Trainee Participation Is Associated With Adverse Outcomes in Emergency General Surgery

An Analysis of the National Surgical Quality Improvement Program Database

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Objective: To identify whether resident involvement affects clinically relevant outcomes in emergency general surgery.

Background: Previous research has demonstrated a significant impact of trainee participation on outcomes in a broad surgical patient population.

Methods: We identified 141,010 patients who underwent emergency general surgery procedures in the 2005–2010 Surgeons National Surgical Quality Improvement Program database. Because of the nonrandom assignment of complex cases to resident participation, patients were matched (1:1) on known risk factors [age, sex, inpatient status, preexisting comorbidities (obesity, diabetes, smoking, alcohol, steroid use, coronary artery disease, chronic renal failure, pulmonary disease)] and preoperatively calculated probability for morbidity and mortality. Clinically relevant outcomes were compared with a t or χ^2 test. The impact of resident participation on outcomes was assessed with multivariable regression modeling, adjusting for risk factors and operative time.

Results: The most common procedures in the matched cohort (n = 83,790) were appendectomy (39.9%), exploratory laparotomy (8.8%), and adhesiolysis (6.6%). Trainee participation is independently associated with intra- and postoperative events, wound, pulmonary, and venous thromboembolic complications, and urinary tract infections.

Conclusions: Trainee participation is associated with adverse outcomes in emergency general surgery procedures.

Keywords: emergency general surgery, graduate medical education, National Surgical Quality Improvement Program, operative time, outcomes, residents, supervision, trainees

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Modern graduate medical education is called to balance 2 important needs: provide affordable, high-quality health care to patients, while simultaneously training junior physicians in their specialty of choice. Previous research has demonstrated both beneficial and adverse effects of trainee participation in all levels and fields of modern medicine including, but not limited to, primary care,[1] cardiology,[2,3] radiology,[4] gastrointestinal medicine,[5–7] and surgery.[8–20] Sandhu et al[3] demonstrated that in patients who underwent percutaneous coronary intervention, there were no differences in mortality, inpatient myocardial infarction, or contrast-induced nephropathy between cases performed at major teaching hospitals and those performed in nonteaching ones. This study revealed both the positive and adverse impacts of trainee involvement: percutaneous coronary intervention at teaching hospitals was associated with a decreased risk of emergency coronary artery bypass grafting compared with nonteaching hospitals but at the expense of a higher complication rate.[3] Highlighting the beneficial effect of trainee involvement, Polanczyk and colleagues[2] found lower mortality in patients with myocardial infarction, heart failure, or stroke at teaching institutions, and Buchner et al[6] demonstrated increased colon malignancy detection during endoscopies performed with resident participation.

Contrary to these reports, however, a significant body of evidence suggests that trainee participation may be associated with adverse outcomes. In a study investigating the diagnostic competency of radiology residents, the majority of junior trainees misidentified prominent trauma abnormalities on imaging,[4] and in primary care, adverse outcomes have been linked to more prescribing errors made by junior trainees than their senior counterparts.[1]

Among the most commonly cited risk factors for adverse outcomes in graduate medical education are inexperience or excessive autonomy. These aspects may be even more pronounced in surgical specialty training programs, where trainees' lack of sophisticated technical skills, experience, and familiarity with complex procedures and evolving surgical technologies may play important roles.[17,20] Papandria and associates[18] reported that even common surgical procedures (such as laparoscopic appendectomy, laparoscopic cholecystectomy, and open hernia repair) required longer operative times with trainee involvement,[18] yet the "resident effect" on outcomes has been shown to be minor in a broad surgical patient population undergoing mostly elective procedures.[21]

One particular population in which the effect of surgical resident participation has yet to be clearly defined is the one requiring *emergency* surgical procedures. The unique characteristic of this specific type of surgical intervention is that time is of the essence, and surgical trainees are available around the clock at teaching institutions to expedite operative intervention, until a board-certified surgeon is called to guide and supervise operative management. However, involving residents in emergency surgical cases may unnecessarily prolong operative time, with a possible negative effect on overall outcomes. With the current project, we aim to identify whether trainee participation is associated with clinically relevant outcomes in patients undergoing emergency general surgical procedures.

METHODS

Data Source and Study Population

Data were extracted from the nationwide American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) database, after excluding patients who underwent nongeneral surgery procedures. Out of all adults (16 years of age and older) enrolled at any of the approximately 400 participating institutions

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in North America between 2005 and 2010, those who underwent an emergency general surgical procedure comprised our *Aggregate Cohort*.

Variables

Variables included baseline demographic (age, sex, body mass index) and clinical characteristics (inpatient status, laboratories, and preexisting comorbid conditions that are known risk factors for adverse surgical outcomes),[22–24] such as obesity (a body mass index of >30); diabetes mellitus (requiring daily oral hypoglycemic agents or insulin); smoking (any history of smoking in the year before index procedure); alcohol (defined as >2 drinks per day in the 2 weeks preceding admission) or steroid use (for a chronic condition); coronary artery disease (defined as anyone with a diagnosis of congestive heart failure or history of angina in the 30 days preceding surgery, myocardial infarction in the 6 months before index operation, or any history of percutaneous coronary intervention or cardiac surgery); renal failure (acute or chronic, requiring dialysis or not); and pulmonary disease (chronic obstructive pulmonary disease or asthma). In addition, each patient's expected probability for morbidity and mortality was obtained, as calculated by the ACS-NSQIP surgical risk calculator.[25]

Procedure-related information was also extracted, such as the procedure performed by current procedural terminology code, whether or not a resident was involved (and, if so, his or her postgraduate level), total anesthesia and operative time, ASA class, and whether or not the patient required an intraoperative transfusion, suffered a postoperative bleed requiring transfusion, or required an unplanned return to the operating room (OR). The level of resident supervision was left out from our analysis, as less than 0.1% of total cases were performed without a staff surgeon present in the OR.

Additional outcome variables included clinically relevant global outcomes (mortality and hospital length of stay) and 30-day postoperative complications, pertaining to wound, pulmonary, cardiovascular, renal, and life-threatening infectious complications, per the standardized ACS-NSQIP definitions.[26]

Matching and Data Analysis

Because patient's assignment to undergo an emergency general surgery procedure with or without trainee participation was not random, a coarsened exact matching algorithm[27] was used to match patients with a 1:1 ratio, on the basis of age; sex; inpatient status; morbid obesity; history of diabetes; smoking, alcohol, or steroid use; and preexisting coronary artery disease, renal failure, and pulmonary disease. As it is not possible to match subjects on the basis of exact procedure performed without significantly compromising sample size, and given the inherent greater complexity of cases managed at teaching institutions, subjects were also matched on their expected probability for morbidity and mortality (risk adjustment) per the validated ACS-NSQIP model. The 2 balanced patient groups obtained after application of the coarsened exact matching algorithm comprised the *Matched Cohort*. Absolute and relative frequencies of the various emergency general surgical procedures grouped by type were calculated in both the aggregate and matched cohorts. Depending on data distribution, continuous variables were compared with Pearson *t* test or Wilcoxon test and binary variables with the χ^2 test. Continuous variables are reported as means ± standard deviations if the data were normally distributed, or as medians (25%, 75% percentiles) if otherwise. Binary variables are reported as percentages.

To *quantify* the effect of resident's participation on the statistically significant outcomes, as identified on the aforementioned analysis, multivariable regression analysis models were fitted on the *matched cohort*, adjusting for the said risk factors *and* total operative time. The effect of total operative time is also reported. For the logistic regression models, postestimation Pearson goodness-of-fit tests were obtained and C-statistics were calculated. For the linear regression models, residuals were assessed for outliers and influential values, using leverage and standardized residuals. Observations with outlying and highly influential residuals were left in our sample as true outliers, if data collection was deemed appropriate and correct. Univariate graph plots were obtained to assess for an association between postgraduate level of trainee participation and case complexity/illness severity (as reflected on the preoperatively calculated expected probability for morbidity) and total operative time. Postgraduate years of 8 or more were combined into 1 group. All statistical analyses were performed using Stata 13.1 (StataCorp LP, College Station, TX). Statistical significance was declared at a 2-sided *P* value of 0.05 or less.

RESULTS

Of the 957,813 patients tracked by the ACS-NSQIP participating institutions, a total of 141,010 underwent emergency general surgical procedures between 2005 and 2010 and comprised our *aggregate cohort*. After matching, 2 equal-sized groups of 41,895 patients each formed our *matched cohort.* The baseline characteristics of all cohorts are summarized in Table 1.

Patients who underwent procedures with resident involvement were more likely to be inpatient (89% vs 85.45%; $P < 0.001$) and, not surprisingly, had more comorbidities at baseline. This is expected, as sicker patients or those requiring more complex procedures are more likely to be referred to teaching institutions.

Table 2 summarizes the procedures the *aggregate* and *matched cohorts* underwent, and Table 3 summarizes the discharge diagnoses between the 2 cohorts. The most common procedures in *aggregate cohort* (n = 141,010) were appendectomies (29.8%), exploratory laparotomies (12%), and colon resections (7.3%). The most common in the *matched cohort* (n = 83,790) were appendectomies (39.9%), exploratory laparotomies (8.8%), lysis of adhesions (6.6%), and cholecystectomies (6.5%). There is an overall balanced distribution of more complex cases (laparotomies, colectomies, small bowel resections, and abdominal wall hernia repairs), with simpler ones (lysis of adhesions, diagnostic laparoscopies, and inguinal herniorrhaphies) across the 2 groups in the *matched cohort*. This is not surprising, as the 2 groups were matched on their expected probability for mortality and overall morbidity, which takes into account not only baseline comorbid conditions but also complexity of the procedure(s) performed (by current procedural terminology code). Similarly, there is a balanced distribution of discharge diagnoses across the resident and no-resident groups in the *matched cohort* (Table 3): The resident group managed slightly fewer uncomplicated appendicitides (41.52% vs 44.44%), acute cholecystitides (3.06% vs 5.30%), diverticulitides (1.69% vs 2.22%), and gastrointestinal tract malignancies (1.46% vs 1.62%), but more operative bowel obstructions (8.78% vs 7.71%), hernias with (6.27% vs 5.64%) and without bowel obstruction (1.57% vs 0.97%), soft tissue abscesses (3.01% vs 2.85%), and intestinal ischemia (1.17% vs 0.95%).

Clinically relevant 30-day postoperative outcomes are listed in Table 4. As expected, due to the higher incidence of preexisting comorbid conditions and overall more complex cases typically managed at teaching institutions, hospital stay was longer (8.36 ± 14.8 vs 6.50 ± 11.2 days; $P < 0.001$) and 30-day mortality was higher (12.45% vs 8.74%; $P < 0.001$) in the *aggregate cohort*. Also, cases performed with resident participation took almost 20 minutes longer to complete (83.30 ± 60.72 vs 64.52 ± 49.4; $P < 0.001$), and total anesthesia time was longer by almost 27 minutes (134.51 ± 75.15 vs 107.54 ± 61.08; $P < 0.001$), likely due to involvement of anesthesia trainees, who may require longer times to secure the airway

TABLE 1. Baseline Demographic and Clinical Characteristics in the Aggregate and Matched Cohorts

	Aggregate Cohort (n = 141,010)			Matched Cohort (n = 83,790)		
	NO RES N = 52,059	**RES N = 88,951**	***P***	**No RES N = 41,895**	**RES N = 41,895**	***P***
Age, yr	49.84 ± 19.67	49.33 ± 19.44	**<0.001**	46.44 ± 18.87	46.43 ± 18.87	0.999
Sex (female)	51.94	50.89	**<0.001**	52.75	52.75	1.000
Inpatient	85.45	89.00	**<0.001**	84.01	84.01	1.000
BMI ≥30	32.77	32.04	**0.007**	31.34	31.34	1.000
Diabetes	10.91	11.51	**0.001**	6.35	6.35	1.000
Smoking	21.90	23.08	**<0.001**	20.08	20.08	1.000
Alcohol use	3.05	3.44	**<0.001**	1.67	1.67	1.000
Steroid use	3.52	4.57	**<0.001**	0.89	0.89	1.000
Coronary artery disease	7.97	8.49	**0.001**	3.44	3.44	1.000
Renal failure	3.25	4.21	**<0.001**	0.26	0.26	1.000
Pulmonary disease	11.83	13.21	**<0.001**	4.38	4.38	1.000
Expected probability for morbidity	0.18 ± 0.19	0.21 ± 0.21	**<0.001**	0.12 ± 0.13	0.12 ± 0.13	0.725
Expected probability for mortality	0.05 ± 0.13	0.06 ± 0.15	**<0.001**	0.016 ± 0.055	0.017 ± 0.055	0.103

No RES indicates without resident participation; RES, with resident participation. Bold values represent statistically significant.

TABLE 2. Procedure Types Performed in the Aggregate and Matched Cohorts Across the 2 Study Groups: RES and No RES

	Aggregate Cohort		Matched Cohort	
	No RES N = 137,955	**RES N = 77,076**	**No RES N = 58,824**	**RES N = 58,114**
Appendectomy	27.9%	33.2%	38.4%	41.4%
Exploratory laparotomy	13.2%	9.8%	9.5%	8.0%
Colon resection	7.5%	7.1%	4.8%	5.2%
Lysis of adhesions	6.8%	6.8%	6.7%	6.5%
Cholecystectomy	5.4%	5.9%	6.7%	6.4%
Small bowel resection	5.4%	4.3%	4.3%	4.1%
Abdominal wall hernia repair	4.9%	4.5%	5.5%	5.1%
Incision and drainage/debridement	3.4%	2.6%	3.0%	3.4%
Repair of perforated viscus	2.4%	1.8%	1.6%	1.5%
Diagnostic laparoscopy	1.4%	1.8%	1.5%	2.2%
Inguinal hernia repair	1.4%	1.4%	1.5%	1.5%
Other	20.3%	21.0%	16.4%	14.8%

N represents the number of procedures by current procedural terminology code performed in each group.
No RES indicates without resident participation; RES, with resident participation.

and establish and reverse anesthesia. Because of the greater number of preexisting comorbidities and increased procedure complexity in the cases performed with resident participation, it is not surprising that this group had greater complication rates [with the exception of wound dehiscence (1.06% vs 1.14%; $P = 0.164$) and postoperative acute coronary events (0.57% vs 0.50%; $P = 0.088$)].

After matching and eliminating the influence of patients' preexisting comorbidities and case complexity, no mortality difference was noted (3.25% vs 2.96%; $P = 0.085$). Total operative and anesthesia times were still longer if trainees were involved (75.10 ± 54.77 vs 59.17 ± 44.78 minutes; $P < 0.001$ and 122.42 ± 66.22 vs 99.92 ± 55.45 minutes; $P < 0.001$, respectively). Moreover, cases performed by residents required more intraoperative transfusions (3.43% vs 2.55%; $P < 0.001$) and unplanned returns to the OR (4.22% vs 3.80%; $P = 0.002$). Interestingly, cases performed by residents had a lower incidence of postoperative transfusion requirement (1.12% vs 1.28%; $P = 0.031$), possibly related to the fact that they received more blood products intraoperatively.

Regarding wound complications, cases performed with residents had a higher incidence of both superficial (SSSI) (3.50% vs 2.78%; $P < 0.001$) and organ space surgical site infections (OSSI) (2.27% vs 1.77%; $P < 0.001$) after surgery. However, there was no statistically significant difference in wound dehiscence between the 2 groups.

Patients whose procedures were performed with trainee involvement developed more pulmonary complications postoperatively, including pneumonia (1.85% vs 1.67%; $P = 0.043$), unplanned reintubation (1.64% vs 1.15%; $P < 0.001$), and prolonged mechanical ventilation (2.87% vs 2.06%; $P < 0.001$). Resident involvement did not seem to affect major cardiac events [such as myocardial infarction (0.27% vs 0.26%; $P = 0.637$) and cardiopulmonary arrest (0.39% vs 0.32%; $P = 0.071$)], cerebrovascular events (0.16% vs 0.13%; $P = 0.205$), or renal complications [including acute renal failure (0.34% vs 0.31%; $P = 0.427$) and renal failure requiring dialysis (0.37% vs 0.43%; $P = 0.209$)]. However, cases performed with trainees had a higher incidence of venous thromboembolic events [deep

TABLE 3. Discharge Diagnoses by *International Classification of Diseases, Ninth Revision* (*ICD-9*) Code in the Aggregate and Matched Cohorts Across the 2 Study Groups: RES and No RES

	Aggregate Cohort		Matched Cohort	
	No RES N = 52,059	RES N = 88,951	No RES N = 41,895	RES N = 41,895
Acute uncomplicated appendicitis	35.70%	32.49%	44.44%	41.52%
Acute complicated appendicitis	10.89%	8.79%	10.09%	10.19%
Bowel obstruction	8.28%	9.37%	7.71%	8.78%
Hernia w/ obstruction	5.84%	5.88%	5.64%	6.27%
Acute cholecystitis	5.18%	4.94%	5.30%	3.06%
Cellulitis or abscess	3.14%	3.51%	2.85%	3.01%
Gastrointestinal tract perforation	4.21%	5.16%	2.95%	2.91%
Symptomatic cholelithiasis/ chronic cholecystitis	2.25%	2.21%	2.43%	2.69%
Diverticulitis	2.62%	2.28%	2.22%	1.69%
Hernia w/o Obstruction	0.95%	1.32%	0.97%	1.57%
Gastrointestinal tract malignancies	1.98%	2.00%	1.62%	1.46%
Intestinal ischemia	2.11%	3.00%	0.95%	1.17%
Gastrointestinal tract hemorrhage	1.11%	1.16%	0.58%	0.44%
Pancreatic disease	0.47%	0.74%	0.33%	0.38%
Other	15.29%	17.14%	11.92%	14.85%

No RES indicates without resident participation; RES, with resident participation.

TABLE 4. Clinically Relevant 30-Day Postoperative Outcomes

	Aggregate Cohort (n = 141,010)			Matched Cohort (n = 83,790)		
	No RES N = 47,178	RES N = 61,353	*P*	No RES N = 41,895	RES N = 41,895	*P*
Mortality	8.74	12.45	**<0.001**	2.96	3.25	0.082
Length of stay	6.50 ± 11.2	8.36 ± 14.8	**<0.001**	4.59 ± 7.98	4.97 ± 9.63	**0.019**
Operative technique						
Operative time	64.52 ± 49.41	83.30 ± 60.72	**<0.001**	59.17 ± 44.78	75.10 ± 54.77	**<0.001**
Anesthesia time	107.54 ± 61.08	134.51 ± 75.15	**<0.001**	99.92 ± 55.45	122.42 ± 66.22	**<0.001**
Intraoperative transfusion	5.64	9.33	**<0.001**	2.55	3.43	**<0.001**
Postoperative bleed requiring transfusion	2.45	3.16	**<0.001**	1.28	1.12	**0.031**
Unplanned return to the operating room	5.66	8.54	**<0.001**	3.80	4.22	**0.002**
Wound complications						
Superficial wound infection	3.13	4.09	**<0.001**	2.78	3.50	**<0.001**
Deep wound infection	1.14	1.06	0.164	0.89	0.73	**0.011**
Organ space infection	2.20	3.27	**<0.001**	1.77	2.27	**<0.001**
Wound dehiscence	1.08	1.27	**0.002**	0.69	0.63	0.266
Pulmonary complications						
Postoperative pneumonia	3.20	4.23	**<0.001**	1.67	1.85	**0.043**
Unplanned reintubation	2.33	3.64	**<0.001**	1.15	1.64	**<0.001**
Prolonged ventilation (>48 hr)	5.82	9.47	**<0.001**	2.06	2.87	**<0.001**
Cardiovascular complications						
Myocardial infarction	0.50	0.57	0.088	0.26	0.27	0.637
Cardiopulmonary arrest	0.80	1.21	**<0.001**	0.32	0.39	0.071
Cerebrovascular Accident	0.28	0.37	**0.006**	0.13	0.16	0.205
Deep venous thrombosis	1.06	1.56	**<0.001**	0.62	0.80	**0.002**
Pulmonary embolism	0.37	0.56	**<0.001**	0.28	0.43	**<0.001**
Renal complications						
Acute renal failure	0.61	0.71	**0.029**	0.31	0.34	0.427
Renal failure requiring dialysis	1.17	1.46	**<0.001**	0.43	0.37	0.209
Urinary tract infection	1.78	2.36	**<0.001**	1.14	1.45	**<0.001**
Life-threatening infectious complications						
Sepsis	2.98	4.13	**<0.001**	2.13	2.42	**0.005**
Septic shock	2.95	3.88	**<0.001**	1.41	1.51	0.205

No RES indicates without resident participation; RES, with resident participation. Bold values represent statistically significant.

TABLE 5. *Matched Cohort* Analysis: Effect of Trainee Participation and Operative Time on Outcomes (Adjusting for Risk Factors and Operative Time)

	Effect of Trainee Participation on Outcomes		Effect of Operative Time on Outcomes (per 30 min)	
	Effect Estimate/Odds Ratio (95% CI)	***P***	**Effect Estimate/Odds Ratio (95% CI)**	***P***
Length of stay	0.07 (−0.04 to 0.17)	0.242	0.62 (0.58–0.65)	**<0.001**
Superficial wound infection	1.23 (1.13–1.34)	**<0.001**	1.10 (1.09–1.12)	**<0.001**
Organ space infection	1.21 (1.09–1.34)	**<0.001**	1.10 (1.08–1.13)	**<0.001**
Intraoperative transfusion	1.20 (1.07–1.34)	**0.001**	1.30 (1.27–1.32)	**<0.001**
Postoperative bleeding requiring transfusion	0.78 (0.69–0.90)	**<0.001**	1.15 (1.12–1.17)	**<0.001**
Unplanned return to the operating room	1.08 (1.00–1.16)	**0.041**	1.06 (1.04–1.08)	**<0.001**
Postoperative pneumonia	1.06 (0.94–1.18)	**0.348**	1.08 (1.06–1.11)	**<0.001**
Unplanned reintubation	1.38 (1.21–1.57)	**<0.001**	1.07 (1.04–1.09)	**<0.001**
Prolonged mechanical ventilation (>48 hr)	1.43 (1.29–1.59)	**<0.001**	1.13 (1.11–1.15)	**<0.001**
Deep venous thrombosis	1.25 (1.05–1.49)	**0.011**	1.07 (1.04–1.11)	**<0.001**
Pulmonary embolism	1.42 (1.11–1.81)	**0.005**	1.09 (1.05–1.13)	**<0.001**
Urinary tract infections	1.23 (1.08–1.40)	**0.001**	1.08 (1.06–1.11)	**<0.001**
Sepsis	1.07 (0.97–1.18)	0.155	1.1 (1.08–1.12)	**<0.001**

Bold values represent statistically significant.

venous thrombosis (0.80% vs 0.62%; $P = 0.002$), pulmonary embolism (0.43% vs 0.28%; $P < 0.001$)], and urinary tract infections (1.45% vs 1.14%; $P < 0.001$), possibly related to the longer total operative time. A greater rate of septic complications was noted in the resident group also (2.42% vs 2.13%; $P = 0.005$), likely due to the greater number of infectious events.

The quantified effect of trainee participation on clinically relevant outcomes (adjusting for aforementioned risk factors, expected probability for morbidity and mortality, and operative time) is summarized in Table 5. The same table demonstrates the independent effect of every 30 minutes added to the total operative time, controlling for risk factors, expected probability for morbidity and mortality, and resident participation. Model fit was highly satisfactory for all logistic regression models, and C-statistics ranged from 0.80 to 0.93. No error in data entry was obvious in the influential or outlying observations in the linear regression model for the length of stay.

When adjusting for the aforementioned risk factors *and* operative time, the resident's involvement was not independently associated with hospital length of stay (β coefficient: 0.07; $P = 0.242$), but it was found to be an independent predictor for most adverse postoperative outcomes, except for postoperative transfusion requirements (possibly due to greater blood product transfusion intraoperatively), in which trainee participation was protective [odds ratio (OR): 0.78 (0.69–090), $P < 0.001$], and pneumonia and sepsis events, for which trainee participation exerted no effect [O.R: 1.06 (0.94–1.18); $P = 0.348$ and 1.07 (0.97–1.18); $P = 0.155$, respectively). Resident-assisted cases were 23% more likely to develop an SSSI ($P < 0.001$), 21% more likely to develop an OSSI ($P < 0.001$), and 20% more likely to require an intraoperative transfusion ($P = 0.001$), independent of total operative time. Cases performed by residents were 8% more likely to require unplanned reoperation ($P = 0.041$), 38% ($P < 0.001$) more likely to necessitate unplanned reintubation, 43% more likely to experience failure to wean off mechanical ventilation ($P < 0.001$), 25% more likely to develop deep venous thrombosis ($P = 0.011$), 42% more likely to develop a pulmonary embolism ($P = 0.005$), and 23% more likely to develop postoperative urinary tract infections ($P = 0.001$).

Similarly, longer operative times seemed to exert a statistically significant effect on outcomes in our secondary analysis, independent of trainee participation or known risk factors: For every 30 minutes a case lasted longer, hospital stay was prolonged by 0.62 days [β coefficient: 0.62 (0.58–0.65), $P < 0.001$). Longer operative times were also associated with a greater incidence of SSSI and OSSI: For every additional half-hour in total operative time, incidence of SSSI and OSSI increased by 10% each ($P < 0.001$), and so did intra- (by 30%, $P < 0.001$) and postoperative (15%, $P < 0.001$) transfusion requirements and unplanned take backs to the operating theater (6%, $P < 0.001$). Pulmonary and thromboembolic complications also increased with added operative time because of the increased length of immobility and the likely inadequacy of extremity compression devices. Finally, urinary tract infections and sepsis incidence were positively influenced by longer operative times [OR: 1.08 (1.06–1.11); $P < 0.001$, and OR: 1.10 (1.08–1.12); $P < 0.001$, respectively, per 30 minutes of operative time).

Evaluating the effect of postgraduate year of training to the total operative time, it seems that senior residents and fellows tend to require more time in the OR (Fig. 1), but this effect may be due to self-selection for participation in more complex surgical cases (Figs. 2 and 3). Attendings are also more likely to perform the majority of the operation, when junior residents scrub in complex cases. The 3 graphs also demonstrate that staff surgeons can perform fairly complex surgical procedures in less time than typically required when trainees participate.

DISCUSSION

Our findings suggest that trainee participation in emergency general surgery procedures is associated with longer operative time and more intraoperative transfusions and is independently associated with adverse postoperative outcomes, including wound, pulmonary and venous thromboembolic complications, and urinary tract infections. Although some residual, unmeasured confounding cannot be completely excluded, as no information on level of supervision is available, it seems that this effect is independent of total operative time, case complexity, and preexisting comorbidities. Operative time

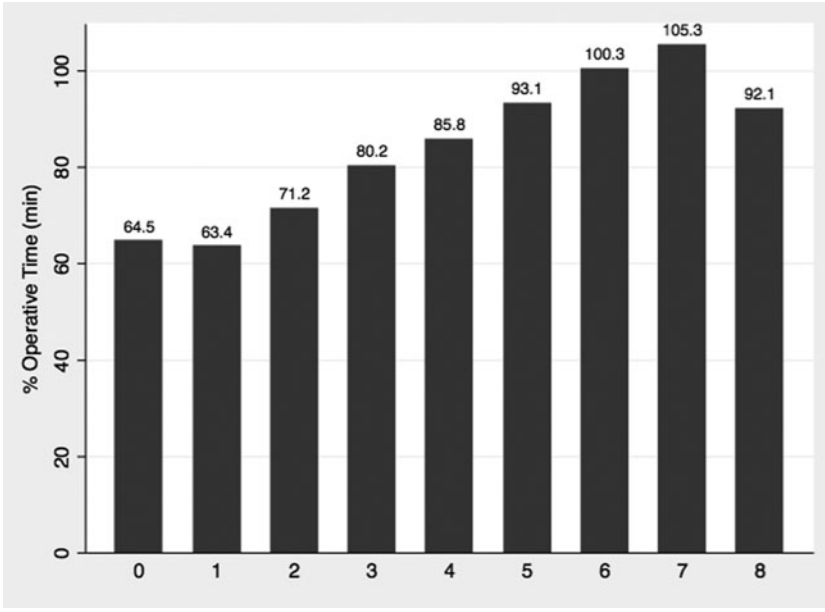

FIGURE 1. Operative time (minutes) versus postgraduate year (year 0 corresponds to cases performed by attending surgeons alone).

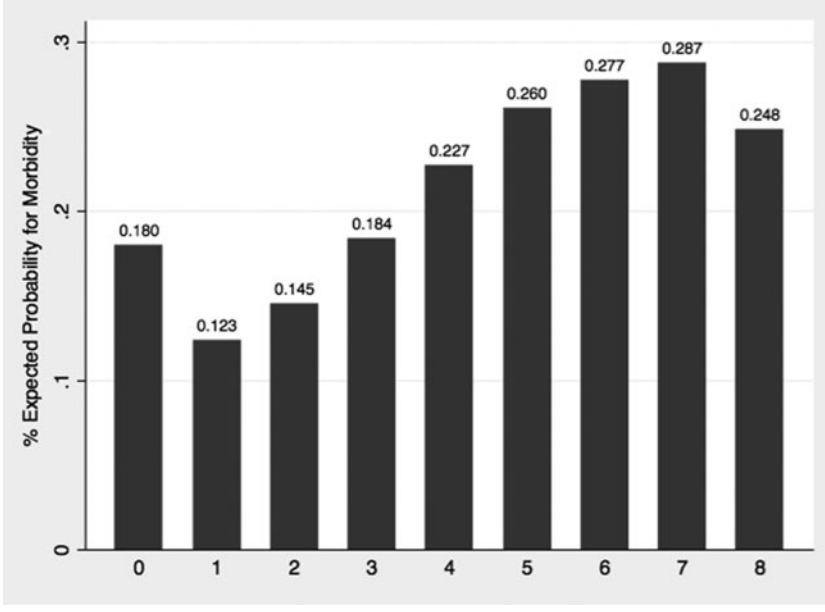

FIGURE 2. Expected probability of morbidity versus postgraduate year (year 0 corresponds to cases performed by attending surgeons alone).

is identified as an another important factor independently associated with intra- and postoperative transfusions; unplanned reoperations; wound, pulmonary, infectious, and venous thromboembolic complications; and longer hospital stays, adjusting for baseline comorbidities, case complexity, and resident participation.

Our findings are similar to several other studies that have shown a similar effect of trainee participation in general surgery: Krell and associates[28] demonstrated that resident involvement was independently associated with postoperative wound complications and venous thromboembolism in patients undergoing laparoscopic gastric bypass, after adjusting for risk factors and surgeon and hospital case volume. They posit that the higher incidence of these complications is likely due to longer operative times. Our findings are similar, although trainee participation was independently associated with postoperative morbidity, even when operative time was controlled for. We additionally demonstrate that operative time itself was independently associated with numerous complications, even when adjusting for trainee participation.

Scarborough et al[19] similarly showed an increased incidence of serious and overall postoperative complications when appendectomies were performed with resident participation, adjusting for baseline comorbidities and total operative time. However, they demonstrated that operative times and risk for postoperative morbidity increased with postgraduate year of training and attributed this effect to the increased level of autonomy senior residents enjoy in the operating theater. However, they did not risk-adjust these 2 outcomes in their analysis for such a conclusion to be definitively drawn. This is in contrast to our findings, which demonstrate that there is indeed a greater incidence of postoperative morbidity in cases performed with senior resident/fellow involvement. However,

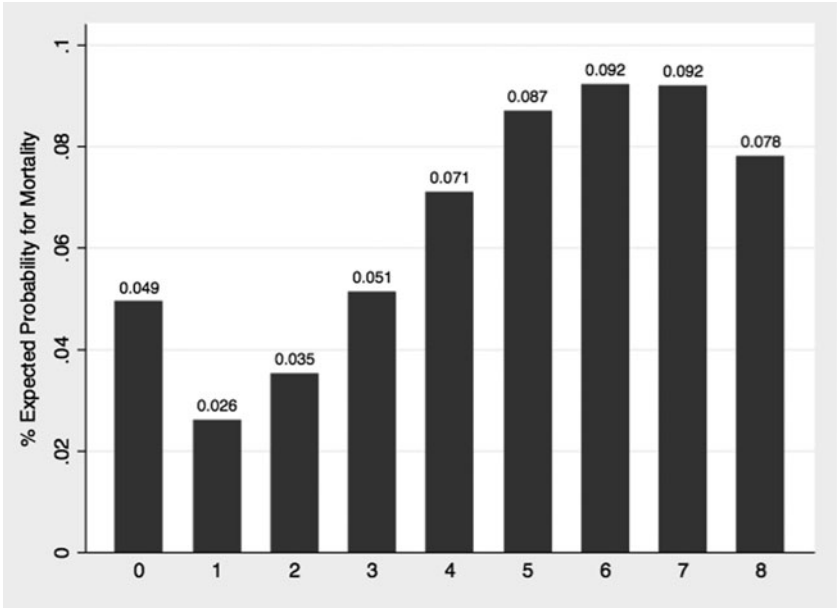

FIGURE 3. Expected probability of mortality versus postgraduate year (year 0 corresponds to cases performed by attending surgeons alone).

this is likely due to the fact that more complex cases are assisted by more senior trainees. Similarly, Wilkiemeyer and colleagues[29] examined the relationship between various levels of resident level and postoperative outcomes in hernia repairs, reporting an increased recurrence rate in the cases performed by junior residents, compared with those performed by their senior counterparts.

Contrasting our findings is the work of Kiran et al,[21] who, following similar methodology as ours, concluded that resident's involvement in surgical procedures is safe, citing that a modest increase in SSSI was likely due to longer operative times. However, that study had a smaller matched sample size and included both elective and emergency cases, rendering comparisons difficult. It is possible that time spent in the OR in an elective setting may not be as significant determinant of postoperative outcomes as in emergency procedures, in which host physiology may be appreciably deranged.

Similarly, Kazaure et al[30] reported no trainee effect in risk of overall complications or hospital length of stay and only a minimal increase in total OR time. However, they grouped all complications in a single binary variable, assessed the effect of trainees who operated alone on only 3 procedures (appendectomies, cholecystectomies, and herniorrhaphies), and included both elective and emergency cases. Finally, their article did not state what variables they controlled for in their multivariable regression model (except for case complexity, using relative value units, and not the more robust calculated risk for morbidity and mortality), making comparisons difficult, if not impossible. Itani and colleagues[31] concluded that the degree of resident's supervision did not affect outcomes; however, in their analysis, they compared cases performed by residents and an attending immediately available against cases performed by staff surgeons alone or with residents participating, rendering it difficult to infer the "trainee effect."

The findings of the present work should be interpreted with caution and in the context of the study design. Major strengths of our analysis lie in our large sample size, matching of the 2 groups on numerous comorbidities known to adversely affect postoperative outcomes, and inclusion of the expected probability for morbidity and mortality, which balances the effect of host risk factors *and* case complexity. However, this is a secondary analysis of prospectively collected data, not originally intended to test our specific hypothesis. In addition, the data, while highly reliable, are derived from ACS-NSQIP–participating institutions and thus are skewed toward larger, tertiary medical centers that perform more complex emergency general surgery procedures, whereas smaller hospitals may be underrepresented.[32] It is also important to note that data are collected for a maximum of 30 days postoperatively, which may underrepresent true surgical-related mortality.[33] Additional considerations include resident's autonomy, which may be greater in fairly simple emergency procedures (in an appendectomy or abscess drainage, for example), as opposed to elective cases that require more advanced technical skills (such as a Whipple or a gastric bypass), and the fact that the ACS-NSQIP database does not report the extent of trainee participation or attending supervision. Such information could potentially improve our understanding of the relationship between resident's involvement and postoperative outcomes and account for residual confounding, although previous research has not demonstrated differences with varying degrees of trainee supervision.[30,31] Finally, the degree of resident's autonomy in postoperative patient care—not tracked by the ACS-NSQIP—likely also influences outcomes.

Our findings underline several important aspects of trainee education and its impact on patient outcomes in emergency general surgical procedures. Resident training and involvement is crucial to the sustainability of any health care system, as the future of health care is highly dependent on our ability to provide high-quality postgraduate medical education. Nonetheless, it is the responsibility of training programs to ensure that patient's safety is maintained with appropriate trainee supervision. The small increase in morbidity associated with resident involvement indicates that appropriate supervision should be a priority, and greater emphasis should be placed on surgical emergency simulation training to improve efficiency in and out of the OR.[34,35]

Improving the channels of communication between trainees and staff surgeons should also be prioritized during surgical emergencies. Residents should be well prepared for emergency procedures through simulation training and aim to maximize their efficiency in the OR. In addition, time objectives for the resident-assigned operative tasks should be established early in operative management, with planned "takeovers" by the attending physician, if these time objectives are not met.[28] Such a strategy could not only allow

effective hands-on training time for residents but also minimize inefficient use of operative time.

CONCLUSIONS

Resident involvement in emergency general surgical procedures seems to be independently associated with longer operative times and both intraoperative and postoperative complications. This association is independent of total operative time, case complexity, and preexisting comorbid conditions. Operative time also seems to be an independent risk factor for postoperative morbidity. Surgeons practicing at teaching institutions should be aware of this association, provide appropriate supervision as needed, and minimize unnecessary operative time. Enhancing residents' preparedness for emergency operations, perhaps through simulation, may also aid in limiting operative times and thus minimizing adverse postoperative outcomes.

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DISCUSSANTS

J.A. Sosa (Durham, NC):

Thank you for an interesting study that highlights the importance of graduate surgical education and its implications for patient safety and policy. The findings are important and notable, as they contradict several other studies using ACS/NSQIP and VASQIP that have demonstrated little to no clinically significant difference in patient outcomes based on resident involvement. If not interpreted with care, policy makers, payers, and the public could construe that surgical care at academic health centers is compromised by trainees, which could have unfortunate ramifications for everyone in the room, and trainees and patients. The authors carefully frame their discussion and limitations but will need to ensure going forward that others' discussions of implications remain evidence based. Statistically significant findings in this study may not represent clinically significant differences, given the large size of the data set.

My worry is about drawing causal inferences from an observational study in the setting of possible selection bias. The authors nicely

acknowledge concern that more complex cases go to teaching institutions and residents, as confirmed by differences in the unmatched cohorts. The authors do a good job trying to match but are constrained by the limitations of the data set itself. Although matching can reduce differences in populations, it cannot adjust for unobserved factors. They attempt to match for case complexity using CPT codes, which does not necessarily account for, say, the difference between a routine appendectomy that takes 15 to 30 minutes or a complex one that, say, takes 3 hours for a perforation. The increasing OR time and morbidity associated with increased postgraduate training here supports the notion that these findings might be swayed by some degree of selection bias. To feel confident in the observed findings, it would be nice to have a control variable.

I have 3 questions.

First, could a comparison of final diagnoses be performed that might be informative if the more interesting or challenging cases are being directed to residents, as evidenced by the diagnosis code? There should be consideration of severity of diagnosis in the model.

Second, would it also lend credibility if the authors could show that increasing year of residency was associated with improved outcomes in their final model, since residents should be more proficient over time as they progress through training? So, was year of training included in the multivariable model?

And, third, could the authors use the NSQIP variable for the availability of the attending surgeon in the OR or surgical suite in their model to supplement their analysis?

Response From G. Kasotakis:

I would agree that we have to be very careful in interpreting our data. We cannot really infer causation when it comes to looking at outcomes whenever residents are involved. And, of course, we cannot do away with residents if we want to have a future in any surgical field.

To answer your questions, we did not use diagnosis codes to not excessively constrain sample size. However, we can easily look at this information in the final article.

With regard to the effect of trainee level, year of training was not included in our multivariable model; however, we noted a univariate trend with longer operative times in cases performed by senior trainees. We found that this was not due to the increased autonomy senior residents enjoy in the operating room, but a self-selection to more complex cases, as we discussed.

Finally, we had hoped to be able to use the NSQIP variable that documents attending availability or presence in the OR; however, more than 99.9% of the cases we analyzed had the attending as present in the operating room, essentially rendering this parameter unusable. Also, when we looked at the type of procedures and diagnoses of patients who went to surgery without a staff surgeon present in the OR, we noted that the vast majority of them were uncomplicated appendectomies and drainage of soft tissue abscesses, limiting further the variable's usability. It would be great if NSQIP tracked degree of trainee and attending involvement in each case; however that is not the case, and at present, we have only very granular information on whether a staff surgeon was simply in the OR.

I have to reiterate that our study was a retrospective look at a database that was not specifically designed to look at the effect of trainee participation in clinically relevant outcomes, and our findings have to be interpreted with caution.

DISCUSSANTS

G. Fried (Montreal, QC):

I have no disclosures. Although large data set analyses like these are vulnerable to methodologic criticisms and the assumptions upon which they're based, I would like to comment more on the philosophic aspects of this.

Resident education is a fundamental responsibility that we own to ensure the provision of quality care to the next generation of our patients. The data that you have presented here show that engaging residents with responsibilities for patient care, although clearly necessary for their training, comes at a cost, both in terms of outcomes and finances. Some dimensions of these costs have been documented in this article.

Unfortunately, development of a strategy to shift the focus of learning from the clinical setting partially to the simulation setting requires a substantial investment in human and financial resources to fulfill these needs. These data, and those from other similar studies, must be captured and used to provide some evidence for us so that we could advocate for the resources that will allow us to provide better educational programs and to protect the best interests of our patients during the learning phase.

Residents provide inexpensive care. There is a cost to that. We need to provide some evidence that really gets the attention of people that will provide some of the resources to balance that out. I think such an approach makes sense both economically and ethically.

Response From G. Kasotakis:

I don't think I could agree more with your remarks. With our findings, we believe that the majority of the additional morbidity can be attributed to 2 major factors that all of us recognize in our daily practice: The prolonged OR time cases take whenever residents participate, and, 2, perhaps to their less than perfect surgical skills. Factors like these may also come into play when junior attendings operate, compared with their senior colleagues.

However, we do have to better prepare residents before they come to the OR and tackle those emergency operations. Also, both surgeons and residents have to be mindful of the time. We have to be mindful of the clock. We have to aim to be more efficient, so that we can improve our outcomes overall.

Again, this is by no means a prospective clinical trial that randomizes emergency cases to resident involvement versus not, and one has to be mindful of the limitations of our analysis. But there is no smoke without fire, and we can certainly use these findings, whatever their limitations, to advocate for more resources in better training the surgery resident of the future.

DISCUSSANTS

M.T. Hawn (Birmingham, AL):

I echo Dr. Sosa's concerns about confounding. I wondered whether you looked at admission source and excluded transfer patients to try and deal with the referral bias to tertiary care centers.

My second question is more philosophical. Why are we ascribing all the increased complications to the trainee, and why isn't your title "Academic Surgeons Affect Outcomes in Emergency General Surgery"? Aren't we ultimately responsible?

Response From G. Kasotakis:

Unfortunately, we did not look at the transfer status of patients. So, of course, that is something that can be taken into consideration when we look further and deeper into the effect of trainee participation in emergency operations.

Also, yes, we do believe that there is some residual confounding that we were not able to address because of the nature of the data set and, again, the main limit was that this was a large data set that was not designed to address this specific question. So, we do acknowledge our limitations, and we are looking to work with something better in the future.

With regard to the effect of academic surgeons or attendings' seniority on outcomes, it's a great idea for future research projects.

DISCUSSANTS

H. Polk (Louisville, KY):

I would like to join the skeptics' lobby, skeptical with the work and skeptical about your conclusions. I have worked with enough large databases to know that you can take any nonsensical comparison you like, and if one makes the denominator big enough, they are all $P < 0.0001$. There's a lot of that in here.

What determined whether or not a resident scrubbed on a case in this comparison? Why didn't you use the Charlson index for some easily understood, reliable comparison of degree of comorbidities? Why did you have more transfusions in the OR when a resident was present but more transfusions postoperatively when a resident was absent? And, finally, what does the presence or absence of residents have anything to do with DVT or pulmonary embolism?

There are lots of failings in this work.

Response From G. Kasotakis:

Deciding what factors come into play on whether residents and of what postgraduate level will scrub into certain cases is a difficult task. Again, that is a variable that is unfortunately missing from the NSQIP data set, so we cannot really comment on that all that much.

I'm not really sure we could have used a Charlson index, given patients' preexisting comorbidities are coded in such a way in NSQIP that precludes reliably calculating such a parameter. However, we did use the preoperatively calculated risk for morbidity and mortality to risk-stratify patients and control for baseline risk factors. This risk calculator contains information on the indication for surgical intervention and more than 22 clinical parameters that are known risk factors for adverse outcomes. It is also one of the key parameters that NSQIP uses to risk-adjust and compare outcomes and is well-validated for that purpose. So, I'm not sure a Charlson index would have performed better. Again, as we did not design the database, we can only use what's already available.

With regard to the association of resident participation and intraoperative transfusions and venous thromboembolic events, I think the common denominator is longer operative time. The longer you dissect through tissue, the more bleeding you are likely to cause, with case complexity controlled for. The longer you leave someone sedated and immobilized, the more likely it is for them to develop venous thrombosis.

DISCUSSANTS

O. Kirton (Hartford, CT):

Obviously, as everyone knows, the ACGME is requiring that we provide some type of clinical assessment back to our residents. And we are looking at NSQIP, all of us, hoping that this could be an appropriate tool. But there are very many limitations to NSQIP, particularly when you look at emergency surgery, there are many variables—whether surgery occurs during the day, whether it occurs at night, is it performed by the lesser experienced junior faculty who are doing the emergency surgery, or whether it is senior faculty. And who is actually operating with the general surgeon faculty when it's not the resident assisting? The Advanced Practitioner, or the surgical technologist.

I think we just need to be cautious, particularly, as brought up by Dr. Hiram Polk, when you look at some of these complications, is it a reflection of the resident, or is it a reflection of supervision and training?

Again, I think more and more, we need to be able to give better feedback and better supervision to our residents because the time we have with them is increasingly limited.

Response From G. Kasotakis:

Again, yes, we do have to be cautious about how we are going to interpret these findings, but I think this is a first look at how resident participation may have a slightly increased risk of complications that do matter. We have to take that in mind before we look toward the future.

Again, we did not attempt to answer the question on whether staff surgeon seniority and level of involvement, or degree of resident supervision, are associated with certain outcomes. These parameters likely contribute to some residual confounding and would have to be addressed in the future. We wanted to address if resident participation, as documented in the NSQIP data set, is associated with certain outcomes after emergency surgery.

DISCUSSANTS

G. Velmahos (Boston, MA):

Even if I must confess that I do not fully agree with your conclusions, and I'm sure that your popularity with the residents must be at an all-time low, I recognize the usual scientific rigor with which you perform your studies.

My question pertains to legal and maybe informed consent aspects, particularly relevant to this audience, because almost everybody here works at a teaching institution.

Are we now, based on this study, supposed to inform patients that there is a resident in the OR with us, and, therefore, the outcomes of the patient may be compromised and they better choose another place?

Response From G. Kasotakis:

It is true, the residents at our training program were not happy to hear our findings, when we presented them recently to them. From a medicolegal aspect, I think that's an important concern that we have to keep in mind. Perhaps training institutions should consider adding a clause to surgical consents that state that residents of varying seniority and skillset will be participating and assisting in a case, explaining to the patients that if staff surgeons believe that their skills are not up to par of what is expected for that case, they can take over.

DISCUSSANTS

M. Malangoni (Philadelphia, PA):

This is an interesting article. Yours is not the first to show an association between resident participation with operating room cases as increasing the operative time or increasing the risk of complications. What's been demonstrated before is that the complications have been relatively minor.

I share others' concerns about attributing this association the operative participation of a resident as opposed to potential factors.

What is surprising about your results is that these increased complications did not result in an increased length of stay. So, that raises the question of whether or not, in your matching, you adjusted for institutional characteristics. Despite the strict definitions within the NSQIP database for each of these complications, there may be differences in screening techniques that could influence the results. An example would be VTE, where an intensive screening technique will pick up more cases of VTE than are necessarily clinically significant, which would support the fact that there's no change in length of stay.

Did you account for institutional differences in your matching?

Response From G. Kasotakis:

Unfortunately, NSQIP does not include information from what institution the patients come. So, it was not possible for us to do that. It would be great if we had that information at hand and could perform a multilevel analysis.

However, I do agree that we are not the first to demonstrate an association with adverse outcomes whenever residents participate. That may be just because of the fact that patients are typically referred to a higher level of training institutions, where residents are more likely to be available and help out in those cases. Now, again, we are very careful to not mention the word "causation" in our article or in our discussion today, because we can obviously not do that.

But coming back to the hospital length of stay, we did not see a direct, independent association between resident participation and length of stay. However, when we compared the 2 groups, the group that had their procedures performed by residents stayed longer in the hospital, just because they had more complications. And, as you mentioned, there was no independent resident effect on overall length of stay, because it's the baseline comorbidities and the case complexity and potentially the complications that would prolong the hospital stay; not the presence of residents in the OR, something that kind of makes sense.

DISCUSSANTS

L. Ratner (New York, NY):

I was struck very much by things like reintubation, failure to wean, transfusion requirements, OR time, and anesthetic time that were all increased in the resident group. As someone who has spent my entire career in academic medical centers, I'm struck by how often the surgical residents are getting a whole lot more supervision than the anesthesia residents. As someone who likes to share the wealth, is there any data in the database regarding the anesthesia residents and whether or not they were supervised or whether or not they participated?

Response From G. Kasotakis:

That is a great observation also. We noted that the anesthesia time was prolonged by a greater amount than the total operative time, suggesting that anesthesia trainees may play a small role somewhere there and perhaps contribute to some small extent to the unmeasured confounding. That is definitely something that we have to keep in mind. However, this information on whether anesthesia trainees participate, how they are supervised, and how aggressive they are with giving IV fluids and blood products, we simply don't have the data to test whether an association exists, but I personally believe that it does.