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Do prolonged operative times obviate the benefits associated with minimally invasive colectomy?

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ABSTRACT

Background: Minimally invasive colectomy is associated with improved length of stay and decreased postoperative morbidity. Little is known regarding the impact of prolonged operative time on the benefits afforded by minimally invasive colectomy.

Methods: The American College of Surgeons National Surgical Quality Improvement Program procedure targeted colectomy dataset was queried to identify elective right and left colectomies performed between 2011 and 2017. Multivariable modeling was used to compare rates of composite 30-day death or serious morbidity, overall morbidity, mortality, anastomotic leak, surgical site infection, and length of stay for prolonged minimally invasive cases to those for average duration open cases.

Results: A total of 16,602 right colectomies and 36,557 left colectomies were identified. Median operative times for open and minimally invasive right colectomies were 107 min and 129 min ($P < .01$), while that for open left colectomies was 128 min and 156 min for minimally invasive left colectomies ($P < .01$). Cohorts were stratified by quartiles of operative time with the highest (fourth) quartile defined as a prolonged operating time. When compared with an average duration open colectomy, prolonged minimally invasive right colectomies and left colectomies were associated with decreased risk-adjusted rates of overall morbidity, surgical site infection, and with lesser lengths of stay ($P < .05$). Prolonged minimally invasive left colectomies were also associated with improved rates of composite 30-day death or serious morbidity relative to average open left colectomies (odds ratio 0.66, 95% confidence interval, 0.54–0.79).

Conclusion: Prolonged operating times of an minimally invasive approach do not obviate the benefits of an minimally invasive approach to colectomy.

Introduction

Previous comparisons of minimally invasive (MIS) and open approaches to colectomy have demonstrated MIS colectomy to provide oncologic outcomes identical to those for open colectomy and to afford decreased durations of inpatient hospitalization, decreased morbidity, and decreased costs.[1–5] MIS colectomy has, however, been associated consistently with increased operative time (OT) and several studies have suggested that the benefits associated with the MIS approach are eliminated or diminished as OT increases.[6–8] Increased operative time has also been independently associated with risk of adverse outcomes after colorectal resection, including risk of anastomotic leak.[9–12] These findings have led some to suggest that there is a limit in operative time beyond which the MIS approach may no longer be sensible and at which time the surgeon should consider conversion to an open approach.

Previous attempts to evaluate the relationship between operative time and the clinical benefit of MIS colectomy have been underpowered, included heterogeneous procedures, and lacked procedure-specific outcomes measures.[6–8,13,14] These analyses have generally compared prolonged MIS cases with prolonged open cases, and have, for that reason, not rightly adjusted for the fact that open colectomy is associated with lesser average operative times. In the present study, we use the procedure targeted colectomy dataset of the American College of Surgeons National Surgical Quality

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Improvement Program (ACS NSQIP) to evaluate the effect of prolonged operative time on the clinical outcomes of MIS colectomy. We compare patient outcomes from prolonged MIS colectomies with those of average duration open colectomies in effort to better determine whether prolonged OTs of a MIS colectomy increase risk of adverse events.

Methods

Data source

The 2011 to 2017 ACS NSQIP participant user files (PUFs) were obtained containing Health Insurance Portability and Accountability Act compliant, deidentified, patient-level aggregated data with >150 variables, including preoperative, intraoperative, and 30-day postoperative outcomes, collected by trained clinical abstractors from 285 sites using validated methods.[15] These PUFs were merged to Procedure Targeted Colectomy files containing 23 additional colon-specific variables. The ACS NSQIP and participating hospitals are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors. A data use agreement was obtained, and this project met criteria for exemption from the Loyola University Chicago Institutional Review Board (LU# 211602).

Study population

Adults undergoing elective segmental colectomy with anastomosis were identified in the ACS NSQIP using primary Current Procedural Technology (CPT) codes from January 1, 2011, to December 31, 2017. Right colectomy (RC) was defined by CPT codes 44160 and 44205, and left colectomy (LC) was defined by CPT codes 44140, 44145, 44204, and 44207.[16] Patients who underwent concurrent procedures other than enterolysis (CPT 44005, or 44180) or splenic flexure mobilization (CPT 44213 or 44139) were excluded, as were patients who underwent a proctectomy or proximal diverting or end enterostomy. Patients undergoing enterolysis were included to allow a better representation of the technical realities faced by operating surgeons. We recognize that an enterolysis can be highly variable in its effect on OT and outcome. To more fully understand how including these patients in the analysis would affect our results, we performed sensitivity testing, repeating the analysis and excluding patients who were coded as having an enterolysis, and the results were unchanged (data not shown). Additional exclusion criteria included the following: emergent or nonelective cases, converted approaches, patients with preoperative infections or requiring preoperative mechanical ventilation, and cases with missing documentation of OT. Patients in the first or 99th percentiles by operative time and procedure category were excluded from analysis to decrease potential false associations from clinically extraordinary case times.

Patients were stratified by operative approach into planned open and MIS cohorts. The MIS approach was defined by cases labeled laparoscopic, laparoscopic with open assist, robotic, or robotic with open assist in the PUF. We elected to include robotic colectomies in the MIS cohort because the robotic approach was thought to involve clinical and intraoperative decision making similar to that for the laparoscopic approach. We recognize that the robotic and laparoscopic approaches have potentially disparate risk profiles and require different durations of OT. To more fully explore the impact of including the robotic approaches in the MIS cohort, we performed sensitivity testing by repeating the analysis excluding the robotic colectomies. In the adjusted analysis excluding robotic cases, the results and associated conclusions were not different statistically than those presented (data not shown).

Outcomes

Our primary outcome of interest was a composite ACS NSQIP outcome of postoperative death or serious morbidity (DSM) modified to include colon-specific adverse events defined by new-onset presence of any of the following complications within 30-days postoperatively: all-cause mortality, anastomotic leak requiring procedural intervention (percutaneous or operative), organ-space surgical site infection (SSI), wound dehiscence, stroke, myocardial infarction, cardiac arrest with cardiopulmonary resuscitation, pulmonary embolism, prolonged ventilation >48 hours, acute renal failure, bleeding requiring >4 unit transfusion, sepsis, or septic shock.[17]

Secondary outcomes included presence of any postoperative morbidity (overall morbidity, OM), all-cause 30-day mortality, anastomotic leak (AL), any SSI, or prolonged length of stay (LOS). OM was defined by new-onset presence of any complication listed in DSM or any of the following within 30 days postoperatively: superficial or deep incisional SSI, pneumonia, unplanned intubation, progressive renal insufficiency, urinary tract infection, deep vein thrombosis, any anastomotic leak, or prolonged period of being withheld food and fluid, or nasogastric tube >48 hours (ileus). Prolonged LOS was defined by a postoperative LOS in the fourth quartile by procedure type ($\geq$6 days for both RC and LC).

Statistical analysis

Unadjusted comparisons of continuous variables were performed using independent, 2-sample Student *t* tests and Wilcoxon rank-sum (Mann-Whitney) tests, as appropriate, and comparisons of proportions between cohorts were performed using Pearson χ^2. Data are presented as means $\pm$ standard deviation, median with interquartile range (IQR), or counts with percentages, as appropriate. Multivariable logistic regression was performed for each outcome comparing the MIS approach to the open approach. Models were formed by considering all ACS NSQIP demographic, clinical, and operative factors, accepting those with $P < .05$ association with the primary outcome. Final models included adjustment for patient age; sex; class of obesity; smoking status; functional status; history of chronic obstructive pulmonary disease, congestive heart failure, or hypertension; preoperative serum creatinine >1.2 mg/dL; presence of ascites; chronic steroid use; >10% body weight loss in past 6 months; wound class; American Society of Anesthesiologists class; chemotherapy within 90 days; diagnosis of colon cancer; and presence or absence of an enterolysis CPT code. This analysis was repeated allowing analysis by OT quartile and by procedure and subsequently to compare prolonged (fourth quartile) MIS cases with open cases with an average (second to third quartile) operative time. Finally, a multivariable logistic regression considering all preoperative and intraoperative variables was performed to identify significant determinants of prolonged OT for MIS colectomies by procedure. The adjusted odds ratios (OR) of the multivariable logistic regression are represented with the 95% confidence intervals (CIs). All statistical analyses were performed using Stata software (version 14.2; StataCorp LLC; College Station, TX).

Results

Cohort characteristics

A total of 53,159 elective segmental colectomies were identified. In the study, 16,602 patients underwent RC and 36,557 LC. The vast majority of cases were done using MIS techniques with 12,456 of RC (75.0%) being done laparoscopically, 1,290 (7.8%) being done robotically, and 2,856 (17.2%) being done open, whereas 27,518 LC were done laparoscopically, 3,679 (10.1%) robotically, and 5,360

Table I
Patient and operative characteristics

Characteristic	Right colectomy n = 16,602					Left colectomy n = 36,557				
	Open n = 2,856 (17.2%)		MIS n = 13,746 (82.8%)		*P* value	Open n = 5,360 (14.7%)		MIS n = 31,197 (85.3%)		*P* value
Age (y), mean (SD)	63.7	16.1	62.5	15.8	<.05	64.4	13.7	61.4	13.2	<.05
Male sex, *n* (%)	1,291	45.2%	6,254	45.5%	.77	2,609	48.7%	15,038	48.2%	.52
Race/ethnicity, *n* (%)										
White	2,093	73.3%	9,949	72.4%	.32	3,756	70.1%	22,581	72.4%	<.05
Black	239	8.4%	1,373	10.0%	<.05	447	8.3%	2,486	8.0%	.36
Hispanic	94	3.3%	423	3.1%	.55	207	3.9%	1,597	5.1%	<.05
Asian	48	1.7%	330	2.4%	<.05	164	3.1%	1,232	3.9%	<.05
Other	382	13.4%	1,671	12.2%	.07	786	14.7%	3,301	10.6%	<.05
Dependent functional status, *n* (%)	64	2.2%	246	1.8%	.11	125	2.3%	393	1.3%	<.05
BMI (kg/m^2), mean (SD)	28.2	6.8	28.4	6.4	.06	28.9	6.9	28.8	6.2	.40
Smoking, *n* (%)	513	18.0%	1,995	14.5%	<.05	893	16.7%	4,533	14.5%	<.05
Steroids, *n* (%)	509	17.8%	1,656	12.0%	<.05	358	6.7%	1,352	4.3%	<.05
Weight loss, *n* (%)	125	4.4%	347	2.5%	<.05	172	3.2%	557	1.8%	<.05
Comorbidities, *n* (%)										
HTN	1,426	49.9%	6,767	49.2%	.50	2,818	52.6%	14,599	46.8%	<.05
DM	466	16.3%	2,178	15.8%	.53	936	17.5%	4,523	14.5%	<.05
COPD	170	6.0%	640	4.7%	<.05	319	6.0%	1,149	3.7%	<.05
CHF	32	1.1%	74	0.5%	<.05	57	1.1%	141	0.5%	<.05
Cr >1.2	399	14.0%	1,666	12.1%	<.05	768	14.3%	3,215	10.3%	<.05
Indication, *n* (%)										
Colon cancer	1,469	51.4%	6,708	48.8%	<.05	2,690	50.2%	13,617	43.6%	<.05
Nonmalignant polyp	398	13.9%	3,722	27.1%	<.05	448	8.4%	4,709	15.1%	<.05
Diverticulitis	18	0.6%	144	1.0%	<.05	1,171	21.8%	9,555	30.6%	<.05
IBD	570	20.0%	1,794	13.1%	<.05	165	3.1%	619	2.0%	<.05
Other/unknown	401	14.0%	1,378	10.0%	<.05	886	16.5%	2,697	8.6%	<.05
ASA ≥3, *n* (%)	1,669	58.4%	6,842	49.8%	<.05	3,023	56.4%	13,474	43.2%	<.05
Lysis of adhesions, *n* (%)	250	8.8%	715	5.2%	<.05	333	6.2%	1,596	5.1%	<.05
Wound class ≥3, *n* (%)	363	12.7%	962	7.0%	<.05	790	14.7%	3,608	11.6%	<.05
Operative time, (min), median (IQR)	107	79–146	129	100–167	<.05	128	97–176	156	118–203	<.05

ASA, American Society of Anesthesiologists; *BMI*, body mass index; *CHF*, congestive heart failure; *COPD*, chronic obstructive pulmonary disease; *Cr*, serum creatinine; *DM*, diabetes mellitus; *HTN*, hypertension; *IBD*, inflammatory bowel disease.

(14.7%) open. Demographic and operative characteristics are summarized in Table I.

On univariate analysis, there were many statistically significant differences between patients undergoing MIS colectomy and those undergoing open colectomy. Few of these differences were of a magnitude thought to be clinically relevant. Patients undergoing open RC and LC were older than those undergoing MIS procedures. A greater proportion of those undergoing open colectomy were smokers and had chronic steroid use, preoperative weight loss, chronic obstructive pulmonary disease, congestive heart failure, and a serum creatinine >1.2 mg/dL ($P < .05$). Open approaches were associated with faster median OTs compared with the MIS approaches (RC: open 107 minutes [IQR: 79–146] vs MIS 129 minutes [IQR: 100–167], $P < .05$; LC: open 128 minutes [IQR: 97–176] vs MIS 156 minutes [IQR: 118–203], $P < .05$). The most common indication for colectomy across cohorts was colon cancer (RC: open 51.4% vs MIS RC 48.8%; LC: open 50.2% vs MIS 43.6%). There were no differences in sex and no differences in mean body mass index (kg/m^2) among cohorts for both RC and LC ($P > .05$).

Adjusted outcomes by OT

We first used multivariable regression to confirm a decrease in the adverse outcome or risk profile associated with MIS colectomy independent of OT. On multivariable logistic regression adjusted for age, sex , race, body mass index class, comorbidities, smoking status, functional status, chronic steroid use, preoperative weight loss >10%, wound class, American Society of Anesthesiologists class, chemotherapy within 90 days preoperatively, enterolysis, and diagnosis of colon cancer, and also including OT as a continuous variable (Table II), both MIS RC and LC were associated with a decrease in adjusted risk for DSM, OM, AL, SSI, and prolonged LOS compared with the open approach ($P < .05$), independent of OT. MIS LC also demonstrated a benefit in overall mortality over open LC (OR 0.57; 95% CI, 0.40–0.81). Notably, adjusted risk of AL requiring operative or percutaneous intervention was decreased in both MIS RC (OR 0.64; 95% CI, 0.50–0.83) and LC (OR 0.70; 95% CI, 0.59–0.84) when compared with open colectomies.

RC and LC cohorts were then split into statistical quartiles by OT as follows: for RC the quartiles were (1) 43 to 96 minutes, (2) 97 to 126 minutes, (3) 127 to 164 minutes, and (4) 165 to 319 minutes; whereas for LC, the quartiles were (1) 52 to 114 minutes, (2) 115 to 152 min, (3) 153 to 199 minutes, (4) 200 to 395 minutes). In an analysis adjusted for aforementioned factors in addition to the OT quartile, in both RC (OR 0.64; 95% CI, 0.46–0.90) and LC (OR 0.57; 95% CI, 0.44–0.73), an MIS approach was associated with less risk of DSM when OTs were prolonged (comparing fourth quartile MIS cases to fourth quartile open cases; Fig 1).

Comparison of a prolonged MIS approach (fourth quartile) to average length of open approach (quartiles 2 and 3)

In an effort to account for the decreased OT associated with the open approach, the MIS cases in the fourth quartile (now referred to as prolonged MIS cases) were compared with average duration (second to third quartile) open cases. Performing this adjusted comparison (Fig 2), both prolonged MIS RC and LC displayed a decreased odds of OM, SSI, and prolonged LOS when compared with their respective average duration open cohort. MIS LC demonstrated a decreased risk of DSM (OR 0.66; 95% CI, 0.54–0.79).

Table II
Adjusted* MIS colectomy outcomes compared with open approach for all operative times

Outcome	MIS right colectomy		MIS left colectomy	
	OR	95% CI	OR	95% CI
Death or serious morbidity	0.62	0.53–0.73	0.52	0.46–0.58
Overall morbidity	0.54	0.49–0.60	0.43	0.40–0.46
Mortality	0.76	0.44–1.30	0.55	0.38–0.78
Anastomotic leak	0.64	0.50–0.83	0.70	0.59–0.84
Surgical site infection	0.56	0.48–0.65	0.46	0.41–0.51
Prolonged LOS	0.29	0.26–0.32	0.23	0.22–0.25

* Outcomes adjusted for age, sex, race, body mass index class, comorbidities, smoking status, functional status, chronic steroid use, preoperative weight loss >10%, wound class, ASA class, chemotherapy in 90 days preoperatively, enterolysis, diagnosis of colon cancer, and operative time.

with colon cancer for both RC (OR 0.73; 95% CI, 0.66–0.80) and LC (OR 0.59; 95% CI, 0.54–0.64).

Discussion

Our aim was to determine whether prolonged OTs eliminate the benefits associated with MIS approaches to colectomy. In a large cohort of elective, MIS-performed segmental colectomies, we found no OT at which a prolonged OT seemed to result in an increased risk of adverse outcomes relative to that for average open colectomy. Even MIS colectomies that were high outliers for OT were associated with decreases in risk of short-term postoperative adverse events, including OM, SSI, and prolonged LOS relative to average duration open colectomy. Although prolonged MIS RC demonstrated no difference in risk of DSM when compared with average duration open

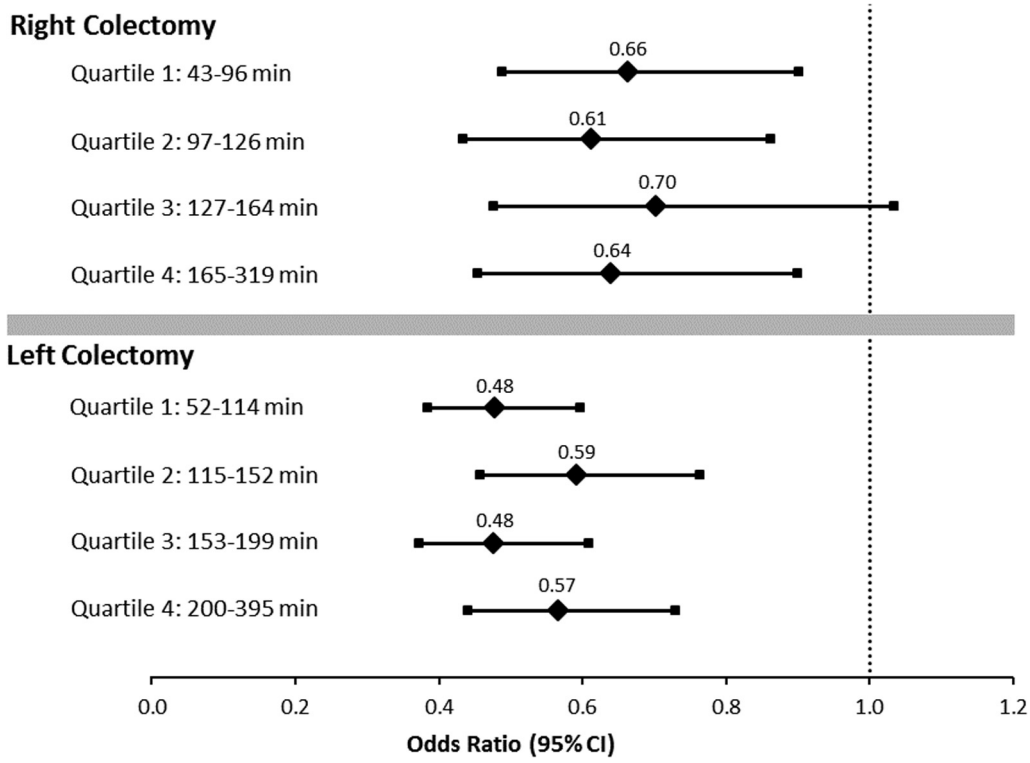

Fig 1. Adjusted odds of death or serious morbidity for minimally invasive colectomy compared with open by operative time quartile. Outcomes were adjusted for age, sex, race, body mass index class, comorbidities, smoking status, functional status, chronic steroid use, preoperative weight loss >10%, wound class, American Society of Anesthesiologists class, chemotherapy in 90 days preoperatively, enterolysis, diagnosis of colon cancer.

For RC, there appeared to be a trend toward decreased rates of DSM (OR 0.82; 95% CI, 0.63–1.08).

Risk factors associated with prolonged MIS OT

To identify preprocedural factors associated with prolonged MIS OT, preoperative and operative factors were analyzed comparing prolonged (fourth quartile) MIS cases to nonprolonged MIS cases. As summarized in Table III, on multivariable analysis of MIS colectomies, the robotic approach yielded an increased risk of prolonged MIS RC (OR 4.06; 95% CI, 3.59–4.59) or LC (OR 2.76; 95% CI, 2.56–2.97). Other notable risk factors for prolonged MIS RC and LC include male sex, black or Hispanic race, obesity, and enterolysis. An operative indication for MIS colectomy of nonmalignant polyp provided a decreased risk of case prolongation when compared RC, prolonged MIS LC was associated with a 34% decreased adjusted risk of DSM compared with the average duration open approach, and prolonged MIS right and left colectomies were not at any level associated with an increased risk of OM.

Previous associations were confirmed with our multivariable analysis of preoperative determinants of prolonged OT. Of note, the robotic approach was associated with a 4-fold and 2-fold increased risk of prolonged OT in comparison with the laparoscopic approach for RC and LC, respectively, which is consistent with numerous previous studies noting increased OT associated with robotic colon resection.[18–20] Other meaningful predictors including obesity, cancer, and the need for an enterolysis provide surgeons with important factors to consider when tailoring the planned operative approach to a particular clinical situation. Despite controlling for perioperative factors, black and Hispanic patients were at increased risk for prolonged MIS operations. This finding may reflect

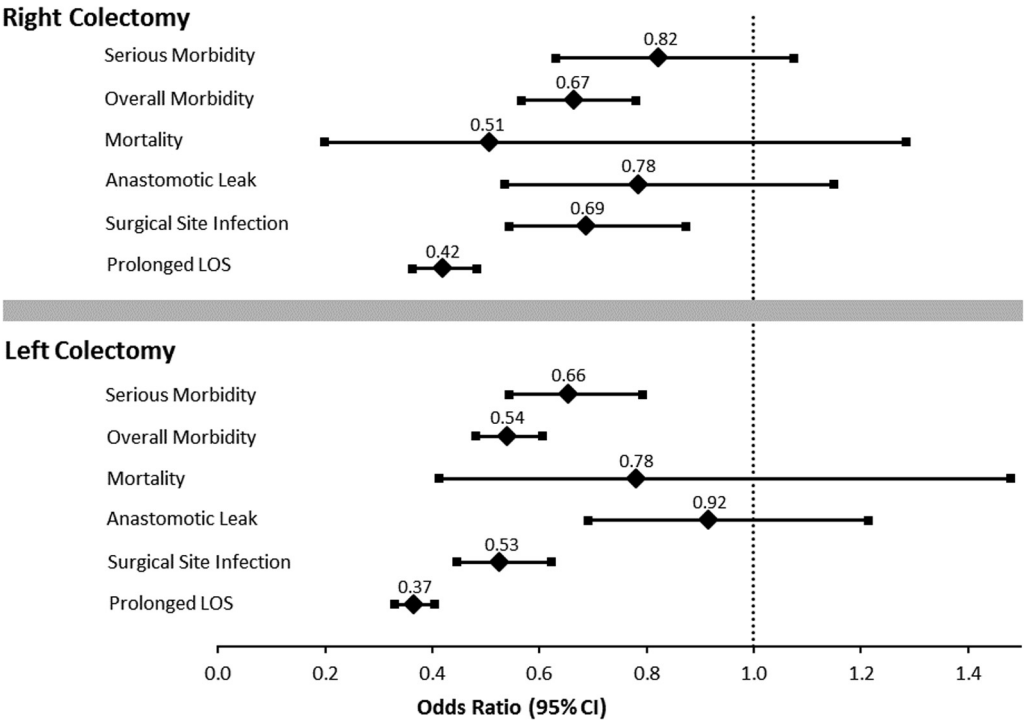

Fig 2. Adjusted outcomes comparing prolonged minimally invansive to average duration open colectomy. Outcomes were adjusted for age, sex, race, body mass index class, comorbidities, smoking status, functional status, chronic steroid use, preoperative weight loss >10%, wound class, American Society of Anesthesiologists class, chemotherapy in 90 days preoperatively, enterolysis, diagnosis of colon cancer.

confounding or a bias introduced via omitted variables but warrants further investigation.

One prior NSQIP analysis of RC for colon cancer between 2005 to 2010 found that laparoscopic RC with >3 hours of OT was associated with increased infectious complications.[8] In contrast, we found on adjusted analysis of prolonged (fourth quartile) MIS colectomies compared with average duration (second to third quartile) open procedures, that prolonged MIS cases had decreased risk of SSI for both RC (OR 0.69; 95% CI, 0.54–0.87) and LC (OR 0.53; 95% CI, 0.45–0.62). Another prior study using NSQIP colectomies and similar inclusion criteria from 2005 to 2012 found that greater OTs were associated with increased adjusted risk of 30-day adverse events, including infectious complications and prolonged LOS.[6] This analysis, however, did not evaluate operative approach or procedure-specific variables that were available to our current analysis; indeed, our analysis demonstrated that prolonged MIS colectomies continued to have a decreased risk of OM even when compared to average duration open procedures (RC: OR 0.67 [0.57–0.78]; LC: OR 0.54 [0.48–0.61]).

Our findings, strengthened by a large sample size, availability of colon-specific variables, and restricted inclusion or exclusion criteria, extend a deeper understanding of conclusions from prior studies that found no adverse effect to increase OTs associated with laparoscopic colon surgery on risk or OM, including SSI and LOS.[13,21,22] Although our study population excluded analysis of cases converted from MIS to open approaches, our results inform surgeons that performing a prolonged MIS segmental colectomies still allows for a decrease in risk of adverse events when compared with a planned open approach. From our analysis, it would seem that in most situations, prolonged OT for a MIS colectomy is not an absolute indication for conversion to open with respect to the measured outcomes.

There are several limitations to this retrospective analysis. We used a large, national, patient-based data source which allows the potential for a sampling bias that limits the external generalizability of our conclusions.[23] Lack of granularity with respect to many perioperative factors, including case complexity, surgeon, or institutional experience, and duration of different portions of the operation limit our analysis; however, we attempted to minimize heterogeneity by excluding factors like concurrent procedures or even the need to create an ostomy. For example, we adjusted for the presence or absence of a concurrent enterolysis by using the CPT code for that procedure. This approach, however, is unlikely to completely account for the continuous range of complexity associated with this procedure. In addition, all available and nonmissing variables were analyzed for potential risk adjustment in multivariate models accounting for patient-level confounding relationships. We acknowledge that owing to our rigid criteria of patient selection criteria and those inherent to the ACS NSQIP patient sampling, our population is unlikely to be nationally representative, especially given that about three-quarters of our population underwent laparoscopic colectomy, whereas national estimates have been closer to 54%.[24] Without appropriate perioperative data regarding indication for conversion, time to conversion, and surgeon experience, we thought that including MIS to open conversions in an intention-to-treat fashion would introduce unjust bias into the MIS cohort and inappropriately affect conclusions drawn about the MIS approach. We would also caution against making strong conclusions about an optimal OT to pursue open conversion in elective segmental colectomy without having the ability to appropriately account for these factors.

Future efforts may utilize more granular perioperative data to evaluate factors relating to conversion to open, including indication and timing of conversion. These data may allow us to better understand whether risk-profiles after MIS-to-open converted cases more closely resemble the initial MIS approach or that of the subsequent open approach, predict patients at greatest risk for potential conversion, or to further our understanding of the

Table III
Multivariable analysis: preoperative risk factors for prolonged operative time

Characteristic	Right colectomy		Left colectomy	
	OR	95% CI	OR	95% CI
Approach				
Laparoscopic (reference)				
Robotic	4.06	3.59–4.59	2.76	2.56–2.97
Age (per year)	1.00	0.99–1.00	0.99	0.99–1.00
Male	1.57	1.44–1.70	1.37	1.30–1.45
Race/ethnicity				
White (reference)				
Black	1.35	1.18–1.54	1.27	1.15–1.39
Hispanic	1.45	1.16–1.80	1.20	1.07–1.35
Asian	1.14	0.87–1.49	1.22	1.06–1.41
Other/unknown	1.25	1.11–1.42	1.43	1.31–1.56
BMI class				
Underweight	0.98	0.72–1.33	0.83	0.63–1.08
Normal (reference)				
Overweight	1.34	1.20–1.49	1.33	1.23–1.43
Obese	1.65	1.46–1.86	1.65	1.53–1.79
Morbidly obese	2.18	1.91–2.49	2.11	1.93–2.31
DM	1.06	0.98–1.15	1.01	0.96–1.07
Smoking	1.02	0.91–1.14	1.09	1.01–1.18
Dependent	0.94	0.69–1.27	0.71	0.55–0.91
COPD	0.90	0.74–1.10	0.94	0.81–1.09
Ascites	1.93	0.48–7.73	1.77	0.68–4.63
CHF	0.91	0.53–1.58	0.77	0.50–1.18
HTN	0.95	0.86–1.05	1.08	1.02–1.15
High Cr >1.2 mg/dL	1.04	0.92–1.18	0.96	0.88–1.05
Chronic steroid use	1.03	0.88–1.21	1.06	0.92–1.22
Weight loss	0.97	0.75–1.26	1.07	0.88–1.31
ASA class				
1 (reference)				
2	1.13	0.85–1.51	1.20	1.02–1.42
3	1.27	0.95–1.71	1.25	1.06–1.48
4	1.41	0.98–2.02	1.12	0.87–1.43
Chemotherapy	1.05	0.68–1.63	2.46	2.05–2.97
Indication				
Colon cancer (reference)				
Nonmalignant polyp	0.73	0.66–0.80	0.59	0.54–0.64
Diverticulitis	1.46	1.01–2.12	1.05	0.98–1.12
IBD	1.36	1.13–1.63	1.01	0.81–1.24
Other/unknown	0.91	0.79–1.05	0.81	0.73–0.90
Enterolysis	2.76	2.35–3.24	1.95	1.75–2.18

Prolonged operative time is 75th percentile by procedure.
ASA, American Society of Anesthesiologists; *BMI*, body mass index; *CHF*, congestive heart failure; *COPD*, chronic obstructive pulmonary disease; *Cr*, serum creatinine; *Dependent*, dependent functional status; *DM*, diabetes mellitus; *HTN*, hypertension; *Weight loss*, >10% weight loss in 90 days preoperatively.

intraoperative factors that lead to a surgeon's decision to persevere through a challenging MIS approach or convert to open. Evaluation of perioperative data may help elucidate populations who would most benefit from prolonged MIS efforts and may allow for increased patient involvement in tailoring operative planning to each clinical situation. Understanding that prolonged OTs have an effect on institutional operative throughput and costs relating to a given procedure occupying the operating room for greater durations of time, future studies may determine if these extended procedures provide a worthwhile attempt at high-quality and cost-efficient surgical care from stakeholder perspectives.

In conclusion, prolonged OT in elective MIS colectomy does not afford an increased risk in adverse events when compared with average duration of an open colectomy. Favorable risks of OM, SSI, and prolonged LOS are maintained even in high outliers of OT (fourth quartile) in MIS RC and LC. Even with prolonged OT, MIS LC is associated with decreases in DSM in comparison to the open approach.

Conflict of interest

Authors P.J.S., E.E., A.N.K., K.A.B., M.H.N., and M.S.B. report no proprietary or commercial interest in any product mentioned or concept discussed in this article. Author M.A.S. discloses consulting interests with Ethicon, Olympus, and Applied.

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