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CLINICAL RESEARCH

# The Effect of Resident Participation on Short-term Outcomes After Orthopaedic Surgery

**Andrew J. Pugely MD, Yubo Gao PhD, Christopher T. Martin MD, John J. Callaghan MD, Stuart L. Weinstein MD, J. Lawrence Marsh MD**

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**Abstract**

*Background* The influence of resident involvement on short-term outcomes after orthopaedic surgery is mostly unknown.

*Questions/purposes* The purposes of our study were to examine the effects of resident involvement in surgical cases on short-term morbidity, mortality, operating time, hospital length of stay, and reoperation rate and to analyze these parameters by level of training.

*Methods* The 2005–2011 American College of Surgeons National Surgical Quality Improvement Program data set was queried using Current Procedural Terminology codes for 66,817 cases across six orthopaedic procedural domains: 28,686 primary total joint arthroplasties (TJAs), 2412 revision TJAs, 16,832 basic and 5916 advanced arthroscopies, 8221 lower extremity traumas, and 4750 spine arthrodeses (fusions). Bivariate and multivariate logistic regression and propensity scores were used to build models of risk adjustment. We compared the morbidity and mortality rates, length of operating time, hospital length of stay, and reoperation rate for cases with or without resident involvement. For cases with resident participation, we analyzed the same parameters by training level.

*Results* Resident participation was associated with higher morbidity in TJAs (odds ratio [OR], 1.6; range, 1.4–1.9), lower extremity trauma (OR, 1.3; range, 1.2–1.5), and fusion (OR, 1.4; range, 1.2–1.7) after adjustment. However, resident involvement was not associated with increased mortality. Operative time was greater (all $p < 0.001$) with resident involvement in all procedural domains. Longer hospital length of stay was associated with resident participation in lower extremity trauma ($p < 0.001$) and fusion cases ($p = 0.003$), but resident participation did not affect length of stay in other domains. Resident involvement was associated with greater 30-day reoperation rates for cases of lower extremity trauma ($p = 0.041$) and fusion ($p < 0.001$). Level of resident training did not consistently influence surgical outcomes.

*Conclusions* Results of our study suggest resident involvement in surgical procedures is not associated with increased short-term major morbidity and mortality after select cases in orthopaedic surgery. Findings of longer operating times and differences in minor morbidity should lead to future initiatives to provide resident surgical skills training and improve perioperative efficiency in the academic setting.

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The American College of Surgeons National Surgical Quality Improvement Program and the hospitals participating in the ACS NSQIP are the source of the data used herein. They have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors.

A. J. Pugely (✉), Y. Gao, C. T. Martin,
J. J. Callaghan, S. L. Weinstein, J. L. Marsh
Department of Orthopaedic Surgery and Rehabilitation,
University of Iowa Hospitals and Clinics, 200 Hawkins Drive,
01008 JPP, Iowa City, IA 52242, USA
e-mail: andrew-pugely@uiowa.edu; ajpugely@gmail.com

*Level of Evidence* Level II, prognostic study. See the Instructions for Authors for a complete description of levels of evidence.

## Introduction

Resident education has long been a system of graduated responsibility under the guidance of an attending physician. This model is in widespread use, and teaching hospitals are recognized as providing excellent levels of care [5]. In surgical graduate medical education, surgical skills are acquired predominantly in the operating room during supervised participation in actual surgical cases. The current Accreditation Council for Graduate Medical Education (ACGME) guidelines place renewed emphasis on reducing perioperative morbidity and mortality [27], and the methods by which residents acquire surgical skills have been specifically identified as a potential area for improvement [9]. Some studies have shown that a significant learning curve exists for orthopaedic procedures and that surgeons reduce their operative times with increasing experience [7, 36].

In the general surgery literature, several studies have directly evaluated the effect of resident involvement in surgical procedures [1, 11, 14, 18, 25, 31]. Some of these studies have used the National Surgical Quality Improvement Program (NSQIP), a quality assessment tool used by the American College of Surgeons (ACS) [34]. The ACS NSQIP prospectively collects more than 250 surgical preoperative patient demographics, comorbidities, laboratory values, operative variables, and 30-day outcome variables from 483 participating institutions split into nearly a 50/50 mix of private and academic hospitals. Postoperative 30-day outcomes across 21 categories of morbidity and mortality are recorded by specially trained surgical clinical reviewers. Data collection continues prospectively for 30 days regardless of inpatient status. High data fidelity is ensured by routine auditing with a disagreement rate less than 1.8% [34]. Given these advantages, the use of the ACS NSQIP database has been accepted for use in short-term surgical outcomes in various surgical specialties, including general surgery, vascular surgery, and orthopaedic surgery [6, 13, 24].

In the general surgery literature, numerous studies have evaluated the effect of resident involvement in surgical procedures [1, 11, 14, 16, 18, 25, 31]. These studies showed there were minor differences in patient morbidity with resident surgical participation without any differences in mortality [1, 11, 18, 25, 31] and that the level of resident supervision in the operating room did not consistently influence complications [16]. Some studies also showed significantly longer operative times with simple and complex procedures [1, 11, 14]. To the best of our knowledge, no study has shown a negative effect of resident participation on short-term patient morbidity or mortality in orthopaedic procedures [4, 37].

The purpose of our study was to use the ACS NSQIP to evaluate whether resident participation in surgery affected (1) morbidity rate; (2) mortality rate; (3) length of operation; (4) hospital length of stay; and (5) reoperation rate across six major domains of orthopaedic surgery (primary total joint arthroplasty [TJA], revision TJA, basic and advanced arthroscopy, lower extremity trauma, and spine arthrodesis). A secondary goal was to subanalyze the influence of resident level of training (junior, senior, fellow) on the same outcomes.

## Patients and Methods

The ACS NSQIP database was queried for patients undergoing orthopaedic surgery between 2005 and 2011. The cases were assigned to one of six procedural domains: primary TKA/THA, revision TKA/THA, basic arthroscopy (shoulder and knee), advanced arthroscopy (ACL reconstruction and rotator cuff repair), lower extremity fracture treatment (hip fracture open reduction and internal fixation [ORIF], femur/tibia intramedullary rodding, ankle fracture ORIF), and spine arthrodesis (cervical and lumbar). These domains were based on those defined by the ACGME for residency training competency. Surgical cases were selected based on Current Procedural Terminology (CPT) codes and then grouped by domain (Appendix 1). Emergency cases (except in lower extremity trauma), preoperative infections, sepsis, and multilevel complex spine fusions (levels greater than three and osteotomies) were excluded. The NSQIP database records whether a resident was present (logged as an assistant) for a case and specifies their year and level of training. In total, 66,817 patients undergoing orthopaedic surgery were identified from the NSQIP data files. In the defined surgical domains, there were 28,686 primary TJAs, 2412 revision TJAs, 16,832 basic arthroscopies, 5916 advanced arthroscopies, 8221 cases of lower extremity trauma, and 4750 spine arthrodeses. Overall, residents participated in 25.7% or 17,011 of these NSQIP cases. In the subgroups, resident involvement ranged from 20% in basic arthroscopies to 44% in revision TJAs (25% in TJAs, 24% in advanced arthroscopies, 31% in lower extremity trauma, 34% in spine arthrodeses). All data were collected prospectively by a trained, onsite, nurse abstractor. Thirty-day followup data are collected regardless of inpatient status, with disagreement rates less than 2% [2]. Multiple methods, including chart review, surgeon

**Table 1.** Patient demographics across six orthopaedic surgery domains, resident vs nonresident

| Characteristic | Resident involvement | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | No (Primary TJA) | Yes (Primary TJA) | p value | No (Revision TJA) | Yes (Revision TJA) | p value | No (Basic arthroscopy) | Yes (Basic arthroscopy) | p value |
| Patient demographics | | | | | | | | | |
| Age (years), mean | 66.9* | 65.5* | < 0.001 | 66.9* | 65.3* | 0.002 | 49.7* | 48.0* | < 0.001 |
| Gender (female %) | 61.6* | 60.1* | 0.029 | 56.8* | 52.8* | 0.056 | 45.0* | 47.3* | 0.018 |
| Race (white %) | 80.0* | 73.8* | < 0.001 | 76.7 | 73.9 | 0.270 | 66.4* | 66.0* | < 0.001 |
| Emergency procedure (%) | 0.4 | 0.5 | 0.385 | | | | 0.4 | 0.9 | < 0.001 |
| Comorbidities | | | | | | | | | |
| BMI (kg/m2), mean | 31.8 | 31.7 | 0.236 | 30.9 | 30.8 | 0.844 | 30.5* | 30.2* | 0.029 |
| Diabetes | 16.2* | 14.8* | 0.004 | 16.6* | 13.9* | 0.067 | 10.4* | 8.3* | < 0.001 |
| Smoking | 10.3 | 10.5 | 0.592 | 12.9 | 13.6 | 0.611 | 18.1 | 19.1 | 0.175 |
| COPD | 4.2* | 3.3* | 0.001 | 5.0 | 3.7 | 0.149 | 1.7 | 1.1 | 0.007 |
| Congestive heart failure | 0.3 | 0.4 | 0.215 | 0.4 | 0.2 | 0.706 | 0.1 | 0.1 | 0.536 |
| Hypertension | 66.5* | 63.3* | < 0.001 | 66.0* | 60.6* | 0.006 | 34.6* | 30.3* | < 0.001 |
| Steroid use (%) | 2.6* | 3.6* | < 0.001 | 3.9 | 4.1 | 0.748 | 0.9 | 0.8 | 0.822 |
| Dialysis (%) | 0.2 | 0.2 | 0.931 | 0.5 | 0.1 | 0.149 | 0.1 | 0.1 | 0.745 |
| ASA class (%) | | | 0.539 | | | 0.255 | | | < 0.001 |
| 1 or 2 – no or mild disturbance | 52.1 | 52.2 | | 44.2 | 47.0 | | 78.7* | 81.9* | |
| 3 – severe disturbance | 46.0 | 45.7 | | 52.3 | 50.2 | | 20.7* | 17.4* | |
| 4 – life-threatening disturbance | 1.9 | 2.1 | | 3.6 | 2.8 | | 0.6* | 0.7* | |

| Characteristic | Resident involvement | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | No (Advanced arthroscopy) | Yes (Advanced arthroscopy) | p value | No (Lower extremity fracture) | Yes (Lower extremity fracture) | p value | No (Spine) | Yes (Spine) | p value |
| Patient demographics | | | | | | | | | |
| Age (years), mean | 45.4* | 47.7* | < 0.001 | 67.1* | 63.5* | < 0.001 | 54.5* | 56.2* | < 0.001 |
| Gender (female %) | 37.9 | 39.8 | 0.232 | 64.9* | 61.3* | 0.002 | 51.8 | 52.1 | 0.850 |
| Race (white %) | 67.8* | 61.6* | < 0.001 | 81.0* | 60.0* | < 0.001 | 79.2* | 72.0* | < 0.001 |
| Emergency procedure (%) | 0.3 | 0.2 | 0.772 | 23.3* | 26.9* | < 0.001 | | | |
| Comorbidities | | | | | | | | | |
| BMI (kg/m2), mean | 29.0 | 28.9 | 0.831 | 27.3 | 27.2 | 0.823 | 30.4* | 29.6* | < 0.001 |
| Diabetes | 7.8 | 8.5 | 0.407 | 15.9 | 15.2 | 0.448 | 14.0 | 12.7 | 0.221 |
| Smoking | 17.6 | 15.5 | 0.073 | 18.2* | 20.2* | 0.033 | 26.5* | 21.6* | < 0.001 |
| COPD | 1.3 | 1.0 | 0.447 | 8.2 | 8.5 | 0.649 | 2.9 | 3.6 | 0.208 |
| Congestive heart failure | 0.1 | 0.1 | 1.000 | 2.2 | 2.1 | 0.686 | 0.2 | 0.3 | 0.481 |
| Hypertension | 27.2* | 30.7* | 0.013 | 54.9* | 52.0* | 0.013 | 47.4 | 47.6 | 0.905 |
| Steroid use (%) | 0.8 | 0.7 | 0.793 | 3.3 | 4.0 | 0.133 | 2.5 | 3.0 | 0.322 |
| Dialysis (%) | 0.1 | 0.0 | 1.000 | 1.3* | 2.5* | < 0.001 | 0.1 | 0.1 | 1.000 |
| ASA class (%) | | | 0.650 | | | 0.009 | | | 0.650 |
| 1 or 2 – no or mild disturbance | 83.3 | 82.3 | | 40.5* | 43.8* | | 65.2 | 64.6 | |
| 3 – severe disturbance | 16.2 | 17.3 | | 47.6* | 44.1* | | 33.4 | 34.2 | |
| 4 – life-threatening disturbance | 0.5 | 0.4 | | 11.9* | 12.1* | | 1.5 | 1.2 | |

* Statistically significant difference, $p < 0.05$, when comparing resident vs nonresident; TJA = total joint arthroplasty; COPD = chronic obstructive pulmonary disease; ASA = American Society of Anesthesiology.

queries, and direct patient (or family) contact are used to ensure high data fidelity. Furthermore, the reliability administrative claims data have been questioned [8, 19], especially when directly compared with the NSQIP [21]. Overall, the use of the ACS NSQIP database has been accepted for use in short-term surgical outcomes by various

**Table 2.** National Surgical Quality Improvement Program reported 30-day perioperative complications

| |
|---|
| Mortality |
| Morbidity |
| Major complication |
| Organ space infection |
| Sepsis |
| Septic shock |
| Deep surgical site infection |
| Wound dehiscence |
| Pulmonary embolism |
| Ventilator > 48 hours |
| Unplanned intubation |
| Acute renal failure |
| Cardiac arrest requiring cardiopulmonary resuscitation |
| Myocardial infarction |
| Stroke |
| Coma > 24 hours |
| Graft/prosthesis/flap failure |
| Return to operating room |
| Minor complication |
| Superficial surgical site infection |
| Pneumonia |
| Urinary tract infection |
| Deep vein thrombosis |
| Blood transfusions |
| Peripheral nerve injury |
| Renal insufficiency |

surgical specialties, including general surgery, vascular surgery, and orthopaedic surgery [6, 13, 24].

We analyzed orthopaedic-relevant NSQIP patient and case variables. These included demographic data (age, sex, and race), adverse health habits, medical comorbidities, preoperative laboratory, and operative variables (Table 1) [2]. For most domains, patient demographics differed between residents and nonresidents. Patient age varied inconsistently between cohorts. In the primary TJA group, for example, patient age was slightly older in the nonresident group (66.9 versus 65.5 years, $p < 0.001$), whereas in the spine arthrodesis group, patient age was older in the resident group (56.2 versus 54.4 years, $p < 0.001$). Total case Relative Value Units were used to assess case complexity and later entered in the adjustment models. Unadjusted mean case Relative Value Units were greater for residents for spine cases (38.2 versus 30.1 units, $p < 0.001$). When Relative Value Units were entered in the multivariate model, they narrowed the morbidity and mortality odds ratio (OR) differences between residents and nonresidents. Each of the six orthopaedic procedural domains was analyzed for 30-day morbidity and mortality. Morbidity was defined as the occurrence of any one of the 30-day complications and mortality was defined as death within 30 days. The NSQIP reports on more than 25 short-term complications (Table 2) in the following categories: local infections, systemic infections, cardiac, hematologic, respiratory, renal, neurologic, and reoperation. Complications were subcategorized into major and minor groups [22, 28, 32]. Minor complications included superficial wound infection, pneumonia, urinary tract infection, deep vein thrombosis, blood transfusion, and renal insufficiency.

Overall and domain-specific rates of morbidity, mortality, operative time, hospital length of stay, and rate of reoperation within 30 days were calculated.

Bivariate, multivariate logistic regression, and propensity scores were used to build models of risk adjustment. Ultimately, our goal was to build six independent propensity score-adjusted models to correct for the inherent selection bias and compare these results with the crude unadjusted resident versus nonresident complication rates. For each domain, bivariate analysis identified differences between patient characteristics and comorbidities. Student's t-tests and chi-square analysis were used and significance was defined as p less than 0.05. SAS 9.3 for Windows (SAS Institute, Cary, NC, USA) was used to perform the statistical analysis.

Propensity scores were introduced as a method to control for selection bias between resident and nonresident groups. The propensity score is defined as the conditional probability of receiving one treatment (resident case) over another (nonresident) based on the inherent patient characteristic of covariants. This score is reported as a continuous variable between zero and one. Historically, teaching hospitals see sicker, more complex patients. The potential for selection bias is high. Although three methods of propensity score analysis have been described, matching and logistic regression [10] were used in this study. The propensity scores were created by identifying any imbalance between cohorts. First, univariate analysis was used to compare resident versus nonresident variables for each of the six domains. Any variable with a p value less than 0.1 was considered for inclusion in the propensity score.

Additionally, case complexity was controlled by including aggregate case Relative Value Units in the propensity scores. The NSQIP captures up to 11 procedural CPT codes and their corresponding Relative Value Units. For certain domains like primary TJA, where usually one CPT code was claimed, there was relatively little imbalance, but for more complex procedures such as spine arthrodesis, this imbalance was significant. Surgical operative time also was included in the propensity score. Finally, the propensity score was incorporated in a multivariate logistic regression model. These adjustments were

**Table 3.** Unadjusted postoperative outcomes after orthopaedic surgery

| Variable | Procedure | Resident involvement | | p value |
|---|---|---|---|---|
| | | No | Yes | |
| Morbidity, % | Primary TJA | 13.45 (95% CI,12.99–13.90) | 13.88 (95% CI, 13.08–14.68) | 0.3534 |
| | Revision TJA | 19.58 (95% CI,17.46–21.66)* | 28.5 (95% CI, 25.76–31.24)* | < 0.0001 |
| | Basic arthroscopy | 1.61 (95% CI,1.40–1.82) | 1.36 (95% CI, 0.97–1.76) | 0.301 |
| | Advanced arthroscopy | 1.37 (95% CI,1.00–1.74) | 1.22 (95% CI, 0.64–1.79) | 0.6783 |
| | Lower extremity trauma | 18.53 (95% CI,17.51–19.54)* | 24.57 (95% CI, 22.91–26.23)* | < 0.0001 |
| | Spine fusions | 13.19 (95% CI,12.02–14.36)* | 23.3 (95% CI, 21.18–25.42)* | < 0.0001 |
| Mortality, % | Primary TJA | 0.22 (95% CI, 0.16–0.30) | 0.21 (95% CI, 0.10–0.32) | 0.8317 |
| | Revision TJA | 0.44 (95% CI, 0.09–0.79) | 0.29 (95% CI, 0.00–0.61) | 0.7401 |
| | Basic arthroscopy | 0.03 (95% CI, 0.00–0.06) | 0.12 (95% CI, 0.00–0.24) | 0.0528 |
| | Advanced arthroscopy | 0 | 0 | |
| | Lower extremity trauma | 3.44 (95% CI, 2.96–3.95) | 3.02 (95% CI, 2.36–3.68) | 0.328 |
| | Spine fusions | 0.22 (95% CI, 0.06–0.38) | 0.46 (95% CI, 0.12–0.80) | 0.1608 |
| Operative time, minutes | Primary TJA | 93.13 (95% CI, 92.63–93.64)* | 109.4 (95% CI, 108.3–110.4)* | < 0.0001 |
| | Revision TJA | 137.5 (95% CI, 134.0–141.0)* | 158.7 (95% CI, 154.1–163.3)* | < 0.0001 |
| | Basic arthroscopy | 44.31 (95% CI, 43.69–44.92)* | 51.47 (95% CI, 50.31–52.63)* | < 0.0001 |
| | Advanced arthroscopy | 95.79 (95% CI, 94.32–97.26)* | 105.9 (95% CI, 103.0 –108.9)* | < 0.0001 |
| | Lower extremity trauma | 65.47 (95% CI, 64.40–66.53)* | 92.45 (95% CI, 90.58–94.32)* | < 0.0001 |
| | Spine fusions | 146.6 (95% CI, 143.2–150.0)* | 187.5 (95% CI, 181.0–194.0)* | < 0.0001 |
| Length of stay, days | Primary TJA | 3.58 (95% CI, 3.54–3.62) | 3.59 (95% CI, 3.51–3.67) | 0.5727 |
| | Revision TJA | 4.24 (95% CI, 4.07–4.41) | 4.35 (95% CI, 4.11–4.58) | 0.4764 |
| | Basic arthroscopy | 0.15 (95% CI, 0.11–0.19) | 0.23 (95% CI, 0.15–0.30) | 0.1057 |
| | Advanced arthroscopy | 0.29 (95% CI, 0.19–0.39) | 0.26 (95% CI, 0.20–0.31) | 0.5278 |
| | Lower extremity trauma | 4.74 (95% CI, 4.56–4.91)* | 5.81 (95% CI, 5.41–6.19)* | < 0.0001 |
| | Spine fusions | 3.17 (95% CI, 3.04–3.30)* | 3.69 (95% CI, 3.38–4.00)* | 0.0026 |
| Reoperation, % | Primary TJA | 1.63 (95% CI, 1.46–1.80) | 1.7 (95% CI, 1.4–2.0) | 0.6756 |
| | Revision TJA | 4.96 (95% CI, 3.81–6.11) | 4.7 (95% CI, 3.42–5.99) | 0.7676 |
| | Basic arthroscopy | 0.69 (95% CI, 0.55–0.83) | 0.54 (95% CI, 0.29–0.80) | 0.3645 |
| | Advanced arthroscopy | 0.5 (95% CI, 0.28–0.72) | 0.29 (95% CI, 0.01–0.57) | 0.3567 |
| | Lower extremity trauma | 2.5 (95% CI, 2.09–2.91)* | 3.29 (95% CI, 2.61–3.98)* | 0.0408 |
| | Spine fusions | 2.61 (95% CI, 2.06–3.16)* | 5.76 (95% CI, 4.59–6.93)* | < 0.0001 |

* Statistically significant difference, $p < 0.05$; TJA = total joint arthroplasty.

performed independently for morbidity and mortality in each of the six surgical domains. Standard OR and 95% CIs were calculated and reported.

In a separate analysis, all resident cases from each of the six domains were subdivided into three groups of increasing resident experience: postgraduate years 1 to 3 (junior), years 4 to 5 (senior), and years greater than 5 (fellow). For each domain, these three resident levels were compared for morbidity, mortality, operative time, hospital length of stay, and 30-day rates of return to the operating room using chi-square and ANOVA statistical methods for categorical and continuous variables.

## Results

Patient morbidity was greater when residents were involved in cases of revision TJA, lower extremity trauma, and spine arthrodesis (Table 3). The increased morbidity OR of resident participation in these domains decreased but still remained after propensity adjustment (Table 4). These morbidity differences were from minor complications in the revision TJA and lower extremity trauma cohorts but major and minor morbidities in spine fusion procedures.

Overall patient mortality was not greater with resident involvement. After propensity score risk adjustment, there

**Table 4.** Crude and propensity score-adjusted odds ratios of 30-day morbidity and mortality

| Procedure | Mortality | | Any morbidity | | Major morbidity | | Minor morbidity | |
|---|---|---|---|---|---|---|---|---|
| | Crude OR | Adjusted OR | Crude OR | Adjusted OR | Crude OR | Adjusted OR | Crude OR | Adjusted OR |
| Primary TJA | 0.94 (0.53–1.68) | 0.98 (0.50–1.91) | 1.04 (0.96–1.12) | 1.05 (0.96–1.14) | | | | |
| Revision TJA | 0.66(0.16–2.63) | 1.01(0.24–4.29) | 1.64 (1.36–1.98)* | 1.55 (1.27–1.88)* | 0.99 (0.73–1.35) | 1.00 (0.73–1.39) | 1.92 (1.54–2.39)* | 1.77 (1.41–2.22)* |
| Basic arthroscopy | 4.10 (1.03–16.40)* | 3.41 (0.75–15.46) | 0.84 (0.61–1.17) | 0.84 (0.60–1.17) | | | | |
| Arthroscopy advanced | N/A | N/A | 0.89 (0.51–1.54) | 0.78 (0.44–1.34) | | | | |
| Lower extremity trauma | 0.88 (0.67–1.14) | 0.89 (0.66–1.20) | 1.43 (1.28–1.60)* | 1.34 (1.17–1.53)* | 1.22 (1.04–1.43) | 1.13 (0.94–1.35) | 1.39 (1.21–1.60)* | 1.32 (1.13–1.56)* |
| Spine | 2.11 (0.74–6.04) | 1.98 (0.63–6.18) | 2.00 (1.71–2.34)* | 1.44 (1.21–1.73)* | 1.92 (1.50–2.46) | 1.71 (1.30–2.25)* | 1.94 (1.61–2.34)* | 1.26 (1.01–1.57)* |

* Indicate statistically significant differences, $p < 0.05$; OR = odds ratio; TJA = total joint arthroplasty; N/A = no calculable zero deaths.

were no differences in mortality (Table 4): primary TJA (OR, 0.98; 95% CI, 0.50–1.91), revision TJA (OR, 0.54; 95% CI, 0.17–1.71), basic arthroscopy (OR, 3.41; 95% CI, 0.75–15.46), advanced arthroscopy (no deaths), lower extremity trauma (OR, 0.84; 95% CI, 0.61–1.14), and spine arthrodesis (OR, 1.94; 95% CI, 0.68–5.40).

Operative time was greater (all $p < 0.001$) with resident involvement in all procedural domains (Table 3).

Longer hospital length of stay was associated with resident participation for lower extremity trauma ($p < 0.001$) and spine arthrodesis ($p = 0.003$); resident participation did not affect length of stay in other domains (Table 3).

Similar to length of stay, resident participation was associated with greater 30-day reoperation rate for lower extremity trauma ($p = 0.041$) and spine arthrodesis ($p < 0.001$).

Level of resident training did not consistently influence operative time, hospital length of stay, or 30-day surgical outcomes (Table 5). In the primary TJA domain, for example, no differences were noted among junior, senior, and fellow levels for operative time ($p = 0.28$), return to the operating room ($p = 0.80$), morbidity ($p = 0.11$), or mortality ($p = 0.96$). Additionally, in 99% of cases the attending surgeon was physically present in the operating room. In the other 36 of 17,011 cases, an attending was not present but was immediately available.

## Discussion

Resident education is pivotal to providing healthcare providers in the future. All current surgeons learned their skills in a residency program. In this study, the ACS NSQIP data were examined to assess the effect resident involvement in procedures had on short-term complications after six major orthopaedic surgery domains of variable technical complexity. Small differences in minor morbidity, after complex procedures, with no associated differences in patient mortality were found. Operative times generally were longer when residents were involved in procedures. Different resident training levels did not affect the hospital length of stay, return to the operating room, morbidity, or mortality.

This study has several limitations. Although our findings show few differences in complications between resident and nonresident cohorts, the adequacy of risk adjustment is a limitation. It is known that academic hospitals often treat patients with a greater medical disease burden, a characteristic we attempted to adjust for with propensity score modeling. In an attempt to adjust for other inequalities in orthopaedic disease severity, we took

**Table 5.** Resident sublevel analysis

| Procedure | Resident level | Morbidity, (%) | Mortality (%) | Length of stay (days) | Operative time (minutes) | Return to operating room (%) |
|---|---|---|---|---|---|---|
| Primary TJA (n = 7162) | Junior (2376) | 13.85 | 0.21 | 3.42 | 110.46 | 2.19 |
| | Senior (3155) | 14.64 | 0.22 | 3.6 | 108.49 | 1.43 |
| | Fellow (1631) | 12.45 | 0.18 | 3.83 | 109.41 | 1.53 |
| | p value | 0.114 | 1.000 | 0.001 | 0.278 | 0.079 |
| Revision TJA (n = 1042) | Junior (348) | 20.11 | 0.57 | 4.06 | 151.46 | 4.02 |
| | Senior (374) | 32.09 | 0 | 4.57 | 158.9 | 6.68 |
| | Fellow (320) | 33.44 | 0.31 | 4.4 | 166.24 | 3.13 |
| | p value | < 0.0001 | 0.411 | 0.191 | 0.041 | 0.067 |
| Basic arthroscopy (n = 3303) | Junior (1361) | 1.32 | 0.15 | 0.2 | 50.25 | 0.44 |
| | Senior (1469) | 1.57 | 0.14 | 0.19 | 51.99 | 0.75 |
| | Fellow (473) | 0.85 | 0 | 0.41 | 53.35 | 0.21 |
| | p value | 0.495 | 1.000 | 0.157 | 0.172 | 0.306 |
| Advanced arthroscopy (n = 1396) | Junior (485) | 1.86 | 0 | 0.29 | 107.3 | 0.21 |
| | Senior (607) | 0.82 | 0 | 0.18 | 107.3 | 0.16 |
| | Fellow (304) | 0.99 | 0 | 0.35 | 100.9 | 0.66 |
| | p value | 0.278 | | 0.041 | 0.211 | 0.439 |
| Lower extremity trauma (n = 2580) | Junior (837) | 21.27 | 3.23 | 4.94 | 87.8 | 3.35 |
| | Senior (1449) | 25.81 | 2.97 | 5.9 | 94.98 | 3.59 |
| | Fellow (294) | 27.89 | 2.72 | 7.79 | 93.25 | 1.7 |
| | p value | 0.019 | 0.894 | 0.001 | 0.003 | 0.254 |
| Spine (n = 1528) | Junior (610) | 22.62 | 0.49 | 3.17 | 199.92 | 4.1 |
| | Senior (220) | 23.18 | 0.45 | 4.12 | 188.93 | 7.73 |
| | Fellow (698) | 23.93 | 0.43 | 4.01 | 176.21 | 6.59 |
| | p value | 0.856 | 1.000 | 0.030 | 0.004 | 0.062 |

TJA = total joint arthroplasty.

several steps including excluding complex CPT codes such as spine osteotomies. In addition, aggregate case Relative Value Units were calculated and entered in our risk adjustment modeling. This technique for case mix adjustment has been described for use with the NSQIP [12, 13]. Although these techniques may help reduce some of bias, they cannot account for the wide range of orthopaedic disease severity as, for example, in patients having revision TJAs. In addition, the NSQIP does not specifically differentiate academic versus private hospitals. A previous NSQIP study [31], however, showed that the hospital type ratio is nearly identical to the resident versus nonresident ratio, implying that nearly every academic case had a resident. Other limitations included short-term, 30-day data collection; some orthopaedic complications occur after this time. In addition, the NSQIP does not capture orthopaedic-specific outcomes such as pain level and functional status. Despite these limitations, we believe the NSQIP provides clinical data of the highest integrity and is worthy of exposure to the orthopaedic community. Programs like the ACS NSQIP have been recognized nationally for decreasing morbidity and mortality for participating general surgery departments [15].

In our study, resident involvement had minimal effect on morbidity and no effect on 30-day mortality. These results are largely consistent with those of studies published in the general surgery literature using the ACS NSQIP data set [1, 11, 14, 18, 25, 31]. In these retrospective reviews, the authors concluded that resident involvement in general surgical cases was associated with a slightly higher risk of morbidity but a lower risk of mortality [31, 35]. The evidence that resident involvement in surgical cases increases errors is mixed [3, 4, 20, 37]. Although few studies in the orthopaedic literature have examined this issue, they concluded that resident involvement did not increase the incidence of complications in TJA [37] or in scoliosis surgery [4]. In the general surgery literature, one study showed a 5% increase in the incidence of complications with junior resident involvement in cholecystectomy [17]. A prospective patient-controlled trial of patients undergoing mastectomy showed no difference in complications with resident involvement [26]. In another recent study, Schoenfeld et al. [33] reviewed 43,343 orthopaedic cases and reported a small increase in morbidity for arthroplasty procedures with resident involvement but no increased morbidity in spine, hand, amputations, or sports cases. When stratified for severity of morbidity, only differences in minor complications were observed. Multiple factors may explain our findings of greater morbidity with resident involvement.

Resident participation alone should not be blamed for greater minor morbidity; the observed differences must be interpreted with caution. First, this increase in morbidity may have low clinical relevance. Second, increased morbidity with resident involvement may represent more widespread inefficacies associated with the training environment. In these hospitals, trainees pervade all aspects of care delivery from the anesthesia to nursing teams. Inexperienced anesthesia personnel may be more likely to cause airway trauma or increase time to intubation. Novice nursing staff may slow operating room setup, lack familiarity with surgeon instrumentation and preferences, and cause greater breaches in the sterile field. These inefficiencies in the academic setting will compound throughout all phases of care, increasing the risk of an adverse event. Third, academic hospitals often treat patients with a greater disease burden, a characteristic we attempted to adjust for with propensity score modeling. Ultimately, efficiency throughout all phases of care should remain an important goal, especially in the academic setting.

There were significant differences in operative time between resident and nonresident cases in all six of the surgical domains. These differences ranged from 7 minutes in basic arthroscopy to 41 minutes with spine fusions. Although statistical differences were detected, the influence of disease severity and the clinical significance of these findings are not known. In the general surgery and orthopaedic literature, resident participation leads to prolonged operative times [1, 11, 33]. It is possible that the slight increases in morbidity we found are primarily the result of the increased operative time necessary for teaching in the operating room. Some studies have associated prolonged operative times with greater morbidity, particularly surgical site infections [23, 29, 30]. Either way, preventing prolonged operative time should be an important goal when residents are involved with surgical procedures.

To our knowledge, the influence of resident participation on patients' hospital length of stay has not been evaluated before. According to our findings, length of stay did not differ for arthroplasty and arthroscopy cases. Patients undergoing these procedures typically have more routine, streamlined postoperative protocols that do not differ much between patients. Length of stay, however, was approximately 1 day longer for patients with lower extremity trauma and ½ day longer for patients having spine arthrodesis. We suspect that the more heterogeneous nature of these types of injuries causes more variability in postoperative discharge protocols. Although we excluded patients with polytrauma and complex spinal procedures, as aforementioned, we cannot guarantee the resident and nonresident groups to be completely equal. As more residents typically work at tertiary referral centers, this may explain some differences in length of stay. Either way, hospitals, payers, and policymakers should recognize this trend and maintain higher funding for graduate medical education.

Our findings regarding reoperation rates showed a similar trend as LOS. Thirty-day reoperation rates were not different with resident participation for arthroplasty and arthroscopy. Both of these numbers were low and similar to previously reported rates [22, 30]. Reoperation rates were slightly greater (less than 1%) in cases with resident involvement for lower extremity trauma. Reoperation rates, however, were almost double for cases with resident involvement. It is known that academic centers treat some complex patients with previously failed surgeries. We also suspect that some of these reoperations may be planned or two-stage surgeries. Although the NSQIP has begun differentiating between planned and unplanned reoperations in their data collection methods, they were not separated in 2005 to 2011. As pay-for-performance programs become more widespread, policymakers should proceed cautiously as the etiology of these differences in reoperation rates are not fully understood.

Interestingly, the experience level of resident participation (junior, senior, or fellow) and supervision did not consistently influence short-term patient complications. In general, variations in patients' length of stay, operative time, reoperation, morbidity, and mortality were not associated with higher or lower resident year in training. For example, in the primary TJA domain, no clinically significant differences were observed; operative time varied by 2 minutes between junior and senior residents, morbidity by less than 2%, and mortality by less than 0.1%. An exception to this, however, was greater morbidity, length of stay, and operative time with fellow participation in lower extremity trauma cases. We suspect these cases were of greater difficulty and more attending autonomy was given. These findings were largely consistent with those of two NSQIP studies in the general surgery literature [1, 11]. These studies reported no consistent variation in morbidity with resident level, but longer operative times with senior resident or fellow participation for select procedures. Nevertheless, we found faculty supervision over residents in the operating room was performed consistently, with the faculty member physically present in the operating room in more than 99% of cases. These results are similar to previously published data from the Veterans Affairs NSQIP [16]. We suspect that these results imply appropriate graduated responsibility among resident surgeons.

Resident involvement in orthopaedic surgery procedures was not associated with increases in major morbidity or mortality across all domains. Operative times were longer for orthopaedic surgery cases with residents involved across the range of operative complexity. These findings highlight the importance of teaching efficient healthcare delivery in the academic setting.

## Appendix 1. Inclusion CPT codes and frequency

| Variable | CPT code | Frequency | Percentage |
|---|---|---|---|
| Primary total joint arthroplasty | | | |
| | 27447 | 10,207 | 35.58 |
| | 27130 | 18,479 | 64.42 |
| Revision total joint arthroplasty | | | |
| | 27134 | 843 | 34.95 |
| | 27137 | 373 | 15.46 |
| | 27138 | 142 | 5.89 |
| | 27487 | 1054 | 43.70 |
| Basic arthroscopy | | | |
| | 29806 | 618 | 3.67 |
| | 29807 | 790 | 4.69 |
| | 29819 | 31 | 0.18 |
| | 29820 | 28 | 0.17 |
| | 29821 | 50 | 0.30 |
| | 29824 | 415 | 2.47 |
| | 29825 | 123 | 0.73 |
| | 29826 | 2620 | 15.57 |
| | 29828 | 78 | 0.46 |
| | 29873 | 261 | 1.55 |
| | 29874 | 167 | 0.99 |
| | 29875 | 492 | 2.92 |
| | 29876 | 358 | 2.13 |
| | 29877 | 999 | 5.94 |
| | 29879 | 477 | 2.83 |
| | 29880 | 2299 | 13.66 |
| | 29881 | 6572 | 39.04 |
| | 29882 | 261 | 1.55 |
| | 29883 | 57 | 0.34 |
| | 29884 | 98 | 0.58 |
| | 29885 | 4 | 0.02 |
| | 29886 | 9 | 0.05 |
| | 29887 | 25 | 0.15 |
| Advanced arthroscopy | | | |
| | 27403 | 1 | 0.02 |
| | 27405 | 1 | 0.02 |

**Appendix 1.** continued

| Variable | CPT code | Frequency | Percentage |
|---|---|---|---|
| | 27407 | 1 | 0.02 |
| | 27418 | 1 | 0.02 |
| | 27427 | 1 | 0.02 |
| | 27428 | 4 | 0.07 |
| | 27429 | 1 | 0.02 |
| | 27447 | 1 | 0.02 |
| | 27599 | 1 | 0.02 |
| | 27881 | 1 | 0.02 |
| | 29827 | 2674 | 45.20 |
| | 29868 | 2 | 0.03 |
| | 29876 | 1 | 0.02 |
| | 29877 | 2 | 0.03 |
| | 29879 | 2 | 0.03 |
| | 29880 | 35 | 0.59 |
| | 29881 | 83 | 1.40 |
| | 29882 | 16 | 0.27 |
| | 29883 | 3 | 0.05 |
| | 29888 | 3077 | 52.01 |
| | 29889 | 8 | 0.14 |
| Lower extremity trauma | | | |
| | 27235 | 615 | 7.481 |
| | 27236 | 1655 | 20.131 |
| | 27244 | 772 | 9.391 |
| | 27245 | 1534 | 18.660 |
| | 27506 | 340 | 4.136 |
| | 27759 | 327 | 3.978 |
| | 27766 | 204 | 2.481 |
| | 27769 | 15 | 0.182 |
| | 27792 | 775 | 9.427 |
| | 27814 | 888 | 10.802 |
| | 27822 | 506 | 6.155 |
| | 27823 | 131 | 1.593 |
| | 27826 | 21 | 0.255 |
| | 27827 | 146 | 1.776 |
| | 27828 | 152 | 1.849 |
| | 27829 | 140 | 1.703 |
| Spine | | | |
| | 22551 | 116 | 2.44 |
| | 22554 | 530 | 11.16 |
| | 22558 | 381 | 8.02 |
| | 22590 | 10 | 0.21 |
| | 22595 | 25 | 0.53 |
| | 22600 | 108 | 2.27 |
| | 22610 | 76 | 1.60 |
| | 22612 | 1232 | 25.94 |
| | 22614 | 117 | 2.46 |
| | 22630 | 481 | 10.13 |
| | 22800 | 22 | 0.46 |

**Appendix 1.** continued

| Variable | CPT code | Frequency | Percentage |
|---|---|---|---|
| | 22842 | 34 | 0.72 |
| | 22851 | 16 | 0.34 |
| | 63001 | 37 | 0.78 |
| | 63003 | 12 | 0.25 |
| | 63012 | 33 | 0.69 |
| | 63015 | 21 | 0.44 |
| | 63020 | 51 | 1.07 |
| | 63030 | 1366 | 28.76 |
| | 63040 | 11 | 0.23 |
| | 63045 | 71 | 1.49 |

CPT = Current Procedural Terminology.

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