

# Outcomes Associated With Resident Involvement in Partial Colectomy

James C. Iannuzzi, M.D. • Aaron S. Rickles, M.D. • Andrew-Paul Deeb, B.S.  
Abhiram Sharma, M.D. • Fergal J. Fleming, M.D., F.R.C.S.  
John R. T. Monson, M.D., F.R.C.S.

Surgical Health Outcomes & Research Enterprise, University of Rochester Medical Center, Rochester, New York

**BACKGROUND:** Surgical cases that include trainees are associated with worse outcomes in comparison with those that include attending surgeons alone.

**OBJECTIVE:** This study aimed to identify whether resident involvement in partial colectomy was associated with worse outcomes when evaluated by surgical approach and resident experience.

**DESIGN:** This is a retrospective study using the National Surgical Quality Improvement Program database.

**SETTINGS:** This study evaluates cases included in the National Surgical Quality Improvement Program database.

**PATIENTS:** All patients were included who underwent partial colectomy including both open and laparoscopic approaches.

**INTERVENTIONS:** Residents were involved.

**MAIN OUTCOME MEASURES:** The primary outcome measures were the association of resident involvement and major complication events, minor complication events, unplanned return to operating room, and operative time.

**RESULTS:** Cases with residents were associated with major complications (OR 1.18, CI 1.09–1.27,  $p < 0.001$ ) on multivariate analysis. However, after including operative time in the model only open cases involving

fifth year residents were still associated with major complications (OR 1.13,  $p = 0.037$ ). Resident involvement was associated with increased likelihood of minor complications (OR 1.3,  $p < 0.001$ ) and an increased risk of unplanned return to the operating room (OR 1.20,  $p < 0.001$ ). Operative time was longer for cases with residents on average by 33.7 minutes and 27 minutes for open and laparoscopic cases.

**LIMITATIONS:** This study was limited by its retrospective design and lack of data on teachings status, case complexity, and intraoperative evaluation of technique.

**CONCLUSIONS:** Resident involvement in partial colectomies is associated with an increased major complications, minor complications, likelihood of return to the operating room, and operative time.

**KEY WORDS:** Colectomy; Resident; Surgical outcomes; National Surgical Quality Improvement Program; Complications; Surgical training.

In the environment of a shifting surgical training paradigm, it is important to identify targets for directed educational improvement. Training can no longer be taken for granted in an era with decreasing work hours, public concerns of practicing new techniques on patients, the increasingly broad scope of general surgery, and changing reimbursement trends dependent on the avoidance of poor outcomes.<sup>1,2</sup> The consequences of changes to training must be closely investigated to ensure that the current educational environment benefits patient care both now and when the next generation of surgeons begins to practice.

Recent literature suggests that for many procedures cases involving residents are associated with higher rates of both major and minor complications.<sup>3–9</sup> Raval et al<sup>5</sup> demonstrated that, after controlling for training program presence, cases involving residents had worse outcomes

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**Correspondence:** James Iannuzzi, M.D., Research Fellow, Surgical Health Outcomes & Research Enterprise, Department of Surgery, University of Rochester, 601 Elmwood Ave, Box Surg, Rochester, NY 14642. E-mail: james\_iannuzzi@urmc.rochester.edu

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across various index cases in the American College of Surgeons National Surgical Quality Improvement Program database (NSQIP). Scarborough et al<sup>7</sup> found that infrainguinal bypasses that involved residents had a higher rate of graft failure. These and similar studies raise a major public health concern: surgical education may be associated with increased risk to patients.

The teaching environment or, in other words, the effect of resident involvement in the operating theater has not been well defined. Partial colectomy has not been evaluated for changes due to trainee presence and is a good candidate for study, because it is a general surgery index case with well-defined steps. Owing to the varying difficulty of these steps, colectomy also lends itself to evaluation by resident experience. Partial colectomy has 2 standard approaches allowing for the evaluation of whether this effect is present in both laparoscopic and open scenarios. In this study, we sought to determine whether resident involvement was associated with disparate outcomes in laparoscopic and open partial colectomy and whether this effect varied by resident experience.

## MATERIALS AND METHODS

The NSQIP is a clinical database with prospective systematic data collection conducted at 258 hospitals throughout the United States. Details of sampling strategy, data abstraction, variables collected, and recorded outcomes have been previously reported.<sup>10</sup> The NSQIP database was queried for patients who underwent either an open or laparoscopic partial colectomy with the use of Common Procedural Terminology (CPT) codes (44140, 44204) in the Participant User File from 2005 to 2010. Resident involvement in a case was defined the use of the NSQIP variable “highest level of supervision” and “highest level of resident involvement (PGY).” Cases were considered to be attending cases alone if marked “Attending Alone” and “PGY = 0.” Residents were considered to be involved if postgraduate year (PGY) was marked from 1 to 5. Cases with PGY 1 level residents were then excluded, because involvement was likely to be unsubstantial. Cases were also stratified by operative approach (laparoscopic vs open).

Preoperative comorbidity variables were grouped by organ system and analyzed along with patient characteristics and intraoperative factors. Postoperative complications were also grouped by organ system and categorized into primary end points of minor complication, major complication, and mortality all within 30 days of surgery. Minor complications included incisional infections and urinary tract infections. Major complications included organ space (intraoperative) infections, cardiac events, neurologic events, ventilator dependence (reintubation or failure to wean), pneumonia, venous thromboembolic

events, return to operating room, renal failure, and sepsis/septic shock. Return to operating room was also evaluated as a unique end point, as well as operative time.

Clinical characteristics associated with resident involvement were assessed by using  $\chi^2$  or Mann-Whitney *U* test as appropriate to the data. Postoperative complications were independently evaluated as binary outcomes, and association with resident involvement was examined in univariate  $\chi^2$  analysis and multivariate (adjusted) logistic regression or independent Student *t* test and linear regression as appropriate. Adjusted ORs are reported for multivariate regression analysis for each outcome stratified by PGY. Cases without residents served as the reference group for all analyses. All regression analyses were adjusted for factors that were associated with each end point on univariate analysis and included patient age, sex, functional status, BMI, alcohol use, steroid use, comorbidities, ASA classification, emergency status, and wound classification. Variables with a *p* value of <0.1 were included in final models, and a *p* value of <0.05 was considered as a significant association. All analyses were performed by using IBM SPSS statistics software, Version 19 (2010 SPSS). This study used readily available deidentified data and therefore was not subject to institutional review board approval or oversight.

## RESULTS

A total of 32,506 patients met inclusion criteria, of which 18,858 (58%) cases involved residents and 13,648 (42%) cases involved attending surgeons alone. Residents were involved in 11,718 (60.6%) of open cases, and 7140 laparoscopic cases (54.2%). Patient characteristics within each group are presented in Table 1. Breakdown of cases by resident level are as follows: PGY 2 = 1534 (8%), PGY 3 = 3405 (18%), PGY 4 = 5638 (30%), and PGY 5 = 8281 (44%).

There was an increased likelihood of minor complications in cases with resident involvement (OR 1.32, CI 1.23–1.42, *p* < 0.001) after adjustment on multivariate logistic regression. When stratified by PGY, the risk of a minor complication following an open case involving a resident had an incremental increase per PGY (Table 2). Cases involving a PGY 5 had the highest risk with a 35% increased likelihood of minor complications. When analyzing laparoscopic cases alone, cases involving PGY2 and PGY3 residents had the greatest risk of minor complications (OR 1.44, CI 1.06–1.97, *p* < 0.001 and OR 1.41, CI 1.14–1.75, *p* = 0.001).

After adjustment for comorbidities on multivariate logistic regression resident cases (as a group) were more likely to be complicated by an unplanned return to the operating room in comparison with cases with attending surgeons alone (OR 1.20, CI 1.08–1.33, *p* < 0.001). After stratifying by surgical approach and PGY (Table 3), only

**TABLE 1.** Clinical characteristics of the patients in attending surgeon and resident cases

	Attending surgeon n = 13,648 n (%)	Resident n = 18,858 n (%)	p
Preoperative factors			
Age >75 y	3777 (27.7)	4856 (25.8)*	<0.001
Emergent	1597 (11.7)	2351 (12.5)*	0.04
Male	6289 (46.3)	8937 (47.5)*	0.03
Race			
White	10,952 (87.4)	13,631 (79.7)*	<0.001
Black	926 (7.4)	2370 (13.9)*	<0.001
Other	653 (5.2)	1104 (6.5)*	<0.001
Transfer status			
Home	13,219 (96.9)	18,038 (95.7)*	<0.001
Acute	165 (1.2)	490 (2.6)*	<0.001
Chronic	205 (1.5)	257 (1.4)*	<0.001
Other	59 (0.4)	462 (1.4)*	<0.001
BMI >30	4422 (33)	5974 (32.5)	0.40
Diabetes mellitus	2047 (15)	2872 (15.2)	0.57
Dependent functional status	1048 (7.7)	1498 (7.9)	0.38
ASA 3, 4, or 5	6599 (48.4)	9374 (49.7)*	0.02
Smoker	2372 (17.4)	3337 (17.7)	0.46
Alcohol use	495 (3.6)	698 (3.7)	0.73
Weight loss >10% in 6 mo before	556 (4.1)	900 (4.8)*	0.003
Pulmonary comorbidity	980 (7.2)	1380 (7.3)	0.64
Hepatic insufficiency	203 (1.5)	345 (1.8)*	0.02
Cardiac comorbidity	1637 (12)	2339 (12.4)	0.27
Renal insufficiency	158 (1.2)	339 (1.8)*	<0.001
Neurological comorbidity	1087 (8)	1535 (8.1)	0.57
Chemo/radiation/disseminated cancer	564 (4.1)	1017 (5.4)*	<0.001
Steroids	456 (3.3)	786 (4.2)*	<0.001
Bleeding disorder	659 (4.8)	1012 (5.4)*	0.03
Preoperative transfusion <sup>a</sup>	170 (1.2)	245 (1.3)	0.67
Preoperative sepsis/SIRS/septic shock	1195 (8.8)	1804 (9.6)*	0.01
Hypoalbuminemia (<3.5 g/dL)	2805 (30.9)	3477 (28.6)*	<0.001
Hematocrit <36	4372 (33.6)	6748 (37.6)*	<0.001
Wound class III/IV	2644 (19.4)	3586 (19)	0.42
Nongeneral anesthesia	79 (0.6)	58 (0.3)*	<0.001
Malignancy	5157 (37.8)	7560 (40.1)*	<0.001
Open	7625 (39.4)	11718 (60.6)*	<0.001
Laparoscopic	6023 (45.8)	7140 (54.2)*	<0.001
End points			
Major complication	1951 (14.3)	3131 (16.6)*	<0.001
Minor complication	1459 (10.7)	2697 (14.3)*	<0.001
Incisional infection	961 (7)	1597 (8.5)*	<0.001
Mortality	400 (2.9)	608 (3.2)	0.14
Postoperative sepsis/shock	808 (5.9)	1290 (6.8)*	0.001

SIRS = systemic inflammatory response syndrome; PRBC = packed red blood cells.

<sup>a</sup>More than 4 units PRBC 72 hours preoperatively.

\* $p < 0.05$ .

open cases with resident involvement were significantly associated with an increased risk for an unplanned return to the operating room across all PGYs (OR 1.20, CI 1.08–1.33,  $p < 0.001$ ). For laparoscopic cases, only those involving a PGY 5 resident were significantly associated with a return to the operating room (OR 1.23, CI 1.09–1.39,  $p = 0.001$ ).

On multivariate linear regression, operative time was significantly longer in both open and laparoscopic cases when residents were involved (Table 4). On average, operative time for attending surgeon and resident in open cases was 123.6 minutes (SD 63.6) vs 157.1 minutes (SD 85.6)

( $p < 0.001$ ) and 138.7 minutes (SD 62.3) vs 165.2 minutes (SD 65.9) ( $p < 0.001$ ) for laparoscopic cases. Overall operative time for resident cases was associated with an adjusted increase of 30.5 minutes ( $p < 0.001$ ). This effect was consistent for both open and laparoscopic approaches regardless of PGY (open, +33.7 minutes,  $p < 0.001$ ; laparoscopic, +27 minutes,  $p < 0.001$ ).

On multivariate analysis, cases involving residents were associated with increased likelihood of major complications (OR 1.18, CI 1.09–1.27,  $p < 0.001$ ) (Table 5). After including increased operative time in the multivariate model, only open cases involving PGY 5 residents

**TABLE 2.** Adjusted (multivariate) likelihood of minor complication in cases with residents vs attending surgeons alone by operative approach and PGY

Minor complication	OR	95% CI	p
All	1.32*	1.23–1.42	<0.001
PGY 5 all	1.35*	1.23–1.47	<0.001
PGY 4 all	1.24*	1.12–1.38	<0.001
PGY 3 all	1.29*	1.14–1.46	<0.001
PGY 2 all	1.39*	1.18–1.63	<0.001
Open	1.32*	1.21–1.44	<0.001
PGY 5 open	1.34*	1.20–1.49	<0.001
PGY 4 open	1.24*	1.14–1.45	<0.001
PGY 3 open	1.21*	1.04–1.40	0.01
PGY 2 open	1.30*	1.07–1.57	0.01
Laparoscopic	1.26*	1.11–1.43	<0.001
PGY 5 laparoscopic	1.31*	1.12–1.52	0.001
PGY 4 laparoscopic	1.10	0.91–1.33	0.31
PGY 3 laparoscopic	1.41*	1.14–1.75	0.001
PGY 2 laparoscopic	1.44*	1.06–1.96	0.02

Analysis adjusted for wound class (III/IV vs I/II), hematocrit <36, preoperative sepsis, preoperative transfusion, bleeding disorder, steroids for chronic condition, neurological/cardiac/hepatic/pulmonary comorbidity, ASA class (III/IV/V vs I/II), dependent functional status, diabetes mellitus, operative time, malignancy, current smoker, alcohol use, BMI>30, sex, emergency status, year of operation.

PGY = postgraduate year.

\*p < 0.05.

remained independently associated with an increased risk of a major complication (OR 1.13, CI 1.01–1.23, p = 0.04). Resident involvement had no significant association with the risk of mortality for either approach or PGY. Resident cases did not demonstrate an association with increased blood transfusions, neither intraoperatively nor postoperatively.

**TABLE 3.** Adjusted (multivariate) likelihood of unplanned return to the operating room in cases with residents vs attending surgeons alone by operative approach and PGY

Return to operating room (resident vs attending surgeon)	OR	95% CI	p
All	1.20*	1.08–1.33	<0.001
PGY 5	1.23*	1.09–1.39	0.001
PGY 4	1.15	1.00–1.32	0.055
PGY 3	1.27*	1.07–1.49	0.005
PGY 2	1.13	0.90–1.42	0.3
Open (all PGY)	1.20*	1.08–1.33	<0.001
PGY 5 open	1.34*	1.16–1.56	<0.001
PGY 4 open	1.29*	1.10–1.52	0.002
PGY 3 open	1.34*	1.10–1.62	0.004
PGY 2 open	1.20	0.93–1.56	0.162
Laparoscopic (all PGY)	0.90	0.75–1.09	0.289
PGY 5 laparoscopic	1.23*	1.09–1.39	0.001
PGY 4 laparoscopic	0.78	0.58–1.03	0.081
PGY 3 laparoscopic	1.06	0.77–1.49	0.708
PGY 2 laparoscopic	0.83	0.49–1.40	0.488

Analysis adjusted for wound class (III/IV vs I/II), hematocrit <36, preoperative sepsis, preoperative transfusion, bleeding disorder, steroids for chronic condition, neurological/cardiac/hepatic/pulmonary comorbidity, ASA class (III/IV/V vs I/II), dependent functional status, diabetes mellitus, operative time, malignancy, current smoker, alcohol use, BMI >30, sex, emergency status, year of operation.

PGY = postgraduate year.

\*p < 0.05.

**TABLE 4.** Adjusted (multivariate) increase in operative time for cases with residents vs attending surgeons alone by operative approach and PGY

Operative time	Op Time Inc, min	95% CI	p
All	30.5*	28.8–32.3	<0.0001
PGY 5	31.9*	29.9–33.9	<0.0001
PGY 4	28.4*	26.1–30.6	<0.0001
PGY 3	33.1*	30.5–35.7	<0.0001
PGY 2	26.6*	23.0–30.3	<0.0001
Open (all PGY)	33.7*	31.3–36.1	<0.0001
PGY 5 open	34.7*	31.9–37.6	<0.0001
PGY 4 open	32.5*	29.4–35.6	<0.0001
PGY 3 open	35.4*	31.9–38.8	<0.0001
PGY 2 open	31.7*	27.1–36.3	<0.0001
Laparoscopic (all PGY)	27.0*	24.7–29.4	<0.0001
PGY 5 laparoscopic	28.8*	26.0–31.6	<0.0001
PGY 4 laparoscopic	23.0*	19.8–26.2	<0.0001
PGY 3 laparoscopic	31.8*	27.8–35.8	<0.0001
PGY 2 laparoscopic	19.8*	13.8–25.9	<0.0001

Analysis adjusted for wound class (III/IV vs I/II), hematocrit <36, preoperative sepsis, preoperative transfusion, bleeding disorder, chemotherapy/disseminated cancer or history of radiation therapy, neurological/renal/cardiac/pulmonary comorbidities, dependent functional status, diabetes mellitus, BMI >30, race.

PGY = postgraduate year; Op Time Inc = relative increase of operative time in minutes.

\*p < 0.05.

## DISCUSSION

This study questioned whether resident involvement changes outcome and found that resident involvement was associated with elevated risk for major complications, minor complications, return to the operating room, and increased operative time, but it was not significantly associated with mortality. The observed resident association with complications varied in magnitude by resident experience and operative approach.

This study's major strength is the large sample size coupled to robust clinical information. The large sample size reduced type I and type II errors, making the results unlikely to be due to random error. Another strength of this study is that the NSQIP dataset itself is well validated, particularly for colorectal procedures, and followed previously used rigorous methods.<sup>11–13</sup>

Accepting the conceptual notion that resident involvement and variables that drive outcome can never be fully described, we attempted to minimize the possibilities of confounding by narrowing analysis to 2 CPT codes for partial colectomy. To account for effect modification by resident experience and operative approach, cases were stratified by postgraduate year and operative approach. Finally, the reported results are consistent with emerging evidence in other areas of surgery including breast, vascular, and general surgery.<sup>3,4,6,7,14–17</sup>

The retrospective study design limits conclusions that can be drawn, and NSQIP is particularly prone to potential errors due to inaccurate coding by nurse reviewers. These errors most drastically would affect whether residents

**TABLE 5.** Adjusted (multivariate) likelihood of major complication

Variable	OR	95% CI	p
Resident involvement	1.175	1.085–1.272	<0.001
Malignancy	.887	0.812–0.969	0.008
Male sex	1.213	1.119–1.314	<0.001
BMI > 30	1.128	1.035–1.230	0.006
Dependent functional status	1.637	1.454–1.843	<0.001
ASA class III/IV/V vs I/II	1.713	1.556–1.885	<0.001
Current smoker	1.250	1.128–1.384	<0.001
EtOH	1.455	1.206–1.755	<0.001
Weight loss	1.241	1.065–1.446	0.006
Pulmonary comorbidity	1.688	1.493–1.909	<0.001
Hepatic insufficiency	1.673	1.338–2.091	<0.001
Cardiac comorbidity	1.117	1.002–1.246	0.046
Renal insufficiency	1.613	1.277–2.038	<0.001
Neurologic comorbidity	1.224	1.081–1.385	0.001
Chemo XRT	1.311	1.126–1.525	<0.001
Chronic steroids	1.422	1.205–1.678	<0.001
Bleeding disorder	1.361	1.182–1.568	<0.001
Preoperative sepsis	1.756	1.554–1.983	<0.001
Hypoalbuminemia (<3.5/dL)	1.426	1.301–1.562	<0.001
Hematocrit <36%	1.191	1.090–1.302	<0.001
Wound class III/IV vs I/II	1.362	1.234–1.503	<0.001
Age >75 y	1.178	1.072–1.294	0.001
Emergency case	1.658	1.479–1.860	<0.001
Open case	1.407	1.262–1.568	<0.001

Chemo XRT = history of chemotherapy, disseminated cancer, or radiation therapy; HCT = hematocrit.

were appropriately coded as being involved and complete identification of complications. Because outcome and exposure assignment error is nondifferential, it is likely to cause an underestimation of the observed association.

Information on hospital teaching status was unavailable, preventing us from controlling for hospital-level effects. Lack of hospital teaching status introduced significant bias due to differences in case mix related to large academic centers that are more likely to involve residents. Attempts were made to minimize referral bias by controlling for patient-level factors; however, residual bias may remain, contributing to the observed association. There is also considerable bias secondary to case selection and, in particular, with regard to resident experience. Chief residents likely choose, or may be required for, the most difficult cases, and, thus, the association with major complications seen in PGY 5 cases may be secondary to selection bias.

Another limitation is the lack of intraoperative data. The NSQIP only captures the documented presence of residents and does not include information on the extent of resident involvement. The lack of intraoperative data prevents specifying whether resident errors occurred or what was the extent of supervision by attending surgeons. The dataset also lacked information on surgical assistance in cases marked as attending alone, and it is unclear whether physician assistants, medical students, or other attending surgeons assisted with these operations. Attending level factors are not captured well in NSQIP. For instance, NSQIP does not capture surgeon volume or colorectal

specialty, which may alter the observed association due to experience and appropriate supervision. It is also possible that the intraoperative period itself is not the relevant exposure, rather postoperative management for cases that include residents create outcome differences. Finally, resident involvement may be a surrogate for some other unmeasured factor requiring further elaboration. The cause of the observed phenomenon cannot be demonstrated by these data because of limitations on intraoperative data, referral bias, and case selection bias, highlighting the need for future investigation.

In comparison with other reports, this study focused on partial colectomy, stratifying by resident level and operative approach. Raval et al<sup>5</sup> found a similar resident association in NSQIP when evaluating colorectal resections; however, they included a large number of CPT codes to represent colorectal resection. A strength of the Raval et al study is that they controlled for hospital teaching status, which was not available in our study. Despite differences in methods, similar to our estimate, they found an OR of 1.15 for increased morbidity in resident cases. The effect estimate had a greater magnitude when teaching status was included in the model than when it was not, suggesting that the effect estimate from our study is an underestimation of the association. Raval et al<sup>5</sup> did not evaluate whether the observed association varied by resident level or surgical approach, nor did they evaluate end points of operative time or return to the operating room. In our study, we classified morbidity into major and minor complications, a distinction also not made in the Raval study.

Hwang et al performed a study with the use of NSQIP from 2005 to 2006 evaluating resident involvement in a range of general surgery operations including small- and large-bowel resections grouped together.<sup>17</sup> Hwang et al noted an increase in complications and operative time, but no difference in return to the operating room on univariate analysis. By comparison, we performed a multivariate analysis using NSQIP from 2005 to 2010 evaluating 32,506 cases in comparison with 2723 cases in the Hwang study. Hwang et al, similar to Raval et al, did not stratify cases by resident experience, operative approach, or type of complication.<sup>17</sup>

Kiran et al<sup>15</sup> evaluated NSQIP 2005 to 2007 for resident involvement and morbidity by using a matched study design matching for age, sex, surgeon specialty, surgical procedure, morbidity probability (as determined by NSQIP), comorbidities, and risk factors. They also found a resident-associated increase in complications. Similar to our study, senior residents were found to have a higher complication rate in comparison with junior resident cases. They also found longer operative times. We did not use the provided NSQIP morbidity probability because it has been previously shown to perform poorly in multivariate analysis.<sup>15,18</sup>

Tseng et al<sup>9</sup> used NSQIP 2005 to 2007 to evaluate 7 common elective general surgery operations including open right colectomy for malignancy. They only evaluated 731 cases, and although resident involvement had an OR of 1.4 for increased morbidity, it did not reach statistical significance. They concluded that there was no difference in morbidity; however, this was likely a type II error. Tseng et al performed a multivariate analysis of operative time, PGY, and morbidity probabilities provided by NSQIP. As previously discussed, NSQIP-provided morbidity probabilities perform poorly in multivariate analysis.<sup>15,18</sup> They did not otherwise control for patient-level comorbidities or risk factors. By comparison, we controlled for patient-level comorbidities, risk factors, and emergent cases, and we stratified by laparoscopic approach.

Although no statistically significant difference in mortality was observed, our study found that resident involvement was associated with increased risk of poor outcomes and increased operative time. The estimate of the increased rate of complications in resident cases is similar in magnitude to commonly accepted risk factors such as obesity and cardiac comorbidity. Although this study was unable to identify the cause of the observed phenomenon, it is imperative that future investigations determine whether the association of resident involvement with outcome is due to inherent differences when trainees are involved or differences in characteristics of systems where residents are trained. Resident involvement was also associated with increased operative time, which may seem intuitive, because training and teaching take time. Whether

or not longer operative time should be considered a poor outcome in this instance is a matter of debate. Longer operative time may have attendant increases in cost or downstream effects such as higher rates of surgical site infections, but it may be necessary to accept that the training environment prolongs the operative period.

There are multiple potential explanations for the observed resident association with postoperative outcomes. The skeptical approach denies that any resident-specific factors are involved in the observed association and would claim that study limitations are to blame, including residual confounding and case selection biases. This might suggest that there are differences in the patient populations and cases performed by residents. If system differences are associated with worse outcomes, they must be recognized and incorporated when evaluating, grading, and ranking hospitals.

The current article does not provide a clear causative relationship between resident involvement and poor outcomes. However, the possibility that resident involvement itself causes worse outcomes cannot be entirely ignored. In such a scenario, a number of possible explanations might be considered. For example, intraoperative resident errors may be the source of worse outcomes. This might imply that residents were using techniques they were not yet competent to perform, and the appropriate level of supervision was not present or was insufficient to prevent the error. Although there may be approaches to surgical education that can mitigate these errors, to some degree, resident errors are inherent in the education process and could be considered collateral damage to a necessary process of medical training. Intraoperative factors themselves may not be part of the mechanism at all, and the observed association could be due to postoperative care. This may imply differences in overall management between teaching and nonteaching environments.

The apparent association of resident operative involvement and differences in outcome does demand attention and future investigation. The surgical community should address whether training environments or trainees change patient outcomes. Should it be the case that residents pose additional risk to patients, strategies should continue to be developed aimed at mitigating any potential differences. These strategies might include operative simulation, competency-based progression, and goal-directed operative teaching.

## CONCLUSION

Consistent with previous evidence, this study demonstrates that the teaching environment is associated with an increased risk of poor outcomes. Although resident involvement did not translate into increased mortality, there was an associated increase in operative time, minor

complications, return to the operating room, and major complications. Thus, resident involvement may represent an increase in both physical and financial burden, which must be addressed. Further study ought isolate the root cause of the observed risk and determine whether this effect is due to intraoperative differences, inherent differences in the teaching hospital environment, or postoperative care by residents. The resident effect may be diminished by the development of realistic simulation, narrowing the focus of educational goals and creating intraoperative objectives based on trainee experience.

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