Life Over Limb

Why Not Both? Revisiting Tourniquet Practices Based on Lessons Learned From the War in Ukraine

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ABSTRACT

The use of tourniquets for life-threatening limb hemorrhage is standard of care in military and civilian medicine. The United States (U.S.) Department of Defense (DoD) Committee on Tactical Combat Casualty Care (CoTCCC) guidelines, as part of the Joint Trauma System, support the application of tourniquets within a structured system reliant on highly trained medics and expeditious evacuation. Current practices by entities such as the DoD and North Atlantic Treaty Organization (NATO) are supported by evidence collected in counterinsurgency operations and other conflicts in which transport times to care rarely went beyond one hour, and casualty rates and tactical situations rarely exceeded capabilities. Tourniquets cause complications when misused or utilized for prolonged durations, and in near-peer or peer-peer conflicts, contested airspace and the impact of high-attrition warfare may increase time to definitive care and limit training resources. We present a series of cases from the war in Ukraine that suggest tourniquet practices are contributing to complications such as limb amputation, overall morbidity and mortality, and increased burden on the medical system. We discuss factors that contribute to this phenomenon and propose interventions for use in current and future similar contexts, with the ultimate goal of reducing morbidity and mortality.

KEYWORDS: *tourniquets; amputation; traumatic injury; war-related injuries*

Introduction

> *There was no time . . . there was no equipment. The challenge was almost impossible: to make civilians ready for the open war against an overwhelmingly well-trained and superiorly equipped enemy.*
>
> —Ukrainian physician in charge of tactical medical training for a brigade of rapidly mobilized armed forces in early 2022

Tourniquet use for limb trauma on the battlefield dates back to ancient Greece.[1–3] Until recently, tourniquets were considered a dangerous, last-resort intervention.[4,5] Brief periods of increased usage swung the pendulum to times of condemnation, as poor equipment, misuse, and prolonged times to definitive care resulted in increased morbidity and mortality.[4–6] As Richey noted in 2007, "opinions have alternated between strong endorsement and outright vilification of the device."[6] In the twenty-first century, however, the tourniquet debate is regarded by most as closed. The body of evidence from the past 30 years shows a clear mortality benefit when high-quality tourniquets are used for life-threatening limb hemorrhage within specific guidelines and a system that promotes training, data collection, and process improvement.[7,8]

Kragh et al. identified major factors facilitating successful implementation of tourniquet practices to be a "critical density of both tourniquets and trained users" and establishing an ability to evaluate data from experiences on the ground.[9,10] The modern movement was initiated by the U.S. Special Operations Command in the early 1990s, led by Dr. Frank Butler and the Naval Special Warfare Biomedical Research and Development Program.[9,11] Analysis of prior conflicts identified limb hemorrhage as a leading cause of preventable death on the battlefield.[11,12] In response, military physicians and Special Operations Forces (SOF) leaders created a system promoting

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evidence-based medicine while still accounting for tactical realities of combat. It is said that "good medicine equals bad tactics"; however, bad tactics can result in greater morbidity and mortality, leading to mission failure. As understood by these leaders, a system to revolutionize battlefield medicine must balance mission, tactical realities, and evidence-based medicine.

Tactical Combat Casualty Care (TCCC) guidelines recommending increased tourniquet use in tactical situations were developed and adopted by many SOF units.[13] In 1999, the 75th Ranger Regiment instituted a mandatory training policy for all Servicemembers.[1,9] A major conflict with casualties provided an opportunity to fully assess the performance of TCCC: Afghanistan and Iraq, also referred to as the Global War on Terrorism (GWOT).[14] SOF units utilizing TCCC and the DoD relying on traditional paradigms served as a study and control group. Comparative data from 2001 to 2010 showed SOF units decreased preventable mortality (0%–3%) as compared with conventional forces (9%–24%).[1,2,15–17] To further target ongoing identified gaps, military leaders formed the CoTCCC to implement near real-time updates to guidelines based on evidence collected through a Joint Trauma Registry (JTR).[1,2] In 2005, all Servicemembers were required to carry tourniquets, and within one year their use was ubiquitous on the battlefield, supported by evidence that prehospital application was superior to in-hospital application.[7,18] Survival rates reflected a 67% decrease in mortality from limb hemorrhage without a significant increase in morbidity. By 2012, it was estimated that tourniquets alone saved approximately 2,000 lives in the GWOT.[5,6,9,19]

TCCC concepts led to the highest survival rates in modern combat.[1,3,15] A paradigm to maximize the ability of tourniquets to decrease mortality without increasing morbidity had finally been realized. These concepts were embraced and adapted internationally by allied nation militaries. In the first decade of the twenty-first century, NATO made tourniquets a standard item for all personnel and standardized training for both conventional and SOF personnel. With civilian entities such as Stop the Bleed, Tactical Emergency Casualty Care (TECC), and Prehospital Trauma Life Support (PHTLS) adapting TCCC guidelines for the prehospital setting, a global generation of soldiers and medical personnel advocating for tourniquet usage and training without hesitation was created.[5,20]

The life-saving potential of tourniquets is undisputed, but the inherent risks of increasing morbidity and mortality still exist. The potential sequelae range from minor reversible complications such as paresthesias to rhabdomyolysis, amputation, and death.[6] Unknown to date is what occurs if similar guidelines are implemented in a less-standardized system and/or in a conflict with different tactical realities. The large-scale invasion of Ukraine since February 2022 provides an unfortunate, yet valuable, opportunity to explore the performance of these concepts in a near-peer conflict. An overwhelming amount of evidence has emerged indicating that despite their life-saving potential, tourniquet practices have also resulted in significant morbidity, mortality, and drain on downstream medical system resources. TCCC concepts have been taught by many training entities ranging from partner nations to non-governmental organizations (NGOs). Laypeople, volunteer forces, armed forces, and civilian medical personnel have all been the recipients of training. The authors of this paper have been a part of these efforts in varying roles.

We will not summarize widely available guidelines. It is not the authors' intent to criticize the practices of Ukrainian military and civilian personnel, who have demonstrated an exceptional ability to adapt to an evolving landscape and have extensive expertise in caring for casualties. Our aim is to explore the effects of the implementation of these TCCC concepts in the Ukrainian war through case reports that collectively highlight major identified gaps contributing to higher complication rates. These gaps include prolonged evacuation times, major systemic differences, and variation in medic training.

We intend to provoke a robust discussion on the risks of directly implementing guidelines outside of the systems in which they were validated. We advocate for an objective discussion to modify current status, both to better serve those affected by this war and to effectively prepare partner nations in future near-peer conflicts. This will be best achieved by revisiting the teaching approach of core TCCC concepts and considering how tourniquet conversion is approached in guidelines. Recent steps taken to address these issues and promote solutions will be summarized.[21]

Cases

The Temple University Institutional Review Board deemed this not to be human subject research. Clinicians provided observations from observed patients after the fact, and all cases were de-identified.

These cases were chosen from several reports of sources caring for patients at or near the point of injury (POI) and are de-identified to protect the personal and operational security of those involved. Details may have been intentionally removed or obscured. Of note, documentation of tourniquet times is, according to many reports, inconsistent and often not carried forward in medical records. All cases occurred between March 2022 and July 2023.

Case 1 (direct patient encounter): An adult male presented with fragmentation injuries to the right lower leg resulting from a drone strike. A non-medic Servicemember placed a tourniquet directly above his knee within minutes at the POI. The casualty stated that after approximately 4 hours, personnel he identified as a medic reached the scene, checked the tourniquet, and placed a second tourniquet proximally near the inguinal region. Approximately 6–8 hours after injury, he stated, he was evacuated and transported to a trauma stabilization point (TSP), where both tourniquets were removed and damage control surgery (an external fixator to the right lower extremity) was performed. At the time of transfer to a surgical hospital in a nearby city, approximately 14–18 hours from the injury, he had palpable limb pulses but was persistently oozing venous blood from his wounds. The lower extremity was grossly edematous and discolored below the knee, consistent with compartment syndrome. Follow-up records were not available.

Case 2 (report from medical personnel at CCP): Following a large artillery strike, seven casualties arrived at a casualty collection point (CCP) that was staffed by non-governmental organization (NGO) medical personnel, including a former military medic. All seven casualties had had limb tourniquets placed prior to arrival. On further assessment by the medic, six casualties, all awake and alert, were found to have only superficial limb wounds and no clear medical indication for

a tourniquet. Dressings were applied to all six limbs and the tourniquets were converted with effective hemostasis. The seventh casualty was pale and unresponsive. A tourniquet had been placed on his left lower extremity high and tight, with blood pooling on the pants and gurney. On exposure, no extremity wound was found but penetrating trauma to the lower thorax was revealed. The casualty was pronounced dead at the CCP. No reassessment of initial care rendered at the POI was reported to have occurred during the prolonged period from injury to evacuation; the first assessment of tourniquet placements occurred at the CCP.

Case 3 (report from transferring team and follow-up from surgical team): An adult male presented to a TSP with several injuries including fragmentation wounds of the face, right arm, and left thigh. At or near the POI, a tourniquet was placed above the wound on the left lower extremity and remained in place for more than 10 hours until evacuation. He was treated and transferred to a higher level of care in a nearby major city. At the time of transfer, he was intubated and placed on a ventilator. On arrival at the surgical hospital, he underwent a decompression fasciotomy of the left thigh and lower leg. It is unclear if a vascular injury was present. The following day, he underwent an amputation of the left lower extremity at the level of the thigh. He had an acute kidney injury that required hemodialysis. The available medical record documentation did not include who placed the tourniquet, if conversion was attempted, or a timeline of following interventions/patient status.

Case 4 (direct patient encounter): An adult male with no known medical history arrived at the first hospital in the evacuation chain with a fragmentation injury to the left leg. The casualty arrived on a litter at the same time as several other casualties and was placed in a waiting area. On first assessment, a tourniquet was noted to have been applied over clothing to the left leg and blood was persistently pooling under the wound. Medical personnel at the hospital first tightened the tourniquet without resolution of the bleeding. The extremity was then exposed by a volunteer NGO medic who noted persistent hemorrhage, suggesting an ineffective venous tourniquet. Direct pressure was applied to the wound and the tourniquet was loosened, with effective hemostasis noted with pressure dressing alone. Tourniquet placement time was unknown.

Case 5 (direct patient encounter): An adult male with multiple injuries following indirect fire was brought to a forward surgical team via combat medics. Prior to arrival, the patient had tourniquets applied to both lower extremities, vented chest seals applied to fragmentation wounds of the chest, and pressure dressings on other wounds. After resuscitation, the patient underwent damage control surgery to address the limb injuries. In the operating room, a tourniquet was loosened to help identify a vascular injury. A wound distal to that tourniquet began to hemorrhage, and the surgeon attempted to re-apply the tourniquet, which broke, resulting in significant blood loss until a new tourniquet was procured. The patient became hypotensive and, while waiting on blood products, died.

Case 6 (direct patient encounter, review of available records): An adult male arrived at a major surgical hospital after undergoing a high right arm and high left leg amputation as damage control surgery. Per the records and the patient, he sustained injuries to his right arm and left leg from a missile strike. At the POI, another soldier helped him apply tourniquets high and tight on both limbs. He remained at the site of the blast for 3 hours before evacuation, and his tourniquets were on for 16 hours total. Per the available records that were transferred with the patient, no vascular injuries were found to either limb, but he had rhabdomyolysis and compartment syndrome requiring amputation of both limbs.

Case 7 (report from combat medic): An adult male arrived at a TSP within an hour of injury with a fragmentation injury to his left upper arm. A tourniquet had been applied in the field high and tight on the limb, and, on reassessment by a combat medic at the TSP, ongoing bleeding from a grapefruit-sized wound was noted. The medic tightened the tourniquet windlass one turn with cessation of bleeding. The casualty was then transferred immediately to the next echelon of care for surgical management. The total time from tourniquet placement to surgical evaluation was less than 2 hours.

Discussion

The network of NGOs, partner nations, and Ukrainian stakeholders involved in the delivery of prehospital medicine and training are currently engaged in multidirectional conversations on how to refine best practices.[21] We aim to contribute to this effort through observations of tourniquet practices and identification of priorities for action. Although biased toward representation of morbidity, these cases demonstrate an observational pattern from multiple parties.

In addition to the lives saved from vascular injury to limbs, medical personnel across Ukraine report high rates of conditions associated with tourniquet complications in casualties suffering limb trauma throughout the casualty care chain. Such complications include renal failure, hemodialysis, compartment syndrome, fasciotomies, amputations, and limb salvage complications such as osteomyelitis. Sequelae from these complications greatly impact the recovery courses of surviving casualties. Additionally, the long-term burden on the healthcare system of not only Ukraine but of supporting European allies may be significant.

Although these patterns of suboptimal tourniquet use are largely due to specific ground truths, potentially confounding variables should be acknowledged. These patterns may be (and likely are, in part) due also to the complexity of injuries, armaments, targeting patterns, and volume of polytrauma. It is difficult to extrapolate from limited data what morbidity is due to injury versus tourniquet, a complex task even in a mature system that gathers meticulous data.[13] Patients with significant limb trauma are more likely to have tourniquets placed, so the presence of both injury and tourniquet can confound outcomes.[13,17] During the GWOT, an increased rate of fasciotomies after implementation of tourniquet practices was noted; it is unclear if this was related to the increased number of lives and limbs saved, increased awareness and training, or tourniquet complications.[14] Variations in medical management and protocols downstream in the casualty care chain in the hours and weeks after injury may also affect outcomes. An additional confounding issue may be the already widely reported use of non-recommended, fraudulent, or fake tourniquets (Figure 1).[21,22] TCCC guidelines depend upon the use of recommended tourniquets. Cheap counterfeit tourniquets, which are readily available on the internet, may contribute to current morbidity and mortality.[23–25]

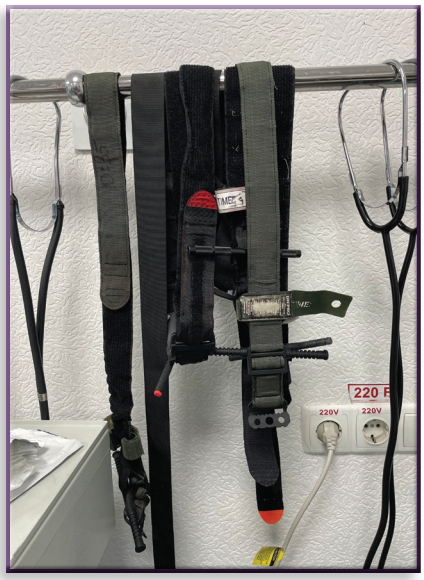

FIGURE 1
A resuscitation area in Ukraine, where tourniquets are routinely washed and re-used for multiple patients.

Tourniquet indications can be tactical or medical; tactical indications are notoriously difficult to analyze in retrospect. Lessons learned from the U.S. SOF community emphasize that promoting other means to control hemorrhage while under immediate danger places both the casualty and responder at increased risk.[26] Although TCCC guidelines contemplate tourniquet application under fire as an appropriate stopgap to manage "life-threatening hemorrhage," this condition can be difficult to diagnose under duress of immediate threat. Studies have found that the majority of tourniquets placed at or near the POI are not medically indicated.[27,28]

A four-year review by Israeli Defense Forces (IDF), also a proponent of liberal tourniquet practices, concluded that 54% of tourniquets had "situational and non-medical" indications.[27] In a U.S. study of GWOT casualties, 74% of limbs with tourniquets applied in the field did not have a major vascular injury, and 83% of tourniquets were venous, meaning the placement was tight enough to occlude venous but not arterial flow.[28] While these tourniquets may have initially been applied correctly, tourniquets will loosen over time due to muscle relaxation, fluid shift, and blood loss.[29] Without proper re-evaluation and tightening, tourniquets can become venous, which increases the risk of ongoing arterial bleeding. Misuses such as these are common, even when applied by highly trained operators.[7,14,26,27]

By the end of the GWOT, the tourniquet pendulum had swung to the point where they were routinely applied to minor wounds during Care Under Fire (CUF), usually "high and tight."[14,30] This trend has continued in the war in Ukraine, with tourniquets being liberally applied at the POI for any signs of limb trauma. They are then often left on without clear reassessment until arrival at the first receiving facility. The NGO medic from Case 2 observed that in 18 months working in CCP settings, including personal assessments of approximately 25 casualties, they did not see any cases in which conversion had been attempted during prolonged evacuation wait times. Multiple other sources in similar positions reported the same observation—conversion is often first attempted at the receiving surgical facility. The lack of tourniquet conversion occurring in the field is complicated and multifactorial and will be addressed further in the discussion.

It is clear that there are many systemic differences at play in the war in Ukraine compared with the GWOT, both in the tactical environment as well as the model of training and protocolization. It is not known whether there were medical indications in these cases. However, we can hypothetically apply GWOT, Israeli, and other data, and extrapolate from these reports that rates of prolonged application are high.[32,33] It would seem very probable that the number-needed-to-treat per tourniquet application for mortality benefit in the war in Ukraine war is less favorable than that of the GWOT.

More data are necessary to understand the impact of the heavily condensed training, based on TCCC/TECC concepts, deployed in rapid fashion to Ukrainian Servicemembers and medical personnel. However, we have identified three major factors impacting tourniquet practices: prolonged evacuation times, rigid protocolization of concepts, and systemic differences in the definition, training, and availability of field medics. Understanding how these factors interact with existing TCCC/TECC paradigms is crucial to guide interventions.

Evacuation Times

In the war in Ukraine, evacuation time is likely the most significant factor impacting tourniquet complications. In the absence of air superiority or mobile aid stations, evacuation times are reported to be significantly longer than those in the GWOT, when there was reliance on chains of evacuation composed of multiple echelons of care and air transport, which typically delivered patients to definitive care within 1 hour.[2,14,30,31,34] In near-peer conflicts, evacuation resources are likely to be limited by contested airspace, resulting in more prolonged, complex, high-risk ground evacuation platforms. Unpublished reports and sources on the ground report that current casualty evacuation times to the first facility in Ukraine often exceed the 4-hour mark and frequently go beyond 12 hours.

The body of evidence documenting the safety of tourniquets reports exceedingly low rates of usage over 150 minutes, and cases that exceed this duration are outliers with high rates of morbidity. [7,8,10,14,27,31] The mean time of tourniquet duration in the IDF study was 78 minutes, and all but one of the small number of complications observed were in cases with times over 150 minutes.[27] Since 2001, there has been only one known case of inappropriate limb loss by a U.S. Servicemember due to prolonged tourniquet use. During a 2014 combat mission in Africa, a tourniquet placed high and tight on a limb was not found by medical personnel until 8 hours after application. There was ultimately no vascular injury, and medical personnel believed that the amputation would have been avoided with earlier tourniquet conversion.[14]

Shackelford et al. anticipated the issue of prolonged evacuation impacting TCCC paradigms in future conflicts in their 2014 proposal of guideline changes.[14] A need for clarification and increased training on tourniquet conversion was emphasized, noting that as a result of the short evacuation times in GWOT, attempts to convert tourniquet to hemostatic dressings had been "de-emphasized in practice by users," despite the recommendation in guidelines that tourniquets placed in CUF should be re-evaluated in the Tactical Field Care (TFC) phase of care.[14] This trend in GWOT is understandable given that casualties arrived in a facility within minutes, and the data analysis by the JTR revealed no complications from this practice.

Tourniquet time principles can be summarized as follows: less than 2 hours is safe, the rate of complications increases after 2 hours, and more than 6 hours has high rates of irreversible complications (although recent evidence suggests that the risk of major limb-threatening complications may increase as soon as 4 hours after tourniquet application).[14] In recent years, the doctrine has been that tourniquets left on more than 6 hours had such high rates of arrhythmias and rhabdomyolysis that amputation was almost mandatory.[31]

If tourniquet timelines exceeding 4 hours are the norm rather than exception, there is no precedent in recent warfare, and the data available strongly indicate that preventable morbidity and mortality due to tourniquet complications will be high.[32] The reality of prolonged evacuation times as an unchangeable ground truth must be accepted as the norm for this war and anticipated for other near-peer conflicts.

Rigid Protocolization of Concepts

The Ukrainian medical system heavily utilizes standardized national protocols. This trend has been reflected in the approach to battlefield medicine with TCCC concepts regarded as best-practice standards and adapted into rigid protocols in the current Ukrainian system. This can be seen through the topic of tourniquet conversion.

The current U.S. DoD TCCC guidelines structure protocols to four tiers of capability: all-Servicemember (ASM), combat lifesaver, combat medic/corpsman, and paramedic/SOF medic/provider.[35] Every tier is provided with didactic and practical instruction on tourniquet application, but most methods of tourniquet conversion have been historically taught to combat medics and higher. Tourniquet conversion is a broad term referring to the act of assessing and removing a tourniquet and can include removal, tourniquet-to-tourniquet conversion, and tourniquet-to-dressing conversion. In his after action report of a 2022 Tourniquet Coverstion Webinar hosted by the Special Operations Medical Association, Dr. John Kragh summarized that a major point covered in the webinar was that conversion "is an obscure task versus tourniquet application; tourniquet conversion is often unclear, unfocused, skipped, or forgotten."[33]

Historically, there has been no clear consensus even among experts regarding exactly who should and can convert a tourniquet per TCCC doctrine, nor how to apply best evidence to peer-nation protocols. Although removal, the most basic form of conversion, may be taught with application—and Dr. Kragh noted anyone can try to convert—most guidelines based on TCCC at the onset of the war specified conversion as a medic or more advanced level skill.[34,35] Regardless of the core principles of TCCC, in practice by the end of GWOT, tourniquet conversion was rarely performed in the field. Experts noted that lack of clear consensus and training guidelines would become an issue in a conflict without air superiority, as demonstrated in Ukraine.[14,21]

Ukrainian law through mid-2023, per the Ministry of Health, protocolized available guidelines into law by stating that tourniquet conversion should be "performed exclusively by medical workers or specialists who have received appropriate training."[36] There is currently a robust dialogue occurring within Ukraine on the topic; a recent memorandum by the Ministry of Armed Forces re-addressed conversion by stating that "as soon as the situation allows, a re-evaluation of the need to use the tourniquet and a decision on its conversion should be made." The memorandum specified that conversion should be performed within two hours by "medical workers or military personnel with appropriate training (senior combat medics, combat medics, and other military personnel who have received training in tactical medicine or follow the instructions of a medical worker)."[37] Feedback from sources on the ground in direct training operations with Servicemembers noted that this topic was frequently discussed and concern over what skills they were allowed to perform on the battlefield was prevalent.

Lessons learned to date in the war in Ukraine have already galvanized experts in the field with calls to action to revisit tourniquet conversion through proposed changes to guidelines and increased training requirements on tourniquet need, conversion, and replacement.[21] To address the lack of consensus on how to best train conversion, the CoTCCC recently voted to add tourniquet conversion as a Tier 2 skill, encouraging flexibility in training the full breadth of TCCC concepts to a relevant audience. Rigid protocolization by partner nations that limit adaptability of concepts to different ground realities should be discouraged.

Standardization of Training and Availability of Medics

When deploying protocols outside the systems that produced and refined them, differences in the definition and training qualifications of "medic" become a complicating factor. As noted above, tourniquet conversion was recently added to Tier 2 in the U.S. DoD. However, the paradigm in the Ukrainian war has been that conversion is a skill only performed by medical personnel, and a systemic gap highlighted by this is different definitions and training of medics.

If the casualty cannot be rapidly evacuated, Ukrainian protocols (at the time of the onset of the war) dictated that only Servicemembers trained at the combat medic level or higher should attempt tourniquet conversion/replacement in the field once out of CUF, ideally within 2 hours but not after 6.[1,2] However, this paradigm is only successful in a tactical environment with a robust availability of trained field medics near the POI. Whether due to tactical considerations, a lack of critical density of personnel with this training, or other factors, if sufficient personnel trained to reassess tourniquets in the setting of prolonged evacuation times do not exist near the POI, casualties will suffer complications.[3–7]

The experience of a Ukrainian physician tasked with training a brigade of rapidly mobilized armed forces on tourniquet practices per national protocols at the beginning of the large-scale invasion reflects this reality. Per their anonymous report, training was approached as follows: "The main rule was to put the tourniquet as high and tight as possible whenever there was massive bleeding. We used to say, 'your job is to use the tourniquet; do not take it off, but call the medic who will know what to do.'" (anonymous personal communication, Ukrainian physician, Ukraine, 2023).

The standardization of qualifications to become a medic in Ukraine is an understandable challenge given the rapid mobilization since the large-scale invasion. The system is complex, with several ministries, agencies, and branches in the armed forces and civilian system that regulate training. Down to the

unit, there can be different curricula and definitions of "medic." "Combat medics" may refer to individuals with a medical background and higher levels of training, but "company medics" have less training and do not currently convert tourniquets per protocol. Current in-country programs to qualify "combat medics" last, on average, 2 weeks. Regular Servicemembers who have no specific medical duties typically receive 1 or two 2 of training that cover the basics of tactical medicine with a heavy focus on the use of tourniquets as the main means of controlling external bleeding. Sources report that training was often condensed ahead of rapid deployment times for some units, and tactical training took precedence among inexperienced service personnel. Some units received as little as 2 hours of tactical medical training prior to deployment (anonymous personal communication, Ukrainian physician, Ukraine, 2023). A small number of advanced medics received SOF-level training and now operate in specialized units. Additionally, NGOs provide training, largely based on existing guidelines and within the scope of national protocols (Figure 2).

FIGURE 2 *NGO-led training on TCCC, instruction on tourniquet use.*

In comparison, the regimented training protocols in the U.S. DoD are the result of decades of refinement. All service personnel receive, at minimum, a 1-day ASM-level training prior to combat deployment. Enlisted medical personnel undergo at least 16 weeks of training, and advanced SOF medic operator courses require at least 26–54 weeks of training "at least" negates the need for "minimum" (and suffer attrition over 70%). Both conventional and SOF medics are required to attend refresher courses.

When considering the low mortality rates by the end of the GWOT, it is important to understand the context of the extensive training and selection processes. It took no less than 10 years and a large-scale conflict to push through a system-wide focus on process improvement and a centralized curriculum promoting best practices, incurring heavy debate and doubt during the process.[17,33,38] While not feasible to expect partner nations engaged in conflict to have the resources or infrastructure to develop a similar system on an accelerated timeline and under duress, efforts should continue to implement and expand standardized training throughout all levels of medical care. Still, systemic differences have been anticipated and noted.

In the reality of the war in Ukraine, and likely future large-scale combat operations, we recommend that entities and nations using tourniquets in the prehospital system reconsider how tourniquet reassessment and conversion is protocolized and taught. Any changes to the guidelines must not be overtly complex and should be applicable to the systems in which they function.

Priorities: Revisit TCCC Core Tenets in Training and Appropriately Adapt Guidelines

In Ukraine, the authors have observed (and participated in) the enthusiastic teaching of the benefits of tourniquets and skill-based training to practice application in high-risk environments. Civilians and military personnel have fully embraced the life-saving benefit of tourniquets. The next phase of support must emphasize familiarity with assessment of life-threatening hemorrhage, reassessment of tourniquets, and appropriate conversion of tourniquets in a tactical environment.

As conversion did not occur frequently in the field during the GWOT, the majority of limb injuries arrived at a facility with tourniquets in place.[18] As a result, the number of GWOT-era personnel with direct experience in field tourniquet conversion is likely small. This potentially translates into a training curriculum and personnel gaps. Relying on the presence of field medics with sufficient training near the POI may result in increased morbidity and mortality in near-peer conflicts, including the current war in Ukraine. Ukrainian physicians directly report that their battlefields are more similar to World War I with trenches, heavy artillery shelling and land mines, complicated evacuation patterns, insufficient resources, and lack of access to trained medics within the first hour of injury (anonymous personal communication, Ukrainian physician, Ukraine, 2023).

As noted by Walters et al. in 2005, "the most effective method of limb salvage is early successful conversion of a tourniquet to a less damaging means of hemorrhage control."[26] This strategy relies on the following competencies and skills: appropriate tactical training to recognize CUF versus TFC, correctly recognizing life-threatening hemorrhage versus minor trauma and appropriately reassessing and converting tourniquets when appropriate. Results of one study from the early TCCC era suggest that among soldiers who completed ASM training, less than half could correctly recognize and treat life-threatening hemorrhage.[26]

Based on our collective experiences of practicing and/or teaching these principles, we stress that the medical skills taught in TCCC take extensive practice to master or even reach a degree of comfort. "Life-threatening hemorrhage" is not a concept with which a layperson will typically have any degree of familiarity, and medical personnel who do not routinely take care of traumatic injuries may not have any level of comfort with hemorrhage. In the studies referenced above, it was highly trained U.S. and IDF Servicemembers applying tourniquets at high rates and without a medical indication. The simple act of unwinding the windlass on a tourniquet, hours away from a facility and away from medical personnel with equipment and training, can be an overwhelmingly intimidating act even in a tactically secure situation. Similarly, cursory training in hemorrhage control techniques such as wound packing may not translate to competency in the field.

The issue that should be immediately addressed is how to best emphasize the core tenets of evidence-based practices in TCCC

germane to all conflict realities. We propose the following immediate steps:

1. *A revisited commitment to training the full spectrum of TCCC concepts*. All entities conducting training in this war should stress the full breadth of best practices in all trainings, including CUF versus TFC, appropriate tourniquet application in CUF (emphasizing identification of life-threatening hemorrhage), continuous reassessment of tourniquets, appropriate attempts at conversion, and an understanding of alternate methods of hemorrhage control. Recognizing that de-emphasizing tourniquet application in combat can increase mortality, we do not advocate any changes to guidelines recommending the *application* of tourniquets. However, avoiding placement of non-indicated tourniquets may significantly decrease morbidity in prolonged evacuation times. Teaching of these principles should occur over an appropriate time frame and include theory, scenario-based learning, and hands-on practice, ideally utilizing high-fidelity simulation models when possible. Training, which should be conducted by subject matter experts, must stress basic skills including patient assessment and reassessment, basic hemorrhage control techniques, and appropriate timing of TCCC skills. Training and teaching materials should be standardized under relevant authorities to deter unauthorized materials and approaches taught by non-SMEs. The most important aspect to revisit is TCCC as a guide, not a protocol. Guidelines need to account for the realities of ground combat and the greater trauma system in place. The available literature regarding tactical medical care, to include TCCC, should be utilized in creating the best care guidelines for a given tactical reality.
2. *Revisiting the role of tourniquet practices in guidelines*. When adapting the evidence-based best practices that TCCC is founded upon, care must be taken to consider the system and ground truths in order to responsibly adapt the knowledge into appropriate guidelines. Rigid protocolization may reduce flexibility and limit the ability of operators to adapt to ground truths. As referenced by many subject matter experts cited in this paper, tourniquet assessment and conversion were not skills emphasized in the GWOT era. Consideration should be given to the fact that a critical threshold of combat medics near the POI may be difficult to achieve. The recent modification to TCCC to include conversion/replacement as a skill taught to combat lifesavers, if reflected in guideline adoption and approach to training in Ukraine, may relieve the burden previously placed on the presence of medics. By offering a platform for expeditious changes, appropriate adaptations made through entities such as CoTCCC may aid and inform internal progress. Any proposed changes must consider the body of evidence that tourniquets without medical indications will occur at high rates even with highly trained operators and be realistic about the likelihood of similar or higher rates depending on training standardizations.

Conclusion

Tourniquets are justly embraced as a life-saving intervention. As an international community, we have effectively moved past the era when tourniquets were referred to as "an instrument of the devil that sometimes saves a life."[38] Additionally, the importance, whether real or perceived, of having a life-saving piece of equipment kept on one's person that can be used by anyone, civilian or military, while living under constant threat in an active conflict should be acknowledged.

The founders of TCCC were well aware of tourniquet risks and accounted for them during the development of the guidelines. Their success is reflected in the all-time low potentially preventable mortality, without significant increase in long-term morbidity, during the GWOT. Training resources, a multi-tiered system of medical care, including rapid evacuation to high-level medical care, and macro-level tactical superiority all factored into the successes of tourniquets.

Ground truths in current or future near-peer conflicts will be more complex than during the GWOT. As Shackelford and Drew predicted, in a conflict with prolonged evacuation times and limited medical assets, failure to reassess and convert tourniquets in a timely manner would lead to prolonged ischemia and "avoidable loss of extremity."[14] This reality is manifesting in current-day Ukraine.

The foundation of TCCC rests in simple, protocolized management based on best-practice medicine and accounting for the tactical realities of conflict. However, as with all guidelines, the context in which they are used and differences in systems must be considered; the concepts cannot be merely translated and deployed as though the systems are parallel. If the reality on the ground and/or system results in significant evacuation delays and does not allow for the training or execution of TCCC concepts as refined during the GWOT, then they must be adapted to new ground truths. Without this evolution, data suggest that a return to the age-old paradigm of tourniquet use only after other methods of hemorrhage control fail could be preferable to liberal tourniquet use. With appropriate intervention, this devastating outcome is avoidable.

The collective network of medical, military, government, and NGO sectors must collaborate to identify actionable interventions that can be executed in a timely fashion, taking into account both the realities of the war in Ukraine and future near-peer or peer-peer conflicts. Although difficult to gather during an active conflict in a stressed system, and only with support from the partner nation, data must be gathered to objectively define best practices.

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JP and MT conceived the study concept. JP, MT, SD, TB, and LR, LS obtained case studies. All authors wrote and/or edited article text. All authors read, edited, and approved the final manuscript.

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JP, CR, and FS are consultants for Global Response Medicine. AL is an employee of Global Response Medicine. KW holds equity in Precision Trauma LLC. JH is Co-founder, member of the and Board of Directors, and equity holder in Decisio Health; a consultant for WFIRM and Aspen; and sits on the Boards of Directors of and is an equity holder in CCJ Medical

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