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REVIEW ARTICLE

Prehospital tourniquet use outcome in civilian limb penetrating trauma: A systematic review

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ABSTRACT

Objectives: This systematic review seeks to offer an overview of the current level of knowledge about the clinical efficacy of prehospital tourniquets (TQ).

Methods: A comprehensive search of relevant databases was conducted to identify studies that met the inclusion criteria. PubMed, Science Direct, and Scopus were systematically searched for relevant literature. Rayyan QRCI was employed throughout this comprehensive process.

Results: Our results included eight studies with a total of 1,434 patients with 1,058 (73.8%). The eight studies were retrospective in nature. TQ application time ranged from 15 minutes to 190 minutes. There were significantly fewer delayed amputations, fewer fatal hemorrhages, fewer acute renal damage cases, more transfusions in those who underwent the prehospital TQ, the average systolic blood pressure of patients in the TQ group was higher, less fresh frozen plasma, less total packed red blood cells, fewer fasciotomy, and less vascular injury in patients with penetrating traumas. Complications included limb ischemia and/or reperfusion damage, temporary sensory impairment, temporary mixed motor and sensory loss, and peroneal nerve palsy. One study reported that in the prehospital TQ group, amputation rates were 8.3%, while in the No-prehospital TQ group, they were 0%.

Conclusion: The studies consistently found that in civilian settings, using a TQ to halt uncontrollably bleeding extremities was associated with a better chance of survival in penetrating injuries. Application times of less than 2 hours appeared to be quite safe in previously healthy persons, while problems with TQ usage appeared to be directly connected to application times. Subsequent research, ideally in the form of randomized controlled trials, should be done to validate the initial findings of observational studies.

Keywords: Tourniquets; limb; trauma; emergency; prehospital; systematic review.

Introduction

Every year, around 1.35 million people are killed as a result of trauma induced by road traffic accidents, while between 20 and 50 million individuals worldwide get nonfatal injuries [1]. Uncontrolled massive bleeding resulting in hemorrhagic shock is a prominent cause of preventable mortality in both civilian and military settings. In fact, bleeding accounts for up to 40% of trauma deaths [2].

Bleeding management in serious trauma is a therapeutic priority that can be accomplished via direct compression or the use of mechanical or pneumatic tourniquets (TQ). Direct pressure is the first and most basic stage. TQs can be used if direct pressure on the bleeding site is insufficient to stop the bleeding [3]. However, in some cases, using a suitable bandage might be more time-consuming and technically demanding than applying a tourniquet [4]. Furthermore, direct compression with a

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bandage may not be effective in controlling significant arterial bleeding. For these reasons, particularly in the presence of protracted prehospital transport durations, the tourniquet may be the preferred device for achieving temporary prehospital control of life-threatening extremities hemorrhage [5].

Recent military studies demonstrate that using a tourniquet before the beginning of shock is associated with improved survival outcomes, contradicting previous concerns [6]. Furthermore, prehospital tourniquet administration for hemorrhage management in limb injuries has been linked to improved survival rates compared to emergency department TQ [7]. As a result, emergency personnel have increasingly used TQ to limit hemorrhages in civilians [8,9].

However, there has been concern that the more liberal use of TQ may enhance the morbidity of serious limb wounds seen in combat due to the consequent transient ischemia [10]. Trauma in the civilian environment may differ from trauma in the military, but in recent decades, terrorist acts and mass-casualty events around the world have rendered penetrating injuries more similar than ever. As a result, expertise from both situations can be useful when developing national guidelines [11,12].

The goal of this study was to look into the prehospital usage of TQ for patients with extremity penetrating injuries in the civilian context. The primary goal was to determine whether the use of prehospital TQ improves survival rates in civilian patients with life-threatening extremity bleeding. Secondary outcomes included the number of transfusions, complications, and other adverse events, if any. Civilian limb penetrating trauma occurrences can cause extensive bleeding, which increases morbidity and fatality rates. It is necessary to assess the role of prehospital tourniquet use in managing such injuries in order to understand its impact on patient outcomes.

The purpose of this systematic review is to objectively examine the available information on prehospital tourniquet usage in civilian limb piercing trauma cases in order to identify mortality, morbidity, and impact on patient outcomes.

Methods

This systematic study followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines [13]. To find relevant papers published in English, a thorough search was conducted using electronic databases such as PubMed, Science Direct, and Scopus. Two reviewers independently screened the search results, selected relevant papers, extracted data, and assessed the quality of the chosen studies using appropriate assessment tools.

Eligibility Criteria

Inclusion criteria

1. Studies that investigate the clinical effectiveness and outcomes of prehospital TQ among civilians.

2. Studies conducted between 2019 and 2024.

3. Studies published in English.

4. Studies involving human participants.

Exclusion criteria

1. Studies published in languages other than English.

2. Animal studies, reviews, case reports, and editorials.

3. Studies with insufficient data on the outcomes of prehospital TQ in major trauma among civilians.

Data extraction

To ensure correctness, the search results were checked with Rayyan (QCRI) [14]. The search results were filtered based on inclusion and exclusion criteria to establish the relevance of titles and abstracts. Reviewers thoroughly reviewed the papers that were selected and met the inclusion criteria. Disagreements were resolved through discussions. A pre-prepared data extraction form was used to enter pertinent study information such as titles, authors, study year, location, participants, setting, intervention, comparison, time of TQ administration, and key outcomes. A separate document was prepared to examine bias risk.

Data synthesis strategy

The data gathered from relevant research was utilized to generate summary tables that provide a qualitative evaluation of the components and study outcomes. Following the collection of data for the systematic review, the optimum approach for utilizing the data from the included studies was determined.

Risk of bias assessment

To assess the study's quality, the Joanna Briggs Institute (JBI) [15] critical assessment criteria for studies reporting prevalence data were applied. This tool contains nine questions. Positive responses receive a score of one, while negative, unclear, or irrelevant replies receive a score of zero. Ratings of less than four, five to seven, and more than eight will be classified as poor, moderate, and outstanding quality, respectively. Scholars evaluated the work independently, and conflicts were resolved through debate.

Results

Search results

The systematic search yielded 633 study papers in total, with 292 duplicates deleted. After reviewing the titles and abstracts of 341 studies, 305 were deleted. Only five of the 36 reports requested for retrieval were discovered. After screening 31 publications for full-text assessment, 15 were rejected owing to inaccurate study results, six due to improper population type, and two were editor's letters. This systematic review included eight study papers that matched the qualifying criteria. Figure 1 shows an overview of the study selection procedure.

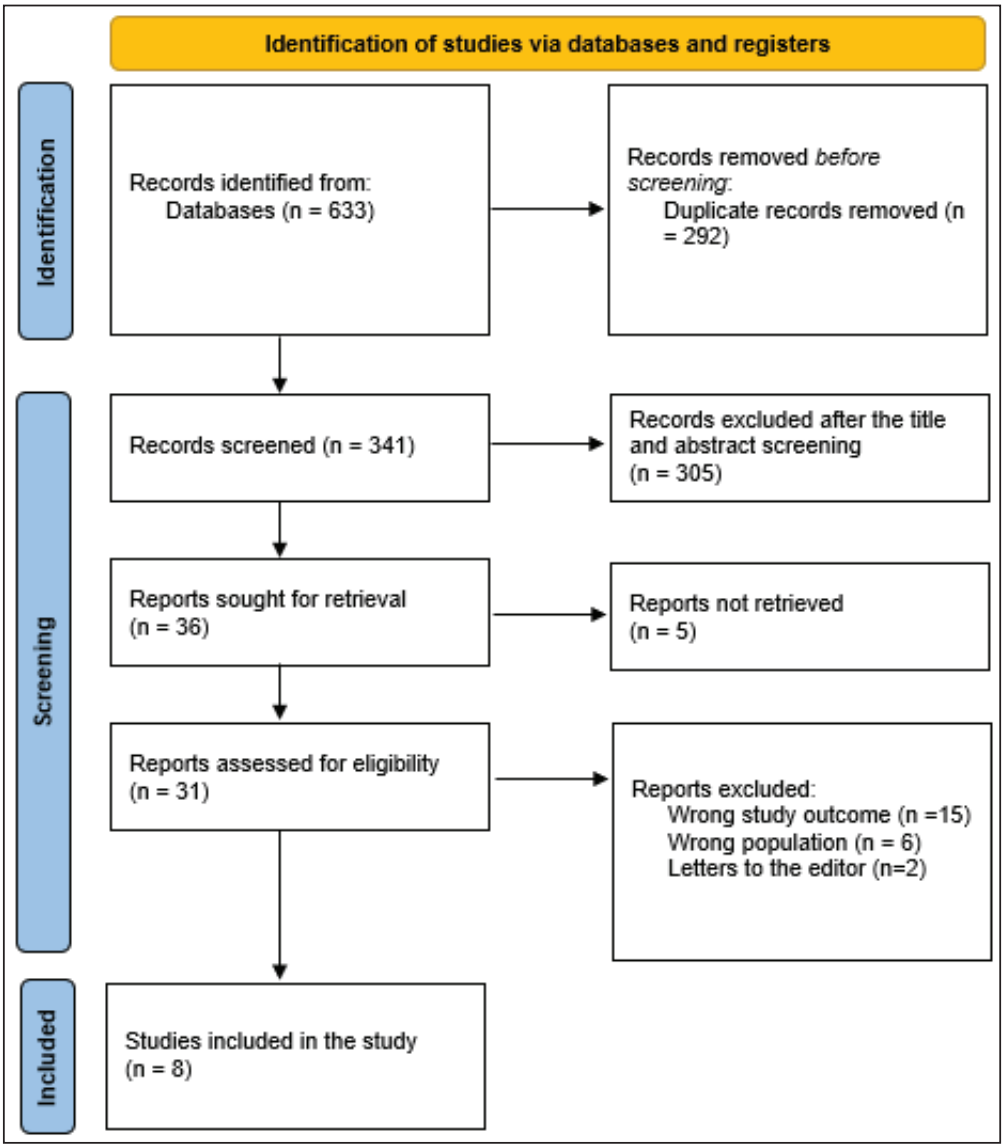

Figure 1*. Study decision is summed up in a PRISMA diagram.*

Characteristics of the included studies

The sociodemographic details of the research articles that are included are shown in Table 1. Our results included eight studies with a total of 1,434 patients with 1058 (73.8%). The eight studies were retrospective in nature [16–23]. Five studies were conducted in the USA [16,18,19,21,23], one in Australia [17], one in the UK [20], and one in Sweden [22].

Clinical outcomes

The clinical features are shown in Table 2. All prehospital data were obtained from level I or II trauma facilities. TQ application time for penetrating traumas varied between 15 and 190 minutes [22,23]. There were significantly fewer delayed amputations [12,16,18,21], fewer fatal hemorrhages [16–23], fewer acute renal damage cases [16], more transfusions in those who underwent the prehospital TQ [16,20,21,23], the average systolic blood pressure of patients in the TQ group was higher [18,23], less fresh frozen plasma [18], less total packed red blood cells [18], fewer fasciotomies [18], and less vascular injury [19].

Complications

Complications of penetrating limb traumas included limb ischemia [12] and/or reperfusion injury, transitory sensory impairment, temporary mixed motor and sensory loss, and peroneal nerve palsy [17,23]. According to one study, amputation rates were 8.3% in the prehospital TQ group and 0% in the non-prehospital TQ group [19].

Discussion

According to this comprehensive review, patients with vascular injuries in their limbs may have a better chance of survival if prehospital TQ is delivered promptly. It also identified eight cohort studies that investigated the benefits of TQ administration in prehospital settings for patients with penetrating limb wounds. We demonstrated that there were significantly fewer delayed amputations [16,18,21], fewer fatal hemorrhages [16–23], fewer acute

***Table 1**. Sociodemographic characteristics of the included participants.*

Study	Study design	Country	Participants	Mean age	Gender (Males)
Thai et al. [16]	Retrospective cohort	USA	TQ (*n* = 98) and No-TQ (*n* = 134)	24-48	197 (84.9%)
Read et al. [17]	Retrospective cohort	Australia	31	23.9–66.3	25 (80.6%)
Smith et al. [18]	Retrospective cohort	USA	Penetrating trauma (*n* = 176) and blunt trauma (*n* = 62)	34.5	207 (87%)
Legare et al. [19]	Retrospective cohort	USA	Prehospital-TQ *n* = 585 and No-prehospital-TQ *n* = 37	37 ± 15.3	428 (68.8%)
Bedri et al. [20]	Retrospective cohort	UK	92	24-51	71 (77.2%)
McNickle et al. [21]	Retrospective cohort	USA	TQ+ (*n* =69) and TQ− (*n* =69)	35 ± 1.5	56 (81%)
Wellme et al. [22]	Retrospective cohort	Sweden	56	17-80	50 (89.3%)
Covey and Gentchos [23]	Retrospective cohort	USA	25	6 -66	24 (96%)

*NM=Not-mentioned

renal damage cases [16], more transfusions in those who underwent the prehospital TQ [16,20,21,23]; the average systolic blood pressure of patients in the TQ group was higher [18,23], less fresh frozen plasma [18], less total packed red blood cells [18], fewer fasciotomies [18], and less vascular injury [19]. Similarly, a systematic review and meta-analysis conducted by Ko et al. found that when utilized in prehospital settings, prehospital-TQ reduced mortality and tended to reduce blood transfusions for civilian patients suffering from vascular traumatic limb injury [24]. Another systematic review by Eilertsen et al. discovered that the use of commercial TQs in a civilian environment to prevent life-threatening extremity hemorrhage appears to be associated with better survival, reduced need for blood transfusion, and minimal and transient side effects, despite the studies' relatively poor evidence [11].

A recent meta-analysis of ten studies indicated no statistically significant difference in all-cause mortality between the use of a TQ and direct pressure alone [25]. Furthermore, another study that employed TQs in the presence or absence of shock discovered no differences in mortality results [26]. Not surprisingly, there was a decreased risk of mortality when a TQ was applied to a military casualty before the onset of shock [27]. The significant impact on survival is most likely owing to the high prevalence of vascular injuries to the limbs in military situations. It is questionable whether TQ use contributes to the death rate in our reference population.

Although the rates of limb complications are low in the studies that report them, it is impossible to determine whether the complications were caused by the use of a TQ or the nature of the limb injury itself due to incomplete reporting of limb injury characteristics and severity, as well as the lack of comparison groups. There is a lack of consistency in the definitions and reporting of complications across research, and no statistical comparisons are conducted to aid in the identification of risk factors. We also discovered that consequences included limb ischemia and/or reperfusion injury, transitory sensory impairment, temporary mixed motor and sensory loss, and peroneal nerve palsy [17,23]. According to one study, amputation rates were 8.3% in the prehospital TQ group and 0% in the non-prehospital TQ group [19]. While the notion of TQ is gaining acceptance in some communities, we must remember that not all TQs are being used correctly, and the process may lead to problems [28]. There are numerous types of extremity injuries, ranging from severe abnormalities to minor injuries that are difficult to recognize. Given the limited experience with prehospital-TQ, the importance of adequate training for first responders or healthcare staff, as well as more consistent methods, cannot be stressed. Furthermore, because the timing of interventions and therapies has a substantial impact on patient outcomes, time is critical in trauma cases. Practitioners must grasp the importance of using TQ fast, as well as possess the appropriate skills and knowledge.

Clinical implications

TQs were mostly used for penetrating injuries to the extremities and were used in a variety of settings with rather uniform injury types and locales. As noted in [25], there was rarely a clear indication and description of TQ exposure time. Only one study defined cases of TQ usage based on extremity vascular damage [10]. Furthermore, TQs should only be used to stop bleeding in the extremities when direct pressure is insufficient or impractical. This includes circumstances with many victims or injuries, inaccessible wounds, or when medical professionals and nurses work together to stabilize and resuscitate severely ill patients. Our findings revealed a trend toward a prehospital-TQ-associated reduction in mortality, albeit not significantly.

Research indicates that personnel who have received prehospital-TQ training are more likely to use it and are less fearful of difficulties than those who have not [29]. Because this course is updated with the most recent information, mandating prehospital trauma life support certification on a regular basis should help prevent skill decline and continued education. TQ usage could be seen as a potential anti-hemorrhagic resource, and its life-saving effect may become more apparent, even though external hemorrhage is frequently controlled through a progressive approach [30].

Limitations

We could not discover any prospectively collected clinical data, and thus, the factors reported by different

Table 2. *Clinical characteristics and outcomes of the included studies.*

Study	Setting	Trauma type	Intervention	Comparison	TQ time	Main outcomes	JBI
Thai et al. [16]	Level I trauma center (Prehospital data)	The majority (84.7%) are penetrating trauma	Prehospital TQ application	No TQ application	NM	Applying TQ before hospital admission was linked to positive results, such as increased functional mobility and a reduction in delayed amputation. Lactate level and mortality were not correlated with prehospital TQ administration (both P >.05). There were fewer delayed amputations, fewer acute renal damage cases, and more transfusions in the prehospital TQ application group (all P <.05).	High
Read et al. [17]	Level I trauma center (Prehospital data)	19.4% are penetrating trauma	Prehospital TQ application	NA	124 (median)	Out of 30 cases, 4 (13.3%) had complications related to the TQ. These included 2 patients (6.7%) who had limb ischemia and/or reperfusion damage, 1 temporary sensory impairment (3.3%), and 1 temporary mixed motor and sensory loss (3.3%).	Moderate
Smith et al. [18]	Level I trauma center (Prehospital data)	All are penetrating major extremity trauma	Prehospital TQ application	NA	23.9	Upon presentation at the emergency department, the average systolic blood pressure of patients in the TQ group was higher (120 ± 2 vs. 112 ± 2, p = 0.003). Less fresh frozen plasma (1.4 ± 0.08 vs. 6.2 ± 0.4, p < 0.001) and total packed red blood cells (2.0 ± 0.1 vs. 9.3 ± 0.6, p < 0.001) were needed by the TQ group. Both fasciotomy (12.6% vs. 31.4%, p < 0.0001) and limb amputation (0.8% vs. 9.1%, p = 0.005) were considerably greater in the N-TQ group.	Moderate
Legare et al. 2022 [19]	Level I and II trauma centers	All are penetrating major extremity trauma	Prehospital TQ application	No TQ application	50.6 ± 51.5	In the prehospital TQ group, there was a greater incidence of patients without severe vascular injury (n = 585/962, 60.8 vs n = 37/88, 42.0%, P <.001). In the prehospital TQ group, amputation rates were 8.3% (n = 49/585), while in the No-prehospital-TQ group, they were 0% (n = 0/37).	Moderate
Bedri et al. [20]	Level I trauma center (Prehospital data)	58.7% are penetrating trauma	Prehospital TQ application	NA	123 minutes in rural vs. 48 minutes in urban settings	Compared to published studies on urban civilian TQ use, early TQ application for bleeding management in rural settings is safe and does not result in considerable attributable morbidity or fatality, even with lengthy transit times. The rates of TQ that are not warranted or ineffective that have been seen point to inadequate TQ application and usage.	Low
McNickle et al. [21]	Level I trauma center (Prehospital data)	58% are penetrating trauma	Prehospital TQ application	No TQ application	78 ± 6	TQ+ patients had higher starting heart rates (110 vs. 100, p=0.02), transfusion frequencies (67% vs. 48%, p<0.01), and initial amputations (23% vs. 6%, p<0.01) in the matched comparison (n=69 pairs). Regardless of whether the upper (n=43 pairs) or lower (n=26 pairs) extremities were involved, TQ+ patients had a higher frequency of first amputations; however, only those with upper extremity involvement experienced a rise in transfusion frequency and volume.	Moderate
Wellme et al. [22]	Trauma center	76.8% are penetrating trauma	Prehospital TQ application	NA	15-100	In 98.2% of the cases, TQ successfully halted the bleeding. While the overall rate of problems was 31%, 3.6% of them may have been caused by the usage of TQ. The TQ was used in 16 (28.6%) cases for a non-life-threatening hemorrhage that might have been stopped with just direct pressure.	High
Covey and Gentchos [23]	Trauma center	56% are penetrating trauma	Prehospital TQ application	NA	58-190	Regardless of concurrent injuries, the need for transfusion was correlated with the existence of an efficient TQ. Compared to the group without TQ or with ineffective ones, the group with compressed bleeding and effective TQ showed higher mean systolic (p = 0.003) and diastolic (p = 0.023) blood pressures. One peroneal nerve palsy was among the complications, and the use of a TQ did not result in any amputations.	Moderate

*NA=Not applicable

centers were diverse. Despite effectively combining data from many publications, we had to make assumptions about how comparable the variable definitions were between studies. Because no two studies provide the same data points and many omit critical parameters such as whether the TQ was applied to the upper or lower limb, the found retrospective reports are not methodologically comparable.

Conclusion

The studies consistently found that in civilian settings, employing a TQ in penetrating wounds to stop uncontrollably bleeding extremities was associated with a better likelihood of survival. Application times of less than 2 hours appeared to be quite safe in previously healthy persons, while problems with TQ usage appeared to be directly connected to application times. Subsequent research, ideally in the form of randomized controlled trials, should be done to validate the initial findings of observational studies.

Acknowledgment
None.

List of abbreviations

JBI	Joanna Briggs Institute
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
TQ	Tourniquets

Conflict of interests
The authors declare that there is no conflict of interest regarding the publication of this article.

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