



Do Not Blame the Resident: the Impact of Surgeon and Surgical Trainee Experience on the Occurrence of Intraoperative Adverse Events (iAEs) in Abdominal Surgery

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OBJECTIVE: Intraoperative adverse events (iAEs) are defined as inadvertent injuries that occur during an operation and are associated with increased mortality, morbidity, and health care costs. We sought to study the impact of attending surgeon experience as well as resident training level on the occurrence of iAEs.

DESIGN: The institutional American College of Surgeons-National Surgical Quality Improvement Program and administrative databases for abdominal surgeries were linked and screened for iAEs using the International Classification of Diseases, Ninth Revision, Clinical Modification-based Patient Safety Indicator “accidental puncture/laceration.” Each flagged record was systematically reviewed to confirm iAE occurrence and determine the number of years of independent practice of the attending surgeon and the postgraduate year (PGY) of the assisting resident at the time of the operation. The attending surgeon experience was divided into quartiles (<6 years, 6-13 years, 13-20 years, >20 years). The resident experience level was defined as Junior (PGY-1 to PGY-3) or Senior (PGY-4 or PGY-5). Univariate/bivariate then multivariable logistic regression analyses adjusting for patient demographics, comorbidities, and operation type and/or complexity (using RVUs as a proxy) were performed to assess the independent impact of resident and attending surgeon experience on the occurrence of iAEs.

SETTING: A large tertiary care teaching hospital.

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PARTICIPANTS: Patients included in the 2007-2012 ACS-NSQIP that had an abdominal surgery performed by both an attending surgeon and a resident.

RESULTS: A total of 7685 operations were included and iAEs were detected in 159 of them (2.1%). Junior residents participated in 1680 cases (21.9%), while senior residents were involved in 6005 (78.1%). The iAE rates for attending surgeons with <6, 6-13, 13-20, and >20 years of experience were 2.7%, 1.7%, 2.4%, and 1.4%, respectively. In multivariable analyses, the risk of occurrence of an iAE was significantly decreased for surgeons with >20 years of experience compared to those with <6 years of experience (odds ratio=0.52, 95% confidence interval 0.32-0.86, $p = 0.011$). On bivariate analyses, iAEs occurred in 1.2% of junior resident cases, while senior residents had an iAE rate of 2.3%. However, after risk adjustment on multivariable analyses, the resident experience level did not significantly impact the rate of iAEs.

CONCLUSIONS: The surgeon’s level of experience, but not the resident’s, is associated with the occurrence of iAEs in abdominal surgery. Efforts to improve patient safety in surgery should explore the value of pairing junior surgeons with the more experienced ones thru formalized coaching programs, rather than focus on curbing resident operative autonomy. (J Surg Ed 75:e156–e167. © 2018 Association of Program Directors in Surgery. Published by Elsevier Inc. All rights reserved.)

KEY WORDS: Accidental puncture or laceration, Intraoperative complications, Intraoperative adverse event, Resident autonomy, Surgical education, Experience

COMPETENCIES: Patient Care, Practice-Based Learning and Improvement, Systems-Based Practice

INTRODUCTION

Most, if not all, surgeons encounter intraoperative adverse events (iAEs) in their practice, with 1 study suggesting the majority report as many as 2-5 iAEs per year.¹ iAEs lead to worse patient postoperative outcomes, with recent studies suggesting an increase in mortality, morbidity, readmissions, as well as hospital charges.²⁻¹⁰ Not surprisingly, redo complex surgery with adhesions is one of the most important risk factors predicting the occurrence of iAEs.¹¹

Many studies support the notion that surgeons' volume and experience is independently associated with better postoperative outcomes.¹²⁻¹⁵ For instance, Damle and colleagues reported that, in colorectal cancer surgery, "high volume surgeons" have significantly less postoperative complications and lower reoperation rates.¹² Data for the operating surgical trainees and their impact on postoperative surgical outcomes is less definitive and more conflicting.¹⁶⁻¹⁹ It is tempting to suggest that there is no other hospital setting where the judgement and technical experience of a physician is so directly linked to immediate patient harm than the operating room.

Despite this emerging literature on both iAEs and the volume and/or outcome relationship, the impact of the operating surgeon or assisting surgical trainee experiences on the incidence of iAEs is still largely unknown.^{20,21} Chen et al. analyzed the incidence of Accidental Puncture and/or Laceration (APL) when an operation was performed by either an attending surgeon or trainee and found no difference. However, this analysis also included nongastrointestinal operations and did not subdivide the experience level of the attending surgeon or the trainee.²⁰ Therefore, in this study, we sought to examine the impact of the attending surgeon's years of independent practice as well as the general surgery resident level on the occurrence of iAEs in abdominal surgery.

MATERIALS AND METHODS

To study the independent impact of both attending and surgical resident experience on the occurrence of iAEs, a 4-step methodology was utilized: (1) Our 2007-2012 institutional American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) and administrative databases for abdominal surgeries were retrospectively matched; (2) the matched database was screened for iAEs using the International Classification

of Diseases, Ninth Revision, Clinical Modification-based Patient Safety Indicator "APL;" (3) operative reports were systematically reviewed to confirm the occurrence of iAEs, classify their severity, describe the complexity of the operation, and determine the experience level of both the resident and the attending surgeon; and finally (4) statistical analyses with univariate then logistic multivariable and bivariate regression models were constructed to assess the independent impact of experience on the rate of iAE. This study was approved by the Partners Institutional Review Board (2014P001456).

Patient Population

Using the ACS-NSQIP database, all patients 18 years or older undergoing abdominal surgery under general anesthesia in a tertiary academic center between January 2007 and October 2012 were included. The data collection for the ACS-NSQIP database has been described and repeatedly validated. Standardized data abstraction on predefined preoperative, intraoperative, and postoperative variables was performed by a trained and dedicated nurse researcher. The ACS-NSQIP database was then matched to the institutional administrative database.

Defining and Identifying iAEs

The International Classification of Diseases, Ninth Revision, Clinical Modification-based Patient Safety Indicator 15, Accidental Puncture and/or Laceration was used to screen for iAEs. It has been reported that APL has a positive predictive value between 85% and 91% for procedure-related complications, but that it is not specific for iAEs.^{11,22,23} For that reason, all operative notes flagged by APL were systematically reviewed to confirm the occurrence of an iAE. We chose to include only data prior to 2012 as the APL code changed significantly in the ICD-10 coding system.

For the purpose of the study, iAE was defined as "an injury caused by medical management rather than the underlying disease" during operative procedure. An iAE was further classified by its severity using a previously validated iAE severity classification system developed by our group (Table 1). In this classification system, a "minor" iAE (Class I, II) includes injuries that required no repair within the same procedure (Class I), or surgical repair without either organ removal or a change in the originally planned procedure (Class II). A "major" iAE (Class III-VI) includes injuries for which repair necessitated tissue and/or organ resection with completion of the originally planned procedure (Class III), significant change in and/or incompleteness of the originally planned procedure (Class IV), reoperation within 7 days of the index procedure (Class V), or intraoperative death (Class VI).

TABLE 1. Classification System of Intraoperative Adverse Events

Class	Description	Example
I	Injury requiring no surgical repair within the same procedure.	Liver traction laceration repaired with electrocautery.
II	Injury requiring surgical repair, without organ removal or a change in the originally planned procedure.	Enterotomy during lysis of adhesions that is primarily repaired.
III	Injury requiring tissue or organ removal with completion of the originally planned procedure.	Splenic injury during a left colectomy that requires a splenectomy.
IV	Injury requiring a significant change* and/or incompleion of the originally planned procedure.	Bile duct injury during cholecystectomy that requires hepaticojejunostomy.
V	Missed intraoperative injury requiring reoperation within 7 days.	Missed iatrogenic enterotomy that is identified on postoperative day 3 requiring reoperation.
VI	Intraoperative death.	Intraoperative death due to uncontrolled bleeding.

Kadfarani HM, et al. Derivation and validation of a novel severity classification for intraoperative adverse events. *J Am Coll Surg* 2014; 218: 112.

* Does not include conversion from laparoscopic to open.

Identifying Surgeon and Resident Level

For each primary operation, the attending surgeon and resident assisting in the operation were identified. The number of years that the attending surgeon had been in practice from the time they completed their fellowship or residency if a fellowship was not pursued was determined. The attending surgeon experience was categorized into quartiles: less than 6 years of experience, 6 or more years but less than 13 years of experience, 13 or more but less than 20 years of experience, and more than 20 years of experience. The resident experience level was defined according to their post graduate year (PGY), specifically as junior resident (PGY1-3), or senior resident (PGY4-5). Residents in their academic development or research time were considered junior residents as they enter this time before the PGY4 year at our residency program.

Exclusion Criteria

Cases were excluded if they were not performed by both an attending surgeon AND a resident, or if a fellow (PGY > 5) assisted in the operation instead of a junior or senior surgical resident. We chose to exclude operations that included a fellow as the numbers were relatively low in our database and included individuals from a variety of fellowships (trauma, endocrine, minimally invasive surgery, and surgical oncology).

Primary Outcome

We studied whether the surgeon's experience, the surgical resident experience, or combinations of the 2 independently correlate with the occurrence of any iAE or a major iAE.

Statistical Analysis

Categorical variables were presented as totals and percentages and continuous variable as median values and interquartile range or as mean and standard deviation if indicated. The chi-square test was used for comparison of categorical variables and Mann-Whitney *U* test, Student's *t* test, or Kruskal Wallis test was used for continuous variables.

Multivariable logistic regression models were constructed to assess the independent impact of surgeon years of experience, PGY level, or combination of surgeon and resident experience on any iAE or major iAE occurrences. Specifically, a subset univariate analysis was performed to identify preoperative and intraoperative risk factors for iAE (i.e., adjusted RVU as a surrogate for case complexity). Variables potentially associated ($p < 0.20$) with iAE in the univariate analysis were included in the initial multivariable models. Out of the

variables included, those with higher p-values in the univariate analysis were excluded to avoid overfitting the model. Statistical analysis was performed using the STATA 14.2 (Stata Corp, College Station, Texas) statistical software package. Statistical significance was set at a p-value less than 0.05.

RESULTS

Study Population

The total number of patients undergoing abdominal surgery in which an attending surgeon and a general surgery resident performed the operation was 7685. The majority of the operations performed were intestinal (49.2) followed closely by hepatobiliary (29.5%); 159 patients (2.1%) had a confirmed iAE. Of the 159 patients that had an iAE, there were 62 (39%) major and 97 (61%) minor iAEs. The iAE most often involved the small bowel (37.1%) or a major blood vessel (23.9%).

Surgical Resident Experience and the Rate of iAEs

Unadjusted comparison of the preoperative and intraoperative variables for patients operated on by either a junior resident or a senior resident is displayed in [Table 2](#). A senior resident assisted the attending surgeon in 6005 (78.1%) operations, while a junior resident assisted in 1680 (21.9%). Compared to junior residents, senior residents more often operated on patients that were older (median age 58 vs 54 years, $p < 0.001$), and more often smoked (16.2% vs 13.2%, $p = 0.003$), had disseminated cancer (8.1% vs 4.5%, $p < 0.001$), were in septic shock (2.3% vs 1.1%, $p = 0.006$) or were in acute renal failure (0.6% vs 0.2%, $p = 0.049$).

Not surprisingly, the cases performed by senior residents were significantly more complex than those performed by the junior residents (fourth quartile adjusted RVU 28.9% vs 14.8%, $p < 0.001$). Senior residents performed hepatobiliary operations more frequently than junior residents (34.7% vs 10.7%, $p < 0.001$). Additionally, senior resident cases were more likely to be open (60.3% vs 46.7%, $p < 0.001$), emergent (16.2% vs 14.1%, $p = 0.031$), and greater than 3 hours in duration (31.3% vs 21.9%, $p = 0.023$) compared to junior resident operations.

A comparison of the unadjusted rate of iAE occurrence between junior and senior resident operations is displayed in [Table 3](#). iAEs occurred at a significantly higher rate in senior resident operations compared to junior resident operations (2.3% vs 1.2%, $p = 0.004$). Furthermore, the rate of major iAE occurrence was also significantly higher for senior resident operations (1.0% vs

0.2%, $p = 0.001$). There was no significant difference in the rate of minor iAEs between groups. While 23.9% of the iAEs of senior resident involved major blood vessels, this type of injury did not occur in the junior resident operations (supplemental Fig. 1). Alternatively, small bowel injuries were the most frequent iAEs in junior resident operations compared to senior resident operations (60% vs 37.1%, $p = 0.022$). The majority of iAEs occurred during the dissection phase of the operation for both groups (senior resident operations 64.7% vs junior resident operations 60%, $p = \text{NS}$).

[Table 6](#) summarizes the multivariable analyses that were performed to identify the impact that resident experience has on the rate of iAE. After adjusting for preoperative patient characteristics, intraoperative variables, and case complexity, there was no significant difference in the rate of iAEs when senior resident performed an operation compared to junior residents.

Attending Surgeon Experience and the Rate of iAE

Unadjusted comparison of the preoperative and intraoperative variables for patients according to the level of the surgeon's experience is displayed in [Table 4](#). The patients of the attending surgeons with less than 6 years of experience (first quartile, 1,792 operations) were more likely to be younger (median age 53 vs 60, $p < 0.001$), totally functionally dependent (4.0% vs 1.0%, $p < 0.001$), ventilator dependent for >48 hours (2.62% vs 0.62%, $p < 0.001$), in septic shock (3.63% vs 0.78%, $p < 0.001$), and on dialysis (1.67% vs 0.57%, $p = 0.005$) compared to those of surgeons with more than 20 years of experience (fourth quartile, 1935 operations).

The complexity of operations performed was the highest for attending surgeons in their third quartile of experience, with a significant difference in comparison to those with the least experience (fourth quartile adjusted RVU 33.3% vs 21.8%, $p < 0.001$). The attending surgeons with the least experience were more likely to perform emergent operations (29.2% vs 7.9%, $p < 0.001$), minimally invasive operations (48.8% vs 37.4%, $p < 0.001$), and have dirty-infected wound classifications (13.6% vs 6.1%, $p < 0.001$).

A comparison of the unadjusted rate of iAE occurrence between attending surgeons by experience level is displayed in [Table 5](#). The attending surgeons in practice for less than 6 years had a significantly higher rate of iAEs compared to their most experienced colleagues (2.7% vs 1.4%, $p < 0.001$). Univariate analysis of iAE characteristics by attending experience level is displayed in supplemental Table 2.

[Table 6](#) summarizes the multivariable analyses that were performed to identify the impact that the

TABLE 2. Preoperative and Intraoperative Characteristics by Resident Level

Patient Characteristic	n (%) (Total n = 7685)	Junior Resident (n = 1680)	Senior Resident (n = 6005)	p Value
Demographics				
Female gender	4059 (52.8)	973 (57.9)	3086 (51.4)	<0.001
Race				0.597
White	6862 (89.3)	1507 (89.7)	5355 (89.2)	
African-American	259 (3.4)	52 (3.1)	207 (3.5)	
Asian	207 (2.7)	39 (2.3)	168 (2.8)	
Other/unknown	357 (4.7)	82 (4.9)	275 (4.6)	
Ethnicity				0.537
Non-Hispanic	7051 (91.8)	1546 (92.0)	5505 (91.7)	
Hispanic	588 (7.7)	122 (7.3)	466 (7.8)	
Unknown	43 (0.6)	12 (0.7)	31 (0.5)	
Age, years; median (IQR)	57 (44-69)	54 (42-66)	58 (45-69)	<0.001
>60 years	3233 (42.07)	637 (37.9)	2596 (43.2)	<0.001
Comorbidities				
ASA class				0.010
1- normal health	714 (9.3)	143 (8.5)	571 (9.5)	
2- mild comorbidity	4301 (56.0)	926 (55.1)	3375 (56.2)	
3- severe comorbidity	2404 (31.3)	570 (33.9)	1834 (30.54)	
4- life-threatening comorbidity	248 (3.2)	39 (2.3)	209 (3.5)	
5- moribund	18 (0.2)	2 (1.1)	16 (0.3)	
Smoking	1194 (15.5)	222 (13.2)	972 (16.2)	0.003
Functional status				0.021
Independent	7242 (94.2)	1588 (94.5)	5654 (94.2)	
Partially dependent	267 (3.5)	67 (4.0)	200 (3.3)	
Totally dependent	176 (2.3)	25 (1.5)	151 (2.5)	
Hypertension	3175 (41.3)	699 (41.6)	2476 (41.2)	0.783
Congestive heart failure	74 (1.0)	13 (0.8)	61 (1.0)	0.369
Ascites	90 (1.2)	25 (1.5)	65 (1.1)	0.172
Diabetes				0.32
No diabetes	6605 (86.0)	1426 (84.9)	5179 (86.2)	
Oral agents	631 (8.2)	145 (8.6)	486 (8.1)	
Insulin	449 (5.8)	109 (6.5)	340 (5.7)	
Disseminated cancer	561 (7.3)	76 (4.5)	485 (8.1)	<0.001
Open or infected wound	209 (2.7)	43 (2.6)	166 (2.8)	0.648
Long-term steroid use	313 (4.1)	98 (5.8)	215 (3.6)	<0.001
Recent weight loss	606 (7.9)	93 (5.5)	513 (8.5)	<0.001
Bleeding disorder	294 (3.8)	61 (3.6)	233 (3.9)	0.638
Transfusion >4 units	90 (1.2)	16 (1.0)	74 (1.2)	0.346
SIRS or sepsis				0.006
None	6732 (87.6)	1504 (89.5)	5228 (87.1)	
SIRS	517 (6.7)	101 (6.0)	416 (6.9)	
Sepsis	282 (3.7)	57 (3.4)	225 (3.8)	
Septic Shock	154 (2.0)	18 (1.1)	136 (2.3)	
Overweight/Obesity	2583 (34.5)	686 (41.7)	1897 (32.5)	<0.001
Ventilator dependent >48 hours	127 (1.7)	20 (1.2)	107 (1.8)	0.093
Chronic obstructive pulmonary disease	309 (4.0)	69 (4.1)	240 (4.0)	0.839
Acute renal failure	36 (0.5)	3 (0.2)	33 (0.6)	0.049
Dialysis	80 (1.0)	13 (0.8)	67 (1.1)	0.222
Intraoperative variables				
General Surgery type				<0.001
Foregut	968 (12.6)	354 (21.1)	614 (10.2)	
Hepatobiliary	2263 (29.5)	180 (10.7)	2083 (34.7)	
Intestinal	3774 (49.1)	941 (56.0)	2833 (47.2)	
Abdominal wall	680 (8.9)	205 (12.2)	475 (7.9)	
Operation complexity (RVU); mean (SD)	35.2 (24.0)	30.3 (18.6)	36.5 (25.1)	<0.001
First IQR	1855 (24.1)	448 (26.7)	1407 (23.4)	<0.001
Second IQR	1612 (21.0)	348 (20.7)	1264 (21.1)	

(continued)

TABLE 2 (CONTINUED)

Patient Characteristic	n (%) (Total n = 7685)	Junior Resident (n = 1680)	Senior Resident (n = 6005)	p Value
Third IQR	2234 (29.1)	635 (37.8)	1599 (26.6)	
Fourth IQR	1984 (25.8)	249 (14.8)	1735 (28.9)	
Emergency operation	1210 (15.7)	236 (14.1)	974 (16.2)	0.031
Wound class				0.001
Clean	908 (11.8)	244 (14.5)	664 (11.1)	
Clean-contaminated	5073 (66.0)	1092 (65.0)	3981 (66.3)	
Contaminated	1040 (14.0)	202 (12.0)	838 (14.0)	
Dirty-infected	664 (8.6)	142 (8.5)	522 (8.7)	
Adhesiolysis	1367 (17.8)	329 (19.6)	1038 (17.3)	0.029
Minimally invasive approach	3280 (42.7)	896 (53.3)	2384 (39.7)	<0.001
Operation duration ≥3 hours	2,360 (30.7)	478 (21.9)	1,882 (31.3)	0.023
Attending surgeon experience level				<0.001
First IQR	1792 (23.3)	440 (26.2)	1352 (22.5)	
Second IQR	1725 (22.5)	379 (22.5)	1346 (22.4)	
Third IQR	2233 (29.1)	188 (11.2)	2045 (34.1)	
Fourth IQR	1935 (25.2)	673 (40.1)	1262 (21.0)	

TABLE 3. Unadjusted Rate of iAE by Resident Level

	Junior Resident (n = 1680)	Senior Resident (n = 6005)	p Value
Any iAE	20 (1.2)	139 (2.3)	0.004
Major iAE	3 (0.2)	59 (1.0)	0.001
Minor iAE	17 (1.0)	80 (1.3)	0.299

experience of the attending surgeon has on the rate of iAEs. After adjusting for preoperative patient characteristics, intraoperative variables, and case complexity, surgeons with >20 years' experience were half as likely to have an iAE compared to their least experienced attending counterparts (odds ratio = 0.52; 95% confidence interval = 0.32-0.86; $p = 0.011$). The other attending surgeon experience did not statistically correlate with the risk of iAEs when adjusting for the aforementioned variables.

The Impact of the Attending Surgeon and Resident Team Experience on the Rate of iAE

Junior and senior residents worked with attending surgeons that had less than 13 years of experience at similar rates (Table 2). However, senior residents were more likely to work with third quartile experienced surgeons (34.1% vs 11.2%) and less likely to work with surgeons with >20 years' experience (21% vs 40%) compared to junior residents ($p < 0.001$).

Table 6 summarizes the multivariable analyses that were performed to identify the impact that experience of the operating team (combination of resident and attending experience) has on the rate

of iAE. After adjusting for preoperative patient characteristics, intraoperative variables, and case complexity, there was no combination of experience levels that independently impacted the rate of iAE occurrence.

DISCUSSION

iAEs have been shown to independently correlate with an increased risk of postoperative mortality, morbidity, readmissions, length of hospital stay, and hospital costs.^{4,11,22-24} In this study, we provide the first detailed analysis of the independent effect of surgical trainee and attending surgeon experience on the rate of iAEs. In summary, risk-adjusted analyses demonstrated that: (1) resident experience level does not independently impact the risk of occurrence of an iAE, (2) greater than 20 years of independent attending surgeon practice significantly decreases the risk of occurrence of an iAE, and (3) the different combinations of pairing junior or senior residents with less or more experienced surgeons does not impact the occurrence of iAEs. We humbly believe that the results of our study may have significant

TABLE 4. Preoperative and Intraoperative Characteristics by Attending Experience Level

Patient Characteristic	First IQR (n = 1792)	Second IQR (n = 1725)	Third IQR (n = 2233)	Fourth IQR (n = 1935)	p Value
Demographics					
Female gender	986 (55.0)	975 (56.5)	1137 (50.9)	962 (49.7)	< 0.001
Race					< 0.001
White	1553 (86.7)	1528 (88.5)	1999 (89.5)	1785 (92.3)	
African-American	72 (4.0)	71 (27.4)	63 (2.8)	53 (2.7)	
Asian	62 (3.46)	35 (2.03)	74 (3.31)	36 (1.86)	
Other/unknown	105 (5.86)	93 (5.39)	98 (4.39)	61 (3.15)	
Ethnicity					< 0.001
Non-Hispanic	1555 (86.77)	1575 (91.25)	2099 (94.00)	1825 (94.36)	
Hispanic	223 (12.44)	144 (8.34)	122 (5.46)	99 (5.12)	
Unknown	14 (0.78)	7 (0.41)	12 (0.54)	10 (0.52)	
Age, years; mean (SD)	53 (38-67)	54 (42-65)	59 (48-70)	60 (48-71)	< 0.001
> 60 years	649 (36.22)	598 (34.63)	1039 (46.51)	949 (49.04)	< 0.001
ASA class					< 0.001
1- normal health	252 (14.06)	185 (10.71)	148 (6.62)	129 (6.67)	
2- mild comorbidity	929 (51.84)	902 (52.23)	1314 (58.82)	1157 (59.79)	
3- severe comorbidity	500 (27.90)	579 (33.53)	706 (31.60)	621 (32.09)	
4- life-threatening comorbidity	104 (5.80)	55 (3.18)	62 (2.78)	27 (1.40)	
5- moribund	7 (0.39)	6 (0.35)	4 (0.18)	1 (0.05)	
Smoking	299 (16.69)	283 (16.39)	355 (15.89)	257 (13.28)	0.015
Functional status					< 0.001
Independent	1622 (90.51)	1628 (94.27)	2130 (95.34)	1864 (96.33)	
Partially dependent	98 (5.47)	47 (2.72)	70 (3.13)	52 (2.69)	
Totally dependent	72 (4.02)	52 (3.01)	34 (1.52)	19 (0.98)	
Hypertension	641 (35.77)	711 (41.17)	964 (43.15)	862 (44.55)	< 0.001
Congestive heart failure	24 (1.34)	20 (1.16)	20 (0.90)	10 (0.52)	0.058
Ascites	38 (2.12)	18 (1.04)	21 (0.94)	13 (0.67)	< 0.001
Diabetes					0.373
No diabetes	1547 (86.33)	1474 (85.35)	1939 (86.79)	1647 (85.12)	
Oral agents	149 (8.31)	146 (8.45)	180 (8.06)	157 (8.11)	
Insulin	96 (5.36)	107 (6.20)	115 (5.15)	131 (6.77)	
Disseminated cancer	115 (6.42)	75 (4.34)	295 (13.21)	77 (3.98)	< 0.001
Open or infected wound	75 (4.19)	44 (2.55)	58 (2.60)	33 (1.71)	< 0.001
Long-term steroid use	94 (5.25)	63 (3.65)	71 (3.18)	85 (4.39)	0.007
Recent weight loss	139 (7.76)	94 (5.44)	194 (8.68)	179 (9.25)	< 0.001
Bleeding disorder	101 (5.64)	80 (4.63)	58 (2.60)	56 (2.89)	< 0.001
Transfusion >4 units	33 (1.84)	20 (1.16)	19 (0.85)	18 (0.93)	0.019
SIRS or sepsis					< 0.001
None	1383 (77.18)	1513 (87.61)	2029 (90.82)	1809 (93.49)	
SIRS	220 (12.28)	113 (6.54)	121 (5.42)	63 (3.26)	
Sepsis	124 (6.92)	59 (3.42)	51 (2.28)	48 (2.48)	
Septic shock	65 (3.63)	42 (2.43)	33 (1.48)	15 (0.78)	
Overweight/Obesity	625 (36.27)	699 (41.86)	664 (30.40)	597 (31.16)	< 0.001

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TABLE 4 (CONTINUED)

Patient Characteristic	First IQR (n = 1792)	Second IQR (n = 1725)	Third IQR (n = 2233)	Fourth IQR (n = 1935)	p Value
Ventilator dependent >48 hours	47 (2.62)	39 (2.26)	30 (1.34)	12 (0.62)	<0.001
Chronic obstructive pulmonary disease	91 (5.08)	79 (4.57)	82 (3.67)	58 (3.00)	0.006
Acute renal failure	16 (0.89)	10 (0.58)	7 (0.31)	3 (0.16)	0.006
Dialysis	30 (1.67)	21 (1.22)	18 (0.81)	11 (0.57)	0.005
Intraoperative variables					
General surgery type					<0.001
Foregut	222 (12.39)	369 (21.37)	111 (4.97)	266 (13.75)	
Hepatobiliary	437 (24.39)	354 (20.50)	925 (41.41)	548 (28.32)	
Intestinal	986 (55.02)	803 (46.50)	1044 (46.73)	943 (48.73)	
Abdominal wall	147 (8.20)	201 (11.64)	154 (6.89)	178 (9.20)	
Operation complexity (RVU); median (SD)	27.0 (11.8-42.2)	29.4 (13.8-43.4)	35.1 (20.9-52.8)	30.1 (20.9-47.7)	<0.001
First IQR	567 (31.64)	482 (27.91)	430 (19.25)	376 (19.43)	
Second IQR	368 (20.54)	314 (18.18)	481 (21.53)	450 (23.26)	
Third IQR	466 (26.00)	581 (33.64)	578 (25.87)	610 (31.52)	
Fourth IQR	391 (21.82)	350 (20.27)	745 (33.35)	499 (25.79)	
Emergency operation	524 (29.24)	304 (17.60)	229 (10.25)	153 (7.91)	<0.001
Wound class					<0.001
Clean	188 (10.49)	245 (14.19)	215 (9.62)	262 (13.54)	
Clean-contaminated	997 (55.64)	1148 (66.47)	1611 (72.11)	1318 (68.11)	
Contaminated	363 (20.26)	175 (10.13)	264 (11.82)	238 (12.30)	
Dirty-infected	244 (13.62)	159 (9.21)	144 (6.45)	117 (6.05)	
Adhesiolysis	355 (19.81)	334 (19.34)	333 (14.91)	347 (17.93)	<0.001
Minimally invasive approach	875 (48.83)	923 (53.45)	759 (33.97)	724 (37.42)	<0.001
Operation duration \geq 3 hours	639 (35.7)	427 (24.7)	658 (29.5)	637 (32.9)	<0.001

TABLE 5. Unadjusted Rate of iAEs by Attending Surgeon Experience Level

	<6 Years (n = 1792)	6-13 Years (n = 1727)	13-20 Years (n = 2234)	>20 Years (n = 1935)	p Value
Any iAE	49 (2.7)	29 (1.7)	54 (2.4)	27 (1.4)	0.012
Major iAE	19 (1.1)	11 (0.6)	21 (0.9)	11 (0.6)	0.269
Minor iAE	30 (1.7)	18 (1.0)	33 (1.5)	16 (0.8)	0.076

implications with respect to both patient safety and quality and surgical graduate medical education.

From the patient safety and quality perspective, not surprisingly, more attending surgeon experience led to less iAEs. However, the learning curve appears to be long and protracted and the difference did not appear, at least statistically, until they had acquired more than 20 years of experience. A number of studies over the last 2 decades detailed the impact that attending surgeons' annual surgical volume, specialty training, years of independent practice, and technical skills have on postoperative patient morbidity and mortality following specific, often complex operations.^{14,25-30} For example, in a recent landmark study by Birkmeyer et al., the authors demonstrate a significant relationship between surgeon operative skills, as evaluated by observing anonymous laparoscopic videos, and postoperative outcomes.²⁷ Specifically, surgeons with the best ranked operative skills had the lowest patient postoperative morbidity and mortality rates. While this relationship is likely multifactorial, iAEs may

represent 1 critical link between experience, surgeon skill, and postoperative outcomes. Despite not directly measuring technical skills in our study, one can imagine that a veteran surgeon's experience and cumulative volume may improve both her and/or his intraoperative judgment and technique, thus leading to a decreased risk of iAEs.

From the surgical education perspective, decreasing resident autonomy across all of graduate medical education has been noted over the last few decades, and the concern for patient safety is often cited as one of the largest barriers to granting operative autonomy to surgical residents.³¹ A review of the current literature regarding patient outcomes when surgical residents are involved in an operation yields a conflicting message. While a number of studies show no differences,^{16,18,21,32,33} many that analyze the ACS-NSQIP have shown an increase in complications, most commonly, superficial surgical site infections, when surgical residents are involved.^{19,34-37} Our study results provide further insight into how the experience level of the trainee

TABLE 6. Multivariate Logistic Regression Analysis Identifying Predictors of iAEs

Independent Variables	OR	iAE 95% CI	p Value
Resident level*			
Junior resident (PGY 1, 2, and 3)	Reference	Reference	Reference
Senior resident (PGY 4 and 5)	1.626	0.981-2.696	0.060
Attending surgeon experience (IQR)*			
<6 years of experience	Reference	Reference	Reference
6-12 years of experience	0.800	0.487-1.316	0.379
13-20 years of experience	0.877	0.566-1.359	0.558
>20 years of experience	0.522	0.316-0.863	0.011
Surgeon and resident combination†			
<6 years of experience with junior resident	Reference	Reference	Reference
<6 years of experience with senior resident	1.690	0.759-3.767	0.199
6-12 years of experience with junior resident	0.375	0.077-1.814	0.223
6-12 years of experience with senior resident	1.493	0.649-3.431	0.346
13-20 years of experience with junior resident	1.082	0.275-4.256	0.910
13-20 years of experience with senior resident	1.465	0.657-3.263	0.351
>20 years of experience with junior resident	0.803	0.281-2.296	0.682
>20 years of experience with senior resident	0.788	0.332-1.873	0.590

* Backward selection and final variables included resident level, attending IQR, age > 60, ASA class, diabetes, cancer, open wound, weight loss, renal failure, surgery type, adjusted RVU, operation time, operation length, wound class, laparoscopic approach, and adhesiolysis.

† Backward selection and final variables included age > 60, ASA class, ascites, diabetes, cancer, open wound, weight loss, renal failure, surgery type, adjusted RVU, operation time, operation length, wound class, laparoscopic approach, and adhesiolysis.

impacts the risk of iAEs, which in turn correlate with increased postoperative complications.³⁸ Compared to junior residents, trainees with more experience operated on patients with a higher degree of preoperative comorbid disease and participated in operations that were more likely to be complex, emergent, and longer than 3 hours in duration. Therefore, it is not surprising that the unadjusted rate of iAEs was higher for senior residents. However, after adjusting for preoperative and intraoperative risk factors, resident experience level did not impact the rate of iAE. As importantly, our risk-adjusted analyses also revealed no independent impact of any resident and/or attending combination.

In summary, only the attending surgeon's experience mattered when we examined iAEs, irrespective of the resident level of experience. As such, the patient safety efforts should focus less on curbing resident autonomy and more on establishing formal operative support programs that facilitate culturally and logistically "calling the senior partner into the OR" before an iAE occurs in challenging surgical procedures.

Formalized coaching programs in which an experienced senior surgeon provides real-time guidance and intraoperative feedback to junior partners may also hold promise as a preventative strategy for iAE occurrence for less experienced surgeons.³⁹⁻⁴³ The Society of Gastrointestinal and Endoscopic Surgeons conducted a multi-institutional study in which they used tele-monitoring as a form of coaching for experts in laparoscopic sleeve gastrectomy to have a "remote presence" and provide feedback to mentees.⁴⁴ The program was feasible, successful, and highly rated by both mentees and mentors. Further, Greenberg et al. conducted multi-institutional study in which coaching was used as a means of continuous professional development for practicing surgeons to have their cases recorded and reviewed by peer-nominated surgeons.³⁹ Coaches provided feedback on technical and nontechnical intraoperative skills and the program was similarly rated highly by participants. Future studies are warranted to determine if coaching programs can help prevent iAEs.

Our study has a few limitations. First, our database is composed of a variety of abdominal surgeries and does not focus on a single type of operation. However, this may help increase the generalizability of our findings. Second, our study was not randomized and both trainees and attending surgeons inherently participated in operations that were likely appropriate for their level of experience. We performed an analysis adjusting for preoperative and intraoperative risk to account for this fact. However, despite our best efforts in constructing the multivariable models, there may still be confounders. Third, the false negative rate of the APL algorithm used to screen our linked database for intraoperative

occurrences ranges between 2% and 6%.^{23,45,46} As a result, a small subset of patients may have been misclassified as not having an iAE. Fourth, our review of operative notes is dependent on the quality of the dictated operative report, which is likely variable with respect to reporting iAEs.

CONCLUSIONS

The surgeon's level of experience, but not the resident's, is associated with the occurrence of iAEs in abdominal surgery. Efforts to improve patient safety in surgery should explore the value of pairing junior surgeons with the more experienced ones thru formalized coaching programs, rather than focus on curbing resident operative autonomy.

DISCLOSURE

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SUPPLEMENTARY INFORMATION

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