The Laryngoscope
© 2015 The American Laryngological,
Rhinological and Otological Society, Inc.

The Impact of Resident Involvement on Otolaryngology Surgical Outcomes

Brittany L. Vieira, BS; David J. Hernandez, MD; Charles Qin, BA; Stephanie S. Smith, MD; John Y. S. Kim, MD; Jose C. Dutra, MD

Objectives/Hypothesis: Intraoperative experience is an essential element of surgical training, but has the potential to impact patient outcomes. The purpose of this study was two-fold: 1) to evaluate the effect of resident involvement on morbidity and mortality following otolaryngology procedures and 2) to examine the influence of resident training level on the same outcomes.

Study Design: Retrospective cohort study.

Methods: This study reviewed 2,320,920 patients captured in the 2005 to 2012 National Surgical Quality Improvement Program databases to identify surgical otolaryngology cases. Outcomes of interest included surgical complications, medical complications, and mortality. Cases with and without resident involvement were propensity matched (caliper = 0.2) to account for nonrandomized assignment, and data were subject to multivariate logistic regression analyses.

Results: Residents participated in 38.4% of the 20,307 cases identified. Cases with resident involvement demonstrated longer operative duration (178.8 minutes vs. 80.1 minutes, $P < .001$), increased surgical complexity (23.5 relative value units [RVU] vs. 12.4 RVU, $P < .001$) and greater overall morbidity burden. Logistic regression analyses of the matched cohort revealed that resident participation did not independently increase morbidity (odds ratio [OR] = 0.969, $P = .751$) or mortality (OR = 0.893, $P = .758$). A separate logistic regression analysis of the unmatched cohort using resident postgraduate year showed that training level did not confer differential risk to patients.

Conclusions: Our data indicate that resident involvement does not increase the risk of morbidity or mortality, and that trainees are being assigned to appropriate cases for their level of experience. These findings suggest that the contemporary paradigm of graduate otolaryngology surgical education does not negatively impact patient outcomes.

Key Words: Resident training, medical education, surgical outcomes, National Surgical Quality Improvement Program, 30-day complications.

Level of Evidence: 2c

***Laryngoscope*, 126:602–607, 2016**

INTRODUCTION

Large tertiary medical centers are known for their high surgical volume, innovative technology, and medical expertise, to which surrounding hospitals refer their most complex cases. These tertiary centers are often affiliated with large, academic institutions that provide an infrastructure for medical education. Though this educational environment plays a supportive role in patient care, it has the potential to negatively impact patient outcomes as relatively inexperienced physicians are incorporated into healthcare teams.

Medical training at all levels entails a system of gradually increased clinical independence and responsibility. Academic institutions depend upon attending physicians to effectively balance their primary role of patient advocates with that of educators of the next generation of physicians. This balance is particularly important in the training of surgical residents, where the educational paradigm is based on supervised involvement in operative cases.[1] If this experiential education is not appropriately titrated, surgical training has the potential to directly harm the patient.

The medical community at large has expressed a renewed interest in the impact of resident training on patient outcomes due to the implementation of resident work-hour restrictions.[2] The mandates are of unique concern to the surgical community, as sound training in surgical skills necessitates direct operating room experience, potentially limited by the 80-hour workweek and subsequent curriculum revisions.[3] Accordingly, previous studies have attempted to assess the safety of resident training paradigms and the effect of resident participation on outcomes in a variety of surgical specialties, with conflicting findings.[4–25] Despite the increased interest of the surgical community at large, there is a paucity of literature evaluating the impact of resident involvement

Additional Supporting Information may be found in the online version of this article.

From the Division of Plastic and Reconstructive Surgery (B.L.V., C.Q., J.Y.S.K.) and the Department of Otolaryngology–Head and Neck Surgery (D.H., S.S.S., J.C.D.), Northwestern University Feinberg School of Medicine, Chicago, Illinois, U.S.A.

Editor's Note: This Manuscript was accepted for publication October 27, 2014.

The authors have no funding, financial relationships, or conflicts of interest to disclose.

Send correspondence to Jose Carlos Dutra, MD, Department of Otolaryngology–Head and Neck Surgery, Northwestern University, Feinberg School of Medicine, NMH/Galter Room 15-200, 675 North St. Clair Street, Chicago, IL 60611. E-mail: j-dutra@northwestern.edu

DOI: 10.1002/lary.25046

on morbidity and mortality following otolaryngologic procedures. In this analysis, we aim to assess the impact of resident participation in a subset of operative procedures performed by otolaryngologists using a validated, prospectively planned surgical outcomes database representing over 400 institutions across the United States. The purpose of our study was two-fold: 1) to evaluate the effect of resident involvement on morbidity and mortality following otolaryngology procedures and 2) to examine the influence of resident experience, as represented by resident postgraduate year (PGY) on the same outcomes.

MATERIALS AND METHODS

Data Acquisition

We performed a retrospective analysis of 2,320,920 patients captured in the 2005 to 2012 American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) data registry. Data collection methods have been previously described in detail.[26,27] In brief, trained research nurses independently abstract data using a systematic sampling of surgical operations. According to this protocol, 240 Health Insurance Portability and Accountability Act of 1996-compliant variables are prospectively collected for each encounter within the database. Collected data are subject to random audits, providing a high fidelity, standardized database that has demonstrated inter-rater disagreement rates of less than 1.8%.[28] Definitions of data points and further information can be found at the program's website (http://site.acsnsqip.org).

Patient Population

We identified all adult patients who had an otolaryngologist reported as the primary surgeon. Patients who underwent one of eight common otolaryngology procedures were identified using Current Procedural Terminology codes (see Supporting Table I in the online version of this article). The ACS-NSQIP data registry captures whether an attending surgeon operated with or without resident participation; for cases with resident participation, resident PGY was recorded. Patients with incomplete data regarding resident involvement or preoperative characteristics were excluded from analysis.

Outcomes

Patients were followed for 30 days after the index operation to assess postoperative outcomes.[26] We combined captured ACS-NSQIP registry data points to characterize our primary outcomes of interest: overall morbidity, surgical complications, medical complications, and mortality. We defined overall morbidity as having one or more adverse events within 30 days. Surgical complications included superficial surgical-site infection (SSI), deep SSI, organ/space SSI, graft/prosthesis failure, or wound dehiscence. Medical complication was defined as having one or more of the following postoperative adverse events: pneumonia, unplanned intubation, pulmonary embolism, ventilator dependence, renal failure, renal insufficiency, urinary tract infection, coma, stroke, peripheral neurologic deficiency, cardiac arrest, myocardial infarction, transfusion, deep venous thrombosis, and sepsis or septic shock. Operative time was defined by skin incision to skin closure, and mortality was defined as death within 30 days, regardless of etiology.

Risk Adjustment Variables

Variables considered for potential confounding include demographic data, medical comorbidities, and operative characteristics. Patient demographics include age, sex, inpatient/outpatient status, and the American Society of Anesthesiology (ASA) classification. General comorbidities, pulmonary risk factors, cardiac risk factors, and neurologic risk factors were tracked, as were behavioral risk factors such as alcohol abuse and smoking. Operative characteristics include procedure type, wound classification, emergent status, and operative time. Additionally, total case relative value units (RVU) was used to account for inherent differences in risk and complexity of cases.[29–31] To adjust for differences in operative time between procedure types, a z score was calculated for each patient by taking the difference between the case operative time and the mean for the procedure undergone and dividing by the standard deviation.

TABLE I.
Comparison of Mean Operative Time z-Score.*

	No Resident	Resident	*P* Value
Laryngectomy	−0.234	0.179	<.001
Neck dissection	−0.006	0.004	.878
Tongue/floor of mouth	−0.172	0.152	<.001
Palate	−0.149	0.158	<.001
Salivary gland	−0.091	0.092	<.001
Tonsillectomy/adenoidectomy	−0.129	0.129	<.001
Thyroidectomy	0.063	0.069	<.001

*Calculated based on index operation Current Procedural Terminology code.

Propensity scores were calculated to adjust for selection bias between resident and nonresident groups.[32] The propensity score represented the conditional probability of resident participation in each case based on patient characteristics and operative factors. These values were used to pair cases with resident participation to cases without resident participation in a one-to-one nearest neighbor manner.[33] We utilized a caliper-matching technique with a 0.02 tolerance in our algorithm to avoid inferior matches.[34] Literature shows that this methodology effectively adjusts for baseline differences between dissimilar cohorts and minimizes bias secondary to nonrandom assignment.[33–37]

Statistical Analysis

Bivariate analyses were used to compare cases with resident involvement to those without resident involvement. Descriptive statistics and outcomes were analyzed in the unmatched cohorts using χ^2 tests for categorical variables and unpaired Student t tests for continuous variables, and in the unmatched cohort using McNemar's tests and paired sample Student t tests. Multivariate logistic regressions were performed on the matched cohort to calculate the adjusted odds ratio (OR) for overall morbidity, surgical complications, medical complications, and mortality. Additionally, we stratified cases by procedure type and employed additional multivariate logistic regression analyses within each of the eight classifications.

A subgroup analysis of all cases with resident involvement assessed the potential impact of resident experience level on morbidity and mortality. Cases with resident participation were stratified into junior resident (PGY 1–3), senior resident (PGY 4–5), and fellow (PGY >5) involvement. Preoperative and perioperative variables, as well as operative time and rates of morbidity and mortality were compared among trainee levels using χ^2 and Student t tests, as appropriate. All preoperative variables with $P < .1$ were identified as possible predictors of clinical outcomes and were included in the multivariate logistic

15314995, 2016, 3, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/lary.25046 by Columbia University Libraries, Wiley Online Library on [08/03/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE II.
Multivariate Logistic Regression Analysis of Resident Involvement as an Independent Predictor of Morbidity and Mortality.

	OR	95% CI	*P* Value
Overall morbidity*	0.969	0.796–1.18	.751
Surgical complication	0.911	0.667–1.245	.599
Medical complication	0.982	0.779–1.239	.880
Mortality	0.893	0.437–1.828	.758

*Overall morbidity is defined as a surgical complication and/or a medical complication.
CI = confidence interval; OR = odds ratio.

regression models with total RVU, operative time, and propensity score. Total RVU was included to control for surgical complexity,[36,37] whereas propensity scores were included as a covariance adjustment to help minimize confounding between the two cohorts.[10,33] Hosmer-Lemeshow and C-statistic were calculated for all logistic regression models to assess goodness of fit and discriminatory capability, respectively.[38,39] All analyses were performed using SPSS version 21.0 (IBM Corp., Armonk, NY).

RESULTS

Population Demographics

A total of 20,307 patients underwent one of eight common otolaryngology procedures (see Supporting Table I in the online version of this article). Data representing patient demographics, comorbidities, and clinical characteristics are listed in Supporting Tables II and III in the online version of this article. Resident involvement was identified in 7,790 (38.4%) of cases, and the most common procedure classifications included thyroidectomy (32.0%) and tonsillectomy (31.4%).

Cases with resident participation involved older patients (52.46 years vs. 44.26 years, $P < .001$), with significantly higher comorbidity burden (see Supporting Table II in the online version of this article). Our analysis also demonstrated that residents tended to participate in more complex cases. Specifically, resident involvement was more common in inpatient and emergent patients, as well as those with higher ASA class and prior operations (see Supporting Table III in the online version of this article) (all $P < .001$). Surgical complexity as represented by total RVUs was also significantly higher in cases with resident involvement (23.51 vs. 12.36, $P < .001$) and operative time was, on average, more than twice as long (178.57 minutes vs. 80.07 minutes, $P < .001$). Analysis of standardized operative times using primary procedure-adjusted z-scores is displayed in Table I and shows significantly longer operative times for residents in all procedure category, with the exception of neck dissections. The 7,790 cases with resident involvement had higher unadjusted rates of morbidity (see Supporting Table III in the online version of this article) (7.3% vs. 2.4%, $P < .001$) and mortality (0.3% vs. 0.2%, $P = .016$), when compared to cases without resident involvement.

Propensity Scoring and Matched Bivariate Analysis

Of the 20,307 patients who met study inclusion criteria, 12,914 patients (6,457 from each of the resident and nonresident cohorts) were included in the matched analyses. Bivariate analyses demonstrated a high degree of similarity between matched cases, confirming that propensity matching eliminated significant preoperative differences between cohorts (see Supporting Table II in the online version of this article). Perioperatively, resident involvement remained associated with inpatient cases, greater surgical complexity, prolonged operative time, and higher rates of medical complications (see Supporting Table III in the online version of this article) (all $P < .01$). The rates of surgical complications and mortality did not significantly differ based on resident involvement in the matched analyses (all $P > .05$).

Logistic Regression Analysis

After controlling for patient characteristics, comorbidities, and surgical complexity using multivariate logistic regression models, our data indicate that resident involvement did not independently increase the risk overall morbidity, surgical complications, medical complications, or mortality (Table II, all $P > .05$). A subgroup analysis of morbidity within each of the eight

TABLE III.
Multivariate Logistic Regression Analysis of Resident Involvement as an Independent Predictor of Complications Within Each Procedural Category.

	Overall Morbidity*			Surgical Complication			Medical Complication		
	P Value	OR	95% CI	*P* Value	OR	95% CI	*P* Value	OR	95% CI
Laryngectomy	0.883	1.042	0.599–1.814	0.814	1.107	0.476–2.573	0.922	1.029	0.578–1.833
Neck dissection	0.845	0.95	0.57–1.585	0.265	0.617	0.264–1.443	0.999	0.999	0.562–1.777
Tongue/floor of mouth	0.525	1.191	0.695–2.039	0.881	1.056	0.516–2.161	0.279	1.481	0.727–3.017
Palate	0.802	0.911	0.438–1.892	0.381	0.624	0.217–1.793	0.602	1.313	0.473–3.644
Salivary gland	0.189	0.717	0.436–1.178	0.882	0.954	0.508–1.789	0.071	0.482	0.218–1.064
Tonsillectomy/adenoidectomy	0.653	1.167	0.595–2.289	0.986	1.014	0.202–5.100	0.601	1.219	0.581–2.557
Thyroidectomy	0.952	0.988	0.67–1.458	0.864	1.075	0.467–2.475	0.601	1.219	0.581–2.557

*Overall morbidity is defined as a surgical complication and/or a medical complication.
CI = confidence interval; OR = odds ratio.

15314995, 2016, 3, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/lary.25046 by Columbia University Libraries, Wiley Online Library on [08/03/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE IV.
Comparison of Complication Rates Among Junior, Senior, and Fellow Resident Education Levels.

	Junior, n = 2550		Senior, n = 3570		Fellow, n = 1332		*P* Value
Overall morbidity	115	4.5%	282	7.9%	157	11.8%	<.001
Surgical complication	86	3.4%	223	6.2%	126	9.5%	<.001
Medical complication	39	1.5%	108	3.0%	50	3.8%	<.001
Mortality	3	0.1%	18	0.5%	5	0.4%	.040
Operative time, min	143.68 ± 138.09		190.77 ± 169.91		229.70 ± 191.10		<.001

procedure classifications further corroborated these findings (Table III, all $P > .05$).

As shown in Table IV, unadjusted rates of morbidity and mortality, as well as operative duration, increased as residents progressed through training. However, as shown in Table V, once we controlled for confounding variables using multivariate logistic regression analyses, the data demonstrate that resident training level does not differentially impact morbidity or mortality.

DISCUSSION

Residency programs have the dual purpose of training future physicians while also providing critical support for patient management at academic medical centers. Surgical residents acquire skills largely through experiential learning in the operating room. This intraoperative experience is an essential component of surgical training; however, as relatively inexperienced yet integral members of the healthcare team, residents have the potential to negatively impact patient care. It is therefore important to evaluate patient outcomes following surgical procedures with resident participation. Previous authors have enumerated the risks associated with resident involvement in a variety of surgical subspecialties, including cardiothoracic, pediatric, neurosurgery, gynecology, urology, vascular, and general and plastic surgery; however, the literature fails to concede a pattern for surgical training at large.[4–25] Recent studies yielded conflicting findings, cumulatively demonstrating that the impact of resident participation remains siloed within each surgical specialty. Despite the importance of specialty-specific data and the trending interest of the surgical community, there has been limited evaluation of the impact of resident participation on patient outcomes in otolaryngology. The current literature presents only a few small, single institutional studies that evaluate thyroidectomy outcomes.[40–43] Results suggest that participation of otolaryngology surgical residents does not increase the risk of complications; however, the data are limited by the sole focus on thyroidectomy and small cohorts.

The present study contributes to the literature an analysis of multi-institutional otolaryngologic surgical outcomes data from 20,307 patients nationwide. It represents the largest multi-institutional cohort of otolaryngologic surgical procedures to date, and the first investigation of the potential impact of resident training on patient outcomes. Our unadjusted analyses suggest that resident involvement is associated with greater patient morbidity and mortality; however, after controlling for higher rates of resident involvement in more complex cases and longer operations, as well as bias related to an attending's selection of "teaching cases," our results demonstrate that resident participation is not associated with increased morbidity or mortality.

Our results demonstrate that 38.5% of otolaryngologic surgery cases involved resident participation. Because academic hospitals tend to treat and manage sicker patients, it is not surprising that in our study resident participation was associated with patients who had greater comorbidity burden, and by extension, cases with inherently greater risk of morbidity and mortality.[44] Additionally, attending surgeons often value these complex patients as learning opportunities for residents, and thus are more likely to incite their participation in such cases.

Considering these two factors, the potential for selection bias and confounding is extremely high. Propensity score analysis is a validated method shown to control for such selection biases.[33] Similar to recent literature in other surgical subspecialties, we employed propensity matching and propensity-adjusted multivariate logistic regression to control for the nonrandom assignment of resident involvement in surgical cases.[10,21,22] Once identifiable biases associated with resident participation were

TABLE V.
Multivariate Logistic Regression Analysis of Resident Training Level as a Differential Predictor of Morbidity.

	Overall Complication			Surgical Complication			Medical Complication		
	P Value	OR	95% CI	*P* Value	OR	95% CI	*P* Value	OR	95% CI
Junior level resident	Reference			Reference			Reference		
Senior level resident	.248	1.167	0.898–1.517	.248	1.264	0.849–1.882	.278	1.181	0.875–1.594
Fellow level resident	.7	1.064	0.777–1.456	.683	1.103	0.69–1.763	.81	0.957	0.669–1.369

CI = confidence interval; OR = odds ratio.

15314995, 2016, 3, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/lary.25046 by Columbia University Libraries, Wiley Online Library on [08/03/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

controlled for using these methodologies, our results indicate that resident participation alone did not increase the risk of morbidity and mortality. Our findings suggest that graduate surgical education does not worsen outcomes with respect to the eight major surgery classifications studied herein. We hope that these findings will help to alleviate patient concerns regarding trainee participation, and also set in motion efforts to further examine the structures and processes of surgical care provided by residents.

Additionally, investigation of the relationship between operative time and resident participation showed that surgical cases with resident participation were significantly longer than those without resident participation (80.07 minutes vs. 178.57 minutes, all $P < .001$), likely reflecting the inherent time of teaching and learning in the operating room, as well as the increased complexity of "teaching cases." These results support the conclusions of a growing body of literature evaluating the economics and effectiveness of surgical residency training.[4–12,44–47] Prolonged operative times have important implications for healthcare quality and cost, as well as patient safety. From a fiscal and administrative standpoint, longer surgical durations necessitate higher direct and indirect operative costs to the institution, underscoring the importance of subsidized surgical graduate education and suggesting that teaching institutions should be held to different cost baselines than nonteaching hospitals. Of particular concern for patient safety, prolonged operative times have been demonstrated to predict higher complication rates—particularly surgical site infection, the complication with the greatest occurrence among procedures in our study.[48] Our analyses demonstrated that prolonged operative time was indeed independently associated with of overall morbidity (OR: 1.323, $P < .05$) Whether resident involvement is associated with longer operative times or is an independent predictor of longer operative times must be confirmed prospectively and represents an interesting topic for future research given the implications for patient safety.

Finally, our evaluation of the impact of resident training level on outcomes demonstrated that as residents progress in their training from junior residents (PGY 1–3) to fellows (PGY >5), incidence of morbidity and mortality, as well as operative time steadily increased. This suggests that as residents progress in their training, they are likely participating in more advanced and complicated cases. Once we controlled for case and patient variation, our data demonstrate that resident training level did not confer differential risk to the patient, implying that attending supervision is adequate and that residents are being assigned to appropriate cases for their skill set. Importantly, the findings of this study suggest that the current teaching paradigm effectively balances patient safety and resident education on a national level.

Our study is not without limitations. One limitation discussed throughout the study concerns the disproportionate complexity and comorbidity burden of patients receiving care at academic hospitals, as well as the potential for selection bias in these "teaching cases". We attempted to control for this confounding with propensity-score matching, which balanced dissimilarities between cohorts. Additionally, although most adverse events are likely captured within the 30-day postoperative period, those that occurred later were missed. Furthermore, the NSQIP database was prospectively planned for universal applicability in all surgical specialties; therefore, some complications unique to the studied procedures may not have been captured. It should also be kept in mind that this study evaluated eight major otolaryngologic surgery classifications, and although this group yields a representative analysis, it is not entirely inclusive of all otolaryngologic procedures. Despite these limitations, we believe that ACS-NSQIP offers high-fidelity surgical outcomes data and that our findings are important to share with the otolaryngology community.

CONCLUSION

Data presented in the current study suggest that the contemporary paradigm of graduate otolaryngology surgical education does not negatively impact patient outcomes. Using a validated multi-institutional database, the authors were able to confirm that even in well-matched patient cohorts, residents were involved in comparatively more complex cases with longer operative durations. The data demonstrate that resident participation does not increase the risk of morbidity or mortality, and that residents are being assigned to appropriate cases for their level of skill. Further studies to identify causes of patient morbidity and subsequent prevention strategies in surgical teaching environments are warranted.

BIBLIOGRAPHY

1. Chung RS. How much time do surgical residents need to learn operative surgery? *Am J Surg* 2005;190:351–353.
2. Curet MJ. Resident work hour restrictions: where are we now? *J Am Coll Surg* 2008;207:767–776.
3. Privette AR, Shackford SR, Osler T, Ratliff J, Sartorelli K, Herbert JC. Implementation of resident work hour restrictions is associated with a reduction in mortality and provider-related complications on the surgical service: a concurrent analysis of 14,610 patients. *Ann Surg* 2009; 250:316–321.
4. Hernández-Irizarry R. Impact of resident participation on laparoscopic inguinal hernia repairs: are residents slowing us down? *J Surg Educ* 2012;69:746–752.
5. Naiditch JA, Lautz TB, Raval MV, Madonna MB, Barsness KA. Effect of resident postgraduate year on outcomes after laparoscopic appendectomy for appendicitis in children. *J Laparoendosc Adv Surg Tech A* 2012;22:715–719.
6. 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 16,489 cases from the ACS-NSQIP. *Am J Surg* 2012;203:347–351.
7. 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.
8. Bakaeen FG. Does the level of experience of residents affect outcomes of coronary artery bypass surgery? *Ann Thorac Surg* 2009;87:1127–1133.
9. 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.
10. Matulewicz RS, Pilecki M, Rambachan A, Kim JY, Kundu SD. Impact of resident involvement on urological surgery outcomes: an analysis of 40,000 patients from the ACS NSQIP database. *J Urol* 2014;192:885–890.
11. Herrick BW, Yap RL. It is safe to teach residents laser prostate surgery in the private practice setting. *Urology* 2013;81:629–632.

15314995, 2016, 3, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/lary.25046 by Columbia University Libraries, Wiley Online Library on [08/03/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

12. Pugley AJ, Gao Y, Martin C, Callaghan J, Weinstein S, Marsh L. The effect of resident participation on short-term outcomes after orthopaedic surgery. *Clin Orthop Relat Res* 2014;472:2290–2300.
13. Krell RW, Birkmeyer NJ, Reames BN, Carlin AM, Birkmeyer JD, Finks JF; Michigan Bariatric Surgery Collaborative. Effects of resident involvement on complicates rates after laparoscopic gastric bypass. *J Am Coll Surg* 2014;218:253–260.
14. Iannuzzi JC. Outcomes associated with resident involvement in partial colectomy. *Dis Colon Rectum* 2013;56:212–218.
15. Baskett RJ. Is it safe to train residents to perform cardiac surgery? *Ann Thorac Surg* 2002;74:1032–1038.
16. 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.
17. 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.
18. Iannuzzi JC, Chandra A, Rickles AS, et al. Resident involvement is associated with worse outcomes after major lower extremity amputation. *J Vasc Surg* 2013;58:827–831.
19. Kern SQ, Lustik MB, McMann LP, Thibault GP, Sterbis JR. Comparison of outcomes after minimally invasive versus open partial nephrectomy with respect to trainee involvement utilizing the American College of Surgeons National Surgical Quality Improvement Program. *J Endourol* 2014;28:40–47.
20. Schoenfeld AJ, Serrano JA, Waterman BR, Bader JO, Belmont PJ Jr. The impact of resident involvement on post-operative morbidity and mortality following orthopaedic procedures: a study of 43,343 cases. *Arch Orthop Trauma Surg* 2013;133:1483–1491.
21. Jordan SW, Mioton LM, Smetona J, et al. Resident involvement and plastic surgery outcomes: an analysis of 10,356 patients from the American College of Surgeons National Surgical Quality Improvement Program database. *Plast Reconstr Surg* 2013;131:763–773.
22. Fischer JP, Wes AM, Kovach SJ. The impact of surgical resident participation in breast reduction surgery-outcome analysis from the 2005–2011 ACS-NSQIP datasets. *J Plast Hand Surg* 2013;48:315–321.
23. Lee SL, Shekherdimian S, Chiu VY. Comparison of pediatric appendicitis outcomes between teaching and nonteaching hospitals. *J of Pediatric Surg* 2010;45:894–897.
24. Kiran RP, Ahmed Ali U, Coffey JC, Vogel JD, Pokala N, Fazio VW. Impact of resident participation in surgical operations on postoperative outcomes: National Surgical Quality Improvement Program. *Ann Surg* 2012;256:469–475.
25. Raval MV, Wang X, Cohen ME, et al. The influence of resident involvement on surgical outcomes. *J Am Coll Surg* 2011;212:889–898.
26. American College of Surgeons, National Surgical Quality Improvement Program. User guide for the 2011 participant use data file. Available at: http://site.acsnsqip.org/participant-use-data-file. Accessed January 16, 2014.
27. Birkmeyer JD, Shahian DM, Dimick JB, et al. Blueprint for a new American College of Surgeons: National Surgical Quality Improvement Program. *J Am Coll Surg* 2008;207:777–782.
28. Shiloach M, Frencher SK Jr, Steeger JE, et al. Toward robust information: Data quality and inter-rater reliability in the American College of Surgeons National Surgical Quality Improvement Program. *J Am Coll Surg* 2010;210:6–16.
29. 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.
30. 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.
31. Khavanin N, Mlodinow A, Kim JY, Ver Halen JP, Antony Ak, Samant S. Assessing safety and outcomes in outpatient versus inpatient thyroidectomy using the NSQIP: a propensity score matched analysis of 16,370 patients [published online ahead of print May 20, 2014]. *Ann Surg Oncol.* doi:10.1245/s10434-014-3785-4.
32. Rosenbaum PR, Rubin DB. Constructing a control group using multivariate matched sampling methods that incorporate the propensity score. *Am Stat* 1985;39:33–38.
33. 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.
34. Austin PC. Optimal caliper widths for propensity-score matching when estimating differences in means and differences in proportions in observational studies. *Pharm Stat* 2011;10:150–161.
35. Stukel TA, Fisher ES, Wennberg DE, et al. Analysis of observational studies in the presence of treatment selection bias: effects of invasive cardiac management on AMI survival using propensity score and instrumental variable methods. *JAMA* 2007;297:278–285.
36. Greenblatt DY, Kelly KJ, Rajamanickam V, et al. Preoperative factors predict perioperative morbidity and mortality after pancreaticoduodenectomy. *Ann Surg Oncol* 2011;18:2126–2135.
37. Davenport DL, Henderson WG, Khuri SF, Mentzer RM Jr. Pre-operative risk factors and surgical complexity are more predictive of costs that post-operative complications: a case study using the National Surgical Quality Improvement Program (NSQIP) database. *Ann Surg* 2005;242: 463–468.
38. Merkow RP, Bilimoria KY, Hall BL. Interpretation of the C-statistic in the context of ACS-NSQIP models. *Ann Surg Oncol* 2011;18:S295.
39. 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.
40. Emre AU, Cakmak GK, Tascilar O, et al. Complications of total thyroidectomy performed by surgical residents versus specialist surgeons. *Surg Today* 2008;28:879–885.
41. Acun Z, Cihan A, Ulukent SC, et al. A randomized prospective study of complications between general surgery residents and attending surgeons in near-total thyroidectomies. *Surg Today* 2004;34:997–1001.
42. Manolidis S, Takashima M, Kirby M, Scarlett M. Thyroid surgery: a comparison of outcomes between expert and surgeon in training. *Otolaryngol Head Neck Surg* 2001;125:30–33.
43. Shaha A, Jaffe BM. Complications of thyroid surgery performed by residents. *Surgery* 1988;104:1109–1114.
44. Khuri SF, Najjar SF, Daley J, et al. National Surgical Quality Improvement Program. Comparison of surgical outcomes between teaching and nonteaching hospitals in the Department of Veterans Affairs. *Ann Surg* 2001;243:370–382.
45. Hwang CS, Wichterman KA, Alfrey EJ. The cost of resident education. *J Surg Res* 2010;163:18–23.
46. 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.
47. Hwang CS, Pagano CR, Wichterman KA, Dunnington GL, Alfrey EJ. Resident versus no resident: a single institutional study on operative complications, mortality, and cost. *Surgery* 2008;144:339–344.
48. Waits SA, Fritze D, Banerjee M, et al. Developing an argument for bundled interventions to reduce surgical site infection in colorectal surgery. *Surgery* 2013;155:602–606.

15314995, 2016, 3, Downloaded from https://onlinelibrary.wiley.com/doi/10.1002/lary.25046 by Columbia University Libraries, Wiley Online Library on [08/03/2026]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License