The Influence of Resident Involvement on Surgical Outcomes

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BACKGROUND: Although the training of surgical residents is often considered in national policy addressing complications and safety, the influence of resident intraoperative involvement on surgical outcomes has not been well studied.

STUDY DESIGN: We identified 607,683 surgical cases from 234 hospitals from the 2006 to 2009 American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP). Outcomes were compared by resident involvement for all general and vascular cases as well as for specific general surgical procedures.

RESULTS: After typical ACS NSQIP comorbidity risk adjustment and further adjustment for hospital teaching status and operative time in modeling, resident intraoperative involvement was associated with slightly increased morbidity when assessing overall general or vascular procedures (odds ratio [OR] 1.06; 95% CI 1.04 to 1.09), pancreatectomy or esophagectomy (OR 1.26; 95% CI 1.08 to 1.45), and colorectal resections (OR 1.15; 95% CI 1.09 to 1.22). In contrast, for mortality, resident intraoperative involvement was associated with reductions for overall general and vascular procedures (OR 0.91; 95% CI 0.84 to 0.99), colorectal resections (OR 0.88; 95% CI 0.78 to 0.99), and abdominal aortic aneurysm repair (OR 0.71; 95% CI 0.53 to 0.95). Results were moderated somewhat after hierarchical modeling was performed to account for hospital-level variation, with mortality results no longer reaching significance (overall morbidity OR 1.07; 95% CI 1.03 to 1.10, overall mortality OR 0.97; 95% CI 0.90 to 1.05). Based on risk-adjusted event rates, resident intraoperative involvement is associated with approximately 6.1 additional morbidity events but 1.4 fewer deaths per 1,000 general and vascular surgery procedures.

CONCLUSIONS: Resident intraoperative participation is associated with slightly higher morbidity rates but slightly decreased mortality rates across a variety of procedures and is minimized further after taking into account hospital-level variation. These clinically small effects may serve to reassure patients and others that resident involvement in surgical care is safe and possibly protective with regard to mortality. (J Am Coll Surg 2011;212:889–898. © 2011 by the American College of Surgeons)
the operative and nonoperative management of patients has come under scrutiny as a potential area for improved surgical safety and efficiency. Concerns of resident inexperience as a contributing factor to surgical error have long sparked debate over the existence of a “July phenomenon,” and resident involvement in surgical patient care is sometimes not preferred by patients. Resident education using technologically advanced simulation laboratory training has been advocated as a mechanism to codify performance and has been gaining acceptance at most teaching centers. Nevertheless, the relationship between surgical outcomes and intraoperative resident participation has not been well studied.

Since 2004, the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) has provided a validated, outcomes-based, risk-adjusted, and peer-controlled assessment of surgical quality based on clinical information. Reliable 30-day outcomes serve as a quality improvement catalyst for ACS NSQIP participating institutions including private-sector academic and nonacademic hospitals. The purpose of this study was to determine whether resident intraoperative involvement was associated with detectable differences in surgical outcomes using the ACS NSQIP data set.

**METHODS**

**Data set, variables, and outcomes**

Current details of the ACS NSQIP, including developmental history, sampling strategy, data abstraction procedures, variables collected, outcomes, and structure have been described elsewhere. In brief, the program collects and audits detailed and standardized data on patient demographics, preoperative risk factors, laboratory values, operative variables, and postoperative events on a systematic sample of general and vascular cases (standard ACS NSQIP), or on a broader group of surgical specialty cases (ACS NSQIP multispecialty program). Data are gathered by trained surgical clinical reviewers (SCRs) using standard ACS NSQIP tools and definitions. Clinical resources including continuing education and monthly conference calls are available to SCRs. From July 1, 2006 to June 30, 2009 (3 complete program years), a total of 607,683 general and vascular surgery cases were entered from 234 participating hospitals.

The ACS NSQIP provides participating hospitals with a variety of risk-adjusted models including mortality and overall morbidity models. Morbidity is defined as the presence of at least one of the following ACS NSQIP defined complications: superficial surgical site infection, deep surgical site infection, organ space surgical site infection, wound dehiscence, neurologic event (stroke or cerebrovascular accident, coma lasting more than 24 hours, or peripheral neurologic deficit), cardiac arrest, myocardial infarction, bleeding requiring transfusion, deep vein thrombosis, pulmonary embolism, pneumonia, unplanned intubation, ventilator dependence more than 48 hours, urinary tract infection, progressive or acute renal insufficiency, and sepsis or septic shock. Patients were excluded from having the following complications if the condition was documented preoperatively: wound infection, pneumonia, ventilator dependence or reintubation, renal failure, stroke, and coma. To determine mortality, SCRs examine medical records, attempt to contact patients via telephone or mail, and query the Social Security Death Index and the National Obituary Archives.

In addition to typical ACS NSQIP risk adjustment using clinically collected preoperative risk factors, laboratory values, and operative variables, case-mix adjustment variables included work relative value units (RVU) based on Current Procedural Terminology (CPT) codes as well as a 134-category CPT procedure group variable that estimates endogenous risk coefficients for each procedure category. The effects of 3 other factors were also considered. First, each operation was classified as associated or not associated with resident intraoperative involvement, as codified in the ACS NSQIP data fields. Second, hospitals were identified as teaching centers if their ratio of interns and residents to hospital beds (as available through the American Hospital Association Annual Survey: n = 211 categorized in this fashion, 90.2%) was greater than 0.10. If the ratio was unavailable, teaching status was assigned based on hospital affiliation with the Council of Teaching Hospitals of the Association of American Medical Colleges and Accreditation Council for Graduate Medical Education (n = 18, 7.7%). If teaching status could not be assigned based on these criteria, ACS NSQIP administrative files were queried for self-reported teaching status (n = 5, 2.1%). Finally, operative times were assessed for each procedure grouping and divided into quartiles within procedure groups (shortest, short, medium, and long).

In addition to the ACS NSQIP overall model, which includes all general and vascular surgery cases at a hospital, several specific procedures with varying levels of complex-

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**Abbreviations and Acronyms**

ACSNSQIP = American College of Surgeons National Surgical Quality Improvement Program

OR = odds ratio

SCR = surgical clinical reviewer

VA = Veterans Affairs
ity were identified based on CPT codes. Complex general surgery procedures studied included pancreatectomy and esophagectomy as well as colorectal cases. Pancreatectomy and esophagectomy were combined due to low volumes when considered individually. Open abdominal aortic aneurysm (AAA) repair was selected as a complex vascular case. Laparoscopic cholecystectomy and open inguinal hernia repair were selected as simple general surgical cases and combined due to low event rates. Conclusions were unchanged when studying the combined procedure groups together or individually.

Statistical analyses
Chi-square statistics were used to compare morbidity and mortality rates overall or for each procedure group of interest. Correlation coefficients were calculated between resident involvement and hospital teaching status and resident involvement and operative time. Logistic regression models were constructed for each outcome (morbidity and mortality) for each procedure grouping. Clinically relevant variables were entered into the logistic models and additional ACS NSQIP variables were selected based on a forward step-wise process, with p for inclusion being 0.05. In addition, models were sequentially forced to incorporate resident involvement, resident involvement and hospital teaching status, or resident involvement, hospital teaching status, and operative time. Random-effects modeling was used to account for clustering of patients at hospitals. Model quality was evaluated through assessment of the c-statistic and the Hosmer-Lemeshow goodness-of-fit statistic. In addition, fixed-effects hierarchical models were used to adjust for the hospital-level factors that might affect outcomes. Fixed-effects models, using hospital identifier variables, allow for more robust isolation of the effect of resident involvement on outcomes. If the differences in outcomes are no longer significant after accounting for hospital-level variation, then the differences can be attributed to variables such as resident involvement.

Risk standardized morbidity and mortality rates were generated using the adjusted odds ratios (ORs) on resident involvement from regressions, in combination with the equation relating rates to odds ratios: Odds ratio on resident involvement = (RateR/[1-RateR])/(RateN/[1-RateN]); where “RateR” is the risk standardized rate with resident involvement and “RateN” is the rate with no resident involvement. Equations were constrained by requiring the weighted average of rates with and without resident to equal the observed event rate in question. Based on these risk standardized rates, estimates for the predicted increase or decrease in events per 1,000 patients with resident intraoperative involvement were calculated (multiply each rate × 1,000, subtract RateN from RateR). Furthermore, mortality event rates were calculated for patients with at least 1 morbidity event and compared by resident involvement. Data manipulation and analyses were done with SAS version 9.2 or Microsoft Excel 2007 (Microsoft Corp). The study was performed under exempt status after review of study protocols by the Northwestern University Institutional Review Board.

RESULTS
Of the 607,683 general and vascular surgery cases identified, there were 8,655 pancreatectomy or esophagectomy cases (1.4%), 55,798 colorectal cases (9.2%), 4,208 open abdominal aortic aneurysm repairs (0.7%), and 92,157 laparoscopic cholecystectomy or open inguinal hernia cases (15.2%). Resident intraoperative involvement ranged from 57.6% for laparoscopic cholecystectomy or open inguinal hernia cases to 85.6% for pancreatectomy or esophagectomy cases (Table 1). Overall morbidity ranged from 2.7% for laparoscopic cholecystectomy or open inguinal hernia cases to 35.5% for pancreatectomy and esophagectomy cases. Mortality ranged from 0.28% for laparoscopic cholecystectomy and open inguinal hernia cases to 10.8% for open abdominal aortic aneurysm repairs. Within each pro-

### Table 1. Procedure Groups Studied from the ACS NSQIP from July 2006 to June 2009

<table>
<thead>
<tr>
<th>Procedures</th>
<th>Cases</th>
<th>Total, %</th>
<th>Teaching, %</th>
<th>Resident, %</th>
<th>Unadjusted morbidity, %</th>
<th>Unadjusted mortality, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall general and vascular surgery</td>
<td>607,683</td>
<td>100</td>
<td>63.27</td>
<td>61.78</td>
<td>11.27</td>
<td>1.83</td>
</tr>
<tr>
<td>Pancreatectomy and esophagectomy</td>
<td>8,655</td>
<td>1.42</td>
<td>76.11</td>
<td>85.58</td>
<td>35.45</td>
<td>2.46</td>
</tr>
<tr>
<td>Colorectal surgery</td>
<td>55,798</td>
<td>9.18</td>
<td>62.60</td>
<td>76.47</td>
<td>26.81</td>
<td>4.17</td>
</tr>
<tr>
<td>Abdominal aortic aneurysm repair</td>
<td>4,218</td>
<td>0.69</td>
<td>71.55</td>
<td>70.01</td>
<td>35.44</td>
<td>10.79</td>
</tr>
<tr>
<td>Laparoscopic cholecystectomy and open</td>
<td>92,157</td>
<td>15.17</td>
<td>58.46</td>
<td>57.62</td>
<td>2.67</td>
<td>0.28</td>
</tr>
<tr>
<td>inguinal hernia repair</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

ACS NSQIP, American College of Surgeons National Surgical Quality Improvement Program.
procedure group, resident involvement was correlated with hospital teaching status (overall general and vascular surgery $R = 0.51$, $p < 0.001$) and longer operative time (overall general or vascular surgery $R = 0.21$, $p < 0.001$).

Resident involvement and outcomes

Figure 1 addresses morbidity and mortality and demonstrates the effect of sequential addition of resident involvement, hospital teaching status, and operative time variables to the typical ACS NSQIP risk modeling variables for each of the procedure groups and modeling techniques. After controlling for hospital teaching status and operative duration quartile, resident intraoperative involvement was associated with higher morbidity for overall general and vascular surgery cases (OR 1.06; 95% CI 1.04 to 1.09), pancreatectomy and esophagectomy (OR 1.26; 95% CI 1.08 to 1.45), and colorectal resections (OR 1.15; 95% CI 1.09 to 1.22). Though results were largely unchanged after random-effects modeling, after fixed-effects hierarchical modeling was performed to account for any hospital-level variation, resident involvement was associated with higher morbidity events only for the overall general and vascular surgery cases (OR 1.07 95% CI 1.03 to 1.10).

After controlling for hospital teaching status and operative duration quartile, resident involvement was associated with lower mortality for overall general and vascular procedures (OR 0.93; 95% CI 0.88 to 0.98), colorectal resections (OR 0.88; 95% CI 0.78 to 0.99), and abdominal aortic aneurysm repair (OR 0.71; 95% CI 0.53 to 0.95). After random-effects and fixed-effects hierarchical modeling was performed to account for any hospital-level variation, resident involvement was not associated with lower

<table>
<thead>
<tr>
<th>Procedure Group</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall general and vascular</td>
<td>1.07</td>
<td>1.03 to 1.10</td>
</tr>
<tr>
<td>Pancreatectomy &amp; esophagectomy</td>
<td>1.26</td>
<td>1.08 to 1.45</td>
</tr>
<tr>
<td>Colorectal surgery</td>
<td>0.88</td>
<td>0.78 to 0.99</td>
</tr>
<tr>
<td>Laparoscopic cholecystectomy &amp; open inguinal hernia repair</td>
<td>0.71</td>
<td>0.53 to 0.95</td>
</tr>
</tbody>
</table>

Figure 1. Odds ratios and 95% confidence intervals for resident versus no resident, and for morbidity and mortality, for 5 groupings of surgical procedures. For each outcome and surgical group, the 5 odds ratios are from models that are based on (from top to bottom): logistic regression using standard ACS NSQIP variables; this model plus hospital teaching status; the former model plus operative time; the model analyzed with a random intercepts (hospital) hierarchical model; and a logistic model in which hospital is treated as a fixed effect. Where only 4 models are reported in a cell, the last model is not available due to lack of convergence. ACS NSQIP, American College of Surgeons National Surgical Quality Improvement Program.
mortality for the various procedure groups studied (at significance of $p < 0.05$). Fixed-effects modeling could not be performed for pancreatectomy and esophagectomy, abdominal aortic aneurysm repair, or laparoscopic cholecystectomy and open inguinal hernia secondary to low event rates and lack of model convergence. Of note, the mortality rate among patients with at least 1 morbidity event was also lower with resident involvement (11.0% vs 11.9%, $p < 0.001$, Fig. 2).

Resident involvement was associated with higher unadjusted complication rates when studying all ACS NSQIP outcomes (Fig. 3). Common complications such as surgical site infections were 21.2% higher when residents were involved (5.34% vs 3.47%, $p < 0.001$). Less common complications such as neurologic events including stroke and coma were only 5.8% higher with resident involvement (0.36% vs 0.32%, $p = 0.017$). Of the 69,215 patients (11.4%) who had at least 1 complication, 7,792 died (11.3%).

**Quantifying resident influence**

Risk standardized morbidity and mortality rates are summarized in Table 2, derived from the results shared in Figure 1 and as described in the Methods section. When evaluating overall general and vascular surgery procedures, there were approximately 6.1 additional patients with morbidity events but 1.4 lives saved per 1,000 cases associated

![Figure 2.](image)

**Figure 2.** Risk-adjusted morbidity, risk-adjusted mortality, and mortality rate after morbidity (“failure to rescue”) occurrence stratified by resident involvement in general and vascular surgical procedures in the ACS NSQIP. Gray bars, no resident; black bars, resident. ACS NSQIP, American College of Surgeons National Surgical Quality Improvement Program.

![Figure 3.](image)

**Figure 3.** Morbidity outcomes studied in the ACS NSQIP stratified by resident involvement for general and vascular surgery procedures (unadjusted rates). Gray bars, no resident; black bars, resident. ACS NSQIP, American College of Surgeons National Surgical Quality Improvement Program.
with resident involvement versus no resident involvement. In parallel to the results in Figure 1, pancreatectomy and esophagectomy procedures as well as colorectal operations demonstrated additional morbidity events with intraoperative resident involvement. Resident involvement with colorectal procedures and abdominal aortic aneurysm repair conferred fewer mortality events. Reiterating the results for evaluation of laparoscopic cholecystectomy and open inguinal hernia repair, resident involvement had a nonsignificant and relatively minor unfavorable effect on absolute numbers of morbidity and mortality events.

**DISCUSSION**

Although residents represent only a single component of the surgical health care team, several recent policy changes have identified resident participation in the care of patients as an area of focus for improving the quality of surgical care. Furthermore, patients often request that residents not be involved in their operations primarily due to concerns over safety. Using ACS NSQIP data, we demonstrate that resident intraoperative involvement is associated with lower risk-adjusted mortality rates but slightly higher risk-adjusted morbidity rates across a variety of general and vascular surgery procedures. Although these findings were significant after typical ACS NSQIP comorbidity risk adjustment, they were largely minimized after accounting for hospital-level effects. Our study demonstrates no meaningful clinical differences in surgical outcomes based on resident involvement.

The role of resident intraoperative involvement on surgical outcomes has been evaluated in the past. Hwang and colleagues used a single center’s experience in 2,293 patients to evaluate complications, mortality, and costs when comparing cases with and without resident involvement. They demonstrated no differences in complications or mortality but higher costs and increased length of stays when residents were involved in a variety of common general surgery procedures including laparoscopic cholecystectomy, bowel resection, and hernia repair. Our study did not evaluate length of stay and other potential meaningful clinical outcomes such as patient satisfaction, but focused on overall morbidity and mortality.

There are 3 key mechanisms by which resident involvement might be associated with increased morbidity. First, intraoperative technical complications could be more common when residents are involved in cases and may represent a source of postoperative morbidity. These technical issues might also manifest in longer operative times. Prolonged operative time has been associated with poor surgical outcomes in a variety of settings. Including operative time in our models moderated the overall effect of resident intraoperative involvement, and resident involvement was highly correlated with longer operative times for the various procedures studied. These findings could reflect an opportunity for quality improvement. As an example, increased use of surgical simulator training might increase surgical efficiency in the operating room. Alternatively, longer operative times might reflect something endoge-

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**Table 2. Risk-Standardized Morbidity and Mortality Rates for Procedures Studied Using the ACS NSQIP and Predicted Increased or Decreased Events per 1,000 Patients with Resident Intraoperative Involvement**

<table>
<thead>
<tr>
<th>Morbidity and mortality rates</th>
<th>Resident involved, %</th>
<th>No resident, %</th>
<th>Risk adjusted odds ratio with resident involvement</th>
<th>Increased (or decreased) events per 1,000 patients with resident involvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk standardized morbidity rate</td>
<td>Overall general and vascular surgery</td>
<td>11.50</td>
<td>10.89</td>
<td>1.063</td>
</tr>
<tr>
<td></td>
<td>Pancreatectomy and esophagectomy</td>
<td>36.18</td>
<td>31.12</td>
<td>1.255</td>
</tr>
<tr>
<td></td>
<td>Colorectal surgery</td>
<td>27.71</td>
<td>24.95</td>
<td>1.153</td>
</tr>
<tr>
<td></td>
<td>Abdominal aortic aneurysm repair</td>
<td>35.11</td>
<td>36.21</td>
<td>0.953</td>
</tr>
<tr>
<td></td>
<td>Laparoscopic cholecystectomy/open inguinal hernia repair</td>
<td>2.69</td>
<td>2.65</td>
<td>1.014</td>
</tr>
<tr>
<td>Risk standardized mortality rate</td>
<td>Overall general and vascular surgery</td>
<td>1.78</td>
<td>1.92</td>
<td>0.926</td>
</tr>
<tr>
<td></td>
<td>Pancreatectomy and esophagectomy</td>
<td>2.42</td>
<td>2.68</td>
<td>0.903</td>
</tr>
<tr>
<td></td>
<td>Colorectal surgery</td>
<td>4.00</td>
<td>4.52</td>
<td>0.879</td>
</tr>
<tr>
<td></td>
<td>Abdominal aortic aneurysm repair</td>
<td>9.74</td>
<td>13.24</td>
<td>0.707</td>
</tr>
<tr>
<td></td>
<td>Laparoscopic cholecystectomy/open inguinal hernia repair</td>
<td>0.29</td>
<td>0.27</td>
<td>1.092</td>
</tr>
</tbody>
</table>

*Significant at p < 0.05 in nonhierarchical logistic regression model.

ACS NSQIP, American College of Surgeons National Surgical Quality Improvement Program.
The presence of a dean’s committee overseeing resident involvement in the hospital based on ratios of residents to beds at the hospital level. Furthermore, ACS NSQIP hospitals represent a fundamentally different cohort of hospitals and patients in the United States than those represented in the VA NSQIP study. Whereas teaching hospitals performed roughly 80% of the total cases in the VA NSQIP, approximately 66% of cases submitted to the ACS NSQIP were from teaching hospitals. The majority of hospitals contributing to the ACS NSQIP are larger, high-volume centers, with 76% of current hospitals having 300 or more beds. This sampling of institutions may limit the generalizability of our results but reduces variation in institutional volumes. Furthermore, Khuri and colleagues31 used a 5-point scale to estimate the complexity of each operation; our study accounts for case-mix more precisely using a data-driven CPT grouping risk-score. By representing a more diverse selection of private sector institutions, strictly defining teaching status, and using a procedural grouping risk-score, our study provides a unique and more developed perspective to evaluate the specific role of resident intraoperative involvement. Despite these intensified efforts to account for differences in case-mix, there are still unrecorded procedure-specific variables that could influence outcomes. Examples include anatomic location, size, and tortuosity of aortic aneurysms being repaired or resection of an initial as opposed to recurrent cancer. This level of procedure-specific data is not currently available in the ACS NSQIP and is being addressed in future program research and development.

A third mechanism to explain the association between resident involvement and increased morbidity may be the increased vigilance toward identifying and recording post-operative complications and occurrences by residents or in teaching facilities. This increased clinical vigilance could even be based on the ordering of additional tests such as surveillance duplex studies for suspicion of deep vein thromboses or urinalysis for asymptomatic urinary tract infections. Residents have been shown to overuse laboratory tests and imaging studies based on experience.35,36

Although a combination of intraoperative technical issues, unmeasured case-mix variation, and increased resident vigilance may partially explain the observed increased morbidity associated with resident involvement, resident involvement was also associated with lower mortality. An increased level of surveillance could assist in the early identification of complications, leading to prompt intervention and “rescue” from further adverse developments. The concept of increased surveillance is also supported by the pres-
ience of higher event rates across all ACS NSQIP morbidity outcomes (Fig. 1) as well as the fact that morbidity detection is potentially more variable than mortality detection. Several studies have demonstrated that early complication recognition may provide an opportunity to rescue patients from mortality at teaching centers and with resident involvement.34,37 Our study supports these findings with a slightly lower mortality rate detected among patients with at least 1 morbidity event when residents were involved in the surgery. Rosenthal and associates38 compared 89,851 patients at 30 hospitals in northeast Ohio and found a 19% lower in-hospital adjusted mortality and 9% lower risk-adjusted length of stay at teaching hospitals.38 Although traditional ACS NSQIP modeling does not account for hospital teaching status, our study evaluated resident intra-operative involvement after accounting for hospital teaching status. Our data include hospitals from 38 states and may be more generalizable than either of the reported New York or Ohio state-wide experiences. Dimick and coauthors59 used the Nationwide Inpatient Sample to evaluate the influence of hospital teaching status for several high risk procedures including pancreatic, hepatic, and esophageal resection. That study identified lower unadjusted mortality rates at teaching hospitals for patients undergoing pancreatic and hepatic resections and prolonged length of stay at nonteaching centers.59 Surgical outcomes for procedures such as pancreatic, hepatic, and esophageal resections also have a well documented relationship with volume, with academic centers often having higher volumes and therefore better outcomes.40 Conversely, more common procedures such as colon resections, for which a nonteaching center may have higher volumes, have been shown to have lower mortality at nonteaching centers.41 Our study includes all general and vascular surgical cases sampled within the ACS NSQIP program including both a spectrum of high risk procedures and lower risk, elective, outpatient procedures.

There are several limitations to this study worth noting. Lack of surgeon-level information and potential for unobserved bias have been mentioned. In addition, hospitals represented in the ACS NSQIP may not be representative of all hospitals performing surgery in the United States. Further, risk-adjusted models of morbidity are currently limited to outcomes being monitored within the ACS NSQIP. Future studies may delve into the specific morbidity events more commonly associated with resident intra-operative involvement such as surgical site infections (which our study notes as being influenced by resident involvement) or specific procedure-related outcomes such as long-term inguinal hernia repair recurrence, which has been previously shown to correlate with junior resident involvement.42 Also, we were able to identify resident involvement in the operating room, but the extent to which residents were involved with the preoperative and postoperative care of patients is not quantified and measured. There are several limitations in ACS NSQIP data collection that prevent consistent identification of fellow level trainees as compared with residents, and determination of when more senior residents may be in a teaching role for junior level residents, precluding reliable stratification of trainees by postgraduate years. Finally, we reiterate that no risk adjustment algorithm is perfect, and the results could yet reflect inherent unobserved factors that influence risk and are in some fashion correlated with resident involvement. This is a topic of ongoing investigation.

CONCLUSIONS
Resident intraoperative participation was associated with a slightly increased morbidity and decreased mortality across a variety of general and vascular surgery procedures after taking hospital teaching status as well as operative time into consideration. These findings were most evident when studying complex procedures and least evident when evaluating low risk procedures such as laparoscopic cholecystectomy and open inguinal hernia repair. The higher morbidity observed might be explained by intraoperative technical issues, unmeasured case-mix variation, or increased resident vigilance. The lower mortality observed with resident involvement could reflect surveillance and rescue functions indicative of a benefit to resident involvement across a variety of general and vascular surgery procedures. Many of the differences in outcomes were minimized once more robust analyses accounting for hospital-level variation were used. Ultimately, there appear to be no major, clinically significant differences in surgical outcomes based on resident involvement and patients and other stakeholders can be reassured that resident involvement in surgical care is safe.

Author Contributions
Study conception and design: Raval, Wang, Cohen, Ingraham, Dimick, Flynn, Hall, Ko
Acquisition of data: Raval, Wang, Cohen, Ko
Analysis and interpretation of data: Raval, Wang, Cohen, Ingraham, Bentrem, Dimick, Flynn, Hall, Ko
Drafting of manuscript: Raval, Wang, Cohen, Ingraham, Dimick, Hall, Ko
Critical revision: Raval, Wang, Cohen, Ingraham, Bentrem, Dimick, Flynn, Hall, Ko

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