



# Tourniquets

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Accepted: 14 June 2024 / Published online: 8 July 2024

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## Abstract

**Purpose of Review** Tourniquets have a longstanding history in combat casualty care, but only became widely accepted in the last 20 years as effective and safe. This review seeks to examine the history of tourniquets in combat casualty care and analyze their translation from military to civilian trauma care.

**Recent Findings** The most recent research focusing on prehospital tourniquet use has focused on the expansion of tourniquets to the civilian trauma patient population. Research has shown that tourniquet use can be effectively taught to civilians without medical training, and that placement of tourniquets in the prehospital environment can reduce blood loss and shock at admission. Other recent research has established the effectiveness of tourniquets in unique military environments such as in cold weather gear and when chemical, biological, radiological, and nuclear (CBRN) gear is worn.

**Summary** Tourniquets have become a standard piece of equipment for deployed servicemembers for their lifesaving potential. Evidence is building that tourniquets can play a similar role in civilian trauma, but more work is needed to demonstrate the cost effectiveness and mortality benefit of widespread civilian tourniquet training and application.

**Keywords** Tourniquet · Trauma · Military · Combat trauma

## Introduction

Tourniquets have a long-standing history in combat casualty care. However, until the Global War on Terror (GWOT), they were often considered to hold limited value in saving lives. Research during the GWOT quickly demonstrated that tourniquets can play a major role in preventing death on the battlefield to the current situation where availability and training is universal for deployed servicemembers. The success of tourniquets in combat has expanded their role to use in civilian trauma. There is a growing body of research that is beginning to demonstrate their beneficial role in this population as well. This paper seeks to provide a review of the use of tourniquets for contemporary battlefield as well as civilian injuries.

## History of Tourniquet Use

The origin of the tourniquet likely stems from India with the first use in treating venomous snake bites in the sixth century B.C. [1]. Introduction to the western civilization likely took place under Alexander the Great's military conquests but still for the purpose of preventing systemic spread following envenomation which was utilized in the Battle of Hydaspes in 326 B.C. [1]. Documented use of tourniquets to control hemorrhage appears first in the late medieval period for reducing pain and limiting blood loss associated with amputation; these applications include the use of a windlass which remains a key feature of modern battlefield tourniquets centuries later [2]. More modern battlefield tourniquets to control bleeding have been well documented in the United States (US) during the Civil War where soldiers were instructed to carry a roller or bandana with a stick to use as a windlass [3]. Training was limited and reports suggest that tourniquets may have been overutilized resulting in limb damage [3]. World War I and II saw increased use of tourniquets but there was a pervasive bias that tourniquets likely caused more harm than good, which prevented widespread dissemination, availability, and proper training of service members [3]. The Manuel of Therapy: European Theater of

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Operations (1944) provided to surgeons prior to the invasion of Normandy specifically discouraged the use of tourniquets except as a temporary measure until vessel ligation or wound packing could be applied stating that a tourniquet required for transport of a patient would lead to limb loss. [4].

### Modern Combat Tourniquet Use

While tourniquets were used with increased success and recognized in the Korean and Vietnam wars to be beneficial [3], and tactical combat casualty care (TCCC) guidelines recommended tourniquet use in its initial publication in 1996, [5], it was not until the more recent Global War on Terror in Iraq and Afghanistan that tourniquets were recognized for a profound lifesaving benefit for extremity major vascular injuries and their use was widely encouraged [6]. Since the start of these conflicts in the early 2000s, tourniquet application has become a central feature of TCCC, a mandated course of instruction on first responder care in a tactical situation. Tourniquet application has been one of only a very small number of interventions recommended while performing first responder casualty care while taking hostile fire (care under fire) [7] and even by 2012 the use of tourniquets is estimated to have saved between 1000–2000 lives in combat in Iraq and Afghanistan. [8].

Conventional US military forces began to distribute tourniquets in 2005 and they were universally part of the service member's operational kit by 2007. The widespread dissemination of tourniquets stemmed from an evidence based need to address loss of life due to extremity hemorrhage determined through an evaluation of data from the Joint Theater Trauma System's (JTTS) Joint Theater Trauma Registry (JTTR) [3]. The initial anecdotal bias against tourniquets from reports in previous wars was quickly overcome by evidence that the global availability of tourniquets by service members was associated with an 85% decrease in mortality due to extremity hemorrhage following implementation [9]. Shackelford et al. [10] identified three publications including a US Army Institute of Surgical Research laboratory study of effectiveness of tourniquets [11], a publication on causes of death in special forces operators [12]), and a front page article in the Baltimore Sun identifying extremity hemorrhage and lack of tourniquets as a cause of death for US troops on the battlefield [13] as leading to the quick changes in both medical, public and even federal government support for the use and wide availability of tourniquets.

Battlefield application of tourniquets was associated with reduced mortality compared to those applied at the combat support hospital [14] and further reports demonstrated that tourniquets had a low risk of complications with approximately 1% of patients developing palsy or nerve injury following tourniquet application [15]. Currently, tourniquets are issued to all deploying service members. The support

and discipline in their use has led to what I have personally witnessed with some United States Marine Corps Forces prepositioning tourniquets on their extremities prior to missions ready to be immediately tightened down should a severe injury occur.

Ultimately multiple experts agree that one of the most significant and defining advancements in combat casualty care that resulted from the War on Terror is the broad application of tourniquets for extremity hemorrhage on the battlefield [3, 6]. This further led to a change in thinking of the order of response to traumatic injuries. Prior to these conflicts, traumatic assessment followed the "A-B-C" approach starting with evaluating for and maintaining a patient's airway, then assessing breathing, and third determining adequate circulation was the established standing. Now, service members are taught to evaluate patients using the "M-A-R-C-H" acronym where massive hemorrhage is focused on and treated first, followed by the airway, respirations, circulation and head trauma or hypothermia following [7]. The American College of Surgeons Advance Trauma Life Support Course (ATLS), while still advocating an airway first trauma assessment, now includes a recommendation for tourniquet use for extremity hemorrhage control that cannot be abated by direct pressure [16].

In the most recent US military conflicts, the value of tourniquets in conjunction with the capability to rapidly evacuate a casualty has been well established in reducing mortality due to extremity hemorrhage. Whether this would apply to future conflicts where evacuation times are longer is not known. Recent research focuses on the transition of tourniquets from the established military application to evaluating the efficacy and practicality of tourniquet use for civilian trauma in the prehospital environment which is reviewed further below. Additional research focusing on training and on special circumstances of military tourniquet use is also ongoing and is discussed further below.

### Transition of Tourniquets to Civilian Trauma

The more recent trends in tourniquet use focus on the transition of the success of tourniquets in combat trauma into the civilian trauma arena. Increases in civilian tragedies such as the Boston marathon bombing as well as other mass casualties involving school and other events have generated increased public awareness of the potential need for bystander and emergency medical services (EMS) to know how to provide lifesaving hemorrhage control [17]. Although the rates of civilian firearm injuries where a tourniquet would potentially play a lifesaving role may be limited to less than 5% of shootings [18], there has been an increased focus on training prehospital and potential bystanders in tourniquet use.

As part of the response to increases in civilian mass casualty events, the White House launched a public awareness campaign known as STOP THE BLEED® in 2015. The American College of Surgeons Committee on Trauma (ACS-COT) developed and began offering the STOP THE BLEED® course in 2016 which provides training on bleeding control techniques to non-medical civilians, including the placement of a tourniquet [19]. The ACS-COT as well as the Eastern Association for the Surgery of Trauma (EAST) developed guidelines for the use of tourniquets that focused on the control of extremity hemorrhage that could not be controlled with direct pressure [20].

### Recent Findings in Civilian Tourniquet Use

Goodwin et al. [6] comments that civilian adoption of tourniquet use for extremity hemorrhage has been relatively slow, despite the strongly established lifesaving benefit in military literature. In their review of trauma activations from the National Emergency Medical Services (NEMESIS) database (a national emergency medical services (EMS) voluntary reporting database of trauma activations) where a tourniquet was used, they noted zero reported tourniquet applications until 2010. They did however note a substantial increase beginning in 2015, representing a 10-year delay from the wider application of tourniquets within the US military. In their review, they highlight a lack of availability of tourniquets and a lack of training for EMS providers being among the primary barriers to increased tourniquet utilization. Specifically, they note that by 2016 only 35% of all US States' EMS protocols included guidelines for tourniquet use [21].

Efforts to increase public and medical provider awareness of appropriate indications and effective application of tourniquets most notably include the Stop the Bleed Campaign. Mikdad et al. [20], in their multi-institutional database review of trauma activations and Emergency Room admissions without a trauma activation, attempted to identify the potential effects of the national campaign in the city of Boston. They identified and evaluated 147 prehospital tourniquet applications and stratified these as appropriate or inappropriate use. The authors defined appropriate use as extremity traumatic amputation, significant blood loss at the scene, patient needing surgery within 2 h of presentation, and hard signs of vascular trauma. They impressively determined that 49% of tourniquets did not have a clear or documented indication for tourniquet placement. They additionally noted that 27% of tourniquets were placed in a manner that could potentially exacerbate an arterial vascular injury including tourniquets placed distal to the site of penetrating trauma and tourniquets with only sufficient pressure to occlude venous return. They also noted prolonged tourniquet times of greater than two hours in multiple cases. While they

admit their study was limited by available documentation that could be abstracted from chart review and did not report on adverse outcomes from non-indicated tourniquet placement, their study highlights that current education efforts may be providing a new tool without sufficient training on appropriate indications.

Other recent studies have also questioned the benefit of mass training of lay-civilians in tourniquet application such as Hsu et al. [22] who in a review of all New York State firearm related trauma admissions determined that only 1.8–4.6% would have potentially benefited from a tourniquet being placed. They ultimately concluded that the number of resources allocated to public education and the potential stress caused to trainees by these programs may not be justified, and that time and efforts may be better allocated to alternative firearm injury prevention programs. However, Friber et al. [23] counter this perspective from their own prospective evaluation where they found that civilians without any medical background were able to retain information after only short amount of time under instruction and even appropriately perform correct tourniquet placement under simulated stressful situations. However, they also found that professionally trained first responders outperformed civilians in their testing program.

Most importantly recent large-scale evaluations have demonstrated similar potentially life-saving benefits of tourniquet use in civilian trauma. Smith et al. [24] in their 8-year single center retrospective review identified 204 tourniquet applications and compared these with a matched group of patients that did not have pre-hospital or emergency department tourniquet placement. They noted increased systolic blood pressure on arrival, decreased blood product transfusion, and decreased incidence of limb related complications (including secondary amputation, nerve palsy, infection, compartment syndrome, deep vein thrombosis, and ischemia–reperfusion injury) in patients who had a tourniquet placed compared to the non-tourniquet group. They concluded that tourniquets could be safely used in penetrating civilian trauma without increased risk of complications, a finding similar to other retrospective analyses [25, 26].

Schroll et al. [27] conducting the first prospective multicenter study of prehospital tourniquet use in civilian major extremity trauma. In comparing 1,310 consecutively enrolled patients who either had a tourniquet placed prehospital to patients who did not but were deemed on arrival to a trauma center to merit tourniquet placement, they noted that though patients with prehospital tourniquet placement had a higher injury extremity score and higher mangled extremity severity score (MESS), they were less likely to arrive in shock. They noted no difference in nerve palsy between groups but did note a higher rate of extremity amputation in the tourniquet group, a finding that is at least possibly attributable to the higher MESS associated with this group. The

authors failed to identify a difference in mortality between prehospital tourniquet placement and no tourniquet. Notably, and similar to a challenge in many studies in the combat trauma population, patients who expired prior to arrival to the hospital (pre-hospital mortality) were not included in this study.

Another area of recent study in civilian trauma given recent devastating school shootings is the effectiveness of tourniquet placement in the pediatric population. The combat application tourniquet (CAT) (Fig. 1) that is the primary tourniquet issued to US service members, and used for training the STOP THE BLEED campaign, was trialed in pediatric patients aged two to seven years old undergoing elective orthopedic operations and shown to be 100% effective for arterial occlusion in both upper and lower extremities [28]. Goolsby et al. [29] demonstrated that instructor-based training can quickly and effectively teach high school aged students to appropriately place a tourniquet. Large scale initiatives have also been developed partnering pediatric trauma centers with local law enforcement to disseminate training and tourniquets to elementary and middle schools [30]. However, others have questioned the cost-effectiveness of these initiatives given low percentages of civilian firearm injuries that would benefit from tourniquet use compared to putting resources towards other violence prevention programs [16].

### Tourniquet use in Unique and Future Military Environments

Other areas of recent research in tourniquets have evaluated the effectiveness of tourniquets in unique military environments. At least two studies have found that in the chemical, biological, radiological, or nuclear (CBRN) threat



**Fig. 1** Combat Application Tourniquet (C-A-T). Photo from manufacturer North American Rescue used with permission

environment where Mission-oriented protective posture (MOPP) gear is required to be worn, available purpose-designed tourniquets remain fully effective when applied overtop of protective suits for occluding arterial blood flow [31, 32]. Additionally, Lechner et al. [33] evaluated the effectiveness of the CAT and SOF Tactical Tourniquet (SOFTT) when applied over the German military's cold weather issued uniform and found that the CAT tourniquet remained fully effective but noted high rates (50%) of insufficient pressure application for complete arterial occlusion using the SOFTT over this winter clothing.

Recent research on the utilization of tourniquets in combat has come from the US military operational environments in the Middle East where American and coalition forces have had the ability to evacuate patients quickly with by ground or air transport with little threat from enemy combatants. However, there is increasing concern in the US for Large Scale Combat Operations (LSCO) resulting in a large number of casualties not seen since World War II due to the recent conflict in Ukraine and the theoretical risk of conflict developing in Taiwan and the South Pacific. [34] In this LSCO setting, evacuation routes, methods, and times would dramatically increase, in part, due to the loss of air superiority. In addition, the volume of casualties would increase substantially potentially overwhelming the military medical system. Thus, a more nuanced approach to tourniquet utilization in earlier phases of surgical care would be required. This may include a focus on definitively treating vascular injuries in the earlier surgical phase of care and accepting the risk of limb loss at greater rates in mass casualty scenarios if tourniquets are left on for prolonged periods of time.

Finally, incorporating experiences from the ongoing conflict in Ukraine, Holcomb et al. [35] recently focused on the important consideration of tourniquet application in settings where prolonged evacuation times represent a challenge. In this publication, the authors highlight in the civilian setting and military conflicts in Iraq and Afghanistan, conditions were more forgiving to overapplication of tourniquets to injuries that did where a tourniquet may not be indicated due to the ability to rapidly evacuate patients to a location where a surgeon could quickly evaluate and take down a tourniquet if not needed. In Ukraine, greater than six hour casualty evacuation times are common due to the operational environment of this theater. Consequently, complications of limb ischemia due to prolonged tourniquet applications have been observed, raising some of the same concerns associated with tourniquet use in military conflicts in the twentieth century. The authors argue that the solution to this challenge is to continue with early tourniquet placement for extremity hemorrhage, but that as soon as can be safely accomplished, injuries need to be reassessed for tourniquet replacement to a site more proximal to the wound or conversion to a hemostatic or pressure dressing to minimize complications of prolonged tourniquet

placement for injuries that can be managed with alternative methods. They argue that this training on tourniquet reassessment will need to be developed and incorporated alongside of training in initial tourniquet application.

## Summary

Tourniquet use for combat extremity injury is now well established as a lifesaving technique with a highly favorable safety profile in military conflicts provided there is the ability to evacuate casualties relatively quickly for definitive surgical care. Whether the same will hold true for a future conflict with a more distributed area of combat operations or without air superiority allowing quick patient transport remains unknown. There is a developing body of evidence demonstrating that tourniquets can be safely and effectively used for civilian extremity injuries including application in the pre-hospital phase. In addition, there is an interest in the civilian community for acquiring the training and equipment for non-medical bystander intervention when necessary. However, a definitive mortality benefit from tourniquets has not been established in the civilian patient population. Future research continues to look to establish the optimal civilian use and training of tourniquets, and to determine if the same lifesaving benefits prove to be present in this patient population.

**Acknowledgements** The authors did not receive support from any organization for the submitted work.

**Author contributions** L.J. wrote the manuscript and conducted the primary literature review.

W.P. conducted additional literature review and reviewed the manuscript.

P.W. conducted additional literature review and reviewed the manuscript.

M.B. assisted in writing the manuscript, conducted additional literature review and reviewed the manuscript.

**Funding** Open access funding provided by SCEL, Statewide California Electronic Library Consortium. No funding was received to assist with the preparation of this manuscript.

No funding was received for conducting this study.

No funds, grants, or other support was received.

**Data Availability** No datasets were generated or analysed during the current study.

## Declarations

**Competing interests** The authors declare no competing interests.

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