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Disparate use of minimally invasive surgery in benign surgical conditions

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Abstract
Background Disparities in outcome across race and ethnicity have been consistently described for medical and surgical care. Given that surgery is a rapidly evolving field, we hypothesized that racial disparities exist in access to minimally invasive surgery (MIS), which importantly influences outcome.
Methods Cohort analysis of all patients who underwent appendectomy, gastric fundoplication, and gastric bypass in the Nationwide Inpatient Sample, a 20% stratified random sample of US hospital discharge abstracts. To determine the effect of race on the use of MIS techniques and morbidity and mortality, we controlled for patient characteristics, comorbidity, and hospital characteristics including surgical volume and MIS conversion to open surgery.
Results Blacks were consistently less likely to be treated with MIS despite adjustment for socioeconomic status, comorbidity, and treatment setting. In addition, in-hospital mortality and complications such as pneumonia, heart disease, infections, and surgical misadventures were higher in black than white patients. These outcomes differences remained despite adjustment for hospital volume, the use of MIS, and MIS conversion to open surgery.
Conclusions We demonstrate evidence of racial disparities in the use of MIS for benign surgical conditions and worse outcomes for patients of black race. Although, the racial differences in outcome were attenuated with adjustment for MIS, further studies are needed to help resolve remaining differences in outcomes across race.

Keywords Disparity · Laparoscopy · Technique · Surgery · Race · Access

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With one of the most racially and ethnically diverse populations, the USA has large racial and ethnic disparities in access to medical and surgical treatment, as well as in outcomes. These disparities have been described for a number of medical treatments including access to kidney transplant [1], osteoarthritis therapies [2], cancer therapy [3], and human immunodeficiency virus (HIV) treatment [4]. Given the vast body of data detailing healthcare disparities, the Department of Health and Human Services, as well as other federal agencies and nongovernment organizations, has decided to make the elimination of healthcare disparities one of two overarching goals [5]. Yet, evidence of persistent healthcare disparities across race and ethnicity pervade the medical literature. These disparities are not simply of academic interest; they produce substantial costs in terms of medical care for more advanced diseases, loss of wages, impact to the economy in terms of life years lost, in addition to the unsettling societal and justice implications. In addition, the Institute of Medicine's report *Crossing the Quality Chasm* recommends that health care should be safe, effective, patient-centered, timely, efficient, and equitable [6].

In the setting of surgical treatment, few studies have sought to assess disparities in access to quality surgical care or innovative techniques. One class of surgical techniques, minimally invasive surgery (MIS), is associated with improved preservation of the immune system, faster recovery, and less postoperative pain, while leading to improved aesthetic results compared with conventional open surgery [7, 8]. Given the outcome benefits of MIS, it is considered state-of-the-art care for many conditions. For appendectomy, gastric bypass, and fundoplication, the safety and advantages of MIS have been consistently documented [9–16]. In addition to the outcomes advantage for MIS, technique adaptation represents a method to understand the diffusion of new technology into the nation's healthcare system. Thus, given the advantages of MIS and the fact that it represents new technology with varying acceptance and performance, we chose to evaluate the presence of disparities in its use.

We hypothesized that minority populations, in particular patients of black race, are less likely to receive surgical care with MIS techniques, leading to worse surgical outcomes as compared with white patients. In order to test our hypothesis, we examined a cohort of patients with benign conditions who underwent surgical treatment (specifically for appendectomy, gastric bypass, and gastric fundoplication). We then developed multivariable models that adjust for patient demographics, comorbidity, and hospital characteristics. The effect of race, other patient demographics, comorbidity, and hospital characteristics on surgical outcomes was tested with and without adjustment for use of MIS.

Methods

Data sources

We obtained 2004 discharge data from the Nationwide Inpatient Sample (NIS) via the Healthcare Cost and Utilization Project of the Agency for Healthcare Research and Quality (AHRQ). The NIS—the largest source of all-payer hospital discharge information in the USA—is a unique and powerful tool. It includes data from about 8,000,000 hospital stays per year in 1,000 hospitals located in 35 states, approximating a 20% stratified sample of the USA's community hospitals. It provides information on patient demographics, socioeconomic factors, admission profiles, hospital profiles, state, discharge diagnoses, procedure codes, total charges, and vital status at hospital discharge. Along with other hospital discharge databases, the NIS has been used extensively to review trends in surgical care and outcomes [17], volume-outcome relationships [18], and disparities in care [19]. A data use agreement is held by AHRQ; for our study, all study protocols were considered exempt by the Lahey Clinic Institutional Review Board.

Patient data

We used procedure codes from the International Classification of Diseases (ICD-9) to identify all patients who were discharged following one of three procedures: appendectomy, gastric bypass, and fundoplication. The ICD-9 procedure code for open appendectomy is 47.09, whereas laparoscopic appendectomy is coded 47.01. Open gastric bypass is coded 44.31, 44.39, 44.50, and 44.69 [16], whereas laparoscopic gastric bypass is coded 44.38. The ICD-9 procedure code for open fundoplication is 44.65 and 44.66, whereas laparoscopic fundoplication is coded 44.67. In order to reduce the possibility of confounding from case mix, we selected out patients treated with the above procedures for similar indication and excluded those treated for reasons other than benign pathology. Appendectomy patients had a diagnostic code for appendicitis (ICD-9 code 540–542). Gastric bypass patients had a diagnosis of morbid obesity (ICD-9 code 278–278.1) and were excluded if they had concomitant diagnosis of gastrointestinal bleeding, gastric cancer, or other malignancy [16]. Fundoplication patients were excluded if there was a concomitant diagnosis of neoplasm. In addition, to reduce the likelihood of procedure heterogeneity, we included only those patients who had undergone these procedures as the principal procedure of the hospitalization.

Covariates

In addition to patient's race, we evaluated the effect of other patient demographics, comorbidity, hospital characteristics, hospital surgical volume, and likelihood of MIS conversion to open surgery. The NIS contains information regarding age, sex, payer (Medicare, Medicaid, private, self-pay, no-charge, and other), and yearly income information at the zip-code level for the place of permanent residence (US $1–35,999, US $36,000–44,999, US $45,000–58,999, and US $59,000 or more). We also evaluated comorbidity with the Deyo modification of the Charlson comorbidity index [20]. Briefly, we ascertained the presence of 17 comorbid conditions and then weighted them according to the original report by Charlson [21]. An elevated Charlson comorbidity index has been shown to correlate with mortality [21].

We also evaluated characteristics of the hospital performing the procedure. We specifically used the variables for teaching status (teaching or nonteaching); hospital region (Northeast, Midwest, South, and West); hospital location (urban or rural); hospital ownership (government/private, public nonfederal, private nonprofit, private investment owned, and private other); and hospital bedsize (small, medium, or large). In addition, we evaluated hospital procedure volume by designating hospitals based on annual procedure volume in quintiles [22]. Finally, in order to adjust for procedure complexity or surgeon inexperience, we calculated the likelihood of MIS conversion to open surgery (ICD-9 code V644–V6441) [23].

Outcomes

Outcomes included: (1) use of MIS, (2) mortality, and (3) surgical complications. We used the standard ICD-9 codes to define access to MIS as described above. To measure mortality, we used the vital status codes at the time of discharge during the inpatient stay. Although the NIS does not include 30-day mortality rates, in-hospital mortality has been shown to correlate closely with 30-day mortality [24]. To evaluate postoperative complications, we used the expanded version, the Utah/Missouri adverse event classification, 2002, version 1 (AE classes) [25, 26]. These adverse event classes are more sensitive and detect far more potential injuries due to medical care, but may include more false positives than the Agency for Healthcare Research and Quality's Patient Safety Indicators [26].

Analysis

We compared patient characteristics and hospital characteristics of patients who underwent open surgery as compared with MIS for the aggregated cohort. We used chi-square tests for categorical variables (sex, payer, income status, and all hospital characteristics) and Student's *t*-test for continuous variables (age and comorbidity). Next, we developed regression models to determine the effect of race on outcomes following the defined procedures. We specifically evaluated the outcomes of in-hospital mortality and postoperative complications as defined by the Utah/Missouri adverse event classification [26]. We adjusted for the patient demographics, comorbidity, hospital characteristics, hospital volume, and likelihood of MIS conversion to open surgery as well as type of procedure performed. For these surgical outcomes we also evaluated the effect of MIS. Because the NIS removes race status for about 20% of all patients, we performed the regression twice: once treating missing race as a separate category and once excluding patients with missing race.

All statistical analyses were performed using SAS version 9.13 (SAS Institute, Cary, NC). All tests of statistical significance were two-sided; a *p*-value of less than 0.05 was considered statistically significant.

Results

Demographics of cohort

The aggregated cohort consisted of 88,545 patients and the most commonly performed procedure was appendectomy, followed by gastric bypass, and then fundoplication. White race was the most common racial designation followed by black race and Hispanic ethnicity (Table 1). The most common payer was a private insurer, followed by Medicaid, and then Medicare. There was a relative equivalency of incomes across zip codes, and the majority of patients were female. The Charlson score averaged 0.25 ± 0.002, indicating a low degree of comorbidity among this group of inpatients with benign surgical conditions. Geographically, these surgical procedures were most commonly performed in the South and in large hospitals located in urban settings (Table 2).

Univariate analysis of patient characteristics

As shown in Table 1, of the 88,545 patients, 58,514 (66.1%) were treated by standard open techniques and 30,031 (33.9%) were treated with MIS. Native Americans and Hispanics were proportionately more likely to have MIS, whereas blacks were the least likely to have MIS. Also, patients treated with MIS were younger than patients treated with open techniques; men were more likely to undergo MIS than women. Although private payers represented the largest insurer group, patients with commercial preferred provider organizations or health maintenance organizations (HMO) insurance were more likely to undergo MIS. Patients in higher income levels were proportionately more likely to undergo MIS. Finally, patients treated with MIS had significantly lower mean Charlson scores than those treated with open techniques.

Univariate analysis of hospital characteristics

Teaching hospitals were slightly more likely to use MIS than nonteaching hospitals (Table 2). Hospitals in the Western part of the USA were proportionately more likely to treat patients with MIS than those hospitals in other regions of the USA. A significantly higher proportion of patients were treated with MIS techniques at urban hospitals and private/nonprofit facilities. However, proportionately the largest hospitals were the least likely to treat patients with MIS (Table 2).

Hospital volume

Blacks were proportionately more likely than other racial and ethnic groups to receive care at the highest-volume

Table 1 Summary of patient characteristics with percentage of total group presented. Age and Charlson score are presented as means. Statistical significance provided for the comparison of the open and MIS technique for each variable

	n	Percentage of total	Open	MIS	*p* value
Procedure					0.0001
Fundoplication	5,648	6.4%	4,948 (87.6%)	700 (12.4%)	
Gastric bypass	24,264	27.4%	21,367 (88.1%)	2,897 (11.9%)	
Appendectomy	58,633	66.2%	32,199 (54.9%)	26,434 (45.1%)	
Total	88,545		58,514 (66.1%)	30,031 (33.9%)	
Race					0.0001
White	46,310	52.3%	30,475 (65.8%)	15,835 (34.2%)	
Black	5,320	6.0%	3,860 (72.6%)	1,460 (27.4%)	
Hispanic	10,436	11.8%	6,353 (60.9%)	4,083 (39.1%)	
Asian	1,232	1.4%	704 (57.1%)	528 (42.9%)	
Native American	253	0.3%	128 (50.6%)	125 (49.4%)	
Other	1,927	2.2%	1,296 (67.3%)	631 (32.8%)	
Missing	23,067	26.1%	15,698 (68.1%)	7,369 (32.0%)	
Age[a]	88,120	35.4 ± 18.2	36.5 ± 18.4	33.3 ± 17.7	0.0001
Sex[b]					0.0001
Male	38,627	44.6%	24,324 (63.0%)	14,303 (37.0%)	
Female	48,066	55.4%	33,071 (68.8%)	14,995 (31.2%)	
Payer					0.0001
Medicare	7,158	8.1%	5,248 (73.3%)	1,910 (26.7%)	
Medicaid	11,301	12.8%	7,374 (65.3%)	3,927 (34.8%)	
Private	58,368	66.0%	38,344 (65.7%)	20,024 (34.3%)	
Commercial PPO	7,898	8.9%	5,015 (63.5%)	3,045 (36.5%)	
HMO	553	0.6%	351 (63.5%)	202 (36.5%)	
Other	3,125	3.5%	2,074 (66.4%)	1,051 (33.6%)	
Income by quartile[d]	88,403				0.0001
US $1–35,999	20,297	23.4%	13,952 (68.7%)	6,345 (31.3%)	
US $36,000–44,999	21,900	25.3%	15,048 (68.7%)	6,852 (31.3%)	
US $45,000–59,999	21,043	24.3%	13,850 (65.8%)	7,193 (34.2%)	
US $60,000 or more	23,378	27.0%	14,431 (61.7%)	8,947 (38.3%)	
Charlson score	88,545	0.25	0.29	0.17	0.0001

[a] Age missing in 425
[b] Sex missing in 1,852
[c] Payer missing in 142
[d] Income by zip code missing in 1,927

hospitals (Table 3). In addition, the highest overall volume hospitals were also the least likely to perform MIS techniques. Also, the lowest volume hospitals had the highest rate of conversion to open surgery (Table 3).

Mortality data

Mortality in this group of surgically treated patients was 0.16% (140 patients). Blacks were much more likely to experience inpatient mortality than whites (2.6/1000 patients versus 1.6/1000 patients, respectively, $p < 0.05$) (Table 4). Patients who underwent MIS were less likely to experience inpatient mortality than were patients treated with conventional open surgery ($p < 0.0001$). There was no significant difference in mortality across volume designations. There was a higher mortality following fundoplication (5.8/1000 patients) as compared with gastric bypass (1.6/1000 patients) and appendectomy (1.1/1000 patients) ($p < 0.001$).

Morbidity

In-hospital surgical complications were rare for this subgroup of patients treated for benign conditions. However, there were large differences in the rate of surgical complications by race. Blacks had higher rates of pneumonia, postoperative gastrointestinal complications, gastrointestinal ulcers and bleeding, respiratory complications, heart disease, infections, and surgical misadventures as compared with white patients (Table 5). Other complication rates were equivalent except that whites experienced more myocardial infarctions than blacks (Table 5).

Multivariable analysis

Multivariable analyses revealed that patient characteristics such as black race, increasing age, government insurance, lower income, and increasing Charlson score were associated with reduced use of MIS. The odds ratio (OR) for MIS

Table 2 Summary of hospital characteristics with percentage of total group presented. Statistical significance provided for the comparison of the open and MIS technique for each variable

	n	Percentage of total	Open	MIS	*p* value
Hospital teaching status					0.03
Nonteaching	48,835	55.2	36,247 (66.4%)	16,408 (33.6%)	
Teaching	39,710	44.8	26,087 (65.7%)	13,623 (34.3%)	
Region of hospital					0.0001
Northeast	19,209	21.7	12,976 (67.6%)	6,233 (32.4%)	
Midwest	17,155	19.4	11,995 (69.9%)	5,160 (30.1%)	
South	30,185	34.1	19,890 (65.9%)	10,295 (34.1%)	
West	21,996	24.8	13,653 (62.1%)	8,343 (37.9%)	
Rurality of hospital					0.0001
Rural	9,534	10.8	6,680 (70.1%)	2,854 (29.9%)	
Urban	79,011	89.2	51,834 (65.6%)	27,177 (34.4%)	
Hospital control					0.0001
Gov/private	52,641	59.4	34988 (66.5%)	17,653 (33.5%)	
Public nonfederal	5,751	6.5	3,820 (66.4%)	1,931 (33.6%)	
Private/nonprofit	17,017	19.2	10,756 (63.2%)	6,261 (36.8%)	
Private/investor owned	9,722	11.0	6,648 (68.4%)	3,074 (31.6%)	
Other private	3,414	3.9	2,302 (67.4%)	1,112 (32.6%)	
Hospital bedsize					0.0001
Small	11,044	12.5	7,265 (65.8%)	3,779 (34.2%)	
Medium	25,627	28.9	16,176 (63.1%)	9,451 (36.9%)	
Large	51,874	58.6	35,073 (67.6%)	16,801 (32.4%)	

Table 3 Summary of patient race, MIS use, and likelihood of conversion by annual hospital volume. Statistical significance provided for the comparison between volume designations for each variable

	Very low volume	Low volume	Mid volume	High volume	Very high volume	*p* value
Race						0.0001
White	9,069 (19.6%)	8,467 (18.3%)	8,289 (17.9%)	9,284 (20.1%)	11,201 (24.2%)	
Black	805 (15.1%)	864 (16.2%)	881 (16.6%)	1,210 (22.7%)	1,560 (29.3%)	
Hispanic	1,362 (13.1%)	2,379 (22.8%)	2,208 (21.2%)	2,566 (24.6%)	1,921 (18.4%)	
Asian	243 (19.7%)	358 (29.1%)	190 (15.4%)	236 (19.2%)	205 (16.6%)	
Native American	87 (34.4%)	30 (11.9%)	49 (19.4%)	56 (22.1%)	31 (12.3%)	
Other	397 (20.6%)	582 (30.2%)	374 (19.4%)	312 (16.2%)	262 (13.6%)	
Missing	5,545 (24.0%)	5,095 (22.1%)	5,597 (24.3%)	4,255 (18.5%)	2,575 (11.2)%	
MIS						0.0001
No	11,354 (64.9%)	11,169 (62.8%)	11,878 (67.5%)	11,308 (63.1%)	12,805 (72.1%)	
Yes	6,154 (35.2%)	6,606 (37.2%)	5,710 (32.5%)	6,611 (36.9%)	4,950 (27.9%)	
Conversion						0.0001
Yes	642 (10.4%)	534 (8.1%)	340 (6.0%)	370 (5.6%)	279 (6.0%)	
No	5,512 (89.6%)	6,072 (91.9%)	5,370 (94.0%)	6,241 (94.4%)	4,671 (94.0%)	
Total	17,508	17,775	17,588	17,919	17,755	

use was 0.77 in black compared with white patients (Table 6). Hospital characteristics such as treatment in the West, nonteaching facility, rural hospital, small hospital, and facilities with very high overall procedure volumes were also associated with reduced use of MIS.

In our multivariable analysis of mortality, MIS was associated with reduced mortality. Despite this finding, persistent racial differences in mortality existed even after adjusting for patient and hospital characteristics. Patients of black race had higher mortality then whites with adjustment for MIS. We noted that male sex, government insurance, increasing age, and Charlson score were all associated with increased mortality. Hospital characteristics such as treatment in the South or West were associated

Table 4 Summary of mortality results as a function of race, surgical access, and hospital volume designation. Statistical significance provided for the comparison within race, or surgical access or hospital volume

	*n**	Died	Proportion	*p* value
Race				0.05
White	46,308	72	0.16%	
Black	5,319	14	0.26%	
Hispanic	10,435	11	0.11%	
Asian	1,232	3	0.24%	
Native American	253	1	0.40%	
Other	1,927	7	0.36%	
Missing	23,066	32	0.14%	
Procedure				0.0001
MIS	30,029	22	0.07%	
Open	58,511	118	0.20%	
Volume				0.1
Very low	17,507	34	0.19%	
Low	17,774	36	0.20%	
Mid	17,585	26	0.15%	
High	17,919	26	0.15%	
Very high	17,755	18	0.10%	
Total	88,540	140	0.16%	

* Information regarding death missing in five patients

Table 5 Summary of morbidity results as a function of race. Statistical significance provided for the comparison between white and black race

	White	%	Black	%	*p* value
Reopening of surgical incision	1	0.00	0	0.00	0.73
Postoperative bleeding	9	0.02	1	0.02	0.97
Perforation or laceration	89	0.19	14	0.26	0.27
Septic complications	152	0.33	25	0.47	0.09
Pneumonia	**393**	**0.85**	**67**	**1.26**	**0.003**
Procedural complication	1,191	2.57	141	2.65	0.73
Complications of specified systems	2,163	4.67	242	4.55	0.69
Complications peculiar to procedures	2	0.00	0	0.00	0.63
Urinary tract infections	223	0.48	32	0.60	0.24
Nausea/vomiting/diarrhea	921	1.99	95	1.79	0.31
Postoperative GI complications	**57**	**0.12**	**12**	**0.23**	**0.05**
GI ulcer or bleed	**181**	**0.39**	**32**	**0.60**	**0.02**
Respiratory complications	**1,637**	**3.53**	**239**	**4.49**	**0.0004**
Diseases of veins and lymphatics	100	0.22	8	0.15	0.32
Heart disease	**16**	**0.03**	**5**	**0.09**	**0.04**
Pulmonary embolism	47	0.10	3	0.06	0.32
Myocardial infarction	**64**	**0.14**	**2**	**0.04**	**0.05**
Other infections	**602**	**1.30**	**103**	**1.94**	**0.0002**
Medical complications	43	0.09	2	0.04	0.2
Accidental cut complication	337	0.73	31	0.58	0.24
Surgical misadventure	**8**	**0.02**	**4**	**0.08**	**0.009**
Surgery abnormal reaction	0	0.00	0	0.00	NS
Other abnormal reaction	0	0.00	0	0.00	NS

with higher mortality but not other factors such as hospital control, bedsize, or rurality of the treatment location. Patients treated with fundoplication and gastric bypass were much more likely to experience mortality than those treated with appendectomy. In addition, although MIS conversion to open surgery was not associated with an increased mortality, patients treated at hospitals with very high volume were less likely to experience inpatient mortality (Table 7).

Among surgical complications, we found an increased risk for pneumonia, gastrointestinal ulcer and bleeding, other respiratory complications, heart disease, infections, and surgical misadventures for black patients as compared with whites. These outcomes differences persisted despite adjustment for other patient factors and hospital characteristics including hospital volume, use of MIS, and likelihood for MIS conversion to open surgery (Table 8).

Discussion

There is extensive evidence demonstrating racial disparities in healthcare access and outcomes, leading to national attention and calls to eradicate healthcare disparities by 2010 [5]. Yet, eliminating long-standing disparities requires greater understanding of the underlying mechanisms of variability. A number of underlying causes have been described, including financial constraints, physician bias, segregated healthcare systems for disadvantaged populations, and a lack of access to advanced technologies [3, 27–32]. A characteristic of surgery is the rapid development of new procedures and minimally invasive technologies which has led to marked reductions in morbidity and mortality [9–16]. Given that advanced surgical methods are seldom available to all patients, we hypothesized that disparate access to MIS may account for outcomes differences in surgical care.

We found significant differences in access to MIS based on racial and economic designations; patients of black race were less likely than whites to undergo MIS techniques in the treatment of benign disorders. This disparity in access to MIS was noted despite the fact that blacks underwent treatment at high-volume hospitals. Others have also described variable access to high-quality surgical care for disadvantaged populations [33–37]. For example, blacks are more likely to forego aggressive operative procedures for prostate cancer than white patients [37]. In colorectal cancer treatment, minority populations are less likely to

Table 6 Results of multivariable analysis determining the likelihood of having MIS technique

Variable	Odds of having minimally invasive surgery, odds ratio (confidence internval)
Race	
White	Referent
Black	0.77 (0.72–0.82)
Hispanic	0.93 (0.88–0.98)
Asian	0.99 (0.88–1.12)
Native American	1.88 (1.46–2.43)
Other	0.77 (0.69–0.85)
Missing	0.95 (0.92–0.99)
Sex	
Female	Referent
Male	1.01 (0.98–1.04)
Age (increasing decade)	0.96 (0.95–0.97)
Payer	
Medicare	0.91 (0.85–0.97)
Medicaid	0.86 (0.82–0.91)
Private	Referent
Commercial PPO	0.92 (0.88–0.97)
HMO	0.85 (0.71–1.01)
Other	0.91 (0.84–0.99)
Income by Quartile	
US $1–35,999	0.78 (0.75–0.82)
US $36,000–44,999	0.83 (0.79–0.86)
US $45,000–59,999	0.89 (0.85–0.93)
US $60,000 or more	Referent
Charlson score (increasing)	0.81 (0.78–0.83)
Hospital teaching status	
Nonteaching	0.79 (0.75–0.83)
Teaching	Referent
Region of hospital	
Northeast	Referent
Midwest	0.95 (0.90–1.00)
South	1.15 (1.09–1.20)
West	0.80 (0.76–0.85)
Rurality of hospital	
Rural	0.73 (0.68 –0.78)
Urban	Referent
Hospital control	
Gov/private	0.87 (0.82–0.92)
Public nonfederal	1.06 (0.99–1.13)
Private/nonprofit	Referent
Private/investor owned	0.94 (0.88–0.99)
Other private	1.24 (1.18–1.38)
Hospital bedsize	
Small	0.91 (0.86–0.95)
Medium	1.06 (1.02–1.09)
Large	Referent
Procedural volume	
Very low volume	Referent
Low volume	0.94 (0.89–0.99)
Mid volume	0.76 (0.72–0.80)
High volume	1.02 (0.96–1.09)
Very high volume	0.73 (0.69–0.78)

have any surgical treatment and are particularly less likely to have sphincter-sparing procedures for rectal cancer [33, 34]. Our data as well as those of others indicate that blacks do not have equal access to surgical advances in the USA, a finding that likely parallels disparities in access to other important techniques. Thus, it would seem particularly important to account for access to high-quality surgical technique when evaluating racial differences in outcomes for surgical conditions.

In addition to disparate access to MIS by race, we found racial differences in outcomes of surgical treatment of benign conditions. After adjusting for other patient characteristics, comorbidity, and hospital characteristics, the data consistently revealed racial differences in outcome. Black patients had poorer morbidity and mortality as compared with white patients for the three analyzed conditions. Given the observed improvement in outcomes afforded by MIS, access to this surgical technique should be offered equally to all populations. Yet, despite the observed improvement in outcome with MIS, black patients had much lower rates of MIS and considerably worse outcomes.

This study uses access to MIS as a marker of new advances in surgical care. Because conventional open procedures provide similar surgical cure, the performance of MIS was considered novel with less short-term morbidity and mortality. When patients are confronted with a choice between open and MIS approaches, most select the less invasive approach because of the perceived general health benefits and smaller incisions [38, 39]. This fact may explain why patients living in higher-income levels and those with private insurance were more likely to receive MIS techniques. Others have used process measures [40] and surgical volume [22] to define high-quality care and relate these measures to outcome. In our study, we adjusted for surgical volume and conversion from MIS to open surgery in order to reduce the role of confounding from hospital quality. We expected that high-volume hospitals were likely to demonstrate improved outcomes and that patients converted to open surgery may have had either

Table 7 Results of multivariable analysis determining the likelihood of mortality

	Odds of mortality, odds ratio (confidence interval)
Minimally invasive surgery	
Open	Referent
MIS	0.53 (0.33–0.86)
Race	
White	Referent
Black	2.01 (1.10–3.69)
Hispanic	1.33 (0.67–2.63)
Asian	1.54 (0.46–5.20)
Native American	4.35 (0.57–32.96)
Other	3.90 (1.73–8.78)
Missing	0.98 (0.63–1.52)
Sex	
Female	Referent
Male	2.10 (1.47–2.99)
Age (increasing decade)	1.58 (1.40–1.79)
Payer	
Medicare	3.91 (2.40–6.36)
Medicaid	3.81 (2.08–7.01)
Private	Referent
Commercial PPO	0.68 (0.21–2.24)
HMO	3.06 (0.40–23.24)
Other	1.28 (0.39–4.21)
Income by quartile	
US $1–35,999	1.58 (0.89–2.80)
US $36,000–44,999	1.278 (0.72–2.28)
US $45,000–59,999	1.50 (0.86–2.64)
US $60,000 or more	Referent
Charlson score (increasing)	1.37 (1.22–1.55)
Hospital teaching status	
Nonteaching	1.07 (0.59–1.95)
Teaching	Referent
Region of hospital	
Northeast	Referent
Midwest	1.67 (0.87–3.20)
South	2.56 (1.32–4.98)
West	2.13 (1.03–4.42)
Rurality of hospital	
Rural	0.68 (0.31 –1.49)
Urban	Referent
Hospital control	
Gov/private	1.82 (0.86–3.86)
Public nonfederal	0.69 (0.29–1.65)
Private/nonprofit	Referent
Private/investor owned	1.24 (0.65–2.36)
Other private	2.16 (0.74–6.28)
Hospital bedsize	
Small	0.64 (0.33–1.22)
Medium	0.69 (0.45–1.05)
Large	Referent
Surgery	
Appendectomy	Referent
Fundoplication	2.51 (1.58–3.97)
Gastric bypass	2.08 (1.27–3.41)
Procedural volume	
Very low volume	Referent
Low volume	1.00 (0.58–1.73)
Mid volume	0.68 (0.34–1.36)
High volume	0.68 (0.34–1.36)
Very high volume	0.41 (0.19–0.89)
Laparoscopic conversion	
No	Referent
Yes	0.35 (0.08–1.42)

Table 8 Results of multivariable analysis determining the likelihood of key morbidity characteristics. Odds ratio and confidence interval listed for each variable for black race as compared with white race

	Black race
Pneumonia	1.50 (1.14–1.97)
Postoperative GI disorders	1.58 (0.82–3.04)
GI ulcer or bleed	1.51 (1.02–2.23)
Respiratory complications	1.24 (1.07–1.43)
Heart disease	2.96 (1.03–8.49)
Myocardial infarction	0.33 (0.07–1.43)
Other infections	1.49 (1.20–1.86)
Surgical misadventure*	4.39 (1.19–16.24)

* Separation of parameter estimates for non-race-related variables

more difficult surgical procedures or less experienced surgeons. Despite these adjustments, we found persistent disparities in MIS access for black patients and persistent racial differences in outcomes. During this adjustment we also noted that the largest hospitals were the least likely to treat patients with MIS and the lowest-volume hospitals had the highest rate of conversion to open surgery. Although our data does not allow clarification of the rationale behind this difference, it may partially explain noted differences in clinical outcomes attributed to the volume–outcome relationship.

Reduced access to MIS techniques partially explains the differences in outcomes that blacks experience as compared with whites. Unfortunately the link between access to high-quality surgery and outcome is often difficult to demonstrate conclusively. For example, in a recent evaluation of current heart failure performance measures, little relationship was noted between these performance measures and patient mortality [41]. However, in the case of colorectal cancer, disparate access to particular surgical techniques has been linked to marked reductions in overall and disease-free survival [42]. It is for this reason that we opted to compare access and outcomes for procedures that can be performed with MIS or with open conventional surgery. Our study does reveal that patients treated with MIS have improved outcomes and that there was an attenuation of the race effect on mortality once we adjusted for MIS technique. Thus, equal access to MIS techniques would certainly reduce some of the outcomes differences of surgery, but further research is needed in order to explain these outcomes differences completely.

Our study has strengths and limitations that are specific to the use of administrative data. NIS data files do not provide clinical details commonly found in the medical record, such as operative risk or patient preference of procedure. In addition, while the small number of in-hospital deaths following these procedures is encouraging, the absolute number of deaths between race categories was small and reduces the strength of our conclusions. Despite these limitations, the ability to compare multiple procedures with appropriate procedure codes for MIS is a significant advantage of our analysis. Also, the representative nature of this large generalizable cohort of hospitalized patients treated surgically in 35 states across different geographic regions of the USA indicates that these differences in procedure use occur across practice settings and locations.

In conclusion, our data reveal large differences in the use of MIS across race even after adjusting for patient factors, comorbidity, and hospital characteristics. These differences were identified across procedures, regions of the nation, and practice settings, indicating a larger problem of access to high-quality procedures and advanced techniques. In addition, we found persistently worse outcomes for black as compared with white patients. This difference in outcome was attenuated after we adjusted for use of MIS, but further studies are needed to help resolve remaining differences in outcomes across race. Thus, given disparate racial access to MIS and the noted improvements when this technique was used, it appears that some of these outcomes differences might be attenuated with equal access to advanced surgical procedures such as MIS.

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