HHS Public Access
Author manuscript
Ann Surg Oncol. Author manuscript; available in PMC 2024 July 10.

Published in final edited form as:
Ann Surg Oncol. 2023 October ; 30(11): 6748–6759. doi:10.1245/s10434-023-13693-z.

Racial/Ethnic Disparities in the Era of Minimally Invasive Surgery for Treatment of Colorectal Cancer

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Abstract

Background.—Minimally invasive (laparoscopic and robotic) surgery (MIS) for colorectal cancer is associated with improved outcomes. We sought to characterize possible disparities in surgical approach and outcomes.

Patients and Methods.—In this cross-sectional study, colorectal adenocarcinoma cases among non-Hispanic white (NHW), non-Hispanic Black (NHB), and Hispanic patients were identified using the National Cancer Database (2010–2017). Logistic and Poisson regressions, generalized logit models, and Cox proportional hazards were used to assess outcomes, with reclassification of surgery type if converted to open.

Results.—NHB patients were less likely to undergo robotic surgery. After multivariable analysis, NHB patients were 6% less likely, while Hispanic patients were 12% more likely to undergo a MIS approach. Lymph node retrieval was higher (> 1.3% more, $p < 0.0001$) and length of stay was shorter (> 17% shorter, $p < 0.0001$) for MIS approaches. Unplanned readmission was lower for MIS colon cancer operations compared with open operations, but not for rectal cancer. Race/ethnicity-adjusted risk of death was lower with MIS approaches for colon as well as rectal cancer. After adjusting for surgery type, risk of death was 12% lower for NHB and 35% lower for Hispanic patients compared with NHW patients. Hispanic patients had 21% lower risk of death, while NHB patients had 12% higher risk of death than NHW patients with rectal cancer, after adjusting for surgery type.

Conclusions.—Racial/ethnic disparities exist in utilization of MIS for colorectal cancer treatment, disproportionately affecting NHB patients. Since MIS has the potential to improve outcomes, suboptimal access may contribute to harmful and thus unacceptable disparities in survivorship.

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Racial/ethnic disparities are seen among many diseases and are influenced by underlying inequities in treatment. Colorectal cancer is no exception to this unfortunate situation; data have shown that non-Hispanic Black (NHB) patients suffer more from rectal cancer disparities than do Hispanic patients, even after accounting for socioeconomic factors. After propensity matching for age, insurance, and income, NHB patients are less likely to receive all treatment modalities (surgery, radiation, and/or chemotherapy) compared with non-Hispanic white (NHW) patients, resulting in significantly shorter survival. However, Hispanic patients' treatment and survival are similar to NHW patients.[1] Similar findings have been shown for NHB patients with colon cancer, as they have been more likely to lack insurance and reside in more financially impoverished areas. After propensity matching, NHB patients had significantly worse 5-year overall and cancer-specific survival compared with NHW patients.[2] Grunvald et al. determined that minority patients were more likely to have treatment delays, which were driven by socioeconomic factors. Treatment at an academic hospital was the strongest mediator of disparities in timely treatment.[3] These disparities in treatment, particularly surgery, emphasize a need for more focused efforts in disparity reduction that may be within the influence of surgeons.

Minimally invasive (laparoscopic and robotic) surgery (MIS) for colorectal cancer treatment has been steadily increasing and is associated with improved perioperative outcomes. Time to adjuvant systemic therapy is shorter and more patients go on to receive systemic therapy after MIS.[4] Furthermore, MIS and early systemic treatment were associated with improved survival.[4] These data demonstrate that receipt of adjuvant chemotherapy is critical to fully treat patients with resected stage III colon adenocarcinoma. In addition to patient-level benefits of MIS, there are implications on a health-systems level. Another study using data from the US National Inpatient Sample database showed that laparoscopic surgery was associated with improved outcomes and lower costs than open surgery, whereas robotic surgery was associated with higher costs without the added benefit of better outcomes compared with laparoscopic surgery.[5]

Our understanding of disparities in the use of MIS is limited to studies focused on socioeconomic factors or demonstrating conflicting results pertaining to race/ethnicity. Alnasser et al. utilized the 2009 Healthcare Cost and Utilization Project database to study racial disparities in use of laparoscopy for treatment of colorectal cancer, finding that use of laparoscopic surgery was associated with private insurance, teaching hospitals, urban settings, and southern regions of the USA, yet was not associated with race.[6] Cairns et al. reported that laparoscopic surgery for colorectal carcinoma is associated with private insurance and higher household income.[7] In this study, race was associated with outcomes in that NHB patients were more likely to have a complication after laparoscopic surgery compared with NHW patients.[7] Given the limited data on racial/ethnic disparities in MIS approaches for colorectal cancer and the demonstrated benefits in the use of MIS, we sought to characterize possible disparities in surgical approach and associated perioperative outcomes.

PATIENTS AND METHODS

Database and Study Population

In this cross-sectional study, colorectal adenocarcinoma cases among NHW, NHB, and Hispanic patients were identified using the National Cancer Database (NCDB) from 2010 to 2017. Specifically, the colon, rectosigmoid, and rectum data files were accessed. The NCDB is a joint project of the Commission on Cancer of the American College of Surgeons and the American Cancer Society that includes data from more than 1500 Commission-accredited cancer programs in the USA. The data used in the study are derived from a deidentified NCDB file. The American College of Surgeons and the Commission on Cancer have not verified and are not responsible for the analytic or statistical methodology employed, or the conclusions drawn from these data by the investigator. The database includes approximately 70% of all newly diagnosed cancers in the USA.

Cases with adenocarcinoma histology (8140) that were clinical stage I, II, or III were abstracted. Only cases with coded surgical approach were included in the analysis. Open surgical approach was the reference group and robot-assisted and laparoscopic approaches were considered MIS. We utilized intention-to-treat analysis with regard to surgical approach for trends and associations (lymph node retrieval, length of stay, 30-day readmission). For outcome analysis (lymph node harvest, length of stay, 30-day readmission, and overall survival), robot-assisted and laparoscopic surgeries that were converted to open were recategorized as “open surgery” and colon cancer (colon + rectosigmoid) was analyzed separately from rectal cancer (rectum only).

Patient variables included in the study were age, which was categorized as 18–49, 50–74, and 75+ years, sex, health insurance, income, education, rurality [area-based measure of population and degree of urbanization and adjacency to a metropolitan area, using rural–urban continuum codes per US Department of Agriculture (USDA) Economic Research Service[8]], and comorbidity score (Charlson–Deyo). Treatment facility variables included the facility type and geographic location. Disease-specific variables included clinical T stage, analytic stage, number of lymph nodes removed, nodal positivity rate, and margin status. Administration of systemic chemotherapy was also obtained.

Statistical Analysis

Baseline characteristics for NHW, NHB, and Hispanic patients were compared using chi-squared test for categorical variables and one-way ANOVA for continuous variables. Odds of MIS were determined by utilizing univariate and multivariate logistic regression. Odds ratios (OR) with 95% confidence intervals are reported. Lymph node harvest and length of stay were analyzed using Poisson regression, with surgical approach and racial/ethnic group as independent variables. Regression coefficients with 95% confidence intervals (CI) are reported, and 30-day unplanned readmission was analyzed using generalized logit model, with surgical approach and racial/ethnic group as independent variables. Odds ratio (OR) estimates with 95% Wald confidence intervals are reported. Survival was analyzed using Cox proportional hazards, with reporting of hazard ratios (HR) and 95% confidence intervals. Statistical significance was set at $p < 0.05$. All statistical analyses were performed with SAS version 9.4 (Cary, NC: SAS Institute Inc.). This study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[9]

RESULTS

Characteristics of Study Population

In total, the study included 216,364 patients with colorectal cancer [NHW, 178,219 (82.8%); NHB, 24,985 (11.5%); and Hispanic, 13,160 (6.1%)] (Table 1). In comparison with NHW, NHB patients were younger, with a slight female predominance, had more comorbidities, were more likely to be uninsured or Medicaid insured, and resided in zip codes with lower income and education. NHB patients predominantly lived in metropolitan areas (88.9%) in the South and were more likely to receive care at academic/research programs and integrated network cancer programs compared with NHW patients. Hispanic patients were also younger, with male predominance, fewer comorbidities, higher rates of no insurance or Medicaid insurance, and resided in zip codes with lower high school education attainment but were more evenly distributed among income brackets. Hispanic patients predominantly lived in metropolitan areas in the western USA and were more likely to receive care at academic/research programs than NHW patients, who had higher rates of care at community programs. NHW were more likely to have lower-stage disease, with fewer lymph-node-positive patients and lower rates of chemotherapy administration. Hispanic and NHB patients had similar distribution of stage I–III disease, with slightly higher nodal positivity among Hispanic patients. The highest rate of chemotherapy administration was among Hispanic patients, as fewer Hispanic patients refused chemotherapy.

Trends in Surgical Approach

Surgical approach significantly differed by race and ethnicity ($p < 0.0001$), with the highest rate of open surgery among NHB patients and similar rates of laparoscopic or robot-assisted surgeries between NHW and Hispanic patients (Table 1). From 2010 to 2017, robot-assisted surgery increased for all groups, yet rates were consistently lower for NHB patients, with this trend worsening over time (Fig. 1). Laparoscopic surgery increased from 2010 to 2015, and by 2016 had stabilized and became equitable across groups. Hispanic and NHW patients had similar rates of overall MIS operations.

Use of Minimally Invasive Surgery

On univariate analysis, NHB patients were 15% less likely ($p < 0.0001$), yet Hispanics were equally likely ($p = 0.14$), to have a MIS approach as NHW patients. After adjusting for covariates, NHB patients were still 6% less likely ($p < 0.0001$), while Hispanic patients were 12% more likely ($p < 0.0001$) than NHW patients to undergo a MIS approach (Table 2). After adjusting for covariates, lower income, less education, government or no insurance, receiving care at a community cancer program, clinical T4 tumor, and receiving care in the East North Central, East South Central, and West South Central USA were associated with statistically significant and clinically meaningful reduced odds of undergoing MIS approach for all patients combined (Table 3). When racial/ethnic groups were stratified, the odds of undergoing MIS approach were even lower for NHB patients in the lowest income quartile, with clinical T4 tumor stage and receiving care at a facility in the East South Central USA. However, for NHB patients, receiving care at comprehensive community cancer programs and/or facilities in New England significantly increased their likelihood of MIS approach. For Hispanic patients, education and clinical tumor stage did not affect the odds of receiving MIS, with the exception of significantly higher odds of MIS with T1 disease [OR 2.18 (95% CI 1.06–4.49), $p = 0.0350$]. Hispanic patients living in metropolitan areas had much higher odds of MIS [OR 1.34 (95% CI 1.11–1.61), $p = 0.0020$] compared with NHB [OR 1.12 (95% CI 1.01–1.24), $p = 0.0308$] and NHW [OR 1.08 (95% CI 1.05–1.11), $p < 0.0001$] patients. Compared with the South Atlantic, Hispanic patients' odds of MIS was significantly reduced in East North Central [OR 0.65 (95% CI 0.054–0.77), $p < 0.0001$], Middle Atlantic [OR 0.78 (95% CI 0.68–0.90), $p = 0.0004$], Mountain [OR 0.73 (95% CI 0.61–0.88), $p = 0.0007$], Pacific [OR 0.75 (95% CI 0.66–0.85), $p < 0.0001$], and West South Central [OR 0.69 (95% CI 0.61–0.78), $p < 0.0001$] regions. NHW patients' odds of undergoing MIS approach largely reflected the data from all patients combined given their relatively large contribution of the overall study population.

Use of MIS and Race/Ethnicity Impacts Outcomes

Lymph node retrieval was significantly affected by surgical approach, although the effect size difference was marginal (Table 4). Specifically, for colon cancer laparoscopic surgery was associated with a 2.0% (95% CI 1.8–2.3%, $p < 0.0001$) increase in expected log counts of lymph node (LN) retrieval, and robotic surgery was associated with a 1.3% (95% CI 0.8–1.7%, $p < 0.0001$) increase in expected log counts of LN retrieval compared with open surgery. Lymph node retrieval with MIS for rectal cancer was also superior to that of open surgery, with laparoscopic surgery being associated with a 4.4% (95% CI 3.9–4.9%, $p < 0.0001$) increase in expected log counts of LN retrieval, and robotic surgery being associated with a 7.0% (95% CI 6.4–7.5%, $p < 00001$) increase in expected log counts of LN retrieval compared with open surgery.

Minority race/ethnicity was associated with a decrease in expected log counts of LN retrieval compared with NHW patients for both colon and rectal cancer resections (Table 4). For colon cancer, NHB patients had a 2.7% (95% CI 2.4–3.0%, $p < 0.0001$) decrease in expected log counts of LN retrieved compared with NHW patients, while Hispanic and NHW patients had similar LN retrieval. For rectal cancer, NHB patients had a 3.0% (95% CI 2.2–3.7%, $p < 0.0001$) decrease in expected log counts of LN retrieval and Hispanic patients likewise had a 1.7% (95% CI 0.9–2.6%, $p = 0.0131$) decrease in expected log counts of LN retrieval compared with NHW patients.

Length of hospital stay following surgery was significantly influenced by surgical approach (Table 4). For colon cancer, laparoscopic surgery was associated with a 30.1% (95% CI 29.7–30.5%, $p < 0.0001$) reduction in expected log counts of length of hospital stay, whereas robotic surgery was associated with a 41.6% (95% CI 40.6–42.5%, $p < 0.0001$) reduction in expected log counts of length of hospital stay compared with open surgery. For rectal cancer, laparoscopic surgery was associated with an 18.9% (95% CI 18.1–19.7%, $p < 0.0001$) reduction in expected log counts of length of hospital stay and robotic surgery was associated with a 27.3% (95% CI 26.3–28.3%, $p < 0.0001$) reduction in expected log counts of hospital length of stay compared with open surgery.

Minority race/ethnicity was associated with longer expected log counts of length of stay compared with NHW patients for both colon and rectal cancer resections (Table 4). For colon cancer, NHB patients had an 8.1% (95% CI 7.5–86%, $p < 0.0001$) longer length of stay compared with NHW patients, while Hispanic and NHW patients had similar length of stay. For rectal cancer, NHB patients had an 18.2% (95% CI 17.1–19.3%, $p < 0.0001$) longer expected log count of length of stay and Hispanic patients likewise had a 1.7% (95% CI 0.4–3.0%, $p = 0.0131$) longer length of stay compared with NHW patients.

In addition, 30-day unplanned readmission was also significantly impacted by surgical approach. Odds of unplanned readmission were 19.4% lower for laparoscopic and 27.8% lower for robotic colon cancer operations ($p < 0.0001$), respectively, compared with open operations, but not for rectal cancer operations (Table 5). Racial disparities were observed in that NHB patients with colon cancer had significantly higher odds of unplanned (16.4%; 95% CI 10–24%; $p < 0.0001$) readmissions within 30 days (Table 5), and 15% higher odds of unplanned readmission for NHB patients with rectal cancer was also observed ($p = 0.012$). Hispanic patients with colon cancer had similar odds of unplanned readmission compared with NHW patients.

Colon cancer race/ethnicity-adjusted risk of death was lower for laparoscopic and robotic surgery (34% and 47%, respectively, $p < 0.0001$) with 5-year estimated survival 10.6–14.2% higher for patients who underwent laparoscopic and robotic surgery, respectively (Table 6). After adjusting for surgery type, risk of death was 12% lower for NHB and 35% lower for Hispanic patients compared with NHW patients ($p < 0.0001$), with 5-year estimated survival 2.2% and 9.9% higher for NHB and Hispanic patients, respectively compared with NHW patients. Rectal cancer race/ethnicity-adjusted risk of death was also lower for laparoscopic and robotic surgery (27% and 36%, respectively, $p < 0.0001$), with superior 5-year estimated survival 6.8% and 9.1% higher for patients who underwent laparoscopic and robotic surgery, respectively, compared with open surgery (Table 6). Hispanic patients had 21% lower risk of death, while NHB patients had 12% higher risk of death than NHW patients with rectal cancer after adjusting for surgery type ($p < 0.0001$). The 5-year estimated survival with rectal cancer was lowest among NHB patients (69.1%), followed by NHW (73.1%) and Hispanic (78.1%) patients (Table 6).

DISCUSSION

This study demonstrates that although there appears to be racial/ethnic equity in provision of laparoscopic surgery, NHB patients have historically undergone less robotic surgery despite its association with superior LN retrieval, shorter hospital stays, lower rates of unplanned readmission, and improved survival. Particularly worrisome is that the disparity gap in rates of robotic surgery is widening for NHB patients. Our study identified insurance as one factor influencing disparate use of robotic surgery, but it is important to note that insurance plans that cover MIS for necessary procedures include provision of both laparoscopic and robot-assisted approaches. NHB patients are notably more likely to be uninsured, in which case treatment options may be negatively impacted by lack of insurance coverage. These findings are consistent with previous work identifying insurance status as a driver of disparities in MIS for rectal cancer.[10] Access to robotic surgery that extends beyond factors such as income, education, insurance, rurality, and distance from treatment facilities likely account for this observation. For example, our findings may reflect receipt of care for NHB patients at hospitals or treatment facilities that lack robotic surgery capabilities or surgeons trained in this technique. Specific to our colon cancer data, NHB patients have improved survival compared with NHW patients when surgical approach is considered, suggesting that systematic improvements in access to MIS, particularly robotic surgery, could have a profoundly positive impact on disparities in survivorship for NHB patients.

Racial disparities pertaining to access and utilization of minimally invasive surgical approaches for a wide variety of operations have existed for many decades. Previous studies examining data from the 1990s have shown that NHW and Hispanic patients are more likely to receive laparoscopic approaches for appendicitis.[11,12] One criticism of these studies was that they did not account for treating hospital type, which is a signifcant factor in advanced minimally invasive approaches and techniques. After controlling for access to more advanced treatment facilities, Pieracci et al. demonstrated no significant differences in rates of laparoscopic appendectomy by race.[12] Lassiter et al. examined the National Inpatient Sample (NIS) and demonstrated that NHB patients with diverticulitis were significantly less likely to receive a minimally invasive surgical approach, although this did not account for treating facility type.[13]

Previous work has shown disparities in surgical approaches to the treatment of colorectal cancer. Simon et al. showed that advancing age was independently associated with significantly lower likelihood of MIS approach to rectal cancer.[14] Gabriel et al. then highlighted differences in access to MIS approaches for rectal cancer, and although the focus was not on racial disparities, they demonstrated that patients with higher income levels and private insurance status were more likely to undergo a MIS approach.[15] Private insurance has been shown to not only influence the surgical approach in treatment of colorectal cancer, but also timeliness to robotic surgery and initiation of adjuvant therapy.[16] Patel et al. likewise found private insurance and higher income levels to be associated with increased odds of MIS, but added that urban teaching hospitals and hospitals with larger bed size were associated with higher use of MIS approaches for patients with colorectal cancer.[17] Horsey et al. recently published data on utilization of robotic surgery for colorectal cancer, and in line with our findings, they reported that NHB patients were less likely to receive a robotic approach.[18]

While our study utilizing NCDB data is well powered, there are several limitations worth noting. Misclassification bias is inherent in retrospectively designed studies. Importantly, the NCDB does not provide data on the availability of robot-assisted surgery or surgeons trained in these advanced techniques at specific facilities. Therefore, we are only able to speculate that access to facilities with robotic capabilities and/or surgeons with robotic training is a significant driver of racial disparities in robotic surgery for colorectal cancer. Furthermore, these data limit our ability to assess bias in referral patterns to surgeons who perform MIS colorectal procedures as well as surgeon bias in choosing a MIS approach. Data for income and education are based on census data from the patient's zip code and may not accurately reflect an individual's socioeconomic status. Lastly, we do not have an explanation for why NHB and Hispanic patients had fewer LN retrieved compared with NHW patients for both colon and rectal cancers.

CONCLUSIONS

Racial/ethnic disparities exist in utilization of MIS for colorectal cancer treatment, disproportionately affecting NHB patients. Since MIS has the potential to improve outcomes, suboptimal access may contribute to harmful and thus unacceptable disparities in survivorship. Efforts to increase the availability of robot-assisted procedures and surgeons trained in this modality are needed, particularly in areas that serve racial/ethnic minority patients.

ACKNOWLEDGEMENT

Services and products in support of the research project were generated by the VCU Massey Cancer Center Biostatistics Shared Resource, supported in part with funding from NIH-NCI Cancer Center Support Grant P30 CA016059. Authors are supported by the National Human Genome Research Institute (T32 HG008958 to ANR, KMH) and National Cancer Institute (R01 CA242003 to JGT, U54 CA233444 to JGT, U54 CA233444–03S1 to ANR, and JGT) of the National Institutes of Health and the Joseph and Ann Matella Fund for Pancreatic Cancer Research (JGT).

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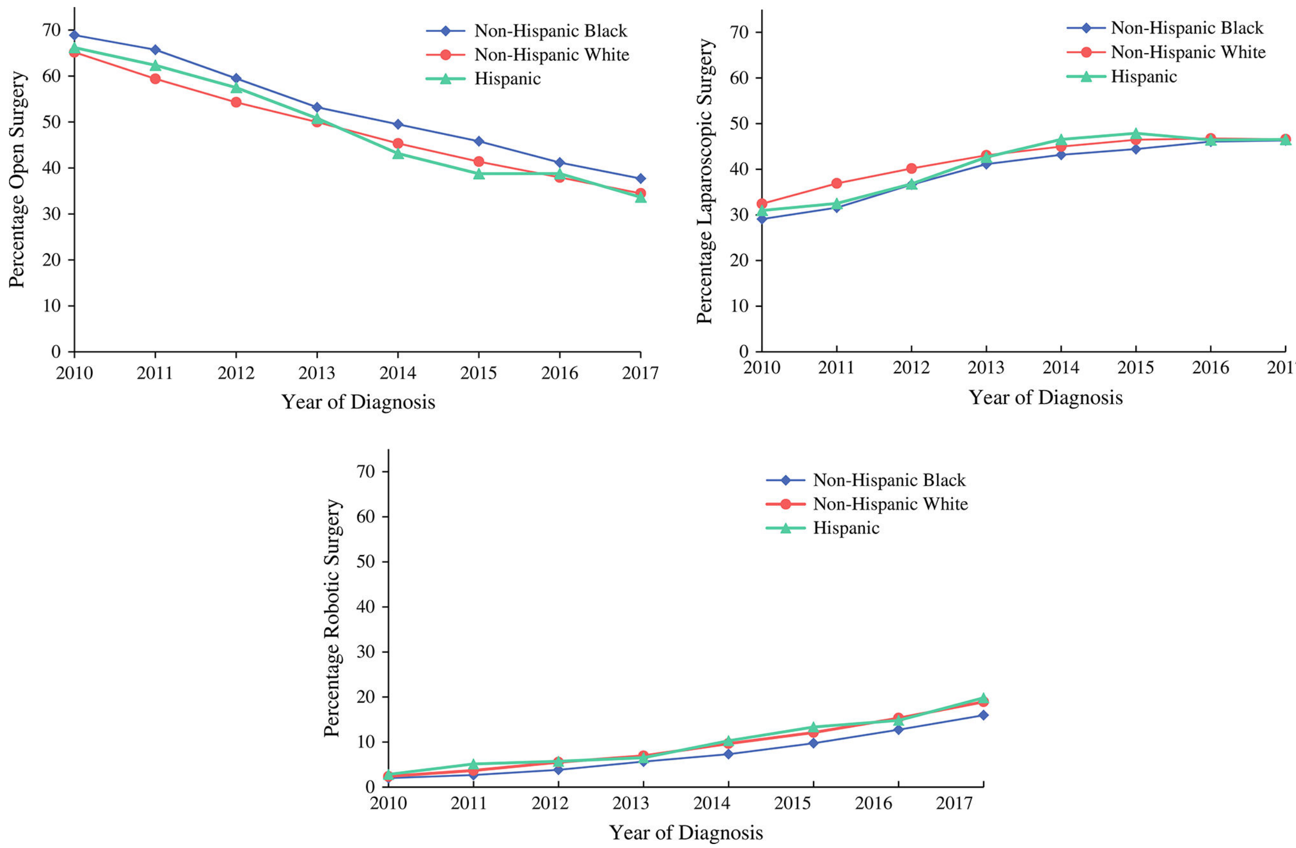

FIG. 1.

Trends in surgical approach for colorectal cancer surgery in the USA, by race/ethnicity. From 2010 to 2017, there has been a steady decline in the use of open surgery; between minimally invasive techniques, robotic surgery has experienced a more rapid increase. These trends were seen across racial/ethnic groups, but non-Hispanic Black patients have consistently higher rates of open surgery and lower rates of robotic surgery compared to non-Hispanic white and Hispanic patients, while the use of laparoscopic surgery equalized between racial/ethnic groups by 2016

TABLE 1

Patient, facility, pathologic, and treatment characteristics, by racial/ethnic group; demographic, socioeconomic, treatment facility, pathology data, and treatment (systemic chemotherapy and surgery type) are reported for non-Hispanic Black, non-Hispanic white, and Hispanic patients; chi-squared test for categorical variables and one-way ANOVA for continuous variables were utilized to determine *p*-values (< 0.05 is denoted with bold text)

	Non-Hispanic Black *N* = 24,985	**Non-Hispanic white *N* = 178,219**	**Hispanic *N* = 13,160**	***p*-Value**
Age group				
18–49	3134 (12.5%)	16,082 (9.0%)	2193 (16.7%)	**< 0.0001**
50–74	16,179 (64.8%)	97,055 (54.5%)	7956 (60.5%)	
75+	5672 (22.7%)	65,082 (36.5%)	3011 (22.9%)	
Sex				
Female	12,846 (51.4%)	85,724 (48.1%)	5879 (44.7%)	**< 0.0001**
Male	12,139 (48.6%)	92,495 (51.9%)	7281 (55.3%)	
Health insurance				
Private	8417 (33.7%)	59927 (33.6%)	4607 (35.0%)	**< 0.0001**
Medicaid	2544 (10.2%)	6864 (3.9%)	1848 (14.0%)	
Medicare	11,838 (47.4%)	103,522 (58.1%)	5122 (38.9%)	
Other government	261 (1.0%)	1666 (0.9%)	63 (0.5%)	
No insurance	1570 (6.3%)	3999 (2.2%)	1297 (9.9%)	
Unknown	355 (1.4%)	2241 (1.3%)	223 (1.7%)	
Income				
< $40,227	10314 (41.3%)	24561 (13.8%)	3378 (25.7%)	**< 0.0001**
$40,227–50,353	4552 (18.2%)	37237 (20.9%)	2786 (21.2%)	
$50,354–63,332	3402 (13.6%)	39194 (22.0%)	2798 (21.3%)	
≥ $63,333	3846 (15.4%)	58,225 (32.7%)	2914 (22.1%)	
Unknown	2871 (11.5%)	19,002 (10.7%)	1284 (9.8%)	
Education (did not graduate from high school)				
< 6.3%	1805 (7.2%)	41,838 (23.5%)	1088 (8.3%)	**< 0.0001**
6.3–10.8%	3827 (15.3%)	48,713 (27.3%)	1769 (13.4%)	
10.8–17.5%	7134 (28.6%)	42542 (23.9%)	2519 (19.1%)	
≥ 17.6%	9393 (37.6%)	26,468 (14.9%)	6513 (49.5%)	
Unknown	2826 (11.3%)	18,658 (10.5%)	1271 (9.7%)	

	Non-Hispanic Black *N* = 24,985	Non-Hispanic white *N* = 178,219	Hispanic *N* = 13,160	*p*-Value
Urban versus rural status				
Urban	2106 (8.4%)	27,511 (15.4%)	618 (4.7%)	**< 0.0001**
Metro	22,201 (88.9%)	142,429 (79.9%)	12,322 (93.6%)	
Rural	272 (1.1%)	3734 (2.1%)	51 (0.4%)	
Unknown	406 (1.6%)	4545 (2.6%)	169 (1.3%)	
Comorbidity score				
0	16,597 (66.4%)	121,750 (68.3%)	9239 (70.2%)	**< 0.0001**
1	5636 (22.6%)	37,793 (21.2%)	2876 (21.9%)	
2	1661 (6.7%)	12,047 (6.8%)	616 (4.7%)	
≥ 3	1091 (4.4%)	6629 (3.7%)	429 (3.3%)	
Facility type				
Academic/research program	9306 (37.3%)	47,343 (26.6%)	4472 (34.0%)	**< 0.0001**
Community cancer program	2069 (8.3%)	20,063 (11.3%)	1168 (8.9%)	
Comprehensive community cancer program	8955 (35.8%)	82,084 (46.1%)	5011 (38.1%)	
Integrated network cancer program	3894 (15.6%)	24,881 (14.0%)	1839 (14.0%)	
Unknown	761 (3.1%)	3848 (2.2%)	670 (5.1%)	
Facility location				
East North Central	4027 (16.1%)	35,015 (19.7%)	906 (6.9%)	**< 0.0001**
East South Central	2550 (10.2%)	13,549 (7.6%)	84 (0.6%)	
Middle Atlantic	3323 (13.3%)	25,262 (14.2%)	1892 (14.4%)	
Mountain	213 (0.9%)	7323 (4.1%)	809 (6.2%)	
New England	514 (2.1%)	9729 (5.5%)	381 (2.9%)	
Pacific	937 (3.8%)	16,343 (9.2%)	2946 (22.4%)	
South Atlantic	8915 (35.7%)	37,019 (20.8%)	2309 (17.6%)	
West North Central	760 (3.0%)	15,769 (8.9%)	193 (1.5%)	
West South Central	2985 (12.0%)	14,362 (8.1%)	2970 (22.6%)	
Unknown	761 (3.1%)	3848 (2.2%)	670 (5.1%)	
T stage				
cT0	73 (0.3%)	522 (0.3%)	34 (0.3%)	**< 0.0001**
cT1	2075 (8.3%)	15,523 (8.7%)	1061 (8.1%)	
cT2	1729 (6.9%)	14,447 (8.1%)	940 (7.1%)	

	Non-Hispanic Black N = 24,985	Non-Hispanic white N = 178,219	Hispanic N = 13,160	p-Value
cT3	5867 (23.5%)	45,518 (25.5%)	3455 (26.3%)	
cT4	1178 (4.7%)	7915 (4.4%)	710 (5.4%)	
cTX	11,720 (46.9%)	78,800 (44.2%)	5561 (42.3%)	
pTis	191 (0.8%)	1239 (0.7%)	71 (0.5%)	
Unknown	2152 (8.6%)	14,255 (8.0%)	1328 (10.1%)	
Analytic stage				
1	5217 (20.9%)	43,057 (24.2%)	2729 (20.7%)	**< 0.0001**
2	9331 (37.4%)	68,448 (38.4%)	4954 (37.6%)	
3	10,437 (41.8%)	66,714 (37.4%)	5477 (41.6%)	
Number of lymph nodes removed (mean, SD)				
Q1 (0–14)	7673 (30.7%)	54,703 (30.7%)	4000 (30.4%)	**0.0020**
Q2 (15–18)	5805 (23.2%)	40,154 (22.5%)	2961 (22.5%)	
Q3 (19–24)	5559 (22.3%)	39,425 (22.1%)	2941 (22.4%)	
Q4 (> 24)	5865 (23.5%)	43,502 (24.4%)	3212 (24.4%)	
Unknown	83 (0.3%)	435 (0.2%)	46 (0.4%)	
Nodal positivity rate (%)				
Mean (range)	7.3 (0.0–100.0)	6.8 (0.0–100.0)	7.6 (0.0–100.0)	**< 0.0001**
Margin status				
Positive	1190 (4.8%)	8654 (4.9%)	655 (5.0%)	0.2114
Negative	23,669 (94.7%)	168,656 (94.6%)	12,425 (94.4%)	
Not assessed	45 (0.2%)	251 (0.1%)	18 (0.1%)	
Unknown	81 (0.3%)	658 (0.4%)	62 (0.5%)	
Systemic chemotherapy				
Yes	10,991 (44.0%)	74,547 (41.8%)	6464 (49.1%)	**< 0.0001**
None	10,480 (42.0%)	80,757 (45.3%)	5167 (39.3%)	
Contraindicated	943 (3.8%)	6575 (3.7%)	328 (2.5%)	
Not administered (no reason)	230 (0.9%)	934 (0.5%)	98 (0.7%)	
Not administered (patient died)	152 (0.6%)	1281 (0.7%)	53 (0.4%)	
Not administered (patient refused)	1292 (5.2%)	9637 (5.4%)	471 (3.6%)	
Unknown	897 (3.6%)	4488 (2.5%)	579 (4.4%)	
Surgery type				

	Non-Hispanic Black *N* = 24,985	**Non-Hispanic white *N* = 178,219**	**Hispanic *N* = 13,160**	***p*-Value**
Endoscopic or laparoscopic	8319 (33.3%)	64,876 (36.4%)	4721 (35.9%)	**< 0.0001**
Endoscopic or laparoscopic converted to open	1654 (6.6%)	10,380 (5.8%)	792 (6.0%)	
Open or approach unspecified	13,127 (52.5%)	86,298 (48.4%)	6285 (47.8%)	
Robotic assisted	1733 (6.9%)	15,460 (8.7%)	1257 (9.6%)	
Robotic converted to open	152 (0.6%)	1205 (0.7%)	105 (0.8%)	

TABLE 2

Logistic regression on use of minimally invasive surgery by race and ethnicity; univariate and multivariate models were implemented to determine the odds of using minimally invasive surgery for non-Hispanic Black and Hispanic patients, in reference to non-Hispanic white patients; non-Hispanic Black patients were less likely to undergo minimally invasive surgery in both models, whereas Hispanic patients were more likely to undergo minimally invasive surgery after adjusting for covariates; multivariate logistic regression model adjusted for income, education, insurance, rurality, comorbidities, distance from facility, facility type, facility region, and clinical T stage

	Univariate logistic regression		Multivariate logistic regression	
Ethnicity and race	**OR (95% CI)**	***p*-Value**	**OR (95% CI)**	***p*-Value**
Non-Hispanic white	Reference		Reference	
Non-Hispanic Black	0.85 (0.83–0.87)	< 0.0001	0.94 (0.91–0.97)	< 0.0001
Hispanic	1.03 (0.99–1.06)	0.1417	1.12 (1.08–1.17)	< 0.0001

TABLE 3

Multivariable logistic regression on use of minimally invasive surgery by race and ethnicity; odds of laparoscopic or robotic surgical approaches are shown by multiple variables related to the patient, facility, and clinical tumor stage

	All patients		Non-Hispanic Black		Non-Hispanic white		Hispanic	
Category	**OR (95% CI)**	***p*-Value**	**OR (95% CI)**	***p*-Value**	**OR 95% CI)**	***p*-Value**	**OR (95% CI)**	***p*-Value**
Income								
≥ $63,333	Reference		Reference		Reference		Reference	
< $40,227	0.76 (0.73–0.79)	< 0.0001	0.75 (0.68–0.84)	< 0.0001	0.77 (0.74 – 0.80)	< 0.0001	0.75 (0.65–0.86)	< 0.0001
$40,227–50,353	0.84 (0.82–0.87)	< 0.0001	0.87 (0.78–0.96)	0.0073	0.85 (0.82 – 0.88)	< 0.0001	0.75 (0.65–0.85)	< 0.0001
$50,354–63,332	0.88 (0.86–0.90)	< 0.0001	0.90 (0.82–1.00)	0.0488	0.88 (0.85 – 0.90)	< 0.0001	0.88 (0.78–0.99)	0.0303
Unknown	0.78 (0.64–0.95)	0.0129	0.68 (0.37–1.25)	0.2130	0.81 (0.65 – 1.00)	0.0547	0.41 (0.12–1.37)	0.1463
Education (did not graduate from high school)								
< 6.3%	Reference		Reference		Reference		Reference	
6.3–10.8%	0.90 (0.88–0.93)	< 0.0001	0.86 (0.76–0.97)	0.0117	0.90 (0.88–0.93)	< 0.0001	0.91 (0.78–1.07)	0.2531
10.8–17.5%	0.89 (0.87–0.92)	< 0.0001	0.89 (0.78–1.00)	0.0587	0.89 (0.86–0.92)	< 0.0001	1.00 (0.85–1.18)	0.9701
≥ 17.6%	0.91 (0.88–0.95)	< 0.0001	0.89 (0.78–1.01)	0.0807	0.92 (0.88–0.96)	< 0.0001	1.00 (0.85–1.18)	0.9935
Unknown	1.02 (0.82–1.27)	0.8595	1.48 (0.77–2.84)	0.2436	0.95 (0.75–1.21)	0.6767	1.68 (0.48–5.93)	0.4182
Facility type								
Academic/research program	Reference		Reference		Reference		Reference	
Community cancer program	0.59 (0.57–0.60)	< 0.0001	0.69 (0.62–0.77)	< 0.0001	0.57 (0.55–0.59)	< 0.0001	0.57 (0.50–0.66)	< 0.0001
Comprehensive community cancer program	0.95 (0.93–0.97)	< 0.0001	1.10 (1.03–1.17)	0.0037	0.93 (0.91–0.96)	< 0.0001	0.83 (0.76–0.91)	0.0001
Integrated network cancer program	1.00 (0.97–1.03)	0.8430	1.08 (0.99–1.18)	0.0775	0.97 (0.93–1.00)	0.0422	1.14 (1.00–1.29)	0.0488
Unknown	0.96 (0.90–1.02)	0.1762	0.89 (0.75–1.05)	0.1680	0.99 (0.92–1.07)	0.8788	0.71 (0.58–0.87)	0.0009
Distance from facility	1.00 (1.00–1.00)	0.0032	1.00 (1.00–1.00)	0.1303	1.00 (1.00–1.00)	0.0171	1.00 (1.00–1.00)	0.1940
Health insurance								
Private	Reference		Reference		Reference		Reference	
Medicaid	0.75 (0.72–0.78)	< 0.0001	0.75 (0.68–0.83)	< 0.0001	0.75 (0.71–0.79)	< 0.0001	0.78 (0.69–0.88)	< 0.0001
Medicare	0.82 (0.81–0.84)	< 0.0001	0.81 (0.77–0.87)	< 0.0001	0.82 (0.80–0.84)	< 0.0001	0.87 (0.80–0.95)	0.0019
Other government	1.02 (0.93–1.12)	0.7173	0.84 (0.65–1.10)	0.2018	1.04 (0.93–1.15)	0.5046	1.36 (0.78–2.36)	0.2816
No insurance	0.54 (0.51–0.57)	< 0.0001	0.58 (0.51–0.65)	< 0.0001	0.53 (0.49–0.57)	< 0.0001	0.52 (0.46–0.60)	< 0.0001
Unknown	0.47 (0.44–0.52)	< 0.0001	0.47 (0.37–0.60)	< 0.0001	0.47 (0.43–0.51)	< 0.0001	0.57 (0.43–0.76)	0.0001

Category	All patients		Non-Hispanic Black		Non-Hispanic white		Hispanic	
	OR (95% CI)	*p*-Value	OR (95% CI)	*p*-Value	OR 95% CI)	*p*-Value	OR (95% CI)	*p*-Value
Urban versus rural status								
Urban	Reference		Reference		Reference		Reference	
Metro	1.09 (1.06–1.12)	< 0.0001	1.12 (1.01–1.24)	0.0308	1.08 (1.05–1.11)	< 0.0001	1.34 (1.11–1.61)	0.0020
Rural	0.90 (0.84–0.97)	0.0049	1.27 (0.97–1.65)	0.0828	0.88 (0.81–0.95)	0.0007	0.83 (0.44–1.54)	0.5486
Unknown	1.01 (0.95–1.08)	0.7400	1.02 (0.81–1.29)	0.8686	1.00 (0.93–1.07)	0.9622	1.47 (1.00–2.15)	0.0481
Comorbidity								
0	Reference		Reference		Reference		Reference	
1	0.98 (0.96–1.00)	0.0763	1.05 (0.98–1.12)	0.1361	0.97 (0.94–0.99)	0.0078	1.02 (0.93–1.11)	0.7012
2	0.98 (0.94–1.01)	0.1915	1.14 (1.02–1.27)	0.0173	0.95 (0.92–0.99)	0.0192	1.03 (0.86–1.22)	0.7714
≥ 3	0.97 (0.92–1.01)	0.1737	1.13 (0.99–1.30)	0.0642	0.94 (0.89–0.99)	0.0213	1.05 (0.85–1.30)	0.6403
T stage								
cT0	Reference		Reference		Reference		Reference	
cT1	1.38 (1.16–1.63)	0.0002	0.96 (0.58–1.59)	0.8692	1.41 (1.17–1.69)	0.0003	2.18 (1.06–4.49)	0.0350
cT2	1.28 (1.08–1.51)	0.0047	0.88 (0.53–1.46)	0.6130	1.32 (1.10–1.59)	0.0034	1.78 (0.86–3.68)	0.1185
cT3	1.10 (0.93–1.30)	0.2571	0.79 (0.48–1.30)	0.3445	1.13 (0.94–1.36)	0.1826	1.54 (0.75–3.15)	0.2358
cT4	0.62 (0.52–0.74)	< 0.0001	0.50 (0.30–0.83)	0.0074	0.63 (0.52–0.76)	< 0.0001	0.78 (0.38–1.63)	0.5158
cTX	1.28 (1.09–1.52)	0.0032	0.91 (0.55–1.49)	0.6958	1.32 (1.10–1.59)	0.0027	1.80 (0.88–3.68)	0.1051
pTis	1.67 (1.37–2.04)	< 0.0001	1.09 (0.61–1.95)	0.7676	1.76 (1.42–2.19)	< 0.0001	1.98 (0.83–4.72)	0.1233
Unknown	1.33 (1.12–1.57)	0.0009	0.90 (0.54–1.49)	0.6763	1.40 (1.16–1.68)	0.0004	1.63 (0.79–3.34)	0.1872
Facility location								
South Atlantic	Reference		Reference		Reference		Reference	
East North Central	0.89 (0.87–0.92)	< 0.0001	0.91 (0.84–0.99)	0.0363	0.91 (0.89–0.94)	< 0.0001	0.65 (0.54–0.77)	< 0.0001
East South Central	0.88 (0.85– 0.91)	< 0.0001	0.79 (0.71–0.87)	< 0.0001	0.92 (0.88–0.96)	< 0.0001	0.74 (0.46–1.18)	0.2029
Middle Atlantic	1.13 (1.10–1.17)	< 0.0001	1.12 (1.02–1.22)	0.0170	1.17 (1.13–1.21)	< 0.0001	0.78 (0.68–0.90)	0.0004
Mountain	1.29 (1.22–1.35)	< 0.0001	1.13 (0.85–1.51)	0.3875	1.38 (1.30–1.46)	< 0.0001	0.73 (0.61–0.88)	0.0007
New England	1.22 (1.16–1.27)	< 0.0001	1.58 (1.30–1.91)	< 0.0001	1.23 (1.17–1.29)	< 0.0001	0.95 (0.75–1.21)	0.6957
Pacific	1.05 (1.01–1.09)	0.0114	1.07 (0.93–1.24)	0.3602	1.09 (1.05–1.13)	< 0.0001	0.75 (0.66–0.85)	< 0.0001
West North Central	1.17 (1.13–1.22)	< 0.0001	1.13 (0.96–1.32)	0.1437	1.21 (1.16–1.26)	< 0.0001	0.75 (0.54–1.03)	0.0725
West South Central	0.86 (0.83–0.89)	< 0.0001	0.85 (0.77–0.93)	0.0003	0.88 (0.84–0.92)	< 0.0001	0.69 (0.61–0.78)	< 0.0001

TABLE 4

Lymph node retrieval and hospital length of stay by surgical approach and race/ethnicity; Poisson regression was used to determine the influence of surgical approach and race/ethnicity on lymph node retrieval and length of hospital stay, with estimates (95% CI) representing the expected log count compared with the reference group; laparoscopic and robotic surgery significantly increased the lymph node harvest for both colon and rectal cancers; Black race was associated with significantly fewer lymph nodes retrieved and Hispanic ethnicity was associated with significantly fewer lymph nodes retrieved for rectal cancer, but significantly higher lymph nodes retrieved for colon cancer, and laparoscopic and robotic surgery significantly reduced the length of stay for both colon and rectal cancers; Black race was associated with significantly longer length of stay and Hispanic ethnicity was associated with longer length of stay for rectal cancer, but not colon cancer

	Estimate (95% CI)	*p*-Value
Lymph node retrieval		
Colon		
Intercept	3.0539 (3.0524, 3.0554)	< 0.0001
Surgical approach		
Laparoscopic versus open	0.0204 (0.0182, 0.0226)	< 0.0001
Robotic versus open	0.0128 (0.0082, 0.0174)	< 0.0001
Race/ethnicity		
Non-Hispanic Black versus non-Hispanic white	−0.0271 (−0.0303, −0.0239)	< 0.0001
Hispanic versus non-Hispanic white	0.0101 (0.0056, 0.0145)	< 0.0001
Rectal		
Intercept	2.7589 (2.7559, 2.7620)	< 0.0001
Surgical approach		
Laparoscopic versus open	0.0440 (0.0389, 0.0490)	< 0.0001
Robotic versus open	0.0696 (0.0638, 0.0754)	< 0.0001
Race/ethnicity		
Non-Hispanic black versus non-Hispanic white	−0.0295 (−0.0373, −0.0217)	< 0.0001
Hispanic versus non-Hispanic white	−0.0178 (−0.0264, −0.0092)	< 0.0001
Length of hospital stay		
Colon		
Intercept	2.0317 (2.0291, 2.0343)	< 0.0001
Surgical approach		
Laparoscopic versus open	−0.3012 (−0.3053, −0.2972)	< 0.0001

	Estimate (95% CI)	*p*-Value
Robotic versus open	−0.4155 (−0.4250, −0.4061)	< 0.0001
Race/ethnicity		
Non-Hispanic black versus non-Hispanic white	0.0807 (0.0751, 0.0863)	< 0.0001
Hispanic versus non-Hispanic white	−0.0044 −0.0126, 0.0039)	0.2996
Rectal		
Intercept	2.0314 (2.0269, 2.0360)	< 0.0001
Surgical approach		
Laparoscopic versus open	−0.1890 (−0.1969, −0.1811)	< 0.0001
Robotic versus open	−0.2728 (−0.2825, −0.2631)	< 0.0001
Race/ethnicity		
Non-Hispanic black versus non-Hispanic white	0.1815 (0.1705, 0.1925)	< 0.0001
Hispanic versus non-Hispanic white	0.0168 (0.0035, 0.0301)	0.0131

TABLE 5

Thirty-day readmission by surgical approach and race/ethnicity; generalized logit model was used to determine odds of unplanned readmission within 30-days by surgical approach and race/ethnicity; odds of unplanned readmission was significantly lower for laparoscopic and robotic colon cancer operations, but not for rectal cancer operations; racial disparities were observed in that non-Hispanic black patients had significantly higher odds of unplanned readmissions within 30 days, and higher odds of unplanned readmission for non-Hispanic black patients with rectal cancer was also observed; Hispanic patients with colon cancer had similar odds of readmission compared with non-Hispanic white patients

	OR Estimate (95% CI)	*p*-Value
Colon		
Surgical approach		
Laparoscopic versus open		
Unplanned readmission	0.806 (0.77–0.84)	< 0.0001
Robotic versus open		
Unplanned readmission	0.722 (0.65–0.80)	< 0.0001
Race/ethnicity		
Non-Hispanic black versus non-Hispanic white		
Unplanned readmission	1.164 (1.10–1.24)	< 0.0001
Hispanic versus non-Hispanic white		
Unplanned readmission	0.992 (0.91–1.09)	0.864
Rectal		
Surgical approach		
Laparoscopic versus open		
Unplanned readmission	0.966 (0.89–1.05)	0.395
Robotic versus open		
Unplanned readmission	1.040 (0.95–1.14)	0.402
Race/ethnicity		
Non-Hispanic black versus non-Hispanic white		
Unplanned readmission	1.157 (1.03–1.30)	0.012
Hispanic versus non-Hispanic white		
Unplanned readmission	1.117 (0.98–1.27)	0.093

TABLE 6

Survival analysis by surgical approach and race/ethnicity; Cox proportional hazards models were utilized to determine race/ethnicity adjusted hazard of death for laparoscopic or robotic surgery compared with open surgery; similarly, surgical approach adjusted hazard of death for non-Hispanic Black and Hispanic patients were determined, compared with non-Hispanic white patients, 5-year survival probability estimates are also shown for colon and rectal cancers by surgical approach and race/ethnicity

	HR (95% CI)	*p*-Value	5-year survival probability estimate (%)
Colon			
Surgical approach			
Open	Ref		61.0
Laparoscopic	0.658 (0.645–0.672)	< 0.0001	71.6
Robotic	0.527 (0.498–0.558)	< 0.0001	75.2
Race/ethnicity			
Non-Hispanic white	Ref		64.8
Non-Hispanic black	0.880 (0.855–0.905)	< 0.0001	67.0
Hispanic	0.650 (0.620–0.682)	< 0.0001	74.7
Rectum			
Surgical approach			
Open	Ref		70.1
Laparoscopic	0.733 (0.701–0.766)	< 0.0001	76.9
Robotic	0.641 (0.601–0.683)	< 0.0001	79.2
Race/ethnicity			
Non-Hispanic white	Ref		73.1
Non-Hispanic black	1.120 (1.052–1.192)	< 0.0001	69.1
Hispanic	0.785 (0.721–0.854)	< 0.0001	78.1