Limb salvage after complex repairs of extremity arterial injuries is independent of surgical specialty training

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BACKGROUND: Major peripheral vascular trauma is managed by several surgical specialties. The impact of surgical specialty training and certification on outcome has not been evaluated. We hypothesized that general surgeons without specialty training in vascular surgery would have outcomes equivalent to surgeons with vascular training in the management of extremity arterial injuries requiring interposition grafting.

METHODS: We performed a multicenter, retrospective study of patients undergoing interposition grafting for peripheral vascular injury between 1995 and 2010. Specialty was defined by training and certification. Outcomes were recorded at the time of discharge from the index hospitalization. Factors affecting limb salvage were determined using logistic regression.

RESULTS: From the 11 participating centers, 615 patients were identified. General surgeons performed 69.9%, cardiac/vascular surgeons performed 27.3%, and surgeons of other specialties performed 2.8% of the grafts. There were 32 amputations (5.2%). Outcomes did not differ by institution. Factors associated with amputation were blunt mechanism, older age, female sex, hospital length of stay, and Injury Severity Score (ISS). There was no significant difference in limb salvage among specialty groups (general surgeons, 94%; cardiac/vascular, 95%; other, 100%).

CONCLUSION: Limb salvage following major peripheral vascular injury is independent of surgeon specialty training. The majority of complex repairs are performed by general surgeons. (*J Trauma Acute Care Surg*. 2013;74: 716–725. Copyright © 2013 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Therapeutic/care management, level III.
KEY WORDS: Peripheral vascular trauma; outcome; surgeon specialty.

Complex extremity vascular injuries are infrequent and have potentially devastating consequences.[1] Successful management of these injuries requires both training and experience in vascular surgical technique and decision making. Currently, peripheral vascular trauma is managed by surgeons with a variety of specialty training backgrounds and certifications. These specialties include cardiac and vascular surgery with training that is focused on the management of cardiac and vascular disease and other specialties with exposure to vascular disease during training, such as general surgery. The impact of surgical specialty training and certification on outcome following complex vascular injury has never been evaluated.

We sought to study the relationship of surgical training and certification to outcomes following peripheral vascular injury. We hypothesized that general surgeons without specialty training in vascular surgery would have outcomes equivalent to surgeons with vascular specialty training in the management of extremity arterial injuries requiring interposition grafting. To validate the hypothesis, we performed a multicenter study with the specific aim of comparing amputation rates and graft patencies following operations for major vascular injuries of the extremities performed by general surgeons with those performed by surgeons with specialty training and certification in vascular, cardiovascular, orthopedic or plastic and reconstructive surgery.

PATIENTS AND METHODS

A convenience sample of 10 American College of Surgeons' Committee on Trauma–verified Level I and II hospitals and 1 nonverified trauma center constituted the multicenter group. Approval by the institutional review board of each center was obtained. Patients older than 18 years with extremity artery injuries (DRG International Classification of Diseases—9th Rev codes, 903.0–904.9) requiring interposition grafting (Current Procedural Terminology codes 35236, 35256, 35266, and 35286) between January 1, 1995, and December 31, 2009, were identified from each center's trauma registry. Arterial injury requiring interposition grafting was chosen because it requires substantial technical skill and judgment[2] and, when compared with other techniques such as end-to-end anastomosis and lateral suture repair, is associated with the highest amputation rates.[3,4] We assumed that the indication for interposition grafting in all cases was a perceived limb-threatening arterial injury.

Five centers provided data for all 15 years (1995–2009), 4 centers provided data for 10 years (2000–2009), and 2 centers provided data for 5 years (2005–2009). The reason for not providing all 15 years for these seven hospitals was a change to a different commercial trauma registry, in which case the new software would require costly programming to extract the needed data from the old registry. The aggregate recent experience of the 11 centers with vascular trauma was 125 years.

Data were collected on demographics, mechanism of injury, patient physiology at the time of admission, associated injuries, procedures performed, specialty of the surgeon performing the vascular surgery, and outcome (Table 1). Specialty was defined by training and certification. For example, a surgeon with a vascular fellowship following general surgical training and a certificate of added qualifications in vascular surgery was classified as a vascular surgeon. Perioperative imaging or noninvasive testing was not routinely performed by any of the centers. Limb viability was assumed if there was no record of major amputation for the index hospitalization (digit and ray amputations were excluded). Graft patency was assumed if there was documentation of a palpable pulse or a viable limb at discharge. Previous work describing the follow-up of interposition grafts has demonstrated that this is a reasonable assumption.[5]

Each center was surveyed regarding their management of vascular injuries. Information was sought concerning the vascular trauma call panel (solely general surgeons, solely specialty surgeons, or a mix), years of experience of each surgeon performing interposition grafting, and surgical management principles (e.g., the use of systemic heparinization, primary fasciotomy, venous repair, or completion angiography).

Data were submitted to a central repository (Scripps Mercy Hospital). Data from each center were reviewed on two separate occasions by two of the authors (S.R.S., J.E.K.) before entry in a composite file. Queries regarding the data

TABLE 1. Data Collected

Demographics
Age
Sex
Mechanism of injury
Blunt: motor vehicle crash, fall, other
Penetrating: cutting/stab, gunshot/shotgun, other
Revised Trauma Score (RTS)
Probability of survival (P_s)
Injury
ISS
Involved limb AIS score
Associated injuries of involved limb
Index operation, interposition grafting of the
Axillary artery (vein or prosthetic)
Brachial artery (vein or prosthetic)
Common femoral artery (vein or prosthetic)
Superficial femoral artery (vein or prosthetic)
Popliteal artery (vein or prosthetic)
Other arm/leg artery (vein or prosthetic)
All operative procedures
All complications
Surgeon specialty (performing the repair) classified as
General surgeon (board certified; practice primarily general surgery)
Cardiothoracic surgeon, board certified
Orthopedic or plastic surgeon with vascular training (i.e., microvascular fellowship)
Vascular surgeon (general surgeon, board certified, with active certificate of added qualifications in vascular surgery)
Outcomes
Limb salvage, patent graft
Amputation, patent graft
Limb salvage, thrombosed graft
Amputation, thrombosed graft
Limb salvage, rescued graft following thrombosis (assisted patency)
Amputation, rescued graft following thrombosis (assisted patency)

were addressed using e-mail and telephone conferences to assure that there was homogeneity in the data (e.g., with regard to the procedures, associated injuries, or missing values). If, after responses were received, there was any concern about the validity of a specific data point, it was considered to be missing. After this data validation, one field (time from admission to initiation of the vascular procedure) had 137 missing values (22.3%). In the remaining fields, missing values occurred in 2.2% to 12%. There were no missing data from the "outcome" field or from the "surgeon specialty" field. Missing data were treated as voids, not as zeroes, reducing the number of total entries in the particular field.

General descriptive statistics were obtained using Student t test and χ^2 analyses. Bivariate analyses were performed to determine if there was an association between center or year of patient admission on either amputation or graft patency. Binary logistic regression was used to identify covariates associated with the primary outcome of limb salvage. Two-level polytomous logistic regression[6] was used to analyze the effect of covariates on the secondary outcome, which consisted of four categories: graft patency with limb salvage, graft patency with limb amputation, graft thrombosis with limb salvage, and graft thrombosis with limb amputation. Five two-level models examined the association of surgeon specialty with the primary and secondary outcome variables among patients nested within the hospital of origin as the hierarchical structure. Fixed effect(s) in Model 1 was surgeon specialty only. Model 2 added patient age and sex to Model 1. Model 3 added injury severity and mechanism of injury to Model 1 and 2 covariates. Model 4 included extremity Abbreviated Injury Scale (AIS) score and complication count to Model 1, 2, and 3 covariates. Model 5 included graft material, artery injured, and associated limb fracture to Model 1 to 4 covariates. Reference groups for binary logistic and polytomous logistic regressions were limb salvage and graft patency with limb salvage, respectively. Data were analyzed with Stata/MP Version 11.0 (StataCorp LP, College Station, TX) and with the Generalized Linear Latent and Mixed Models (GLLAMM) program.[7] Data are presented as mean (SD), percentages, or odds ratios with confidence intervals, as appropriate. Significance was attributed to a $p < 0.05$.

RESULTS

A total of 615 interposition grafts were performed on 615 patients during the study interval. The total number of cases submitted per center varied from 9 to 151 or an average of 4.7 cases per year of participation (range, 1–10.1). The panel of surgeons who performed the interposition grafting was solely general surgeons at five centers; a mixed panel of general, orthopedic, plastic and reconstructive, as well as cardiac/vascular surgeons at four centers; and solely cardiac/vascular surgeons at two centers. The average years of experience (following the last year of training) of the surgeons on the panels at the time of the study varied among centers from 5.8 to 28.6 years with an average of 15.0 years for all participating surgeons. Based on information from the surveys, there was moderate variability among the centers in the management of vascular injury (Table 2).

The majority of the 615 patients were young males sustaining a penetrating injury of moderate severity with little physiologic derangement (Table 3). The brachial artery was the most frequently injured (206, 33.5%), followed by the superficial femoral (138, 22.4%), popliteal (127, 20.7%), axillary (70, 11.4%), common femoral (27, 4.4%), other upper extremity (radial or ulnar, 26, 4.2%), and other lower extremity (peroneal or tibial, 21, 3.4%).

Most of the procedures were performed by general surgeons (69.9%), 27.3% were performed by vascular and cardiothoracic surgeons, and 2.8% by surgeons of other specialties (either orthopedic or plastic and reconstructive). Because there were no amputations in the 17 patients who underwent interposition grafting by surgeons of the other specialties, these patients were dropped from further analysis, resulting in a study cohort of 598.

Data on the time from hospital arrival to the initiation of the index vascular procedure were available in 478 patients and had a mean (SD) of 5.4 (48.3) hours. Start time for the vascular/cardiovascular surgeons averaged 9 hours longer than for the general surgeons (11.3 hours compared with 2.3 hours, $p = 0.058$). There was, however, no significant association between amputation and the time interval from admission to the index operation.

Revascularization of 288 patients with upper extremity injury and 310 patients with lower extremity injury constituted the cohort. Venous conduit was used in 506 patients (85%), and polytetrafluoroethylene was used in 92 (15%). Fasciotomy was performed in association with 56 upper extremity (22%) and 147 lower extremity (53%) revascularizations. Following the initial procedure, 21 grafts occluded or required revision (3.5%) and secondary patency (following catheter thrombectomy or revision or both) was achieved in 14 (67%).

There were 32 amputations (5.4%) in the cohort (12 upper extremity and 20 lower extremity amputations). Of the 32 amputations, 13 (40.6%) were associated with a graft thrombosis. There was no statistically significant association between center or year of admission and either amputation or graft patency. Bivariate analyses of factors associated with amputation revealed that female sex, blunt mechanism of injury, patient age, the presence of one or more complications, injury severity (by Injury Severity Score [ISS]), and hospital length of stay (LOS) were significantly associated with limb loss. Surgeon specialty was not significantly associated with amputation (Table 4). Further analysis of these factors was performed with specialty classification (Table 5). No significant association was found between surgeon specialty and either the primary or the secondary outcome with respect to any of the factors associated with amputation, except for LOS.

Unadjusted and adjusted odds ratios for the association between surgeon specialty and the primary and secondary outcomes are shown in Table 6 with general surgeons as the reference group. Sequential adjustment for relevant covariates found that in none of the models was surgeon specialty significantly associated with either outcome.

There were 12 deaths (2%) including 6 from severe shock, 3 from anoxic brain injury, 2 from traumatic brain injury, and 1 from sepsis.

TABLE 3. Patient Characteristics

	Value
Sample size, n	615
Age, mean (SD)	30.7 (12.5)
Sex, %	
Female	12.4
Male	87.6
ISS, mean (SD)	14.0 (8.3)
RTS, mean (SD)	7.2 (1.4)
Limb AIS score, %	
1	2.0
2	11.2
3	67.5
4	18.9
5	0.3
Surgeon specialty, %	
General	69.9
Cardiothoracic/vascular	27.3
Other	2.8
Probability of survival, mean (SD)	0.930 (0.18)
Hospital LOS, mean (SD)	13.9 (17.4)
Complication count ≥ 1, %	67.7
Shock (SBP < 90 mm Hg), %	18.4

SBP, systolic blood pressure.

DISCUSSION

This is the first study to investigate the effect of the type of surgical training and certification on outcome following peripheral vascular trauma. The outcome measures of early amputation and early graft patency were selected because they best reflect, in the aggregate, surgical technique, surgical judgment, and experience. We report an overall amputation rate of 5.4%, which is consistent with that reported in the literature for peripheral vascular trauma.[3,5,8–11] We show that there is no significant difference in amputation rate and short-term

TABLE 2. Center Survey of Principles of Management of Vascular Injury*

	Never†	Sometimes†	Always†
1. In the presence of a known or suspected vascular injury and no objective evidence of intracranial, extremity, or cavitary hemorrhage, do you systemically heparinize the patient?			
a. Before going to the operating room	6	4	1
b. Before obtaining vascular control in the operating room	5	5	1
c. Immediately before proximal and distal occlusion	3	2	6
2. Is catheter thrombectomy of proximal and distal vessels performed?		2	9
3. Do you use regional heparinization?	1	6	4
4. Do you do completion angiography?	1	6	4
5. Do you do completion continuous wave Doppler interrogation?	2		9
6. Do you do completion color flow Doppler imaging?	8	3	
7. Do you shunt the injured artery	1	10	
8. Do you shunt the vein, if there is significant concomitant venous injury?	3	8	
9. Do you repair "named" (i.e., popliteal or greater) veins?		6	5
10. Do you perform fasciotomy at the time of the repair?		11	

*For the sake of simplification, "sometimes" includes the responses "rarely" and "frequently."
†Values indicate the number of centers with the indicated response.

TABLE 4. Amputation Status

Sample size	Amputation 32	Limb Salvage 566	*p*
Outcome type, n (%)			<0.001
Patent graft	18 (56)	545 (96)	
Thrombosed graft	13 (41)	8 (2)	
Secondary patency	1 (3)	13 (2)	
Surgeon specialty, n (%)			0.689
General	24 (75)	406 (72)	
Cardiothoracic/vascular	8 (25)	160 (28)	
Patient sex, n (%)			<0.001
Female	12 (37)	61 (11)	
Male	20 (63)	505 (89)	
Mechanism of injury, n (%)			<0.001
Blunt	22 (69)	171 (30)	
Penetrating	10 (31)	395 (70)	
Blunt mechanism, n (%)			0.046
Motor Vehicle Crash	12 (55)	60 (35)	
Motorcycle Crash	1 (5)	33 (19)	
Other, crush injury	2 (9)	17 (10)	
Pedestrian struck	4 (18)	9 (5)	
Fall	2 (9)	27 (16)	
Other, not described	1 (5)	25 (15)	
Penetrating mechanism, n (%)			0.182
Stab wound/cut	0 (0)	104 (26)	
Gunshot wound	9 (90)	273 (69)	
Shotgun wound	0 (0)	6 (2)	
Other	1 (10)	12 (3)	
Hospital LOS, mean (SD), d	28.9 (25.1)	12.9 (15.7)	<0.001
ISS, mean (SD)	17.2 (10.6)	13.9 (8.2)	0.031
RTS, mean (SD)	7.1 (1.3)	7.2 (1.5)	0.776
Complication count ≥ 1, n (%)	29 (91)	376 (68)	0.007
GCS total, mean (SD)	13.1 (3.6)	13.4 (3.4)	0.636
Extremity AIS score, mean (SD)	3.2 (0.4)	3.0 (0.6)	0.113
SBP, mean mm Hg (SD)	118.7 (30.0)	116.1 (31.8)	0.651
Shock (SBP < 90 mm Hg), n (%)	7 (22)	104 (18)	0.624
Location of procedure, n (%)			0.062
Axillary	4 (13)	66 (12)	
Brachial	8 (25)	191 (34)	
Common femoral	0 (0)	27 (5)	
Superficial femoral	4 (13)	133 (23)	
Popliteal	13 (40)	112 (20)	
Other	3 (9)	37 (6)	
Graft material, n (%)			0.296
Venous conduit	25 (78)	481 (85)	
Polytetrafluoroethylene	7 (22)	85 (15)	
Patient age, mean (SD) y	36.1 (14.3)	30.3 (14.8)	0.011
Time to procedure, mean (SD), h	2.6 (2.9)	5.6 (49.7)	0.758
Limb associated fracture, n (%)	6 (19)	41 (7)	0.019

GCS, Glasgow Coma Scale; SBP, systolic blood pressure.

graft patency following injuries requiring interposition grafting whether performed by general surgeons or surgeons with specialty training and certification in either vascular surgery or cardiothoracic surgery. The 4-day difference in LOS between the two specialties is likely caused by the 10% higher incidence of lower extremity injuries treated by the general surgeons (Table 5), which is confirmed by multivariate logistic regression when analyzing factors associated with LOS. It is also clinically intuitive because lower extremity injuries

TABLE 5. Comparison of Demographic and Clinical Variables by Surgeon Specialty

	General	Vascular/ Cardiothoracic	*p*
Sample size	430	168	
Outcome type, n (%)			0.211
Patent graft	402 (93)	161 (96)	
Thrombosed graft	15 (3)	6 (4)	
Secondary patency	13 (3)	1 (1)	
Amputation, n (%)			0.689
Limb salvage	406 (94)	160 (95)	
Amputation	24 (6)	8 (5)	
Patient sex, n (%)			0.678
Female	51 (12)	22 (13)	
Male	379 (88)	146 (87)	
Mechanism of injury, n (%)			0.352
Blunt	134 (31)	59 (35)	
Penetrating	296 (69)	109 (65)	
Blunt mechanism, n (%)			0.528
Motor vehicle crash	49 (36)	23 (39)	
Motorcycle crash	22 (16)	12 (20)	
Other, crush injury	12 (9)	7 (12)	
Pedestrian struck	10 (7)	3 (5)	
Fall	19 (14)	10 (17)	
Other, not described	22 (16)	4 (7)	
Penetrating mechanism, n (%)			0.001
Stab wound/cut	62 (21)	41 (39)	
Gunshot wound	223 (75)	59 (54)	
Shotgun wound	3 (1)	3 (3)	
Other	2 (3)	5 (5)	
Hospital LOS, mean (SD), d	14.9 (17.8)	10.7 (12.9)	0.005
ISS, mean (SD)	13.9 (8.4)	14.5 (8.4)	0.421
RTS, mean (SD)	7.2 (1.5)	7.4 (1.3)	0.109
Complication count ≥ 1, n (%)	287 (68)	118 (72)	0.409
GCS total, mean (SD)	13.3 (3.3)	13.4 (3.7)	0.771
Extremity AIS score, mean (SD)	3.1 (0.6)	3.0 (0.6)	0.369
SBP, mean (SD), mm Hg	115.5 (32.3)	117.9 (30.0)	0.423
Shock (SBP < 90 mm Hg), n (%)	77 (18)	34 (20)	0.489
Location of procedure, n (%)			0.001
Axillary	55 (13)	15 (9)	
Brachial	126 (29)	73 (43)	
Common femoral	19 (4)	8 (5)	
Superficial femoral	115 (27)	22 (13)	
Popliteal	89 (21)	36 (21)	
Other	26 (6)	14(8)	
Graft material, n (%)			0.026
Venous conduit	355 (83)	151 (90)	
Polytetrafluoroethylene	75 (17)	17 (10)	
Patient Age, mean (SD), y	31.2 (13.1)	29.1 (10.9)	0.060
Time to procedure, mean (SD), h	2.3 (3.3)	11.3 (82.7)	0.058
Limb-associated fracture, n (%)	33 (8)	14 (8)	0.788

GCS, Glasgow Coma Scale; SBP, systolic blood pressure.

increase the time to walking and rehabilitation, particularly if they are associated with fractures.

Specialty training is purported to result in better patient outcomes. This is particularly true in the specialty of vascular surgery. Several reports suggest that formal vascular fellowship training results in better patient outcomes,[12,13] while others show equivalency of outcome.[14,15] Still, others maintain that outcomes are more dependent on surgeon volume than on surgeon training.[16–18] These reports were either generated from administrative data or used historical controls, however, and did not include trauma patients. Furthermore, future fellowship-trained vascular surgeons may have no requirement to complete a general surgery residency and will likely have very limited exposure to injured patients.[19,20] Finally, a recent survey of general surgeons, trauma surgeons, and vascular surgeons suggested that more than 50% of vascular injuries are currently managed by trauma surgeons. The authors of the survey concluded, "In the short term, graduates from the traditional 5–2 [5 years of general surgery and 2 years of fellowship—as opposed to the new paradigm of 0–5] vascular training programs will be best suited to manage the complete spectrum of vascular injury. The logical group of surgeons to spearhead vascular injury management and training in the long term are more completely trained trauma surgeons."[20] The authors, however, offered no data to validate their assertions. Our data provide the initial evidence base for these claims. We have shown that 70% of the procedures in this study were performed by general surgeons, many of whom had extensive experience in the management of trauma. The finding that the outcomes, both primary and secondary, were similar is important. It suggests that knowledge of the basic disease (in this case trauma, often multisystem) as well as experience and commitment may trump the certification of the surgeon. It also suggests that exposure to a specialty, such as vascular surgery during general surgery training, may provide sufficient training to repair a vessel that does not have underlying vascular disease. This finding lends support to the current curriculum of the Acute Care Surgery Fellowship, which provides additional exposure to vascular surgery to augment that provided by the classical general surgery training program. It further underscores the importance of continued vascular training of general surgical residents.

Despite the differences in the management principles of the various centers, there was no association between the institution and the primary or secondary outcomes. This suggests that these principles of management should come under the scrutiny of comparative effectiveness research, as is currently planned by the American Association for the Surgery of Trauma (Joseph DuBose, personal communication, July 4, 2012). Despite the heterogeneity in practice, we have reported one of the higher fasciotomy rates in the recent literature.[4,5,21]

We found that the covariates significantly associated with amputation included female sex, older age, and injury severity (by ISS). We did not use any of the various scoring systems to risk adjust each individual limb undergoing revascularization not only because they lack sensitivity and specificity[22] but also

TABLE 6. Association Between Surgeon Specialty with Primary and Secondary Outcomes Using General Surgeons as Reference

Amputation	OR	95% CI	*p*	Secondary	OR	95% CI	*p*
Model 1	0.81	0.33–1.99	0.639	Model 1			
				Patent/Amp	0.93	0.30–2.84	0.896
				Thromb/Salv	0.57	0.18–1.83	0.344
				Thromb/Amp	0.66	0.17–2.53	0.543
Model 2	0.76	0.29–1.97	0.572	Model 2			
				Patent/Amp	0.92	0.30–2.85	0.883
				Thromb/Salv	0.55	0.17–1.77	0.317
				Thromb/Amp	0.61	0.15–2.45	0.488
Model 3	0.64	0.24–1.73	0.377	Model 3			
				Patent/Amp	0.79	0.25–2.53	0.696
				Thromb/Salv	0.56	0.17–1.85	0.343
				Thromb/Amp	0.51	0.12–2.10	0.348
Model 4	0.67	0.26–1.75	0.416	Model 4			
				Patent/Amp	0.78	0.25–2.42	0.662
				Thromb/Salv	0.53	0.16–1.72	0.291
				Thromb/Amp	0.50	0.12–2.07	0.341
Model 5	0.57	0.20–1.62	0.290	Model 5			
				Patent/Amp	0.81	0.25–2.55	0.715
				Thromb/Salv	0.51	0.16–1.68	0.270
				Thromb/Amp	0.51	0.12–2.19	0.362

Model 1, unadjusted.
Model 2, adjusts for age and sex.
Model 3, adjusts for Model 2 covariates + ISS and mechanism of injury.
Model 4, adjusts for Model 2 and 3 covariate + Extremity AIS score and one or more complications.
Model 5, adjusts for Model 2, 3, and 4 covariates + graft material, artery operated upon, and associated limb fracture.
Reference category for binary logistic regression is "limb salvage." Reference category for polytomous logistic regression is "graft patency with limb salvage."
OR, odds ratio; CI, confidence interval; Amp, amputation; Thromb, thrombosis; Salv, salvage

because the data necessary to calculate the various scores were not uniformly available in the medical records. The significant association of increasing age, increasing severity of injury, and blunt mechanism with amputation is not surprising. The association of amputation with female sex is interesting. Of note, 54% of the amputations associated with graft thrombosis occurred in women, who made up only 12% of the cohort. This finding may be caused by a number of factors including the smaller vessel caliber and the vasospasm often seen with arterial trauma. Sex and race have been noted to have a synergistic effect on vein graft failure following revascularization for vascular disease.[23] Future work is needed to investigate this association.

This work has a number of limitations. First, it was a convenience sample comprised of Level I and II trauma centers and a hospital that did not have American College of Surgeons' Committee on Trauma verification. This sample may not adequately represent the current mix of centers caring for trauma patients in the United States. Second, surgeons (all specialties) participating in this study had significant trauma and/or vascular experience (mean, 15 years). It may be that the experience, rather than the certification, is responsible for the observed effects on outcome. Our results may not be applicable to centers with surgeons less experienced in trauma care. This, however, brings into sharp relief our concern (and the concerns of Rasmussen et al.[24]) that the increasing number of vascular fellowships may lessen the exposure of general surgery residents to vascular procedures, especially open vascular procedures. Third, this is a retrospective study from multiple centers. We tried to accommodate the differences in data capture and data definitions by repeated queries and communication with the participating centers. Questionable or inconsistent data were eliminated, whenever possible. Fourth, we obtained data from disparate time intervals from the various centers. At inception, all centers had confirmed their participation and received institutional review board approval but, on data retrieval, found that the programming necessary to interface with an older version of their current registry was cost prohibitive. Rather than eliminate a center, we made a decision to use data available in the centers' current registries, resulting in the different time intervals. Fifth, careful examination of Table 6 reveals that the odds ratios in all models suggest that specialty training in cardiac or vascular surgery had an overall protective effect for amputation and the secondary outcomes. Although this association did not reach statistical significance, caution must be exercised in the interpretation of our results. Variables linked to the primary and secondary outcomes not measured in our study, such as individual surgeon experience (we did not link individual surgeon to an outcome to preserve anonymity), physiology at the time of the procedure (cardiac/vascular surgeons began procedures an average 9 hours later in the hospital course than did general surgeons), or institutional culture should be examined if the association between specialty and outcome is studied in the future. Finally, we removed those 17 patients from the analysis who had interposition grafting performed by plastic and orthopedic surgeons. None of these patients had an amputation and, if added to the study, would be expected to slightly reduce the overall amputation rate. In consideration of their training background, however, plastic surgeons and orthopedic surgeons receive exposure to vascular surgery during training. Thus, if they were to remain in the analysis, they would most appropriately be assigned to the general surgery group.

From these data, we conclude that general surgeons are performing the majority of the arterial repairs following complex extremity vascular injury and that limb salvage is independent of specialty training and certification.

AUTHORSHIP

S.R.S. and M.J.S. designed this study. M.C.S., E.E.M., and H.B.M. conducted the literature searches. J.E.K., M.C.S., L.A.D., J.W.D., G.A.V., E.E.M., H.B.M., M.M.K., B.M.H., R.S.C., T.W.C., SC.B., G.T.T., K.B.S., J.T.S., F.R.K., and T.H.C. collected data, which S.R.S., J.E.K., R.Y.C., M.C.S., E.E.M., and H.B.M. then analyzed. S.R.S., J.E.K., R.Y.C., M.C.S., D.V.F., E.E.M., M.M.K., R.S.C., and T.W.C. interpreted the data. J.E.K. and R.Y.C. performed the statistical analysis. S.R.S. and M.J.S. wrote the article. S.R.S., J.E.K., and R.Y.C. prepared the figures and tables. S.R.S., J.E.K., M.C.S., L.A.D., J.W.D., G.A.V., D.V.F., E.E.M., H.B.M., M.M.K., B.M.H., M.J.S., R.S.C., T.W.C., S.C.B., G.T.T., K.B.S., J.T.S., F.R.K., and T.H.C. edited the final article.

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DISCLOSURE

The authors declare no conflicts of interest.

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DISCUSSION

Dr. Norman M. Rich (Bethesda, Maryland): Drs. Shackford, Sise, and their colleagues are all established contributors, as identified. They provide us with detailed and interesting information. The results should not be surprising as they are from centers of excellence where outstanding results are expected from very experience surgeons.

The authors have carefully analyzed seven limitations to their study. My first question for additional emphasis is related to the centers themselves. And I wonder if a randomly selected similar number of health care centers today would have similar results.

As we all recognize in this twenty-first century, surgical training is changing very rapidly and the conditions that existed during this study are even changing as we have our meeting today.

Appreciating the majority of the patients were young with healthy arteries, do the authors believe that this could be duplicated in an elderly population with atherosclerotic arteries? They do emphasize that one of the limitations is advancing ages.

During the Vietnam War we worked very hard at the former Walter Reed Army Medical Center to ensure that all general surgery residents had at least 40 major vascular procedures prior to deploying to Vietnam over an eight year period. This was the same time that we were developing an early vascular fellowship program.

During a debate the impact of the new vascular fellowship on the general surgery training program was analyzed and presented to the Association for Academic Surgery.

We were able to document the number of vascular cases performed by general surgery residents essentially doubled because of the presence of a dedicated vascular clinic in the vascular fellowship program.

While we did not have the sophisticated scientific approach used by Drs. Shackford, Sise and their colleagues, we developed a similar belief that the documentation in the Vietnam Vascular Registry demonstrated that the results were the same with those with a general surgery training background as with a few vascular fellowship-trained individuals at that time.

In this twenty-first century, however, we are in the endovascular revolution which is having an increasing impact on vascular surgery in general and specifically on the management of vascular trauma. Do the authors believe their results will be duplicated in the future?

With a predominance of catheter-based interventions, even vascular fellows today in their current training programs are neither exposed to the volume nor the complexity of open vascular procedures of the latter half of the twentieth century.

The question that has plagued us for the past 50 years is who is best prepared to manage the severed popliteal artery, the vascular fellowship-trained surgeon with minimal exposure to managing injured patients or the general surgeon who has moderate exposure in managing injured patients but with limited exposure to vascular repair and catheter-based interventions?

The simple answer, of course, is that the surgeon with the best training and the most experience will probably be the most successful.

With our surgical training programs undergoing significant changes, hopefully there will be an answer to this question in the near future. Do the authors recommend any additional changes to today's surgical training programs?

Again, the authors are to be congratulated for providing us with very detailed information that will be referenced in the future and that will lead to additional studies during the ever-changing challenges of surgical education. Thank you very much.

Dr. Todd Rasmussen (Houston, Texas): Thank you. I congratulate the authors on an important study but I would say that its ability to test the hypothesis is limited and hinges on the definition of the word "outcomes."

And my question is: do the authors accept that successful outcomes following this complex injury pattern can really be assessed by the methods of the study, meaning the outcomes or the endpoints are only tested with in-hospital follow-up, which really was measured in days, not weeks or months? Thank you.

Dr. Ajai K. Malhotra (Richmond, Virginia): This was touched on by Dr. Rich: for surgeons who are being trained today, will these results be applicable? I doubt it very much.

Dr. Demetrios Demetriades (Los Angeles, California): Steve, that was an excellent and practical study. This issue is often discussed at our mortality and morbidity conferences. Probably the most unforgiving injuries are the popliteal artery injuries. Did you look into this group of patients? Thank you.

Dr. Gregory A. Timberlake (Brandon, Mississippi): Thank you, Steve. That was great and certainly shows what, in very advanced trauma centers, the outcome can be. And the military experience, I think, is approaching that.

Two specific questions for you which I will combine: venous injury, did that complicate if you had a concomitant disruption of the popliteal veins? Did that tend to make any difference? Because that wasn't discussed.

And, at the same time we've all seen that upper extremity injuries are less likely to result in amputation. If you stratified your data by upper extremity versus lower extremity, did that then result in a difference? Thank you.

Dr. Matthew J. Wall, Jr. (Houston, Texas): How many of the vascular and cardiothoracic surgeons in your group also take trauma call? Many of us do both and are a hybrid bringing both skill sets to trauma cases?

Second, in an age where the most common index case in general surgery training for vascular cases is an amputation, how do we assure our residents are appropriately trained to handle acute care vascular cases?

Dr. Weidun Alan Guo (Buffalo, New York): I have a question about the experience of a general surgeon. Did they perform vascular procedures on a daily basis? Secondly, did they have vascular backup on call or not?

Dr. Steven R. Shackford (San Diego, California): First of all, Norm, I really appreciate your comments. The motivation for this work was recalling that there was a learning curve of our surgeons in Vietnam when vascular repair had to happen. As you and I discussed, none of those surgeons had a vascular fellowship, but they still did a fine job, based on the results of the Vietnam Vascular Registry.

The centers were not randomly selected. In the analysis, we did nest the patients within the center and the center had no impact on outcome.

Yes, Norm, I believe vascular trauma is a different disease. I am a card-carrying vascular surgeon. And when the Board of Vascular Surgery came into being, the mainstay that underpinned that movement was the fact that vascular disease is a different disease. There is no doubt about it.

Managing vascular disease does take special training and special experience–it's a horrible feeling to put a suprarenal clamp on the aorta and having a shard of plaque go through the aorta above the clamp. Managing that is something that really does take some experience and it is a different disease.

Similarly, I think vascular injury in a trauma patient is trauma, and that the disease of trauma requires people familiar with trauma to take care of it. Will endoluminal therapy make any difference? You know, it's like when you ask the pizza man what is for dinner, it's always pizza. And you ask an endoluminal surgeon how he wants to fix an injury, pretty much it's always going to be an endoluminal solution, which is fine in many cases, but not all of them.

My concern, I think Todd's concern as well, is that the vascular surgeons we're producing now don't have a lot of open experience. And that is really concerning to me.

I think we need more data. Joe DuBose and Todd have an ongoing MITC study here that will help us sort out the endoluminal question.

Who is best to take care of these patients? I think it's someone with experience and commitment to trauma, frankly.

Would I recommend any changes to current surgical residency training programs? Having run a program for almost 20 years with Jim Hebert in Vermont it's very, very hard to add anything in now with the 80-hour work week. That's why 70% of surgeons finishing general surgery training are taking fellowships now, because they don't really feel adequately trained. They're going to have to get their vascular training in acute care surgery fellowship probably.

Ajai, you asked if this data were applicable to centers with less experience. I think that that will be dependent highly on what Joe DuBose's and Todd Rasmussen's study will show when we have good comparative effectiveness data.

Todd, you asked about long-term outcomes. Because it is so difficult to get trauma patients to come back to the hospital for evaluation, we looked only at outcome at the time of discharge. As a vascular surgeon, you know that some of these will need revision, but we can't answer that question right now.

Demetri, we did look at popliteal artery injuries. They are associated with the highest amputation rate, blunt and penetrating. No significant difference among the surgeon specialties.

Greg, I know your experience with ligation of venous injuries. We did look at that. There was no effect on out come, whether they were repaired or ligated.

I would point out that I did survey all eleven centers on various issues related to management. I was shocked and amazed at the disparity in the way these experienced surgeons manage vascular trauma.

It's different with regard to post-operative imaging, with regard to conduit, with regard to the use of fasciotomy, and with the management of venous injuries.

So I am hoping that comparative effectiveness research, now being done by the multi-institutional trials group, will provide us with answers to these very important questions.

Matt Wall asked the question how were surgeons with more than one certificate classified, for example those with general and a specialty certificate. None of the CT surgeons in the study actually took trauma call. At Scripps Mercy Hospital, out of our panel of five there are three of us with a vascular certificate—myself, Mike Sise and Jack Yang—and we all take trauma call, but in the study we were classified as vascular surgeons, not as trauma surgeons. So it was the specialty certificate that trumped the general surgery ticket for the study.

I think that's it. Thank you for the floor.