Resident Involvement and Plastic Surgery Outcomes: An Analysis of 10,356 Patients from the American College of Surgeons National Surgical Quality Improvement Program Database

Sumanas W. Jordan, M.D.
Lauren M. Mioton, B.S.
John Smetona, B.A., B.S.
Apas Aggarwal
Edward Wang, Ph.D.
Gregory A. Dumanian, M.D.
John Y. S. Kim, M.D.

Chicago and Evanston, Ill.; and Nashville, Tenn.

Background: Intraoperative experience is an essential component of surgical training. The impact of resident involvement in plastic surgery has not previously been studied on a large scale.
Methods: The authors retrospectively reviewed the American College of Surgeons National Surgical Quality Improvement Program database from 2006 to 2010 for all reconstructive plastic surgery cases. Resident involvement was tracked as an individual variable to compare outcomes.
Results: A total of 10,356 cases were identified, with 43 percent noted as having resident involvement. The average total relative value units, a proxy for surgical complexity, and operative time were higher for procedures with residents present. When balanced by baseline characteristics using propensity score stratification into quintiles, no differences in graft, prosthesis, or flap failure or mortality were observed. Furthermore, there were no differences in overall complications or wound infection with resident involvement for a majority of the quintiles. Multivariable logistic regression analysis revealed that resident involvement was a significant predictor of overall morbidity, but not associated with increased odds of wound infection, graft, prosthesis or flap failure, or overall mortality.
Conclusions: Residency has the dual mission of training future physicians and also providing critical support for academic medical centers. Using a large-scale, multicenter database, the authors were able to confirm that well-matched cohorts with—and without—resident presence had similar complication profiles. Moreover, even when residents were involved in comparably more complex cases with longer operative times, infection, graft and flap failure, and mortality remained similar. (*Plast. Reconstr. Surg.* 131: 763, 2013.)
CLINICAL QUESTION/LEVEL OF EVIDENCE: Risk, II.

Large tertiary care centers are known for their expertise in rare diseases, high surgical volume, multidisciplinary teams dedicated to complex medical problems, and, importantly, attending staff committed to research and advancement of surgical techniques and technologies. These specialized hospitals often exist as part of major academic centers whose mission also includes the training of surgical residents and fellows. When patients seek out "experts" in their field, they often find themselves within a teaching environment interacting frequently with trainees. Media attention over resident work hours and inexperience has led some patients to request that house

From the Division of Plastic and Reconstructive Surgery, the Department of Surgery, and the Biostatistics Core, Northwestern University, Feinberg School of Medicine, and Vanderbilt University School of Medicine.
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staff not participate in their care.[1,2] In addition, as medical reimbursement shifts toward a pay-for-performance scheme, as in the Value-Based Purchasing System recently implemented by Medicare in 2012, the impact of residents on outcomes becomes of financial interest to both academic physicians and health policy personnel.[3,4]

Several studies have attempted to assess the impact of resident participation on surgical outcomes and the safety of the current resident training paradigm. Although a number of smaller studies have demonstrated no difference in morbidity or mortality when residents were involved, recent reports using the American College of Surgeons National Surgical Quality Improvement Program database have found small but statistically significant increases in complication rates for a variety of general surgical procedures.[5–9] Mortality rates were found to be similar or even lower with intraoperative and postoperative house staff involvement.[7] Some studies have attempted to stratify the data based on resident seniority, but results have been mixed—a finding likely attributable to the inability to control for attending surgeon involvement and case complexity.[8,10,11] Nearly all studies have reported longer operating room times when a resident was involved.[12]

To our knowledge, the impact of resident involvement in plastic surgery has not been studied on a large scale. We used the American College of Surgeons National Surgical Quality Improvement Program database, which is a robust, multicenter program that prospectively collects surgical outcomes data from participating institutions across the country to address this issue. The National Surgical Quality Improvement Program tracks 240 distinct variables describing patient demographics, comorbidities, intraoperative variables, and postoperative outcomes. Primary surgical service and surgical house staff involvement are included among the tracked variables, allowing for stratification of procedures by resident presence. Between 2006 and 2010, over 1.3 million total procedures were captured at over 240 hospitals.[13] With its rigorous and uniform data collection from a wide selection of hospitals, the National Surgical Quality Improvement Program provides a large data set for the assessment of resident influence on surgical outcomes. Our study represents the first assessment of this impact on plastic surgery procedures.

METHODS

Data Acquisition

The particulars of the National Surgical Quality Improvement Program database have been described elsewhere.[13] In brief, trained, independent, surgical clinical nurse reviewers carry out data collection from patient medical records, physician office records, and telephone interviews by means of a standardized process, and internal audits are performed to ensure accuracy. Patient information is deidentified to comply with the Health Insurance Portability and Accountability Act of 1996 and the American College of Surgeons National Surgical Quality Improvement Program hospital participation agreement. Deidentified patient information is freely available to all institutional members who comply with the American College of Surgeons National Surgical Quality Improvement Program Data Use Agreement. The Data Use Agreement implements the protections afforded by the Health Insurance Portability and Accountability Act of 1996 and the American College of Surgeons National Surgical Quality Improvement Program Hospital Participation Agreement. This study conforms to the Declaration of Helsinki.

We identified all operations in the National Surgical Quality Improvement Program database from 2006 and 2010 with "plastics" listed as the primary service. Cosmetic procedures were denoted as such based on the American Society for Aesthetic Plastic Surgery procedure list.[14] Procedures coded with any cosmetic component were excluded to obtain a population of reconstructive cases. Resident involvement was tracked as an individual variable. Outcomes of primary interest included overall complication, wound infection, graft/prosthesis/flap failure, and mortality rates, as defined by the National Surgical Quality Improvement Program. We defined overall complications as having one or more adverse events within 30 days. Complications were classified as surgical or medical. Surgical complications included wound infection, categorized as superficial surgical-site infection, deep surgical-site infection, and organ/space surgical-site infection; graft/prosthesis/flap failure; and wound disruption. Medical complications included pneumonia, unplanned intubation, pulmonary embolism, mechanical ventilation for over 48 hours, progressive renal insufficiency, acute renal failure, urinary tract infection, coma, stroke, peripheral neurologic deficit, cardiac arrest, myocardial infarction, requirement for blood transfusion, deep venous thrombosis, and sepsis or septic shock. Reoperation was defined as any return to the operating room for surgical intervention within 30 days of the primary procedure. Length of hospital stay was defined as time from operation to hospital discharge. Mortality was defined as a death within 30 days, regardless of cause.

Risk-Adjustment Factors

Commonly published preoperative risk factors—specifically, age, sex, smoking status, diabetes, obesity, hypertension requiring medication, and chemotherapy within the last 30 days—were tracked as potential confounders. Total relative value units for the case were used to control for inherent differences in the complexity of the procedures.[15–17] Work relative value units have been shown to be more predictive of surgical outcomes than complexity scores assigned by panels of surgeons.[17] Of note, the Centers for Medicare and Medicaid Services does not assign relative value units for cosmetic cases. Thus, case complexity may only be used as a covariate adjustment for reconstructive cases.

A propensity score for resident presence at surgery was calculated using all variables describing patient demographics, preoperative condition, and comorbidities.[18,19] Specifically, the propensity score represented the probability of having a resident present in an operation based on preoperative patient characteristics; the propensity score ranged from 0, representing the lowest probability of resident presence, to 1, representing the highest probability of resident presence. Three common methods for using propensity scores are matching, stratification, and logistic adjustment. We used two of the three techniques. Propensity score stratification into quintiles was performed to control for baseline differences in the populations who were treated by residents with attending physicians versus attending physicians alone. The literature has shown that using five strata reduces bias attributable to nonrandom assignment by over 90 percent.[19] In addition, the propensity score was incorporated into the multivariate logistic regression model as a covariance adjustment.

Statistical Analysis

Complication, wound infection, graft/prosthesis/flap failure, and mortality rates were compared between patients with residents present or absent at surgery. Chi-square and *t* tests were used to analyze categorical and continuous variables, respectively. A two-tailed value of $p < 0.05$ was considered significant. Clinically significant preoperative risk factors, resident presence, total relative value units, operative time, and propensity score, as described above, were incorporated into multivariable regression models to calculate adjusted odds ratios for overall complication, wound infection, graft/prosthesis/flap failure, and mortality rates. Hosmer-Lemeshow and C-statistic values were computed to assess goodness-of-fit and discrimination of all logistic regression models.[20–22] Variables with fewer than 10 events were excluded from the final analyses.[23,24] All analyses were performed using SPSS version 20.0 (IBM Corp., Armonk, N.Y.).

Table 1. Reconstruction Case Patient Characteristics by Resident Presence

	Resident Present (%)	Resident Not Present (%)	*p*
No. of patients	4453	5903	
Characteristic			
Age, yr			
mean ± SD	50.22 ± 15.72	51.31 ± 15.51	<0.001*
Race			
Asian	80 (1.80)	92 (1.56)	—
African American	537 (12.06)	464 (7.86)	<0.001*
White	3367 (75.61)	4518 (76.54)	—
Other	469 (10.53)	829 (14.04)	<0.001*
Female	2869 (64.43)	4289 (72.66)	<0.001*
Obesity (BMI ≥ 30)	1461 (32.81)	1815 (30.75)	0.007*
Diabetes	419 (9.41)	644 (10.91)	0.013*
Smokers	978 (21.96)	1127 (19.09)	<0.001*
Hypertension	1377 (30.92)	1837 (31.12)	0.83
Chemotherapy	59 (1.32)	126 (2.13)	0.002*

BMI, body mass index.
*Significant value, $p < 0.05$.

RESULTS

We identified 15,289 patients with plastic surgery as the primary service. One hundred fifteen patient records did not include information regarding resident presence and were excluded from analysis, and 4818 cases were coded with at least one cosmetic Current Procedural Terminology code and excluded because of the inability to accurately quantify surgical complexity data. This resulted in a reconstructive population of 10,356 patients for analysis. A total of 4453 cases (43 percent) were identified with a resident present, and 5903 cases (57 percent) were identified for which no resident was present.

Demographic and patient comorbidity information is reported in Table 1. Reconstructive procedures with resident involvement had a higher percentage of obese patients and smokers; procedures without resident involvement had a higher percentage of women, diabetics, and patients who had received chemotherapy in the past 30 days.

Comparison of Outcomes

A comparison of surgical and medical complications, mortality rates, operative time, and total relative value units is shown in Table 2. Reconstructive procedures with residents present had higher rates of any complication (10.06 percent versus 6.03 percent, $p < 0.001$) and reoperation (7.75 percent versus 4.93 percent, $p < 0.001$). Resident involvement trended toward a lower mortality, but this comparison did not reach significance (0.36 percent versus 0.59 percent, $p = 0.093$). Surgical complications were higher in reconstructive procedures with residents (5.70 percent versus 3.44 percent, $p < 0.001$). Superficial surgical-site infection (2.45 percent versus 1.30 percent, $p < 0.001$), organ/space surgical-site infection (0.63 percent versus 0.32 percent, $p = 0.021$), graft/prosthesis/flap failure (1.24 percent versus 0.64 percent, $p = 0.002$), and wound disruption (0.90 percent versus 0.42 percent, $p = 0.002$) were higher in procedures with residents. Medical complications are listed by specific complication. Only ventilator dependence for greater than 48 hours (0.76 percent versus 0.46 percent, $p = 0.044$) and requirement for a blood transfusion (2.31 percent versus 0.73 percent, $p < 0.001$) were higher in the resident group. Rates of pneumonia, unplanned intubation, venous thromboembolic events, renal insufficiency, acute renal failure, urinary tract infection, neurologic complications, cardiac adverse events, and sepsis/septic shock were not significantly associated with resident presence. Length of stay from operation to discharge was higher with resident involvement (3.29 ± 9.58 days versus 2.26 ± 8.26 days, $p < 0.001$). Operative time was longer with resident involvement (139.32 ± 134.62 minutes versus 107.88 ± 93.88 minutes, $p < 0.001$). Mean total relative value units were higher for procedures with resident involvement (18.30 ± 15.65 versus 15.66 ± 13.73, $p < 0.001$), indicating a bias toward a more complex case mix in this group.

Propensity Score Stratification

Propensity score stratification resulted in appropriately matched demographics and comor-

Table 2. Postoperative Outcomes of Patients with and without a Resident Present

	Resident Present (%)	Resident Not Present (%)	*p*
No. of patients	4453	5903	
Outcome			
Overall complications	448 (10.06)	356 (6.03)	<0.001*
Surgical complications	254 (5.70)	203 (3.44)	<0.001*
Wound infection	181 (4.06)	152 (2.57)	<0.001*
Superficial SSI	109 (2.45)	77 (1.30)	<0.001*
Deep SSI	49 (1.10)	58 (0.98)	0.557
Organ/space SSI	28 (0.63)	19 (0.32)	0.021*
Graft/prosthesis/flap failure	55 (1.24)	38 (0.64)	0.002*
Wound disruption	40 (0.90)	25 (0.42)	0.002*
Medical complications	250 (5.61)	189 (3.20)	<0.001*
Pneumonia	21 (0.47)	31 (0.53)	0.703
Unplanned intubation	22 (0.49)	19 (0.32)	0.167
PE	7 (0.16)	4 (0.07)	0.224
Ventilator >48 hr	34 (0.76)	27 (0.46)	0.044*
Renal insufficiency	5 (0.11)	2 (0.03)	0.148
Acute renal failure	6 (0.13)	6 (0.10)	0.624
UTI	47 (1.06)	42 (0.71)	0.06
Coma	2 (0.04)	2 (0.03)	1
Stroke	4 (0.09)	4 (0.07)	0.732
Peripheral nerve deficit	3 (0.07)	1 (0.02)	0.321
Cardiac arrest	6 (0.13)	8 (0.14)	0.991
MI	5 (0.11)	5 (0.08)	0.754
Blood transfusion	103 (2.31)	43 (0.73)	<0.001*
DVT	17 (0.38)	17 (0.29)	0.409
Sepsis/septic shock	68 (1.53)	71 (1.20)	0.156
Reoperation	345 (7.75)	291 (4.93)	<0.001*
Mortality	16 (0.36)	35 (0.59)	0.093
Length of stay, days	3.29 ± 9.58	2.26 ± 8.26	<0.001*
Operative time, min	139.32 ± 134.62	107.88 ± 93.88	<0.001*
Total RVUs	18.30 ± 15.65	15.66 ± 13.73	<0.001*

SSI, surgical-site infection; PE, pulmonary embolism; UTI, urinary tract infection; MI, myocardial infarction; DVT, deep vein thrombosis; LOS, length of stay; RVUs, relative value units.
*Significant value, $p < 0.05$.
Length of stay, operative time, and total RVUs are displayed as mean ± SD.

bidities across all quintiles (Table 3). A comparison of operative time; total relative value units; and overall complication, wound infection, graft/prosthesis/flap failure, and mortality rates, stratified by propensity score quintile, is shown in Table 4. Operative time was longer in the resident-present cohort for quintiles 3 to 5. Total relative value units was well matched for quintiles 1 to 3 (Fig. 1). Notably, there were no significant differences in overall complication rates between resident and nonresident cohorts in quintiles 1 to 3 (Fig. 2). The difference in relative value units in quintile 4 did not reach statistical significance (p = 0.055). However, it may be observed that as total relative value units between the resident and nonresident groups diverged in quintiles 4 and 5 (Fig. 1), so too did the overall complication rates (Fig. 2). A similar effect was observed with wound infection rates, with no difference seen in four of five quintiles. There were no significant differences in graft/prosthesis/flap failure across all subgroups. In addition, there were no significant differences in mortality across all subgroups.

Multivariable Analysis

Risk-adjusted ORs and 95 percent CIs for overall complications, wound infection, graft/prosthesis/flap failure, and mortality are listed in Table 5. Our multivariable model revealed that there were several risk factors that play a role in the development of a postoperative complication. Variables associated with an increased odds of overall complications included increasing age, smoking within the past year, diabetes, obesity, hypertension requiring medication, total relative value units, operative time, and resident presence (OR, 1.193; 95 percent CI, 1.005 to 1.417). Notably, the adjusted ORs for smoking, diabetes, obesity, and hypertension were all higher than the OR for resident presence. Increased risk of wound infection was associated with diabetes, obesity, and operative time. Resident presence did not significantly predict wound infection in the risk-adjusted model (OR, 1.26; 95 percent CI, 0.981 to 1.618). Smoking, diabetes, hypertension, and operative time were the only predictors of graft/prosthesis/flap failure. Resident presence was not associated with reconstructive failure (OR, 1.088; 95 percent CI, 0.669 to 1.771). Finally, age, diabetes, hypertension, and chemotherapy were associated with increased odds of death within 30 days of surgery. Resident presence had no impact on mortality and actually trended toward a decreased risk (OR, 0.611; 95 percent CI, 0.295 to 1.268, p = 0.186).

Table 3. Reconstructive Patient Characteristics by Resident Presence after Propensity Score Stratification

	Quintile 1		Quintile 2		Quintile 3		Quintile 4		Quintile 5	
Characteristic	Resident Present (%)	Resident Not Present (%)	Resident Present (%)	Resident Not Present (%)	Resident Present (%)	Resident Not Present (%)	Resident Present (%)	Resident Not Present (%)	Resident Present (%)	Resident Not Present (%)
No. of patients	309	1694	618	1385	807	1196	1061	943	1472	532
Age, yr	53.84 ± 14.79	53.20 ± 15.46	50.34 ± 14.90	51.02 ± 14.96	51.06 ± 15.33	50.60 ± 15.41	49.56 ± 15.72	50.33 ± 15.30	49.44 ± 16.10	49.83 ± 16.45
Race										
Asian	3 (0.97)	17 (1.00)	12 (1.94)	21 (1.52)	16 (1.98)	18 (1.51)	17 (1.60)	21 (2.23)	31 (2.11)	13 (2.44)
African American	12 (3.88)	84 (4.96)	37 (5.99)	63 (4.55)	66 (8.18)	91 (7.61)	129 (12.16)	114 (12.09)	267 (18.14)	100 (18.80)
White	230 (74.43)	1211 (71.49)	472 (76.38)	1113 (80.36)	645 (79.93)	966 (80.77)	833 (78.51)	723 (76.67)	1065 (72.35)	388 (72.93)
Other	64 (20.71)	382 (22.55)	97 (15.70)	188 (13.57)	80 (9.91)	121 (10.12)	82 (7.73)	85 (9.01)	109 (7.40)	31 (5.83)
Female	252 (81.55)	1334 (78.75)	472 (76.38)	1099 (79.35)	584 (72.37)	858 (71.74)	718 (67.67)	644 (68.29)	765 (51.97)	271 (50.94)
Obesity (BMI ≥ 30)	93 (30.10)	485 (28.63)	160 (25.89)	397 (28.66)	266 (32.96)	405 (33.86)	359 (33.84)	325 (34.46)	574 (38.99)	197 (37.03)
Diabetes	49 (15.86)	266 (15.70)	49 (7.93)	125 (9.03)	70 (8.67)	115 (9.62)	91 (8.58)	79 (8.38)	141 (9.58)	47 (8.83)
Smoking	56 (18.12)	264 (15.58)	120 (19.42)	238 (17.18)	146 (18.09)	253 (21.15)	233 (21.96)	201 (21.31)	382 (25.95)	140 (26.32)
Hypertension	106 (34.30)	552 (32.59)	169 (27.35)	394 (28.45)	257 (31.85)	348 (29.10)	314 (29.59)	304 (32.24)	479 (32.54)	188 (35.34)
Chemotherapy	8 (2.59)	69 (4.07)	8 (1.29)	21 (1.52)	18 (2.23)	20 (1.67)	14 (1.32)	13 (1.38)	11 (0.75)	1 (0.19)

BMI, body mass index.
*No variables reached statistical significance.

Table 4. Propensity Score Stratification Data from Reconstructive Patients*

	No.	Operative Time (min)	Total RVUs	Overall Complications (%)	Wound Infection (%)	Graft/Prosthesis/ Flap Failure (%)	Mortality (%)
Quintile 1							
Resident	309	99.06 ± 82.25	14.02 ± 11.18	6.15	3.24	0.97	0.65
Nonresident	1694	97.72 ± 72.33	13.39 ± 11.82	5.79	1.68	0.47	1.06
Quintile 2							
Resident	618	102.65 ± 78.80	15.07 ± 12.25	5.18	2.75	0.49	0.00
Nonresident	1385	98.65 ± 74.07	15.08 ± 13.73	4.62	2.67	0.43	0.36
Quintile 3							
Resident	807	127.82 ± 123.796†	17.27 ± 14.48	7.19	3.47	0.87	0.12
Nonresident	1196	109.17 ± 96.76†	16.97 ± 14.67	6.10	2.17	0.59	0.17
Quintile 4							
Resident	1061	155.28 ± 153.373†	19.25 ± 16.13	9.99†	4.24	1.04	0.19
Nonresident	943	128.97 ± 119.89†	17.93 ± 14.73	7.32†	4.24	0.64	0.42
Quintile 5							
Resident	1472	164.33 ± 151.07†	20.81 ± 17.80†	14.47†	5.10†	1.97	0.54
Nonresident	532	130.30 ± 129.16†	17.68 ± 13.09†	8.46†	2.26†	1.88	0.75

RVU, relative value units.
*Quintiles are grouped by ascending propensity score (i.e., likelihood to receive a resident based on preoperative patient characteristics). Quintile 1 has the lowest propensity scores and therefore the lowest odds of receiving a resident. Conversely, quintile 5 has the highest propensity scores and therefore the greatest odds of receiving a resident.
†Significant value, $p < 0.05$.

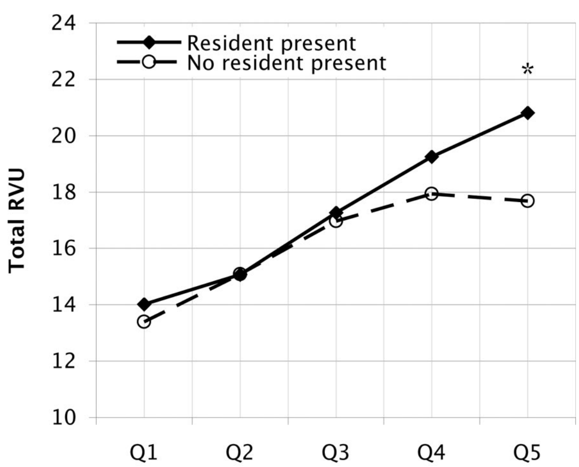

Fig. 1. Mean total relative value units with and without resident present by propensity score–matched quintiles. *Asterisk* denotes significance ($p < 0.05$).

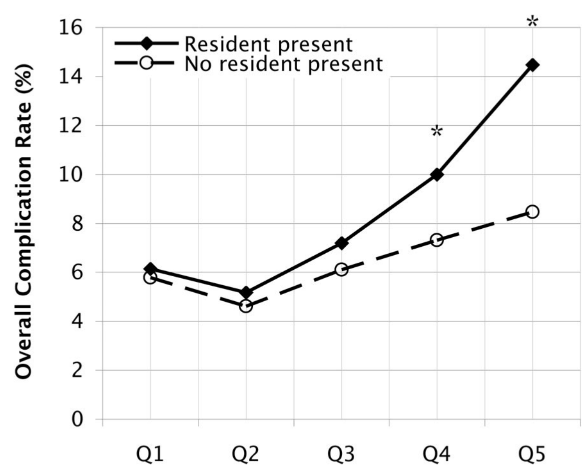

Fig. 2. Overall complication rate with and without resident present by propensity score–matched quintiles. *Asterisk* denotes significance ($p < 0.05$).

Hosmer-Lemeshow and C-statistic values demonstrated goodness-of-fit and discrimination for all regression models.

DISCUSSION

Thus far, much of the literature suggests that resident presence during surgery is safe. Studies from several surgical specialties including cardiothoracic surgery, neurosurgery, gynecology, urology, vascular surgery, and routine and complex general surgery have demonstrated no differences in outcomes when trainees are involved.[25–35] Even when statistical differences in morbidity have been demonstrated, it has been argued that these increases in complication rates were not clinically significant.[5–7,9] To our knowledge, there has been only one study in the plastic surgery literature looking at the presence of residents during surgery. Patel et al. studied resident involvement in 295 cases of bilateral reduction mammaplasty at a single institution.[36] In all cases, the resident operated on the left breast while the attending surgeon operated on the right breast. The authors found that resident participation did not affect patient complications. The study is advantageous in its design of an internal control and the clearly defined resident role. The study is limited, how-

Table 5. Risk-Adjusted Odds Ratios and 95% Confidence Intervals for Overall Complications, Wound Infection, Graft/Prosthesis/Flap Failure, and Mortality in the Reconstructive Cases

	Overall Complications		Wound Infection		Graft/Prosthesis/ Flap Failure		Mortality	
Variable	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Resident presence	1.193*	1.005–1.417	1.26	0.981–1.618	1.088	0.669–1.771	0.611	0.295–1.268
Female sex	0.756*	0.638–0.897	1.183	0.911–1.536	0.809	0.504–1.298	0.515*	0.278–0.952
Age	1.009*	1.003–1.015	1.002	0.994–1.011	1.006	0.99–1.023	1.08*	1.051–1.11
Smoking	1.317*	1.087–1.596	1.166	0.877–1.551	2.103*	1.29–3.427	1.478	0.63–3.471
Diabetes	2.701*	2.191–3.331	1.799*	1.304–2.482	2.065*	1.15–3.706	2.635*	1.385–5.013
Obesity	1.378*	1.173–1.62	1.864*	1.476–2.355	1.19	0.761–1.861	1.455	0.777–2.727
Hypertension	1.34*	1.112–1.614	1.102	0.837–1.451	1.701*	1.022–2.832	2.436*	1.073–5.535
Chemotherapy	1.532	0.909–2.582	0.504	0.158–1.602	1.201	0.282–5.122	13.68*	4.442–42.128
Total RVU value	1.012*	1.007–1.017	1.003	0.995–1.011	1.004	0.992–1.016	0.993	0.964–1.022
Operative time	1.004*	1.003–1.004	1.002*	1.001–1.003	1.005*	1.004–1.006	1	0.997–1.004
Propensity score	2.51*	1.662–3.792	2.117*	1.159–3.865	2.649	0.834–8.415	0.666	0.135–3.285
HL test	0.518		0.859		0.13		0.688	
C-statistic	0.744		0.691		0.805		0.879	

RVU, relative value unit; HL, Hosmer-Lemeshow.
*Significant value, $p < 0.05$.

ever, by its narrow scope and small sample size. The present study aims to contribute to the surgical training literature, with plastic surgery data representing a multiinstitutional setting and large sample size of 10,356 patients.

Our analysis focuses specifically on reconstructive plastic surgery procedures. This patient population was selected on the premise that controlling for surgical complexity through the integration of relative value unit data would allow us to better determine the independent impact of resident involvement on surgical outcomes. Therefore, although cosmetic procedures make up a component of many plastic surgeons' practices, we eliminated such operations from our analysis because they do not have assigned relative value units.

We found that for reconstructive plastic surgery procedures, residents participated in more complex cases and longer operations, involving a patient population skewed to increased preoperative risk factors, specifically, smoking status and obesity. Despite these biases, resident involvement had no impact on wound infection, graft/prosthesis/flap failure, or mortality. Furthermore, when compared in quintiles of similar surgical complexity as measured by relative value units and operative time, overall complication rates were statistically similar with or without a resident present. Only when a pattern of procedural bias emerged did overall complication rates differ. Our results echo recent studies that demonstrated modestly increased morbidity and similar or decreased mortality with intraoperative resident involvement. Kiran et al. reported overall complication rates of 7.5 percent versus 6.7 percent ($p < 0.001$) for resident involvement and no resident involvement, respectively.[9] Mortality, reoperation, and severe complications were unaffected by resident presence. Raval et al. reported that house staff involvement was associated with a 6.3 percent increase in morbidity for general and vascular surgical procedures and up to a 25.5 percent increase in morbidity for more complex procedures, such as pancreatectomy.[7] Tseng et al. looked at seven common elective general surgery procedures and found an overall increase in morbidity with resident involvement (OR, 1.14; 95 percent CI, 1.001 to 1.29), but no differences were statistically significant when stratified by procedure.[9]

As a retrospective review, our study was nonrandomized, resulting in a potential bias in procedures performed by the two cohorts. Specifically, total relative value units were a mean of 16.9 percent higher for cases involving a resident (18.30 ± 15.65 versus 15.66 ± 13.73; $p < 0.001$). Because plastic surgery is an expansive field, with operations ranging from microsurgery-based reconstruction to cosmetic procedures, different practice settings may lend themselves more to performing certain operations. Teaching hospitals are often tertiary care centers that receive referrals from nonteaching hospitals for rare or difficult cases. Substantiating this point, Khuri et al. found that, among the Veterans Affairs hospitals, teaching hospitals performed the majority of complex and high-risk procedures when compared with nonteaching Veterans Affairs hospitals.[37] Raval et al. noted in their study of the National Surgical Quality Improvement Program database that differences in outcomes with resident involvement were moderated when adjusted for hospital-level variation.[7] Moreover, residents are often recruited to "teaching cases," or those that are not considered routine or straightforward. Thus, to some degree, resident presence may have acted as a surrogate for case complexity.

The difference in relative value units between our two cohorts may have confounded our data because use of relative value units has been shown to correlate to increased complications. In a large, multiinstitutional study of general and vascular surgical procedures from the Veterans Affairs National Surgical Quality Improvement Program database, work relative value units were found to be significantly associated with increased risk of surgical-site infections, venous thromboembolic events, cardiac adverse events, and respiratory failure.[38–41] Indeed, in our subgroup analysis by propensity score quintile stratification, those subgroups that showed similar relative value units also demonstrated similar overall complication and wound infection rates. Conversely, when relative value units were found to be divergent between resident and nonresident cohorts, differences were observed in overall morbidity rate.

Operative time was 31.4 minutes longer for reconstructive cases when residents were present, and this may have both confounded and contributed to our findings. Although increased operative time may be an effect of resident training, this should not be assumed. Particularly in plastic surgery, a two-team approach, whereby donor and recipient sites are addressed simultaneously—one by the attending surgeon and one by the resident with attending surgeon supervision—may expedite operative time. Moreover, differences in case complexity as described above may have contributed to increased operative time. Kiran et al. suggested in their study of resident participation that the increased operative time associated with surgical training may explain the increase in superficial surgical-site infection and overall complication rates.[6] American College of Surgeons National Surgical Quality Improvement Program studies of laparoscopic procedures, open general surgery procedures, mastectomy without reconstruction, and lower extremity bypass have associated operative time greater than the 75th percentile with increased complication rates, surgical-site infection, and length of stay.[42–45] From the plastic surgery literature, operative time greater than 120 minutes is a recognized risk factor of surgical-site infection.[46,47] Thus, longer operative times in the resident cohort may account for some of the observed increase in complications.

Residents were also involved in cases with a higher percentage of smokers and obese patients. Smoking is a well-documented predictor of complications.[48,49] In one series of 1170 tissue expander/implant breast reconstructions, smoking was associated with an unadjusted OR of 2.4 (95 percent CI, 1.5 to 3.7) for the development of a complication and an unadjusted OR of 4.9 (95 percent CI, 1.8 to 12.9) for reconstructive failure.[48] Similarly, we found an increase in complications (adjusted OR, 1.317; 95 percent CI, 1.087 to 1.596) and graft/prosthesis/flap failure (adjusted OR, 2.103; 95 percent CI, 1.29 to 3.427). Obesity is also known to be associated with wound healing complications, with reported adjusted ORs as high as 11.84.[48,50] In our study, obesity was the strongest predictor of wound infection, with an adjusted OR of 1.864 (95 percent CI, 1.476 to 2.355). Conversely, there were more diabetic patients in the cohort without a resident present. Diabetes has been associated with wound healing complications and perioperative morbidity; however, the extent to which this effect is related to long-term preoperative glycemic control or acute perioperative glycemic control, variables not tracked in our study, remains unclear.[51–53] Finally, a higher percentage of patients who had received chemotherapy within the past 30 days were operated on by an attending surgeon alone. Chemotherapy has not been associated with surgical complications.[48] However, chemotherapy suggests a greater oncologic burden and was found to be the strongest predictor of mortality (adjusted OR, 13.68; 95 percent CI, 4.442 to 42.128). Although our multivariate analysis adjusted for these recognized preoperative factors, the difference in baseline characteristics may indicate an inherently different patient population for cases involving a resident.

Our study is not without limitations. Differences in case complexity, operative time, and preoperative comorbidities between the two cohorts have been mentioned. In addition, it is difficult to obtain specific details regarding resident involvement from the National Surgical Quality Improvement Program database. Because resident participation may range from retraction and skin closure to shared planning and autonomous execution, a record of resident presence does not necessarily equal resident participation. Few studies have attempted to account for the level of resident involvement. Itani et al. analyzed 610,660 cases from the Veterans Affairs National Surgical

Quality Improvement Program database from 1998 to 2004 and documented the impact of "level 3 supervision" on patient outcomes.[30] Level 3 supervision was designated when the attending surgeon was available but not physically present in the operating room. Although level 3 supervision accounted for only 2.69 to 8.72 percent of cases, the authors found no adverse effect of level 3 supervision.

Despite the robust statistical power of the National Surgical Quality Improvement Program database, there are also limitations related to the database itself. First, the database tracks only 30-day postoperative outcomes and may not capture long-term complications, such as prosthesis-related infections, which are conventionally tracked for a 1-year period, or hernia recurrence. Second, the database was queried for cases with plastic surgery as the primary service. Depending on how the primary procedure was listed, some combined cases may have been missed in our analysis, such as hernia repairs with general surgery, cranial reconstruction with neurosurgery, flap closures with vascular surgery, and so forth. Nonetheless, our approach limits the potential confounders imposed by a second service, particularly if resident involvement differed between the two services. Finally, cosmetic cases were excluded from analysis. Compared with reconstructive cases, cosmetic cases are generally low-morbidity, outpatient procedures. Because of the elective nature of cosmetic cases, there exists a selection bias from preoperative screening for high-risk conditions such as smoking status. Moreover, the Centers for Medicare and Medicaid Services does not assign relative value units to cosmetic cases, and thus data for this important covariate would have been missing in a large sample of the population.

CONCLUSIONS

Residency has the dual mission of training future physicians and also providing critical support for academic medical centers. The structured supervisory system based on graduated responsibility ensures that patient safety is maintained while educational goals are met. Our study is the first large-scale study to evaluate outcomes comparing resident involvement in plastic surgery cases. Using an independent, multicenter, prospectively maintained database, we were able to confirm that well-matched cohorts with—and without—resident presence had similar complication profiles. Moreover, even when residents were involved in comparably more complex cases with longer operative times, graft and flap failure and mortality remained similar.

John Y. S. Kim, M.D.
Division of Plastic and Reconstructive Surgery
Northwestern University
Feinberg School of Medicine
675 North St. Clair Street
Galter Suite 19-250
Chicago, Ill. 60611
jokim@nmh.org

REFERENCES

1. Dutta S, Dunnington G, Blanchard MC, Spielman B, DaRosa D, Joehl RJ. "And doctor, no residents please!" *J Am Coll Surg.* 2003;197:1012–1017.
2. Cowles RA, Moyer CA, Sonnad SS, et al. Doctor-patient communication in surgery: Attitudes and expectations of general surgery patients about the involvement and education of surgical residents. *J Am Coll Surg.* 2001;193:73–80.
3. Rosenthal MB, Landon BE, Normand SL, Frank RG, Epstein AM. Pay for performance in commercial HMOs. *N Engl J Med.* 2006;355:1895–1902.
4. The Affordable Care Act. Available at: http://www.healthcare.gov/law/full/. Accessed September 2, 2012.
5. Advani V, Ahad S, Gonczy C, Markwell S, Hassan I. Does resident involvement effect surgical times and complication rates during laparoscopic appendectomy for uncomplicated appendicitis? An analysis of 16,849 cases from the ACS-NSQIP. *Am J Surg.* 2012;203:347–351; discussion 351–352.
6. Kiran RP, Ahmed Ali U, Coffey JC, Vogel JD, Pokala N, Fazio VW. Impact of resident participation in surgical operations on post-operative outcomes: National surgical quality improvement program. *Ann Surg.* 2012;256:469–475.
7. Raval MV, Wang X, Cohen ME, et al. The influence of resident involvement on surgical outcomes. *J Am Coll Surg.* 2011; 212:889–898.
8. Scarborough JE, Pappas TN, Cox MW, Bennett KM, Shortell CK. Surgical trainee participation during infrainguinal bypass grafting procedures is associated with increased early post-operative graft failure. *J Vasc Surg.* 2012;55:715–720.
9. Tseng WH, Jin L, Canter RJ, et al. Surgical resident involvement is safe for common elective general surgery procedures. *J Am Coll Surg.* 2011;213:19–26; discussion 26–28.
10. Kauvar DS, Braswell A, Brown BD, Harnisch M. Influence of resident and attending surgeon seniority on operative performance in laparoscopic cholecystectomy. *J Surg Res.* 2006; 132:159–163.
11. Wilkiemeyer M, Pappas TN, Giobbie-Hurder A, Itani KM, Jonasson O, Neumayer LA. Does resident post graduate year influence the outcomes of inguinal hernia repair? *Ann Surg.* 2005;241:879–882; discussion 882–884.
12. Papandria D, Rhee D, Ortega G, et al. Assessing trainee impact on operative time for common general surgical procedures in ACS-NSQIP. *J Surg Educ.* 2012;69:149–155.
13. American College of Surgeons. Data collection, analysis, and reporting. Available at: http://site.acsnsqip.org/program-specifics/data-collection-analysis-and-reporting/. Accessed August 31, 2012.
14. American Society for Aesthetic Plastic Surgery. 15th annual cosmetic surgery national data bank statistics. 2012. Available at: http://www.surgery.org/sites/default/files/ASAPS-2011-Stats.pdf. Accessed August 30, 2012.

15. Henderson WG, Daley J. Design and statistical methodology of the National Surgical Quality Improvement Program: Why is it what it is? *Am J Surg.* 2009;198 (Suppl):S19–S27.
16. Dillon P, Hammermeister K, Morrato E, et al. Developing a NSQIP module to measure outcomes in children's surgical care: Opportunity and challenge. *Semin Pediatr Surg.* 2008; 7:131–140.
17. Davenport DL, Henderson WG, Khuri SF, Mentzer RM Jr. Pre-operative risk factors and surgical complexity are more predictive of costs than post-operative complications: A case study using the National Surgical Quality Improvement Program (NSQIP) database. *Ann Surg.* 2005;242:463–468; discussion 468–471.
18. Little RJ, Rubin DB. Causal effects in clinical and epidemiological studies via potential outcomes: Concepts and analytical approaches. *Annu Rev Public Health* 2000;21: 121–145.
19. D'Agostino RB. Propensity score methods for bias reduction in the comparison of a treatment to a non-randomized control group. *Stat Med.* 1998;17:2265–2281.
20. Paul P, Pennell ML, Lemeshow S. Standardizing the power of the Hosmer-Lemeshow goodness of fit test in large data sets. *Stat Med.* 2013;32:67–80.
21. Merkow RP, Bilimoria KY, Hall BL. Interpretation of the C-statistic in the context of ACS-NSQIP models. *Ann Surg Oncol.* 2011;18(Suppl 3):S295.
22. Cohen ME, Bilimoria KY, Ko CY, Hall BL. Development of an American College of Surgeons National Surgery Quality Improvement Program: Morbidity and mortality risk calculator for colorectal surgery. *J Am Coll Surg.* 2009;208:1009–1016.
23. Peduzzi P, Concato J, Kemper E, Holford TR, Feinstein AR. A simulation study of the number of events per variable in logistic regression analysis. *J Clin Epidemiol.* 1996;49:1373–1379.
24. Peduzzi P, Concato J, Feinstein AR, Holford TR. Importance of events per independent variable in proportional hazards regression analysis: II. Accuracy and precision of regression estimates. *J Clin Epidemiol.* 1995;48:1503–1510.
25. Bakaeen FG, Dhaliwal AS, Chu D, et al. Does the level of experience of residents affect outcomes of coronary artery bypass surgery? *Ann Thorac Surg.* 2009;87:1127–1133; discussion 1133–1134.
26. Baskett RJ, Buth KJ, Legaré JF, et al. Is it safe to train residents to perform cardiac surgery? *Ann Thorac Surg.* 2002;74:1043–1048; discussion 1048–1049.
27. Coates KW, Kuehl TJ, Bachofen CG, Shull BL. Analysis of surgical complications and patient outcomes in a residency training program. *Am J Obstet Gynecol.* 2001;184:1380–1383; discussion 1383–1385.
28. Emre AU, Cakmak GK, Tascilar O, et al. Complications of total thyroidectomy performed by surgical residents versus specialist surgeons. *Surg Today* 2008;38:879–885.
29. Hutter MM, Glasgow RE, Mulvihill SJ. Does the participation of a surgical trainee adversely impact patient outcomes? A study of major pancreatic resections in California. *Surgery* 2000;128:286–292.
30. Itani KM, DePalma RG, Schifftner T, et al. Surgical resident supervision in the operating room and outcomes of care in Veterans Affairs hospitals. *Am J Surg.* 2005;190:725–731.
31. Jan A, Riggs DR, Orlando KL, Khan FJ. Surgical outcomes based on resident involvement: What is the impact on vascular surgery patients? *J Surg Educ.* 2012;69:638–642.
32. Kazaure HS, Roman SA, Sosa JA. The resident as surgeon: An analysis of ACS-NSQIP. *J Surg Res.* 2012;178:126–132.
33. Nguyen CT, Babineau DC, Jones JS. Impact of urologic resident training on patient pain and morbidity associated with office-based cystoscopy. *Urology* 2008;71:782–786.
34. Sethi GK, Hammermeister KE, Oprian C, Henderson W. Impact of resident training on postoperative morbidity in patients undergoing single valve replacement. Department of Veterans Affairs Cooperative Study on Valvular Heart Disease. *J Thorac Cardiovasc Surg.* 1991;101:1053–1059.
35. Weaver KJ, Neal D, Hoh DJ, Mocco J, Barker FG II, Hoh BL. The "July phenomenon" for neurosurgical mortality and complications in teaching hospitals: An analysis of more than 850,000 neurosurgical patients in the nationwide inpatient sample database, 1998 to 2008. *Neurosurgery* 2012;71:562–571; discussion 571.
36. Patel SP, Gauger PG, Brown DL, Englesbe MJ, Cederna PS. Resident participation does not affect surgical outcomes, despite introduction of new techniques. *J Am Coll Surg.* 2010; 211:540–545.
37. Khuri SF, Najjar SF, Daley J, et al. Comparison of surgical outcomes between teaching and nonteaching hospitals in the Department of Veterans Affairs. *Ann Surg.* 2001;234:370–382; discussion 382–383.
38. Davenport DL, Ferraris VA, Hosokawa P, Henderson WG, Khuri SF, Mentzer RM Jr. Multivariable predictors of postoperative cardiac adverse events after general and vascular surgery: Results from the patient safety in surgery study. *J Am Coll Surg.* 2007;204:1199–1210.
39. Johnson RG, Arozullah AM, Neumayer L, Henderson WG, Hosokawa P, Khuri SF. Multivariable predictors of postoperative respiratory failure after general and vascular surgery: Results from the patient safety in surgery study. *J Am Coll Surg.* 2007;204:1188–1198.
40. Neumayer L, Hosokawa P, Itani K, El-Tamer M, Henderson WG, Khuri SF. Multivariable predictors of postoperative surgical site infection after general and vascular surgery: Results from the patient safety in surgery study. *J Am Coll Surg.* 2007; 204:1178–1187.
41. Rogers SO Jr, Kilaru RK, Hosokawa P, Henderson WG, Zinner MJ, Khuri SF. Multivariable predictors of postoperative venous thromboembolic events after general and vascular surgery: Results from the patient safety in surgery study. *J Am Coll Surg.* 2007;204:1211–1221.
42. Campbell DA Jr, Henderson WG, Englesbe MJ, et al. Surgical site infection prevention: The importance of operative duration and blood transfusion. Results of the first American College of Surgeons-National Surgical Quality Improvement Program Best Practices Initiative. *J Am Coll Surg.* 2008;207: 810–820.
43. Jackson TD, Wannares JJ, Lancaster RT, Rattner DW, Hutter MM. Does speed matter? The impact of operative time on outcome in laparoscopic surgery. *Surg Endosc.* 2011;25:2288–2295.
44. Tan TW, Kalish JA, Hamburg NM, et al. Shorter duration of femoral-popliteal bypass is associated with decreased surgical site infection and shorter hospital length of stay. *J Am Coll Surg.* 2012;215:512–518.
45. Davis GB, Peric M, Chan LS, Wong AK, Sener SF. Identifying risk factors for surgical site infections in mastectomy patients using the National Surgical Quality Improvement Program database. *Am J Surg.* 2013;205:194–199.
46. Andenaes K, Amland PF, Lingaas E, Abyholm F, Samdal F, Giercksky KE. A prospective, randomized surveillance study of postoperative wound infections after plastic surgery: A

study of incidence and surveillance methods. *Plast Reconstr Surg.* 1995;96:948–956.
47. Kompatscher P, von Planta A, Spicher I, et al. Comparison of the incidence and predicted risk of early surgical site infections after breast reduction. *Aesthetic Plast Surg.* 2003; 27:308–314.
48. McCarthy CM, Mehrara BJ, Riedel E, et al. Predicting complications following expander/implant breast reconstruction: An outcomes analysis based on preoperative clinical risk. *Plast Reconstr Surg.* 2008;121:1886–1892.
49. Selber JC, Kurichi JE, Vega SJ, Sonnad SS, Serletti JM. Risk factors and complications in free TRAM flap breast reconstruction. *Ann Plast Surg.* 2006;56:492–497.
50. Chen CL, Shore AD, Johns R, Clark JM, Manahan M, Makary MA. The impact of obesity on breast surgery complications. *Plast Reconstr Surg.* 2011;128:395e–402e.
51. Dronge AS, Perkal MF, Kancir S, Concato J, Aslan M, Rosenthal RA. Long-term glycemic control and postoperative infectious complications. *Arch Surg.* 2006;141:375–380; discussion 380.
52. Jackson RS, Amdur RL, White JC, Macsata RA. Hyperglycemia is associated with increased risk of morbidity and mortality after colectomy for cancer. *J Am Coll Surg.* 2012;214:68–80.
53. King JT Jr, Goulet JL, Perkal MF, Rosenthal RA. Glycemic control and infections in patients with diabetes undergoing noncardiac surgery. *Ann Surg.* 2011;253:158–165.