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Perioperative Mortality Does Not Explain Racial Disparities in Gastrointestinal Cancer

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Abstract

Background Racial minorities with gastrointestinal cancer suffer disproportionately poor overall and disease-specific survival. We used a nationally representative sample to examine the relationship between race/ethnicity and mortality and determine whether these disparities were observed in the perioperative period.

Materials and Methods The Nationwide Inpatient Sample (NIS) was used to examine patients undergoing surgery for cancers of the esophagus, stomach, pancreas, colon and rectum ("GI cancer") between 2008 and 2012. Logistic regression was used to evaluate whether race/ethnicity was associated with perioperative mortality after adjusting for sociodemographic characteristics, perioperative factors and presentation (ER vs elective).

Results A total of 110,044 subjects were identified, including 75.8% Whites, 10.5% Black patients, 7.2% Hispanic patients, and 3.1% Asian/Pacific Islanders (API). Whites were generally older than minorities. In adjusted multivariable generalized linear mixed logistic models, no increase in perioperative mortality was seen for minorities. Worse outcomes were observed for those with higher Elixhauser comorbidity score (OR 6.90, CI 5.96–7.99), lower income region (OR 1.24, CI 1.10–1.40), males (OR 1.54, CI 1.42–1.68), and those without private insurance (Medicare OR 1.34, CI 1.16–1.55; Medicaid OR 1.27, CI 1.02–1.58; self-pay OR 1.64, CI 1.24–2.17). Differences in mortality were predominantly driven by comorbidities (pseudo %ΔR^2 = 38.56%) and only minimally by race (pseudo %ΔR^2 = 0.49%).

Conclusion Minority groups do not suffer higher rates of perioperative mortality for GI cancer surgeries after controlling for clinical and demographic factors. Future work to address cancer disparities should focus on areas in the cancer care trajectory such as cancer screening, surveillance, socioeconomic factors, and access.

Keywords Disparities · Cancer · Outcomes · Perioperative mortality · Socioeconomic status

Introduction

Health outcomes for different racial and ethnic groups in the USA are unequal. Understanding and addressing disparities has

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been recognized a national priority by the US Agency for Healthcare Research and Quality (HCUP), among others.[1,2] Pronounced disparities in outcomes have been identified for patients with cancer. The American Cancer Society reported in 2017 that the death rate for all cancers combined is 24% and 14% higher for Black men and women, respectively, as compared to White men and women.[3]

A potential contributor to differences in cancer outcomes is in the surgical management of cancer patients. Disparities can exist at each of three phases in the surgical care trajectory: preoperative, perioperative, and postoperative.[4] Disparities in preoperative factors include patient factors such as education level[5] and socioeconomic status,[6] provider factors such as implicit bias, and systemic factors such as access to screening.[4,7] Disparities in perioperative mortality have been identified in surgeries unrelated to cancer, such as appendectomy, gastric fundoplication, and gastric bypass.[8] Disparities can be

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┌─────────────────────────────┐
│ 213,742 adults with known sex│
│ and GI cancer diagnosis      │
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              ↓
┌─────────────────────────────┐
│ 195,577 known admission type │
│ [emergent or elective]       │
└─────────────────────────────┘
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┌─────────────────────────────┐
│ 172,990 known race/ethnicity │
└─────────────────────────────┘
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┌─────────────────────────────┐
│ 110,044 had GI cancer surgery:│
│      2,770 Esophagus         │
│      8,269 Stomach           │
│      7,404 Pancreas          │
│     68,281 Colon             │
│     23,320 Rectum            │
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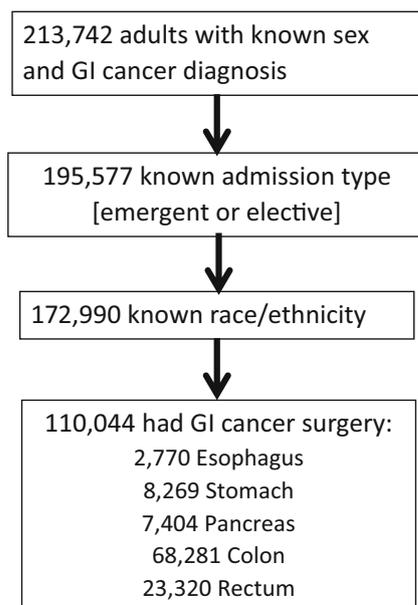
Fig. 1 Inclusion diagram

significant even after controlling for age, insurance and region; for example, Black patients undergoing anterior cervical spine surgery had 1.57 times the odds of death as White patients in one study.[9] Similarly, racial disparities in the post-operative care, such as significant disadvantages in access to rehabilitation for patients of lower socioeconomic status, contribute to overall differences in surgical outcomes for cancer patients.[10] Furthermore, aspects of care that are not subsumed under the cancer diagnosis are less likely to be covered by less comprehensive insurance programs.

The role of perioperative factors in the overall survival disparity has not been investigated as thoroughly. Given that racial minorities with gastrointestinal cancer suffer disproportionately poor overall and disease-specific survival, we sought to examine the relationship between race/ethnicity and mortality during the perioperative period and determine whether racial minorities suffer worse in-hospital mortality. The Nationwide Inpatient Sample (NIS), an all-payer database designed to represent national inpatient admissions administered by HCUP, was used to explore whether racial disparities existed in the perioperative stage for patients who underwent surgery for GI cancers.[11]

Methods

We used the Nationwide Inpatient Sample database to identify all patients with cancers of the esophagus,

stomach, pancreas, colon, or rectal ("GI cancer") undergoing resection in the USA over a 5-year period from 2008 to 2012. The NIS uses a 20% stratified random sample of all US community hospitals from states that contribute to HCUP to estimate a nationally representative sample of inpatient admissions. The NIS is the largest all-payer inpatient care database in the US and contains data from as many as 8 million hospital stays annually.[11,12] Patients were included based on International Classification of Diseases (ICD) codes for hospital discharges of adults in the NIS database as well as diagnosis codes of GI cancer and coincident procedure codes for the related GI cancer surgery (see Appendix). Our outcome of interest was in-hospital mortality following the GI surgery procedure. Persons who had missing data for in-hospital death or race were excluded from our analysis. Other variables included age, sex, race, ZIP code income quartile, comorbidities, admission through the emergency department ED, hospital size, hospital ownership, hospital affiliation with university/regional context, and region. The NIS categorizes race as White, Black or African American, Hispanic, API, and other. Age was categorized as < 55, 56–65, 66–75, and > 75. Selected, mortality-predictive comorbidities were categorized by count according to the Elixhauser method (0, 1, 2, or 3 or more).[13] Sensitivity analyses were also performed to evaluate whether using comorbidities as individual variables rather than as a combined score affected the outcome. Comorbidity variables included were lymphoma, hypothyroid, liver disease, fluid/electrolyte disorders, neurological disorders, obesity, paralysis, peripheral vascular disorders, psychoses, pulmonary/circulation disorders, renal failure, psychiatric disorders, solid tumors, peptic ulcer disease, valvular disease, weight loss and metastatic disease. ZIP code income quartile represents the income quartile of the patient's home ZIP code. Age-adjusted mortality was calculated based on age categories of < 45 and then 10-year intervals. To be classified as an admission through the ED, the case had to be recorded as being admitted though the ED and not recorded as being elective. Hospital ownership was recorded as nonprofit, for profit, or government. Region was divided into south, west, midwest, and northeast. Hospital size was divided into small, medium, and large with the bed count for each category dependent on the university affiliation/regional context (rural, urban teaching, or urban nonteaching).

All analyses were performed for GI cancers in aggregate and for each cancer diagnosis separately. Descriptive statistics were calculated for each variable. Multivariable

Table 1 Descriptive statistics, parsed by race with crude death rates

	White (%)	Black (%)	Hispanic (%)	API (%)	Other (%)	Total %	Total N	Crude death rate (%)
Total percent	75.8	10.5	7.2	3.3	3.1	100		2.4
Total N	83,435	11,578	7940	3631	3460		110,044	2636
Organ								
Esophagus	2.9	1.3	1.8	0.9	2.2	2.5	2770	5.4
Stomach	6.1	10.1	12.8	18.5	9.2	7.5	8269	3.8
Pancreas	6.9	5.9	6.3	5.3	6.9	6.7	7404	3.6
Colon	62.5	66.7	56.6	51.5	58.8	62.0	68,281	2.3
Rectum	21.6	16.1	22.5	23.9	22.9	21.2	23,320	1.4
Age								
< 55	16.6	24.6	25.7	22.2	23.2	18.5	20,371	0.8
56–65	20.8	27.5	22.6	22.5	24.6	21.8	23,994	1.4
66–75	27.1	25.2	25.9	27.5	26.0	26.8	29,502	2.2
> 75	35.5	22.7	25.8	27.8	26.2	32.9	36,177	4.1
Sex								
Male	52.5	48.2	54.4	52.0	54.0	52.2	57,455	2.7
Female	47.5	51.8	45.6	48.0	46.0	47.8	52,589	2.1
Comorbidities								
None	32.0	30.4	34.5	41.0	33.9	32.4	35,622	0.7
One	36.1	35.8	36.4	36.3	38.2	36.2	39,822	1.5
Two	20.0	20.4	18.7	14.8	18.3	19.7	21,706	3.9
Three or more	11.9	13.4	10.4	7.9	9.7	11.7	12,894	7.3
Zip income quartile								
First	21.1	47.1	32.7	11.5	24.5	24.4	26,887	2.7
Second	25.7	21.2	21.2	16.7	22.6	24.5	26,935	2.5
Third	25.1	16.8	25.4	25.6	25.5	24.3	26,737	2.4
Top	26.4	12.4	18.0	44.3	22.9	24.8	27,258	2.1
Missing	1.8	2.5	2.8	1.8	4.6	2.0	2227	2.8
Insurance status								
Medicare	58.8	47.2	45.1	44.8	45.4	55.7	61,277	3.3
Medicaid	3.5	11.3	12.4	12.8	9.0	5.5	6003	1.9
Private	33.7	33.0	32.8	35.1	36.6	33.7	37,095	1.1
Self-pay	1.8	4.7	5.0	3.7	5.2	2.5	2789	2.3
Missing	2.2	3.8	4.7	3.6	3.7	2.6	2880	1.7
ED admission								
No	83.9	74.6	76.8	80.3	81.5	82.2	90,461	1.7
Yes	16.1	25.4	23.2	19.7	18.5	17.8	19,583	5.4
Hospital size								
Small	11.4	9.2	9.1	10.9	9.6	10.9	12,042	2.1
Medium	22.8	24.1	21.3	21.3	21.9	22.7	25,013	2.5
Large	65.8	66.7	69.6	67.9	68.6	66.3	72,989	2.4
Hospital ownership								
Government	10.9	15.3	18.1	17.3	16.0	12.2	13,473	2.5
Nonprofit	78.7	72.4	63.2	70.3	69.7	76.4	84,040	2.3
Private	10.4	12.3	18.8	12.4	14.3	11.4	12,531	2.9
Hospital region								
Northeast	23.3	18.6	15.9	15.6	22.7	22.0	24,231	2.5

Table 1 (continued)

	White (%)	Black (%)	Hispanic (%)	API (%)	Other (%)	Total %	Total N	Crude death rate (%)
Midwest	19.7	16.5	4.4	5.8	18.7	17.8	19,538	2.2
South	37.9	55.8	43.1	16.9	37.9	39.4	43,409	2.4
West	19.1	9.1	36.7	61.7	20.7	20.8	22,866	2.4
Hospital location and teaching status								
Rural	10.4	6.3	3.6	2.3	8.3	9.1	10,067	2.5
Urban nonteaching	38.7	30.6	42.5	41.0	35.6	38.1	41,965	2.6
Urban teaching	50.9	63.1	53.9	56.7	56.2	52.7	58,012	2.2

logistic models were generated to examine the association between race and in-hospital death while adjusting for other covariates. Generalized linear mixed model estimations (GLMM) were used to estimate the regression parameters while accounting for clustering by institutions via random effects. To further characterize the influence of hospital factors on the model, a logistic model that accounted for the specific hospital factors was also used. The contribution of each variable to the logistic model was made by calculating the alterations made by each variable to the Nagelkerke/Cragg and Uhler pseudo R^2 [14] All analyses were performed using SAS 9.4 for Windows, copyright 2002–2012, SAS Institute Inc.[15]

Results

A total of 110,044 admissions met inclusion criteria (Fig. 1). Descriptive statistics for patient composition are given in Table 1. Overall, White patients were older. Death rates per cancer diagnosis varied from 1.4% for rectal cancer to 5.4% for esophageal cancer. In-hospital
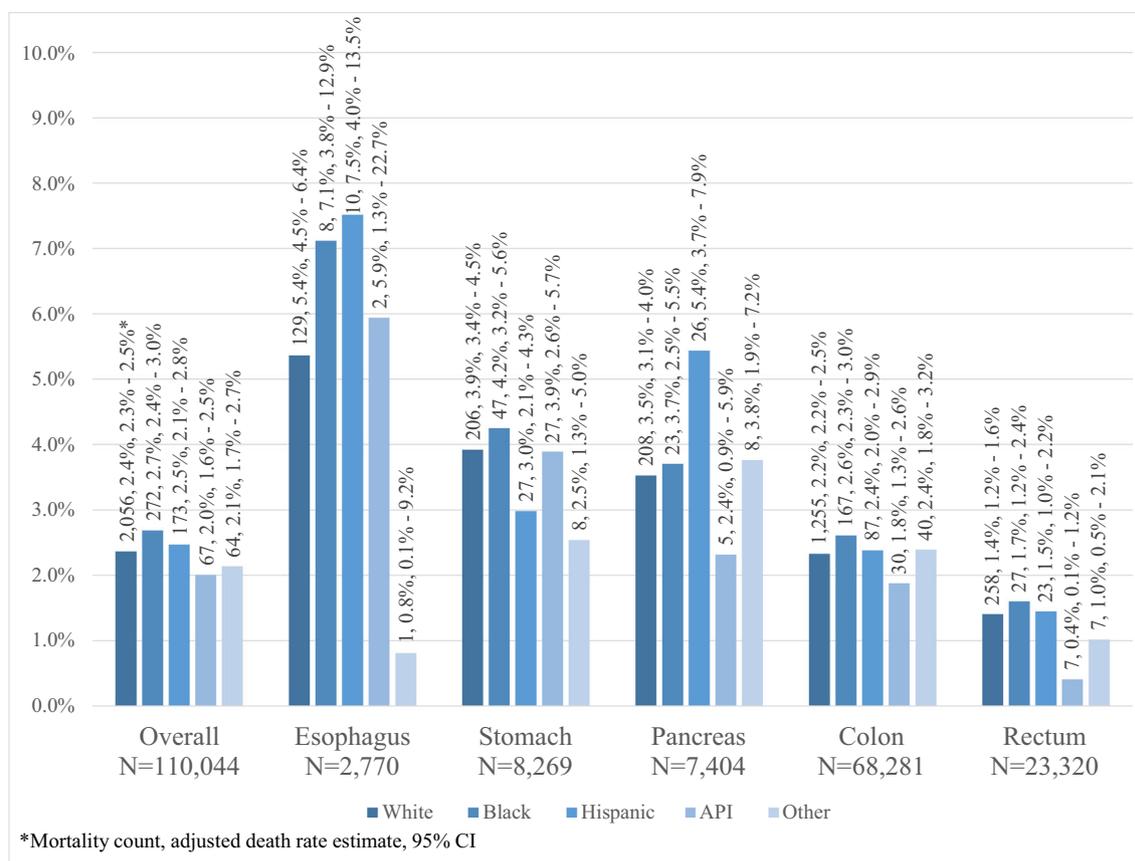

Fig. 2 Age-adjusted death rates by organ and race with mortality count and log-transformed CI

Table 2 Multivariate regression for in-hospital death: all organs

	Generalized linear model with random effects				Esophagus			Stomach			Pancreas			Colon			Rectum		
	OR	95% CI		P	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
Race vs White																			
AA	0.90	0.78	1.03	0.1310	0.79	0.36	1.75	0.79	0.55	1.12	0.98	0.61	1.56	0.95	0.80	1.13	0.90	0.59	1.38
Hispanic	0.88	0.75	1.04	0.1452	1.17	0.58	2.40	0.62	0.40	0.96	1.48	0.94	2.34	0.88	0.70	1.11	0.85	0.54	1.32
Asian	0.82	0.63	1.06	0.1319	1.26	0.27	5.78	1.05	0.68	1.63	0.72	0.28	1.82	0.85	0.58	1.24	0.30	0.09	0.94
Other	0.80	0.61	1.04	0.0908	0.29	0.04	2.18	0.65	0.31	1.37	0.89	0.42	1.88	0.90	0.65	1.25	0.66	0.31	1.43
Male vs female	1.54	1.42	1.68	<0.0001	1.82	1.07	3.09	1.33	1.03	1.72	1.18	0.91	1.52	1.59	1.43	1.76	1.84	1.44	2.34
Zip quartile vs 4th																			
1st [bottom]	1.24	1.10	1.40	0.0007	1.49	0.90	2.47	1.85	1.30	2.64	1.05	0.71	1.56	1.25	1.07	1.46	1.19	0.85	1.67
2nd	1.20	1.06	1.35	0.0040	1.22	0.74	2.01	1.46	1.01	2.10	1.29	0.90	1.85	1.20	1.03	1.40	1.18	0.84	1.65
3rd	1.12	0.99	1.26	0.0744	1.18	0.72	1.93	1.32	0.91	1.91	1.00	0.69	1.44	1.16	1.00	1.36	1.01	0.71	1.42
Missing	1.42	1.07	1.87	0.0142	1.33	0.43	4.18	1.74	0.71	4.23	1.01	0.42	2.45	1.42	0.98	2.04	1.98	1.01	3.89
Age																			
55–65 vs <55	1.65	1.36	2.00	<0.0001	1.82	0.95	3.47	2.32	1.31	4.11	1.05	0.63	1.76	1.80	1.36	2.39	1.43	0.90	2.26
66–75 vs <55	2.18	1.78	2.67	<0.0001	2.83	1.39	5.76	3.32	1.83	6.04	1.91	1.12	3.28	1.98	1.48	2.67	2.23	1.34	3.70
>75 vs <55	3.71	3.03	4.54	<0.0001	4.38	2.00	9.60	4.84	2.66	8.83	2.57	1.46	4.53	3.75	2.81	5.00	3.72	2.24	6.17
Comorbidities																			
1 vs 0	1.87	1.61	2.17	<0.0001	1.83	1.07	3.13	1.85	1.20	2.85	1.35	0.86	2.11	1.95	1.59	2.40	1.85	1.26	2.72
2 vs 0	4.11	3.55	4.75	<0.0001	3.31	1.96	5.59	4.08	2.68	6.21	2.78	1.80	4.29	4.26	3.50	5.20	4.50	3.09	6.55
3+ vs 0	6.90	5.96	7.99	<0.0001	4.38	2.48	7.72	4.94	3.20	7.62	4.29	2.75	6.69	7.50	6.16	9.14	9.09	6.19	13.36
Payer vs private:																			
Medicare	1.34	1.16	1.55	<0.0001	0.91	0.55	1.50	1.28	0.86	1.92	1.12	0.75	1.69	1.49	1.22	1.82	1.33	0.89	1.97
Medicaid	1.27	1.02	1.58	0.0346	1.09	0.51	2.36	1.20	0.66	2.18	1.66	0.91	3.02	1.30	0.95	1.79	1.23	0.69	2.19
Self pay	1.64	1.24	2.17	0.0005	1.57	0.43	5.64	4.33	2.25	8.35	1.51	0.66	3.48	1.25	0.83	1.89	2.25	1.14	4.43
Missing	1.34	0.99	1.83	0.0594	1.81	0.67	4.95	1.10	0.42	2.86	0.65	0.20	2.13	1.38	0.90	2.12	1.90	0.92	3.92
ER vs elective admission	2.35	2.15	2.57	<0.0001	3.06	1.37	6.83	1.83	1.38	2.44	1.60	1.06	2.41	2.44	2.19	2.71	2.64	2.02	3.45
Organ vs colon:																			
Esophagus	4.05	3.35	4.90	<0.0001															
Stomach	2.01	1.76	2.29	<0.0001															
Pancreas	2.24	1.94	2.59	<0.0001															
Rectum	0.99	0.87	1.12	0.8433															

Table 3 Contributions of variables to model

Relative contributions to Nagelkerke/Cragg and Uhler's R^2

Variable		% ΔR^2
Patient factors	Sex	4.27
	Race	0.49
	Zip income quartile	0.00
	Organ	11.70
	ER admit	9.02
	Age category	8.63
	Comorbidity burden	38.56
	Insurance category	0.50
Hospital factors [separate models for individual factors and random effects]	Size	0.14
	Ownership	0.47
	Region	0.45
	Teaching/urban	0.21
	Random effects	6.81

mortality was higher for ED admissions (5.4% vs 1.7%), the elderly (4.1% for > 75 vs 0.8% for < 55), men (2.7% vs 2.1%), and patients with higher comorbidity burden (7.3% for 3+ comorbidities vs 0.7% for 0) (Table 1). Age-adjusted death rates are given in Fig. 2. The rate was lower in APIs (2.0%), lower in colorectal cancer, and highest among Black patients (2.7%).

The regression models for all GI cancers combined showed no increased in-hospital mortality for any race compared to White patients (Table 2). Adjusting for hospital factors did not alter findings for all cancers, so the GLMM model with random effects is presented. Worse outcomes were observed for increased comorbidities (OR 6.90, 95% CI 5.96–7.99 for > 3 comorbidities vs 0), lower income ZIP quartile (OR 1.24, 95% CI 1.08–1.40), males (OR 1.54, 95% CI 1.42–1.68), and those without private insurance (Medicare OR 1.34, 95% CI 1.16–1.55; Medicaid OR 1.27, 95% CI 1.02–1.58; self-pay OR 1.64, 95% CI 1.23–2.17 vs private insurance) (Table 2). There were higher odds of death associated with government-owned (OR 1.20, 95% CI 1.06–1.36) and for-profit hospitals (OR 1.19, 95% CI 1.05–1.35) as compared to private nonprofit hospitals.

Cancer-specific models did not show worse outcomes for any minority group (Table 2). They showed improved outcomes for Hispanic patients undergoing stomach cancer surgery (OR 0.62, 95% CI 0.40–0.96) and APIs undergoing rectal surgery (OR 0.30, 95% CI 0.09–0.94). Across organ sites, ED admission, advanced age,

and higher number of comorbidities were generally associated with a higher risk of in-hospital mortality. Sensitivity analyses were performed related to the comorbidity count variable: (1) the effects of comorbidities were examined by entering individual comorbidities in the model instead of using an aggregate number of comorbidities and (2) the effects of primarily palliative (as opposed to curative) resections were assessed by examining metastatic disease as a separate variable. Neither change altered the primary result; we found no disadvantage for any racial/ethnic group compared to White patients (tables provided in the Appendix). Observed differences in in-hospital mortality were predominantly driven by comorbidities (%ΔR^2 = 38.56%), with other significant contributions from cancer organ site (11.70%), ER admission (9.02%), and age (8.63%). Individual hospital factors did not contribute substantially to differences in mortality. However, using random effects for clustering by hospital resulted in improved model fit (6.81%). Race contributed minimally to the model (0.49%) (Table 3).

Discussion

This study sought to examine the relationship between racial race/ethnicity and inpatient mortality among patients in the NIS who had an operation for GI cancer between 2008 and 2012. We found that mortality differences among racial groups are largely driven by clinical factors including comorbidities, context of presentation, age, and primary organ. No racial group suffered a disproportionate disadvantage in perioperative mortality compared to White patients after controlling for these clinical factors.

The lack of a difference in in-hospital mortality based on race in this study suggests that the existing disparities in cancer outcomes are not attributable to the inpatient stage, particularly for colorectal cancer. The known disparities in survival are likely attributable to prehospital and possibly post-hospital factors, such as disproportionate comorbidity burdens, gaps in insurance coverage, and lower rates of screening. Minorities suffer higher rates of chronic diseases and complications of those diseases,[16] such as diabetes and amputations[17] or hypertension and stroke,[18] leaving them with a higher surgical risk. Minorities are generally poorly insured and more likely to delay or forgo necessary care as well, although this gap has been partially reduced by the expansion in coverage under the Affordable Care Act[19] and the similar

measures in Massachusetts.[20,21] Furthermore, under a statewide intervention in Delaware, improved screening, expansion of treatment to the uninsured, and specific focus on the Black population eliminated disparities in colorectal cancer screening and incidence for that population. The increase in screening from 40 to 74% of Black people was associated with a 39% absolute reduction in late-stage diagnosis, a relative reduction in cancer incidence of 35%, and a relative reduction in disease-specific mortality of 42%. The program significantly improved outcomes for White patients as well and nearly eliminated the mortality disparity, without any intervention addressing the inpatient stage of care. This emphasizes the contribution of screening and access differences to cancer mortality disparities.[6]

Our findings are not completely consistent with a review of non-cancer operations. Racial inpatient mortality disparities have been observed for non-cancer surgeries, such as appendectomy, spine fixation, pneumonectomy,[22] and kidney donation.[23] Recent relative decreases in mortality rates for Black people may partially explain this finding.[24,25] Also, known racial disparities in non-mortality outcomes at the perioperative period, such as complications, length of stay,[26] stay in the ED prior to admission,[27] and cost,[28] may simply not be severe enough to lead to measurable mortality disparities at the level of statistical power available. Another possible reason for our negative finding is the outcome measure we used; a recent publication found an increase in 30-day perioperative mortality when 20 cancers were pooled, with an odds ratio of 1.08 (95% CI 1.02–1.15) for Black patients compared to White patients.[29] The surgical decision-making in the inpatient context for GI cancer may be fundamentally more objective than in settings where disparities have previously been noted, such as critical limb ischemia,[30] gallstone pancreatitis,[31] or outpatient care of pancreatic cancer.[32] It must also be noted that our study did not evaluate whether a disparity existed in the proportion of GI cancer patients who did not undergo surgery. Disproportionalities in who undergoes surgery could contribute to adverse outcomes.

Hispanic and API patients appear to have a statistical advantage in mortality for certain cancers. This is consistent with previous findings. According to Surveillance, Epidemiology and End Results program (SEER) statistics, API men and women had 40% and 39% lower overall cancer mortality than White men and women in 2010–2014 including reduced mortality for colorectal cancer specifically.[3] The underlying factors responsible for these findings have not been clearly elucidated in the literature, but differences in laparoscopic approach, behavior, diet, education, and affluence

have been proposed as potential factors and are not captured by the NIS dataset.[33] Expected advantages were also identified for patients with private insurance, patients outside of the northeast, and patients at private hospitals.

Our study has limitations. The NIS dataset does not include direct information about disease stage or outcomes after discharge. As an administrative database, it was developed for billing purposes rather than measuring outcomes, and this could create unpredictable biases.[34] It should also be noted that the sample size varies substantially by cancer; for colectomies, the sample size is large, leading to relatively precise OR confidence intervals, whereas for esophageal and pancreatic surgeries, the sample sizes are small and intervals are wide.

Conclusions

This study shows relationships between some sociodemographic factors, such as context of presentation, socioeconomic status and region, and perioperative mortality in GI cancer. Factors that have both biological and sociological roots—gender, comorbidities, and organ—substantially affect perioperative mortality. However, we found no evidence that minority groups suffer disproportionately higher rates of inpatient mortality for GI cancer surgeries once these factors are accounted for. Future work to address cancer disparities among minorities should investigate other areas in the cancer care trajectory such as cancer screening, patient selection, socioeconomic factors, and access to care, as well as aspects of inpatient care such as appropriate timing and choice of operation.

Compliance with Ethical Standards

Appendix

Table 4　Procedures Included/Procedure Codes (ICD-9)

Esophagus	42.4	Excision of esophagus	Rectum	48.4	Pull Through Resection of Rectum
	424.0	Esophagectomy NOS		484.0	Pull Through Resection of Rectum NOS
	424.1	Partial Esophagectomy		484.1	Soave Submucosal resection of Rectum
	424.2	Total Esophagectomy		484.2	Laparoscopic Pull Through Resection of Rectum
Stomach	43.5	Partial gastrectomy with anastomosis to esophagus		484.3	Open Pull Through Resection of Rectum
	43.6	Partial gastrectomy with anastomosis to duodenum		484.9	Other Pull Through Resection of Rectum
	43.7	Partial gastrectomy with anastomosis to jejunum		48.5	Abdominoperineal Resection of Rectum
	43.8	Other Partial Gastrectomy		485.0	Abdominoperineal Resection of Rectum, NOS
	438.1	Partial Gastrectomy with Jejunal Transposition		485.1	Laparoscopic Abdominoperineal Resection of Rectum
	438.2	Laparoscopic Vertical (Sleeve) Gastrectomy		485.2	Open Abdominoperineal Resection of Rectum
	438.9	Open and Other Partial Gastrectomy		485.9	Other Abdominoperineal Resection of Rectum
	43.9	Total Gastrectomy		48.6	Other Resection of Rectum
	439.1	Total Gastrectomy with Intestinal Interposition		486.1	Transsacral rectosigmoidectomy
	439.9	Other Total Gastrectomy		486.2	Anterior resection of Rectum with synchronous Colostomy
Pancreas	52.5	Partial Pancreatectomy		486.3	Other anterior resection of rectum
	525.1	Proximal Pancreatectomy		486.4	Posterior Resection of Rectum
	525.2	Distal Pancreatectomy		486.5	Duhamel Resection of Rectum
	525.3	Radical subtotal pancreatectomy		486.9	Other Resection of Rectum
	525.9	Other Partial Pancreatectomy	Diagnostic	1500-9	Malignant Neoplasm of Esophagus
	52.6	Total Pancreatectomy	Codes		(Cervical, Thoracic, Abdominal, Upper/Middle/Lower Third, Other/Unspecified)
	52.7	Radical Pancreaticoduodenectomy			
Colon	173.1	Laparoscopic multiple segmental resection of large intestine		1510-19	Malignant Neoplasm of Stomach
	173.2	Laparoscopic cecectomy			(Cardia, Pylorus, Antrum, Fundus, Body, Lesser/Greater Curvature, Other/Unspecified)
	173.3	Laparoscopic right hemicolectomy		1530-39	Malignant Neoplasm of Colon/Appendix
	173.4	Laparoscopic resection of transverse colon			(Hepatic Flexure, Transverse, Descending, Sigmoid, Cecum, Appendix, Ascending, Splenic flexure, Other/Unspecified)
	173.5	Laparoscopic left hemicolectomy			
	173.6	Laparoscopic sigmoidectomy		1540-41	Malignant Neoplasm of Rectum
	173.9	Other laparoscopic partial excision of large intestine			(Rectosigmoid, Rectum)
	45.7	Partial Excision of Large Intestine		1570-79	Malignant Neoplasm of Pancreas
	457.1	Multiple Segmental Resection of Large Intestine			(Head, Body, Tail, Duct, Islets, Other/Unspecified)
	457.2	Cecectomy			
	457.3	Right Hemicolectomy			
	457.4	Resection of Transverse Colon			
	457.5	Left Hemicolectomy			
	457.6	Sigmoidectomy			
	457.9	Unspecified Partial Excision of Large Intestine			
	45.8	Total Intra-Abdominal colectomy			
	458.1	Laparoscopic total Intra-Abdominal Colectomy			
	458.2	Open total Intra-Abdominal Colectomy			
	458.3	Other and Unspecified Total Intra-abdominal colectomy			

Table 5 Model with metastatic cancer as separate variable and random effects

	Generalized linear model		Esophagus		Stomach		Pancreas		Colon		Rectum	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Race vs White												
AA	0.89	0.78 1.03	0.77	0.35 1.70	0.78	0.54 1.11	0.95	0.59 1.52	0.90	0.75 1.09	0.90	0.59 1.37
Hispanic	0.88	0.74 1.04	1.11	0.54 2.27	0.62	0.40 0.96	1.49	0.94 2.35	0.92	0.72 1.17	0.84	0.54 1.32
Asian	0.83	0.64 1.08	1.23	0.27 5.66	1.06	0.68 1.64	0.73	0.29 1.86	0.64	0.40 1.01	0.31	0.10 0.99
Other	0.80	0.61 1.04	0.29	0.04 2.17	0.66	0.32 1.40	0.90	0.42 1.90	0.87	0.61 1.24	0.68	0.31 1.46
Male vs female	1.55	1.43 1.69	1.83	1.07 3.11	1.33	1.03 1.72	1.19	0.92 1.54	1.54	1.38 1.72	1.84	1.44 2.35
Zip quartile vs 4th												
1st (bottom)	1.23	1.08 1.39	1.50	0.90 2.48	1.86	1.30 2.66	0.98	0.66 1.46	1.11	0.94 1.32	1.16	0.82 1.63
2nd	1.19	1.05 1.34	1.18	0.72 1.93	1.45	1.01 2.10	1.24	0.86 1.78	1.10	0.93 1.30	1.12	0.80 1.57
3rd	1.11	0.98 1.25	1.15	0.70 1.88	1.32	0.91 1.92	0.97	0.67 1.40	1.11	0.94 1.30	0.97	0.69 1.37
Missing	1.43	1.08 1.89	1.34	0.43 4.21	1.74	0.71 4.23	0.99	0.41 2.41	1.19	0.79 1.79	1.92	0.98 3.77
Age												
55–65 vs <55	1.60	1.32 1.93	1.73	0.91 3.31	2.27	1.28 4.03	0.99	0.59 1.66	1.70	1.27 2.27	1.37	0.86 2.17
66–75 vs <55	2.11	1.72 2.58	2.82	1.38 5.74	3.25	1.79 5.92	1.76	1.03 3.01	1.67	1.22 2.27	2.11	1.27 3.50
>75 vs <55	3.51	2.87 4.30	4.41	2.00 9.71	4.71	2.58 8.59	2.25	1.28 3.96	3.07	2.27 4.15	3.45	2.08 5.73
Comorbidities												
1 vs 0	2.46	2.18 2.79	2.34	1.41 3.88	2.26	1.60 3.21	2.31	1.56 3.43	2.26	1.90 2.69	2.62	1.88 3.66
2 vs 0	4.82	4.25 5.47	4.53	2.76 7.45	4.52	3.17 6.44	4.99	3.35 7.42	4.15	3.48 4.96	5.71	4.03 8.08
3+ vs 0	7.21	6.30 8.26	4.50	2.45 8.27	4.14	2.75 6.25	7.19	4.63 11.18	6.38	5.30 7.69	9.88	6.78 14.40
Metastatic cancer												
Yes vs no	1.33	1.23 1.45	0.88	0.55 1.40	1.25	0.98 1.59	0.72	0.55 0.95	1.41	1.26 1.58	1.37	1.07 1.75
Payer vs private:												
Medicare	1.31	1.14 1.51	0.85	0.52 1.41	1.27	0.85 1.89	1.10	0.73 1.65	1.57	1.27 1.95	1.30	0.87 1.94
Medicaid	1.27	1.02 1.59	1.05	0.48 2.29	1.22	0.67 2.21	1.69	0.93 3.09	1.31	0.94 1.82	1.24	0.70 2.21
Self pay	1.62	1.22 2.14	1.56	0.43 5.67	4.21	2.18 8.15	1.50	0.65 3.46	1.19	0.78 1.83	2.27	1.15 4.49
Missing	1.34	0.99 1.83	1.82	0.67 4.97	1.09	0.42 2.85	0.59	0.18 1.95	1.27	0.80 2.03	1.94	0.94 4.01
ER vs elective admission	2.36	2.15 2.58	3.16	1.41 7.07	1.85	1.39 2.46	1.61	1.07 2.43	2.32	2.07 2.60	2.71	2.07 3.56
Organ vs colon:												
Esophagus	3.862	3.194 4.67										
Stomach	2.001	1.753 2.285										
Pancreas	2.262	1.958 2.614										
Rectum	0.985	0.868 1.117										

Table 6 Model with separate comorbidities

	Generalized linear model with random effects		Esophagus		Stomach		Pancreas		Colon		Rectum	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Race vs White												
AA	0.80	0.69, 0.93	0.63	0.28, 1.43	0.73	0.51, 1.05	0.91	0.56, 1.48	0.83	0.68, 1.00	0.81	0.52, 1.25
Hispanic	0.86	0.72, 1.02	1.18	0.58, 2.41	0.62	0.40, 0.97	1.48	0.93, 2.37	0.86	0.68, 1.11	0.79	0.50, 1.25
Asian	0.63	0.48, 0.84	1.25	0.26, 5.92	0.90	0.57, 1.41	0.62	0.24, 1.59	0.56	0.35, 0.89	0.25	0.08, 0.79
Other	0.75	0.57, 0.99	0.33	0.05, 2.50	0.64	0.30, 1.37	0.90	0.42, 1.92	0.83	0.58, 1.20	0.65	0.30, 1.44
Male vs female	1.43	1.32, 1.56	1.67	1.02, 2.74	1.27	0.99, 1.63	1.14	0.89, 1.47	1.47	1.32, 1.64	1.70	1.34, 2.16
Zip quartile vs 4th												
1st (bottom)	1.12	0.99, 1.27	1.45	0.90, 2.35	1.69	1.20, 2.38	0.94	0.65, 1.38	1.11	0.94, 1.30	1.01	0.73, 1.41
2nd	1.09	0.97, 1.24	1.16	0.73, 1.87	1.37	0.97, 1.94	1.16	0.82, 1.64	1.07	0.91, 1.25	1.09	0.78, 1.50
3rd	1.07	0.94, 1.20	1.14	0.71, 1.83	1.21	0.84, 1.73	0.99	0.70, 1.41	1.10	0.94, 1.29	0.91	0.65, 1.27
Missing	1.12	0.84, 1.50	1.21	0.39, 3.75	1.29	0.52, 3.17	0.84	0.35, 2.06	1.08	0.73, 1.61	1.70	0.88, 3.29
Age												
55–65 vs < 55	1.70	1.41, 2.04	1.97	1.05, 3.68	2.38	1.38, 4.10	1.25	0.77, 2.02	1.70	1.29, 2.24	1.58	1.00, 2.48
66–75 vs < 55	2.09	1.71, 2.55	3.29	1.65, 6.55	3.07	1.73, 5.45	1.88	1.13, 3.15	1.77	1.32, 2.39	2.28	1.39, 3.77
> 75 vs < 55	3.62	2.97, 4.42	4.79	2.23, 10.32	4.81	2.70, 8.57	2.76	1.61, 4.73	3.38	2.53, 4.52	4.12	2.50, 6.80
Presence of comorbidity												
Hypothyroidism	0.81	0.70, 0.93	0.67	0.32, 1.39	0.62	0.39, 0.97	0.82	0.54, 1.25	0.84	0.71, 1.00	0.76	0.49, 1.17
Liver disease	2.75	2.30, 3.29	1.60	0.70, 3.65	2.88	1.77, 4.69	3.04	1.93, 4.77	2.53	1.96, 3.26	3.49	2.10, 5.81
Lymphatic disease	1.60	1.05, 2.42	5.32	1.45, 19.53	0.74	0.16, 3.46	2.20	0.67, 7.24	1.26	0.72, 2.21	2.78	0.80, 9.72
Electrolyte disorder	2.70	2.48, 2.94	2.49	1.77, 3.50	2.95	2.32, 3.75	3.61	2.80, 4.67	2.42	2.17, 2.70	3.13	2.48, 3.95
Metastatic disease	1.20	1.10, 1.30	0.83	0.53, 1.31	1.28	1.01, 1.62	0.64	0.49, 0.84	1.31	1.17, 1.46	1.24	0.97, 1.57
Neurological disease	1.48	1.27, 1.73	0.69	0.23, 2.05	1.58	0.98, 2.55	1.33	0.73, 2.43	1.43	1.18, 1.73	2.16	1.43, 3.26
Obesity	0.82	0.70, 0.95	0.56	0.26, 1.21	0.68	0.41, 1.14	0.95	0.60, 1.50	0.86	0.70, 1.05	0.81	0.53, 1.23
Paralysis	2.26	1.78, 2.87	4.74	1.33, 16.94	2.06	0.94, 4.52	6.63	2.70, 16.28	1.87	1.37, 2.55	2.95	1.60, 5.42
Peripheral vascular	1.41	1.22, 1.62	1.67	0.89, 3.16	1.02	0.65, 1.62	2.01	1.33, 3.02	1.34	1.11, 1.61	1.47	0.99, 2.20
Psychiatric disease	1.02	0.79, 1.30	1.28	0.48, 3.41	0.72	0.30, 1.74	1.19	0.59, 2.41	0.83	0.58, 1.18	1.77	1.03, 3.05
Pulmonary/circulatory	2.95	2.55, 3.42	2.52	1.27, 5.00	3.17	2.06, 4.87	4.22	2.52, 7.06	2.52	2.09, 3.04	4.59	3.06, 6.89
Renal failure	1.60	1.42, 1.81	1.52	0.83, 2.77	1.34	0.92, 1.95	1.59	1.00, 2.51	1.54	1.33, 1.79	2.09	1.51, 2.88
Solid tumor	1.02	0.82, 1.27	1.28	0.59, 2.74	0.72	0.32, 1.60	1.02	0.56, 1.85	1.01	0.76, 1.35	1.19	0.65, 2.16
Gastric ulcer	0.12	0.02, 0.93	0.10	., 1.46	< 0.001	< 0.001, > 999.9	2.80	0.25, 30.90	0.03	< 0.001, > 999.9	0.05	< 0.001, > 999.9
Valvular disease	0.80	0.68, 0.95	0.55	0.21, 1.39	0.51	0.28, 0.92	0.55	0.29, 1.08	0.90	0.73, 1.10	0.78	0.48, 1.27
Weight loss	1.99	1.81, 2.18	1.98	1.39, 2.83	1.52	1.18, 1.96	1.27	0.95, 1.69	2.22	1.97, 2.51	2.10	1.60, 2.74
Payer vs private:												
Medicare	1.32	1.15, 1.52	0.86	0.53, 1.39	1.40	0.95, 2.05	1.03	0.70, 1.50	1.50	1.22, 1.83	1.24	0.85, 1.82
Medicaid	1.26	1.02, 1.56	1.16	0.57, 2.37	1.29	0.74, 2.24	1.32	0.74, 2.37	1.34	0.99, 1.82	1.18	0.68, 2.05
Self pay	1.40	1.06, 1.85	1.45	0.39, 5.34	3.41	1.76, 6.60	1.46	0.67, 3.16	1.04	0.68, 1.58	1.96	0.98, 3.93
Missing	1.25	0.92, 1.68	2.10	0.83, 5.32	1.00	0.39, 2.59	0.59	0.21, 1.70	1.29	0.84, 1.98	1.72	0.83, 3.54
ER vs elective admission	2.05	1.87, 2.25	2.43	1.09, 5.43	1.63	1.22, 2.16	1.54	1.03, 2.29	2.09	1.87, 2.33	2.49	1.90, 3.25
Organ vs colon:												
Esophagus	3.101	2.584, 3.721										
Stomach	1.74	1.529, 1.981										
Pancreas	2.003	1.743, 2.302										
Rectum	0.856	0.757, 0.968										

Table 7 Model with separate hospital factors

	Generalized linear model with random effects			Logistic model			
	OR	95% CI		P	OR	95% CI		P	OR

	OR	95% CI low	95% CI high	P	OR	95% CI low	95% CI high	P	OR
Race vs White									
AA	0.90	0.78	1.03	0.1310	0.93	0.81	1.06	0.2648	
Hispanic	0.88	0.75	1.04	0.1452	0.86	0.73	1.02	0.0774	
Asian	0.82	0.63	1.06	0.1319	0.81	0.63	1.05	0.1070	
Other	0.80	0.61	1.04	0.0908	0.80	0.62	1.03	0.0831	
Male vs female	1.54	1.42	1.68	< 0.0001	1.53	1.41	1.66	< 0.0001	
Zip quartile vs 4th									
1st	1.24	1.10	1.40	0.0007	1.29	1.14	1.46	< 0.0001	
2nd	1.20	1.06	1.35	0.0040	1.23	1.10	1.39	0.0006	
3rd	1.12	0.99	1.26	0.0744	1.15	1.02	1.29	0.0238	
Missing	1.42	1.07	1.87	0.0142	1.39	1.06	1.84	0.0178	
Age									
55–65 vs < 55	1.65	1.36	2.00	< 0.0001	1.64	1.35	1.98	< 0.0001	
66–75 vs < 55	2.18	1.78	2.67	< 0.0001	2.16	1.77	2.65	< 0.0001	
> 75 vs < 55	3.71	3.03	4.54	< 0.0001	3.67	3.00	4.48	< 0.0001	
Comorbidities									
1 vs 0	1.87	1.61	2.17	< 0.0001	1.86	1.61	2.16	< 0.0001	
2 vs 0	4.11	3.55	4.75	< 0.0001	4.07	3.53	4.71	< 0.0001	
3+ vs 0	6.90	5.96	7.99	< 0.0001	6.80	5.88	7.87	< 0.0001	
Payer vs private:									
Medicare	1.34	1.16	1.55	< 0.0001	1.34	1.17	1.55	< 0.0001	
Medicaid	1.27	1.02	1.58	0.0346	1.29	1.04	1.60	0.0234	
Self pay	1.64	1.24	2.17	0.0005	1.67	1.27	2.20	0.0003	
Missing	1.34	0.99	1.83	0.0594	1.35	0.99	1.83	0.0552	
ER vs elective admission	2.35	2.15	2.57	< 0.0001	2.32	2.12	2.54	< 0.0001	
Organ vs colon:									
Esophagus	4.05	3.35	4.90	< 0.0001	3.98	3.30	4.80	< 0.0001	
Stomach	2.01	1.76	2.29	< 0.0001	1.97	1.73	2.24	< 0.0001	
Pancreas	2.24	1.94	2.59	< 0.0001	2.23	1.93	2.57	< 0.0001	
Rectum	0.99	0.87	1.12	0.8433	0.98	0.87	1.12	0.7926	
Hospital size vs large:									
Small					0.93	0.81	1.06	0.2743	
Medium					1.01	0.92	1.12	0.7791	
Hospital ownership vs nonprofit:									
Government					1.20	1.06	1.36	0.0034	
For profit					1.19	1.05	1.35	0.0067	
Hospital region vs northeast:.									
Midwest					0.82	0.72	0.94	0.0035	
South					0.87	0.77	0.97	0.0110	
West					0.92	0.81	1.04	0.1989	
Hospital type vs urban teaching:									
Rural					1.13	0.98	1.31	0.1042	
Urban nonteaching					1.05	0.96	1.15	0.2690	

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