The American Journal of Surgery (2016) 211, 1026-1034

The American Journal of Surgery®

Clinical Science

Surgical resident involvement differentially affects patient outcomes in laparoscopic and open colectomy for malignancy

Megan Sippey, M.D., Konstantinos Spaniolas, M.D., Mark L. Manwaring, M.D., Walter E. Pofahl, M.D., Kevin R. Kasten, M.D.*

Department of Surgery, Brody School of Medicine at East Carolina University, 600 Moye Boulevard, 2MA234, Greenville, NC, 27834, USA

KEYWORDS:
NSQIP;
Resident;
Outcome;
Cancer;
Morbidity;
Oncology;
SSI;
Colectomy

Abstract

BACKGROUND: We evaluated effect of resident involvement on outcomes after laparoscopic and open colon resection for malignancy.

METHODS: Patients undergoing colectomy were queried using the American College of Surgeons' National Surgical Quality Improvement Program. "Attending alone" and "Resident" cohorts were compared with primary end point of overall morbidity.

RESULTS: Of 37,330 patients, residents were involved in 26,190 (70.2%) cases. Attending alone patients were older with higher vascular, cardiac, and pulmonary comorbidity. Univariate analysis demonstrated increased operative time (181.0 ± 98.4 vs 138.7 ± 77.0, $P < .001$), reoperation (5.7% vs 5.2%, $P = .041$), and readmission rates (11.9% vs 9.6%, $P = .037$) with resident involvement. Serious (16.0% vs 13.9%, $P < .001$), minor (17.5% vs 14.1%, $P < .001$), and overall morbidity (26.4% vs 22.5%, $P < .001$) were higher with resident participation. Mortality (2.0% vs 2.8%, $P < .001$) and failure to rescue (.8% vs 1.2%, $P < .029$) were lower with resident involvement. Resident involvement showed independent association with overall morbidity in both laparoscopic (odds ratio, 1.2; 95% confidence interval, 1.13 to 1.38, $P < .001$) and open cases (odds ratio 1.3, 95% confidence interval, 1.18 to 1.35, $P < .001$).

CONCLUSIONS: Resident participation in colectomy for malignancy is associated with lower mortality at the expense of higher overall morbidity.

The authors declare no conflicts of interest.

Disclosures: The American College of Surgeons-National Surgical Quality Improvement Program and the hospitals participating in the American College of Surgeons-National Surgical Quality Improvement Program are the source of the data used here; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

* Corresponding author. Tel.: +1-252-744-2033; fax: +1-252-744-5775.

E-mail address: kastenk14@ecu.edu

Manuscript received May 6, 2015; revised manuscript July 16, 2015

0002-9610/$ - see front matter © 2015 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.amjsurg.2015.07.019

Since the imposition of resident duty hour restrictions by the Accreditation Council for Graduate Medical Education in 2003, surgeon educators and leaders have labored to develop a more robust and efficient training environment.[1–8] Simultaneously, governmental and societal pressures have championed a renewed focus on delivery of high-quality, cost-effective care using metrics, such as readmission, length of stay, and compliance, with Surgical Care Improvement Project benchmarks.[9,10] Given the pressures of decreasing physician reimbursement, reduced time for training and mentoring, and societal need for continued high-quality surgical care, it behooves surgeons to develop a robust training system addressing all areas. Unfortunately, the myriad roles played by surgeons greatly contribute to the complexity of training, especially when consideration is given to the broad range of training environments (ie, academic, community, rural).

To help address obstacles in creation of an efficient resident training system, we need to better understand the effect of residents on patient care. Although technological advances allow for simulation and competency-based assessment of skills without ill-patient effect, most are neither widely available nor practiced.[11–14] Additionally, evaluation of residents in the operative setting is nonstandardized, making it difficult to objectively assess competency.[15–19] As such, when a patient asks what effect a resident's presence has on his outcome, some blithely discard the question and answer that minimal effect exists.[20–26] However, recent data suggest that residents are responsible for worsened outcomes in certain populations after surgical procedures.[27–32] In patients with diagnosed malignancies, these worsened 30-day outcomes may produce dire long-term effects on receipt of subsequent treatment and overall survival.[33–37] Despite minimal literature addressing this subject, the question of resident involvement for particular patient populations and procedures is of paramount importance.

In our present study, we sought to elucidate what role surgical residents may play in postoperative outcomes. Specifically, we aimed to evaluate the effect of resident involvement on 30-day postoperative morbidity. We hypothesized that resident participation would be associated with worse outcomes.

Methods

The American College of Surgeons' National Surgical Quality Improvement Program (ACS-NSQIP) database participant use file was used as a data source for this study. This is a national database with data entered by trained clinical reviewers. It includes preoperative risk factors, laboratory values, intraoperative variables, and 30-day postoperative morbidity and mortality data.[38–40] The ACS-NSQIP administration periodically audits the data to ensure high reliability. Patients were included if postoperative diagnosis, using *International Classification of Diseases, Ninth Edition*, codes, indicated malignancy (Index 1). Current Procedural Terminology (CPT) codes were used to identify patients who underwent either laparoscopic or open colon (CPT 44140, 44141, 44143, 44144, 44145, 44146, 44147, 44150, 44151, 44160, 44320; CPT 44204, 44205, 44206, 44207, 44208, and 44210, respectively) procedures from 2005 to 2012. Patients were excluded if the procedure was performed emergently. Combined multivisceral operations (colectomy + hepatectomy) were excluded from analysis. ATTEND variable was used, defining "attending alone" as follows: "Attending alone: Staff practitioner performed the procedure; resident not present." Additionally, we cross-referenced ATTEND against the variable PGY, defined as "highest PGY of resident who scrubbed for the surgical procedure. Choose from 1 to 10. Enter "0" if no resident is scrubbed." This ensured attending alone cases were truly free of resident involvement. Importantly, the data set defines presence or absence of a resident for a given case but does not quantify or qualify resident involvement. Patients were excluded from analysis if either variable was missing.

Baseline demographics included age, body mass index, gender, calendar quarter of admission, and the presence of comorbid disease. Vascular comorbidities included history of hypertension, amputation or revascularization procedure, rest pain, and gangrene. Cardiac comorbidities were defined as congestive heart failure within 30 days, myocardial infarction within 6 months or history of angina within 1 month before the index procedure, and previous percutaneous coronary intervention or cardiac surgery. Pulmonary comorbidities included chronic obstructive pulmonary disease, current pneumonia, and preoperative ventilator dependence. Neurologic comorbidities included impaired sensorium, coma, transient ischemic attack, cerebral vascular accident, hemiplegia, paraplegia, quadriplegia, and tumor involving the central nervous system. Hepatic comorbidities included ascites and esophageal varices. Renal comorbidities included renal failure and the need for renal replacement therapy. In previous reports, Spaniolas et al[41,42] used similar groupings of comorbidities for analysis. Diabetes, history of active smoking, steroid use, and weight loss greater than 10% within 6 months were analyzed individually. American Society of Anesthesiology classification of patient's physical condition was also analyzed, comparing those with scores 1 and 2 vs 3 and 4.

The primary outcome assessed was 30-day overall morbidity. This included surgical site infection, organ space infection, sepsis, septic shock, wound disruption, pneumonia, deep venous thrombosis or thrombophlebitis, pulmonary embolism, unplanned reintubation, ventilator dependence greater than 48 hours after surgery, progressive renal insufficiency, acute renal failure, urinary tract infection, stroke, coma, peripheral nerve injury, cardiac arrest requiring cardiopulmonary resuscitation, myocardial infarction, blood transfusion for bleeding, and graft,

prosthesis, or flap failure. Serious morbidity was defined as organ space infection, sepsis, septic shock, wound disruption, pulmonary embolism, ventilator dependence greater than 48 hours after surgery, progressive renal insufficiency, acute renal failure, stroke, coma, cardiac arrest requiring cardiopulmonary resuscitation, myocardial infarction, or blood transfusion for bleeding. Additional outcomes assessed on univariate analysis included operative time, length of hospital stay, readmission, reoperation, serious morbidity, minor morbidity, mortality, rescue, and failure to rescue. The Agency for Healthcare Research and Quality Patient Safety Network defines failure to rescue as an inability to prevent clinical deterioration (death and disability) after complication of illness or surgical care. This usually represents failure of monitoring, failure of actions taken by medical staff after identification of early complication, or both.

Approval for this study was obtained through an agreement with ACS-NSQIP and exempt status from the East Carolina University Institutional Review Board. Data analysis was performed using SPSS for Windows, version 22 (IBM, Somers, NY). Univariate analysis was performed using the chi-square for nominal and ordinal variables with frequencies reported. Independent-samples t test was used for continuous variables with median and interquartile range or mean and standard deviation reported, as indicated. This univariate analysis was performed for all colon procedures and then repeated for both laparoscopic and open colon procedures individually. Multivariate logistic regression was then performed for both laparoscopic and open colon procedures with all baseline variables with a P value $< .1$ on univariate analysis entered into the model. Hosmer and Lemeshow test was used to assess for goodness of fit of the multivariate models with overall morbidity as the dependent variable. This test remained nonstatistically significant ($P < .001$) for both models, suggesting adequate fit. Odds ratios (ORs) with 95% confidence intervals (CIs) were reported. A P value $< .05$ was considered statistically significant.

Results

We identified 37,330 patients who underwent elective colon procedures for malignancy from 2005 to 2012: 18,620 (49.9%) were male, median age was 67 (IQR 57 to 77) years, and median body mass index was 27.1 (IQR 23.6 to 31.3). Residents were involved in 26,190 (70.2%) cases. Patients were slightly younger (65.6 ± 13.3 vs 67.8 ± 12.7, $P < .001$), more likely to be male (50.5% vs 48.7%, $P = .002$), and were less likely to have vascular comorbidity (55.6% vs 59.9%, $P < .001$), cardiac comorbidity (12.8% vs 14.7%, $P < .001$), pulmonary comorbidity (5.8% vs 7.5%, $P < .001$), and neurologic comorbidity (7.8% vs 9.5%, $P < .001$) in cases with resident involvement. American Society of Anesthesiology classification was more likely to be 3 or 4 in cases in which an attending operated alone (57.4% vs 56.3%, $P = .044$). An attending without resident assistance was also more likely to perform a laparoscopic procedure (40.4% vs 36.1%, $P < .001$). The only less favorable patient factor seen more frequently in resident cases was weight loss greater than 10% within the preceding 6 months (7.2% vs 6.5%, $P = .011$). Subgroup analyses of laparoscopic and open procedures were performed with baseline patient characteristics displayed in Tables 1 and 2, respectively. Laparoscopic procedures involved 13,965 (37.4%) patients compared with 23,365 (62.6%) performed open. Of procedures performed laparoscopically, 32.2% did not involve a resident. In comparison, 28.4% of open colon procedures for malignancy did not involve a surgical resident.

Table 1 Univariate analysis of preoperative characteristics of patients with elective laparoscopic procedure for colon malignancy

Variables	Attending alone (n = 4,503), n (%)	Resident involved (n = 9,462), n (%)	P value
Age, mean ± SD, y	67.29 ± 12.51	65.68 ± 13.23	<.001
BMI, mean ± SD	27.98 ± 6.23	28.03 ± 6.37	.666
Male gender	2,206 (49.3%)	4,648 (49.3%)	.976
Vascular comorbidity	2,662 (60.2%)	5,292 (56.1%)	<.001
Cardiac comorbidity	606 (14.0%)	1,136 (12.1%)	.002
Pulmonary comorbidity	277 (6.4%)	455 (4.8%)	<.001
Neurologic comorbidity	347 (8.0%)	667 (7.1%)	.050
Hepatic comorbidity	34 (.8%)	44 (.5%)	.021
Renal comorbidity	26 (.6%)	34 (.4%)	.066
Diabetes	823 (18.3%)	1,599 (16.9%)	.044
Smoker	554 (12.3%)	1,167 (12.3%)	.963
Steroid use	102 (2.3%)	212 (2.2%)	.927
Weight loss >10%	168 (3.7%)	340 (3.6%)	.685
ASA 3 or 4	2,294 (51.0%)	4,613 (48.8%)	.015
Work relative value unit	26.78 ± 3.35	26.75 ± 3.72	.716

Definition of comorbidity groupings is described in the Methods section.
ASA = American Society of Anesthesiology; BMI = body mass index.

Table 2 Univariate analysis of preoperative characteristics of patients with elective open procedure for colon malignancy

Variables	Attending alone (n = 6,637), n (%)	Resident involved (n = 16,728), n (%)	*P* value
Age, mean ± SD, y	68.15 ± 12,87	65.58 ± 13.38	<.001
BMI, mean ± SD	28.01 ± 6.75	28.03 ± 6.85	.804
Male gender	3,204 (48.4%)	8,562 (51.2%)	<.001
Vascular comorbidity	3,921 (59.8%)	9,258 (55.4%)	<.001
Cardiac comorbidity	981 (15.1%)	2,198 (13.1%)	<.001
Pulmonary comorbidity	536 (8.3%)	1,050 (6.3%)	<.001
Neurologic comorbidity	682 (10.5%)	1,367 (8.2%)	<.001
Hepatic comorbidity	160 (2.5%)	368 (2.2%)	.226
Renal comorbidity	40 (.6%)	119 (.7%)	.362
Diabetes	1,254 (18.9%)	3,072 (18.4%)	.347
Smoker	1,007 (15.2%)	2,696 (16.1%)	.075
Steroid use	145 (2.2%)	436 (2.6%)	.062
Weight loss >10%	551 (8.3%)	1,542 (9.2%)	.027
ASA 3 or 4	4,095 (61.8%)	10,116 (60.5%)	.077
Work relative value unit	24.34 ± 4.55	24.99 ± 5.63	<.001

Definition of comorbidity groupings is described in the Methods section.
ASA = American Society of Anesthesiology; BMI = body mass index.

Unadjusted outcomes of all patients undergoing elective colon resection for malignancy are listed in Tables 3 and 4. Resident involvement was associated with increased operative time (181.0 ± 98.4 vs 138.7 ± 77.0, $P < .001$), length of stay (8.9 ± 16.1 vs 8.5 ± 10.3, $P = .002$), reoperation (5.7% vs 5.2%, $P = .041$), and readmission rates (11.9% vs 9.6%, $P = .037$). Serious (16.0% vs 13.9%, $P < .001$), minor (17.5% vs 14.1%, $P < .001$), and overall morbidity (26.4% vs 22.5%, $P < .001$) were higher in cases with resident participation. However, mortality rate was lower with resident involvement (2.0% vs 2.8%, $P < .001$), as was failure to rescue (1.6% vs 2.2%, $P < .001$). Although operative time was increased in both laparoscopic (172.6 ± 79.9 vs 143.8 ± 72.5, $P < .001$) and open cases (183.4 ± 107.9 vs 133.1 ± 78.9, $P < .001$) with resident participation, this difference was more pronounced in the open group. Despite being statistically significant, there was no clinically significant difference in length of stay identified based on presence of resident surgeon in the operating room. Univariate analyses of outcomes for subgroups of laparoscopic and open procedures are further detailed in Tables 3 and 4, respectively. Mortality and failure to rescue were higher when an attending surgeon operated alone across both subgroups. Surgical site infection was increased with resident participation regardless of whether the case was laparoscopic or open. Furthermore, serious, minor, and overall

Table 3 Univariate analysis of outcomes of patients with elective laparoscopic procedure for colon malignancy

Variables	Attending alone (n = 4,503), n (%)	Resident involved (n = 9,462), n (%)	*P* value
OR time, mean ± SD, min	143.81 ± 72.51	172.55 ± 79.85	<.001
LOS, mean ± SD, d	6.70 ± 7.09	6.96 ± 7.48	.039
Mortality	65 (1.4%)	94 (1.0%)	.019
Serious morbidity	431 (9.6%)	1,015 (10.7%)	.036
Minor morbidity	464 (10.3%)	1,193 (12.6%)	<.001
Overall morbidity	745 (16.5%)	1,793 (18.9%)	.001
Rescue	693 (15.4%)	1,719 (18.2%)	<.001
Failure to rescue	52 (1.2%)	74 (.8%)	.029
Cardiovascular complication	227 (5.0%)	531 (5.6%)	.164
Pulmonary complication	141 (3.1%)	315 (3.3%)	.539
Renal complication	45 (1.0%)	78 (.8%)	.301
Neurologic complication	21 (.5%)	33 (.3%)	.295
Septic complication	166 (3.7%)	376 (4.0%)	.411
SSI	338 (7.5%)	893 (9.4%)	<.001
Reoperation	207 (4.6%)	441 (4.7%)	.867
Readmission	44 (8.6%)	188 (10.3%)	.280

Definitions of morbidity and complication groupings are described in the "Methods" section.
LOS = length of stay; OR = operative; SSI = surgical site infection.

Table 4 Univariate analysis of outcomes of patients with elective open procedure for colon malignancy

Variables	Attending alone (n = 6,637), n (%)	Resident involved (n = 16,728), n (%)	*P* value
OR time, mean ± SD, min	133.11 ± 78.93	183.41 ± 107.88	<.001
LOS, mean ± SD, d	9.76 ± 12.00	10.13 ± 19.26	.077
Mortality	250 (3.8%)	420 (2.5%)	<.001
Serious morbidity	1,123 (16.9%)	3,182 (19.0%)	<.001
Minor morbidity	1,106 (16.7%)	3,390 (20.3%)	<.001
Overall morbidity	1,764 (26.6%)	5,120 (30.6%)	<.001
Rescue	1,573 (23.7%)	4,782 (28.6%)	<.001
Failure to rescue	191 (2.9%)	338 (2.0%)	<.001
Cardiovascular complication	576 (8.7%)	1,656 (9.9%)	.004
Pulmonary complication	422 (6.4%)	1,112 (6.6%)	.421
Renal complication	138 (2.1%)	298 (1.8%)	.129
Neurologic complication	50 (.8%)	110 (.7%)	.423
Septic complication	457 (6.9%)	1,345 (8.0%)	.003
SSI	736 (11.1%)	2,536 (15.2%)	<.001
Reoperation	367 (5.5%)	1,047 (6.3%)	.035
Readmission	55 (10.5%)	336 (13.0%)	.113

Definitions of morbidity and complication groupings are described in the "Methods" section.
LOS = length of stay; OR = operative; SSI = surgical site infection.

morbidity were significantly higher in laparoscopic and open cases when a resident was present. Although reoperation rates were higher in open cases with resident participation (6.3% vs 5.5%, $P = .035$; Table 4), those undergoing laparoscopic procedures showed no association between resident involvement and need for reoperation (4.7% with resident vs 4.6% without resident, $P = .867$; Table 3).

Multivariate analyses (Table 5 for laparoscopic, Table 6 for open cases) were then performed with overall morbidity as the primary outcome. After adjusting for baseline characteristics, resident involvement showed independent association with morbidity in both laparoscopic (OR 1.2, 95% CI 1.13 to 1.38, $P < .001$) and open colectomy for malignancy (OR 1.3, 95% CI 1.18 to 1.35, $P < .001$).

Comments

As surgical outcomes come under increased scrutiny, it remains essential for surgeons to ensure optimal patient results while effectively training our next generation of residents. In this study, we confirm previous literature,

Table 5 Multivariate analysis evaluating overall morbidity following elective laparoscopic procedure for colon malignancy

Variables	β estimate	SE	Adjusted OR (95% CI)	*P* value
Age	.003	.002	1.0 (1.0–1.01)	.186
BMI	.016	.004	1.0 (1.01–1.02)	<.001
Male gender	.152	.047	1.2 (1.06–1.28)	.001
Vascular comorbidity	−.048	.054	1.0 (.86–1.06)	.374
Cardiac comorbidity	.182	.069	1.2 (1.05–1.37)	.008
Pulmonary comorbidity	.279	.093	1.3 (1.10–1.59)	.003
Neurologic comorbidity	.360	.081	1.4 (1.22–1.68)	<.001
Hepatic comorbidity	.836	.248	2.3 (1.42–3.75)	.001
Diabetes	.009	.061	1.0 (.90–1.14)	.883
Smoker	.232	.068	1.3 (1.10–1.44)	.001
Steroid use	.435	.134	1.6 (1.19–2.01)	.001
Weight loss >10%	.471	.109	1.6 (1.3–1.98)	<.001
ASA class*				
ASA class 2	.417	.186	1.5 (1.06–2.18)	.025
ASA class 3	.836	.189	2.3 (1.59–3.34)	<.001
ASA class 4	1.259	.214	3.5 (2.31–5.36)	<.001
ASA class 5	1.190	1.261	3.3 (.28–38.91)	.345
Resident involvement	.219	.051	1.2 (1.13–1.38)	<.001

Definitions of morbidity and complication groupings are described in the "Methods" section.
ASA = American Society of Anesthesiologists; CI = confidence interval; BMI = body mass index; OR = odds ratio.
*Reference group is ASA class 1.

Table 6 Multivariate analysis evaluating overall morbidity following elective open procedure for colon malignancy

Variables	β estimate	SE	Adjusted OR (95% CI)	*P* value
Age	.002	.001	1.0 (1.00–1.00)	.159
BMI	.016	.002	1.0 (1.01–1.02)	<.001
Male gender	.058	.031	1.1 (1.00–1.13)	.060
Vascular comorbidity	−.007	.035	1.0 (.93–1.06)	.852
Cardiac comorbidity	.020	.046	1.0 (.93–1.12)	.658
Pulmonary comorbidity	.392	.057	1.5 (1.32–1.66)	<.001
Neurologic comorbidity	.169	.053	1.2 (1.07–1.31)	.001
Hepatic comorbidity	.709	.094	2.0 (1.69–2.44)	<.001
Renal comorbidity	.179	.171	1.2 (.86–1.67)	.295
Diabetes	.056	.040	1.1 (.98–1.14)	.163
Steroid use	.227	.091	1.3 (1.05–1.50)	.012
Weight loss >10%	.396	.051	1.5 (1.34–1.64)	<.001
ASA class*				
ASA class 2	.560	.152	1.8 (1.30–2.36)	<.001
ASA class 3	1.025	.152	2.8 (2.07–3.76)	<.001
ASA class 4	1.521	.162	4.6 (3.33–6.29)	<.001
ASA class 5	1.035	.759	2.8 (.64–12.46)	.173
Work relative value unit	.041	.003	1.0 (1.04–1.05)	<.001
Resident involvement	.229	.035	1.3 (1.18–1.35)	<.001

Definitions of morbidity and complication groupings are described in the "Methods" section.
ASA = American Society of Anesthesiologists; BMI = body mass index; CI = confidence interval; OR = odds ratio.
*Reference group is ASA class 1.

suggesting that resident involvement worsens clinical outcomes. More specifically, analysis of cancer patients undergoing elective laparoscopic or open colectomy demonstrates resident involvement as an independent risk factor for increased overall morbidity. In laparoscopy, resident involvement produced higher rates of surgical site infection. During open cases, resident involvement produced higher rates of cardiovascular complications, surgical site infection, sepsis, and reoperation. Furthermore, multivariate analysis indicates that resident participation is associated with overall morbidity in open and laparoscopic cases. Increased postoperative morbidity occurred despite resident involvement in patients with comparatively fewer comorbidities. Interestingly, we found resident involvement associated with lower mortality and lower failure to rescue, results most pronounced in cancer patients undergoing open colon resection. Overall, we show that resident involvement with oncology patients undergoing laparoscopic or open colectomy yields lower patient 30-day mortality at a cost of higher 30-day morbidity.

Here, we confirm an effect of resident involvement for oncology patients undergoing colectomy previously shown by Castleberry et al[27] in a mixed population. Interestingly, no mortality difference was demonstrated in that study, in contrast to our results. This difference in short-term mortality underlies a clinically significant difference in failure to rescue, which may indicate a benefit of resident involvement. Namely, presence of residents in the operating room implies presence on the wards, providing an opportunity for earlier rescue of surgical patients. Furthermore, presence of surgical residents may indicate other support systems, such as intensive care units, inhouse attendings, and rapid response teams. To support this notion, Raval et al,[25] when controlling for multiple factors including operative time, demonstrated that 6.1 additional patients undergoing general surgical/vascular procedures had morbidity events when a resident was involved; however, 1.4 more lives were saved. It is important to note that failure to rescue has previously been associated with staffing levels, both physician and nursing.[43] As such, our data may be a proxy for the notion that more eyes on the surgical patient, whether resident physician, attending physician, nurses, or other ancillary staff, produce less failure to rescue. Furthermore, as larger tertiary care centers tend to use more "eyes," failure to rescue may be lessened as a result. This notion requires further study to fully elucidate the impact of appropriate staffing and the medical center in which that staffing is provided.

Along with failure to rescue, we build on published data through subset analysis of laparoscopic and open procedures in patients previously diagnosed with colon cancer (Tables 3–6). Additionally, we demonstrate another group of procedures whereby resident involvement negatively affects rates of complications.[44,45] Our findings are at odds with literature, suggesting no effect on surgical morbidity when residents are involved.[46–48] Furthermore, our results are contrary to recent articles, suggesting that resident involvement in laparoscopic[49] and open colectomy[50] produces no difference in postoperative complications. Given the large, heterogenous population included in our study of the NSQIP database, it is reasonable to conclude that smaller, single-institution studies are underpowered to detect a statistical effect of resident involvement.

The determination of resident effect in oncology patients undergoing laparoscopic and open colectomy is vitally important for improving patient outcomes. There are increasing reports in the literature documenting worsened long-term outcomes in oncology patients who have postoperative complications.[51–53] Attie et al[54] recently showed worsened cancer-specific surgical outcomes in colorectal patients with any bacterial infection during cancer treatment. In fact, infection was determined as an independent predictor of worsened survival. Xia et al[55] used multivariate analysis to demonstrate that postoperative complications after laparoscopic colectomy were independently associated with worsened overall and relapse-free survival. After evaluation of 868 elective colorectal resections, Odermatt et al[56] identified major complications as a significant negative predictor of overall survival, although not a predictor of time to recurrence. Here, we demonstrate significantly increased rates of surgical site infections (including superficial, deep, and organ space infections) in patients where surgical residents were involved. Surprisingly, resident effect on surgical site infection persisted in laparoscopic procedures, suggesting an underlying effect we do not entirely understand. Given the increasing body of literature showing worsened oncologic outcomes in colon cancer patients who suffer complications, it is imperative for surgeons to fully elucidate the true short- and long-term effects of resident involvement on elective colectomy. This understanding allows for true informed consent and may alter decisions by the attending surgeon regarding operative approach and extent of resident involvement.

In colorectal surgery, operative approach is of utmost importance when evaluating postoperative outcomes. The benefits of laparoscopic vs open colectomy are numerous and well documented.[57–59] Here, we demonstrate a lower association of complications from resident involvement in laparoscopic vs open colectomy. Interestingly, our data demonstrate that laparoscopic procedures were more likely to be performed without the assistance of a resident, despite being more technically challenging. However, even when a resident was involved in a laparoscopic procedure, there were fewer complications noted vs open procedures. As such, this study provides another reason surgeons should seek to complete more colectomies for cancer using a minimally invasive approach. To assist in surgical education during these technically complex procedures, the use of simulations and other training aids allows improved resident skill development without subjecting patients to risk of worsened outcomes. Through providing a low-stress environment and shortening the learning curve, residents are more likely to obtain and retain necessary skills that lessen patient harm in the operating room.[60] Additionally, competency-based assessments, such as the National Training Programme in Laparoscopic Colorectal Surgery and the Fundamentals of Laparoscopic Surgery, should be considered before participation in oncologic procedures to further improve outcomes.[60–62] Future areas of study may involve evaluation of competency-based assessments in surgical residency training and how these programs affect postoperative morbidity.

Because of study design, our retrospective review of prospectively collected data in the ACS-NSQIP participant use file is limited by the possibility of confounding, selection, information, and misclassification bias. Appropriate corrections were made during statistical analysis to reduce effects of these biases but cannot account for all biases. Other limitations include heterogeneous patient factors including procedures performed, differences in hospitals, surgical expertise (both resident and attending), and lack of randomization. Because we compared patient outcomes based on resident involvement on specific surgical procedures, these limitations may be significant. Surgical expertise, especially in laparoscopic colectomy, plays a significant role in patient outcomes. As such, differences in hospital volume and case inclusion in the NSQIP data set may be inappropriately represented in this study. Furthermore, specific data on type of institution (tertiary academic center, community hospital, etc.) are not available from the data set. As such, we cannot control for type of institution during analysis, which may limit the generalizability of this study. However, work relative value units were used to control for case complexity and to improve general application of our findings.[63] The lack of longer term outcomes is a significant limitation of this study, precluding our ability to link postoperative complications with long-term outcomes. Last, 30-day surgical outcomes are influenced by factors not accounted for in this study including medical staff, resident involvement outside the operating room, patient compliance, and many others not included in the NSQIP data set. These limitations should be taken into account when reviewing our data. Despite these limitations, the data analyzed are considered the most complete multi-institutional clinical data available, with the added advantage of impartial clinical reviewers to help reduce error and bias.

Conclusions

In this study, we confirmed an association of resident operative involvement with higher rates of morbidity in oncology patients undergoing laparoscopic and open colon procedures. This occurred despite univariate analysis, suggesting that attending alone cases involved patients with higher preoperative comorbidities. Interestingly, morbidity was limited to surgical site infection in laparoscopic cases, providing further evidence of patient benefit using this modality vs open colectomy. Despite higher overall morbidity associated with resident involvement, attending only cases demonstrated higher 30-day mortality and increased failure to rescue. These findings suggest the cost of reduced patient mortality with resident involvement is higher rates of operative complication. Unfortunately, in cancer patients, this cost may prove too high as operative complications lead to worsened long-term outcomes. Further work is necessary to identify the source of these

apparent discrepancies and to explore opportunities for reducing failure to rescue in settings without resident support. An understanding of these discrepancies, and a strong push toward increased resident skill development outside of the operating room, will produce improved short- and long-term outcomes for our oncology patients.

Index 1

International Classification of Diseases, Ninth Edition, codes for patients with malignancy included in this study

151, 151.0, 151.1, 151.2, 151.3, 151.4, 151.5, 151.6, 151.8, 151.9, 152, 152.0, 152.1, 152.2, 152.3, 152.8, 152.9, 153, 153.0, 153.1, 153.2, 153.3, 153.4, 153.5, 153.6, 153.7, 153.8, 153.9, 154, 154.0, 154.1, 154.2, 154.3, 154.8, 155, 155.0, 155.1, 155.2, 156, 156.0, 156.1, 156.2, 156.8, 156.9, 157, 157.0, 157.1, 157.2, 157.3, 157.4, 157.8, 157.9, 158, 158.0, 158.8, 158.9, 159, 159.0, 159.1, 159.8, 159.9, 162, 162.0, 162.2, 162.3, 162.4, 162.5, 162.8, 162.9, 163, 163.0, 163.1, 163.8, 163.9, 164, 164.0, 164.1, 164.2, 164.3, 164.8, 164.9, 165, 165.0, 165.8, 165.9,172, 172.0, 172.1, 172.2, 172.3, 172.4, 172.5, 172.6, 172.7, 172.8, 172.9, 173, 173.0, 173.1, 173.2, 173.3, 173.4, 173.5, 173.6, 173.7, 173.8, 173.9,174, 174.0, 174.1, 174.2, 174.3, 174.4, 174.5, 174.6, 174.8, 174.9, 175, 175.0, 175.9, 179, 180, 180.0, 180.1, 180.8, 180.9, 181, 181, 182, 182.0, 182.1, 182.8, 183, 183.0, 183.2, 183.3, 183.4, 183.5, 183.8, 183.9, 184, 184.0, 184.1, 184.2, 184.3, 184.4, 184.8, 184.9, 185, 186, 186.0, 186.9, 187, 187.1, 187.2, 187.3, 187.4, 187.5, 187.6, 187.7, 187.8, 187.9, 188, 188.0, 188.1, 188.2, 188.3, 188.4, 188.5, 188.6, 188.7, 188.8, 188.9, 189, 189.0, 189.1, 189.2, 189.3, 189.4, 189.8, 189.9, 193, 194, 194.0, 194.1, 194.3, 194.4, 194.5, 194.6, 194.8, 194.9, 209, 209.0, 209.1, 209.2, 209.3, 209.4, 209.5, and 209.6.

Acknowledgments

Author contributions: K.R.K. had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis; acquisition of data: K.R.K.; analysis and interpretation of data: M.S., K.S., and K.R.K; drafting of the manuscript: M.S., K.S., and K.R.K.; critical revision of the manuscript for important intellectual content: M.S., K.S., M.L.M., W.E.P., and K.R.K; statistical analysis: M.S., K.S., and K.R.K; and study supervision: K.R.K. The study has been approved by all authors in the present format.

References

1. Hutter MM, Kellogg KC, Ferguson CM, et al. The impact of the 80-hour resident workweek on surgical residents and attending surgeons. Ann Surg 2006;243:864–71; discussion 865–71.
2. Stain SC, Biester TW, Hanks JB, et al. Early tracking would improve the operative experience of general surgery residents. Ann Surg 2010; 252:445–9; discussion 449–451.
3. Bell RH. Surgical council on resident education: a new organization devoted to graduate surgical education. J Am Coll Surg 2007;204: 341–6.
4. Malangoni MA, Biester TW, Jones AT, et al. Operative experience of surgery residents: trends and challenges. J Surg Educ 2013;70: 783–8.
5. Canal DF, Torbeck L, Djuricich AM. Practice-based learning and improvement: a curriculum in continuous quality improvement for surgery residents. Arch Surg 2007;142:479–82; discussion 473–82.
6. Bhatti NI, Cummings CW. Competency in surgical residency training: defining and raising the bar. Acad Med 2007;82:569–73.
7. Kelz RR, Sellers MM, Reinke CE, et al. Quality in-training initiative—a solution to the need for education in quality improvement: results from a survey of program directors. J Am Coll Surg 2013;217: 1126–1132.e1–5.
8. Sellers MM, Reinke CE, Kreider S, et al. American College of Surgeons NSQIP: quality in-training initiative pilot study. J Am Coll Surg 2013;217:827–32.
9. Surgical Care Improvement Project Available at: http://www.jointcommission.org/surgical_care_improvement_project/. Accessed July 1, 2015.
10. Bratzler DW, Hunt DR. The surgical infection prevention and surgical care improvement projects: national initiatives to improve outcomes for patients having surgery. Clin Infect Dis 2006;43:322–30.
11. Akhtar KS, Chen A, Standfield NJ, et al. The role of simulation in developing surgical skills. Curr Rev Musculoskelet Med 2014;7: 155–60.
12. Dawe SR, Windsor JA, Broeders JA, et al. A systematic review of surgical skills transfer after simulation-based training: laparoscopic cholecystectomy and endoscopy. Ann Surg 2014;259:236–48.
13. Egle JP, Malladi SV, Gopinath N, et al. Simulation training improves resident performance in Hand-Sewn vascular and bowel anastomoses. J Surg Educ 2015;72:291–6.
14. Shetty S, Zevin B, Grantcharov TP, et al. Perceptions, training experiences, and preferences of surgical residents toward laparoscopic simulation training: a resident survey. J Surg Educ 2014;71:727–33.
15. Carlsen CG, Lindorff-Larsen K, Funch-Jensen P, et al. Is current surgical training efficient? A national survey. J Surg Educ 2014;71: 367–74.
16. D'Angelo AL, Cohen ER, Kwan C, et al. Use of decision-based simulations to assess resident readiness for operative independence. Am J Surg 2015;209:132–9.
17. Hopmans CJ, den Hoed PT, van der Laan L, et al. Assessment of surgery residents' operative skills in the operating theater using a modified Objective Structured Assessment of Technical Skills (OSATS): a prospective multicenter study. Surgery 2014;156:1078–88.
18. Glarner CE, McDonald RJ, Smith AB, et al. Utilizing a novel tool for the comprehensive assessment of resident operative performance. J Surg Educ 2013;70:813–20.
19. Larson JL, Williams RG, Ketchum J, et al. Feasibility, reliability and validity of an operative performance rating system for evaluating surgery residents. Surgery 2005;138:640–7; discussion 647–9.
20. Haughom BD, Schairer WW, Hellman MD, et al. Resident involvement does not influence complication after total hip arthroplasty: an analysis of 13,109 cases. J Arthroplasty 2014;29:1919–24.
21. Kiran RP, Ahmed Ali U, Coffey JC, et al. Impact of resident participation in surgical operations on postoperative outcomes: National Surgical Quality Improvement Program. Ann Surg 2012;256:469–75.
22. Ruhotina N, Dagenais J, Gandaglia G, et al. The impact of resident involvement in minimally-invasive urologic oncology procedures. Can Urol Assoc J 2014;8:334–40.
23. Igwe E, Hernandez E, Rose S, et al. Resident participation in laparoscopic hysterectomy: impact of trainee involvement on operative times and surgical outcomes. Am J obstet Gynecol 2014;211: 484.e1–7.

24. Monteiro R, Mino JS, Siperstein AE. Trends and disparities in education between specialties in thyroid and parathyroid surgery: an analysis of 55,402 NSQIP patients. Surgery 2013;154:720–8; discussion 728–9.
25. Raval MV, Wang X, Cohen ME, et al. The influence of resident involvement on surgical outcomes. J Am Coll Surg 2011;212:889–98.
26. Venkat R, Valdivia PL, Guerrero MA. Resident participation and postoperative outcomes in adrenal surgery. J Surg Res 2014;190: 559–64.
27. Castleberry AW, Clary BM, Migaly J, et al. Resident education in the era of patient safety: a nationwide analysis of outcomes and complications in resident-assisted oncologic surgery. Ann Surg Oncol 2013;20: 3715–24.
28. Davis Jr SS, Husain FA, Lin E, et al. Resident participation in index laparoscopic general surgical cases: impact of the learning environment on surgical outcomes. J Am Coll Surg 2013;216:96–104.
29. Iannuzzi JC, Rickles AS, Deeb AP, et al. Outcomes associated with resident involvement in partial colectomy. Dis Colon Rectum 2013; 56:212–8.
30. Advani V, Ahad S, Gonczy C, et al. Does resident involvement effect surgical times and complication rates during laparoscopic appendectomy for uncomplicated appendicitis? An analysis of 16,849 cases from the ACS-NSQIP. Am J Surg 2012;203:347–51; discussion 342–51.
31. Fischer JP, Wes AM, Kovach SJ. The impact of surgical resident participation in breast reduction surgery—outcome analysis from the 2005-2011 ACS-NSQIP datasets. J Plast Surg Hand Surg 2014;48: 315–21.
32. Iannuzzi JC, Chandra A, Rickles AS, et al. Resident involvement is associated with worse outcomes after major lower extremity amputation. J Vasc Surg 2013;58:827–831.e1.
33. Artinyan A, Orcutt ST, Anaya DA, et al. Infectious postoperative complications decrease long-term survival in patients undergoing curative surgery for colorectal cancer: a study of 12,075 patients. Ann Surg 2015;261:497–505.
34. Li QG, Li P, Tang D, et al. Impact of postoperative complications on long-term survival after radical resection for gastric cancer. World J Gastroenterol 2013;19:4060–5.
35. Tevis SE, Kohlnhofer BM, Stringfield S, et al. Postoperative complications in patients with rectal cancer are associated with delays in chemotherapy that lead to worse disease-free and overall survival. Dis Colon Rectum 2013;56:1339–48.
36. Barlesi F, Doddoli C, Chetaille B, et al. Survival and postoperative complication in daily practice after neoadjuvant therapy in resectable stage IIIA-N2 non-small cell lung cancer. Interactive Cardiovasc Thorac Surg 2003;2:558–62.
37. Becker K, Furch C, Schmid I, et al. Impact of postoperative complications on overall survival of patients with hepatoblastoma. Pediatr Blood Cancer 2015;62:24–8.
38. American College of Surgeons National Surgical Quality Improvement Program. 2013 Available at: http://www.acsnsqip.org. Accessed July 1, 2015.
39. American College of Surgeons National Surgical Quality Improvement Program: User Guide.
40. Khuri SF, Daley J, Henderson W, et al. The Department of Veterans Affairs' NSQIP: the first national, validated, outcome-based, risk-adjusted, and peer-controlled program for the measurement and enhancement of the quality of surgical care. National VA Surgical Quality Improvement Program. Ann Surg 1998;228:491–507.
41. Spaniolas K, Laycock WS, Adrales GL, et al. Laparoscopic paraesophageal hernia repair: advanced age is associated with minor but not major morbidity or mortality. J Am Coll Surg 2014;218:1187–92.
42. Spaniolas K, Trus TL, Adrales GL, et al. Early morbidity and mortality of laparoscopic sleeve gastrectomy and gastric bypass in the elderly: a NSQIP analysis. Surg Obes Relat Dis 2014;10:584–8.
43. Griffiths P, Jones S, Bottle A. Is "failure to rescue" derived from administrative data in England a nurse sensitive patient safety indicator for surgical care? Observational study. Int J Nurs Stud 2013;50:292–300.
44. Scarborough JE, Bennett KM, Pappas TN. Defining the impact of resident participation on outcomes after appendectomy. Ann Surg 2012; 255:577–82.
45. Scarborough JE, Pappas TN, Cox MW, et al. Surgical trainee participation during infrainguinal bypass grafting procedures is associated with increased early postoperative graft failure. J Vasc Surg 2012; 55:715–20.
46. Patel SP, Gauger PG, Brown DL, et al. Resident participation does not affect surgical outcomes, despite introduction of new techniques. J Am Coll Surg 2010;211:540–5.
47. Shaked A, Calderom I, Durst A. Safety of surgical procedures performed by residents. Arch Surg 1991;126:559–60.
48. Tseng WH, Jin L, Canter RJ, et al. Surgical resident involvement is safe for common elective general surgery procedures. J Am Coll Surg 2011;213:19–26; discussion 18–26.
49. Mehall JR, Shroff S, Fassler SA, et al. Comparing results of residents and attending surgeons to determine whether laparoscopic colectomy is safe. Am J Surg 2005;189:738–41.
50. Montroni I, Ghignone F, Rosati G, et al. The challenge of education in colorectal cancer surgery: a comparison of early oncological results, morbidity, and mortality between residents and attending surgeons performing an open right colectomy. J Surg Educ 2014;71:254–61.
51. Cheung WY, Neville BA, Earle CC. Etiology of delays in the initiation of adjuvant chemotherapy and their impact on outcomes for stage II and III rectal cancer. Dis Colon Rectum 2009;52:1054–63; discussion 1064.
52. Hendren S, Birkmeyer JD, Yin H, et al. Surgical complications are associated with omission of chemotherapy for stage III colorectal cancer. Dis Colon Rectum 2010;53:1587–93.
53. Regenbogen SE, Veenstra CM, Hawley ST, et al. The personal financial burden of complications after colorectal cancer surgery. Cancer 2014;120:3074–81.
54. Attie R, Chinen LT, Yoshioka EM, et al. Acute bacterial infection negatively impacts cancer specific survival of colorectal cancer patients. World J Gastroenterol 2014;20:13930–5.
55. Xia X, Wu W, Zhang K, et al. Prognostic significance of complications after laparoscopic colectomy for colon cancer. PLoS One 2014;9: e108348.
56. Odermatt M, Miskovic D, Flashman K, et al. Major postoperative complications following elective resection for colorectal cancer decrease long-term survival but not the time to recurrence. Colorectal Dis 2015;17:141–9.
57. Asgeirsson T, Jrebi N, Feo L, et al. Incremental cost of complications in colectomy: a warranty guided approach to surgical quality improvement. Am J Surg 2014;207:422–6; discussion 425–6.
58. Shaligram A, Smith L, Pallati P, et al. Can laparoscopy for colon resection reduce the need for discharge to skilled care facility? Surg Endosc 2013;27:4038–43.
59. Schwenk W, Haase O, Neudecker J, et al. Short term benefits for laparoscopic colorectal resection. Cochrane Database Syst Rev; 2005: CD003145.
60. Samia H, Khan S, Lawrence J, et al. Simulation and its role in training. Clin Colon Rectal Surg 2013;26:47–55.
61. Foster JD, Francis NK. Objective assessment of technique in laparoscopic colorectal surgery: what are the existing tools? Tech Coloproctol 2015;19:1–4.
62. Leblanc F, Senagore AJ, Ellis CN, et al. Hand-assisted laparoscopic sigmoid colectomy skills acquisition: augmented reality simulator versus human cadaver training models. J Surg Educ 2010;67:200–4.
63. Merkow RP, Bentrem DJ, Cohen ME, et al. Effect of cancer surgery complexity on short-term outcomes, risk predictions, and hospital comparisons. J Am Coll Surg 2013;217:685–93.