†]
– Other	0.88 (0.81–0.97) [†]	0.84 (0.78–0.90) [†]
Insurance		
– Private insurance (reference)	1.00	1.00
– Medicare	1.30 (1.20–1.41) [†]	1.46 (1.36–1.57) [†]
– Medicaid	1.45 (1.31–1.60) [†]	1.52 (1.39–1.66) [†]
Generalized estimating equation models were generated and were adjusted for the following: age, sex, race, insurance payer status, median income level, Elixhauser Comorbidity Index, year of surgery, state of surgery, hospital volume and type of surgery (open, laparoscopic and robotic). Table only depicts the variables of interest: race, insurance payer status and median income level.		
[†] p ≤ 0.05.		

Table 6. Adjusted odds for 30- and 90-day readmission rates among patients undergoing colectomy by race/ethnicity, insurance and median income – stratified by surgical subtype (cont.).

	30-day readmission aOR (95% CI)	90-day readmission aOR (95% CI)
– Self-pay	0.93 (0.76–1.14)	0.98 (0.84–1.14)
– Other	1.02 (0.87–1.20)	1.08 (0.94–1.23)
Median household income		
– First quartile (reference)	1.00	1.00
– Second quartile	0.96 (0.89–1.03)	0.95 (0.90–1.01)
– Third quartile	0.94 (0.89–1.01)	0.92 (0.87–0.98) [†]
– Fourth quartile	0.89 (0.83–0.95) [†]	0.87 (0.82–0.92) [†]

Generalized estimating equation models were generated and were adjusted for the following: age, sex, race, insurance payer status, median income level, Elixhauser Comorbidity Index, year of surgery, state of surgery, hospital volume and type of surgery (open, laparoscopic and robotic). Table only depicts the variables of interest: race, insurance payer status and median income level.

[†]p ≤ 0.05.

Table 7. Race/ethnicity by insurance interaction effects.

Outcome	Significant (p < 0.05) interaction terms	Reference category	Linear combination OR (95% CI)	p-value
30-day readmissions	Black race + Medicaid insurance	White race + private insurance	1.39 (1.27–1.52)	<0.0001
30-day readmissions	Black race + Medicare insurance	White race + private insurance	1.43 (1.34–1.53)	<0.0001
30-day readmissions	Hispanic ethnicity + Medicaid insurance	White race + private insurance	1.23 (1.13–1.35)	<0.0001
30-day readmissions	Hispanic ethnicity + Medicare insurance	White race + private insurance	1.35 (1.26–1.45)	<0.0001
30-day readmissions	Other race + Medicaid insurance	White race + private insurance	1.18 (1.02–1.37)	0.0260
30-day readmissions	Other race + Medicare insurance	White race + private insurance	1.17 (1.08–1.27)	<0.0001
30-day readmissions	Other race + self-pay	White race + private insurance	0.67 (0.46–0.99)	0.0422
90-day readmissions	Black race + Medicaid insurance	White race + private insurance	1.27 (1.17–1.37)	<0.0001
90-day readmissions	Black race + Medicare insurance	White race + private insurance	1.34 (1.27–1.41)	<0.0001
90-day readmissions	Hispanic ethnicity + Medicaid insurance	White race + private insurance	1.18 (1.09–1.29)	0.0001
90-day readmissions	Hispanic ethnicity + Medicare insurance	White race + private insurance	1.30 (1.22–1.38)	<0.0001
90-day readmissions	Hispanic ethnicity + self-pay	White race + private insurance	0.85 (0.75–0.96)	0.0082
90-day readmissions	Missing race + self-pay	White race + private insurance	0.49 (0.25–0.95)	0.0354
90-day readmissions	Other race + Medicare insurance	White race + private insurance	1.10 (1.02–1.18)	0.0156
90-day readmissions	Other race + self-pay	White race + private insurance	0.63 (0.46–0.85)	0.0027

OR: Odds ratio.

Our study is consistent with previous studies showing association between low SES and worse outcomes in colectomy patients. It has been well established that patients of the black race perform poorer postoperatively after colectomy. Hendren *et al.*, in a cohort of 477,461 colectomy patients, identified the black race as an independent risk factor for increased 30-day readmissions [21]. Damle *et al.*, in a cohort of 82,474 patients undergoing colectomy, identified that black patients were more likely to be readmitted specifically with open surgery [18]. Several other studies have also identified the association [10,20,29,30]. We hypothesized that patients who are black and Hispanic, who are of lower SES, will have higher odds of readmissions; however, our data showed that there is only association between the black race and readmissions, but no association between Hispanic ethnicity and readmissions. This may be explained by the ‘Hispanic Paradox,’ a paradox in which Hispanics have a mortality-advantage over non-Hispanic whites [42,43]. Several factors have proposed to contribute to this phenomenon – selective return of less healthy immigrants to their native country [43], lower rates of smoking and hypertension in the Hispanic population [42], and the heterogeneity of medical outcomes among multiple generations of the Hispanic population [44]. It is also important to note the significant decrease in readmissions for patients of ‘other’ race – which includes Asians, Pacific Islanders, Native Americans and others. This trend was also noted in a study by Basu *et al.*, looking at all-cause readmissions for 7,306,286 patients, which may suggest a generalizable association between patients of other race and lower readmissions [45]. Statistical significance was not seen in our stratified analysis comparing black versus white for readmissions in laparoscopic and robotic surgical cohorts; we believe the trend is consistent with

the main findings, but not statistically significant due to inadequate statistical power for the exploratory stratified analysis. However, based on the stratified data, we suggest that the racial disparity is greater for those undergoing open colectomy than it is for those undergoing laparoscopic or robotic surgeries. We further note the evidence of patient selection bias by race and ethnicity for the different surgical procedures.

In terms of insurance, numerous studies have highlighted the underinsured status of nonprivate insurances, particularly those of Medicaid and Medicare. For example, Bliss *et al.*, in a cohort of 93,913 patients from 2007 to 2011, showed that patients with Medicare or Medicaid were more likely to be readmitted than those with private insurance [10]. Sastow *et al.*, in a cohort of 444,877, also identified that Medicaid and Medicare patients had higher odds of being readmitted compared with private insurance holders [28]. We also report that at 30 days, nonprivate insurance payer status increased the odds of readmissions. One notable exception was for patients who were self paying, which was not associated with an increase in readmissions; this might be explained by the speculation that uninsured patients have a strong financial barrier to readmission even when necessary. At 90 days, we further observed that self-pay patients showed a greater, statistically significant, decrease in readmissions.

At last, our study observed a significant reduction in readmissions for patients in the upper quartiles of median income, implicating that the converse is true – that patients with poorer income are at increased risk for worse surgical outcomes and increased readmissions. Fry *et al.*, evaluating a cohort of 86,624 patients, concluded that disparity in outcomes exist across different geographical regions with varying SES, including median income level [19]. Although there are numerous studies looking at the socioeconomic disparities in surgical outcomes such as in-hospital mortality, complications and type of surgery performed, there are limited studies looking at the association between income and readmissions [17,23,26]. Notably, in our stratified analysis, the relationship between median income and readmissions was not observed for the open colectomy cohort. Nonetheless, there was a decreasing trend with increasing income for all surgical subtypes – with statistical significance for laparoscopic and robotic groups – which may suggest that the relationship exists but our post-stratification models may lack sufficient statistical power.

Several relationships in our analysis between social determinants of health, type of surgeries, hospital volume, hospital safety net burden and readmissions can be highlighted for possible causal pathways. For race and readmissions, we identified that black patients were more likely to be readmitted for the following possible causal pathways: black patients were more likely to undergo nonlaparoscopic surgeries, more likely to be initially admitted to high safety net burden hospitals and more likely to undergo emergent surgeries ([Supplementary Table 1](#)); each of these three factors were associated with increased odds of readmissions ([Supplementary Table 2](#)) [4,20,23,31]. It is also worthy to highlight the following possible causal pathways between insurance and readmissions: nonprivate insurance holders were more likely to receive open surgeries, nonprivate insurance holders were more likely to receive emergent surgeries, Medicaid patients were less likely to be admitted to hospitals within largest volume quartile and Medicare patients were less likely to be admitted to hospitals among second and third quartile hospital volumes, and five Medicare patients were more likely to be admitted to high safety net burden hospitals ([Supplementary Table 1](#)), and each of these factors were associated with higher odds of readmissions ([Supplementary Table 2](#)) [8,19,28,30,31,45–47]. Notably, these insurance status findings remained robust even after analysis was performed stratified by surgical subtype – pointing to other intrinsic differences between these insurance cohorts and care received [6,10,24,28,46,47]. In terms of household income, it was notable that as median income decreases the rate of open colectomies increases, the rate of emergent surgeries increases, patients are more likely to be admitted to smaller hospitals, the rate of high safety net burden increases ([Supplementary Table 1](#)) and each of these factors were associated with increased odds of readmissions ([Supplementary Table 2](#)) [5,26,27,30]. These above associations provide a possible connection between individual studies that have described some relationships between studied variables and readmissions [18,36,38,40,41].

As policies are made at both federal- and hospital-level to decrease readmissions and associated costs, it is imperative to fully understand which patients are at higher risk for readmission. By identifying higher-risk patients, resources can be more effectively allocated and prevent readmission risks posed by these factors. In 2010, the Hospital Readmissions Reduction Program (HRRP) was implemented by the Affordable Care Act with a clearly stated goal – to reduce the number of readmissions to hospitals after discharge [48]. The program mandates that hospitals are financially penalized for more than expected readmission rates within 30 days for selected surgeries. The Centers for Medicare & Medicaid Services adjusts expected readmission rates for factors such as age and overall health of the patient population, but the HRRP does not yet incorporate other significant socioeconomic factors such as race and median income level – which the present study demonstrates in a large cohort including data

after the implementation of HRRP. Without complete adjustment, it is possible that certain hospitals, such as minority-serving or high safety-net burden hospitals become more vulnerable to financial penalties as they serve more patients with increased odds of readmissions [5,6,31].

Since the implementation of HRRP, thousands of hospitals have been penalized through reduced Medicare payments, with total penalties in the hundreds of millions of dollars [49,50]. In response, hospitals have engaged large efforts to reduce readmissions via institution of guidelines and policies – improved patient education; transition coordination at discharge; reformed medication reconciliation; and social, financial and logistical support for patients of low SES [51]. However, some evidence suggests that some methods used by hospitals to lower readmissions may cause harm to patients, such as sending patients home after treatment in the emergency department or observation unit rather than readmitting them [52]. Indeed, denial of the lifesaving readmissions has been suggested as a probable contributor to increased death rates among patients [53,54]. As the HRRP begins to include more diagnoses and procedures, including colectomy, we suggest that the HRRP should adjust for all significant variables that affect readmissions in order to fairly allocate resources without compromising patient safety.

Our study presents with multiple strengths. First, the SID data has been validated and verified by quality control measures, and its data represents of about 97% of the total US hospitalizations; the states included in our analysis represent more than a quarter of total US population [34]. The study utilizes the most current data, and the states included are demographically and geographically diverse [34]. The study also has a number of limitations. Despite efforts to remove confounding, there is risk of selection bias in this observational retrospective study. The SID data lacks important medical information that may affect readmissions and outcome in colectomy patients; this information may include lab results and imaging results, which have not been incorporated in the analysis. There are also other socioeconomic factors that influence readmissions such as education, diet and treatment noncompliance that this study cannot adjust for. At last, there are potential raw data errors, such as errors in administrative data collection and data input/coding. We also recognize that this study does not address the causality of its findings. Although this study shows existing generalizable risk for low SES and surgical outcomes, these risks may not be easily modifiable without identifying the underlying cause of the observed disparities.

Conclusion

In conclusion, our findings suggest that race/ethnicity, primary payer status and median household income level are all independent predictors of disparity in readmissions and should be considered as preoperative risk factors for increased readmissions. Additionally, we found significant interaction effects between race/ethnicity and primary payer status, highlighting the intersectionality of patient level social determinants of health. Implementation of protocols or programs targeted at these increased risk populations could potentially conserve healthcare costs related to readmissions. Finally, protocols and programs that aim to reduce readmissions by penalizing hospitals should adjust for these risk factors to avoid unfairly penalizing hospitals serving economically or socially vulnerable patient populations.

Summary points

- Social determinants of health including race/ethnicity, median household income and insurance status independently affect readmission rates in colectomy cohort.
- For race, black patients had statistically higher odds of being readmitted after colectomy. Possible causal pathways include black patients being more likely to undergo nonlaparoscopic procedures, more likely to be admitted to high safety net burden hospitals, and more likely to undergo emergent surgeries, which independently had higher odds of readmissions.
- For insurance, Medicare and Medicaid patients had higher odds of being readmitted after colectomy. Possible causal pathways include nonprivate insurance holders having higher rates of open surgeries and emergent surgeries, both of which had higher odds of readmissions. Medicare and Medicaid patients were also shown to have higher rates of admissions to smaller volume hospitals, which had higher odds of readmissions.
- For median household income, patients with richer income were less likely to be readmitted after colectomy. Possible causal pathways include patient with poorer income being more likely to receive open colectomies, more likely to receive emergent surgeries, and more likely to be admitted to smaller volume hospitals with high safety net burden, all of which had higher odds of readmissions independently.
- Hospital Readmission Reduction Program and enhanced recovery after surgery should understand and apply all aspects of social determinants of health when making policies and protocols to address postcolectomy outcomes and readmissions.

Supplementary data

To view the supplementary data that accompany this paper please visit the journal website at: www.futuremedicine.com/doi/full/10.2217/ce-2019-0114

Financial & competing interests disclosure

The authors have no relevant affiliations or financial involvement with any organization or entity with a financial interest in or financial conflict with the subject matter or materials discussed in the manuscript. This includes employment, consultancies, honoraria, stock ownership or options, expert testimony, grants or patents received or pending, or royalties.

No writing assistance was utilized in the production of this manuscript.

Ethical conduct of research

The authors state that they have obtained appropriate institutional review board approval or have followed the principles outlined in the Declaration of Helsinki for all human or animal experimental investigations. In addition, for investigations involving human subjects, informed consent has been obtained from the participants involved.

References

Papers of special note have been highlighted as: ● of interest; ●● of considerable interest

- Kocher RP, Adashi EY. Hospital readmissions and the Affordable Care Act: paying for coordinated quality care. *JAMA* 306(16), 1794–1795 (2011).
- Wasfy JH, Zigler CM, Choirat C, Wang Y, Dominici F, Yeh RW. Readmission rates after passage of the hospital readmissions reduction program: a pre-post analysis. *Ann. Intern. Med.* 166(5), 324–331 (2017).
- Zuckerman RB, Sheingold SH, Orav EJ, Ruhter J, Epstein AM. Readmissions, observation, and the hospital readmissions reduction program. *N. Engl. J. Med.* 374(16), 1543–1551 (2016).
- Arroyo NS, White RS, Gaber-Baylis LK, La M, Fisher AD, Samaru M. Racial/ethnic and socioeconomic disparities in total knee arthroplasty 30- and 90-day readmissions: a multi-payer and multistate analysis, 2007–2014. *Popul. Health Manag.* 22(2), 175–185 (2019).
- Feng TR, White RS, Gaber-Baylis LK, Turnbull ZA, Rong LQ. Coronary artery bypass graft readmission rates and risk factors – a retrospective cohort study. *Int. J. Surg.* 54(Pt A), 7–17 (2018).
- White RS, Sastow DL, Gaber-Baylis LK, Tangel V, Fisher AD, Turnbull ZA. Readmission rates and diagnoses following total hip replacement in relation to insurance payer status, race and ethnicity, and income status. *J. Racial Ethn. Health Disparities* 5(6), 1202–1214 (2018).
- Institute of Medicine (U.S.). Committee on the changing market managed care and the future viability of safety net providers. *America's Health Care Safety Net: Intact But Endangered*. Lewin ME, Altman SH (Eds). Institute of Medicine, National Academy Press, Washington DC, USA (2000).
- Chang AL, Kim Y, Ertel AE *et al.* Case mix adjusted cost of colectomy at low-, middle-, and high -volume academic centers. *Surgery* 161(5), 1405–1413 (2017).
- Fu R, Brown H, Francis DM. Comparison of characteristics and hospital costs in patients undergoing open, laparoscopic, and robotic-assisted colectomy. *Value Health* 19(3), A313–A313 (2016).
- Bliss LA, Maguire LH, Chau ZL *et al.* Readmission after resections of the colon and rectum: predictors of a costly and common outcome. *Dis. Colon Rectum* 58(12), 1164–1173 (2015).
- Kassin MT, Owen RM, Perez SD *et al.* Risk factors for 30-day hospital readmission among general surgery patients. *J. Am. Coll. Surg.* 215(3), 322–330 (2012).
- Schilling PL, Dimick JB, Birkmeyer JD. Prioritizing quality improvement in general surgery. *J. Am. Coll. Surg.* 207(5), 698–704 (2008).
- Borzellino G, Francis NK, Chapuis O, Krastinova E, Dyeve V, Genna M. Role of epidural analgesia within an ERAS program after laparoscopic colorectal surgery: a review and meta-analysis of randomised controlled studies. *Surg. Res. Pract.* 2016, 7543684 (2016).
- Haverkamp MP, De Roos MA, Ong KH. The ERAS protocol reduces the length of stay after laparoscopic colectomies. *Surg. Endosc.* 26(2), 361–367 (2012).
- Roulin D, Blanc C, Muradbegovic M, Hahnloser D, Demartines N, Hubner M. Enhanced recovery pathway for urgent colectomy. *World J. Surg.* 38(8), 2153–2159 (2014).
- Varadhan KK, Neal KR, Dejong CH, Fearon KC, Ljungqvist O, Lobo DN. The enhanced recovery after surgery (ERAS) pathway for patients undergoing major elective open colorectal surgery: a meta-analysis of randomized controlled trials. *Clin. Nutr.* 29(4), 434–440 (2010).
- **Highlights the significance of development of enhanced recovery after surgery protocols in reducing length of stay and complication rates after major elective open colorectal surgery without compromising patient safety.**

17. Birkmeyer NJO, Gu N, Baser O, Morris AM, Birkmeyer JD. Socioeconomic status and surgical mortality in the elderly. *Med. Care* 46(9), 893–899 (2008).
18. Damle RN, Flahive JM, Davids JS, Maykel JA, Sturrock PR, Alavi K. Examination of racial disparities in the receipt of minimally invasive surgery among a national cohort of adult patients undergoing colorectal surgery. *Dis. Colon Rectum* 59(11), 1055–1062 (2016).
- **This study, using 82,474 patient cohort, identified racial difference in the receipt of a minimally invasive approach for colorectal surgeries. This study identified the black race having lower likelihood of receiving minimally invasive surgery.**
19. Fry DE, Nedza SM, Pine M, Reband AM, Huang CJ, Pine G. Risk-adjusted regional outcomes in elective medicare colorectal surgery. *Am. J. Surg.* 215(3), 430–433 (2018).
20. Girotti ME, Shih T, Revels S, Dimick JB. Racial disparities in readmissions and site of care for major surgery. *J. Am. Coll. Surg.* 218(3), 423–430 (2014).
21. Hendren S, Morris AM, Zhang WY, Dimick J. Early discharge and hospital readmission after colectomy for cancer. *Dis. Colon Rectum* 54(11), 1362–1367 (2011).
22. Lapar DJ, Bhamidipati CM, Mery CM *et al.* Primary payer status affects mortality for major surgical operations. *Ann. Surg.* 252(3), 544–550 (2010).
- **Evaluates 893,658 major operations to identify that Medicaid and uninsured payer status confers increased risk-adjusted mortality.**
23. Lassiter RL, Talukder A, Abrams MM, Adam BL, Albo D, White CQ. Racial disparities in the use of laparoscopic surgery to treat colonic diverticulitis are not fully explained by socioeconomics or disease complexity. *Am. J. Surg.* 213(4), 673–677 (2017).
24. Lidor AO, Gearhart SL, Wu AW, Chang DC. Effect of race and insurance status on presentation, treatment, and mortality in patients undergoing surgery for diverticulitis. *Arch. Surg. Chicago* 143(12), 1160–1165 (2008).
25. Mulhern KC, Wahl TS, Goss LE *et al.* Reduced disparities and improved surgical outcomes for Asian Americans with colorectal cancer. *J. Surg. Res.* 218, 23–28 (2017).
26. Nguyen GC, Laveist TA, Gearhart S, Bayless TM, Brant SR. Racial and geographic variations in colectomy rates among hospitalized ulcerative colitis patients. *Clin. Gastroenterol. Hepatol.* 4(12), 1507–1513 (2006).
27. Sadler MD, Ravindran NC, Hubbard J *et al.* Predictors of mortality among patients undergoing colectomy for ischemic colitis: a population-based, United States study. *Can. J. Gastroenterol.* 28(11), 600–604 (2014).
28. Sastow DL, White RS, Mauer E, Chen Y, Gaber-Baylis LK, Turnbull ZA. The disparity of care and outcomes for Medicaid patients undergoing colectomy. *J. Surg. Res.* 235, 190–201 (2019).
29. Schneider EB, Haider AH, Hyder O, Efron JE, Lidor AO, Pawlik TM. Assessing short- and long-term outcomes among black vs white Medicare patients undergoing resection of colorectal cancer. *Am. J. Surg.* 205(4), 402–408 (2013).
30. Tsai TC, Orav EJ, Joynt KE. Disparities in surgical 30-day readmission rates for medicare beneficiaries by race and site of care. *Ann. Surg.* 259(6), 1086–1090 (2014).
- **This study, using a cohort of 444,877, identified Medicaid and Medicare holders to have higher odds of being readmitted compared with private insurance holders.**
31. La M, Tangel V, Gupta S, Tedore T, White RS. Hospital safety net burden is associated with increased inpatient mortality and postoperative morbidity after total hip arthroplasty: a retrospective multistate review, 2007–2014. *Reg. Anesth. Pain Med.* doi:10.1136/rapm-2018-100305 (2019) (Epub ahead of print).
- **This study using a 500,189 patient discharge records using the Healthcare Cost and Utilization Project data identified that among patients undergoing total hip arthroplasty, high or medium safety net burden hospitals were associated with increased postoperative complications and longer length of stay.**
32. Tangel V, Gupta S, White RS. Penalties for hospital readmissions. *Health Aff. (Millwood)* 38(8), 1410 (2019).
33. Elixhauser A, Steiner C, Harris DR, Coffey RN. Comorbidity measures for use with administrative data. *Med. Care* 36(1), 8–27 (1998).
34. Overview of the state inpatient databases. Healthcare cost and utilization project (2019). <https://www.hcup-us.ahrq.gov/sidoverview.jsp>
- **Description of available data in the state inpatient databases and their classifications, including patient demographics (age, race, sex, primary insurance type, and median income), comorbid medical conditions, hospital specific data (state, hospital volume and safety net burden) and surgery specific data (surgical subtype and surgery type).**
35. Van Walraven C, Austin PC, Jennings A, Quan H, Forster AJ. A modification of the Elixhauser comorbidity measures into a point system for hospital death using administrative data. *Med. Care* 47(6), 626–633 (2009).
- **This study proposed methods, a fundamental basis for our own analysis, to condense the Elixhauser Comorbidity system into single numeric scores to summarize disease burden that is still adequate for outcomes analysis.**
36. Esemuede IO, Gabre-Kidan A, Fowler DL, Kiran RP. Risk of readmission after laparoscopic vs. open colorectal surgery. *Int. J. Colorectal Dis.* 30(11), 1489–1494 (2015).
37. Fitch K, Bochner A, Keller DS. Cost comparison of laparoscopic colectomy versus open colectomy in colon cancer. *Curr. Med. Res. Opin.* 33(7), 1215–1221 (2017).

38. Berenson J, Shih A. Higher readmissions at safety-net hospitals and potential policy solutions. *Issue Brief (Commonw Fund)* 34, 1–16 (2012).
39. Hechenbleikner EM, Zheng CY, Lawrence S *et al.* Do hospital factors impact readmissions and mortality after colorectal resections at minority-serving hospitals? *Surgery* 161(3), 846–854 (2017).
40. Hoehn RS, Wima K, Vestal MA *et al.* Effect of hospital safety-net burden on cost and outcomes after surgery. *JAMA Surg.* 151(2), 120–128 (2016).
41. Lidor AO, Schneider E, Segal J, Yu Q, Feinberg R, Wu AW. Elective surgery for diverticulitis is associated with high risk of intestinal diversion and hospital readmission in older adults. *J. Gastrointest. Surg.* 14(12), 1867–1873 (2010).
- **This study, using a 23,764 cohort, identified that patients undergoing emergent/urgent surgical treatment had significantly increased risks of poor outcomes, including 30-day readmissions, as compared with elective patients.**
42. Liu XF, Zhu TH, Manojlovich M, Cohen HW, Tsilimingras D. Racial/ethnic disparity in the associations of smoking status with uncontrolled hypertension subtypes among hypertensive subjects. *PLoS ONE* 12(8), e0182807 (2017).
43. Markides KS, Eschbach K. Aging, migration, and mortality: current status of research on the Hispanic paradox. *J. Gerontol. B Psychol.* 60, 68–75 (2005).
44. Vega WA, Rodriguez MA, Gruskin E. Health disparities in the Latino population. *Epidemiol. Rev.* 31(1), 99–112 (2009).
45. Basu J, Hanchate A, Bierman A. Racial/ethnic disparities in readmissions in US hospitals: the role of insurance coverage. *Inquiry* 55, 1–12 (2018).
46. Connolly TM, White RS, Sastow DL, Gaber-Baylis LK, Turnbull ZA, Rong LQ. The disparities of coronary artery bypass grafting surgery outcomes by insurance status: a retrospective cohort study, 2007–2014. *World J. Surg.* 42(10), 3240–3249 (2018).
47. Xu HF, White RS, Sastow DL, Andrae MH, Gaber-Baylis LK, Turnbull ZA. Medicaid insurance as primary payer predicts increased mortality after total hip replacement in the state inpatient databases of California, Florida and New York. *J. Clin. Anesth.* 43, 24–32 (2017).
48. [Cms] CFMMS. Hospital inpatient prospective payment systems for acute care hospitals and the long-term care hospital prospective payment system and policy changes and fiscal year 2018 rates, final rule. *Fed. Regist.* 82(155), 38000 (2017).
49. Boccuti C, Casillas G. Aiming for fewer hospital U-turns: the medicare hospital readmission reduction program. The Henry J. Kaiser Family Foundation website (2015).
<http://kff.org/medicare/issue-brief/aiming-for-fewer-hospital-u-turns-the-medicare-hospital-readmission-reduction-program/>
50. Rau J. Half of nation's hospitals fail again to escape Medicare's readmission penalties. *Kaiser Health News* (2015).
<http://khn.org/news/half-of-nations-hospitals-fail-again-to-escape-medicare-readmission-penalties/>
51. Hospital Readmissions Reduction Program (HRRP). *NEJM Catalyst* (2018).
<https://catalyst.nejm.org/hospital-readmissions-reduction-program-hrrp/>
52. Gerhardt G, Yemane A, Apostle K, Oelschlaeger A, Rollins E, Brennan N. Evaluating whether changes in utilization of hospital outpatient services contributed to lower Medicare readmission rate. *Medicare Medicaid Res. Rev.* 4(1), 1–7 (2014).
53. Fonarow GC. Unintended harm associated with the hospital readmissions reduction program. *JAMA* 320(24), 2539–2541 (2018).
54. Wadhera RK, Maddox KEJ, Wasfy JH, Haneuse S, Shen CY, Yeh RW. Association of the hospital readmissions reduction program with mortality among medicare beneficiaries hospitalized for heart failure, acute myocardial infarction, and pneumonia. *JAMA* 320(24), 2542–2552 (2018).