

SPECIAL REPORT

Management and Outcomes of Major Extremity Vascular Injuries in Armed Conflict: Challenges and Experience from Ukraine

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Introduction: Extremity vascular injuries constitute the majority of combat vascular trauma and present a complex management challenge due to hemorrhage, ischemia, and associated musculoskeletal destruction.

Methods: This is a retrospective multicenter review of 900 consecutive cases treated at Level II–IV military and civilian referral centers between 2022 and 2024. Major vascular injury was defined as injury to a named extremity vessel causing ischemia, major hemorrhage, or requiring operative vascular intervention.

Results: Femoral–popliteal injuries accounted for 689/900 of the cases (76.6%). Combined arterial–venous injuries were present in 490/900 (54.4%). Complex trauma with bone, nerve, or combined trauma occurred in 711/900 (79.0%). Massive soft-tissue destruction occurred in 776/900 (86.3%). Interventions included vascular reconstructions (15.0%), temporary shunts (5.3%), and fasciotomies (35.8%). Primary amputation rate was 8.3% (75/900) and the secondary rate was 15.6% (140/900), yielding a 23.9% overall amputation rate, primarily driven by massive blast-induced soft-tissue destruction. Mortality was 1.7% (15/900). Chronic arterial insufficiency (17.7%) and thrombosis (13.7%) occurred long term.

Conclusion: Modern combat extremity injuries highlight persistent limb-salvage challenges. Decreasing time to reperfusion is crucial. Key recommendations include: protocolization of damage-control strategies with clear indications for temporary shunts and fasciotomy; preferential use of autologous conduits in contaminated wounds; and early, aggressive soft-tissue management and infection control to reduce secondary amputations.

Keywords: *Vascular Injury; Extremity; Temporary Intravascular Shunt; Amputation; War in Ukraine; Vascular Trauma*

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INTRODUCTION

During the ongoing Russian invasion of Ukraine a marked rise in gunshot wounds and blast injuries affecting named vessels of the upper and lower extremities has been observed. These injuries are frequently complex and combined with bone, nerve, and extensive soft-tissue damage. Rapid evacuation to specialized care

with effective prehospital hemorrhage control are critical determinants of successful reconstruction and limb salvage [1].

Extremity vascular injuries complicate hemorrhage control and reconstruction, increasing the risk of limb loss, infection, and long-term disability. Advances in prehospital hemorrhage control (tourniquets and hemostatic dressings), damage-control surgery, temporary intravascular shunts, rapid evacuation and staged reconstruction have improved survival in recent conflicts, but limb-salvage rates remain variable and are strongly influenced by mechanism of injury and extent of soft-tissue destruction [2–4].

This study aims to describe the results of treatment in a modern cohort treated for combat injuries.

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METHODS

This retrospective observational study analyzed 900 consecutive cases of major vascular injury sustained during the ongoing Russian invasion of Ukraine and

treated in Ukrainian military and civilian referral hospitals. We focus on combat-related injuries of the major vessels of the extremities requiring surgical assessment and/or intervention.

Study Design and Setting

The study was conducted as a multicenter retrospective review of medical records from patients evacuated from battlefield and frontline medical facilities to higher-level surgical centers. These included Level II facilities, mobile surgical hospitals, regional vascular units, and tertiary trauma centers involved in the treatment of war casualties.

Study Population

Included were patients with major arterial and/or venous injuries of the upper or lower extremities caused by combat trauma, including gunshot wounds, shrapnel injuries, blast trauma, and mine-explosive mechanisms. Only patients with documented injury to a named major vessel and sufficient clinical or operative data were included in the analysis.

Inclusion criteria

Inclusion criteria included: combat-related vascular injury sustained during the war in Ukraine; injury to a major artery and/or vein of the extremities; admission to a surgical facility where definitive or staged vascular management was performed; availability of operative records, imaging findings, or discharge documentation.

Exclusion criteria

Exclusion criteria included: isolated minor vessel injury not requiring vascular surgical evaluation; superficial soft-tissue wounds without confirmed vascular damage; non-combat vascular trauma; incomplete records preventing assessment of injury pattern, treatment, or outcome.

Data Collection

Data were extracted retrospectively from hospital charts, operative logs, discharge summaries, and follow-up records. The following variables were analyzed:

- Demographic characteristics (age);
- Mechanism and anatomical location of injury;
- Type of vascular injury (arterial, venous, combined arterial-venous);
- Associated injuries to bone, nerves, and soft tissues;
- Presence of multiple or combined trauma involving other anatomical regions;
- Type and number of surgical procedures performed;
- Limb salvage, amputation, and mortality outcomes;
- Late postoperative complications documented during follow-up.

Injury Classification

Vascular injuries were categorized according to:

- Anatomical segment involved, with particular attention to the femoral–popliteal and tibial/peroneal regions.
- Vessel type, classified as isolated arterial, isolated venous, or combined arterial and venous injury.
- Injury complexity, defined by the presence or absence of associated fractures, nerve damage and extensive soft-tissue destruction.
- Extent of trauma, including isolated extremity injury versus multiregional trauma. Massive soft-tissue destruction was recorded when operative and clinical documentation described extensive devitalization, contamination, tissue loss, crush injury, or blast-related destruction affecting treatment strategy or prognosis.

Diagnostic Assessment

Initial diagnosis was based on clinical examination, including signs of hemorrhage, distal ischemia, pulse deficit, expanding hematoma, bruit, thrill, or shock. Depending on hemodynamic stability, available resources, and level of care, additional diagnostic methods included: Doppler ultrasonography, angiography, or computed tomography (CT), and intraoperative vascular assessment. In unstable patients with active hemorrhage or overt limb ischemia, immediate surgical exploration was prioritized over additional imaging.

Treatment Strategy

Prehospital and early hospital measures included temporary hemorrhage control by tourniquet application, compression or hemostatic dressings, vessel ligation when necessary and temporary intravascular shunting in selected cases. Definitive surgical treatment was individualized according to the injury pattern, ischemia time, contamination, associated trauma, and patient condition. Surgical procedures included arterial repair by lateral suture or end-to-end anastomosis, interposition grafting or bypass reconstruction, venous repair or ligation, thrombectomy when indicated, fasciotomy and repeated debridement or staged wound management. Amputation or re-amputation was done in cases of irreversible ischemia, uncontrolled infection, or non-salvageable limb destruction.

In complex extremity trauma, treatment was performed in cooperation with trauma, orthopedic, plastic, and intensive care specialists. Limb salvage decisions

were based on overall viability of the extremity, degree of soft-tissue and skeletal destruction, duration of ischemia, and the patient's physiological status. In selected severe injuries, the Mangled Extremity Severity Score (MESS) was used as an adjunct to support decision-making regarding reconstruction versus amputation.

Outcome Measures

The primary outcomes were mortality, limb salvage, and amputation rate.

Secondary Outcomes

Secondary outcomes included: frequency and type of late complications, including chronic arterial insufficiency, thrombosis, false aneurysm, arteriovenous fistula, chronic venous insufficiency, anastomotic infection, and erosive bleeding. Other outcomes were distribution of vascular injuries by anatomical site and associated trauma pattern and overall operative workload and structure of procedures performed.

Follow-up

Patients were followed during inpatient treatment and, where available, in the outpatient or rehabilitation period. Long-term outcomes were assessed using documented clinical examinations, vascular status and recorded postoperative complications. Because of wartime conditions, duration and completeness of follow-up varied between patients and centers.

Statistical Analysis

The analysis was primarily descriptive. Continuous variables are presented as means $\pm$ standard deviation or medians (interquartile range (IQR)) as appropriate; categorical variables are presented as absolute numbers and percentages. For comparisons data we used Chi-square or Fisher's exact test for categorical variables and Student's *t* test or Mann-Whitney *U* test for continuous variables. Variables with $p < 0.1$ in univariable analysis were entered into multivariable logistic regression to identify independent predictors; statistical significance was set at $p < 0.05$. All statistical processing was performed using IBM SPSS, version 26.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Cohort Characteristics

Nine hundred patients with major extremity vascular injuries were identified and included. Age distribution was 21–30 years 336/900 (37.3%); 31–40 years

265/900 (29.4%); 41–50 years 264/900 (29.3%); >50 years 35/900 (3.9%). There was a male predominance of 872/900 (96.9%) males and 28/900 (3.1%) females. Mechanisms of injury were gunshot wounds in 482/900 patients (53.6%), blast/explosive in 312/900 (34.7%), and shrapnel/fragments in 106/900 (11.8%).

Anatomic Distribution and Associated Injuries

Femoral–popliteal segment was injured in 689/900 (76.6%) of the patients, tibial/peroneal in 194/900 (21.6%), and combined femoral–tibial in 17/900 (1.9%). Vessel-type distribution was arterial-only in 316/900 (35.1%), venous-only in 95/900 (10.5%), and combined arterial–venous in 490/900 (54.4%). Bilateral limb injuries occurred in 205/900 (22.8%). Bone fractures were present in 300/900 (33.3%), nerve injuries in 190/900 (21.1%), combined vessel–bone–nerve trauma in 221/900 (24.6%), and massive soft-tissue destruction was seen in 776/900 (86.2%) of the patients. Multiregional trauma (involvement of other body regions) was documented in 490/900 (54.4%), including head/neck 16/900 (1.8%), chest 31/900 (3.4%), and abdomen 31/900 (3.4%).

Operative Workload and Techniques

A total of 9,234 surgical procedures were performed in this time period. Major vascular reconstructions were undertaken in 135/900 patients (15.0%). Wound-related procedures (debridements, negative pressure dressing–vacuum-assisted closure) constituted the majority of procedures. Autologous vein interposition (great saphenous vein) was used in 72/135 reconstructions (53.3% of the reconstructions), primary end-to-end anastomosis in 32/135 (23.7% of the reconstructions), and synthetic grafts (polytetrafluoroethylene (PTFE)) in 31/135 (23.0% of the reconstructions). Temporary intravascular shunts were used in 48/900 patients (5.3%) as damage-control adjuncts. Fasciotomy was performed in 322/900 patients (35.8%).

Amputations and Outcomes

Primary amputations were performed in 75/900 patients (8.3%); secondary (delayed) amputations after attempted salvage occurred in 140/900 (15.6%), resulting in an overall amputation rate of 215/900 (23.9%). Indications for primary amputation included massive soft-tissue and skeletal destruction, irreversible ischemia, or uncontrolled infection/sepsis on arrival. Limb preservation was achieved in 671/900 patients (74.6%). Overall in-hospital mortality was 15/900 (1.7%); causes included uncontrollable hemorrhage ($n = 6$), severe multisystem trauma with refractory shock ($n = 6$), and sepsis with multi-organ failure ($n = 3$).

Long-Term Complications

During available follow-up, 388/900 (43.1%) had no documented late complications. The most frequent late adverse outcomes were chronic arterial insufficiency in 159/900 (17.7%) and verified thrombosis with arterial insufficiency in 123/900 (13.7%). Less common late complications included false aneurysm in 28/900 (3.1%), arteriovenous fistula in 22/900 (2.4%), chronic venous insufficiency in 30/900 (3.3%), and anastomotic site infection or erosive bleeding in 35/900 (3.9%).

Comparison of Gunshot Versus Blast Injuries

Blast injuries were more frequently associated with massive soft-tissue destruction (blast 290/312 [92.9%] vs. gunshot 360/482 [74.7%], $p < 0.001$) and had a higher rate of secondary amputations (blast 128/312 [41.0%] vs. gunshot 66/482 [13.7%], $p < 0.001$) and a lower proportion of successful reconstructions (reconstructions in gunshot 92/482 [19.1%] vs. blast 28/312 [9.0%], $p < 0.001$).

Predictors of Amputation

In univariable analyses, massive soft-tissue loss, ischemia time >6 h, high MESS, presence of open fracture, and blast mechanism were associated with amputation ($p < 0.05$). In multivariable logistic regression, massive soft-tissue destruction, ischemia time >6 h, and blast mechanism were identified as independent predictors of amputation.

DISCUSSION AND LESSONS LEARNED

The management of vascular trauma in armed conflict remains one of the greatest challenges in battlefield medicine. During the ongoing Russian invasion of Ukraine a marked rise in gunshot wounds and blast injuries affecting named vessels of the upper and lower extremities has been observed. These injuries are frequently complex and combined with bone, nerve, and extensive soft-tissue damage. Despite advances in diagnostic imaging (angiography, ultrasound), diagnostic uncertainty persists in the chaotic conditions of war; early recognition and timely intervention are essential, as delays in diagnosis or revascularization can result in irreversible ischemia, infection, limb loss, or death [5].

Time to reperfusion remains the single most important determinant of outcome for patients with major vascular injury. Efficient triage, rapid evacuation, and streamlined treatment algorithms are therefore critical. Management requires multidisciplinary collaboration among trauma, vascular, orthopedic, plastic, and intensive care teams. Damage-control surgery at Level II facilities, mobile surgical hospitals, and regional centers plays a vital role in stabilizing patients and controlling

hemorrhage prior to transfer for definitive repair. When ischemia is irreversible, primary ligation and amputation are sometimes unavoidable; the MESS may be a useful adjunct in decision-making [6].

Our cohort demonstrates low in-hospital mortality (1.7%) even when injuries are complex. However, the overall amputation rate remained substantial (23.9%), largely driven by the high prevalence of massive soft-tissue destruction and a significant proportion of blast injuries. Notably, secondary (delayed) amputations after attempted salvage constituted a large proportion of limb losses, underlining the difficulty of staged limb salvage in heavily contaminated or structurally devastated wounds.

Temporary intravascular shunts were used selectively as damage-control adjuncts to restore distal perfusion during transport or staged reconstruction; fasciotomy was frequently performed to prevent or treat compartment syndrome after reperfusion, consistent with prolonged ischemia and high compartment risk in this population. Autologous vein grafting was preferred in contaminated wounds; synthetic grafts were reserved for situations without available conduits or when rapid reconstruction was required.

Comparison with prior conflicts highlights evolving patterns: historical series are limited by differences in weaponry and systems of care, while contemporary campaigns (Iraq, Afghanistan) documented improvements in survival with routine tourniquet use, shunt application, and rapid evacuation. This report's mortality numbers compare favorably with modern series, but the amputation rate is higher than other reports—likely reflecting the high proportion of blast injuries and massive soft-tissue loss in this cohort. Blast wounds in this report were associated with significantly more extensive soft-tissue destruction, higher secondary amputation rates, and lower reconstruction success rate compared with gunshot wounds. Recommendations arising from our findings include: protocolization of damage control versus definitive strategies with clear indications for temporary shunts and fasciotomy; preferential use of autologous conduits in contaminated extremity reconstructions; early aggressive soft-tissue management and infection control to reduce secondary amputations; and establishment of prospective, harmonized registries with routine severity scoring to improve comparative effectiveness research [6–8].

LIMITATIONS

Limitations of this study include its retrospective multicenter design, variability in record completeness (including ischemia time and some severity scores) and heterogeneity of follow-up because of wartime conditions. Despite these limitations, the large sample and real-world multicenter data provide valuable insights into operational vascular trauma care.

CONCLUSIONS

In conclusion, the Ukrainian experience confirms that timely evacuation, early hemorrhage control, and coordinated multidisciplinary care keep mortality relatively low, but persistent high amputation rates are driven largely by blast-related soft-tissue destruction and delayed reperfusion.

Ethics Statement

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Protocol approval for this retrospective analysis of routinely collected clinical data was formally granted by the Local Ethics Committee of the National Military Medical Clinical Center. Patient confidentiality was strictly maintained and all personal data were fully anonymized prior to statistical processing and analysis. Owing to the retrospective nature of the study and the use of de-identified aggregate data, the requirement for individual informed consent was waived by the institutional review board.

Conflicts of Interest

The author declares that they have no conflicts of interest.

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Author Contributions

As the sole author, I was responsible for the study design and clinical implementation. The practical work was conducted during my service at a military hospital, involving direct surgical treatment of wounded patients. I performed the retrospective data analysis, reviewed the existing literature, and drafted the entire manuscript.

Data Availability

The data supporting the findings of this study are not publicly available due to privacy and ethical restrictions related to the nature of the clinical cases and the sensitive

status of the medical facility. Requests to access the anonymized data should be directed to the corresponding author and are subject to institutional approval.

Declaration of the Use of Generative AI and AI-assisted technologies in the writing process

No artificial intelligence (AI) was used in the writing process or generation of this manuscript.

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