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Enhanced Recovery After Surgery (ERAS) Eliminates Racial Disparities in Postoperative Length of Stay After Colorectal Surgery

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Abstract

Objective: To investigate the effects of enhanced recovery after surgery (ERAS) on racial disparities in postoperative length of stay (pLOS) after colorectal surgery.

Background: Racial disparities in surgical outcomes exist. We hypothesized that ERAS would reduce disparities in pLOS between black and white patients.

Methods: Patients undergoing ERAS in 2015 were 1:1 matched by race/ethnicity, age, sex, and procedure to a pre-ERAS group from 2010 to 2014. After stratification by race/ethnicity, expected pLOS was calculated using the American College of Surgeons National Surgical Quality Improvement Project Risk Calculator. Primary outcome was the observed pLOS and observed-to-expected difference in pLOS. Secondary outcomes were National Surgical Quality Improvement Project postoperative complications including 30-day readmissions and mortality. Adjusted sensitivity analyses on pLOS were also performed.

Results: Of 420 patients (210 ERAS and 210 pre-ERAS) examined, 28.3% were black. Black and white patients were similar in age, body mass index, sex, American Anesthesia Association class, and minimally invasive approaches. Within the pre-ERAS group, black patients stayed a mean of 2.7 days longer than expected compared with white patients ($P < 0.05$). Overall, ERAS patients had a significantly shorter pLOS (5.7 vs 8 days) and observed-to-expected difference (−0.7 vs 1.4 days) compared with pre-ERAS patients ($P < 0.01$). In the ERAS group, disparities in pLOS were reduced with no differences in readmissions or mortality between black and white patients. On sensitivity analyses, race/ethnicity remained a significant predictor of pLOS among pre-ERAS patients, but not for ERAS patients.

Conclusions: ERAS eliminated racial differences in pLOS between black and white patients undergoing colorectal surgery. Reduced pLOS occurred without increases in mortality, readmissions, and most postoperative complications. ERAS may provide a practical approach to reducing disparities in surgical outcomes.

Racial disparities in health outcomes exist across many surgical disciplines including colorectal surgery.[1–4] Black patients, in particular, experience more postoperative complications with higher mortality,[5] longer postoperative length of stay (pLOS),[5,6] and more unplanned readmission[7–9] than similar white patients after colorectal resection. With colorectal operations accounting for nearly 25% of all complications in general surgery,[5] these disparities result in worsened health outcomes for an already vulnerable population. As the problem of surgical disparities is increasingly recognized, and as studies work to understand driving mechanisms, a concurrent need exists to develop practical clinical strategies that reduce racial disparities.[1]

Enhanced recovery after surgery (ERAS) pathways use standardized, multimodal perioperative strategies to reduce physiologic stress induced by surgery and to promote early recovery. ERAS protocols span the continuum of surgical care and include processes such as patient education, multimodal analgesia, and early mobility. Implementation of ERAS involves the collaboration of a multidisciplinary team supporting the systematic coordination of processes. Studies have consistently shown that ERAS reduces pLOS and may also reduce postoperative complications after surgery without worsening readmission or mortality rates.[10–15] However, the evidence to date on ERAS effectiveness in minority populations is limited by the historic use of homogenous patient samples. No study has examined the potential benefits of ERAS in black populations nor evaluated its potential utility in reducing disparities in surgical outcomes.

Health disparities arise from variations in access and delivery of care at the patient, provider, and healthcare system level.[2,16] ERAS is uniquely positioned to reduce these variations in care by systematically delivering best-evidence care to all surgical patients. We therefore hypothesized that ERAS would reduce racial disparities in pLOS for black patients undergoing colorectal surgery and used a retrospective matched analysis of pre-ERAS and ERAS patients to test this hypothesis.

METHODS

Our study was designed as a retrospective matched cohort study of patients who underwent colorectal surgery at a single institution, minority-serving, tertiary-referral center. The study protocol was reviewed and approved for a waiver of consent by the University of Alabama at Birmingham Institutional Review Board (IRB X160506002).

Study Sample and Variables

All patients undergoing elective colorectal surgery in 2015 were enrolled in the institutional ERAS pathway with no inclusion or exclusion criteria applied. Patients were consecutively identified from a prospectively maintained ERAS database. ERAS patients were stratified by race/ethnicity to black or white groups and 1:1 matched by race/ethnicity, age, sex, and procedure to patients who underwent surgery from 2010 to 2014 (pre-ERAS) in our institutional American College of Surgeons National Surgical Quality Improvement Project (ACS-NSQIP) colorectal registry. Patient and procedure-specific covariates and outcomes were defined using ACS-NSQIP variables.[17] An expected pLOS was obtained for patients by applying the ACS-NSQIP Risk Calculator to their individual and procedure-specific characteristics.[18] The primary outcome was the observed pLOS and observed-to-expected difference (OED) in pLOS. Secondary outcomes assessed from the time of surgery included

30-day readmission, 30-day mortality, and all 30-day ACS-NSQIP assessed postoperative complications. Additional secondary ERAS-specific outcomes to evaluate adherence to ERAS protocol components included intraoperative fluid administration, estimated blood loss, ileus rate requiring insertion of a nasogastric tube, and overall protocol adherence.

Socioeconomic factors such as marital status, insurance type, and social determinants of health (SDOH) were also included. To summarize SDOH, we used the area or neighborhood summary score, which is derived from a summation of z-scores [based on mean and standard deviation (SD)] for 6 validated measures of SDOH obtained from individual zip code census data. An increasing index signifies increasing socioeconomic advantage compared with the national mean.[19] The [6] SDOH variables included: log median household income; percentage households with interest dividend, or rental income; log median value of housing units; percentage persons aged 25 years or older with complete high school; percentage persons aged 25 years or older with complete college; and percentage persons in executive, managerial, or professional specialty occupations.[19]

Traditional Care (Pre-ERAS)

Perioperative surgical management was not standardized or audited at our institution before 2015, and practices varied per discretion of anesthesia and surgical providers (Table 1). Preoperative patient education was provider-dependent with no standardized education forms. Patients were instructed to fast at midnight, the night before surgery irrespective of start times. Postoperative recovery did not incorporate standardized protocols for early mobilization, intravenous (IV) hydration, or diet advancement. Patients were routinely started on IV patient-controlled analgesia (PCA). Patients were discharged when tolerating an appropriate diet, ambulating with adequate oral pain control, and demonstrating return of bowel function.

Enhanced Recovery After Surgery Protocol

An ERAS pathway was implemented in December 2014 in accordance with the ERAS Society Guidelines for Colorectal Surgery (Table 1).[20] In brief, patients undergoing elective colorectal resection were identified in clinic, enrolled, and educated on the ERAS protocol including expectant management for their perioperative care. Patients received revised fasting instructions including a carbohydrate-rich drink the morning of surgery and a prescription for oral antibiotic and/or mechanical bowel preparation, if indicated. On the day of surgery, patients received multimodal analgesia including oral acetaminophen, celecoxib, and gabapentin, in addition to a single intrathecal (L4-S1) injection using preservative-free hydromorphone or morphine if consented. All patients at risk for postoperative nausea and vomiting (PONV) (female, nonsmoker, history of PONV or motion sickness, and/or planned use of postoperative opioids) were given prophylaxis (Table 1). ERAS standardized intraoperative approaches for protective lung ventilation, goal-directed IV fluid algorithms, opioid and nonopioid adjuncts, and avoidance of residual enteric tubes at the completion of the procedure. Immediately after surgery, patients were advanced to a regular diet, maintained on goal-directed fluid management, ambulated, and provided first-line nonopioid analgesia before opioid adjuncts for pain control. On postoperative day (POD) 1, IV fluids were disconnected, urinary catheters removed, and patients were mobilized until discharge.

Patients' discharge condition was similar to traditional standards: tolerating diet with bowel function, ambulating with pain controlled on oral analgesia, and any special needs or follow-up arranged.

Statistical Analysis

Matched pre-ERAS and ERAS patients were compared by patient and procedure-specific characteristics, and by primary and secondary outcomes. Univariate and bivariate analyses with McNemar and paired t tests, where appropriate, were utilized to account for paired data. Pre-ERAS and ERAS patients were then stratified by race/ethnicity and compared in an identical method. The OED was calculated as the difference between the observed pLOS and expected pLOS provided by the ACS-NSQIP Risk Calculator. Protocol adherence was calculated as the number of components received divided by the 17 total components assessed. All analyses were performed using SAS (SAS Institute, Cary, NC), with an alpha level of 0.05 considered statistically significant.

Sensitivity Analysis

Sensitivity analyses were performed given the potential limitations and biases of matched analyses. Pre-ERAS patient and procedure-specific factors between matched and un-matched patients from 2010 to 2014 were compared using chi-square and Wilcoxon rank-sum tests, where appropriate. An additional analysis was performed between the pre-ERAS matched sample and un-matched pre-ERAS patients from only 2014, the year before ERAS implementation. Additionally, the average pLOS for each year between 2010 and 2014 was compared to account for any secular trends over time that may influence pLOS. To account for potential immortal time bias in observed 30-day readmission rates from surgery, we calculated a rate ratio using an unadjusted Poisson regression model with an offset for days at risk of readmission determined as the number of days after discharge within 30 days of surgery. To account for additional confounding effects, patient and procedure-level characteristics with significant unadjusted differences between pre-ERAS and ERAS groups were included into generalized linear models for pLOS stratified by group.

RESULTS

Patient and Procedure-specific Characteristics

Our study included 420 patients: 210 pre-ERAS and 210 ERAS patients. Overall, 28.3% of patients were black. No differences were observed between pre-ERAS and ERAS groups among matched variables (age, sex, procedure, and race/ethnicity) or characteristics including body mass index, smoking status, diabetes, hypertension, and American Anesthesia Association (ASA) class (Table 2). Compared with ERAS patients, pre-ERAS patients underwent more surgeries for malignancies (38.6% vs 24.3%; $P < 0.01$) and ostomy-related indications (13.3% vs 3.3%; $P < 0.01$). Conversely, ERAS patients underwent more surgery for diverticular (15.2% vs 7.6%) and inflammatory bowel disease (IBD) (28.6% vs 11.4%) indications ($P < 0.01$). ERAS patients were also more likely to have an ostomy constructed (colostomy: 12.4% vs 8.6%; ileostomy: 27.6% vs 19.5%; $P = 0.01$). On socioeconomic factors, pre-ERAS and ERAS patients had similar insurances and marital status. ERAS patients were slightly more socially advantaged by area summary z-score than pre-ERAS patients (P < 0.01), but both groups were below national means (Table 2). A detailed summary of all SDOH by race/ethnicity and pathway are described in Supplement Table 1 (http://links.lww.com/SLA/B236).

When stratified by race/ethnicity, pre-ERAS and ERAS black patients were similar to white patients with respect to age, body mass index, sex, smoking status, ASA class, ostomy construction and reversal, and surgical approach (Table 2). Few differences in patient and procedure-specific factors were seen between black and white patients. Pre-ERAS black patients did have higher rates of insulin-dependent diabetes compared with pre-ERAS whites, whereas all black patients were more likely to have hypertension compared with all white patients. Black patients underwent surgery for colorectal cancer more often than whites (pre-ERAS: 50% vs 34%; P = 0.02; ERAS: 32.2% vs 21.2%, respectively; P < 0.01) and less often for IBD (pre-ERAS: 1.7% vs 15.3%; P = 0.02; ERAS: 13.3% vs 34.4%, respectively; P < 0.01). Although no racial differences were observed in procedure type performed among pre-ERAS patients, black ERAS patients underwent more partial colectomy procedures (40.7% vs 20.5%) and less abdominoperineal/low anterior/Hartmann (20.3% vs 31.8%) or small bowel resections (1.7% vs 8.6%) than whites. Overall, black patients were significantly more socioeconomically disadvantaged than white patients with lower area summary z-scores in both the pre-ERAS and ERAS groups (P < 0.01).

On same-race/ethnicity comparisons, pre-ERAS black patients were similar to ERAS black patients in most patient and procedure characteristics, with the exception of surgical indication and approach. Pre-ERAS black patients had higher rates of open approaches (75% vs 51%) and colorectal cancer indications (50% vs 32%) than ERAS black patients (P < 0.01). ERAS black patients had more IBD compared with pre-ERAS black patients (13.6% vs 1.7%; P < 0.01). White patients were similar between pre-ERAS and ERAS except for surgical indication. ERAS white patients were more likely to have IBD than pre-ERAS whites (34% vs 15%) and less likely to have an ostomy reversal (3% vs 12%; P < 0.01). On socioeconomic comparison, pre-ERAS black patients had lower area summary z-scores than ERAS black patients (Table 2). On the contrary, pre-ERAS and ERAS white patients had similar scores.

Primary Outcome

Patients undergoing ERAS had significantly shorter pLOS compared with pre-ERAS patients {median 4 [interquartile range (IQR) 3–6] vs 6 (IQR 4–8) days; P < 0.01; mean 5.7 vs 8 days; P < 0.01} (Table 3). Whereas there was no significant difference in the expected pLOS between pre-ERAS and ERAS patients (6.6 vs 6.4 days; P = 0.13), significant differences in observed pLOS and OED were measured with pre-ERAS patients staying 1.4 days longer than expected and ERAS patients staying 0.7 days shorter than expected (P < 0.01) (Fig. 1A and B).

In the pre-ERAS group, a significant disparity was observed in pLOS between race/ethnicity with black patients staying longer than white patients (10.1 vs 7.1 days; P = 0.03). Even though no racial disparity was expected based on ACS-NSQIP expected pLOS, the OED was significantly higher for black patients compared with white patients (3.3 vs 0.6; P = 0.04). After ERAS implementation, these disparities in pLOS were no longer observed. Black and white patients had similar observed pLOS (5.4 vs 5.8 days; P = 0.66). Furthermore, the OED for black and white patients were both below their expected pLOS (−0.9 vs −0.7 days; P = 0.74; Fig. 1C).

Within same-race/ethnicity comparisons, black pre-ERAS patients had longer pLOS compared with black ERAS patients (10.1 vs 5.4 days; P < 0.01) despite having similar expected pLOS (6.8 vs 6.3 days, respectively P = 0.18). We observed differences in the OED between pre-ERAS and ERAS black patients. Pre-ERAS black patients stayed longer than expected, whereas ERAS black patients stayed shorter than expected (OED 3.3 vs −0.9 days; P < 0.01). Similarly, white patients undergoing ERAS also showed a reduced mean pLOS compared with pre-ERAS whites (5.8 vs 7.1 days; P = 0.02) despite similar expected pLOS (6.4 vs 6.6 days, respectively; P = 0.39). Again, differences in OED exist with white ERAS patients staying shorter than expected compared with pre-ERAS whites staying longer than expected (−0.7 vs 0.6 days; P = 0.03).

Secondary Outcomes

Patients undergoing ERAS achieved reductions in pLOS without increased morbidity and mortality (Table 4). Overall, ERAS patients had similar outcomes as pre-ERAS patients in 30-day readmission, mortality, and the majority of complications. Although ERAS patients suffered from more wound disruptions than pre-ERAS patients (4.8% vs 0.5%; P = 0.01), ERAS patients had lower rates of pneumonia (0.5% vs 3.3%; P = 0.03) and ileus (7.6% vs 17.6%; P < 0.01) with less intraoperative IV fluid use (median 2300 vs 2600mL; P = 0.02) compared with pre-ERAS patients.

Overall, racial disparities among 30-day postoperative outcomes were not observed after ERAS intervention with black and white patients experiencing similar outcomes. Black ERAS patients experienced similar readmission, mortality, and 30-day complication rates including surgical site infection (SSI). Although the overall SSI rates were not different between races/ethnicities before and after ERAS, black ERAS patients experienced less organ space infections compared with white ERAS patients (0% vs 6.6%; P = 0.04). Black ERAS patients were more likely to experience an ileus requiring insertion of a nasogastric tube compared with whites (13.6% vs 5.3%; P = 0.04).

Protocol Adherence

Overall, 166 (79%) ERAS patients received or adhered to at least 12 of 17 intervention components for an overall ERAS adherence rate of 71%. Although there was no significant difference in overall adherence between black and white patients (86.4% vs 76.2%; P = 0.10), fewer black patients adhered to the revised fasting protocol compared with white patients (32% vs 47%; P = 0.05; Table 5). Additionally, fewer black patients were maintained at normal intraoperative body temperatures (>36°C) compared with whites (34% vs 52%; P = 0.02). Preoperative education and intraoperative antimicrobial and thromboembolic prophylaxis initiatives were performed on every patient. The majority of patients undergoing colectomy are routinely prescribed preoperative bowel preparations at our institution given evidence for reduced SSI,[21,22] hence the low guideline compliance to avoid bowel preparations. Multimodal analgesia strategies were followed in over 85%

of ERAS patients. Intraoperative compliance for goal-directed fluid therapy reached 62%, whereas floor compliance was >61%. Early regular diet was initiated >71% of the time. Postoperative mobilization improved with time from 59% (day of surgery) to 62% POD 1 and 77% POD 2. Compliance with urinary catheter removal by POD 1 reached 77%, with the remaining patients having a need for persistent urinary drainage (planned reason 16% or resuscitation 6%). Only 14 (7%) patients required urinary catheter reinsertion due to retention (11) or resuscitation (3).

Sensitivity Analyses

Among those pre-ERAS patients from 2010 to 2014 not included in this analysis (unmatched), no significant differences in patient demographics or characteristics were observed compared with the matched pre-ERAS patients. Similarly, there were no significant differences between matched pre-ERAS patients and potential unmatched patients from only 2014. Additionally, no significant differences in pLOS by year were observed from 2010 to 2014 to suggest confounding secular trends on pLOS. Readmission rate ratio analysis, accounting for variations in follow-up time from surgery to discharge, shows that pre-ERAS patients were 2.5 times more likely to be readmitted compared with ERAS patients [rate ratio (RR) 2.5, 95% confidence interval (CI) 1.57–4.05, $P < 0.01$). Although not statistically significant, pre-ERAS white patients were 3% more likely to be readmitted than pre-ERAS black patients (RR 1.03, 95% CI 0.45–2.34, $P = 0.95$) and ERAS white patients were 2.1 times more likely to be readmitted than ERAS black patients (RR 2.1, 95% CI 0.93–4.84, $P = 0.07$).

Differences in perioperative characteristics between pre-ERAS and ERAS patients included in the stratified generalized linear models were operative indication, operative approach, ostomy formation, operative time, postoperative ileus requiring nasogastric tube insertion, and wound disruption complication. Socioeconomic factors (marital status, insurance type, and area summary z-score) were also included. After adjustment for these perioperative differences, race/ethnicity remained a significant predictor of pLOS among pre-ERAS patients, with black patients staying 1.8 days longer than white patients ($P = 0.04$); however, race/ethnicity was no longer significant in predicting pLOS among ERAS patients (Table 6). Pre-ERAS patients with postoperative ileus requiring nasogastric tube insertion or a wound disruption complication experienced prolonged pLOS of 8.6 and 24.7 days, respectively ($P < 0.01$). Among ERAS patients, those who underwent ostomy construction stayed 1.3 days longer than patients without an ostomy ($P = 0.04$). Patients with postoperative ileus stayed 5.6 days longer compared with patients without an ileus ($P < 0.01$). Finally, patients not compliant with at least 70% of the ERAS protocol stayed 1.2 days longer than those with at least 70% compliance ($P < 0.01$).

DISCUSSION

In our study, ERAS reduced racial disparities in pLOS for black patients when compared with white patients undergoing colorectal surgery. Based on the ACS-NSQIP Risk Calculator, which does not consider race/ethnicity, we would not have expected any racial disparities in pLOS in our sample. In contrast, we observed significant disparities between black and white patients in pLOS in 2010 to 2014, consistent with other national observations.[5,6] With the implementation of ERAS, we found a significant reduction in pLOS for blacks and improvements for both black and white patients. Further, whereas both black and white patients benefitted from ERAS, the magnitude of reduction in pLOS was greatest for black patients. These reductions came without significant increases in 30-day mortality, readmissions, and major postoperative complications. To our knowledge, our study includes the largest heterogeneous group of patients undergoing ERAS and is the first to report the effect of ERAS on reducing racial disparities in pLOS.

Our study has significant strengths compared to other studies on ERAS. First, while disparities in surgical outcomes have been identified previously, our study is the first to include a sufficient sample of black and white surgical patients to allow assessment of the potential impact of ERAS on racial disparities in pLOS.[5,6] Whereas the driving mechanism(s) are unclear, and require further investigations, these findings have significant implications in developing practical strategies to reduce disparities and provide a model to further understand mechanisms of disparities. Second, our large ERAS cohort allows for a robust analysis of outcomes. Most colorectal ERAS implementation studies to date are limited to sample sizes ranging from 66 to 176 patients.[23–26] Third, our sensitivity analyses support our matched analyses and conclusions on the effect of ERAS. On adjustment for additional covariate differences, these analyses show that race/ethnicity is no longer associated with prolonged pLOS in the setting of ERAS. Fourth, use of an OED, based on the expected pLOS calculated for each patient via the ACS-NSQIP Risk Calculator, allows for direct comparison of an individual patient to a national pLOS benchmark adjusted for 21 variables. Together, these strengths suggest that the effects of ERAS on reducing racial disparities in pLOS may be real and significant.

Compared with other institutional reports, patients undergoing ERAS at our institution experienced similar outcomes with respect to pLOS, complications, and mortality rates. ERAS patients in this study experienced an overall reduction in pLOS by 2.3 days, which is similar to other reports showing reductions by [2],[25] 2.2,[26] and 324 days. Thiele et al[26] also utilized the ACS-NSQIP Risk Calculator and found pre-ERAS patients stayed 1.6 days longer, on average, than expected, which is comparable with our OED of +1.4 days. ERAS implementation improved their OED to −0.6 days, which is also comparable to our −0.8 days. Their study, however, did not include or analyze race/ethnicity as a contributory factor. In secondary outcomes, our complication rates are similar to other institutional experiences. The overall SSI rate of 12.9% is similar with reported rates of 5.2% to 28.8%.[24–26] Racial disparities in SSI with more organ space infections among whites in this study may be attributable to the higher proportion of IBD in this group, a disease commonly associated with postoperative infection rates.[27] Rates of having any complication in this study (22.4%) are comparable with other reports of 15%26 and 31.8%23. Further, ileus events requiring insertion of a nasogastric tube (7.6%) are also in range with other ERAS implementation event rates of 0.1% to 17%.[23,24,26] However, ERAS patients in our study experienced higher readmission rates (17.6%), as assessed by ACS-NSQIP, compared with other ERAS reports of 9% to 15.6%.[23–26] Although ostomy data in these studies are not reported for comparison, the high readmission rate may be related to stoma-related issues such as dehydration and acute kidney injury, a well-documented reason for readmission after stoma formation.[28,29] Since ACS-NSQIP assesses 30-day readmission from the time of surgery instead of discharge, we adjusted for variation in follow-up time from the time of surgery to discharge, and found readmission rates were significantly higher in the pre-ERAS group with no significant racial disparities before and after ERAS implementation.

Improved adherence to ERAS has been shown to improve clinical outcomes in a dose-dependent relationship.[30] In this study, patients with at least 70% protocol adherence experienced shorter pLOS. Interestingly, black patients had lower compliance rates with ERAS fasting protocols compared with white patients. The reason for these disparities is not clear, but these findings evoke similar observations of disparities in medication adherence for black patients in oncology[31] and infectious disease[32] literature. Additionally, fewer black patients were managed with intraoperative normothermia compared with white patients, and white patients were less likely to have restricted IV fluid management by POD 1. Clinical circumstances or patient and provider factors may contribute to these findings, but further investigation is warranted to better understand these disparities.

While significant work has focused on identifying disparities such as pLOS,[5,6] few practical strategies exist to reduce them. In one of the few examples, Lau et al[33] utilized health information technology through a clinical decision support tool to standardize care in prescribed, risk-appropriate venous thromboembolism (VTE) prophylaxis among black and white patients. Before uniform approaches with support tool implementation, providers were making clinical decisions entirely independently. Lau et al found that providing uniform clinical decision tools or pathways result in reduced disparities, possibly by modifying decisional behavior and mitigating the impact of provider bias. Our study suggests that ERAS may be similarly positioned to provide patients with access to best available surgical practices while delivering equitable care to patients at every point in their continuum of care. It remains unclear, however, which contributing factors, both known and unknown, are influenced by ERAS. Whereas big data approaches are often used to study patient, provider, and systemic factors influencing disparities, less is understood about determinants such as patient-level factors of engagement and preferences that are not captured in administrative data.[34] Future research in understanding these determinants of disparities will likely require more innovative approaches such as qualitative ones.[16]

Our study has several limitations that are important to note. First, we present an observational retrospective comparison using matched analyses and cannot assign causation. Because our matched analyses would not be expected to fully address selection and time bias, we performed multiple sensitivity analyses to increase our confidence in the results. Second, healthcare documentation varies by provider resulting in difficult acquisition of complete data for true protocol adherence assessment. To address overestimation of effects, we assumed that missing information was nonadherent biasing our statistical decisions towards the null. Third, the current ACS-NSQIP Risk Calculator does not include race/ethnicity, socioeconomic status, or surgical indication as factors in adjustments for expected pLOS calculations and may confound estimates.

CONCLUSIONS

In our study, ERAS eliminated racial disparities in pLOS for black patients compared with white patients undergoing colorectal surgery. By targeting the entire continuum of perioperative care, ERAS provides a practical approach to achieving health equity in surgery. What remains unclear is the exact mechanism(s) by which ERAS may reduce disparities, but future research will likely require qualitative, non-administrative based approaches to understanding these mechanisms.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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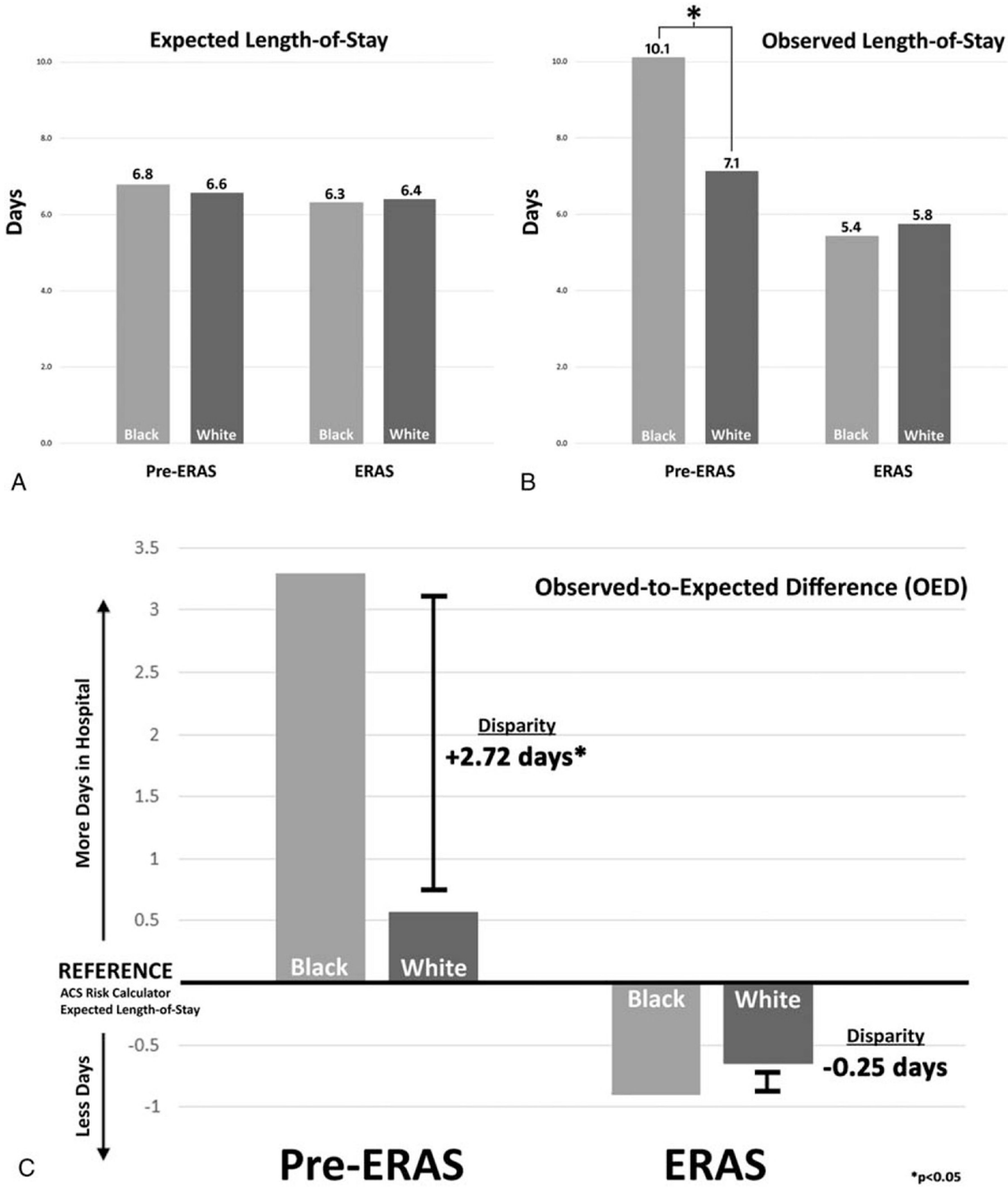

FIGURE 1:

Figure represents the (A) expected, (B) observed, and (C) observed-to-expected difference (OED) in postoperative length of stay (pLOS) by pathway stratified by race/ethnicity. Expected pLOS was calculated using patient and procedure-specific NSQIP variables with the ACS-NSQIP Risk Calculator.

Table 1:

Traditional Care and Enhanced Recovery After Surgery (ERAS) Protocols

Phase	Location	Traditional Care	ERAS
Preoperalive	Clinic	Education	Education/set expectations Discuss patient-specific modifications
		Standard fasting	No solids after midnight; clear liquids until 5 AM Review bowel and chlorhexidine prep Discuss multimodal analgesia strategy Recommend carbohydrate rich drink preop
	Preop	Ensure NPO status Analgesia per provider	Identify ERAS status and ensure universal awareness Offer multimodal analgesia (*age and renal function dosing) Oral acetaminophen, celecoxib*, gabapentin* Intrathecal spinal analgesia L4-S1 level
		No PONV assessment	PONV protocol assessment
Intraoperative	OR	Thromboprophylaxis Antimicrobial prophylaxis Transurethral catheter No PONV prophylaxis	Thromboprophylaxis Antimicrobial prophylaxis Transurethral catheter for 1 to 2 d PONV prophylaxis (unless contraindicated) Dexamethasone 4 to 8 mg IV at induction Ondansetron 4 mg IV at end of case Propofol infusion (25 mcg/kg/min) if 4 risk factors Protective lung ventilation: 6 to 8mL/kg TV per IBW; PEEP 4
		IVF support as indicated	Goal-directed IVF therapy LR or normosol <500mL/h (MIS) or <800 mL (open) For MAPs <60 mm Hg (stepwise): Ensure volatile concentration < 1 MAC Administer 250 mL crystalloid bolus x 2 Communication regarding hypotension Administer l00mL albumin 25% bolus
		Analgesia per provider	Opioid and nonopioid adjuncts Fentanyl per discretion Ketamine: 0.5 mg/kg IBW with induction Lidocaine infusion: 1 to 2 mg/kg bolus induction, 1.5 mg/kg IBW/h Dexamethasone: 0.1 mg/kg IBW with max 8 mg Ketorolac 15 mg after skin closure Ketamine infusion for opioid tolerance: 0.2mg/kg/h
		Avoid hypothermia <36°C	Avoid hypothermia <36°C Remove enteric drain/tubes routinely end of case
Postoperative	Recovery	IVF support as indicated	Goal-directed fluid therapy IV fluid rate KVO (40mL/h) For MAPs <60mm Hg (stepwise): Early notification of surgeon Administer 250 mL crystalloid bolus Administer lOOmL albumin 25% bolus PONV prophylaxis
		Analgesia per provider	Analgesia control (stepwise as needed) Fentanyl 50 meg IV every lOmin up to 250 meg Hydromorphone 0.4 mg IV up to 2 doses PCA per surgeon discretion
	Ward	Advance diet as tolerated Mobilization encouraged	Initiate regular night of surgery Early mobilization Night of surgery: out of bed >1 walks + up to chair POD I to discharge: out of bed >4 walks + up to chair
		Opioids as main analgesia Catheter removal varied	Optimize analgesia with minimal opioids Remove urinary catheter POD 1

PONV risk factors: female, history of PONV or motion sickness, nonsmoker, planned use of postoperative opioids.

IBW, ideal body weight: kg, kilogram; KVO, keep vein open; LR, lactated ringers; MAC, minimum alveolar concentration; MAP, mean arterial pressure; meg, microgram; mg, milligrams; MIS, minimally invasive; mL, millilitre; NPO, nil per os (nothing by mouth); PCA, patient-controlled administration; PEEP, positive end-expiratory pressure; TV, tidal volume.

TABLE 2:

Patient and Operative Characteristics

	Pre-ERAS				ERAS				
	Overall (N = 210)	**Black (n = 60)**	**White (n = 150)**	***P***	**Overall (N = 210)**	**Black (n = 59)**	**Whiten n = 151)**	***P***	**Overall *P***
Patient level									
Age, median (IQR)	56.8 (47.9 – 65.7)	55.7 (47.1– 63,6)	57.4 (48.4– 66.8)	0.22	55.9 (44.5– 65.8)	54,5 (46.7– 62.5)	57.7 (41.5– 67.1)	0.53	0.36
BMI, median (IQR)	27.1 (23.4– 32.0)	28.9 (24.3– 33.2)	26.2 (23.3– 31.2)	0.06	27.5 (24.2– 31.4)	29.2 (24.2– 35.4)	27.2 (24.2– 31.0)	0.06	0.60
Sex				0.79				0.59	0.84
Female	95 (45.2)	28 (46.7)	67 (44.7)		97 (46.2)	29 (49.2)	68 (45.0)		
Male	115 (54,8)	32 (53.3)	83 (55.3)		113 (53.8)	30 (50.9)	83 (55.0)		
Marital status				0.01				0.15	0.07
Single	96 (45.8)	36 (60)	60 (40)		80 (38.0)	27 (45.8)	53 (35.1)		
Married	114 (54.3)	24 (40)	90 (60)		130 (62.0)	32 (54.2)	98 (64.9)		
Insurance status				0.03				0.01	0.081
Government	100 (47.6)	33 (55.0)	67 (44.7)		90 (42.9)	25 (42.4)	65 (43.1)		
Private	87 (41.4)	17 (28.3)	70 (46.7)		105 (50)	25 (42.4)	80 (53.0)		
Charity care/self	23 (11.0)	10 (16.7)	13 (8.7)		15 (7.1)	9 (15.3)	6 (4.0)		
Social determinants of health *	−2.16 (−4.61– 2.28)	−3.56 (−5.74– 0.05)	−0.24 (−3.46– 4.81)	0.01	−1.61 (−4.09– 1.24)	−1.98 (−5.22– 0.38)	−0.73 (−3.71– 2.54)	<0.01	<0.01
Area summary Z-score, median (IQR)									
Smoker	49 (23.3)	17 (28.3)	32 (21.3)	0.28	41 (19.5)	15 (25.4)	26 (17.2)	0.18	0.34
Diabetes mellitus				0.03				0.35	0.59
Insulin	10 (4,8)	6 (10.0)	4 (2.7)		15 (7.1)	6 (10.2)	9 (6.0)		
Noninsulin	20 (9.5)	8 (13.3)	12 (8.0)		19 (9.1)	7 (11.9)	12 (8.0)		
Hypertension	101 (48.1)	37 (61.7)	64 (42.7)	0.01	95 (45.2)	40 (67.8)	55 (36.4)	<0.01	0.56
ASA class				0.09				0.33	0.40
2: mild disturb	28 (13.3)	9 (15.0)	19 (12.7)		31 (14.8)	10 (17.0)	21 (13.9)		
3: severe disturb	176 (83.8)	47 (78.3)	129 (86.0)		168 (80.0)	44 (74.6)	124 (82.1)		
4: life threat	6 (2.9)	4 (6.7)	2 (1.3)		11 (5.2)	5 (8.5)	6 (4.0)		
Indication				0.02				<0.01	<0.01
Benign disease	43 (20.5)	8 (13.3)	35 (23.3)		39 (18.6)	10 (17.0)	29 (19.2)		
Colorectal cancer	81 (38.6)	30 (50.0)	51 (34.0)		51 (24.3)	19 (32.2)	32 (21.2)		
Diverticular disease	16 (7.6)	4 (6.7)	12 (8.0)		32 (15.2)	8 (13.6)	24 (15.9)		
IBD	24 (11.4)	1 (1.7)	23 (15.3)		60 (28.6)	8 (13.6)	52 (34.4)		
Nonmalignant mass	18 (8.6)	7 (11.7)	11 (7.3)		21 (10.0)	12 (20.3)	9 (6.0)		
Ostomy reversal	28 (13.3)	10 (16.7)	18 (12.0)		7 (3.3)	2 (3.4)	5 (3.3)		
Operative level									

	Pre-ERAS				ERAS				
	Overall (N = 210)	**Black (n = 60)**	**White (n = 150)**	***P***	**Overall (N = 210)**	**Black (n = 59)**	**Whiten n = 151)**	***P***	**Overall *P***
Procedure				0.06				0.04	1
APR/LAR/ Hartmann	54 (25.7)	11 (18.3)	43 (28.7)		60 (28.6)	12 (20.3)	48 (31.8)		
Other	4 (1.9)	0 (0.0)	4 (2.7)		4 (1.9)	0 (0.0)	4 (2.7)		
Partial colectomy	59 (28.1)	25 (41.7)	34 (22.7)		55 (26.2)	24 (40.7)	31 (20.5)		
Stoma revision	20 (9.5)	6 (10.0)	14 (9.3)		20 (9.5)	6 (10.2)	14 (9.3)		
Small bowel	14 (6.7)	1 (1.7)	13 (8.7)		14 (6.7)	1 (1.7)	13 (8.6)		
Stoma reversal	41 (19.5)	12 (20.0)	29 (19.3)		40 (19.1)	12 (20.3)	28 (18.5)		
TAC/TPC	18 (8.6)	5 (8.3)	13 (8.7)		17(8.1)	4 (6.8)	13 (8.6)		
Ostomy creation				0.18				0.32	0.01
No ostomy created	151 (71,9)	48 (80.0)	103 (68.7)		126 (60.0)	40 (67.8)	86 (57,0)		
Colostomy	18 (8,6)	5 (8,3)	13 (8.7)		26 (12.4)	5 (8.5)	21 (13,9)		
Ileostomy	41 (19.5)	7 (11.7)	34 (22.7)		58 (27,6)	14 (23.7)	44 (29.1)		
Approach type				0.15				0.33	0.02
MIS	68 (32.4)	15 (25.0)	53 (35.3)		92 (43.8)	29 (49.2)	63 (41.7)		
Open	142 (67.6)	45 (75.0)	97 (64.7)		118 (56.2)	30 (50.9)	88 (58.3)		

All data represented as n (column %) unless otherwise specified.

*See Supplement Table (http://links.lww.com/SLA/B236) for complete Social Determinants of Health.

APR, abdominoperineal resection; BMf. body mass index; LAR. low anterior resection; MIS. minimally invasive; TAC. total abdominal colectomy; TPC, total proctocolectomy.

TABLE 3:

Postoperative Length of Stay Before and After ERAS

	Pre-ERAS				ERAS				
	Overall (N = 210)	**Black (n = 60)**	**White (n = 150)**	***P***	**Overall (N = 210)**	**Black (n = 59)**	**White (n = 151)**	***P***	**Overall *P***
Length of stay, d									
Observed pLOS. median (IQR)	6 (4–8)	6 (4.5–12.5)	6 (4–7)	0.18	4 (3–6)	4 (2–5)	4 (3–7)	0.36	<0.01
Observed pLOS, mean (SD)	7.97 (7.2)	10.07 (9.5)	7.13 (5.9)	0.03	5.66 (4.8)	5.42 (5.0)	5.75 (4.8)	0.66	<0.01
Expected pLOS, mean (SD)	6.63 (2.0)	6.78 (2.0)	6.57 (2.1)	0.51	6.38 (1.7)	6.32 (1.6)	6.40 (1.7)	0.75	0.13
OED pLOS, mean (SD)	1.35 (6.8)	3.29 (9.4)	0.57 (5.2)	0.04	−0.72 (4.9)	−0.90 (5.4)	−0.65 (4.8)	0.74	<0.01

TABLE 4:

Secondary 30-Day Outcomes Before and After ERAS

	Pre-ERAS				ERAS				Overall
	Overall (N = 210)	Black (n = 60)	White (n = 150)	*P*	Overall (N = 210)	Black (n = 59)	White (n = 151)	*P*	*P*
Readmission	33 (15.7)	7 (11.7)	26 (17.3)	0.31	37 (17.6)	7 (11.9)	30 (19.9)	0.17	0.77
Mortality	1 (0.5)	0 (0.0)	1 (0.7)	0.72	1 (0.5)	1 (1.7)	0 (0.0)	0.11	1
Any complication	53 (25.2)	19 (31.7)	34 (22.7)	0.17	47 (22.4)	11 (18.6)	37 (24.5)	0.36	0.18
SSI	21 (10.0)	5 (8.3)	16 (10.7)	0.61	27 (12.9)	4 (6.8)	23 (15.2)	0.10	0.69
Superficial	14 (6.7)	2 (3.3)	12 (8.0)	0.22	12 (5.7)	3 (5.1)	9 (6.0)	0.81	0.69
Deep	2 (1.0)	1 (1.7)	1 (0.7)	0.50	7 (3.3)	1 (1.7)	6 (4.0)	0.41	0.09
Organ space	6 (2.9)	2 (3.3)	4 (2.7)	0.79	10 (4.8)	0 (0.0)	10 (6.6)	0.04	0.31
Wound disruption	1 (0.5)	1 (1.7)	0 (0.0)	0.11	10 (4.8)	1 (1.7)	9 (6.0)	0.19	0.01
Pneumonia	7 (3.3)	4 (6.7)	3 (2.0)	0.09	1 (0.5)	0 (0.0)	1 (0.7)	0.53	0.03
Intubation	4 (1.9)	2 (3.3)	2 (1.3)	0.34	1 (0.5)	0 (0.0)	1 (0.7)	0.53	0.18
PTE	0 (0.0)	0 (0.0)	0 (0.0)	-	1 (0.5)	0 (0.0)	1 (0.7)	0.53	0.32
Prolonged vent	4 (1.9)	1 (1.7)	3 (2.0)	0.87	2 (1.0)	0 (0.0)	2 (1.3)	0.37	0.41
Renal insufficiency	3 (1.4)	2 (3.3)	1 (0.7)	0.14	5 (2.4)	2 (3.4)	3 (2.0)	0.55	0.48
Acute renal failure	0 (0.0)	0 (0.0)	0 (0.0)	-	2 (1.0)	0 (0.0)	2 (1.3)	0.37	0.16
UT1	3 (1.4)	2 (3.3)	1 (0.7)	0.14	1 (0.5)	0 (0.0)	1 (0.7)	0.53	0.32
CVA	1 (0.5)	1 (1.7)	0 (0.0)	0.11	0 (0.0)	0 (0.0)	0 (0.0)	-	0.32
Cardiac arrest	1 (0.5)	1 (1.7)	0 (0.0)	0.11	0 (0.0)	0 (0.0)	0 (0.0)	-	0.32
MI	3 (1.4)	2 (3.3)	1 (0.7)	0.14	3 (1.4)	0 (0.0)	3 (2.0)	0.28	1
Bleeding	19 (9.0)	6 (10.0)	13 (8.7)	0.76	16 (7.6)	6 (10.2)	10 (6.6)	0.38	0.13
VTE	4 (1.9)	2 (3.3)	2 (1.3)	0.34	1 (0.5)	0 (0.0)	1 (0.7)	0.53	0.18
Sepsis	10 (4.8)	4 (6.7)	6 (4.0)	0.41	5 (2.4)	1 (1.7)	4 (2.6)	0.68	0.19
Septic shock	0 (0.0)	0 (0.0)	0 (0.0)	-	2 (1.0)	0 (0.0)	2 (1.3)	0.37	0.16
Return to OR	9 (4.3)	4 (6.7)	5 (3.3)	0.28	12 (5.7)	4 (6.8)	8 (5.3)	0.68	0.50
Total OR IVF, median (IQR)	2600 (2000–3600)	2650 (1650–3900)	2600 (2000–3500)	0.83	2300 (1700–3400)	2100 (1450–3300)	2300 (1800–3500)	0.22	0.02
EBL, mL	100 (50–200)	100 (50–250)	100 (30–200)	0.51	75 (30–200)	50 (30–150)	75 (45–200)	0.44	0.15

	Pre-ERAS				ERAS				Overall
	Overall (N = 210)	**Black (n = 60)**	**White (n = 150)**	***P***	**Overall (N = 210)**	**Black (n = 59)**	**White (n = 151)**	***P***	***P***
OR vasopressor	17 (8.1)	5 (8.3)	12 (8)	0.94	10 (4.8)	2 (3.4)	8 (5.3)	0.56	0.16
OR time, median (IQR)	155,5	159.5	155	0.66	190	167	202	0.04	0.01
	(103–225)	(91.0–273.5)	(105–215)		(135–258)	(115–242)	(146–270)		
Ileus	37 (17.6)	14 (23.3)	23 (15.3)	0.17	16 (7.6)	8 (13.6)	8 (5.3)	0.04	<0.01

All data represented as n (column %) unless otherwise specified.

CPR, cardiopulmonary resuscitation; bleeding, bleed requiring >4 uniis blood transfusion; CVA, cerebrovascular accident; EBL, estimated blood loss; NGT, nasogastric tube; OR, operating room; PTE, pulmonary thromboembolism; UTI, urinary tract infection.

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TABLE 5:

ERAS Protocol Adherence by Race/Ethnicity

	All	Black	While	
Preoperative	**N (%)**	**n (%)**	**n (%)**	***P***
Education	210 (100.0)	59 (100.0)	151 (100.0)	1
Fasting per protocol	90 (42.9)	19 (32.2)	71 (47.0)	0.05
Multimodal pain control				
Acetaminophen	193 (91.9)	54 (91.5)	138 (91.4)	0.98
Celecoxib	167 (79.5)	47 (79.7)	120 (79.5)	0.98
Gabapentin	183 (87.1)	51 (86.4)	132 (87.4)	0.85
Intrathecal spinal	179 (85.2)	51 (86.4)	128 (84.8)	0.76
PONV treated	195 (92.9)	53 (89.8)	142 (94.0)	0.29
Intraopcrative				
Antimicrobial prophylaxis	210 (100)	59 (100)	151 (100)	1
Thromboprophylaxis	210(100)	59 (100)	151 (100)	1
Restricted IV fluid use	130 (61.9)	37 (62.7)	93 (61.6)	0.77
Maintain normothermia (>36°C)	98 (46.7)	20 (33.9)	78 (51.7)	0.02
Remove residual enteric tube	201 (95.7)	56 (94.9)	145 (96.0)	0.72
Postoperative				
Early mobilization				
Mobilization POD 0	124 (59.0)	35 (59.3)	89 (58.9)	0.68
Mobilization POD 1	131 (62.4)	34 (57.6)	97 (64.2)	0.21
Mobilization POD 2	161 (76.7)	46 (78.0)	115 (76.2)	0.81
Diet advancement				
Clears POD 0	149 (71.0)	44 (74.6)	105 (69.5)	0.29
Solids given POD #1	177 (84.3)	54 (91.5)	123 (81.5)	0.53
Restricted IV fluid use				
POD 0	139 (66.2)	41 (69.5)	98 (64.9)	0.53
POD 1	129 (61.4)	42 (71.2)	87 (57.6)	0.07
Foley removal POD 1	161 (76.7)	47 (79.7)	114 (75.5)	0.52
Reason foley not removed				0.33

	All	Black	While	
Preoperative	**N (%)**	**n (%)**	**n (%)**	***P***
Resuscitation	13 (6.2)	4 (6.8)	9 (6.0)	
Planned/related to surgery	33 (15.7)	7 (11.9)	26 (17.2)	
Other	1 (0.5)	1 (1.7)	0 (0.0)	
Urinary catheter reinsertion	14 (6.7)	3 (13.0)	11 (11.0)	0.57
Retention	11 (5.2)	3 (5.1)	8 (5.3)	0.55
Resuscitation	3 (1.4)	0 (0.0)	3 (2.0)	
Patients with 70% adherence	166 (79.0)	51 (86.4)	115 (76.2)	0.1

C, Celsius; NOT, nasogastric tube.

TABLE 6:

Covariates Associated With Prolonged Postoperative Length of Stay (pLOS) Stratified by Pathway

Variable		Pre-ERAS Adjusted Mean Difference	Confidence Interval	*P*
Race/Ethnicity	White	Referent	—	0.04
	Black	1.83	(0.05–3.62)	
NGT placed	No	Referent	—	<0.01
	Yes	8.64	(6.52–10.77)	
Wound disruption	No	Referent	—	<0.01
	Yes	24.72	(12.9–36.5)	

Variable		ERAS Adjusted Mean Difference	Confidence Interval	*P*
Ostomy formation	No	Referent	—	0.04
	Yes	1.28	(0.03–2.52)	
NGT placed	No	Referent	—	<0.01
	Yes	5.59	(3.34–7.85)	
70% compliance	Yes	Referent	—	<0.01
	No	1.24	(0.49–1.98)	

Adjusted mean differences reflect pLOS in days.

Models are adjusted for area summary Z-score, marital status, insurance type, operative indication, operative approach, ostomy formation, operative time, postoperative ileus requiring nasogastric tube insertion, wound disruption complication.

NGT, postoperative nasogastric tube placement for ileus.