Impact of Resident Involvement in Surgery (IRIS-NSQIP): Looking at the Bigger Picture Based on the American College of Surgeons-NSQIP Database

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BACKGROUND: Surgical residency training aims to prepare the surgical resident to become an independent practitioner of surgery. Because surgical residency training remains the sole educational channel to prepare surgeons for independent practice, our study aimed to explore the effect of resident involvement in surgery across a broad spectrum of surgical specialties to answer questions patients, surgeons, and surgical residency program directors may have concerning the effect of having residents participate in performing surgical operations.

STUDY DESIGN: This analysis used the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database to establish whether patients having operations involving residents were at a risk of postoperative mortality or morbidity similar to patients having operations performed by attending surgeons alone, across a wide array of surgical procedures.

RESULTS: For operations in which residents were involved, the adjusted odds ratio (OR) for mortality was 0.93 (95% CI 0.90 to 0.97), as compared with the group of patients on whom attending surgeons operated alone without any level of resident involvement. For operations in which residents were involved, the adjusted OR for morbidity was 1.02 (95% CI 1.00 to 1.04), as compared with the group of patients on whom attending surgeons operated alone without any level of resident involvement. There was a slightly statistically significantly higher risk of cardiac and respiratory morbidities in the group with any level of resident involvement as compared with the "attending alone" group.

CONCLUSIONS: Our study confirms that, across different surgical subspecialties, resident involvement in surgery is associated with comparable morbidity and lower mortality outcomes. This provides a reassuring answer to patients, attending surgeons, and surgical program directors. (J Am Coll Surg 2016;222:30–40. © 2016 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

Surgical residency programs aim to prepare trainees to become qualified independent practitioners of surgery, meeting the level of board-certified surgeons. During surgical residency, trainees are prepared to ultimately practice independently through acquiring a suitable fund of knowledge and technical skills, learning to integrate the assimilated knowledge into the clinical setting, and developing surgical judgment without compromising excellent patient care throughout the educational process.[1] As surgical residents advance through their residency training years, they are gradually and progressively given more responsibility, with more room for independent action, whether in operating on patients, caring for patients admitted to surgical wards, or teaching and supervising junior residents and medical students.[1] Since Dr William S Halsted started the first modern surgical residency training program at Johns Hopkins Hospital in the late 19th century, the concept of gradual, progressive increase in resident responsibilities has remained one of the

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cornerstones of surgical training.[2] However, the momentous continuous advances in medicine, the recent institution of resident work-hour restrictions, the continuous changes in the medico-legal system, and the introduction of subspecialized surgical training have put substantial strains on the traditional surgical training model. The impact of all these recent changes on actual resident performance and competence are subject to intense scrutiny,[3-5] including investigations about the effect of resident participation in surgery on postoperative morbidity and mortality across different surgical specialties.[6-15] In addition, although many patients prefer to receive their care at teaching hospitals, some patients are reluctant to have residents involved in their surgical care.[16-18]

No studies have evaluated the effect of resident involvement across all surgical specialties regardless of the type of the procedure or specialty, although published research has already explored the effect of resident involvement in surgery on operative time[6,7,19] and on mortality and morbidity in specific surgical specialties.[8,11-13,20-23] Different studies reported on the effect of surgical resident involvement on a specific group or type of surgical procedures. Therefore, the literature lacks studies that look at the surgical landscape as a whole, analyzing effects of resident involvement across different specialties while adjusting for variables that affect postoperative morbidity and mortality. In order to draw conclusions that would better help guide the national status of surgical residency training and prove that the involvement of residents in surgical procedures does not negatively affect patient outcomes, an analysis of outcomes spanning all different surgical specialties was essential. Moreover, because surgical residency training remains the sole educational channel to prepare surgeons for independent practice, it is important to reliably answer the question patients, surgeons, and surgical residency program directors may have concerning the effect of having residents participate in performing surgical operations. To answer this question, we used the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database to establish whether patients having operations involving residents were at a risk of postoperative mortality or morbidity similar to that of patients having operations performed by attending surgeons alone, across a wide array of surgical procedures.

The ACS NSQIP database collects surgical outcomes data from more than 500 non-Veterans' Affairs administration hospitals—private, public, academic, and nonacademic—in the United States.[24,25] Variables included in the database include demographic characteristics, preoperative comorbidities, operative characteristics, and risk-adjusted postoperative morbidity and mortality outcomes for 30 days.

METHODS

Study design and study population

Our study is a retrospective cohort study of the prospective validated ACS NSQIP database from 2008 to 2013. The data in the ACS NSQIP database are collected by trained surgical clinical reviewers based on standard definitions. Adult patients who had undergone major surgery between 2008 and 2013 were identified from the database. Only the index case was included for patients undergoing more than 1 procedure; patients were not included more than once in the analysis. Patients undergoing minor procedures with a work relative value unit of 0, patients who underwent cardiac surgery, and patients with missing information on sex or the level of resident supervision (independent variable) were excluded. Patients who underwent cardiac surgery were excluded because they have a different risk profile. A total of 1,349,684 patients were included in the analysis.

Definitions of variables

Resident involvement in surgery was defined using the variable "highest level of resident supervision by attending surgeon." Four categories were used: attending alone, attending and resident in operating room, resident in the operating room and attending in the operating suite, and resident alone but attending available. A fifth category reflecting any level of resident involvement was created by combining categories 2, 3, and 4. The main comparison was done between categories 1 and 5.

Age was analyzed both as a continuous and as a categorical variable. For the continuous age variable, mean ages were compared among categories. For the categorical age variable, patients were divided into 2 groups, the first including patients 65 years and older and the second including patients younger than 65 years. Body mass index (BMI) was analyzed both as a continuous and as a categorical variable. For the continuous BMI variable, mean BMI was compared among categories. For the categorical BMI variable, patients were divided into 2 groups, the first including patients with BMI 30 kg/m^2 and higher and the second including patients with BMI less than 30 kg/m^2. Preoperative comorbidities were grouped by organ system: cardiorespiratory, renal, neurologic, hematologic, oncologic, and hepatobiliary. Concerning laboratory values, we analyzed the preoperative values that were the latest available in a period of 90 days preceding surgery.

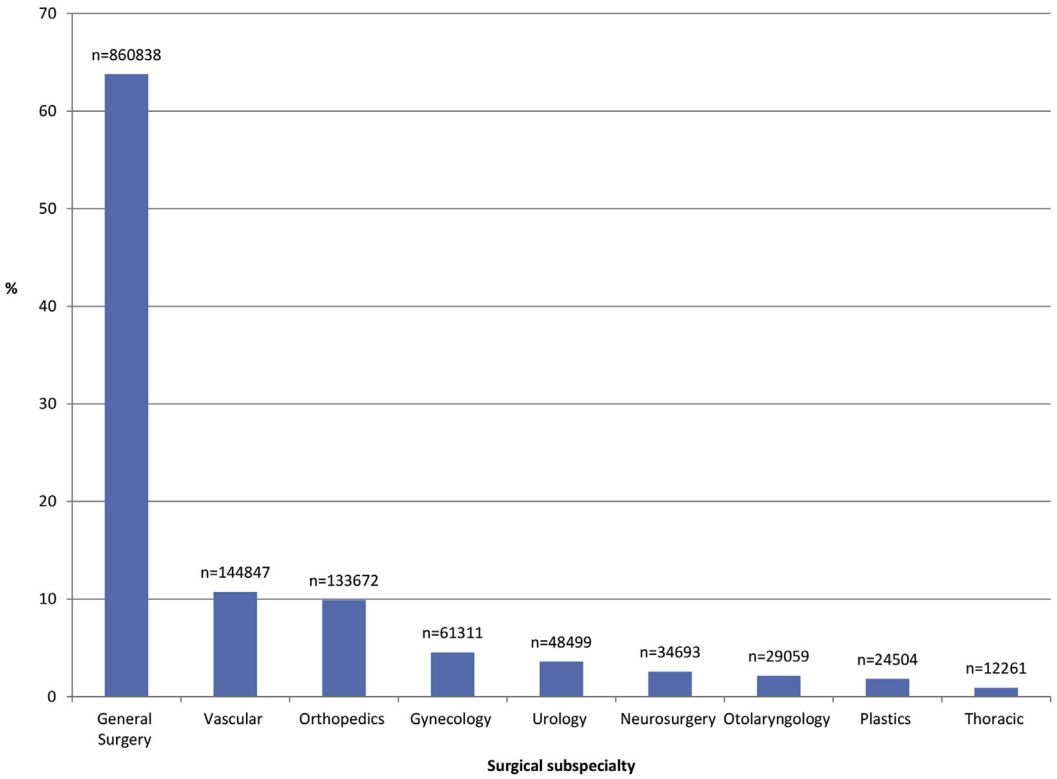

Figure 1. Distribution of patients among surgical subspecialties.

Definitions of outcomes

Postoperative outcomes were mortality and morbidity at 30 days, including cardiac events (acute myocardial infarction or cardiac arrest), respiratory events (pneumonia, need for ventilator support for more than 48 hours, or unplanned intubation), central nervous system events (stroke or coma lasting more than 24 hours), renal/urinary tract events (progressive renal insufficiency or acute renal failure), wound-related events (deep incisional surgical site infection, organ or space surgical site infection, or wound dehiscence), sepsis events (sepsis or septic shock), and venous thromboembolic events (deep venous thrombosis or pulmonary embolism). Composite morbidity was defined as the presence of 1 or more of the aforementioned major morbidities. The primary outcomes measure was mortality within 30 days of the index surgery in the group with any resident involvement compared with the "attending alone" group. The secondary outcomes measure was morbidity—composite or individual morbidity—within 30 days of the index surgery in the group with any resident involvement compared with the "attending alone" group.

Statistical analysis

Categorical variables were compared using the chi-square test among different categories. Continuous variables were compared using the independent *t* test. The "attending alone category" was set as the reference category. Separate multivariate logistic regression models for 30-day mortality, composite morbidity, and specific morbidity categories were created with adjusted odds ratios (OR_{adj}). Clinically relevant potential confounders in each separate model were considered for adjustments, as outlined in Appendix A (available online). Stepwise regression was performed with an entry level of 0.25 and a stay level of 0.15.

The association was further evaluated across strata of age, sex, surgical subspecialty, and emergency status. The interaction was assessed for both the 30-day mortality and the composite morbidity outcomes. All p values were 2-sided with level of significance <0.05. Statistical analysis was done using Statistical Analysis System (SAS).

Ethical considerations

According to the guidelines of the American University of Beirut Institutional Review Board (IRB), review and approval by the IRB was not needed for our analysis because it involves de-identified data collected as part of a quality assurance activity. The IRB at the American University of Beirut follows the US Code of Federal Regulations for the Protection of Human Subjects. This study was not funded by an external source.

Table 1. Baseline Characteristics of Patients and Respective Surgical Procedures

Variable	Attending alone (n = 597,630)	Attending and resident in OR (n = 747,350)	Attending in OR suite and resident in OR (n = 3,886)	Resident alone in OR but attending available (n = 818)	Any level of resident involvement (n = 752,054)
Demographic and general variables					
Age, y, mean (±SD)	56.31 (17.11)	55.56 (16.87)*	55.08 (17.42)*	51.87 (19.39)*	55.56 (16.87)*
Age ≥ 65 y, %	34.39	32.11*	32.12	28.12†	32.11*
Sex, female, %	58.30	56.65*	53.86*	49.27*	56.63*
Race, white, %	78.07	72.79*	73.11*	54.28*	72.77*
BMI, kg/m^2, mean (±SD)	30.19 (8.14)	29.81 (8.21)*	29.05 (7.79)*	29.46 (7.35)†	29.81 (8.21)*
BMI ≥ 30 kg/m^2, %	42.29	39.97*	36.00*	43.40	39.96*
Functional status before surgery, %					
Independent	94.97	94.08	93.90	92.18	94.08
Partially dependent	3.93	4.24*	4.40	4.89	4.24*
Dependent	1.10	1.67*	1.70†	2.93*	1.68*
Do-not-resuscitate status, %	0.73	0.53*	0.75	2.20*	0.53*
Inpatient, %	57.12	68.80*	68.84*	77.63*	68.81*
Anesthesia-related variables					
ASA class (%)					
ASA I–II	58.15	53.56	60.67	59.10	53.61
ASA III	36.22	39.42*	33.87†	32.17	39.38*
ASA IV–V	5.64	7.02*	5.46	8.73†	7.01*
Anesthesia, general	88.44	92.54*	93.85*	90.34	92.55*
Airway trauma, %	0.28	0.25‡	0.14	0.00	0.25‡
Surgical variables					
Work relative value units, mean (±SD)	15.10 (9.70)	17.15 (10.78)*	15.75 (8.98)*	13.71 (8.79)*	17.15 (10.78)*
Surgical subspecialty, %					
General	55.31	70.42	86.88	71.88	70.5
Gynecologic	5.70	3.64*	1.08*	1.22*	3.62*
Neurosurgery	3.29	2.00*	1.31*	0.98*	2*
Orthopaedics	15.29	5.64*	1.62*	12.59*	5.63*
Otolaryngology (ENT)	2.80	1.63*	1.44*	2.81	1.64*
Plastics	2.38	1.37*	1.57*	1.34†	1.37*
Thoracic	0.98	0.85*	0.33*	0.37‡	0.85*
Urology	4.70	2.72*	0.67*	1.71*	2.71*
Vascular	9.54	11.72*	5.10*	7.09*	11.68*
Emergency case, %	10.38	12.96*	18.27*	42.18*	13.02*
Total operative time, min, mean (±SD)	87.76 (72.96)	125.45 (100.35)*	116.91 (97.00)*	103.20 (90.19)*	125.45 (100.35)*
Infected surgical wound class, %	5.20	6.92*	9.21*	15.16*	6.94*
Perioperative transfusion, %	0.70%	0.95*	0.64	0.86	0.95*
Previous operation, within 30 d, %	2.12%	2.95*	3.29*	4.03†	2.95*
Cardiorespiratory variables, %					
CHF within 30 days	0.71	0.84*	1.21†	1.10	0.84*
Hypertension on medications	46.15	45.87†	38.91*	34.72*	45.82†
History of angina, within 30 d	0.63	0.59†	0.54	1.10	0.59†
Myocardial infarction, within 6 mo	0.45	0.60*	0.75†	0.49	0.60*
Smoker within past 1 y	19.30	20.29	16.98†	22.74‡	20.28*
Severe COPD	4.95	4.72*	4.19‡	3.91	4.71*
Ventilator-dependent in previous 48 h	0.45	1.06*	0.87*	1.34†	1.06*
Current pneumonia	0.45	0.53*	0.39	0.37	0.52*
Renal variables					
Acute renal failure within 24 h, %	0.44	0.61*	0.49	0.98‡	0.61*
Currently on dialysis, %	1.46	1.98*	1.16	2.20	1.98*

(Continued)

Table 1. Continued

Variable	Attending alone (n = 597,630)	Attending and resident in OR (n = 747,350)	Attending in OR suite and resident in OR (n = 3,886)	Resident alone in OR but attending available (n = 818)	Any level of resident involvement (n = 752,054)
Serum creatinine >90 μmol/L for females and >100 μmol/L for males, %	32.87	32.06*	28.68*	28.42‡	32.04*
Neurologic variables, %					
History of TIAs	2.85	2.62*	2.75	1.34†	2.62*
History of CVA, with or without neurologic deficit	4.03	4.10‡	4.35	4.65	4.10*
Hematologic variables, %					
Bleeding disorders	4.80	5.62*	4.32	4.03	5.61*
INR > 1.4	6.25	6.98*	8.66†	6.05	6.98*
Platelet count ≤ 150,000/μL	6.59	7.64*	6.61	8.93†	7.63*
Hematocrit <39% in males or <36% in females	26.38	32.10*	32.01*	34.24*	32.10*
White-blood-cell count > 11,000/μL	15.11	16.90*	22.89*	34.85*	16.95*
Oncologic variables, %					
Disseminated cancer	1.24	2.48*	2.60*	2.32†	2.48*
>10% weight loss in last 6 mo	1.16	2.37*	2.86*	1.96‡	2.37*
Chemotherapy within 30 d	0.89	1.70*	1.16	1.22	1.70*
Radiotherapy within 90 d	0.41	0.89*	0.44	1.22†	0.88*
Hepatobiliary variables, %					
Ascites in previous 30 d	0.46	0.84*	0.64	0.98‡	0.84*
Esophageal varices within 6 mo	0.06	0.13*	0.15‡	0.24‡	0.13*
Total bilirubin >17.1 μmol/L	98.14	98.30*	98.92‡	99.20	98.30*
Other variables, %					
Open wound	3.74	4.77*	3.37	5.87†	4.76*
Steroid/immunosuppressant use	2.41	3.50*	3.55*	4.40†	3.51*
Alcohol, >2 drinks/d over past 2 wk	2.49	2.66*	2.80	3.30	2.67*
Sepsis within 48 h	6.15	8.27*	9.50*	17.97*	8.29*
Serum albumin < 3.5g/dL	20.45	23.61*	21.95	30.36*	23.61*
Diabetes mellitus, insulin- and noninsulin-dependent	14.95	15.14‡	11.35*	11.86‡	15.12†

*$p < 0.0001$ compared with attending alone group.
†$p < 0.01$ compared with attending alone group.
‡$p < 0.05$ compared with attending alone group.
ASA, American Society of Anesthesiologists; CHF, congestive heart failure; CVA, cerebrovascular accident; INR, international normalized ratio; OR, operating room; TIA, transient ischemic attack.

RESULTS

A total of 1,349,684 patients met the inclusion criteria and were included in the analysis. Figure 1 shows the distribution of the patients among surgical specialties. The mean age of the patients was 55.89 years (SD 16.99 years), and 774,299 patients (57.37%) were female. There were 747,350 patients (99.4%) of the 752,054 patients whose operations had any level of resident involvement and who belonged to the group in which both the attending surgeon and the resident participated in the surgery.

Table 1 displays the demographic, general, anesthesia-related, surgical, preoperative, and other variables. The table compares these variables among the different categories. Compared with patients who were operated on by attending surgeons alone, the patients with operations involving residents were more likely to be younger than 65 years, male, not white, functionally dependent, and inpatients. Patients with operations involving residents were less likely to be obese or under a do-not-resuscitate order. Patients in whose operations residents participated were more likely to have a higher American Society of Anesthesiologists (ASA) class or to have undergone general anesthesia. Surgical cases in which residents had any level of involvement had higher work value units, a measure of surgical complexity, as compared with cases in which only attending surgeons were involved. Mean total operative time was significantly longer for surgical cases in which residents were involved as compared with those performed by attending surgeons alone. Operations with

Table 2. Effect of Resident Involvement in Surgical Procedures on Mortality

Variable	Attending alone (n = 597,630)	Attending and resident in operating room (n = 747,350)	Attending in operating suite and resident in operating room (n = 3,886)	Resident alone in operating room but attending available (n = 818)	Any level of resident involvement (n = 752,054)
Mortality, n (%)	7,049 (1.18)	12,236 (1.64)	60 (1.54)	17 (2.08)	12,313 (1.64)
$OR_{unadjusted}$	Reference	1.39 (1.35–1.44)	1.31 (1.02–1.70)	1.78 (1.10–2.88)	1.39 (1.35–1.44)
$OR_{adjusted}$	Reference	0.93 (0.90–0.97)	0.90 (0.67–1.20)	0.84 (0.49–1.46)	0.93 (0.90–0.97)
Strata $OR_{adjusted}$					
Age, y					
<65 (n = 902,686)	Reference	0.92 (0.86–0.98)	1.36 (0.85–2.18)	0.53 (0.15–1.91)	0.92 (0.86–0.98)
65+ (n = 446,998)	Reference	0.94 (0.90–0.98)	0.73 (0.51–1.06)	1.00 (0.54–1.84)	0.94 (0.90–0.97)
Sex					
Male (n = 575,385)	Reference	0.93 (0.89–0.98)	1.02 (0.70–1.50)	0.69 (0.32–1.51)	0.93 (0.89–0.98)
Female (n = 774,299)	Reference	0.93 (0.88–0.98)	0.76 (0.49–1.20)	1.06 (0.49–2.27)	0.93 (0.88–0.97)
Surgical subspecialty					
General (n = 860,838)	Reference	0.94 (0.89–0.98)	0.91 (0.67–1.25)	0.62 (0.28–1.40)	0.93 (0.89–0.98)
Gynecologic (n = 61,311)	Reference	1.52 (0.92–2.53)	NA	NA	1.52 (0.92–2.53)
Neurosurgery (n = 34,693)	Reference	0.98 (0.80–1.19)	2.94 (0.57–15.28)	7.05 (0.11–470.37)	0.98 (0.81–1.19)
Orthopaedics (n = 133,672)	Reference	0.87 (0.74–1.02)	1.74 (0.22–14.04)	1.47 (0.53–4.05)	0.88 (0.75–1.03)
Otolaryngology (n = 29,059)	Reference	0.87 (0.52–1.47)	NA	NA	0.87 (0.52–1.46)
Plastics (n = 24,504)	Reference	0.95 (0.53–1.74)	NA	NA	0.95 (0.52–1.74)
Thoracic (n = 12,261)	Reference	0.79 (0.63–0.99)	NA	NA	0.79 (0.63–0.99)
Urology (n = 48,499)	Reference	0.72 (0.54–0.96)	NA	NA	0.72 (0.54–0.95)
Vascular (n = 144,847)	Reference	0.97 (0.91–1.04)	0.68 (0.29–1.60)	1.28 (0.36–4.51)	0.97 (0.91–1.04)
Emergency					
No (n = 1,189,749)	Reference	0.91 (0.87–0.95)	0.93 (0.61–1.39)	0.27 (0.06–1.14)	0.91 (0.87–0.95)
Yes (n = 159,935)	Reference	0.98 (0.93–1.03)	0.91 (0.61–1.35)	1.27 (0.69–2.33)	0.98 (0.93–1.03)

OR, odds ratio.

any level of resident involvement or those in which residents operated alone were more likely to be emergency cases as compared with operations performed by attending surgeons alone. As compared with patients with operations done by attending surgeons alone, patients in whose operations residents were involved were more likely to have an infected surgical wound preoperatively, to have received perioperative blood transfusion, to have had an operation within the previous 30 days, to be diabetic, to be septic, to have abnormal preoperative laboratory values, and to have disseminated cancer.

Unadjusted mortality was 1.64% ($OR_{unadjusted}$ 1.39, 95% CI 1.35 to 1.44) for the group with any level of resident involvement and 1.18% for the group operated on by attending surgeons alone. Table 2 shows the non-stratified and stratified results on mortality across the different groups. Unadjusted composite morbidity was 8.17% ($OR_{unadjusted}$ 1.61, 95% CI 1.59 to 1.63) for the group with any level of resident involvement and 5.24% for the group operated on by attending surgeons alone. Table 3 shows the non-stratified and stratified results on composite morbidity across the different groups. For operations in which residents were involved, the adjusted OR for mortality was 0.93 (95% CI 0.90 to 0.97) as compared with the group of patients on whom attending surgeons operated alone without any level of resident involvement. Based on the adjusted OR, the involvement of residents in surgery was significantly and independently associated with lower 30-day mortality. For operations in which residents were involved, the adjusted OR for morbidity was 1.02 (95% CI 1.00 to 1.04), as compared with the group of patients on whom attending surgeons operated alone without any level of resident involvement. Although this result is of borderline statistical significance, it clearly suggests that there was no major or clinically significant difference in morbidity between the group with any level of resident involvement and the "attending alone" group.

The adjusted OR for 30-day mortality suggested a lower mortality in the group with any level of resident involvement, as compared with the "attending alone" group, across age categories and sex categories.

Table 3. Effect of Resident Involvement in Surgical Procedures on Composite Morbidity at 30 Days

Variable	Attending alone (n = 597,630)	Attending and resident in operating room (n = 747,350)	Attending in operating suite and resident in operating room (n = 3,886)	Resident alone in operating room but attending available (n = 818)	Any level of resident involvement (n = 752,054)
Composite morbidity, n (%)	31,318 (5.24)	61,091 (8.17)	266 (6.85)	67 (8.19)	61,424 (8.17)
$OR_{unadjusted}$	Reference	1.61 (1.59−1.63)	1.33 (1.17−1.51)	1.61 (1.26−2.07)	1.61 (1.59−1.63)
$OR_{adjusted}$	Reference	1.02 (1.01−1.04)	0.84 (0.73−0.97)	0.89 (0.67−1.18)	1.02 (1.00−1.04)
Strata $OR_{adjusted}$					
Age, y					
<65 (n = 902,686)	Reference	1.03 (1.01−1.06)	0.87 (0.72−1.06)	0.94 (0.64−1.37)	1.03 (1.01−1.06)
65+ (n = 446,998)	Reference	1.01 (0.98−1.03)	0.80 (0.65−0.98)	0.85 (0.56−1.29)	1.00 (0.98−1.03)
Sex					
Male (n = 575,385)	Reference	1.03 (1.01−1.05)	0.80 (0.66−0.98)	0.92 (0.63−1.34)	1.03 (1.00−1.05)
Female (n = 774,299)	Reference	1.01 (0.99−1.03)	0.88 (0.72−1.08)	0.83 (0.54−1.28)	1.01 (0.99−1.03)
Surgical subspecialty					
General (n = 860,838)	Reference	1.02 (1.00−1.04)	0.81 (0.70−0.94)	0.87 (0.62−1.22)	1.02 (0.99−1.04)
Gynecologic (n = 61,311)	Reference	1.04 (0.93−1.17)	1.50 (0.36−6.18)	NA	1.04 (0.93−1.17)
Neurosurgery (n = 34,693)	Reference	1.19 (1.08−1.31)	0.71 (0.18−2.89)	0.90 (0.05−17.53)	1.19 (1.08−1.31)
Orthopaedics (n = 133,672)	Reference	1.08 (1.01−1.15)	0.98 (0.29−3.26)	1.25 (0.64−2.44)	1.08 (1.01−1.15)
Otolaryngology (n = 29,059)	Reference	1.04 (0.88−1.24)	NA	2.63 (0.48−14.57)	1.04 (0.88−1.24)
Plastics (n = 24,504)	Reference	0.98 (0.83−1.15)	1.95 (0.59−6.42)	NA	0.98 (0.84−1.15)
Thoracic (n = 12,261)	Reference	0.91 (0.81−1.03)	NA	NA	0.91 (0.81−1.03)
Urology (n = 48,499)	Reference	0.95 (0.86−1.06)	NA	0.58 (0.05−6.84)	0.95 (0.85−1.05)
Vascular (n = 144,847)	Reference	1.01 (0.97−1.05)	0.96 (0.60−1.52)	0.69 (0.28−1.70)	1.01 (0.97−1.05)
Emergency					
No (n = 1,189,749)	Reference	1.02 (1.00−1.04)	0.81 (0.68−0.96)	0.96 (0.65−1.42)	1.02 (1.00−1.04)
Yes (n = 159,935)	Reference	1.03 (1.00−1.07)	0.92 (0.72−1.18)	0.86 (0.57−1.31)	1.03 (1.00−1.07)

OR, odds ratio.

Concerning surgical subspecialty, there was a statistically significant lower mortality in the group with any level of resident involvement as compared with the "attending alone" group in general surgery, thoracic surgery, and urology. There was no statistically significant difference in mortality between the 2 groups in gynecology, neurosurgery, orthopaedics, otolaryngology, plastic surgery, and vascular surgery. For non-emergent cases, involvement of residents in surgery was associated with statistically significantly lower 30-day mortality. For emergent cases, there was no statistically significant difference in mortality between the "attending alone" group and the group with any level of resident involvement.

The adjusted OR for 30-day composite morbidity suggested no difference in 30-day morbidity between the group with any level of resident involvement as compared with the "attending alone" group, across age categories and sex categories. This was also true for emergent and non-emergent cases. Concerning surgical subspecialty, there was no statistically significant difference in morbidity between the group with any level of resident involvement as compared with the "attending alone" group in all surgical subspecialties except neurosurgery and orthopaedics. In neurosurgery and orthopaedics, there was a slightly statistically significant increase in the risk of morbidity in the group with any level of resident involvement as compared with the "attending alone" group.

On dissection of the specific morbidities, there was no statistically significant difference in CNS, urinary tract, wound, sepsis, and venous thromboembolism morbidities between the group with any level of resident involvement and the "attending alone" group. There was slightly statistically significant higher risk of cardiac and respiratory morbidities in the group with any level of resident involvement as compared with the "attending alone" group. Table 4 shows the specific morbidities across the different levels of resident involvement.

DISCUSSION

Although studies have explored the effect of resident participation in surgery across different subspecialties,

Table 4. Effect of Resident Involvement in Surgical Procedures on Specific Morbidities at 30 Days

Variable	Attending alone (n = 597,630)	Attending and resident in operating room (n = 747,350)	Attending in operating suite and resident in operating room (n = 3,886)	Resident alone in operating room but attending available (n = 818)	Any level of resident involvement (n = 752,054)
Specific morbidity					
Cardiac					
n (%)	3,233 (34.58)	6,096 (65.20)	17 (0.18)	4 (0.04)	6,117 (65.42)
$OR_{unadjusted}$	Reference	1.51 (1.45−1.58)	0.81 (0.50−1.30)	0.90 (0.34−2.41)	1.51 (1.44−1.57)
$OR_{adjusted}$	Reference	1.10 (1.05−1.15)	0.62 (0.38−1.01)	0.57 (0.21−1.55)	1.10 (1.05−1.15)
Respiratory					
n (%)	12,954 (31.78)	27,657 (67.85)	115 (0.28)	33 (0.08)	27,805 (68.22)
$OR_{unadjusted}$	Reference	1.73 (1.70−1.77)	1.38 (1.14−1.66)	1.90 (1.34−2.69)	1.73 (1.70−1.77)
$OR_{adjusted}$	Reference	1.12 (1.09−1.14)	0.90 (0.73−1.12)	1.01 (0.68−1.52)	1.11 (1.09−1.14)
CNS					
n (%)	1,713 (36.76)	2,931 (62.90)	11 (0.24)	5 (0.11)	2,947 (63.24)
$OR_{unadjusted}$	Reference	1.37 (1.29−1.45)	0.99 (0.54−1.79)	2.14 (0.89−5.16)	1.37 (1.29−1.45)
$OR_{adjusted}$	Reference	0.98 (0.92−1.04)	0.75 (0.41−1.37)	1.37 (0.56−3.35)	0.97 (0.92−1.04)
Urinary tract					
n (%)	3,178 (33.68)	6,236 (66.08)	15 (0.16)	8 (0.08)	6,259 (66.32)
$OR_{unadjusted}$	Reference	1.57 (1.51−1.64)	0.72 (0.44−1.20)	1.85 (0.92−3.71)	1.57 (1.50−1.64)
$OR_{adjusted}$	Reference	1.02 (0.97−1.06)	0.53 (0.32−0.89)	1.03 (0.50−2.12)	1.01 (0.97−1.06)
Wound					
n (%)	9,517 (32.34)	19,793 (67.26)	96 (0.33)	22 (0.07)	19,911 (67.66)
$OR_{unadjusted}$	Reference	1.68 (1.64−1.72)	1.56 (1.28−1.92)	1.71 (1.12−2.61)	1.68 (1.64−1.72)
$OR_{adjusted}$	Reference	1.02 (0.99−1.04)	0.87 (0.71−1.07)	1.00 (0.65−1.54)	1.01 (0.99−1.04)
Sepsis					
n (%)	9,787 (30.12)	22,608 (69.58)	77 (0.24)	19 (0.06)	22,704 (69.88)
$OR_{unadjusted}$	Reference	1.87 (1.83−1.92)	1.21 (0.97−1.52)	1.43 (0.91−2.25)	1.87 (1.82−1.91)
$OR_{adjusted}$	Reference	1.21 (1.18−1.24)	0.83 (0.66−1.06)	0.78 (0.49−1.25)	1.21 (1.18−1.24)
Venous thromboembolism					
n (%)	4,059 (34.01)	7,836 (65.66)	33 (0.28)	6 (0.05)	7,875 (65.99)
$OR_{unadjusted}$	Reference	1.55 (1.49−1.61)	1.25 (0.89−1.77)	1.08 (0.48−2.41)	1.55 (1.49−1.61)
$OR_{adjusted}$	Reference	1.16 (1.12−1.21)	0.97 (0.69−1.38)	0.72 (0.32−1.63)	1.16 (1.11−1.21)

OR, odds ratio.

there is a paucity of studies in the literature that explore the "resident effect" across different surgical subspecialties to influence the general attitude of patients, attending surgeons, and surgical residency training programs toward involvement of trainees in surgery. Studies in neurosurgery, cardiac surgery, gynecology, vascular surgery, general surgery, plastic surgery, and urology showed similar morbidity and/or mortality risks with or without resident involvement in surgery.[14,15,26-30] Other studies in general and vascular surgery showed differential effects on the risks of morbidity and mortality, slightly increasing the former and decreasing the latter.[8,31] Some studies in vascular surgery even suggested a protective effect of resident participation on mortality.[28]

Studies analyzing the effect of resident participation in specific operations may help guide the optimization of those specific surgical procedures, but their study design is not ideal to draw conclusions affecting the broader landscape of surgical medical training.[11,12,20] For instance, a study on laparoscopic appendectomy for uncomplicated appendicitis showed an increase in serious and overall morbidity with resident involvement.[32] However, another study, pertaining to the field of general surgery, showed that resident involvement in laparoscopic cholecystectomy was associated with a shorter length of hospital stay, lower morbidity, and comparable overall mortality.[19] Our study concludes, through a robust statistical analysis and a sufficiently large sample size drawn from a large, multi-center database of hospitals throughout the United States, that resident participation in surgery does not negatively affect clinical outcomes, in terms of morbidity and mortality. This is despite the fact that residents were typically involved

in more complex cases, as evidenced by the fact that the resident involvement subgroup had higher work value units and a higher percentage of emergency cases, infected surgical wounds preoperatively, perioperative blood transfusions, previous surgical interventions within 30 days, diabetes, sepsis, abnormal preoperative laboratory values, and disseminated cancer. In fact, resident participation was associated with a decreased mortality risk in general surgery, thoracic surgery, and urology. In other surgical subspecialties, mortality outcomes were comparable between the group with resident involvement and that with no resident involvement. There was no increased risk of mortality in any of the subspecialties when residents were involved. This confirms and validates studies done across different surgical subspecialties. In terms of morbidity, the only subspecialties with slightly increased risk of morbidity were orthopaedics and neurosurgery.

Previous studies have shown prolonged operative time in different subspecialties, such as gynecology, vascular surgery, plastic surgery, general surgery, neurosurgery, and urology, with resident involvement.[7,14,15,27-29,31] In light of the results of some studies that suggest that prolonged operative time is associated with increased morbidity (surgical site infection and venous thromboembolism), the question remains whether the prolonged operative time resulting from resident involvement is associated with increased morbidity.[6,33-35] Our analysis concluded that the increased operative time with resident involvement was not associated with increased morbidity. It is noteworthy that mean total operative time was significantly longer when residents and attending surgeons were both in the operating room as compared to the operative time when residents were scrubbed in alone with the attending surgeon in the operating suite or not present but available. This may be partly explained by the extra time taken by attending surgeons to teach residents and explain every step of the procedure. However, the prolongation in operative time associated with resident involvement in surgery is not coupled with an increase in 30-day morbidity and mortality. The results of our study may also be considered more reassuring when taking into consideration the fact that residents usually overuse laboratory tests and may be more vigilant in recording postoperative morbidity outcomes, which may bias our results away from the null hypothesis.[8,36,37] This would have been important only had there been a significant increase in mortality and morbidity with resident involvement. On the other hand, possible ways to address the prolonged operative time include increasing exposure to simulation experiences, especially with the new duty hour rules that may allow more time for formal surgical educational sessions. Although resident participation in surgery was not associated with increased morbidity and mortality, the significantly prolonged operative time may result in significantly higher costs of care.[6,21]

The occasional protective nature of resident involvement in surgery may be explained by a number of factors. First of all, having a resident physician in the operating room, rather than a scrub nurse or other first assistant, can serve as a safety and quality checkpoint. Second, surgical procedures in which residents may be participating are more likely to be at teaching hospitals, usually academic medical centers, where attending surgeons may have more advanced experience and surgical expertise and where postoperative care may be of better quality.

Our study confirms previous findings of low rates of independent resident involvement in the operating room.[13] Residents were involved in 55.7% of almost 1.3 million surgical procedures. However, only about 0.3% of the cases were performed with limited presence of an attending physician in the operating room (attending in operating suite or not present but available).

Our study suggests a higher risk of cardiac (myocardial infarction and cardiac arrest) and respiratory (pneumonia, need for ventilator support for more than 48 hours, or unplanned intubation) complications with resident involvement in surgery. Therefore, future studies should evaluate the effect of resident involvement in surgery on specific cardiac and respiratory complications. Each of the different cardiac and respiratory outcomes was more common in the group with resident involvement compared with the "attending alone" group (statistical analysis not shown).

One of the strengths of our study is that it is based on the large, multicenter ACS NSQIP database, and ACS NSQIP provides standardized definitions for clinical outcomes and patient characteristics. The variety and multitude of variables analyzed allow for appropriate risk adjustment. However, the ACS NSQIP database represents a subset of American hospitals and may not be fully representative of all sites in which surgery residency training is provided. In addition, ACS NSQIP reports outcomes for only 30 days postoperatively; therefore, the database may miss long-term outcomes. Specifically for this retrospective analysis, the degree of resident involvement and the postgraduate year of the resident involved were not available for our analysis. Nevertheless, the aim of our study was to show that resident involvement in surgery, regardless of the extent of this involvement, was not associated with worse operative outcomes. Our study, including an analysis of different surgical subspecialties that usually coexist within a hospital or medical center, shows that resident involvement in surgery is generally safe.

One missing potential confounder could be the lack of data on the type of institution, ie, community hospital vs academic university hospital. Another potential confounder can be the presence and/or participation of an anesthesiology resident or a medical student at any step during the procedure. Therefore, future studies should focus on the specific factors in the surgical learning milieu that may contribute to the prolongation of operative time. Our analysis did not examine the effect of postgraduate year of residency on the outcomes because the database used does not include information on that. This is less important in the context of our study, which aims to answer the general question of whether resident involvement in surgical operations, across subspecialties, is safe in order to reassure patients, attending surgeons, and surgical residency program directors about the safety of a crucial part of surgical training. Finally, now that it is clear that resident participation in surgery is not associated with increased morbidity and mortality, future studies should also focus on other important operative outcomes, such as rate of positive margins in tumor resection and rate of satisfaction with esthetic outcomes in plastic surgery.

CONCLUSIONS

In conclusion, our study confirms that, across different surgical subspecialties, resident involvement in surgery is associated with comparable morbidity and lower mortality outcomes. This provides a reassuring answer to patients, attending surgeons, and surgical program directors.

Author Contributions

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Drafting of manuscript: Saliba, Harb

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