Understanding the Clinical Implications of Resident Involvement in Uncommon Operations

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OBJECTIVE: The objective of this study was to examine uncommon operations in greater detail given that the outcomes of uncommon operations are largely understudied. This study examines the incidence of postoperative events and the role of the resident following uncommon operations.

DESIGN: We identified uncommon general surgical operations using the ACS National Surgical Quality Improvement Program Participant Use file (2008-2011). Death or serious morbidity (DSM) within 30 days of the operation was the primary outcome of interest. Failure to rescue (FTR) and prolonged operative time (PRopt) were evaluated as secondary outcome measures. PRopt was defined as ≥90 percentile of operative time for each procedure type. Independent multivariate logistic regression models were generated to examine the impact of these descriptors on the outcomes of interest.

SETTING/PARTICIPANTS: The dataset utilized was the United States National Surgical Quality Improvement Program Participant Use File which leverages data points from over 700 hospitals that range from primary to quaternary care centers. Resident participation was defined as resident involved (RI) or no resident involved (NRI), and stratified by postgraduate year (PGY): 1-3, 4-5, and 6+.

RESULTS: Resident participant data was available for 21,453 (84.5%) uncommon operations with NRI in 25.4% (5447). With regard to resident participation, PGY1-3 were found in 12.6% (2699), PGY4-5 in 50.4% (10,817), and PGY6+ in 11.6% (2490). The overall observed DSM rate was 28.6% and the observed FTR rate was 5.8%. Overall, there was no difference in DSM by RI status (NRI: 1528; 28.1% vs RI: 4602; 28.8%; $p = 0.324$); however, PGY level was associated with DSM (PGY1-3: 774, 28.7%, PGY4-5: 3210, 29.7%, PGY6+: 618, 24.8%; $p < 0.001$). Any RI was associated with a lower rate of FTR (5.1%) when compared to NRI (8.3%, $p < 0.001$) with decreasing FTR events by increasing PGY (PGY1-3: 6.4%, PGY4-5: 5.2%, PGY6+: 3.3%; $p < 0.001$). After adjustment for patient risk factors, any RI remained associated with a lower likelihood of FTR than NRI (odds ratio: 0.65, 95% confidence interval: 0.49-0.87) while only the PGY4-5 and PGY6+ groups were associated with lower likelihood of FTR in comparison to NRI. RI was associated with PRopt in univariate and multivariable analyses.

CONCLUSIONS: Uncommon operations were associated with substantial DSM. The involvement of PGY4-5 residents was associated with the greatest likelihood of DSM. With increasing PGY of the involved resident, cases with PGY > 5 demonstrated a lower likelihood of risk-adjusted FTR. The explanation for these findings is not clear; however, the involvement of more senior residents in the technical aspects of uncommon operations may lead to improved results. (J Surg Ed 76:1319−1328.

KEY WORDS: uncommon operations, uncommon surgical procedures, resident involvement, patient safety, resident education, surgical education

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

INTRODUCTION

Unlike common operations, uncommon operations have longer learning curves because they occur infrequently.[1] Moreover, because these operations are few in number, multicenter studies have rarely been conducted and the

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outcomes of these operations remain largely understudied.[2] These operations occur in a variety of settings by specialists and nonspecialists. For example, in large, academic centers, total abdominal colectomies are often performed by colorectal surgeons or general surgeons, whereas, in the rural setting, general surgeons perform these operations almost exclusively.[3,4] As a result, adequate preparation for general surgeons in these rare operations is imperative to properly care for the United States population.

Previous research has indicated that there is a significant gap between what general surgery residency program directors believe residents should be competent to perform at the end of their training and the actual operative experience in those operations during their residency training.[5,6] For example, graduating residents only performed 15% of the operations classified as those that they should be proficient in performing independently over the course of their entire residency training. Furthermore, for >50% of these operations, the mode experience was zero.[2] Additionally, while the annual operative volume of graduating surgical residents has increased, the number of uncommon operations performed in 1 year of residency training ranged from 0 to 4.[1]A survey of general surgery fellowship program directors assessing graduate trainees readiness of entering surgical subspeciality fellowships in North America revealed that 21% of program directors felt that new fellows arrived unprepared for the operating room, and 66% were deemed unable to operate for 30 unsupervised minutes of a major procedure. Additionally, 28% of fellows were unfamiliar with therapeutic options and 24% were unable to recognize the early signs of complications.[6] This research highlights serious issues for medical educators as a main objective of residency training is to prepare surgical residents to enter practice with well-developed skills and adequate exposure to a diverse set of operations.

To address these concerns, the Surgical Council on Resident Education curriculum outline was developed and disseminated to general surgery program directors. The curriculum defines a group of operations as "essential" operations that residents should have a great understanding of prior to entering clinical practice. Essential operations were subsequently classified as common vs uncommon. By highlighting less observed, uncommon operations, the classification may facilitate program directors' enhancement of resident exposure to specific cases that would ensure trainee competency.[7] Here, we aim to further evidence that uncommon operations are a category of operations with a significant discrepancy between training expectations and actual operative experience, and hence, expose a large population of patients to substantial risk.[8,9]

Because only limited research exists on uncommon operations in the context of resident education, this study sought to define the outcomes of uncommon operations and evaluate the level of resident participation with particular attention to residents' postgraduate year (PGY) levels. We hypothesized that these operations would be associated with fewer failure to thrive (FTR) events with increasing PGY, decreasing prolonged operative time (PRopt) with increasing PGY, and fewer death or serious morbidity (DSM) events with increasing PGY.

METHODS

In this retrospective study, we identified uncommon general surgical operations using the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) Participant Use File from 2008 to 2011.[10] The PUF was obtained from the ACS NSQIP website. The ACS NSQIP is a national database with data entered by trained clinical reviewers and its reliability has been described by numerous sources.[11-13] The PUF is a Health Insurance Portability and Accountability Act compliant data file and contains patient-level, aggregate data that does not identify hospitals, health care providers, or patients.[14] PUF data includes 240 variables such as preoperative risk factors, intraoperative variables, and 30-day postoperative mortality and morbidity outcomes for patients undergoing major surgical operations.

We identified all patients age 18 years and older using Current Procedural Terminology (CPT) codes for the following uncommon inpatient operations: gallbladder anastomoses (47760, 47765, 44780, 47785), distal pancreatectomies (48140, 48145, 48146), open antireflux operations (43324, 43325, 43326), gastrectomies not indicated for weight loss (43620, 43621, 43622, 43631, 43632, 43633, 43634), truncal vagotomies (43640, 43641, 43855, 43865), repair of ulcer/duodenal perforations (43501, 43840, 44602, 44603), laparoscopic enterectomies (44202, 44203), and total colectomies (44150, 44151, 44155, 44156, 44210, 44211, 44212). These surgical operations were selected using the 2013 to 2014 classification system used in surgical education and defined by the Surgical Council on Resident Education.[7]

Patient characteristics included in analyses were: age, gender, race (Caucasian, black or African American, Asian, and other), American Society of Anesthesiologists Physical Status class (ASA), body mass index (BMI), and inpatient vs outpatient. We categorized ASA class according to the 2014 ASA Physical Status classification system: class I (normal and healthy), class II (mild systemic disease), class III (severe systemic disease), class IV (severe systemic disease that is a constant threat to life), class V (moribund), and class VI (declared brain

dead with organs being removed for donor purposes).[15] We categorized BMI (kg/m2) using the National Institutes of Health classification system: underweight (<18.5), normal (18.5-24.9), overweight (25.0-29.9), and obese (>30). Medical comorbidities observed included diabetes mellitus with oral agents or insulin, dyspnea, ventilator dependence, current pneumonia, history of severe COPD, congestive heart failure 30 days prior to surgery, history of myocardial infarction, history of angina, history of peripheral vascular disease, history of transient ischemic attack, history of central nervous system tumor, ascites, esophageal varices, recent administration of radiotherapy, recent administration of chemotherapy, current steroid use, weight loss of >10% body weight in last 6 months, current dialysis treatment, previous percutaneous coronary intervention, previous cardiac surgery, hypertension requiring medication, open wound or wound infection, current rest pain or gangrene, impaired sensorium, hemiplegia, paraplegia, quadriplegia, presence of disseminated cancer, presence of bleeding disorders, recent blood transfusion, and prior operation within 30 days.

Perioperative variables analyzed were resident involvement in the case and resident PGY. Resident participation was defined as resident involved (RI) or no resident involved (NRI), and stratified by PGY: 1-3, 4-5, and 6+.

DSM within 30 days of the operation was the primary outcome of interest. Serious morbidity included organ space surgical site infection, wound dehiscence, pulmonary embolism, failure to wean from ventilator, acute rental failure, stroke or cerebrovascular accident, coma, cardiac arrest, myocardial infarction, postoperative bleed, sepsis, and septic shock.[16] FTR and PRopt were secondary outcome measures. FTR was recorded as a binary variable defined by inpatient mortality of patients who experienced any postoperative complication. PRopt was defined by procedure type as ≥90 percentile of operative time. Specific postoperative complications were examined and further categorized as either surgical or medical postoperative complications. Surgical complications included superficial surgical site infection, deep incisional surgical site infection, organ space surgical site infection, wound dehiscence, bleeding requiring transfusion, graft/prosthesis/flap failure, unplanned reintubation, failure to wean from ventilation, and peripheral nerve injury. Medical complications included pneumonia, pulmonary embolism, progressive renal insufficiency, acute renal failure, urinary tract infection, cerebrovascular accident, cardiac arrest, myocardial infarction, deep vein thrombosis/thrombophlebitis, sepsis, and septic shock.

We used descriptive statistics to characterize uncommon surgery patients and compare patients based on procedure type and resident involvement. Patient demographics, NSQIP preoperative characteristics, operative characteristics, and postoperative outcomes were described and compared. Multivariable logistic regression models were created for each outcome of interest to examine the association between any RI or PGY and outcomes using independent models. A p value <0.05 was considered statistically significant. Data was transferred into STATA format using Stat/Transfer Version 11.0 statistical program (Circle Systems Inc, Seattle, Washington) and analysis was performed using STATA 12.0/IC statistical software (STATA Corp, College Station, Texas).[17-19] This study was reviewed and approved by the University of Pennsylvania Institutional Review Board.

RESULTS

The subset of uncommon procedures constituted 2.8% (n = 25,183) of all surgical procedures in the NSQIP dataset between 2008 and 2011. Resident participant data was available for 21,453 (85.2%) operations. A resident participated in 74.6% (n = 16,096) operations [PGY1-3:12.6% (n = 2699); PGY4-5 50.4% (n = 10,817); PGY6+ 11.6% (n = 2490)]. Among the patients that met criteria for inclusion, the most prevalent uncommon procedures included total colectomy (n = 5875, 27.4%), gastrectomy (n = 4414, 20.6%), and ulcer repair (n = 3778, 17.6%). NRI was most common for gastric or truncal vagotomies (n = 85, 45.5%), laparoscopic enterectomies (n = 444, 34.2%, and open antireflux procedures (n = 261, 32.4%). For every uncommon operation examined, the PGY4-5 group was most commonly involved in the operations except for truncal vagotomy and laparoscopic enterectomy for which NRI were most common. See Table 1 for further information on the distribution of procedure type and level of resident involvement.

Within the cohort, the median age was 60 years (interquartile range 48-72), 53% were female, 77% were Caucasian, and 99% were inpatient. Patients undergoing uncommon operations were more frequently ASA class 3 or higher (63.8 versus 36.2%) and normal weight (35.3 versus 5.2% underweight, 30.2% overweight, and 29.3% obese). Female gender and Caucasian race were significantly associated with no resident involvement, whereas male patients and Black, Asian, or other races were significant associated with any resident involvement. When patient characteristics were further organized by PGY level, gender, race, ASA class, and inpatient vs outpatient status were significantly associated with stratification by PGY level. For example, patients undergoing procedures with no resident involvement were more likely to be female, Caucasian, ASA class 3 or greater, and inpatient status. BMI was not significantly associated with resident involvement or stratification by PGY level. See Tables 2a

TABLE 1. Uncommon Procedures by Resident Involvement

EU Procedure	Total	NRI	PGY1-3	PGY4-5	PGY6+
Overall = n (%)	**21453**	**5447 (25.4)**	**2699 (12.6)**	**10817 (50.4)**	**2490 (11.6)**
Total colectomy	5875 (27.4)	1400 (25.7)	825 (30.6)	2653 (45.2)	997 (17.0)
Gastrectomy	4414 (20.6)	1159 (26.3)	418 (9.5)	2468 (55.9)	369 (8.4)
Ulcer	3778 (17.6)	1201 (31.8)	643 (17.0)	1743 (46.1)	191 (5.1)
Distal pancreatectomy	3481 (16.2)	633 (18.2)	307 (8.8)	2154 (61.9)	387 (11.2)
Gallbladder anast	1614 (7.5)	264 (16.4)	165 (10.2)	907 (56.2)	278 (17.2)
Lap enterectomy	1299 (6.1)	444 (34.2)	211 (16.2)	51 (3.9)	131 (10.1)
Open antireflux	805 (3.8)	261 (32.4)	115 (14.3)	298 (37.0)	131 (16.3)
Gastric/truncal vag	187 (0.9)	85 (45.5)	15 (8.0)	81 (43.3)	6 (3.2)

TABLE 2A. Patient Characteristics by Resident Involvement

	Overall = n (%)	NRI = n (%)	RI = n (%)	p Value
Total #	21453	5447 (25.4)	16006 (74.6)	
Gender				
Female	11,435 (53.4)	2992 (55.1)	8443 (52.9)	0.005*
Male	9962 (46.6)	2439 (44.9)	7523 (47.1)	0.005*
Race				
White	16,276 (77.2)	4315 (79.9)	11,961 (76.3)	< 0.001*
Black	2269 (10.8)	465 (8.6)	1804 (11.5)	< 0.001*
Asian	705 (3.3)	168 (3.1)	537 (3.4)	< 0.001*
Other	1825 (8.7)	454 (8.4)	1371 (8.7)	< 0.001*
ASA class				
Class 1, 2	7745 (36.2)	1892 (34.8)	5853 (36.6)	0.015
Class 3, 4, 5	13,677 (63.8)	3457 (65.2)	10,130 (63.4)	0.015
In vs outpatient				
Inpatient	21,231 (99.0)	5375 (98.7)	15,856 (99.1)	0.015
Outpatient	222 (1.0)	72 (1.3)	150 (0.9)	0.015

BMI was not significantly associated with resident involvement or stratification by PGY level.
* Significant if less than 0.05.

TABLE 2B. Patient Characteristics by PGY Level

	Overall = n (%)	NRI = n (%)	PGY1-3 = n (%)	PGY4-5 = n (%)	PGY6+ = n (%)	p Value
Total #	21,453	5447 (25.4)	2699 (12.6)	10,817 (50.4)	2490 (11.6)	
Gender						
Female	11,435 (53.4)	2992 (55.1)	1399 (52.1)	5728 (53.1)	1316 (52.9)	0.03*
Male	9962 (46.6)	2439 (44.9)	1287 (47.9)	5065 (46.9)	1171 (47.1)	0.03*
Race						
White	16,276 (77.2)	4315 (79.9)	2000 (76.7)	8021 (75.4)	1940 (79.7)	<0.001*
Black	2269 (10.8)	465 (8.6)	298 (11.4)	1293 (12.2)	213 (8.8)	<0.001*
Asian	705 (3.3)	168 (3.1)	87 (3.3)	386 (3.6)	64 (2.6)	<0.001*
Other	1825 (8.7)	454 (8.4)	224 (8.6)	931 (8.8)	216 (8.9)	<0.001*
ASA Class						
Class 1, 2	7745 (36.2)	1892 (34.8)	1007 (37.4)	3832 (35.5)	1014 (40.8)	<0.001*
Class 3, 4, 5	13,677 (63.8)	3457 (65.2)	1689 (62.6)	6969 (64.5)	1472 (59.2)	<0.001*
In vs Outpatient						
Inpatient	21,231 (99.0)	5375 (98.7)	2658 (98.5)	10,736 (99.3)	2462 (98.9)	<0.001*
Outpatient	222 (1.0)	72 (1.3)	41 (1.5)	81 (0.7)	28 (1.1)	<0.001*

BMI was not significantly associated with resident involvement or stratification by PGY level.
* Significant if less than 0.05.

and 2b for additional information on patient characteristics by resident involvement and stratification by PGY level.

The overall complication rate was 36% (n = 7702), the medical complication rate was 24% (n = 5189) and the surgical complication rate was 23% (n = 4826). On univariate and multivariate analysis, any resident involvement was associated with an increased likelihood of any postoperative complication (n = 5811, 36.6%) and a surgical complication (n = 3702, 23.1%), but not a medical complication. However, when stratified by PGY levels, a univariate analysis demonstrated that the PGY1-3 and PGY4-5 groups were associated with an increased likelihood of any postoperative complication and medical complications, whereas the PGY6+ group was associated with a decreased likelihood of any postoperative complication and medical complications. All PGY groups were associated with an increased likelihood of a surgical complication (Table 3b). In the risk-adjusted multivariable analysis of complications by PGY level, the statistically significant results included the PGY4-5 group associated with an increased risk of any postoperative complication, a medical complication, or a surgical complication in addition to the PGY6+ group associated with an increased risk of a surgical complication but a decreased risk of a medical complication (Table 4b).

The most common postoperative complications included bleeding requiring transfusion (n = 3074, 12.1%), failure to wean from ventilation (n = 2477, 9.8%), sepsis (n = 1796, 7.1%), organ space infection (n = 1688, 6.7%), and superficial wound infection (n = 1567, 6.2%). Additional information regarding overall postoperative complication rates for uncommon operations can be seen in Table 5. Bleeding requiring transfusion was the most common postoperative complication for NRI (9.8%), whereas failure to wean from ventilation was the most common postoperative complication for PGY1-3 (10.8%), and PGY4-5 (10.6%). Bleeding requiring transfusion (9.1%), deep incisional surgical site infection (8.9%), superficial wound infection (8.4%), and sepsis (8.4%) were the most common complications observed for PGY6+.

The observed DSM rate was 28.6% and the observed FTR rate was 5.8%. Overall, there was no difference in DSM by RI status on univariate (NRI: 1,528; 28.1% versus RI: 4,602; 28.8%; p = 0.324) and multivariate analyses; however, the PGY level was associated with DSM (Tables 3b and 4b). Specifically, the PGY4-5 group was associated with an increased risk of DSM on multivariate analysis (Table 4b) in comparison to NRI. Any RI was associated with a lower rate of FTR (5.1%) when compared to NRI (8.3%, p < 0.001) with decreasing FTR events by increasing PGY (See Table 3b). After adjustment for patient risk factors, any RI remained associated with a lower likelihood of FTR than NRI (odds ratio: 0.65, 95% confidence interval: 0.49-0.87). Additionally, for the PGY4-5 and PGY6+ cohorts, there was a decreased likelihood of FTR in comparison to the reference group, NRI. (See Table 4b) Both RI and each PGY level were associated with PRopt in comparison to the NRI reference group in the analyses (See Tables 3a, 3b, 4a, 4b).

DISCUSSION

This study used a multi-institutional database to analyze preoperative, perioperative, and postoperative characteristics associated with uncommon operations by PGY level. Given, the overall number of general surgery operations registered in the ACS NSQIP (2008-2011), the number of uncommon operations performed represented 2.8%. We found that uncommon operations are associated with high rates of postoperative complications, death or serious morbidity, failure to rescue, and prolonged operative time. Moreover, the incidence of the most common postoperative complications including bleeding requiring transfusion, failure to wean from ventilation, sepsis, organ space infection, and superficial wound infection are consistent with previous studies.[20,21] The rates of

TABLE 3A. Univariate Analysis of Postoperative Outcomes of Uncommon Operations by Resident Involvement

	Overall = n (%)	NRI = n (%)	RI = n (%)	p Value
Total #	21,453	5447 (25.4)	16,006 (74.6)	
Factor				
Death & serious morbidity (DSM)	6130 (28.6)	1528 (28.1)	4602 (28.8)	0.32
Any postoperative complication	7702 (35.9)	1891 (34.7)	5811 (36.3)	0.035*
Medical complication	5189 (24.1)	1307 (24.0)	3882 (24.3)	0.7
Surgical complication	4826 (22.5)	1124 (20.6)	3702 (23.1)	<0.001*
Failure to rescue (FTR)	252 (5.8)	79 (8.3)	173 (5.1)	<0.001*
Prolonged operative time (PRopt)	2141 (10.0)	368 (6.8)	1773 (11.1)	<0.001*

*Significant if less than 0.05.

3B. Univariate Analysis of Postoperative Outcomes of Uncommon Operations by PGY Level

	Overall = n (%)	NRI = n (%)	PGY1-3 = n (%)	PGY4-5 = n (%)	PGY6+ = n (%)	p Value
Total #	21,453	5447 (25.4)	2699 (12.6)	10,817 (50.4)	2490 (11.6)	
Factor						
DSM	6130 (28.6)	1528 (28.1)	774 (28.7)	3210 (29.7)	618 (24.8)	<0.001*
Any postop complication	7702 (35.9)	1891 (34.7)	959 (35.5)	4028 (37.2)	824 (33.1)	<0.001*
Medical complication	5189 (24.1)	1307 (24.0)	669 (24.8)	2735 (25.3)	478 (19.2)	<0.001*
Surgical complication	4826 (22.5)	1124 (20.6)	574 (21.3)	2530 (23.4)	598 (24.0)	<0.001*
FTR	252 (5.8)	79 (8.3)	30 (6.4)	123 (5.2)	20 (3.3)	<0.001*
PRopt	2141 (10.0)	368 (6.8)	299 (11.1)	1164 (10.8)	310 (12.4)	<0.001*

TABLE 4A. Risk-Adjusted Postoperative Outcomes of Uncommon Operations by Resident Involvement, Bold Highlights Statistical Significance

	All operations	NRI	RI
DSM, n (%)	6130 (28.6)	1528 (28.1)	4602 (28.8)
Adjusted DSM, OR (95% CI)		Ref	1.06 (0.99-1.15)
Any post-operative complication, n (%)*	9452 (37.2)	1891 (34.7)	5811 (36.6)
Adjusted post-operative complication, OR (95% CI)		Ref	**1.09 (1.02-1.17)**
Any medical complication, n (%)	6190 (24.4)	1307 (23.4)	3882 (24.3)
Adjusted medical complication, OR (95% CI)		Ref	1.04 (0.97-1.13)
Any surgical complication, n (%)	6215 (24.5)	1124 (20.6)	3702 (23.1)
Adjusted surgical complication, OR (95% CI)		Ref	**1.14 (1.05-1.23)**
FTR, n (%)	252 (5.8)	79 (8.3)	173 (5.1)
Adjusted FTR, OR (95% CI)		Ref	**0.65 (0.49-0.87)**
PRopt (min), n (%)	2141 (10.0)	368 (6.8)	1773 (11.1)
Adjusted PRopt, OR (95% CI)		Ref	**1.73 (1.54-1.95)**

CI, confidence interval; OR, odds ratio.

*Significant if less than 0.05.

*Model included adjustment for diabetes, history of angina, history of transient ischemic attack, history of central nervous system tumor, esophageal varices, recent chemotherapy, previous cardiac surgery, presence of open wound or infection, rest pain/gangrene, paraplegia, quadriplegia, recent blood transfusion, and uncommon procedure type (total colectomy, gastrectomy, ulcer, distal pancreatectomy, gallbladder anastomosis, laparoscopic enterectomy, open antireflux procedure, gastric/truncal vagotomy).

complications were consistent regardless of the nature of the event (i.e., medical or surgical).

In the overall cohort of patients undergoing uncommon procedures, RI was associated with a decreased risk of FTR and an increased operative time; however, RI was not associated with an increased risk of DSM. Our findings are consistent with previous studies examining RI and outcomes for common and complex procedures.[22-26] These findings build upon previous studies. Furthermore, our results demonstrated that RI in uncommon procedures is associated with a higher likelihood surgical complications but not medical complications which are consistent with the literature on common surgical procedures.[24]

RI was significantly associated with prolonged operative time across all PGY groups. Based on findings of previous studies that have demonstrated increased operative time with RI in common and complex operations, this may simply reflect the cost of training.[22,25] Alternatively, in our cohort, the longer length of operative time may include the time it takes the surgical team to complete an operation that is less familiar.

Previous studies focused on common surgical procedures have demonstrated that resident participation was associated with surgical complications; however, increasing PGY is inversely related to the risk of surgical complications22—this is in contrast to our findings that demonstrated that patients undergoing uncommon procedures are more likely to have a surgical complication with increasing PGY. This finding may be explained by the inference that residents in their later years of residency training may be permitted greater operative independence in comparison to the PGY1-3 subset; however, the PGY4-5 and 6+ residents may not have the

TABLE 4B. Risk-Adjusted Postoperative Outcomes of Uncommon Operations by PGY Level, Bold Highlights Statistical Significance

	All Operations	NRI	PGY1-3	PGY4-5	PGY6+
DSM, n (%)	6130 (28.6)	1528 (28.1)	774 (28.7)	3210 (29.7)	618 (24.8)
Adjusted DSM, OR (95% CI)		Ref	0.99 (0.89 to 1.11)	**1.13 (1.04 to 1.22)**	**0.88 (0.79 to 0.99)**
Any post-operative complication, n (%)*	9452 (37.2)	1891 (34.7)	959 (35.5)	4028 (37.2)	824 (33.1)
Adjusted postoperative complication, OR (95% CI)		Ref	1.01 (0.91 to 1.11)	**1.15 (1.07 to 1.23)**	0.95 (0.85 to 1.05)
Any medical complication, n (%)	6190 (24.4)	1307 (23.4)	669 (24.8)	2735 (25.3)	478 (19.2)
Adjusted medical complication, OR (95% CI)		Ref	1.01 (0.90 to 1.13)	**1.12 (1.03 to 1.21)**	**0.78 (0.69 to 0.89)**
Any surgical complication, n (%)	6215 (24.5)	1124 (20.6)	574 (21.3)	2530 (23.4)	598 (24.0)
Adjusted surgical complication, OR (95% CI)		Ref	1.02 (0.91 to 1.16)	**1.16 (1.07 to 1.26)**	**1.19 (1.06 to 1.33)**
FTR, n (%)	252 (5.8)	79 (8.3)	30 (6.4)	123 (5.2)	20 (3.3)
Adjusted FTR, OR (95% CI)		Ref	0.84 (0.54 to 1.32)	**0.66 (0.49 to 0.90)**	**0.46 (0.28 to 0.77)**
PRopt (min), n (%)	2141 (10.0)	368 (6.8)	299 (11.1)	1164 (10.8)	310 (12.4)
Adjusted PRopt, OR (95% CI)		Ref	**1.73 (1.47 to 2.03)**	**1.67 (1.48 to 1.90)**	**2.01 (1.71 to 2.36)**

CI, confidence interval; OR, odds ratio.

*Significant if less than 0.05.

*Model included adjustment for diabetes, history of angina, history of transient ischemic attack, history of central nervous system tumor, esophageal varices, recent chemotherapy, previous cardiac surgery, presence of open wound or infection, rest pain/gangrene, paraplegia, quadriplegia, recent blood transfusion and uncommon procedure type (total colectomy, gastrectomy, ulcer, distal pancreatectomy, gallbladder anastomosis, laparoscopic enterectomy, open antireflux procedure, gastric/truncal vagotomy).

technical mastery of surgical attendings that is required to perform uncommon procedures. Alternatively, the overall lack of experience with uncommon operations may result in senior resident involvement when the cases are more challenging and therefore, observed findings may be due to unmeasured severity of illness.

This study represents the first of its size reviewing complications with respect to resident participation and PGY status in uncommon operations within the nationwide ACS-NSQIP dataset. Given the increased DSM associated with PGY4-5 and surgical complications associated with both PGY4-5 and PGY 6+, it is important to turn attention to educational measures that can more adequately prepare residents for entry into clinical practice especially in the setting of the constant evolution of training programs that may limit residents' direct exposure to cases and training via the traditional Halsted and Osler approach.[27,28]

One such educational measure that has been documented as successful when used in conjunction with traditional surgical training is the use of simulation-based mastery learning (SBML).[29,30] Although the cost of surgical simulation implementation is large, there is consistent evidence demonstrating positive and clinically significant downstream effects of SBML on patient outcomes. The SBML model allows for the reproduction of operative conditions with adequate time spent allowing surgical trainees to reach a high level of technical mastery that can later be translated into direct operative skills. These skills include but are not limited to an increase in trainees' overall dexterity, an understanding of the steps of an unfamiliar procedure, and an ability to interpret anatomical variations. Furthermore, simulation centers allow for the concurrent assessment of residents with prompt results that can provide them with constructive feedback that guide them to the appropriate level of clinical mastery.[31-33] Additionally, previous research by Bridges and Diamond calculated that the current additional time associated with resident involvement in surgical cases is $50,000 per resident over 4 years, and thus the time invested in concurrent resident surgical simulation centers could lead to decreased operative times.[34] Therefore, increased attention toward and implementation of surgical simulation training could serve multiple yet intertwined purposes that include increasing patient

TABLE 5. Overall Postoperative Complication Rate by Resident Involvement and PGY Level

	Overall = n (%)	NRI = n (%)	PGY1-3 = n (%)	PGY4-5 = n (%)	PGY6+ = n (%)	p Value
Total # Complication	21,453	5447 (25.4)	2699 (12.6)	10,817 (50.4)	2490 (11.6)	
Superficial wound infection	1567 (6.2)	255 (4.7)	176 (6.5)	694 (6.4)	208 (8.4)	<0.001*
Deep incisional surgical site infection	408 (1.6)	105 (1.9)	41 (1.5)	163 (1.5)	30 (8.9)	0.07
Organ space infection	1688 (6.7)	299 (5.5)	156 (5.7)	741 (6.9)	174 (7.0)	0.002*
Wound dehiscence	428 (1.7)	105 (1.9)	41 (1.5)	192 (1.8)	34 (1.4)	0.26
Pneumonia	1456 (5.7)	356 (6.5)	157 (5.8)	630 (5.8)	74 (3.0)	<0.001*
Unplanned reintubation	1195 (4.7)	246 (4.5)	138 (5.1)	576 (5.3)	235 (3.7)	<0.001*
Pulmonary embolus	285 (1.1)	43 (0.8)	37 (1.4)	133 (1.2)	26 (1.0)	0.04*
Failure to wean from ventilation	2477 (9.8)	521 (9.6)	291 (10.8)	1148 (10.6)	134 (5.4)	<0.001*
Renal insufficiency	257 (1.0)	58 (1.1)	33 (1.2)	112 (1.0)	14 (0.6)	0.09
Acute renal failure	408 (1.6)	100 (1.8)	42 (1.6)	167 (1.5)	18 (0.7)	0.003*
UTI	1112 (4.4)	193 (3.5)	116 (4.3)	529 (4.9)	100 (4.0)	0.001*
Cerebrovascular accident	115 (0.5)	21 (0.4)	13 (0.5)	51 (0.5)	7 (0.3)	0.54
Coma < 24 hrs	51 (0.2)	13 (0.2)	9 (0.3)	23 (0.2)	6 (0.2)	0.7
Peripheral nerve injury	13 (0.1)	4 (0.1)	3 (0.1)	4 (0.04)	2 (0.08)	0.5
Cardiac arrest	370 (1.5)	79 (1.5)	50 (1.9)	156 (1.4)	24 (1.0)	0.06
Myocardial infarction	450 (1.0)	56 (1.0)	32 (1.2)	99 (0.9)	13 (0.5)	0.07
Bleeding requiring transfusion	3074 (12.1)	531 (9.8)	255 (9.5)	1119 (10.3)	227 (9.1)	0.2
Graft/prosthesis / flap	8 (0.03)	2 (0.04)	0 (0.00)	6 (0.06)	0 (0.00)	0.4
DVT/thrombophlebitis	628 (2.5)	111 (2.0)	71 (2.6)	268 (2.5)	52 (2.1)	0.2
Sepsis	1796 (7.1)	310 (5.7)	176 (6.5)	811 (7.5)	208 (8.4)	<0.001*
Septic shock	1072 (4.2)	279 (5.1)	125 (4.6)	452 (4.2)	62 (2.5)	<0.001*

* Significant if less than 0.05.

safety, increasing resident exposure to uncommon operations, and decreasing operative time.

LIMITATIONS

There are a number of limitations associated with the ACS NSQIP data for this analysis that are worth noting. The database does not capture complications and mortality beyond 30 days and thus could not be incorporated in evaluating the primary outcome of interest, DSM. Additionally, the hospitals that participate in NSQIP do so electively and thus are more likely to be large academic centers that may not be representative of smaller community and rural hospitals. Furthermore, the database does not record individual attending or resident volumes which limited our ability to assess the impact that raw surgical volume has on our outcomes of interest. Future studies examining the long-term outcomes of patients undergoing uncommon operations in both large academic and small community hospitals that are stratified by surgeon-volume could better inform future training of residents involved in uncommon operations. Additionally, the Surgical Council on Resident Education criteria have been updated to eliminate the training variables associated with procedures; however, the procedures examined remain of interest given they are uncommon in nature and affect patient outcomes.

Furthermore, the stratification of residents by PGY level does not universally align with what general surgery training programs might classify as junior versus senior surgical residents. Moreover, this study assumes that residents that are in a higher PGY level will get to perform a greater portion of the technical aspects of these operations in comparison to residents in lower PGY levels; however, the data does not provide the extent of resident involvement in these uncommon operations. Further studies examining the level of supervision of residents stratified by PGY level would better inform the resident categories organized by training level.

Finally, we were not able to determine if NRI meant that the operation was performed in a nonteaching hospital or if the case was uncovered in a teaching hospital. As such, conclusions regarding differences in outcomes of the 25% of cases without resident involvement should be avoided.

CONCLUSIONS

We found that uncommon operations as a group were associated with substantial DSM, and the involvement of PGY4-5 residents was associated with the greatest likelihood of DSM. Cases with PGY4-5 and PGY6+ demonstrated a lower likelihood of risk-adjusted FTR highlighting the protective effect senior residents can have on patient outcomes. The explanation for these findings is not clear; however, the involvement of more senior residents in the technical aspects of uncommon operations and larger implementation of surgical simulation-based mastery learning may lead to improved uncommon operations' results.

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SUPPLEMENTARY INFORMATION

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