Resident involvement is associated with worse outcomes after major lower extremity amputation

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Background: **Despite the recent major changes in vascular and general surgery training, there has been a paucity of literature examining the effect of these changes on training and surgical outcomes. Amputations represent a common cross-section in core competencies for general surgery and vascular surgery trainees. This study evaluates the effect of trainee participation on outcomes after above-knee and below-knee amputations.**
Methods: **The American College of Surgeons-National Surgical Quality Improvement Program (NSQIP) database (2005 to 2010) was queried using Current Procedural Terminology codes (American Medical Association, Chicago, Ill) for below-knee amputation (27880, 27882) and above knee-amputation (27590, 27592). Resident involvement was defined using the NSQIP variable and was narrowed to postgraduate year 1 to 5. Variables associated with resident involvement were identified, and mortality, morbidity, intraoperative transfusion, and operative time (75th percentile vs the bottom three quartiles) were evaluated as distinct categoric end points in logistic regression. Included in the model were variables with a *P* value <.1 on χ^2 or independent *t*-test, as appropriate. Significance was defined at $P < .05$.**
Results: **Residents were involved in 6587 of 11,038 amputations (62%). After adjustment for preoperative and intraoperative factors on logistic regression, there was a significant increase in major morbidity (odds ratio [OR], 1.27; 95% confidence interval [CI], 1.14-1.42; $P < .001$), intraoperative transfusion (OR, 1.78; 95% CI, 1.50-2.11; $P < .001$), and operative time (OR, 1.64 95% CI, 1.46-1.84; $P < .001$) in resident cases.**
Conclusions: **Resident involvement was associated with increased odds of major morbidity after amputation and also with increased operative time and risk for intraoperative transfusions. (J Vasc Surg 2013;58:827-31.)**

Whether resident involvement changes patient outcomes remains controversial not only secondary to the nature of the topic but also due to inconsistent evidence. Although half of all surgical procedures performed in the United States are performed at teaching centers, few studies have adequately addressed whether the presence of a trainee changes patient outcomes.[1] Specific studies that have evaluated resident involvement have not shown any associated changes in mortality[2-7]; however, resident involvement has been associated with complications. In vascular surgery, infrainguinal bypass cases that involved residents were associated with increased early graft failure rates.[8] Conversely, a study evaluating resident involvement in carotid endarterectomy did not demonstrate any difference in outcomes.[9] These disparate findings suggest the effect of resident involvement may depend on procedure type. This study questioned whether resident involvement was associated with adverse outcomes after below-the-knee amputations (BKAs) and above-the-knee amputations (AKAs).

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METHODS

This study used readily available deidentified data and therefore was not subject to Investigational Review Board approval or oversight.

Study design. This was a retrospective study using the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) from years 2005 to 2010. NSQIP is a clinical database with prospective systematic data collection conducted at >258 hospitals throughout the United States in 2010. Details about sampling strategy, data abstraction, collected variables, and recorded outcomes have been previously reported.[10]

Case evaluation was restricted using Current Procedural Terminology codes (American Medical Association, Chicago, Ill) for BKA (27880, 27882) and AKA (27590,

27592). Resident involvement in a case was defined using the NSQIP variable "highest level of supervision" and "highest level of resident involvement" recorded by postgraduate year (PGY). Residents were considered to be involved if PGY was coded from 1 to 5. Senior residents were considered PGY 3 to 5 and junior residents PGY 1 to 2. Cases were considered to be attending cases (ACs) alone if marked "Attending Alone" and PGY 0. Cases where PGY was >5 were considered fellow cases. The analysis excluded 1227 fellow cases.

Definitions. Preoperative comorbidities were grouped by organ system.[11] NSQIP provides wound classification in accordance with the Centers for Disease Control and Prevention as an assessment of surgical wound contamination at the time of operation. A wound class of I is designated for clean cases, II for clean/contaminated, III for contaminated, and IV for dirty/infected cases.

Laboratory values were captured as the last recorded value 90 days before surgery. Hypoalbuminemia and anemia were evaluated as categoric variables, with thresholds for albumin of 3.5 g/dL and hematocrit of 36%.

Preoperative transfusion was evaluated using the NSQIP parameter representing >4 units of blood transfused ≤72 hours before the index procedure. Intraoperative transfusion was treated as a categoric variable due to the narrow interquartile range as any transfusion vs none. Bleeding disorder was defined as any condition putting the patient at risk for bleeding due to a deficiency of blood clotting elements, including vitamin K deficiency, hemophilia, thrombocytopenia, and use of chronic anticoagulants (excluding aspirin) not discontinued before surgery.

Outcomes. Death at 30 days was evaluated as a unique end point. Postoperative clinical complications were classified as major or minor and identified by organ system measured at 30 days after surgery. The methodology for outcome classification has been previously published.[12]

The primary end point was major complications at 30 days, which was evaluated as a binary outcome defined as any life-threatening or debilitating complication and included organ space infection, sepsis, postoperative hemorrhage requiring transfusion, dependence on ventilator (reintubation or failure to wean), cardiac event, neurologic event, pneumonia, venous thromboembolic event, return to operating room, graft failure, or acute renal failure. Return to the operating room was recorded as any unplanned major surgical procedure ≤30 days postoperatively that was a result of an adverse outcome related to the principal procedure. Minor complications were defined as incisional infections (superficial to the fascia) and urinary tract infections.

Statistical analysis. Association with resident involvement was first examined using univariate χ^2 analysis. Variables meeting criteria of a P value < .1 on univariate analysis were considered for inclusion in multivariable models. Multivariable logistic regression was performed for each end point, and a P < .05 was considered a significant association for factors in these logistic regressions. All analyses were done using IBM SPSS 19 software (IBM Corp, Armonk, NY).

Table I. Patient demographics

Variable[a]	*Attending alone (n = 4181)*	*Resident (n = 6857)*	P
Age, years	68.8 ± 13.5	66.7 ± 13.9	<.001
Male sex	2577 (61.6)	4185 (61.0)	.776
ASA 3-5	4072 (97.4)	6616 (96.6)	.006
Wound class III/IV	1393 (33.3)	2578 (37.6)	<.001
General anesthesia	3414 (81.7)	5700 (83.2)	.046
Preoperative sepsis	1345 (32.2)	2341 (34.1)	.033
Hypoalbuminemia	2561 (85.1)	3877 (83.4)	.048
Anemia, hematocrit <36	3226 (77.2)	5525 (80.6)	<.001
Neurologic comorbidity	1421 (34)	2105 (30.7)	<.001
Renal insufficiency	1047 (25)	1667 (24.3)	.387
Cardiac comorbidity	3283 (78.5)	5338 (77.8)	.42
Hepatic insufficiency	32 (0.8)	84 (1.2)	.022
Pulmonary comorbidity	774 (18.5)	1048 (15.3)	<.001
10% weight loss in last 6 months	146 (3.5)	274 (4)	.179
Dependent function status	2525 (60.4)	4027 (58.8)	.09
Obese, BMI >30 kg/m^2	1132 (28)	1872 (27.3)	.437
Transfer status from home	2927 (70)	4910 (71.6)	<.001
Emergency	453 (10.8)	892 (13)	.001
Procedure			.068
BKA (n = 6302)	2341 (37.1)	3961 (62.9)	<.001
AKA (n = 4736)	1840 (38.9)	2896 (61.1)	<.001

AKA, Above-knee amputation; *ASA,* American Society of Anesthesiologists; *BKA,* below-knee amputation; *BMI,* body mass index.
[a]Categoric data are presented as number (%) and continuous data as the mean ± standard deviation.

RESULTS

A total of 11,038 patients met inclusion criteria, including 6302 BKAs and 4736 AKAs. Residents were involved in 6857 cases (62.1%), with attendings alone in the remaining 4181 (37.9%). Patient characteristics are presented in Table I. Distribution of resident cases (RCs) was 1820 PGY 1 (29%), 1185 PGY 2 (18.9%), 1158 PGY 3 (18.5%), 1099 PGY 4 (17.5%), and 1006 PGY 5 (16.0%). The resident-level analysis excluded 589 cases coded as involving residents that lacked PGY data.

Crude complication rates by resident involvement are presented in Table II. Although crude rates of mortality were lower in RCs than in ACs, no association with mortality (odds ratio [OR], 0.92; 95% confidence interval [CI], 0.80-1.07; P = .277) was found after multivariable adjustment. RCs were associated with an increased risk of major complications after adjustment for patient characteristics on multivariable analysis (OR, 1.27; 95% CI, 1.14-1.42; Table III), and the effect was similar when stratifying by procedure. The full multivariable model is presented in the Supplementary Table (online only). RCs were also associated with increased odds of a return to the operating room (OR, 1.60; 95% CI, 1.38-1.84; Table III), and the effect was larger in BKA (OR, 1.73; 95% CI, 1.45-2.06) than in AKA (OR, 1.34; 95% CI, 1.04-1.72). No

Table II. Crude operative outcome rates by resident involvement

Variable[a]	*Total*	*Attending alone (n = 4181)*	*Resident (n = 6857)*	P
Death	985 (8.9)	409 (9.8)	576 (8.4)	.013
Major complication	3570 (32.3)	1237 (29.6)	2333 (34)	<.001
Respiratory	910 (8.2)	311 (7.4)	599 (8.7)	.016
Venous thromboembolism	190 (1.7)	64 (1.5)	126 (1.8)	.229
Renal	259 (2.3)	90 (2.2)	169 (2.5)	.293
Neurologic	124 (1.1)	54 (1.3)	70 (1.0)	.191
Cardiac	145 (3.5)	145 (3.5)	231 (3.4)	.780
Graft/prosthesis/flap failure	59 (0.5)	19 (0.5)	40 (0.6)	.368
Postoperative bleeding	620 (5.6)	239 (5.7)	381 (5.6)	.723
Minor complications	1380 (12.5)	527 (12.6)	853 (12.4)	.80
Operative time, minutes	65.4 ± 36.0	59.5 ± 33.3	69 ± 37.1	<.001
Return to operating room	1788 (16.2)	529 (12.7)	1259 (18.4)	<.001
Length of stay, days	14.7 ± 16.4	13.8 ± 16.0	15.2 ± 16.5	.006
Surgical site infection	198 (4.5)	183 (4.4)	315 (4.6)	.594
Wound disruption	182 (1.6)	80 (1.9)	102 (1.5)	.09
Incisional infection	924 (8.4)	354 (8.5)	570 (8.3)	.777
Transfusion	920 (8.3)	217 (7.6)	703 (13.5)	<.0001

[a]Categoric data are presented as number (%) and continuous data as the mean ± standard deviation.

Table III. Adjusted odds ratios (*ORs*) for resident involvement compared with attendings alone[a]

	Adjusted OR (95% CI) for					
Variable	*AKA and BKA*	P	*BKA*	P	*AKA*	P
Major complications[b]	1.27 (1.14-1.42)	<.001	1.26 (1.09-1.45)	.002	1.28 (1.07-1.53)	.007
Return to operating room[c]	1.60 (1.38-1.84)	<.001	1.73 (1.45-2.06)	<.001	1.34 (1.04-1.72)	.025
Intraoperative transfusion[d]	1.78 (1.50-2.11)	<.001	1.80 (1.43-2.27)	<.001	1.77 (1.37-2.29)	<.001
Operative time (75th percentile)[e]	1.64 (1.46-1.84)	<.001	1.61 (1.39-1.87)	<.001	1.70 (1.40-2.05)	<.001

AKA, Above-knee amputation; *BKA,* below-knee amputation; *CI,* confidence interval.
[a]Adjusted ORs from binary logistic regression for each end point with results stratified by procedure.
[b]Adjusted for age, sex, obesity (body mass index >30 kg/m^2), diabetes, functional status; pulmonary, cardiac, neurologic comorbidities; American Society of Anesthesiologists class, wound class, operative time, anemia, intraoperative transfusion, emergency, and preoperative sepsis.
[c]Adjusted for age, sex, obesity (body mass index >30 kg/m^2), diabetes, functional status; pulmonary, cardiac, hepatic, neurologic, renal comorbidities; American Society of Anesthesiologists class, wound class, anemia, hypoalbuminemia, operative time, emergency case, preoperative sepsis, race, smoking, alcohol use, radiotherapy, chemotherapy or disseminated cancer, and transfer status.
[d]Adjusted for age, sex, obesity (body mass index >30 kg/m^2), emergency, diabetes, functional status, American Society of Anesthesiologists class; pulmonary, cardiac, renal, hepatic, neurologic comorbidities; preoperative sepsis, preoperative anemia, wound class, anesthesia technique, operative time, bleeding disorder, and preoperative transfusion.
[e]Adjusted for sex, age, obesity (body mass index >30 kg/m^2), emergency, functional status, American Society of Anesthesiologists class; pulmonary, cardiac, neurologic comorbidities; preoperative sepsis, wound class, anesthesia technique, and intraoperative transfusion.

statistically significant difference was found between junior and senior residents for any end point, such as major complications in senior vs junior cases (OR, 1.11; 95% CI, 0.99-1.25; $P = .069$).

RCs were associated with a 78% increased risk for intraoperative transfusion on multivariable analysis (OR, 1.78; 95% CI, 1.50-2.15; Table III). There was no statistically significant difference between ACs and RCs with respect to postoperative transfusion requirements.

Mean operative time for RCs was 69 minutes compared with 59.5 minutes for ACs ($P < .001$). On logistic regression of prolonged surgical time (operative duration >75th percentile), RCs were associated with 64% increased odds of a prolonged operative time (OR, 1.64; 95% CI, 1.46-1.84; Table III). The effect was greater for AKA cases (OR, 1.70; 95% CI, 1.40-2.05) than for BKA cases (OR, 1.61; 95% CI, 1.39-1.87). There was no significant difference in minor complication rates between ACs and RCs.

DISCUSSION

Resident involvement with lower extremity amputation is associated with adverse outcomes, including major complications, return to the operating room, increased intraoperative transfusion requirements, and prolonged operative time. Evidence across multiple surgical specialties has demonstrated a similar association for teaching cases in breast, colon, pancreas, and general surgery.[3,6,8,9,13-15] The association appears to vary depending on the procedure, which might be expected as appropriate resident participation changes based on competency, resident level, and case complexity.[16,17] For instance, surgical resident involvement was associated with early graft failure after infrainguinal arterial bypass[8] but was not associated with

adverse outcomes after carotid endarterectomy.[9] One might hypothesize that resident participation in infrainguinal bypasses is substantive, whereas in carotid endarterectomies, the trainee is less likely to perform critical portions of the case.

Amputations have a relatively high risk of complications, making lower extremity amputations a logical focus to improve overall vascular surgery-related outcomes.[18] Resident involvement in general surgery has been associated with major complications, mostly attributed to surgical site infections.[15] This study found no clear difference in surgical site infections; however, resident involvement remained significantly associated with a 27% increased risk of major complications. The estimated association between resident involvement and major complications was similar in magnitude to other well-described risk factors, such as cardiac comorbidities, which were independently associated with a 17% increased risk for major complications.

A major contributor of the poor outcomes in RCs was an associated increased risk of return to the operating room. It is unclear what the cause of return to the operating room is, and the range of potential explanations includes, but is not limited to, case selection or resident technical failures leading to dehiscence, infection, and revision.

This study found an association between resident involvement and increased intraoperative transfusion. This finding has multiple potential explanations, including increased blood loss due to technical differences, longer operative times, case selection, transfusion practices at teaching hospitals, or even trainee anesthesiologists. In particular, it may highlight a symptom of the changing training paradigm where general surgery residents are performing fewer vascular cases and are less experienced in achieving vascular control. Given the number of limitations of this study, it is difficult to draw any real conclusions about the nature of this association, and further study is necessary.

Across most studies evaluating resident involvement, these teaching cases are associated with longer operative times.[5] In this study, there was a 64% increased risk for RCs being in the 75th percentile for operative time. Increased operative time has been associated with wound infection and other poor outcomes. It is imperative to note that given the limitations of this study, it is not possible to state that residents themselves cause increased operative time, because this could be a characteristic of teaching hospitals.

With changes in general surgery residency and specialized training paradigms along with the major challenge of decreased work hours, the evolving training system must be evaluated for unintended consequences. Inclusion of vascular residents may decrease general surgery residents' exposure to vascular cases that are still deemed core competencies, such as amputations, while limited general surgery exposure for vascular surgery residents may affect vascular residents' open surgical skills. Although this study does not directly address this issue, it does provide a baseline for future studies to evaluate these programs for changes over time. Furthermore, the increased risk associated with trainees of any kind highlights the necessity to track every training paradigm shift, because unintended consequences may be severe in terms of poor outcome for patients. This study highlights the need for formal prospective evaluation of training changes and their effects on clinical care.

The use of NSQIP, albeit robust with regards to certain outcomes, remains limited by data collection methods, its retrospective nature, and the limited variable detail. In particular, this study is limited by lack of intraoperative data on resident-performed portions of the case, amount of attending supervision, lack of data on teaching hospital status, and major case selection biases. This study suggests teaching cases are fundamentally different but is unable to provide clues about what the mechanism of this difference is. Attending supervision is one relevant part of that mechanism that may help mitigate any resident-associated differences, and it is possible these results are secondary to poor supervision. Resident involvement may itself be a surrogate for other factors, and the association may be due to unmeasured confounders. This study is unable to determine whether residents or the teaching environment increase the associated risk for complications, and future study is required to elucidate this point. The strengths of this study are the robust clinical data available to risk-adjust patients and the large sample size.

The potential for resident involvement to increase adverse events in patients is a concerning one that requires attention from the surgical community. More study is necessary to confirm these findings and to better describe the potential mechanism behind resident-associated outcomes. This study highlights the necessity to track resident-related outcomes and suggests surgical education may require improvement. Particularly, appropriate supervision should be provided for all trainee cases, a concept echoed by the American Council of Graduate Medical Education.[17] There are many techniques largely lacking from the surgical culture that might help diminish any negative impact of trainees. Such strategies might include adoption of debriefing tools with a focus on coaching, better use of technology to track resident progression and competency through smart phone applications, and continued integration of simulation.[19-22]

CONCLUSIONS

Resident involvement in amputation is associated with an increased risk for major morbidity, prolonged operative time, and intraoperative transfusion. Future study should be aimed at distinguishing between resident-related and teaching environment-related risk and whether supervision might mitigate the observed association of resident involvement with poor outcomes after lower extremity amputation.

AUTHOR CONTRIBUTIONS

Conception and design: JI, AR, NK
Analysis and interpretation: JI
Data collection: JI, NK
Writing the article: JI, AC
Critical revision of the article: KK, FF, JM, DG, AC
Final approval of the article: FF
Statistical analysis: JI
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Supplementary Table (online only). Multivariable analysis of major complications

Variables	*OR (95% CI)*	P
Resident involvement	1.27 (1.14-1.42)	<.001
BKA vs AKA	1.50 (1.34-1.68)	<.001
Dependent functional status	1.29 (1.15-1.45)	<.001
Preoperative sepsis	2.28 (2.04-2.54)	<.001
Emergency case	2.28 (1.96-2.66)	<.001
Wound class (III/IV vs I/II)	1.23 (1.11-1.37)	<.001
Pulmonary comorbidity	1.49 (1.30-1.71)	<.001
Operative time (75th percentile)	0.77 (0.68-0.87)	<.001
Sex (male vs female)	0.83 (0.75-0.93)	.001
Obesity (BMI >30 kg/m^2)	1.16 (1.03-1.31)	.013
Anemia (hematocrit <36)	1.19 (1.03-1.36)	.017
Cardiac comorbidity	1.17 (1.02-1.33)	.025
Age	0.90 (0.81-1.01)	.062
Intraoperative transfusion	1.17 (0.99-1.37)	.064
ASA class (3-5 vs 1-2)	1.36 (0.96-1.912)	.085
Diabetes	1.02 (0.92-1.15)	.681
Neurologic comorbidity	1.02 (0.91-1.14)	.737

AKA, Above-knee amputation; *ASA,* American Society of Anesthesiologists; *BKA,* below-knee amputation; *BMI,* body mass index; *CI,* confidence interval; *OR,* odds ratio.