From the Peripheral Vascular Surgery Society

# Patient-based outcomes and quality of life after salvageable wartime extremity vascular injury

**Daniel J. Scott, MD,[a,b] Zachary M. Arthurs, MD,[b] Adam Stannard, MRCS,[a,b,c] Howard M. Monroe, PhD,[a] W. Darrin Clouse, MD,[d,e] and Todd E. Rasmussen, MD,[a,c,e]** *San Antonio and Fort Sam Houston, Tex; Birmingham, United Kingdom; Sacramento, Calif; and Bethesda, Md*

***Objective:*** **To date, contemporary studies on wartime vascular trauma have focused on acute management strategies and early results, with no characterization of enduring functional limb salvage or its relation to quality of life. The objective of this study was to describe long-term, patient-based quality of life and function after extremity vascular injury (EVI).**

***Methods:*** **The Joint Theater Trauma Registry was queried for U.S. troops with EVI. Injury and management data was obtained and the Medical Outcomes Study Short Form 36 (SF-36) Health Survey administered after patient contact and consent. Demographic, injury, and management variables were analyzed and examined for correlation with the primary end points of favorable or unfavorable outcome defined by SF-36 Mental (MCS) or Physical Component Summary (PCS) scores of >42 or <42 (effect size ≥0.8).**

***Results:*** **Surveys were completed by 214 patients, who were a median age of 25 years (range, 19-52 years). The Injury Severity Score was 15.3 ± 8.6 and the Mangled Extremity Severity Score was 5.65 ± 1.4. Amputation-free survival was 84% at mean follow-up of 61 ± 24 months. Overall SF-36 PCS and MCS scores were 43.0 ± 9.2 and 46.6 ± 12.4, respectively, with 92 respondents (43%) reporting favorable outcomes on both MCS and PCS. On multivariate analysis, older age, severe extremity injury (Mangled Extremity Severity Scores ≥7), and chronic pain were predictive of unfavorable physical outcomes (*P* < .05). Presence of pain, nerve injury, and junior rank (<E7) were predictive of unfavorable MCS scores (*P* < .05). Higher educational background (baccalaureate or above) was associated with favorable outcome (*P* < .05).**

***Conclusions:*** **This study reports the first long-term patient-centered outcomes data after wartime EVI. At 5 years after injury, quality-of-life measures are reduced compared with national norms. Understanding high-risk characteristics, both demographic- and injury-specific, that are associated with unfavorable outcomes will help guide future acute management and long-term recovery strategies. (J Vasc Surg 2014;59:173-9.)**

The wars in Afghanistan and Iraq have witnessed an increase in the incidence of vascular injury compared with previous reports from combat.[1-6] Similar to previous wartime experience, most of the injuries in the modern combat setting involve the extremities. The frequency and distribution of vascular injury today likely results from a combination of increased explosive-based attacks, force protection measures in the form of body armor, rapid evacuation, and improved survivability of wounds.[7] Despite this burden of injury, few if any studies have focused on quality of life or long-term functional outcome after this significant injury pattern.

Reports on vascular injury from the civilian sector, including those using the National Trauma Data Bank, have been limited by an inability to monitor patients in a longitudinal fashion.[8] As a result, meaningful long-term outcomes have been relegated to single-institution case series.[9,10] Likewise, contemporary wartime reports have focused on acute management strategies within a dual-theater trauma system and thus have suffered the same challenges of securing long-term follow-up.[2,11,12] This limitation was recognized, and a concentrated effort was initiated to obtain longitudinal follow-up on patients having sustained wartime vascular injury in Afghanistan and Iraq. Based on the legacy of the Vietnam Vascular Registry and using the contemporary Joint Theater Trauma Registry (JTTR), the Global War on Terror-Vascular Injury Initiative (GWOT-VII) was initiated with the goal of prospectively gathering patient-centered outcomes data after this injury pattern.[13-15]

This report represents an interim analysis of this longitudinal outcomes program. The objective of this study was to characterize quality of life and quality-of-limb function after extremity vascular injury (EVI) and to identify patient, injury, and management factors that affect long-term

From the 59th Clinical Research Division, Lackland Air Force Base, San Antonio[a]; the U.S. Army Institute of Surgical Research, Chambers Pass, Fort Sam Houston[b]; the Academic Department of Military Surgery & Trauma, The Royal Centre for Defence Medicine, Birmingham[c]; the Division of Vascular Surgery, University of California at Davis, Sacramento[d]; and the Norman M. Rich Department of Surgery, The Uniformed Services University of the Health Sciences, Bethesda.[e]

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Reprint requests: Zachary M. Arthurs, MD, San Antonio Military Medical Center, 3851 Fort Sam Houston, TX 78234 (e-mail: zarthurs@mac.com).

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outcomes, favorable and unfavorable, after this challenging injury pattern.

## METHODS

This study was conducted under approval from the U.S. Army Medical Research and Material Command Institutional Review Board.

**Data acquisition.** A recurring query of the JTTR is conducted identifying U.S. troops who have sustained EVI in what was initially termed the GWOT, which primarily included Operation Iraqi Freedom (Iraq, 2003 to 2011) and Operation Enduring Freedom (Afghanistan, 2001 to present). The search criteria are provided in Table I. To limit potential confounding variables in relation to recovery from EVI, the study excluded patients who sustained concomitant blunt or penetrating head injuries and those with severe traumatic brain injury with ongoing sequelae and inability to complete a survey. Finally, patients who underwent primary or traumatic amputation without an attempt at limb salvage were excluded from this aspect of the initiative.

A record review for those patients meeting inclusion criteria was performed by research nurse coordinators, which included the following electronic charting systems: Patient Administration Systems and Biostatistics Activity, Theater Medical Data Store, and the Armed Forces Health Longitudinal Technology Application. After confirmation of EVI data points pertaining to demographics, injury characteristics early management factors, including perioperative details, was recorded into the GWOT-VII database (Oracle; Oracle Corp, Redwood Shores, Calif). Pertinent preinjury, injury, and postinjury variables are outlined in Table II.

**Definitions.** All patients underwent an attempt at limb salvage in their initial operative intervention. This included all injuries managed intraoperatively with demonstrable limb viability and perfusion at completion of the operation (regardless of whether the vessel in question was ligated or repaired). Secondary amputation was defined as amputation of the extremity in question after the initial attempts at limb salvage during the first operation. Amputations performed in the field, in the emergency department, or at the initial operation were considered primary and excluded for this interim analysis of the GWOT-VII.

**Patient interview.** Patient contact information was confirmed using the Defense Enrollment Eligibility Reporting System. After patient contact, informed consent was obtained, and individuals were enrolled in the study. Depending on personal preference, surveys were provided by telephone, e-mail/Web link using SurveyMonkey (SurveyMonkey, Palo Alto, Calif), paper copy, or in person. Surveys included the Medical Outcomes Study Short Form 36 (SF-36) Health Survey and an independent 17-item demographic questionnaire (Appendix, online only).

**Quality of life evaluation.** The SF-36 consists of 36 multiple-choice questions that seek to evaluate the overall quality of life of a patient in a variety of disease states. The questions within the SF-36 target eight specific scales of well-being, each with its own score. Four scales (Vitality, Social Functioning, Role Emotional, and Mental Health) contribute to a Mental Component Summary (MCS) score and four scales (Physical Functioning, Role Physical, Bodily Pain, and General Health) contribute to a Physical Component Summary (PCS) score. Each raw score is scaled from 0 to 100, with higher scores denoting better health. These scores are then converted to norm-based scores to allow direct comparison with the average U.S. population (mean score $50 \pm 10$).[16]

**Statistical analysis and cohort definition.** To define clinical significance, an effect size (ES) of 0.8 was used to delineate "unfavorable" quality of life (SF-36) outcome. Traditionally used to evaluate a "before-and-after" effect of a variable (ie, drug, injury, treatment, etc) on a study group, the use of an ES has been broadened in the context of health quality evaluations. Mathematically defined as a difference of means divided by the standard deviation [$ES = (m_1 - m_2)/s_1$], an ES of 0.8 was selected for this study because it is considered a significant or "large" effect.[17] Using the predefined National Population Norm SF-36 score of 50 ($m_1$), an ES of 0.8 corresponded to SF-36 scores of $\leq 42$ ($m_2$) in each scale and component summary score. Overall unfavorable outcome is defined as a reported MCS or PCS score of $\leq 42$. Conversely, favorable outcome is defined as reported MCS and PCS scores $>42$ for both.

**Table I.** Joint Theater Trauma Registry (JTTR) inclusion criteria

- Active duty injury
- Injury sustained in battle (OIF/OEF)
- Vascular injury (AIS 2-6)
- Vascular ICD-9
- No concomitant head injury
- March 2002-August 2011

*AIS,* Abbreviated Injury Scale; *ICD-9,* International Classification of Diseases, 9th Revision; *OEF,* Operation Enduring Freedom; *OIF,* Operation Iraqi Freedom.

**Table II.** Variables analyzed

| *Variables* | | |
|---|---|---|
| **Preinjury** | | |
| Age | Rank | |
| Educational status | Branch of service | Commission status |
| **Injury** | | |
| Injury date | Theater of operation | Vessel injured |
| ISS | MESS | Shunt placement |
| Mechanism of injury | Amputation (nonindex limb) | Concomitant injury |
| | Surgical management | |
| **Postinjury** | | |
| Secondary amputation | Marital status | Occupation |
| Disability status | Chronic pain | Psychiatric disorder |

*ISS,* Injury Severity Score; *MESS,* Mangled Extremity Severity Score.

Parametric continuous variables were compared by unpaired, two-tailed *t*-test or one-sided analysis of variance with post hoc intergroup analysis. Proportions were analyzed by $\chi^2$ or the Fisher exact test. Continuously distributed variables were summarized by the mean and standard deviation (SD) or median and range. Descriptive statistics were used to summarize univariate and multivariate associations between SF-36 scores and preinjury-, injury-, and postinjury-specific variables. Kaplan-Meier analysis with log-rank testing was used to describe amputation-free survival. All statistical testing was two-sided with a significance level of $P < .05$. SAS 9.2 software (SAS Institute, Cary, NC) and SPSS 20 software (IBM, Armonk, NY) were used for statistical analysis.

## RESULTS

**Search and survey results.** The JTTR query revealed 3255 service members from March 2002 to August 2011 who had sustained any vascular injury (including abdominal, cervical, and EVI) in the GWOT. At the time of this interim analysis, 2393 records (74%) had been reviewed, with confirmed EVI in 1018 (43%). Of those with EVI, successful contact was made in 891 (88%), with 214 participants having completed surveys. Of these, 122 patients (57%) reported unfavorable outcomes in the PCS or MCS scores, and 92 (43%) reported favorable outcomes with respect to both MCS and PCS scores. The average time to follow-up (time from injury to survey completion) was 61.1 ± 24.1 months (range, 7-116 months).

The total respondent average SF-36 scale scores were Body Physical, 43.9 ± 9.9; General Health, 45.3 ± 10.1; Physical Functioning, 42.3 ± 10.2; Role Physical, 42.7 ± 11.2; Vitality, 47.2 ± 11.3; Role Emotional, 43.9 ± 12.7; Mental Health, 45.9 ± 11.3; and Social Functioning, 44.2 ± 11.3. The total respondent average MCS score was 46.6 ± 12.4 and the average PCS score was 43.0 ± 9.2.

**Preinjury characteristics.** Respondent preinjury characteristics and demographics are outlined in Table III. Respondents were predominately male (98%), junior rank (73% ≤E7), and young, with a median age of 25.0 years (range, 19-52 years). Compared with those with a favorable outcome, unfavorable outcome groups demonstrated greater proportions of patients with older age (≥40 years; $P < .05$), junior rank (<E7; $P < .05$), and those with lower educational background (high school or GED test [GED Testing Service, Wash, DC]; $P < .05$). Those with favorable outcomes had higher proportions of patients with a college degree ($P < .05$).

A comparison of mean SF-36 component summary scores demonstrated similar distinctions. Compared with younger patients, those aged ≥40 had an average mean PCS of 35.6 ± 7.8 vs 43.5 ± 9.1 ($P = .002$). Of the four scales contributing to overall PCS score, older age was greatly affected by Physical Functioning, with mean scores generally 10 points lower than those aged <40 years (43.0 ± 10.0 vs 32.8 ± 7.6; $P < .001$). Multivariate analysis showed older age was predictive of unfavorable PCS scores

**Table III.** Preinjury characteristics

| *Variable* | *Overall (n = 214), %* | *Unfavorable outcome (n = 122), %* | *Favorable outcome (n = 92), %* | P[a] |
|---|---|---|---|---|
| Male sex | 98 | 98 | 99 | NS |
| Age range, years | | | | |
| 18-24 | 49 | 47 | 51 | NS |
| 25-29 | 21 | 23 | 19 | NS |
| 30-34 | 15 | 12 | 17 | NS |
| 35-39 | 10 | 8 | 12 | NS |
| ≥40 | 6 | 10 | 1 | <.05 |
| Rank <E7 | 73 | 80 | 65 | <.05 |
| Educational status | | | | |
| High school/ GED | 19 | 24 | 12 | <.05 |
| Some college | 49 | 53 | 44 | NS |
| College graduate | 21 | 16 | 29 | <.05 |
| Postgraduate | 11 | 8 | 15 | NS |

*NS,* Not significant.
[a]Denotes comparisons between groups with unfavorable and favorable outcomes. Proportions were analyzed by $\chi^2$ test or the Fisher exact test.

(odds ratio [OR], 11.64; 95% confidence interval [CI], 2.12-64; $P = .0048$).

Junior rank respondents (<E7) had a lower average MCS score of 45.6 ± 12.7 compared with 49.4 ± 11.3 for those attaining ≥E7 ($P = .045$). For those with education beyond high school, average PCS scores were higher at 43.6 ± 9.1 vs 40.2 ± 9.0, with high school diploma/ GED test ($P = .034$). This trend was confirmed on multivariate analysis, with higher education predictive of both improved PCS (OR, 0.32; 95% CI, 0.15-0.65; $P = .0018$) and MCS (OR, 0.32; 95% CI, 0.14-0.69; $P = .0037$) scores.

**Injury characteristics.** Most of the respondents were injured in Operation Iraqi Freedom/Operation New Dawn (83%) vs Operation Enduring Freedom (17%). Approximately three-quarters of respondents' injuries occurred from 2004 to 2007. As summarized in Table IV, explosive mechanisms were most common (68%), followed by nonexplosive penetrating injuries (30%). There were relatively few blunt or crush type injuries (2%), all of which were incurred secondary to motor vehicle crashes.

In 214 respondents, 237 limbs were injured. Of these EVIs, most were singular (90%), arterial (66%), or proximal (58%; designated as at or proximal to the popliteal and brachial vessels in the lower and upper extremity, respectively). Lower extremity vascular injuries were more common (61%) than those affecting the upper extremities (39%). Of those with a qualifying EVI, 5% sustained a primary or traumatic amputation of another or different extremity. Generally, patients were considered moderate to severely injured, with an average 2005 Injury Severity Score of 15.3 ± 8.6 and an average Mangled Extremity Severity Score (MESS) of 5.7 ± 1.4. Associated bone (54%), nerve (57%), and soft tissue (87%) injuries were common among those with EVI. After initial attempts at

**Table IV.** Injury characteristics

| *Variable* | *Overall (n = 214)* | *Unfavorable outcome (n = 122)* | *Favorable outcome (n = 92)* | P[a] |
|---|---|---|---|---|
| MESS ≥7, % | 24 | 28 | 20 | NS |
| ISS, mean ± SD | 15.3 ± 8.6 | 15.8 ± 7.7 | 15.9 ± 9.7 | NS |
| Amputation, % | | | | |
| Primary (nonindex limb) | 5 | 4 | 7 | NS |
| Secondary | 15 | 17 | 13 | NS |
| Multiple limb injury, % | 10 | 12 | 9 | NS |
| Vessel type injured, % | | | | |
| Artery | 66 | 61 | 74 | <.05 |
| Vein | 12 | 13 | 10 | NS |
| Combined | 22 | 26 | 16 | NS |
| Shunt placement, % | 12 | 12 | 13 | NS |
| Initial management, % | | | | |
| Repair | 58 | 63 | 62 | NS |
| Ligation | 53 | 54 | 51 | NS |
| Mechanism of injury, % | | | | |
| Blunt | 2 | 3 | 1 | NS |
| Penetrating | 30 | 26 | 36 | NS |
| Blast | 68 | 71 | 63 | NS |
| Associated injury, % | | | | |
| Soft tissue | 87 | 88 | 87 | NS |
| Bone | 54 | 55 | 53 | NS |
| Nerve | 57 | 62 | 51 | NS |

*ISS,* Injury Severity Score; *MESS,* Mangled Extremity Severity Score; *NS,* not significant; *SD,* standard deviation.
[a]Denotes comparisons between unfavorable outcome and favorable outcome groups. Continuous variables were analyzed by *t*-test. Proportions were analyzed by $\chi^2$ test or the Fisher exact test.

limb salvage, secondary amputation was required in 33 patients, 11 of which were considered delayed (>30 days postinjury). At 5 years of follow-up, the amputation-free survival was 84%.

Compared with those with unfavorable outcome, the favorable outcome group had a higher proportion of patients with isolated arterial injuries. This was consistent when mean MCS scores for isolated arterial injury were compared with isolated venous or combined injuries ($P =$ .012). The difference was most pronounced when arterial injuries were compared with venous injuries (mean MCS score, 47.0 vs 39.9; $P = .008$). Additional comparison of SF-36 component summary scores demonstrated a lower mean PCS score in those with severe limb injury (MESS, ≥7; 41.1 ± 8.8) vs less severe (43.7 ± 9.2; $P = .079$). On multivariate analysis, an elevated MESS was predictive of unfavorable PCS scores (OR, 2.36; 95% CI, 1.14-4.9; $P = .02$). With respect to concomitant injuries, those with associated bone injuries had lower PCS scores (44.5 ± 9.2 vs 41.8 ± 9.0; $P = .028$), whereas nerve injuries were predictive of unfavorable MCS scores (OR, 2.19; 95% CI, 1.09-4.40; $P = .0272$). Additional characteristics, including method of management, vessel location, mechanism of injury, shunt use or nonuse, and associated primary amputation, were not predictive of unfavorable outcomes on multivariate analysis.

Secondary amputees reported lower mean Physical Functioning scores than those with limb salvage (38.3 ± 10.8 vs 43.1 ± 9.9; $P = .013$). Despite a lower physical score, secondary amputees reported elevated Vitality scores (50.8 ± 10.6 vs 46.5 ± 11.3; $P = .046$). Secondary amputation was not associated with overall mental or physical quality of life, as assessed by MCS or PCS scores, on univariate or multivariate analysis.

**Postinjury characteristics.** As reported in Table V, at the time of survey completion, most of the study cohort remained on active duty (42%), was employed (22%), or had returned to school after separation from the military (13%). Only 21% of patients were separated and unemployed. With regard to employment status, those with favorable outcomes had a greater proportion of patients who remained on active duty and fewer proportions of patients reporting unemployment (both $P < .05$). Group comparison demonstrated higher mean MCS scores in those serving actively compared with separation (50.6 vs 43.8; $P < .001$). When compared with those separated and unemployed, active duty respondents reported an average 7.4-point higher MCS (95% CI, 1.3-13.5; $P = .008$).

Only one-quarter of patients were considered disabled (Medicare Part A); however, those qualifying had lower mean MCS scores (42.9 ± 12.7 vs 48.4 ± 11.8; $P =$ .005). Pain and psychiatric disorders, including anxiety, depression, post-traumatic stress disorder (PTSD), and substance abuse, were prevalent among those with combat-related EVI, with significantly higher proportions among those with unfavorable outcomes. Multivariate analysis demonstrated that chronic pain was predictive of unfavorable MCS (OR, 4.51; 95% CI, 1.95-10.45; $P = .0004$) and also PCS (OR, 6.3; 95% CI, 2.97-13.38; $P < .0001$) outcomes. Also predictive of unfavorable MCS outcomes were depression (OR, 3.19; 95% CI, 1.51-6.76; $P =$ .0024) and PTSD (OR, 2.5; 95% CI, 1.18-5.28; $P = .0169$).

## DISCUSSION

**Combat-related vascular injuries.** The following report is the first wartime vascular injury report with long-term follow-up and an evaluation of quality-of-life metrics. Coupling the increased incidence and severity of wartime EVIs, the management of this injury pattern has significant implications on mortality and long-term morbidity.[1,18] Although significant advances have been made to save life and limb, there exists a lasting burden of battlefield EVIs. Secondary amputation rates remain laudable in this cohort, at 16%, but more than half of those sustaining an EVI continue to report unfavorable mental or physical quality of life nearly 5 years after the injury. These results implore further investigation into specific preinjury, injury, and postinjury variables associated with unfavorable quality of life.

**Preinjury.** Contributions of a patient's background to long-term quality of life were pronounced. Perhaps the most prominent variable was the patient's age. Nearly a 12-fold increased risk for unfavorable physical outcomes was demonstrated in respondents aged ≥40 years. No studies currently exist evaluating long-term outcomes among age groups after extremity vascular trauma. Nevertheless, age does

**Table V.** Postinjury characteristics

| *Variable* | *Overall (n = 214)* | *Unfavorable outcome (n = 122)* | *Favorable outcome (n = 92)* | P[a] |
|---|---|---|---|---|
| Follow-up, mean ± SD, months | 61 ± 24.0 | 59 ± 24 | 63 ± 24 | NS |
| Employment, % | | | | |
| Active duty | 42 | 34 | 52 | <.05 |
| Separated | | | | |
| Employed | 22 | 21 | 24 | NS |
| Unemployed | 21 | 27 | 13 | <.05 |
| In school | 13 | 16 | 9 | NS |
| Disability (Medicare Part A) | 26 | 33 | 16 | <.05 |
| Pain/psychiatric disorder, % | | | | |
| Chronic pain | 68 | 87 | 43 | <.05 |
| Anxiety | 45 | 56 | 27 | <.05 |
| Depression | 39 | 51 | 22 | <.05 |
| PTSD | 55 | 63 | 42 | <.05 |
| Substance abuse | 11 | 10 | 12 | NS |

*NS,* Not significant; *PTSD,* post-traumatic stress disorder; *SD,* standard deviation.
[a]Denotes comparisons between unfavorable outcome and favorable outcome groups. Continuous variables were analyzed by *t*-test. Proportions were analyzed by $\chi^2$ test or the Fisher exact test.

play a significant role in the baseline health of the extremity vasculature and subsequent capability for recovery.

Additional preinjury characteristics predictive of outcome pertained primarily to a patient's socioeconomic or educational status. Although these findings are the first to be described in combat EVIs, they are not unique to severe limb injury. Results from the Lower Extremity Assessment Project (LEAP) were significantly influential, with risk factors for unfavorable outcome being predicted primarily by demographic factors such as level of education or income.[19,20] Similarly, within the EVI cohort, higher educational background (a surrogate of self-efficacy) was predictive of favorable mental and physical outcomes, whereas lower rank (a surrogate for socioeconomic status or income level) was associated with unfavorable mental and physical outcomes.

Although a patient's preinjury background is not directly modifiable by perioperative planning, these findings should direct long-term therapy and social work practices with redirected focus and effort on these vulnerable subgroups.

**Injury characteristics.** Injuries sustained on the battlefield are often complex. With most of the vascular injuries involving additional soft tissue, bone, or nerve injuries, or combinations of these, management often requires cooperation and consultation among several surgical specialists, including vascular, orthopedic, and plastics/reconstructive experts. However, similar to the results of the LEAP project, no particular management approach conferred an increased risk of unfavorable outcome.[19] Instead, only characteristics of the injury itself were predictive of long-term quality of life.

Although initially developed for predicting amputation in severely injured lower extremities, the MESS was used as an objective scale to define and compare injury severity of any afflicted limb.[21-23] When used as such, the MESS was significantly predictive of an unfavorable outcome. When a conventional cutoff of ≥7 was used, elevated MESS was associated with a twofold increased risk for an unfavorable long-term physical outcome. This is the first description of the reutilization of the MESS scale to predict long-term quality of life after EVIs.

**Postinjury characteristics.** Perhaps the most influential factor predictive of long-term quality of life is the patient's postinjury state. Before injury, patients were healthy and fully employed on active duty status. After injury, more than one-fifth were separated from the military and unemployed (nearly double the national unemployment rate), and more than one-quarter qualify for disability (Medicare Part A). These results provide insight into the burden that vascular injuries impart from a socioeconomic standpoint.

Although no civilian EVI data exist for comparison, several studies have evaluated outcomes after mangled extremity injuries. Again, the best available data come from the LEAP investigators, who found that of patients who were previously employed, only 53% of those with amputation and 49% with limb-salvage returned to employment after severe lower extremity injuries.[24] Other studies, such as Dagum et al,[25] found rates as low as 40% when evaluating outcomes after severe lower extremity injury. Acknowledging inherent differences between military populations and civilian trauma populations, these results are promising. Nevertheless, there still exists a significant impact socioeconomically, because all patients in this cohort were both fully capable and employed before injury. Univariate analysis found that the ability to maintain active duty status was associated with improved mental component outcomes compared with those separated from the military, with the greatest difference between those on active duty status and those separated and unemployed.

Psychologic wellness has proven to be greatly influential on long-term quality of life after injury. Psychiatric and pain disorders were prevalent among the military cohort and had a significant effect on a patient's quality of life. Depression and PTSD imparted a twofold to threefold increased risk for unfavorable mental outcomes, whereas chronic pain syndromes increased the risk for unfavorable mental and physical outcomes nearly fourfold and sixfold, respectively.

These findings are not unique to those with severe extremity injuries. O'Toole et al[26] found that in patients with severe lower extremity injuries, absence of pain and depression were associated with improved outcome. Reflection on the subgroups from LEAP also identified the high concordance of psychiatric and pain disorders associated with mangled extremities. McCarthy et al[27] found that 48% of patients tested positive for any psychologic disorder 3 months after injury and 42% at 2 years. With respect to pain, only 23% of the LEAP study population was pain-free at 7 years of follow-up.[28] These findings again highlight a key feature of patient management that is shared with the civilian community. Contrary to civilian counterparts, however, wounded warriors are currently customarily evaluated by a psychologist or psychiatrist stateside. Despite access, this feature needs to be highlighted and re-emphasized in providing quality care to wounded service members.

**Limitations.** We emphasize that this study is an observational analysis, and although associations between study variables and outcomes can be determined, these associations should not be misconstrued as a cause-and-effect relationship. There are many potential confounding variables that must be acknowledged.

As with other JTTR studies, the population is greatly influenced by fidelity of coding at level III care centers. Patients are identified solely by International Classification of Diseases, 9th Revision, or Abbreviated Injury Scale codes. As a result, there remain several service members with vascular injuries who might have been missed as a result of miscoding.

This analysis included a heterogeneous population of EVIs. The effect of limb salvage and quality of life can potentially be skewed by location of injury, because quality of life could conceivably be more afflicted in the setting of upper extremity injuries or amputations. Further analysis and dedicated quality-of-life/quality-of-limb analysis is required to elucidate particular characteristics that afflict particular limbs or vessels individually.

Additional limitations are inherent in survey-based studies: subjective variability and nonresponse. These are limited by the use of validated surveys and dedicated research nurses to limit nonresponse, but considerations of these limitations are necessary. Although survey-based functional outcomes studies are inherently weakened by nonresponse, the military offers a unique opportunity due in combination to close follow-up and the foresight of the JTTR. At the time of this interim analysis, more than one-half of the records had been reviewed and demonstrated >800 patients with EVIs. Successful contact has been consistently >80%, with consent rates >95% and acceptable return rates of 50% to 60% thus far. Other trauma-related survey-based studies often quote higher return rates but are often smaller or have significantly shorter follow-up.[29,30]

This study is the first to evaluate long-term patient-based outcomes in salvageable EVIs. As a result, no quality-of-life surveys have been validated for this particular patient population. As previously described, the selection of the SF-36 was based on the conclusion that the long-term impact of EVIs is translatable to other chronic extremity pathologies (ie, claudication).[31] The SF-36 has been demonstrated to be superior to other quality-of-life surveys (ie, the Sickness Impact Profile or Nottingham Health Profile) in evaluating the mental and physical burden of intermittent claudidcation.[32]

## CONCLUSIONS

Quality of life after EVIs is reduced globally compared with population norms. However, long-term outcomes were not associated with any particular perioperative management strategy or injury-specific characteristic, including manner of vascular injury management, presence of primary amputation, secondary amputation, number of amputations, or mechanism of injury. Instead, the most influential factors contributing to a patient's quality of life depended on a patient's particular demographic status, socioeconomic background (preinjury and postinjury), and mental health.

The results of this interim analysis are meant to provide novel insight into management and long-term outcomes of a previously under-reported injury pattern whose outcomes hinge significantly on decision-making ability, surgical technique, postinjury therapy, and long-term surveillance. Future analysis will help to delineate particular modifiable factors that can, hopefully, produce improved outcomes among those with EVIs.

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## AUTHOR CONTRIBUTIONS

Conception and design: DS, ZA, AS, TR
Analysis and interpretation: DS, ZA, HM, TR
Data collection: DS
Writing the article: DS, ZA, TR
Critical revision of the article: DS, ZA, TR
Final approval of the article: DS, ZA, AS, HM, WC, TR
Statistical analysis: DS, ZA, HM
Obtained funding: TE
Overall responsibility: ZA

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## APPENDIX (online only).

### Demographic questionnaire

1. What is your current employment status?
2. What is your highest level of education?
3. What is your current marital status?
4. Has your marital status changed since your injury?
5. Upon discharge from the military hospital, were you given instructions concerning care of your vascular repair or need to be followed in the future by a physician?
6. When was your last vascular follow-up appointment?
7. Have you had any of the following radiographic studies of your injury (a. Ultrasound, b. CT, c. MRI)?
8. Have you had an amputation?

9-10. Where is (are) your amputation(s)?

11. Do you have a prosthesis (artificial arm or leg) fitted to an amputated arm or leg?
12. Were you able to participate in the discussion to decide whether to repair or amputate your arm or leg?
13. Are you satisfied with the decision to repair or amputate your injured arm or leg?
14. Does pain impact your ability to perform daily activities?
15. Do you take pain medication daily because of pain in your injured arm or leg?
16. Since your injury, have you ever received a mental health evaluation and/or therapy to control one or more of the following: a. Anxiety, b. Depression, c. PTSD, d. Substance Abuse?
17. Since your injury, have you taken medicine to control one or more of the following: a. Anxiety, b. Depression, c. PTSD, d. Substance Abuse?