Forward Assessment of 79 Prehospital Battlefield Tourniquet Use in the Current War

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ABSTRACT

Introduction: Battlefield tourniquet use can be lifesaving, but most reports are from hospitals with knowledge gaps remaining at the forward surgical team (FST). The quality of tourniquet applications in forward settings remain unknown. The purpose of this case series is to describe observations of tourniquet use at an FST in order to improve clinical performance. **Methods:** War casualties with tourniquet use presenting to an FST in Afghanistan in 2011 were observed. We identified appliers by training, device effectiveness, injury pattern, and clinical opportunities for improvement. Feedback was given to treating medics. **Results:** Tourniquet applications (79) were performed by special operations combat medics (47, 59%), flight medics (17, 22%), combat medics (12, 15%), and general surgeons (3, 4%). Most tourniquets were Combat Application Tourniquets (71/79, 90%). With tourniquets in place upon arrival at the FST, most limbs (83%, 54/65) had palpable distal pulses present; 17% were pulseless (11/65). Of all tourniquets, the use was venous in 83% and arterial in 17%. In total, there were 14 arterial injuries, but only 5 had effective arterial tourniquets applied. **Discussion:** Tourniquets are liberally applied to extremity injuries on the battlefield. 17% were arterial and 83% were venous tourniquets. When ongoing bleeding or distal pulses were appreciated, medics tightened tourniquets under surgeon supervision until distal pulses stopped. Medics were generally surprised at how tight a tourniquet must be to stop arterial flow – convert a venous tourniquet into an arterial tourniquet. Implications for sustainment training should be considered with regard to this life-saving skill.

Keywords: *first aid; hemorrhage; extremity; damage control; resuscitation*

Introduction

Extremity hemorrhage control has dramatically improved on the battlefield in the past decade, largely attributable to the availability and early application of tourniquets to massively bleeding extremity wounds.[1-4] Although much data exists Kragh O'Neill Walters Jones 2011; Kragh 2011; Kragh 2010.) regarding effectiveness of tourniquets in the controlled environment of the civilian hospital,[2-12] combat support hospital, or laboratory, little data is available examining the effectiveness of tourniquets placed on the battlefield in the prehospital (Level I) environment. We thought that, although tourniquets were being applied liberally at point-of-injury on the battlefield,[13,14] they were not providing optimal control of extremity bleeding. The purpose of the present series is to characterize the effectiveness of prehospital tourniquets in the current war, in a far-forward setting, in order to improve the performance of prehospital providers at a Forward Surgical Team (FST) in Afghanistan.

Methods

As part of a quality of care improvement effort during Operation ENDURING FREEDOM, all combat casualties with signs of life such as a palpably detectable pulse[15] presenting to an FST at Forward Operating Base Shank (Level II), from August 2011 through November 2011, were identified and examined for presence of a tourniquet. Initial prehospital care for combat casualties included self-aid, buddy care, and care by medics or physicians (Level I). Only casualties evacuated directly from point-of-injury to the FST were included. When tourniquets were identified, the injury mechanism, anatomic location, number of tourniquets, correctness of application as intended, presence of distal pulses, and corresponding vascular injuries were noted. Vascular injuries were identified at surgical exploration, when clinically indicated, or excluded based upon release of the tourniquet and presence of a normal clinical and handheld Doppler auscultation examination of the affected limb. All observations and examinations were made by an FST trauma surgeon. Our battlefield management algorithm for limbs with tourniquets at Level II (FST) is presented in Figure 1.

Upon casualty arrival at the FST, immediate real-time feedback was given to the prehospital provider who applied the tourniquet(s) such as at medic handing off

Figure 1 *Management Guideline for Limbs with a Tourniquet at Presentation to Level II on the Battlefield. TQ is tourniquet. Vascular examination is conducted at 10 minutes in order to allow for resuscitation, reperfusion, and resolution of vasospasm. "Operating room" entails surgical exploration to identify and repair vascular injury. The guideline concerns emergent exploration for bleeding or ischemia; many limbs have associated skeletal or other injuries beyond the scope of the guideline, but in absence of bleeding and ischemia, such injuries may be triaged so casualties with bleeding may be treated first.*

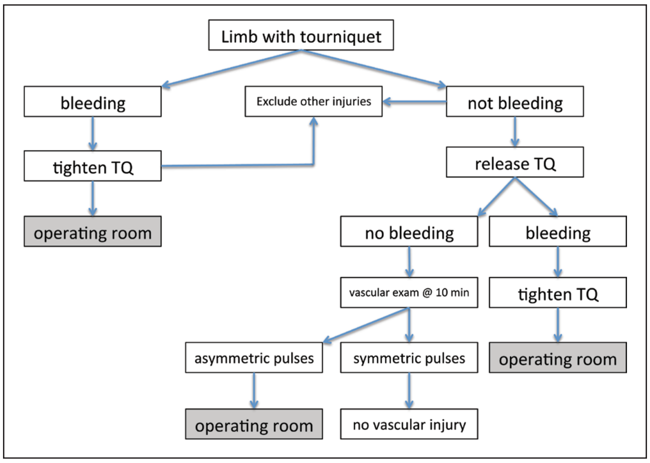
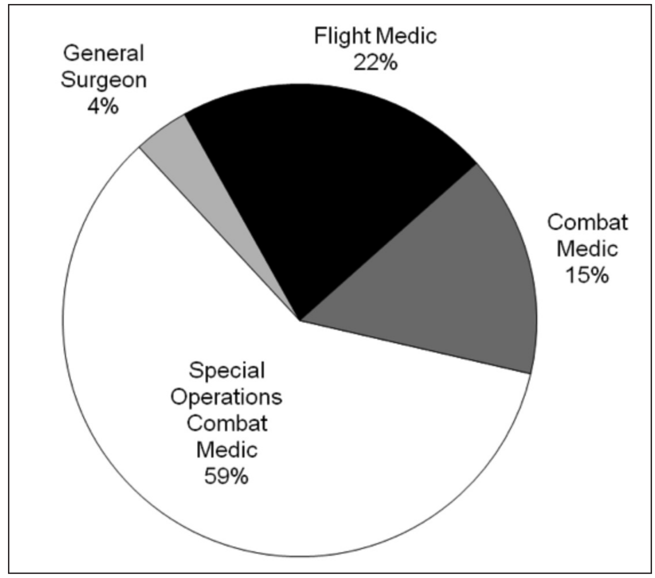


Figure 2 *Pie chart of proportions of tourniquet users by job title. Most tourniquets were placed by special operations combat medics (18D, 47 applications, 59%), flight medics (68WF3, 17 applications, 22%), combat medics (military operational specialty [MOS] 68W, 12 applications, 15%), or general surgeons (61J, 3 applications, 4%).*



casualty to the FST. Discussions often were continued afterward such as when medics checked in with their casualties at the FST within the next day. Each prehospital provider's military occupational specialty (MOS) was noted. When presence of the provider who applied the tourniquet was delayed, feedback was given after completion of the mission or operational objective. This report was reviewed by the U.S. Army Institute of Surgical Research Regulatory Affairs Office in July 2012 and was determined to be performance improvement in accordance with good clinical practices.

Results

Appliers were 96% medics and 4% surgeons. Tourniquet applications were performed by special operations combat medics (47 applications, 59%), flight medics (17 applications, 22%), combat medics (12 applications, 15%), or general surgeons (3 applications, 4%, Figure 2). Follow-up of casualties was limited to their length of stay at the FST, and no casualty died. During the entire quality improvement effort, no casualty presented with a major vascular injury without a tourniquet in place. Of the 54 combat casualties in this series, 38 had associated injuries involving an organ, cavity, or system other than an extremity.

A total of 79 tourniquets were identified on 65 limbs of 54 combat casualties (1.2 devices per limb [79/65], 1.5 devices per casualty [79/54]) arriving at the FST directly from the point-of-injury. The tourniquets identified were 90% Combat Application Tourniquets (CAT, 71/79), 5% Special Operations Forces Tactical Tourniquets (SOFTT, 4/79), 2.5% ratchet-type tourniquets (2/79), and 2.5% improvised tourniquets (2/79, Figure 3). With tourniquets in place upon arrival at the FST, most limbs (83%, 54/65) had palpable distal pulses present; 17% were pulseless (11/65). Of 10 casualties with 11 pulseless limbs with tourniquets in place, 5 (50%, 5/10) had return of distal pulses upon tourniquet release. No patient with return of bilateral and symmetrically palpable pulses within 10 minutes of tourniquet release had injury of an anatomically named artery such as the popliteal artery.[15] Both improvised tourniquets, of the band-and-stick design, presented with palpable distal extremity pulses and no vascular injuries identified.

Wounding mechanism was explosion with fragmentation in 41 limbs (improvised explosive device, rocket-propelled grenade, hand grenade, or other explosion), gunshot in 21 limbs, and crush in 3 limbs. All limbs had an open soft-tissue defect from fragmentation, gunshot, explosion, or crush (open fractures with degloving injury). Most limbs (45/65, 69%) had only soft-tissue and orthopedic injuries without vascular injury identified.

In total, there were 17 limbs with major vascular injury, of which 3 were combined arterial-venous injuries. There were 14 major arterial injuries, but only 5 had

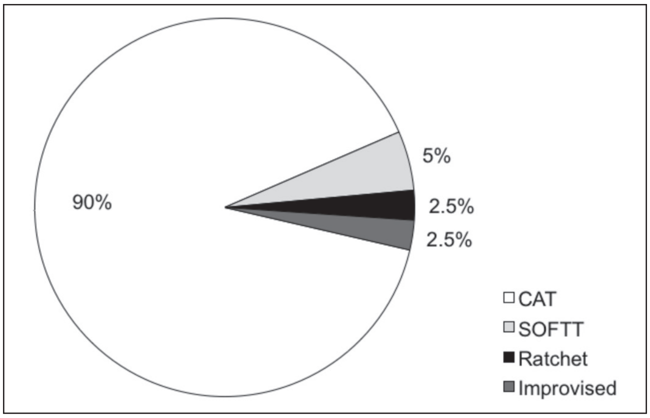


Figure 3 *Pie chart of proportions of tourniquets by model. Most tourniquets were the standard issue Combat Application Tourniquet (CAT, 90%). Other included the Special Operations Forces Tactical Tourniquets (SOFTT, 5%), ratchet tourniquets (2.5%), and improvised tourniquets (2.5%).*

no palpable pulse distal to the tourniquet. There were 3 superficial femoral artery injuries, 1 profunda femoris artery injury, 1 brachial artery injury, 6 popliteal artery injuries, and 3 infra-popliteal arterial injuries at or below the trifurcation. Six major venous injuries were identified: two brachial and four of the popliteal vein. The maximum number of tourniquets per limb was 3 (Figure 4) in a casualty with combined arterial and venous injuries. These three tourniquets were placed far apart from one another, making them act independently as single, narrow devices and not together side-by-side as if one wide device; wider is more effective. The two improvised tourniquets were narrow and too loose; all other tourniquets were applied with the correct technique.

Twelve arterial injuries presented with massive bleeding, either before or after tourniquet removal. The remaining 2 arterial injuries presented as ongoing, submassive hemorrhage and persisting distal pulse asymmetry (or total absence of a palpable pulse or Doppler signal) 10 minutes after tourniquet release.

Discussion

The main lesson learned in this series of 79 prehospital battlefield tourniquet uses in war is the necessity for continual re-evaluation of the casualty after application of a tourniquet. Just as with serial re-examination following needle decompression of the chest, careful re-examination following tourniquet placement is required to ensure that the tourniquet remains as tight and as hemostatic as originally intended. The current report findings serve as a well evidenced reminder that just as with all clinical interventions, a key is to continually re-assess the casualty. Controlling hemorrhage is priority #1 especially in tactical field care.[15] Battlefield medics have an

Figure 4 *Clinical photograph of a supine casualty with a left lower extremity wound with three tourniquets for combined popliteal artery and venous injuries confirmed later at surgical exploration. The three tourniquets are placed in no coherent plan as they are so far apart as to not be side by side. Side by side, they act as one wide and effective tourniquet. Separately, they add nothing; together, they work well. Tourniquet width is a key design trait for effectiveness.*

extremely difficult job in war with many competing goals and priorities, but refocusing on serial reassessment of casualties is required to improve care. Our observations indicate that tourniquets are being applied liberally for extremity wounds in accordance with current military policy. However, of 65 limbs with tourniquets, only 17 had a vascular injury identified, indicating that 74% of limbs had a tourniquet applied without underlying vascular (that is, major arterial or venous injury). On initial review, 74% may seem like an apparent overuse of tourniquets; however, during this same period, no casualty presented with vascular injury *without* a tourniquet in place, suggesting 100% capture. Because tourniquet use risks minor morbidity and tourniquet absence (when clinically indicated) is lethal,[2,4,5,7,15] then tourniquet overuse appears more desirable than missing a life and limb in need of hemorrhage control during evacuation.

Use of tourniquets controlled venous bleeding in 83% of uses and arterial bleeding in 17%, meaning that arterial tourniquets also controlled arterial bleeding. A reason for such a low rate of arterial tourniquet use is that although providers apply tourniquets liberally for all wounds to the extremities, only the “squeaky wheel gets the grease”; that is, the most noticeable (visually impressive or severe wounds) bleeding is most likely to get tourniquets tightened properly to both bleeding and pulse absence.[16] From the field user of medic’s perspective, liberal use appears practical given the chaos and danger of war with the little time a prehospital provider has to assess and treat wounds, particularly during care under fire as use limits risk to the casualty and recuer.[7] Of casualties with an identified arterial injury, only 35% presented with an effective arterial tourniquet, and this rate is near those previously reported.[7] There may be reasons for this observation. First, perhaps initially when the casualty was hypotensive, tourniquets were tightened well until there was no bleeding and no pulse; but on resuscitation blood pressure rose, pulses returned, and bleeding passed the tourniquet. Second, by the squeaky wheel premise above, providers may tighten a tourniquet until bleeding slows until it is visually unimpressive and move on to care for other injuries or casualties, thereby inadvertently allowing some ongoing bleeding with a distal pulse – the flood turns to trickle. Third, prehospital assessment of pulse persistence may be poor. The first and second reasons were not directly measured in the present survey but were found in similar surveys, as visual cues can be prioritized instinctively unless training over rides instinct.[7,15]

For most combat casualties in this series, their treating medics routinely presented with the casualty to the FST. Medics commonly went to the FST to get medical updates for their unit’s personnel section in order to understand dispositions, prognoses, and translate jargon for casualty status as a routine good practice. The personal medical knowledge gained by the medic and surgeon regarding reciprocal, two-way feedback was invaluable to medic, surgeon, and unit. When ongoing limb bleeding or distal pulses were appreciated (generally after undressing the wound), the medics tightened tourniquets under supervision of the surgeon until distal pulses became absent. All medics were surprised) as to how tight a tourniquet must be to stop arterial flow; that is, convert a venous tourniquet into an arterial tourniquet. Opportunities for the prehospital medic and the surgeon to work, teach, and learn together are invaluable and all too rare in war.

Venous tourniquet use risks much both morbidity commonly and mortality rarely unless corrected promptly (Figure 5).[1,4,5] A comprehensive historical review of emergency tourniquet use recently highlighted the significance of unintentional venous tourniquets.[1] For the majority of these 54 casualties, a venous tourniquet was present

Figure 5 *Clinical photograph of a supine casualty with bilateral lower extremity tourniquets released and loose in place. The limbs have passive venous congestion and reperfusion rubor. Pulses distal were palpable but diminished before release and normal afterward. No vascular injuries were identified. Doppler auscultation was normal.*

without vascular injury, which likely resulted in no directly attributable harm.[2-5] Vascular lesions were the fourth most common anatomic indication in the present study at 17%, and arterial injuries have ranged from only 8% to 28% of the injured casualties with emergency tourniquet use in recent wars.[6-7] Recent experience may have changed and broadened what was, historically, considered safe as the new evidence shows much use is safe. Additionally, prehospital differentiation of venous vs. arterial bleeding may still be poor.[7]

While a few studies report high rates of prehospital tourniquet use, none fully address tourniquet effectiveness far forward as at an FST.[8-11] Knowledge gaps in tourniquet use are not primarily at the emergency rooms of hospitals but forward as at the point-of-care. The present case series supports continued liberal use as there appears to be little risk, in general, to such use on the modern battlefield given short evacuation times and short ischemic times for the great majority of casualties.[15]

The limitations of the present case series are many in part due to the design of observing consecutive cases. Having no intervention, control, or follow-up beyond the scope of performance improvement, this case series increases awareness of topics worthy of study, education, and remediation.

In summary, prehospital tourniquet use is ubiquitous for extremity injury on the battlefield today, but only 26% of casualties with a vascular injury had an effective arterial tourniquet upon presentation at the FST.[2,12,17] All medics who placed the tourniquets were surprised at how tight arterial tourniquets had to be, and they were easily educated with real-time feedback to address the importance of serial reassessment and adjustment of tourniquets during evacuation to control hemorrhage. Degree of tightening to control arterial pulse and serial reassessment skills should be developed for tourniquet users and be reinforced in skill sustainment training.

Author Contributions

Dr J. F. Kragh literature search, study design, data collection, analysis, and interpretation, writing, revision. Gwendolyn van der Wilden: analysis, writing, revision. Dr. L. H. Blackbourne: data analysis, interpretation, writing, revision.

JF Kragh, COL (ret), MC, USA, Assistant Professor of Surgery, USUHS, Bethesda, MD. Financial disclosures that might relate to this work: Dr. Kragh is an employee of the US Government and receives institutional support where he works, the US Army Institute of Surgical Research. He has offered feedback on scientific matters at no cost to Operative Experience, M2, Inc., Tiger Surgical, LLC, Tactical Medical Solutions, LLC, Combat Medical Systems, Inc., Composite Resources Inc., Delfi Medical Innovations, Inc., North American Rescue Products LLC, H & H Associates, Inc., Creative & Effective Technologies, Inc., TEMS Solutions, LLC, Blackhawk Products Group, Hemaclear, Tactical Development Group, Compression Works, LLC, Tier-One Quality Solutions, Kforce Government Solutions, CHI Systems, Tactical Emergency And Medical Simulations Training (TeamsT), Athena GTX, Pelagique LLC, RevMedx Inc, and Entrotech, Inc. He has received honoraria for work for the Food and Drug Administration for device consultation. He has received honoraria for trustee work for the non-profit Musculoskeletal Transplant Foundation. He has worked as a technical representative to the US Government's contracting officer in agreements with Physical Optics Corporation, Resodyn Corporation, International Heart Institute of Montana Foundation, Daemen College, Noble Biomaterials, Inc., Wake Forest Institute of Regenerative Medicine, National Tissue Engineering Center, Pittsburgh Tissue Engineering Initiative, University of Texas Southwestern Medical Center, Arteriocyte, Inc., and Kelly Space and Technology, Inc.

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