# Flap Coverage Outcomes following Vascular Injury and Repair: Chronicling a Decade of Severe War-Related Extremity Trauma

LCDR Kevin Casey, M.D.
CPT Jennifer Sabino, M.D.
LCDR Elliot Jessie, M.D., M.B.A.
COL Barry D. Martin, M.D.
LCDR Ian Valerio, M.D., M.B.A.

*Kandahar, Afghanistan; San Diego, Calif.; and Bethesda, Md.*



**Background:** Combat-related extremity injuries frequently require vascular repair within the combat theater before undergoing definitive reconstruction. This study examines the outcomes of early vascular repair with secondary soft-tissue extremity reconstruction over the past decade of war trauma.
**Methods:** War-related extremity injuries necessitating a downrange vascular procedure followed by a definitive limb reconstruction were reviewed. Patient demographics, type and location of vascular injuries, vascular intervention, and soft-tissue reconstruction procedures were examined. Outcomes of vascular repair, tissue transfer, and limb salvage were analyzed.
**Results:** From 2003 to 2012, 79 extremities in 78 patients had a vascular injury requiring in-theater intervention followed by 87 staged flap reconstructions performed distal to the vascular repair. Of the 74 arterial injuries requiring intervention, 27 were proximally located, with 73 percent requiring bypass. The early primary patency rate was 66 percent and the early primary-assisted patency rate was 93 percent for proximal artery repair procedures. The flap complication rate was 31 percent. Overall complications were examined by subtype and were not significantly different compared with flaps performed without a proximal vascular injury in the same limb. The flap success rate (93 percent) and the limb salvage rate (81 percent) were similar to the comparison cohort.
**Conclusions:** This represents one of the largest series of traumatic extremity injuries requiring secondary limb reconstruction with tissue transfer following a vascular intervention. The authors identified no significant difference in outcomes related to flap coverage or limb salvage for patients with or without vascular injuries. Reconstructive options in combat extremity trauma are not limited by proximal vascular injury. (*Plast. Reconstr. Surg.* 135: 301, 2014.)
**CLINICAL QUESTION/LEVEL OF EVIDENCE:** Therapeutic, III.

The conflicts in Iraq and Afghanistan have extended over a decade, making the Global War on Terror the longest war in which the United States has been directly involved. One of the signature injury patterns is a major single injury or multiple extremity injuries secondary to blast-related trauma.[1] Improvised explosive devices are the most common cause of such

*From the Department of Surgery, Kandahar Air Field NATO Role III, Multinational Medical Unit; the Division of Vascular Surgery, Department of General Surgery, Naval Medical Center San Diego; and the Department of General Surgery and the Plastic and Reconstructive Surgery Service, Walter Reed National Military Medical Center.*
*Received for publication March 19, 2014; accepted July 10, 2014.*
*Presented at the 2013 Annual Meeting of the American Society for Reconstructive Microsurgery, in Naples, Florida, January 12 through 15, 2013; the 2013 World Society for Reconstructive Microsurgery Congress, in Chicago, Illinois, July 11 through 14, 2013; the 99th Clinical Congress of the American College of Surgeons, in Washington, D.C., October 6 through 19, 2013; and the 55th Annual Meeting of the Society of Military Orthopaedic Surgeons, in Vail, Colorado, December 9 through 13, 2013.*
*Copyright © 2014 by the American Society of Plastic Surgeons*
DOI: 10.1097/PRS.0000000000000769

**Disclosure:** *The authors have no financial interest to declare in relation to the content of this article.*

A Video Discussion by Eamon O'Reilly, M.D., accompanies this article. Go to PRSJournal.com and click on "Video Discussions" in the "Videos" tab to watch.

extremity injuries.[2–4] Blast-related injuries exhibit a complex injury pattern, with both high- and low-velocity penetrating and blunt mechanisms of injury that often result in extensive soft-tissue and bony destruction.[3] These patients suffer from high rates of concomitant vascular and neurologic injuries and severe orthopedic and soft-tissue extremity patterns of injury.

The majority of patients who die as a result of high-energy explosions do so within the combat field from bleeding and exsanguination.[4] However, hemorrhagic deaths from extremity injuries have decreased substantially during the course of this war and compared with previous wars. Over 90 percent of blast-related combat casualties survive, with the majority of survivors being subsequently treated at stateside military treatment facilities.[5] The improved survival rates during the current conflict stem from early stabilization and aggressive resuscitation measures, universal adoption and application of extremity tourniquets, and early advanced care measures and surgical intervention within the initial injury setting (i.e., in-theater military care system).

Complex extremity injuries often require immediate vascular assessment and repair to permit potential secondary limb salvage measures. Such casualties typically require multiple procedures and repeated débridements as they progress through the echelons of medical care and until they are ready for definitive reconstruction. Stateside military treatment facilities perform the majority of the definitive orthopedic stabilization and flap coverage procedures that are performed for limb salvage and preservation.

The objective of this study was to examine the outcomes of early vascular intervention followed by delayed flap coverage procedures for complex extremity injuries at risk for amputation. Our group examined vascular repair patency rates, flap success, limb salvage rates, and complications in this combat casualty care cohort. These results were compared with a cohort of extremity salvage cases that did not sustain vascular injuries in the same limb.

## PATIENTS AND METHODS

A retrospective review of a single-institution database containing consecutively treated combat casualty care patients who sustained extremity injuries necessitating flap coverage over a 10-year period (2003 through 2012) was performed. Walter Reed National Military Medical Center Institutional Review Board approval was obtained before this study. The aforementioned group was divided into two distinct cohorts: (1) patients who sustained a vascular injury within the extremity requiring secondary flap coverage procedures, and (2) patients who had extremity flap coverage procedures but did not suffer a major vascular injury. Patient demographics and outcomes were examined for both groups.

Patients with an extremity vascular injury necessitating an immediate vascular intervention in the combat theater and a concomitant soft-tissue defect needing eventual reconstruction were evaluated. The type of vascular repair, conduit, and use of a vascular shunt were at the discretion of the combat casualty care in-theater operating surgical teams. Soft-tissue and orthopedic injuries were typically treated with early surgical débridement followed by external fixator placement for fracture stabilization. Serial tissue débridements were completed throughout the course of care. On arrival to our stateside military treatment facility (Walter Reed National Military Medical Center), the individual treatment plans for severe extremity injuries were reviewed, with the reconstruction algorithm dependent on the tissue defect and coverage option and donor-site availability and with consideration of the patient's concomitant injuries and eventual rehabilitation goals.

Duplex ultrasonography was performed for all patients who had an arterial bypass or primary arterial repair. Any necessary revision was performed before tissue transfer by the vascular surgery team. Indications for revision included an anastomotic peak systolic velocity greater than 3.5, decreased distal arterial waveforms, or technical problems with the graft or anastomosis. An ipsilateral extremity arterial angiogram or computed tomographic angiogram was also obtained for all patients before any tissue transfer procedure. These studies confirmed patency of the vascular repair, examined the extremity's distal runoff, and aided in preoperative planning for flap vessel target anastomotic sites.

Primary outcomes measured included primary and primary-assisted arterial patency rates, flap complication rates, extremity complication rates, and overall limb salvage rates. The Injury Severity Score was calculated in standard fashion using the highest Abbreviated Injury Scale scores from the most severely injured body regions.[6] Primary patency was defined as a graft that remained patent throughout follow-up. Primary-assisted patency was defined as a graft that was patent at the completion of follow-up, including those that

required an intervention to maintain patency. Flap and extremity complications were defined as complications that required operative intervention or a prolonged hospital stay for wound care. Failed limb salvage was defined as secondary limb amputation or amputation to a joint level above the previous amputation site.

Descriptive variables were compared using the *t* test for means and Mann-Whitney test for medians. Categorical variables were compared as a proportion using chi-square or Fisher's exact test, as appropriate. Significance was defined as a two-tailed value of $p \leq 0.05$. Analysis was performed using IBM SPSS Statistics Version 22 (IBM Corp., Armonk, N.Y.).

## RESULTS

Three hundred fifty-nine flap procedures were performed for tissue defects sustained during combat trauma from 2003 through 2012. Eighty-seven procedures were performed distal to an associated vascular injury (24 percent) (Table 1). These 87 procedures were performed on 79 extremities in 78 patients. One patient had two separate extremities reconstructed in this series. The mean age of the patients was 26 years (SD, 6.3 years; range, 19 to 50 years). All patients were healthy men with no documented comorbidities before injury. The mean Injury Severity Score was 19 (SD, 9.1; range, 9 to 42). The mechanism of injury was an explosion in 83 percent of patients, gunshot wound in 12 percent, and blunt trauma in 5 percent. There were no differences in age or in Injury Severity Score for those patients who underwent flap procedures with or without proximal vascular injury ($p = 0.572$ and $p = 0.976$, respectively) (Table 2). The mean follow-up was 26 months.

**Table 1. Demographic and Clinical Factors for Patients and Extremities with Vascular Injury That Underwent In-Theater Intervention followed by a Secondary Procedure for Tissue Coverage**

| Factors | Value (%) |
|---|---|
| Patient | |
| No. | 78 |
| Age, yr | |
| Mean | 26 |
| SD | 6.3 |
| ISS | |
| Mean | 19 |
| SD | 9.1 |
| Male sex | 78 (100) |
| Mechanism | |
| Blast | 65 (83) |
| Gunshot wound | 8 (10) |
| Blunt | 5 (7) |
| Extremities | |
| No. | 79 |
| Extremity | |
| Upper | 42 (53) |
| Lower | 37 (47) |
| Location | |
| Proximal arterial | 28 (36) |
| Distal arterial | 46 (58) |
| Venous only | 5 (6) |
| Concomitant arterial and venous injury | 9 (11)* |
| Concomitant fracture | 71 (90) |
| Concomitant nerve injury | 27 (34) |

ISS, Injury Severity Score.
*Concomitant venous injuries were likely not documented in the theater medical record and treated with ligation during arterial repair.

### Vascular Injuries and Intervention

Of the 79 reconstructed extremities with associated vascular injury, 42 (53 percent) occurred in the upper extremities (Figs. 1 through 3) and 37 (47 percent) occurred in the lower extremities (Fig. 4 and Table 1). Of 74 arterial injuries, 28 occurred in a proximal artery and 46 occurred in a distal artery. Five patients sustained isolated venous injuries. Ninety percent of extremities had associated open fractures (Gustilo grade B or C) and 30 percent had concomitant nerve injuries. The most common proximal and distal upper extremity vessels injured were the brachial and radial arteries, respectively. The most common proximal and distal lower extremity vessels injured were popliteal and anterior tibial artery systems, respectively (Fig. 5).

For the 27 proximal vascular injuries, 74 percent were treated with a bypass using an

**Table 2. Cohort Comparison**

| | Vascular Injury (%) | No Vascular Injury (%) | *p* |
|---|---|---|---|
| No. of patients | 78 | 230 | |
| No. of procedures | 87 | 272 | |
| Age, yr | | | 0.572 |
| Mean | 26.4 | 25.7 | |
| SD | 6.3 | 6.3 | |
| ISS | | | 0.976 |
| Mean | 18.8 | 18.7 | |
| SD | 9.1 | 9.5 | |
| Time to flap, days | | | 0.580 |
| Mean | 19 | 18.5 | |
| SD | 77 | 86 | |
| Prior procedures | | | 0.235 |
| Mean | 5 | 5 | |
| SD | 4 | 4 | |
| Transfer type | | | |
| Pedicled flap | 42 (57) | 169 (62) | |
| Free flap | 37 (43) | 103 (38) | 0.321 |
| Tissue type | | | |
| Muscle | 38 (44) | 153 (56) | |
| Fasciocutaneous | 48 (55) | 118 (43) | |
| Other | 1 (1) | 1 (1) | 0.411 |
| Composite with bone | 4 (5) | 4 (1) | 0.228 |

ISS, Injury Severity Score.

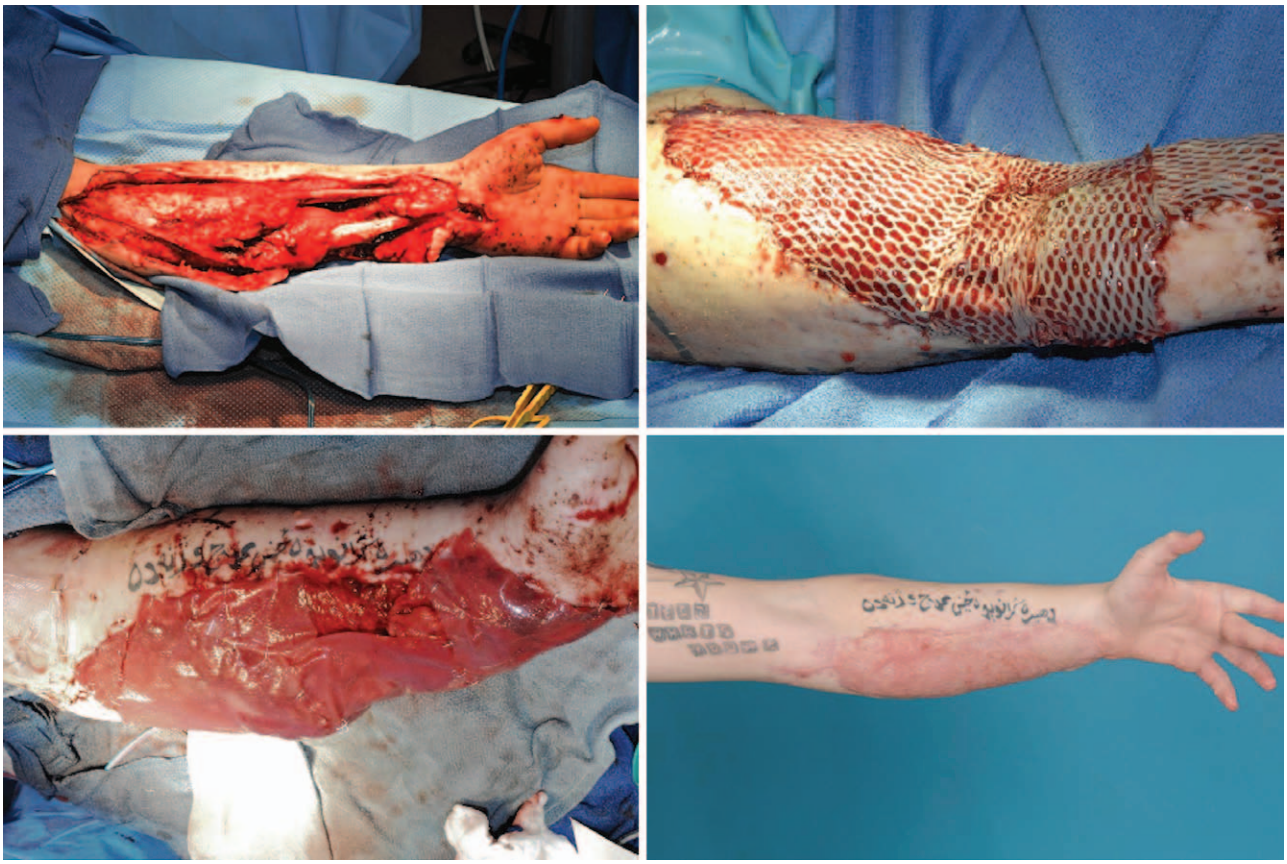

**Fig. 1.** (*Above*, *left*) Complex left upper extremity soft-tissue injury with segmental ulnar artery injury, exposed radial artery, and grade 3B both bone fracture. (*Below*, *left*) Omental flow-through flap reconstructing ulnar artery and soft-tissue defect covered with bilayer dermal regenerate matrix. (*Above*, *right*) Split-thickness skin grafting after free flap surgery. (*Below*, *right*) Appearance at 2-year follow-up.

autogenous conduit, with the saphenous vein used in 95 percent of the cases. The remaining injuries underwent primary arterial or patch angioplasty repairs. Complications required operative revision in nine grafts, resulting in an early primary patency rate of 66 percent. The most common complication necessitating revision was pseudoaneurysm formation, which occurred in 19 percent of cases. Graft revision procedures salvaged all grafts except two cases. In these cases, one patient required a new distal bypass and the other patient went on to undergo above-knee amputation for persistent inadequate perfusion. The primary-assisted graft patency rate was 93 percent at 26 months.

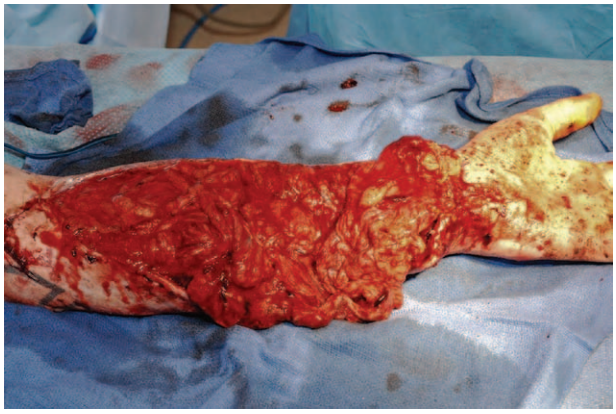

**Fig. 2.** Free omental flow-through flap for a left upper extremity complex injury with segmental ulnar artery injury.

Ninety percent of distal arterial injuries underwent a direct ligation procedure. For two radial arteries that were repaired, a saphenous vein graft was used in one case and an omental flow-through flap was used in another case for arterial reconstruction. Four of the five extremities (80 percent) with isolated venous injuries underwent venous ligation during the primary procedure.

### Flap Coverage Procedures and Outcomes

The average interval from vascular repair until definitive flap coverage was 33 days (median, 19 days; SD, 77 days). There was an average of six wound irrigation and débridement procedures per patient before the definitive flap coverage procedure

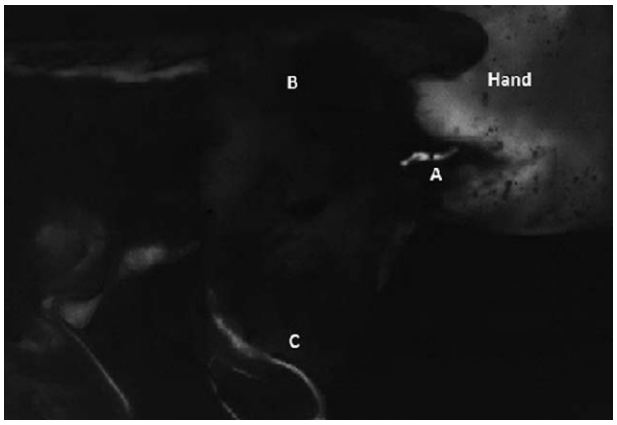


**Fig. 3.** Indocyanine green angiography demonstrating perfusion through the omental flap. *A*, Ulnar artery anastomosis and flow during radial artery compression; *B*, proximally compressed radial artery preventing distal runoff from vessel; *C*, flow through the gastroepiploic vessels acting as interposition arterial graft to repair segmental ulnar artery defect.

(median, five procedures; SD, four procedures). Pedicled flaps were the most common type of flap transfer technique used, representing 57 percent of flaps ($n$ = 50) performed. Free tissue transfers were used in the remaining 43 percent of cases ($n$ = 37). Forty-eight muscle flaps (55 percent), 38 fasciocutaneous flaps (44 percent), and one omental flap (1 percent) were used for extremity coverage procedures. Four flaps (5 percent) were composite flaps. There was no difference in preoperative care or flap characteristics between patients with and without vascular injury (Table 2).

The total flap complication rate was 31 percent, with infection and hematoma occurring most frequently (Table 3). Flap or donor-site infections occurred in 10 percent of cases ($n$ = 9), whereas flap or donor-site hematoma occurred in 8 percent of cases ($n$ = 7). Eight percent of the extremity flaps failed ($n$ = 7). The most common cause of flap failure was venous congestion in four flaps (5 percent). These outcomes are similar to the flap complication (28 percent) and failure (10 percent) rates in the cohort of patients undergoing flap-based extremity reconstructions who did not suffer a concurrent vascular injury.

### Extremity Outcomes

Fifty-four percent of extremities with vascular injuries had a non–flap-related complication during the course of their care. These complications consisted of soft-tissue infection (15 percent), osteomyelitis (10 percent), chronic pain (10 percent), heterotopic ossification (9 percent), bony nonunion (5 percent), or other complications

**Fig. 4.** (*Above*) Large left lower extremity injury with open joint. (*Below*) Appearance at 1-year follow-up after lateral gastrocnemius flap and skin grafting.

such as dysfunction or poor perfusion (5 percent) (Table 3). The overall limb salvage rate was 81 percent, with 15 limbs amputated during the observed study period. The average time to amputation was 10 months, with the majority being lower extremity amputations ($n$ = 13). Only one amputation was the result of a flap failure. The remaining amputations were performed primarily for persistent infection or chronic pain. However, one patient did go on to an above-knee amputation because of continued limb ischemia following a failed saphenous vein bypass for a popliteal artery injury despite multiple attempts at revision. Distal arterial ligation was performed in nine amputated limbs.

## DISCUSSION

Thousands of combat casualties have been treated during the past 12 years of military operations. The high rates of blast trauma encountered during the Global War on Terror have led to a high volume of combat casualties suffering from severe, complex extremity injuries.[5,7] Given this mechanism of trauma, it is not surprising that casualties present with higher Injury Severity Scores, have large zones of injury with multiple concomitant injuries, and have worse wound contamination

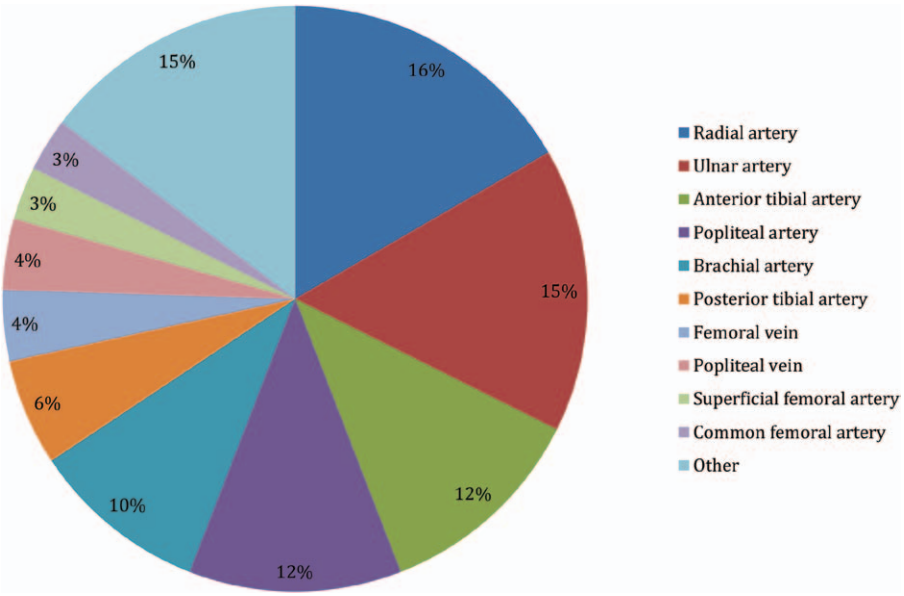


**Fig. 5.** Location of vascular injuries.

**Table 3. Complications**

| | Vascular Injury (%) | No Vascular Injury (%) | *p* |
|---|---|---|---|
| No. | 87 | 272 | |
| Total complications | 27 (31) | 76 (28) | 0.446 |
| Infection | 9 (10) | 16 (6) | 0.334 |
| Hematoma | 7 (8) | 15 (6) | 0.183 |
| Flap failure | 7 (8) | 28 (10) | 0.322 |
| Extremity | | | |
| No. | 79 | 253 | |
| Complications | 43 (54) | 141 (56) | 0.576 |
| Soft-tissue infection | 12 (15) | 40 (14) | 0.209 |
| Osteomyelitis | 8 (10) | 36 (13) | 0.115 |
| Failed limb salvage | 15 (19) | 32 (12) | 0.526 |

compared with typical civilian trauma populations.[8] As a result, combat casualties provide challenging extremity reconstructions, including a relatively high percentage of vascular trauma in limbs that also require additional delayed tissue coverage for limb salvage.

Revascularization followed by tissue coverage was first described in the 1980s and has since become an acceptable approach in many patients with chronic disease states. Several studies have examined and reported good outcomes with revascularization followed by flap coverage for disease states such as peripheral vascular disease and diabetes mellitus.[9–14] These studies have reported limb salvage rates between 70 and 80 percent, with acceptable flap outcomes for these disease states after the critical ischemia has been addressed with revascularization procedures.[9–14] However, blast-related trauma and associated outcomes in those combat casualties suffering significant extremity vascular injuries remain underreported.

The combat casualties examined in this study were primarily young, active men with minimal comorbidities. This study cohort thus had a low associated mortality rate and relatively low associated major morbidity rate compared with other populations studied. For example, the mortality and the combined incidence of myocardial infarction, pulmonary complications, and renal failure within the group was 0 percent. However, other morbidities and complications such as chronic pain, heterotopic ossification, bony nonunion or malunion, and soft-tissue infection/osteomyelitis had a combined incidence of 54 percent in our cohort, which was not statistically different from the complication rate of the comparison nonvascular injury cohort (56 percent) (Table 3).

In reviewing the vascular outcomes for our population, the arterial bypass primary patency rate of 66 percent was lower than expected. This finding may be associated with several factors. Within the in-theater hospital setting, many of these patients entered the operating theater emergently after transfer from varying hostile settings, under variable climates and exposure times, and having sustained multiple concomitant injuries, all of which predispose many of these patients to a hypotensive, hypothermic, and acidotic medical condition. Despite aggressive resuscitation measures, "damage-control" operations were performed under less-than-ideal or controlled circumstances. Furthermore, the massive tissue

defects that result from blast-related trauma often can lead to unusual and unfamiliar graft tunneling routes, which increases the potential for graft kinking and thrombosis. Finally, multiple transfers between medical facilities and reexploration over subsequent days may have increased the risk of complications and graft occlusion.

Although the primary arterial bypass primary patency rate was lower than expected, our primary-assisted patency rate of 93 percent was acceptable and a reflection of close monitoring and follow-up care provided throughout patients' prolonged treatment courses. For our combat casualties suffering vascular injury, each patient with a vascular intervention performed in-theater underwent a vascular consultation and duplex ultrasound examination on arrival to Walter Reed National Military Medical Center. The duplex ultrasound examination was performed to ensure no evidence of a failing graft or technical issue. Regardless of the outcome of the ultrasound examination, all patients underwent arterial angiography or computed tomographic angiography before the flap procedure. This allowed for further imaging of the vascular repair and also assisted the reconstructive team with preoperative flap planning.

The flap success rate was 92 percent for our vascular injury cohort and is better than that of previous studies.[9,10] Our study population consisted of young healthy patients with devastating trauma yet relatively few comorbidities. Unlike other study populations, no patient in our cohort had chronic kidney disease, diabetes mellitus, or peripheral vascular disease. These other chronic medical conditions have a profound influence on flap-related outcomes and have been directly shown to increase the risk of complications, flap failure rates, and subsequent amputation rates and limb salvage failure.

The limb salvage rate of 81 percent did not differ from other military populations having sustained high-energy lower extremity trauma undergoing extremity reconstruction.[11,12] The extent of soft-tissue injury, number and extent of fractures, and Injury Severity Score have all been identified as independent risk factors for amputation in this study population. Not infrequently, patients suffering from severe trauma progress to amputation and failed limb salvage despite having adequate perfusion and tissue coverage. In this study, 14 of 15 patients who went on to undergo amputation had continuous in-line blood flow, whereas flap failure led to amputation in only one case of the entire cohort of patients.

The long-term complication rate of 54 percent underscores the complexity of blast trauma and this cohort examined. The risk of heterotopic ossification increases with number of procedures and degree of tissue loss and likely contributed to the 10 percent rate of heterotopic ossification in our study patient population.[13] The risk of chronic infection following combat casualties is well known, with rates exceeding 30 percent in many reports.[14,15] Eighty-eight percent of patients had associated open orthopedic fractures, which also significantly increases the risk of infection, bony nonunion, and malunion.[16,17] In addition, chronic pain remains a challenge in this population.[18,19] All of these significantly impacted amputation and failed limb salvage rates. These long-term risks also underscore the need for continued multidisciplinary follow-up.

To our knowledge, this is the largest series of combat extremity injuries in which patients required an immediate vascular intervention followed by delayed tissue coverage for war-related trauma. Our results demonstrate that these procedures can be performed with acceptable outcomes and successful limb salvage rates. Nonetheless, there are several limitations to this study. The Mangled Extremity Severity Score is recognized as a reliable indicator of limb injury severity and a predictor for limb salvage.[20,21] Given that all injuries were sustained distant from where the definitive treatment occurred, this scoring system and limb salvage predictor was not available for this cohort. The Injury Severity Score was recorded and is a less accurate surrogate for limb injury severity. The challenges with retrospective studies are well documented. In addition, there was no ability to standardize the treatment of in-theater vascular injuries. Such decisions are dependent on the facility's capabilities, the surgeon's comfort level, and the available resources. Furthermore, as combat casualties are transported between multiple military treatment facilities over the course of many days to weeks, incomplete or inaccurate documentation is a significant risk.

Combat-related extremity injuries are significant, complex, and challenging. They require a multidisciplinary approach beginning immediately after the injury to long after the patient's return to a stateside hospital. This report outlines outcomes in extremity salvage patients who have suffered vascular injuries requiring an immediate vascular repair followed by delayed definitive soft-tissue coverage procedures. Our group has illustrated that despite the significant challenges encountered in this traumatic war

casualty population, successful limb salvage can be achieved in the majority of patients.

***Ian L. Valerio, M.D., M.S., M.B.A.***
Department of Plastic and Reconstructive Surgery
Walter Reed National Military Medical Center
8901 Wisconsin Avenue
Bethesda, Md. 20889
ian.l.valerio.mil@health.mil

## ACKNOWLEDGMENTS

*The authors thank the Departments of General Surgery, Trauma Surgery Service, Orthopaedic Surgery, and Plastic and Reconstructive Surgery at Walter Reed National Military Medical Center and Fort Belvoir Community Hospital for their contribution to this work and the care of wounded warriors. In particular, they thank Patrick Basile, M.D., E. Richard Bonnecarrere, M.D., Thomas Chung, D.O., Mark Fleming, D.O., Robert Howard, M.D., Anand Kumar, M.D., Kerry Latham, M.D., George Nanos, M.D., Carlos Rodriguez, D.O., M.B.A, F.A.C.S., Mark Shashikant, M.D., and Scott Tintle, M.D.*

## DISCLAIMER

*The views expressed in this article are those of the authors and do not necessarily reflect the official policy or position of the Department of the Navy, the Department of Defense, or the United States Government.*

## REFERENCES

1. Owens BD, Kragh JF Jr, Macaitis J, Svoboda SJ, Wenke JC. Characterization of extremity wounds in Operation Iraqi Freedom and Operation Enduring Freedom. *J Orthop Trauma* 2007;21:254–257.
2. Starnes BW, Beekley AC, Sebesta JA, Andersen CA, Rush RM Jr. Extremity vascular injuries on the battlefield: Tips for surgeons deploying to war. *J Trauma* 2006;60:432–442.
3. Champion HR, Holcomb JB, Young LA. Injuries from explosions: Physics, biophysics, pathology, and required research focus. *J Trauma* 2009;66:1468–1477; discussion 1477.
4. Eastridge BJ, Mabry RL, Seguin P, et al. Death on the battlefield (2001–2011): Implications for the future of combat casualty care. *J Truama Acute Care Surg.* 2012;73:S431–S437.
5. Markov NP, DuBose JJ, Scott D, et al. Anatomic distribution and mortality of arterial injury in the wars in Afghanistan and Iraq with comparison to a civilian benchmark. *J Vasc Surg.* 2012;56:728–736.
6. Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: A method for describing patients with multiple injuries and evaluating emergency care. *J Trauma* 1974;14:187–196.
7. Fox CJ, Gillespie DL, O'Donnell SD, et al. Contemporary management of wartime trauma. *J Vasc Surg.* 2005;41;638–644.
8. Valerio I, Sabino J, Heckert R, et al. Known preoperative deep venous thrombosis and/or pulmonary embolus: To flap or not to flap the severely injured extremity? *Plast Reconstr Surg.* 2013;132:213–220.
9. Illig KA, Moran S, Serletti J, et al. Combined free tissue transfer and infrainguinal bypass graft: An alternative to major amputation in selected patients. *J Vasc Surg.* 2001;33:17–23.
10. Tukiainen E, Kallio M, Lepantalo M. Advanced leg salvage of the critically ischemic leg with tissue loss by vascular and plastic surgeon teamwork: A long-term outcome. *Ann Surg.* 2006;244:949–958.
11. Swiontkowski MF, MacKenzie EJ, Bosse MJ, et al. Factors influencing the decision to amputate or reconstruct after high-energy lower extremity trauma. *J Trauma* 2002;52:641–649.
12. Scott DJ, Arthurs ZM, Stannard A, Monroe HM, Clouse WD, Rasmussen TE. Patient-based outcomes and quality of life after salvageable wartime extremity vascular injury. *J Vasc Surg.* 2014;59:173–179.e1.
13. Potter BK, Forsberg JA, Davis TA, et al. Heterotopic ossification following combat-related trauma. *J Bone Joint Surg Am.* 2010;92(Suppl 2):74–89.
14. Sheppard FR, Keiser P, Craft DW, et al. The majority of US combat casualty soft-tissue wounds are not infected or colonized upon arrival or during treatment at a continental US military medical facility. *Am J Surg.* 2010;200:489–495.
15. Mody RM, Zapor M, Hartzell JD, et al. Infectious complications of damage control orthopedics in war trauma. *J Trauma* 2009;67:758–761.
16. Brown KV, Ramasamy A, Tai N, MacLeod J, Midwinter M, Clasper JC. Complications of extremity vascular injuries in conflict. *J Trauma* 2009;66(Suppl):S145–S149.
17. Johnson EN, Burns TC, Hayda RA, Hospenthal DR, Murray CK. Infectious complications of open type III tibial fractures among combat casualties. *Clin Infect Dis.* 2007;45:409–415.
18. Castillo RC, MacKenzie EJ, Wegener ST, Bosse MJ; LEAP Study Group. Prevalence of chronic pain seven years following limb threatening lower extremity trauma. *Pain* 2006;124:321–329.
19. Burkhardt GE, Cox M, Clouse WD, et al. Outcomes of selective tibial artery repair following combat-related extremity injury. *J Vasc Surg.* 2010;52:91–96.
20. Johansen K, Daines M, Howey T, Helfet D, Hansen ST Jr. Objective criteria accurately predict amputation following lower extremity trauma. *J Trauma* 1990;30:568–572; discussion 572.
21. Lin CH, Wei FC, Levin LS, Su JI, Yeh WL. The functional outcome of lower-extremity fractures with vascular injury. *J Trauma* 1997;43:480–485.