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Assessing the effort associated with teaching residents☆

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Summary *Background:* Intraoperative resident education is an integral mission of academic medical centers and serves as the basis for training the next generation of surgeons. The actual effort associated with teaching residents is unknown as it pertains to additional operative time. Using a large validated multi-institutional dataset, this study aims to quantify the effect of having a resident present in common plastic surgery procedures on operative time. Future directions for developing standardized methods to record and report teaching time are proposed, which can help inform prospective studies.
Study design: The 2006–2012 American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database was queried to identify seven isolated plastic surgical procedures that were categorized based on resident involvement and supervision. Linear regression models were used to calculate the difference in operative time with respect to resident participation while controlling for patient and operative factors.
Results: Resident involvement was associated with longer operative times for muscle flap trunk procedures (53 min, 95% CI = [25, 80], p-value = 0.0002) and breast reconstruction procedures with a latissimus dorsi flap (55 min, 95% CI = [22, 88], p-value = 0.001). For six of the seven surgeries evaluated, resident involvement was associated with longer operative times, as compared to no resident involvement.
Conclusion: Resident involvement is associated with an increase in operative time for certain plastic surgery procedures. This finding underscores the need for a mechanism to quantify the

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time and effort that the attending surgeons allocate toward intraoperative resident education. Further study is also necessary to determine the causal impact on patient care.

Introduction

Large academic medical centers are under increasing pressure to improve healthcare efficiency and patient outcomes. Hospitals, owing to this pressure, have started using lower risk educational technologies and methods, although actual operating room experience remains the most effective way to teach surgical residents.[1] For attending physicians to be able to provide quality education to surgical residents while promoting the highest level of patient care, it is important for physicians and academic institutions to accurately understand and value the effort dedicated to teaching them.

The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database provides reliable, risk-adjusted data based on 30-day postoperative surgical outcomes in both inpatient and outpatient settings.[2] While many NSQIP studies investigating trainee association with outcomes report on operative time and resident involvement,[3–18] the majority of them do not focus their primary analysis on this association for specific procedures of interest. Additionally, these studies do not define resident participation using the data acquisition techniques that we have proposed for the NSQIP database.

Currently, there is a paucity of studies in the NSQIP plastic surgery literature that examine the effect of resident participation on surgical outcomes. In this study, we utilized NSQIP to isolate each surgery of interest in order to ensure proper analysis of operation time for plastic surgery cases spanning reconstructive, cosmetic, and hand surgery. Furthermore, this study aimed to capture both resident and attending physician presence to identify whether certain surgical procedures have longer operating times with resident involvement. Insights derived from this study indicate a need to develop more robust models and interventions in order to more accurately quantify the effort dedicated to resident education.

Methods

Study population

Patients over the age of 18 who underwent a single plastic surgery procedure in the 2006–2012 NSQIP dataset were identified. The plastic surgery procedures examined in this study are shown in Table 1. These procedures were chosen to represent a variety of common plastic surgery procedures of varying complexity. Cases were included only if patients underwent a single plastic surgery procedure with only one primary current procedural terminology (CPT) code listed. Cases where a plastic surgery procedure was performed in addition to other or concurrent procedures (multiple CPT codes) were excluded from the analysis.

Definition of resident participation in plastic surgery

Resident participation in surgery was defined using two NSQIP variables: 1) the presence of an attending physician and the level of his/her involvement and 2) the presence and level of a resident involved. In NSQIP, the ATTEND or "level of residency supervision" variable has six levels ("Attending Alone," "Attending & Resident in OR," "Attending in OR," "Attending in OR Suite," "Attending Not Present, but Available," or "Not entered"), while the PGY or "highest level of resident surgeon" variable has 11 levels ranging from 0 to 11, with 0 corresponding to no resident present during a surgery and >0 corresponding to at least one resident present during a surgery (increasing values from 1 to 11 correspond to increase in resident training levels). As this was an associational study and the definition of PGY varies across institutions and within surgical specialties, the variable was dichotomized into 0 or 1.

First, a primary analysis was performed using our definition of resident participation, which incorporated both resident (PGY) and attending (ATTEND) involvement variables. If a resident was present during surgery, then resident participation equaled 1. In this case, an ATTEND variable that equaled "Attending & Resident in OR," "Attending in OR," "Attending in OR Suite," "Attending Not Present, but Available," or "Not entered" had to be concordant with a PGY variable between 1 and 11. If a resident was not present during a surgery, then resident participation equaled 0. In this case, the ATTEND variable that equaled "Attending Alone," "Attending in OR," or "Not entered" had to be concordant with a PGY variable that equaled 0. Cases for which the PGY and ATTEND variables were discordant were excluded from the analysis. For comparison, a sensitivity analysis was performed using only

Table 1 Examined CPT codes.

CPT	Procedure
19364	Unilateral breast free flap reconstruction (UBrFF)
19357	Unilateral breast tissue expander (UTE)
15830	Abdominoplasty (AbP)
15734	Muscle flap trunk (MFT)
19361	Breast reconstruction with lat dorsi flap (BrLD)
25111	Excision of ganglion cyst (Gang)
26615	Open treatment of metacarpal fracture (MtcFx)

the dichotomized PGY variable to define resident participation, 0 for no resident and 1–11 for resident presence. The PGY variable is the variable that is most commonly used to define resident involvement. Thus, this secondary analysis served as a mechanism to evaluate and substantiate our study's refined definition of resident participation.

Outcomes

The primary outcome that was analyzed in this study was operative time. In NSQIP, operative time is defined from skin incision to skin closure. Procedures with an operative time less than or equal to 2 min, or greater than 1000 min were excluded from the analysis. This exclusion did not apply to unilateral breast free flap reconstruction UBrFF (19364), which had a large median operation time of 464 min, compared to other procedures with a median operation time of less than 200 min.

The secondary outcome was overall complications, which included postoperative surgical and medical complications $\leq$30 days post surgery. Surgical complications included superficial and deep surgical-site infections, organ/space surgical-site infection, graft/prosthesis/flap failure, and wound disruption. Medical complications included pneumonia, unplanned intubation, pulmonary embolism, ventilation for over 48 h, progressive renal insufficiency, acute renal failure, urinary tract infection, stroke/CVS with neurological deficit, coma $>$48 h, peripheral nerve injury, cardiac arrest requiring CPR, myocardial infarction, requirement for blood transfusion, deep venous thrombosis, sepsis, septic shock, and return to the OR. Overall complications were coded as 0 if none of the complications were present and 1 if at least one complication was recorded.

Statistical analysis

Student's *t*-tests were used in the univariate analysis to examine the mean difference in operation time for each procedure in the presence or absence of residents. For the primary outcome of operation time, the empirical distribution was right skewed. However, we did not transform the data due to the large sample size and the goal was to estimate the average effort required for teaching plastic surgery procedures to residents. The association between operation time and resident participation and procedure types were evaluated using linear regression with an interaction for resident participation and procedure types. Similarly, logistic regression was used for the secondary outcome of overall complications. These models were adjusted for available confounders such as age, BMI, American Society of Anesthesiologists (ASA) classification, smoking status within the year of surgery, and diabetes (on oral hypoglycemic medications or insulin). A likelihood ratio test was applied to compare the goodness of fit of the interaction model and main effects model. Contrast statements were used to estimate and test the effect of resident participation within each procedure. There was an assumption of fixed variance of the error terms in the linear regression model; due to the violation of this assumption, HC3 standard errors were used in place of the ordinary least squares standard errors.[19] The Bonferroni correction for multiple testing was applied to conservatively adjust significance level and control for Type I error rate. The p-values associated with the resulting contrasts from the linear model should be compared to a significance level of 0.007 (0.05/7). Sensitivity analysis was conducted to examine whether the use of the secondary definition of resident participation impacted the conclusions of the study. All statistical analyses were performed using SAS software version 9.4 (SAS Institute Inc, Cary, NC) and R software version 3.3.1 (The R Foundation for Statistical Computing; Vienna, Austria).

Results

Characteristics of the patient cohort

A total of 4190 cases were eligible for inclusion in our study. However, 1936 cases did not fit our definition of resident participation because of discordance between the resident level and attending physician involvement variables. After excluding missing values from covariates, we had 1884 observations for the analysis of operative time and 1888 for the analysis of complications rates (Table 2).

The average age among cases with resident participation was 48.3 years (SD = 13.4) compared to 47.9 years (SD = 13.7) among cases without resident participation ($p = 0.80$). In four of seven procedures, the average age among patients who had a resident was larger than that among patients who did not have a resident. The average BMI among patients who had a resident in their surgery was 30.4 (SD = 8.3) compared to 27.9 (SD = 7.6) among those who did not have a resident ($p < 0.001$). The average ASA classification, which describes the patient's physical condition on a scale of 1 (normal healthy) to 5 (moribund), was between 2 and 3. The proportion of smokers in cases with and without a resident were similar (16.8% and 17.8%, respectively, $p = 0.72$) (Table 2).

A relative value unit (RVU) is defined as a pre-calculated value based on case complexity. The median RVU for procedures examined in this study was 18.37. Using this median RVU, we classified all CPTs with work RVU greater than or equal to the median as high RVU procedures and others as low RVU procedures. Among the high RVU procedures, two of four procedures showed that resident participation was significantly associated with increased operative time (MFT (15734) – 52.61 and BrLD (19361) – 55.17). UBrFF (19364) had the largest work RVU (42.49) and largest increase in operative time; however, this association was not significant ($p = 0.08$). Among the low RVU procedures, three procedures had an increase in mean operative time of less than 20 min. There was no significant association between the work RVU and operative time or resident participation.

Resident involvement is associated with increased operative time in plastic surgery procedures

In the primary analysis, the likelihood ratio test comparing the interaction model with the main effect model showed that the former provided a better fit to the data ($p < 0.001$), both including confounders. Thus, using

Table 2 Patient characteristics by resident participation.

Characteristics	No. res (N = 1052)	Res (N = 880)	Total (N = 1932)	p-value
CPT				<0.0001
MFT, 15734	85 (8.1%)	100 (11.4%)	185 (9.6%)	
AbP, 15830	440 (41.8%)	304 (34.5%)	744 (38.5%)	
UTE, 19357	233 (22.1%)	155 (17.6%)	388 (20.1%)	
BrLD, 19361	82 (7.8%)	57 (6.5%)	139 (7.2%)	
UBrFF, 19364	27 (2.6%)	102 (11.6%)	129 (6.7%)	
Gang, 25111	110 (10.5%)	90 (10.2%)	200 (10.4%)	
MtcFx, 26615	75 (7.1%)	72 (8.2%)	147 (7.6%)	
Age, mean (SD)	47.9 (13.7)	48.3 (13.4)	48.1 (13.5)	0.55
Missing	2 (0.19%)	0	2 (0.1%)	
BMI, mean (SD)	29.4 (7.6)	30.4 (8.3)	29.8 (7.9)	0.004
Missing	18 (1.71%)	23 (2.61%)	41 (2.12%)	
ASA, mean (SD)	2.1 (0.7)	2.2 (0.7)	2.1 (0.7)	<0.0001
Missing	1 (0.1%)	1 (0.11%)	2 (0.1%)	
Smoker	177 (16.8%)	156 (17.7%)	333 (17.2%)	0.64
Diabetes	103 (9.8%)	84 (9.5%)	187 (9.7%)	0.92

No. res = number of residents who participated in a surgery; Res = number of residents present in a surgery.
MFT = muscle flap trunk; AbP = abdominoplasty; UTE = unilateral breast tissue expander; BrLD = breast reconstruction with lat dorsi flap; UBrFF = unilateral breast free flap reconstruction; Gang = excision of ganglion cyst; MtcFx = open treatment of metacarpal fracture.
Mean and standard deviation (SD) are reported for continuous variables along with p-value from Student's *t*-tests and frequency and percentage for categorical variables along with p-value from χ^2 tests.

contrast statements on the interaction model controlling for age, BMI, ASA, smoking status, and diabetes, we obtained the estimates for the effect of resident participation within each procedure type (Table 3). The majority of plastic surgery cases involving residents were associated with longer operative times. We observed a statistically significant association between resident participation and operative times for MFT (15734) and BrLD (19361) procedures while controlling for confounders. Resident involvement in MFT (15734) procedures was associated with an average increase of 52 min in operative time compared to cases without a resident (95% CI = [25, 80], p = 0.0002). Similarly, resident involvement for BrLD (19361) was associated with an average increase of 55 min in operative time (95% CI = [22, 88], p = 0.001).

The largest increase in operative time with respect to resident involvement was 85 min for unilateral breast free flap reconstruction (UBrFF, 19364) (95% CI = [−9, 179], p = 0.08). It should be noted that only 20% of these cases did not involve a resident. Therefore, the significant difference in operative time observed for UBrFF (19364) may be in part due to the imbalance in sample sizes and large variability in operative time with respect to resident participation. Table 3 represents the ratio of operation time among residents to the operation time among no residents during plastic surgery. In the sensitivity analysis, these results were consistent with the primary findings presented here.

Resident involvement in plastic surgery cases may be associated with increased odds of complications

Complications were assessed with respect to resident participation, procedure type, the interaction between resident participation and procedure type while controlling for age, BMI, ASA class, smoking, and diabetes. The overall

Table 3 Unadjusted and adjusted analysis of operation time on resident participation.

CPT (RVU)	Unadjusted[a]				Adjusted[b]			
	Difference in means	p	Lower	Upper	Contrast	p	Lower	Upper
25111 (3.47)	4	0.08	−1	9	5	0.11	−1	12
26615 (6.53)	7	0.23	−4	18	10	0.11	−2	23
15830 (17)	10	0.15	−4	23	11	0.10	−2	24
15734 (19.74)	54	0.0001	27	81	53	0.0002	25	80
19357 (20.07)	−2	0.83	−18	14	−2	0.77	−19	14
19361 (22.69)	54	0.001	22	87	55	0.001	22	88
19364 (42.49)	88	0.06	−5	182	85	0.08	−9	179

[a] Student's *t*-tests were used for the unadjusted analysis of operation time on resident participation.
[b] Contrast estimates obtained from multivariable linear regression model with HC3 standard errors correcting for the variance of the error terms assumed in the linear regression model. Lower and upper denote the lower and upper limits of a 95% confidence interval, respectively. CPT code was ordered by work RVU from low to high.

complication rate for all seven procedures was 12% (232/1888). The complication rates for procedures with and without residents were 16.7% and 8.6%, respectively. Resident involvement in surgery was associated with increased odds of complications, controlling for procedure type, age, BMI, ASA class, smoking status, and diabetes (OR = 1.68, 95% CI = [1.24, 2.27], $p < 0.001$) (Table 4). Sensitivity analysis for complications using the secondary definition of resident participation showed results consistent with the primary findings.

To further assess the association between resident involvement and complications, a separate logistic regression analysis of complications was performed for each procedure. In this analysis, AbP (15830) was the only procedure with increased odds of complications with resident participation. On the basis of these results, all observations from AbP (15830) were excluded and the model was refitted using the other six procedures. An increased odds of complications with resident participation were still observed (OR = 1.51, 95% CI = [1.01, 2.23], $p = 0.04$). The inconsistencies of our model may affect the estimation and inference of resident effect on the complications in this study. In the interpretation of these associations, it is important to consider the limitations inherent to NSQIP and the design of our study.

Discussion

In a changing the healthcare scenario, the funding of hospital departments and divisions has become increasingly reliant on payment from clinical activities, which includes the education of surgical residents.[19] As a result, attending physicians have found themselves spending more time carrying out medical education, with little recognition and compensation for their efforts. To combat this issue, hospitals have started developing models that use RVUs, performance feedback from house staff, and pre-assigned teaching activity values to compensate attending physicians for their efforts.[20] Research, however, has shown that such models are limited because of the increasing financial burden of decreased reimbursements in medical practice, which often puts pressure on physicians to decrease teaching time to maximize clinical efficiency.[20] Our study is the first to use data from a large validated database to guide the development of new models that account for operative time to assign increased emphasis and worth toward a service that has been undervalued.

Table 4 Parameter estimates, 95% Wald confidence intervals (CIs), and p-values from the logistic regression model that assessed the association between resident involvement in surgery and postoperative complications while controlling for procedure type, age, BMI, ASA class, smoking status, and diabetes.

Variables	OR (95% CI)	p-value
Resident	1.68 (1.24, 2.27)	<0.001
15734	Reference	
15830	0.48 (0.3, 0.77)	0.002
19357	0.54 (0.32, 0.89)	0.016
19361	0.68 (0.36, 1.26)	0.218
19364	1.41 (0.81, 2.45)	0.226
25111	0.08 (0.02, 0.27)	<0.0001
26615	0.14 (0.04, 0.48)	0.002
Age	1 (0.99, 1.01)	0.796
BMI	1.03 (1.02, 1.05)	<0.001
ASA	2.02 (1.55, 2.65)	<0.0001
Smoker	0.92 (0.6, 1.42)	0.718
Diabetes	0.86 (0.54, 1.36)	0.512

Current evidence derived from NSQIP indicates that resident involvement in surgical cases may be associated with increased operative time.[3–18] While some earlier studies also suggest resident participation to have no impact on 30-day postoperative complications,[1,2,13,14,16,21–30] recent studies have observed a significant association between these two variables.[12,15] The first study in plastic surgery, by Patel et al., to examine these associations found that complication rates remained largely unchanged with resident involvement. This study, however, focused exclusively on bilateral reduction mammoplasty cases performed by a single-institution surgeon and was limited by its small sample size.[1] For a better comprehension of these associations, Fischer et al. investigated and evaluated a large NSQIP dataset; they found that resident participation was associated with higher complication rates.[15] Their study was advantageous in its use of NSQIP; however, it only detailed outcomes for breast reduction surgery. Our study contributes to the currently available body of literature by analyzing a large range of plastic surgery procedures that vary in complexity.

In another study, Jordan et al. utilized NSQIP plastic surgery dataset to explore the same associations while controlling for procedure complexity, but looked only at reconstructive surgical procedures. Their study found resident involvement to be associated with increased operative time and did not find sufficient evidence to suggest a difference in complication rates between cases with and without residents. While this study queried NSQIP for plastic surgery cases as the primary service, its sample included cases with combined and secondary surgeries and found resident involvement as an individual variable.[14] A more recent examination of the NSQIP database examining only outpatient plastic surgery procedures found similar results.[31] While their study was advantageous in that it utilized two NSQIP variables to study resident participation, it did not exclude the discordant variables from its sample cases and retained cases with combined and secondary surgeries. For a more robust investigation, we excluded cases that had discordance between ATTEND and PGY variables and used a secondary definition of resident participation to rigorously characterize trainee impact on postoperative outcomes. Additionally, we excluded cases that had multiple additional CPT codes to control for concurrent surgeries that could affect the results of operative time and complications.

In this study, the majority of plastic surgery cases involving residents were associated with longer operative times, with the exception of unilateral tissue expander cases. These results are consistent with those obtained from previous studies, providing further evidence that intraoperative resident participation may be associated

with increased operative time. Our study showed that unilateral breast free flaps, breast reconstruction with a latissimus dorsi flap, and muscle flap trunk procedures took an average of 85, 55, and 52 minutes longer, respectively, when a resident was involved. Accordingly, these procedures performed in 1 week accounted for 192 additional minutes devoted to teaching residents in the operating room, compared to similarly matched patients. Physicians could use these mean values or mean values derived from large pooled datasets to account for the variability in their operating times and assess their dedicated teaching time accordingly.

This study also has its limitations, mainly related to its retrospective nature. NSQIP is limited in that it does not provide information about the hospital where surgical cases are performed. Teaching hospitals are often more likely to perform longer, higher risk cases that make for good learning opportunities for the residents,[32–34] which may alone account for the observed longer operative times and complication rates. NSQIP is also limited in that it does not provide information about the experience level of the attending physician nor any information about the number of other attending surgeons involved with the primary case. Additionally, the database does not specify whether the primary attending surgeon was present for all aspects of the case or if he/she was present only for a period of time during the case. Lastly, while NSQIP provides information about resident training level, it only pertains to the highest PGY resident involved in the surgery and excludes information about the number of other residents present.

While the NSQIP database is unique in its depth and considered the gold standard in surgical outcomes research, operative time is known to be affected by patient and procedural confounders not captured in the database.[15] For example, in this study, unilateral breast tissue expander placement was the only procedure that showed a decreased operative time with a resident. This finding may be attributed not only to trainee involvement, but also to the unilateral nature of this procedure allowing for increased attending supervision over the operative site, as compared to bilateral or tissue transfer procedures. Additionally, this study found that patients with a higher ASA classification and BMI were more likely to have residents involved in their surgeries. According to the literature, these baseline characteristics are associated with higher rates of complications[32,35–39]; therefore, they may be contributing to the observed association between resident participation and operative time and complications. Prospective interventions that take these cofactors into account are necessary and can pave the way for future studies.

Conclusions

Physicians are motivated to dedicate time and effort toward teaching to help better the next generation of physicians; however, with the dual mission of ensuring patient safety and meeting education goals, physicians' teaching efforts are often undervalued. Using a large, risk-adjusted, multicenter database, this study is the first to measure the effect of resident involvement on operative time and its potential correlation with the effort involved in teaching plastic surgery residents. Confirming that resident involvement in plastic surgery is associated with increased operative time, our study is expected to guide the development of models that more accurately compensate physicians for their teaching efforts.

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Conflict of interest

There are no conflicts of interest to declare.

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