Albanian Journal of Trauma and Emergency Surgery (2025) 9/2:1829 - 1836
DOI: 10.32391/ajtes.v9i2.482

OPEN ACCESS JOURNALS

REVIEW ARTICLES

Tourniquet Use for Major Hemorrhage in Prehospital and Hospital Settings: A Systematic Review of the Literature

Basri Lenjani[1], Dardan Lenjani[2], Entela Lenjani[2], Agron Dogjani[3,4,*]

Received: 15 June 2025 / *Accepted:* 5 July 2025 / *Published online:* 20 July 2025
This article is published with open access at **https://journal.astes.org.al**
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Abstract

Introduction: Major hemorrhage remains a leading cause of preventable death in both civilian and military trauma settings. Tourniquets have emerged as a critical intervention for hemorrhage control; however, their optimal application across various clinical environments requires systematic evaluation.

Objective: To systematically review the effectiveness, safety, and clinical outcomes of tourniquet use for major extremity hemorrhage in prehospital and hospital settings.

Materials and Methods: We conducted a comprehensive systematic search of PubMed, Scopus, Web of Science, and the Cochrane Library databases for studies published between 2000 and 2024. The inclusion criteria covered randomized controlled trials, cohort studies, and observational studies that assessed the use of tourniquets for major limb hemorrhage. Primary outcomes included survival rates, effectiveness of hemorrhage control, and complication rates. Secondary outcomes included time to hemorrhage control and functional results. Data extraction focused on clinical indications, patient demographics, tourniquet specifications, application timing, and adverse events.

Results: Thirty-two studies met the inclusion criteria. Tourniquet use in the prehospital setting was consistently associated with improved survival in patients with severe extremity bleeding, particularly when applied early. Hospital-based tourniquet use has proven effective in surgical or resuscitative contexts but requires careful monitoring to avoid ischemic complications. When used correctly and for limited periods, complication rates remain low.

Conclusions: The current evidence strongly supports the use of tourniquets as an effective and safe intervention for major extremity hemorrhage in both prehospital and hospital settings. The early application improves survival outcomes and helps reduce complications. Implementing standardized protocols, comprehensive training programs, and quality improvement initiatives is crucial to maximizing clinical benefits and ensuring patient safety.

Keywords: tourniquet, hemorrhage control, trauma, prehospital care, systematic review

Original article, no submission or publication in advance or in parallel

* ***Corresponding author:***
Prof. Dr. Agron DOGJANI, M.D., Ph.D., FACS, FISS, FICS,
✉ *agrondogjani@yahoo.com*

[1] *Emergency Clinic, University Clinical Centre of Kosovo, Pristina, KOSOVO*
[2] *Alma Mater Europaea Campus College "Rezonanca," Pristina, KOSOVO*
[3] *Department of Surgery, Faculty of Medicine, University of Medicine of Tirana, ALBANIA*
7 The University Hospital of Trauma, Tirana, ALBANIA

Introduction

The first recorded efforts to prevent arterial bleeding have been ascribed to Sushruta, the father of surgical art and science, in 600 BC. At that time, he pressed the arteries with pieces of leather that he made himself, and it is said that he had used a device which we now call the tourniquet [1]

The use of the tourniquet, which prevents blood from entering and exiting the limb, has historically been close to amputation. The tourniquet was first used in 200 BC and continued up to 500 AD during the Roman Empire's era [2]

The use of tourniquets dates back to ancient times. During Alexander the Great's campaigns in the 4th century

BC, tourniquets were used to stop bleeding in wounded soldiers. [3, 4, 5]

The Romans adopted this practice, particularly during amputations, crafting narrow straps made of bronze and leather. [4,5, 6]

Significant progress occurred in the 18th century. In 1718, French surgeon Jean Louis Petit invented a screw-based tourniquet to occlude blood flow at surgical sites. [7]

Before this, tourniquets were primitive garrotes tightened with rods (from the French word tourner, meaning "to turn").[7, 8]

History. In 1785, Sir Gilbert Blane proposed that every British Royal Navy sailor carry a personal tourniquet during battle to prevent fatal bleeding before medical help could arrive. By 1864, Joseph Lister had successfully created a bloodless field for surgery using tourniquets. Later, in 1873, Friedrich von Esmarch introduced a rubber bandage to both control bleeding and evacuate blood from limbs—an innovation known today as Esmarch's bandage.[9]

However, by 1881, concerns about nerve damage and paralysis from tight elastic tourniquets had arisen, particularly with the use of the Esmarch device. In response, Dr. Harvey Cushing developed the **pneumatic tourniquet** in 1904, offering quicker application and safer pressure control.[10]

Further developments followed. In 1908, August Bier used two pneumatic tourniquets to perform intravenous regional anesthesia (IVRA).[11] In the 1980s, James McEwen designed microprocessor-based pneumatic systems that provided real-time pressure monitoring, alarms for over- or under-pressure, and built-in safety features like backup power and calibration.[12]

In the 2000s, Noam Gavriely introduced the **silicone ring tourniquet**, a sterile, elastic device used especially in surgery. However, rare but serious complications such as pulmonary embolism have been reported in trauma patients using this method. [13, 14]

Use of Tourniquets in Kosovo

In Kosovo, the use of tourniquets is a recognized and integrated practice within emergency medical protocols, particularly for controlling severe limb bleeding. However, specific statistics on tourniquet usage are limited and generally not detailed. [15, 16, 17, 18]

Tourniquet Usage in Kosovo:

- **Training Provided by KFOR:**
- The Multinational Specialized Unit (MSU) of the KFOR mission, a group of experienced medical professionals, has conducted Basic Life Support (BLS) courses in Pristina. These courses included comprehensive training on the use of tourniquets and Israeli bandages to control bleeding. [19, 20]

Studies on Emergency Services:

- A 2024 study on prehospital emergency services in Kosovo highlighted the importance of triage methods and rapid patient care, including the use of tourniquets for controlling bleeding. [21, 22]

Epidemiology:

Tourniquet use has increased significantly in recent decades, especially in emergency and trauma settings. Its application varies depending on the geographical context, whether it is for civilian or military use, and the level of medical training available. [23, 24, 25]

In military settings: During armed conflicts, particularly in Iraq and Afghanistan (2001–2011), early and systematic tourniquet use played a key role in reducing deaths from severe hemorrhage. Studies report that over 2,000 lives were saved during this period due to the proper application of battlefield techniques. [25, 26]

In civilian settings: In countries with advanced trauma systems, prehospital tourniquet use is now part of standardized protocols. It has proven especially effective in managing bleeding from road traffic accidents, industrial injuries, and gunshot wounds.[27]

Usage is higher in urban areas with well-trained emergency teams. In contrast, in many developing countries, the use of tourniquets remains limited due to a lack of equipment and proper training.[27]

Modern Advancements and Applications

Modern pneumatic tourniquet systems have improved safety and efficacy. They allow for:

(LOP) to set appropriate tourniquet pressure. [28]

- Real-time monitoring of inflation and deflation times
- Sterile use in surgical settings
- Alarm systems for pressure irregularities

These systems are now standard in both military and civilian trauma care.

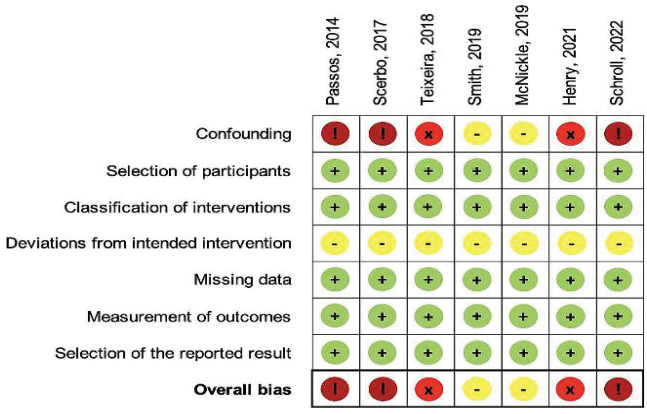

Table 1. Results of risk of bias assessment for included studies using the ROBINS-I tool, a widely accepted tool for assessing the risk of bias in non-randomized studies. Published: Mar 19, 2024[29]

Between 2005 and 2011, data from military operations in Iraq and Afghanistan indicated that tourniquets saved over 2,000 lives by rapidly controlling extremity hemorrhage. In civilian emergencies, the use of prehospital tourniquets has increased, with practices now recommending early application even before first responders arrive on the scene. Some public spaces now include tourniquets alongside defibrillators for emergency use.[30]

Foto 1: Cuff designs with offset ports (top and middle) and cuff designs without offset ports (bottom). Figure. JA McEwen tourniquets.org.[31]

How to Apply a Tourniquet (e.g., C-A-T®):

Apply the tourniquet around the injured limb: Place it **2.5–5 cm (1–2 inches)** above the bleeding wound (never over a joint, such as the knee or elbow). If the wound is not visible (such as in dark conditions), place the tourniquet **as high on the limb as safely possible**.[32]

Tighten the main strap: Pull the strap as tight as possible and secure it with Velcro.

Twist the windlass rod: Twist it until **the bleeding completely stops**. It will be painful for the person, but it is **necessary to save their life**.

Secure the windlass rod: Once the bleeding has stopped, place the rod into its holder to prevent it from loosening.

Record the application time: There is a space on the tourniquet where you can record the time it was applied. This is very important for medical personnel.

Effectiveness and Benefits

Tourniquets have proven effective in:

- **Saving lives** by quickly stopping life-threatening limb hemorrhages
- **Reducing the incidence of shock** in patients with major extremity trauma
- **Improving survival rates**, especially when applied early in the prehospital setting
- **Military operations**, where their use has shown dramatic improvements in survivability from combat injuries

A growing body of civilian trauma research supports these findings. In particular, patients with peripheral vascular injuries treated with tourniquets before hospital arrival demonstrate better outcomes, including reduced blood loss and fewer complications during surgery. [27-30]

Risks and Considerations

Despite their life-saving benefits, tourniquets carry

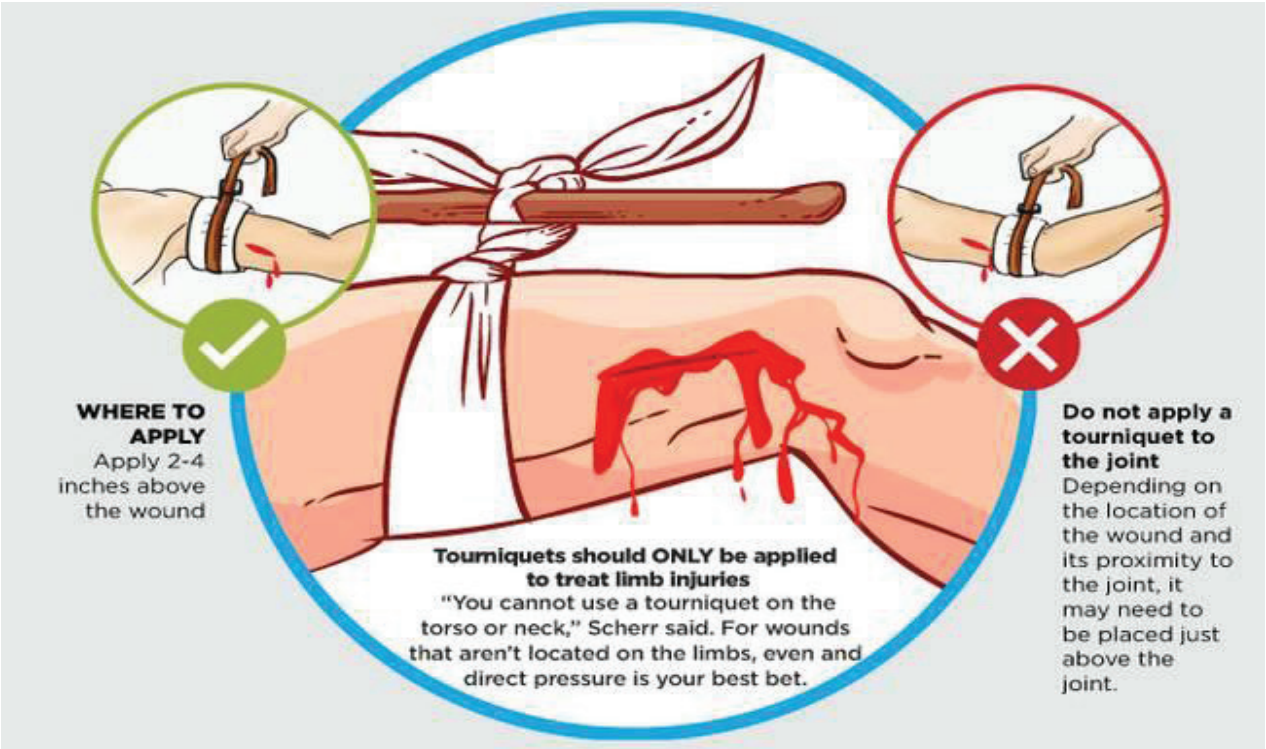

Figure 1: How to correctly apply a tourniquet to stop bleeding.

Step	Description
1. Indications	- Severe bleeding that cannot be stopped with direct pressure - Wound is difficult to control - Severely injured or amputated limb
2. Positioning	- Place 2.5–5 cm above the wound (not over a joint) - If the wound is not visible, place it as high on the limb as safely possible - Ensure the skin is dry and clean
3. Tightening	- Tighten the strap firmly and secure with Velcro or a fastener - Twist the windlass until the bleeding stops - Secure the windlass in position
4. Documentation	- Record the time of application on the tourniquet, the patient's body, or accompanying paperwork - Inform medical personnel of the application time
5. Care and Monitoring	- Do not remove the tourniquet without medical supervision

Table 1: The protocols for applying a tourniquet

certain risks, especially when misused or left on too long:

- **Ischemia:** Prolonged application can deprive tissue of oxygen, potentially causing irreversible damage or necrosis.
- **Nerve Injury:** Excessive pressure or incorrect placement can lead to neuropraxia or permanent nerve damage.
- **Amputation Risk:** Although rare, prolonged use without proper monitoring can lead to limb loss. [33, 34]

Limited Use Cases: Tourniquets are mainly suitable for extremity hemorrhage. Their effectiveness in **junctional** (groin, armpit) or torso bleeding remains under investigation.

Proper training and protocol are essential. Tourniquets should only be applied by individuals trained in trauma care, using appropriately sized and approved devices.[34]

Best Practices in Tourniquet Selection and Use

Several factors must be considered when selecting the correct tourniquet:

- Cuff location and limb size
- The shape of the limb (cylindrical or contoured)
- **Limb circumference and required cuff length**
- **Cuff width and pressure distribution**
- **Sterile vs. non-sterile cuffs**, depending on the surgical environment
- **Single vs. dual bladder design** (e.g., for IVRA procedures).[34]

Medical personnel must also monitor the inflation time and ensure that the total application does not exceed the safe duration guidelines, generally recommended as under 2 hours, unless in exceptional cases.

A tourniquet is a medical device used to apply pressure to a limb to stop blood flow, creating temporary ischemia. It

Foto. 1. The patented C-A-T® is a proper one-handed tourniquet proven to be 100% effective by the US Army's Institute of Surgical Research. Tests proved that the C-A-T® completely occluded blood flow of an extremity in the event of a traumatic wound with significant hemorrhage.

is commonly used in emergency trauma care, surgery, and postoperative settings to control major hemorrhage. While early versions could be improvised with rope and sticks, modern tourniquets are commercial-grade devices designed for safety and effectiveness. Improvised devices are less effective and carry a higher risk of complications such as soft tissue and nerve damage. [33, 34]

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Purpose of the Work

This study aims to assess the role of the tourniquet as a vital tool in controlling severe limb hemorrhage. The review addresses:

- The use of tourniquets in both civilian emergency and military trauma settings
- Their impact on improving survival rates and reducing the necessity of application
- The importance of adequate training for medical professionals and first responders
- The need for continued research to optimize tourniquet application and understand its long-term effects

Ultimately, the goal is to support the establishment and dissemination of standardized, evidence-based guidelines to ensure the safe and effective use of tourniquets in hemorrhage control.

Materials and Methods

This systematic review examines the existing scientific literature on the use of tourniquets to control major limb hemorrhage in both prehospital and hospital settings. The methodology involved:

- A comprehensive search of electronic databases, including PubMed, Scopus, and Web of Science, using keywords such as "tourniquet," "major hemorrhage," "prehospital care," and "hemorrhage control."
- The inclusion criteria focused on clinical studies, comparative research, reviews, and case reports related to tourniquet application and its outcomes.
- Screening of titles, abstracts, and full texts to select relevant studies.
- Extraction and synthesis of data regarding tourniquet effectiveness, benefits, complications, and recommended practices.
- Identification of gaps in the current literature to highlight areas needing further investigation.

Additionally, retrospective data from the Emergency Clinic archives at UCCK (January–December 2022) were included, encompassing cases of electric shock and lightning injuries, as well as information on healthcare personnel training in basic and advanced care related to hemorrhage control. [35, 36]

Result & Discussion

This systematic review identified seven cohort studies investigating the benefits of PH-TQ use in patients with vascular extremity injuries, demonstrating that early placement of TQ in the prehospital setting may confer a survival benefit for patients with vascular extremity injuries.

The analysis did not reveal any significant differences in the transfusion of blood products, ICU and hospital lengths of stay, or the occurrence of potential complications associated with the intervention. Substantial heterogeneity was noted across the pooled effect estimates.

In the USA, a 2017 study analyzed data from a national US database and estimated an incidence of 0.2 tourniquet applications per 1,000 emergency service activations.[36]

Increase in Use in Major Cities: A report from New Orleans showed a rise in tourniquet use from 2.2 per 1,000 trauma activations in 2010 to 44. er, 1,000 activations in 2018.[37]

Effectiveness: The review confirms that tourniquets are highly effective in controlling major limb hemorrhage in both prehospital and hospital settings. Studies consistently report improved survival rates and reduced blood transfusion requirements when tourniquets are applied promptly and correctly.

Military vs. Civilian Use: Military data demonstrate significant life-saving benefits of tourniquet use in combat injuries, which has influenced civilian trauma protocols. Civilian studies show similar trends, with prehospital tourniquet application leading to better outcomes in severe limb trauma.[38]

Risks and Complications: While tourniquets effectively stop bleeding, prolonged application increases the risk of ischemia and potential nerve damage. Delayed amputations, though rare, have been associated with extended tourniquet use. Proper training and adherence to recommended application times are crucial to minimizing these risks. [35-38]

Training and Protocols: The importance of adequate training for healthcare providers and first responders is a key factor in ensuring the safe and effective use of tourniquets. Standardized protocols help ensure proper placement, pressure, and duration of use. [51, 52]

Research Gaps: The literature reveals a need for more high-quality studies on the long-term outcomes of tourniquet use, optimal application durations, and effectiveness in non-extremity hemorrhage (e.g., junctional bleeding).

A flow diagram of the included studies is shown. After the literature search, 230 records were identified. A total of 67 duplicates and 250 irrelevant articles were removed after screening the titles and abstracts, resulting in 28 reports for full-text review that were considered potentially relevant. Overall, seven articles met the inclusion criteria and were included in our study [42, 43, 44, 45, 46, 47, 48, 49].

All studies included in our analysis were non-randomized cohort studies conducted in North America between 2014 and 2022, comprising six studies from the United States [42, 43, 44] and one study from Canada [45].

Effectiveness and safety of tourniquet utilization for civilian vascular extremity trauma in the prehospital

settings: a systematic review and meta-analysis. “Based on the study of...” Ying-Chih Ko, *World Journal of Emergency Surgery*, volume 19. [53] The meta-analysis revealed that early placement of a TQ in the prehospital setting may provide a survival advantage for patients with extremity vascular injuries and decrease the use of blood products. There was no increase in the risk of amputation or compartment syndrome. Further large-scale prospective studies are needed to verify these findings.

These goals are essential throughout the patient’s acute care. In the future, new guidelines for treating electrical trauma will be based on a clearer understanding of the relevant pathophysiological features.

These strategies will rely on improving diagnostic imaging and reversing the underlying problem of cell membrane damage. Furthermore, the complex biochemical and pathophysiological interactions of the organ system will require careful management.

If successful, research efforts currently underway should improve the prognosis of victims of electrical trauma. [47, 48]

Given the discrepancies found in reporting path membrane damage. Furthermore, the complex biochemical and pathophysiological interactions of the organ system will require careful management. If successful, research efforts currently underway should improve the prognosis of victims of electrical trauma.[53]

Recommendations

- Prehospital Use: Tourniquets should be used for life-threatening limb bleeding when direct pressure is ineffective or not feasible.
- Hospital Use: Tourniquets are appropriate for controlling major limb hemorrhage in hospital trauma care.
- Training: Comprehensive training on the correct application of tourniquets is essential for both prehospital responders and hospital staff.
- Continued Research: Further studies are needed to clarify the long-term effects of tourniquet use and to refine application guidelines across various clinical situations.

In Kosovo, the use of tourniquets is a recognized and integrated practice within emergency medical protocols, particularly for controlling severe limb bleeding. However, specific statistics on tourniquet usage are limited and generally not detailed.

The use of tourniquets in Kosovo is a known and integrated practice within emergency response protocols, especially for controlling severe limb bleeding. However, specific statistics on usage are generally limited and not readily available. To improve tourniquet use, ongoing training and access to quality equipment for emergency services are essential.

In Kosovo, several initiatives and courses offer such training; however, there is always room for improvement and expansion of these programs, particularly for staff in rural areas and prehospital emergency services.

Yes, absolutely! Training is essential as soon as possible to enhance the skills and preparedness of healthcare and emergency staff in Kosovo, particularly in the use of tourniquets to save lives in emergencies. The sooner these trainings start, the better it will be for the safety and effectiveness of medical aid in the field.

COI Statement: This paper has yet to be submitted in parallel, presented fully or partially at a meeting, podium, or congress, published, or submitted for consideration beforehand.

This research received no specific funding from the public, commercial, or non-profit sectors. The authors declare that they, their relatives, or next of kin have no financial relationships with external companies that could be considered relevant or minor.

Disclosure: The authors declared no conflict of interest. No funding was received for this study.

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