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# Systematic Review of Prehospital Tourniquet Use in Civilian Limb Trauma

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**Abstract**

BACKGROUND: Military enthusiasm for limb tourniquet use in combat casualty care has resulted in acceptance by the trauma community for use in the prehospital care of civilian limb injuries. To date there has been no report synthesizing the published data on civilian tourniquet use. The objective of this systematic review was to compile and analyze the content and quality of published data on the civilian use of tourniquets in limb trauma.

METHODS: The MEDLINE database was searched for studies on civilian limb tourniquet use in adults published between 2001 and 2017. Search terms were "tourniquet," "trauma," and "injury." Military reports and case series lacking systematic data collection were excluded. Counts and percentages were aggregated and weighted for analysis.

RESULTS: Reports were included from six regional trauma centers and one inter-regional collaboration (total 572 cases). One national prehospital database report was included but analyzed separately (2,048 cases). All were retrospective cohort studies without prospective data collection. Three reports defined a primary outcome, two had a non-tourniquet control group, and no two papers reported the same variables. Limb injury severity and characteristics were inconsistently and incompletely described across reports, as were tourniquet indications and effectiveness. Arterial injury was reported in two studies and was infrequent among cases of tourniquet use. Mortality was low and limb-specific complications infrequent but variably reported.

CONCLUSION: The rapid increase in the civilian use of tourniquets for limb hemorrhage control has occurred without a large amount or high quality of data. Adoption of a multicenter registry with standardized data collection specific to limb trauma and tourniquet use can serve to improve the trauma community's understanding of the safety and effectiveness of tourniquet use in civilian trauma settings.

LEVEL OF EVIDENCE: Systematic Review, level IV

KEYWORDS: Tourniquet, Extremity, Limb, Injury, Trauma

## Introduction

Decades of controversy surrounde the use of tourniquets to control limb hemorrhage.[1, 2] The United States military, motivated by the potential to prevent battlefield deaths due to extremity exsanguination in Iraq and Afghanistan, has adopted tourniquets as a first-line method for limb hemorrhage control. The rapid adoption and acceptance of tourniquets by the combat casualty care community after September 11 belies decades of research, deliberation, and testing which formed the basis for the proliferation of modern military tourniquet devices and doctrine.[3]

The civilian trauma care community has recognized the military's enthusiasm for tourniquets used to treat combat injuries under battlefield conditions. They have responded with guidelines for limb hemorrhage control that encourage the use of tourniquets in civilian trauma settings.[4-6] The evidence underlying these guidelines and their recommendations is based principally on military data. The existing civilian experience with tourniquet use has not been systematically evaluated. The objective of this research was to systematically compile and analyze the content and quality of published data on the use of tourniquets in civilian trauma settings.

## Methods

This systematic review was performed according to the principles set forth in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement.[7] Studies published from January 2001 to December 2017 reporting on the use of tourniquets for limb hemorrhage control in civilian prehospital settings were targeted. Since one of the goals of the review was to determine the nature of the reported data on civilian tourniquet use, no

restrictions were placed on outcome measure reporting. The MEDLINE database was searched via the National Library of Medicine's PubMed.gov platform using the search terms "tourniquet," "trauma," and "injury" on 17 December 2017. The search was limited to adult (ages 19 and over) reports published in English. A single investigator (DSK) performed eligibility assessment by reviewing the titles of all returned results and selecting and reviewing the abstracts of potentially relevant papers. Full articles were procured based on assessment of abstract content. Reference lists were screened for additional inclusions. Case reports and series in which data had not been systematically acquired and analyzed were excluded, as were military rand junctional tourniquet reports.

In order to determine the nature of data reported, we neither precisely defined nor limited which data points were to be collected prior to reviewing reports that met inclusion criteria. We collected the most relevant data presented within the included reports and compiled them into a customized database (Excel, Microsoft Corporation, Redmond, WA). Penetrating injuries included stab, laceration, or gunshot wounds. Other mechanisms, including explosions and injuries described as "traumatic amputations," were categorized as blunt injuries.

Counts from individual reports were aggregated, with percentages reported using a denominator from only those papers that contained the data point. Continuous data were weighted by their respective reports' contributions to the total. Descriptive statistics were performed on the combined data. This resulted in weighting of the reported results by the number of patients in each study containing the specific parameter.

## Results

*Report Characteristics*

The MEDLINE search returned 426 reports. After abstract review, eleven were selected for full-text evaluation. One was excluded because the report was biased by including only cases of isolated extremity arterial injury and therefore might have excluded other injury patterns in which tourniquets were used.[8] This Canadian report was the only report from outside of the United States. Another report was excluded because it included very little clinical data.[9] Eight of the remaining nine studies were reported from one or more regional trauma centers.[10-17] The remaining report was a review of records from the National Emergency Medical Systems Information System (NEMSIS) database.[18] This study was unique in that it used data from a registry and not hospital patient records. It was included but analyzed separately. There were two instances where a single center published distinct reports of tourniquet use during overlapping time periods. In one case, the more recent report (which contained more cases) was included.[17] The other duplicate reports used distinct data sources (one used trauma center medical records and the other EMS records) and their data were combined. We included cases from the trauma center paper (which contained more detailed patient-level data) as the report denominator and applied additional data from the EMS report to these in reporting aggregate data from the reporting trauma center. **Figure 1**

All of the reports were retrospective cohort studies detailing medical record reviews published from 2015 to 2017. Data were presented on patients treated at the reporting centers from 2005 through 2016 and from the NEMSIS database from 2011-2014. The trauma center reports included a total of 719 cases of tourniquet use, and the NEMSIS report contained 2,048

cases. The largest trauma center report case contributor was the most recent, a single-center report from Houston contributing over a third of the total cases. This report contained data on cases of both pre- and in-hospital tourniquet placement, but only the prehospital cases are included in the review. Additionally, the report contains detailed physiologic and outcome data on only those cases of prehospital tourniquet use deemed to be "indicated," therefore these (comprising 89 percent) were the only cases included.[17] **Table 1**

All cases were of prehospital use of tourniquets except those from a one in which 39 percent were first placed in the ED and 10 percent in the operating room.[11] Three trauma center reports defined a primary outcome measure: overall mortality in one,[10] death from hemorrhagic shock in the second,[17] and limb loss in the third.[11] None included a control group against which the rate of the primary outcome could be assessed. One report indicated that one of its purposes was to determine the effect of tourniquets on hemorrhage control but did not report any outcome measure of hemorrhage control.[12] This, however, was the only study to include a non-tourniquet control group of patients with limb hemorrhage. The NEMSIS study used a non-tourniquet control group to identify variables predictive of tourniquet use, but this group was not limited to only patients with limb injuries.

*Demographics and Injuries*

One of the reports contained no demographic data.[12] The average age of patients in the remaining trauma center reports was 36 years with a large majority (85 percent) of males. While the NEMSIS report contained a similar male predominance of 76 percent, the average age reported was older at 44 years. All reports included injury mechanism data. Trauma centers

reported penetrating mechanisms in 47, with blunt injury comprising 45 percent and non-traumatic hemorrhage 8 percent. This distribution differed form that in the NEMSIS report, which found most (68 percent) extremity tourniquets were applied for blunt trauma while 29 percent were used in penetrating and 2 percent in nontraumatic mechanisms. The most commonly reported sources of non-trauma extremity hemorrhage from the trauma center reports were bleeding from dialysis access sites and from varicose veins.[12, 17] Traumatic amputation as a specific mechanism was reported by five centers and was present in 11 percent of cases. Level of amputation was not specified.

All but one trauma center report contained the percentage of patients arriving to the ED hypotensive (systolic blood pressure < 90mmHg), with an average of 13 percent. The other center reported a mean prehospital blood pressure of 119mm Hg. The Injury Severity Score (ISS) was reported in five studies with a weighted mean of 9 (range 6-11). The Extremity Abbreviated Injury Scale (AIS) was available in only three reports, with a weighted mean of 3, serious (range 2-3, moderate-serious). **Table 2**

*Tourniquet Use*

Four trauma center reports included data on the location of tourniquet placement. Placement was about evenly distributed between the upper (55 percent) and lower (45 percent) limbs. The NEMSIS paper did not report the tourniquet location in all cases, with 39 percent of tourniquets on the upper and 27 percent on the lower limb; proportionally similar to the other reports. Laterality was not presented. Tourniquet duration was reported by all but one trauma center and was included in NEMSIS. We estimated duration as the prehospital transport time

from one report. The weighted mean duration from the trauma centers was 49 minutes (range, 21-103 minutes); this value was 33 minutes in the NEMSIS report. All centers reported the general nature of the tourniquet devices used. Overall, 21 percent of the devices were classified as "improvised," meaning neither designed nor commercially produced for the purpose of stopping limb hemorrhage. **Table 2** Only one study compared outcomes between improvised and non-improvised devices, finding no difference in mortality or limb outcomes.[10] The most commonly mentioned commercial tourniquet device used was the Combat Application Tourniquet (Composite Resources, Rock Hill, SC), which was reported as being carried as standard equipment on EMS transport vehicles by two regional EMS organizations.[14, 15, 17] One report contained only data from improvised tourniquets; a system of rubber tubing secured by a surgical clamp system in common use by Boston EMS providers.[13]

*Tourniquet Effectiveness and Indications*

Three studies reported tourniquet effectiveness in hemorrhage control, averaging 90 percent. None reported an *a priori* definition of "effectiveness," however. One study found a small (5.1mmHg) mean increase in SBP from pre-tourniquet baseline, but no non-tourniquet comparison was provided.[10] Two studies reported on whether or not tourniquet use was indicated or appropriate but used different criteria to define these. One used the presence of "shock, vascular injury, or continued hemorrhage," while the other stratified absolute indications as "…vascular injury requiring repair or ligation, an emergent operation for extremity injury within 2 hours of hospital arrival, or a traumatic amputation." Relative indications included "a documented significant blood loss at the scene or major musculoskeletal/soft tissue injury requiring an urgent (between 2 and 8 hours of hospital arrival) operation.[12, 17] Four studies

reported on the presence of arterial injuries with were present in 43 percent of cases. The timing and nature of the arterial injury diagnosis was not reported. **Table 3** Two of the four studies reported the level of named arterial injury. Multiple arterial injuries were not specified. **Figure 2**

*Patient and Limb Outcomes*

Mortality was reported by five centers, averaging 6.0 percent. Only one report contained data on cause-specific mortality, with hemorrhagic shock accounting for 60 percent of deaths.[17] The one study that included a non-tourniquet group did not provide a intergroup mortality comparison but did ascribe one ED death to limb exsanguination in a patient with a tourniquet and a bleeding dialysis fistula.[12] Amputation as a surgical intervention (not reported as traumatic amputation or completion of a traumatic amputation) was reported by four studies, with a rate of 5.4 percent. No study directly attributed amputation as a complication of tourniquet use, but one case of extensive muscle necrosis at the time of tourniquet removal after 8 hours was reported in a limb that was later amputated. The rate of any complication was reported in three studies and averaged 24 percent. Limb-specific complications were reported, including extremity compartment syndrome (four studies, 4.0 percent), peripheral nerve dysfunction (three studies, 3.7 percent), and wound infection (three studies, 4.0 percent). **Table 3**

## Discussion

Despite their apparent enthusiastic and rapid adoption following decades of controversy, sparse data have been published on the safety and effectiveness of tourniquets for use in civilian limb trauma. Our review identified few reports containing useful clinical data. Though EMS protocols now include tourniquet use across most of the nation, published reports on the clinical

aspects use come from very few trauma centers. Data from many urban areas with high volumes of trauma and rates of penetrating injury are absent, likely representing publication bias.[19] The single national report using a centralized EMS database contains minimal clinical information and has limited utility in describing national patterns of tourniquet use. Our systematic review demonstrates that the available published data on civilian limb tourniquet use are not only of low quantity, but are also of low quality, arising solely from retrospective reports from existing clinical records and databases, inviting information and selection biases. Relevant clinical information may not have been available to researchers, and the selection of cases to include in reports was dependent on accurate and timely documentation.

We failed to discover any prospectively collected clinical data, resulting in heterogeneous variables reported from disparate centers. Though we successfully aggregated data from multiple reports, doing so required making assumptions about variable definition similarity across studies. The identified retrospective reports are not fully comparable methodologically as no two studies report the same data points and many omit basic information such as whether the tourniquet was placed on the upper or lower limb. Only one study reports a comparison group of non-tourniquet limb trauma, but this study completely omits demographic data and despite having a primary outcome measure of "hemorrhage control," does not report it.

The reason for the age difference between trauma center and NEMSIS studies is unclear. Because NEMSIS is a nationwide database presenting epidemiologic-level data, the discrepancy suggests selection bias in the trauma center reports. All but one of the center reports offer data from urban trauma centers with a patient population likely younger than the average age of

trauma patients nationwide. The percentages of blunt and penetrating injury differ between the trauma center and NEMSIS reports as well. The trauma center reports contain a majority of penetrating trauma, while the rural and NEMSIS reports have a majority blunt trauma population. This discrepancy again suggests that these data represent an inadequate sample of the nationwide population of tourniquet cases. Reported mean tourniquet use durations are generally short, with the exception of one urban center reporting over an hour (Charlotte) and another over an hour and a half (Los Angeles). Unexpectedly, the second-shortest application time (21 minutes) is reported from the rural trauma center. No data on patients with tourniquets that had been removed prior to arrival at a center and no information about additional methods of hemorrhage control prior to tourniquet placement are reported. The majority of improvised tourniquet data comes from a single center with a single referring EMS system. The centers that report the use of both improvised and commercial devices do not compare them, and no comparison of effectiveness between commercial and improvised tourniquets is possible given the nature of the available data. It seems clear that in order to fully understand the characteristics of tourniquet use across the country, a nationwide registry with standardized data collection will be necessary.

Four of six trauma center reports present data on extremity AIS, and one provides a mean Mangled Extremity Severity Score (MESS). Neither of these fully characterizes limb injuries treated with tourniquets. Limb tourniquets are intended for use to prevent hemorrhage and exsanguination death, and while the AIS and MESS can correlate with shock severity and mortality, they are post-hoc measures and cannot be used alone to determine the appropriateness of tourniquet placement.[20] Three reports contain data on tourniquet effectiveness, however none

identifies specific effectiveness criteria. No *a priori* definition of effectiveness is available or suggested in the reports, making comparative study of tourniquet effectiveness in different injury patterns fruitless. Limb tourniquets are designed to provide circumferential compression to the point that arterial flow ceases proximal to a limb injury.[21] Arterial injury is only reported by four studies, and is present in fewer than half of patients. The majority of reported arterial injuries are to small vessels distal to the elbow or knee. Hemorrhage from these may be amenable to a pressure dressing or other hemostatic procedure, but no information is reported regarding alternative hemorrhage control methods. Serious limb injuries involve damage to multiple tissue types in various patterns.[22] Without more specific description of the limb injuries treated with tourniquets, the use profile and effectiveness of tourniquets cannot be adequately understood.

Patient and limb outcomes are inconsistently and incompletely reported. The all-cause mortality reported is low but cause-specific mortality is not reported. Only one study employs a non-tourniquet control group and its analysis includes only ED mortality but not limb outcomes. In this study, ED mortality was over twice as high in the tourniquet group, which had a higher incidence of shock.[12] Such a finding of shock-related mortality in tourniquet patients is similar to a military report of tourniquet use in combat situations.[23] Among the studies in which they are reported, rates of limb complications are low but due to incomplete reporting of limb injury characteristics and severity and the lack of comparison groups, it is impossible to ascertain whether complications were potentially due to tourniquet use or to the limb injury. Definitions of complications and their reporting are not standardized across the studies and no statistical comparisons are performed to enable the identification of risk factors. The clinical presentation of peripheral nerve injury due to tourniquet compression is referred to as tourniquet palsy. This

phenomenon is more common in emergency than elective tourniquet use, specific to the actual level of tourniquet application, primarily manifests as motor weakness, and typically resolves in three days or less.[24] Palsy findings may be subtle in the face of major limb trauma, so careful serial examination by a specialist may be necessary to differentiate between the complication and traumatic nerve injury manifestations.[25] Urgency and extended duration of surgical tourniquet use has also been identified as a risk factor for venous thromboembolism (VTE).[26] Symptomatic and asymptomatic VTE is present in up to 15 percent of patients undergoing elective knee arthroscopy with surgical tourniquets but it is not reported in any of the presently reviewed studies.[27] Limb tourniquets have a unique and potentially devastating complication profile.[28, 29] Further study of their use in civilian limb trauma should include specific attempts to identify tourniquet-related complications so as to better understand their occurrence. Gaining this understanding will require examining clinical parameters at presentation such as detailed limb injury pattern and severity and degree of shock. Data should also be gathered regarding patient stabilization, operation, and recovery and rehabilitation. The best quality of comprehensive data representing a patient's hospital and rehabilitation course will come from prospective collection. To better understand the effect of tourniquet use on outcomes, future study should include comparative analyses of tourniquet and non-tourniquet control limbs and patients.

Only two of the studies in this review detail whether tourniquet use was indicated, and no common definition is used or suggested. The indication criteria reported are based on clinical information only available following patient arrival to the hospital, and no information regarding situational indications is presented. In order for tourniquet indications to have utility in guiding prehospital use, they must contain information readily available in the prehospital setting. While

42 US states have EMS extremity exsanguination protocols and 38 of these mention tourniquets, only 15 provide specific guidance as to the type, indication, technique, and safety concerns regarding their use.[19] Military authors identify two broad categories of limb tourniquet indication: anatomic and situational.[30] Anatomic indications such as traumatic amputation and arterial disruption and the situational indication of providing care under active fire are supported by weak evidence. Remaining potential anatomic tourniquet indications such as venous disruption, open fracture, and expanding hematoma and situational indications such as mass-casualty and multiple injury situations are only supported by low quality evidence.[30] We found the frequency of traumatic amputation and arterial injury to be low in civilian tourniquet use settings. The majority of tourniquets were used for limb injuries (even as minor as bleeding from varicose veins) that might have been controlled with a conventional dressing. Additionally, no situational information is provided in the civilian reports to allow determination of whether tourniquets were used for expediency such as to permit another near-simultaneous lifesaving intervention. Further civilian data on tourniquet use in civilian limb trauma is required to assess how tourniquet indications may translate from military to civilian injuries and situations.

The use of tourniquets for limb hemorrhage by civilian EMS services has been widely advocated in the trauma care community. During an interactive discussion at the 2011 meeting of the American Association for the Surgery of Trauma, almost 90 percent of audience respondents agreed that prehospital tourniquets should be available for use.[31] The American College of Surgeons Committee on Trauma (ACSCOT) has recommended prehospital tourniquet use "for the control of significant extremity hemorrhage if direct pressure is ineffective or impractical."[4] This recommendation is based on the belief that "tourniquets used to treat severe

extremity hemorrhage have a clear survival benefit." This survival benefit has not been substantiated by high level comparative research in civilian trauma and the existing military studies which form the evidentiary basis for the ACSCOT recommendation suffer from considerable survival bias and confounding.[23, 32]

International recommendations for use of limb tourniquets in civilian first aid also draw principally on military data arising from tourniquet use for combat wounds on the battlefield in Iraq and Afghanistan.[5, 6] While encouraging, the applicability of such data to civilian extremity wound patterns and care situations is questionable. This is because the clinical factors and settings differ by base rates of severe limb injury and setting contexts. Even in civilian multiple casualty settings such as mass-shooter situations, fatal limb wounds are uncommon and the effect of tourniquets on survivability has not been studied.[33] The lethality of limb wounds from exsanguination in combat settings is much higher than that seen in most civilian trauma.[34, 35] In addition, the 8 percent rate of traumatic amputation in the reviewed civilian reports does not begin to approach the greater than 30 percent incidence seen in military tourniquet use settings and the overall civilian injury burden was much lower with a mean ISS of 9 versus 17-19 military reports.[36-38] Furthermore, the situational indications for tourniquet use as an expediency such as care under fire or mass casualty situations are more common in war than in civilian prehospital settings. The needs of the combat medic caring for casualties on the battlefield make limb tourniquets reasonable and expedient hemorrhage control adjuncts, but those needs may not apply to civilian prehospital personnel faced with a bleeding limb. Wartime experience has demonstrated the benefits of tourniquets used for hemorrhage control, but their utility in aiding civilian patients has not been well established.

The available military and civilian data suggest that potentially tourniquet-related complication rates appear to be low.[38] Military data, although not directly comparable to the civilian experience due to clinical and situational differences, is compelling as to the lifesaving potential of limb tourniquets. Increasing the civilian use of tourniquets is a central feature of the American College of Surgeons' "Stop the Bleed" program. This widely disseminated public education campaign recommends a tourniquet be used if available as a first-line therapy for life threatening limb hemorrhage.[39] In many large cities (including the authors' home of San Antonio), commercial tourniquets are stocked as standard EMS equipment and are used frequently as first-line agents for prehospital limb hemorrhage in routine clinical situations. It is therefore doubtful that equipoise exists such as would be necessary for a randomized prospective trial to be considered ethical and given the likely low complication rate, it seems reasonable for EMS organizations to continue to implement severe limb hemorrhage protocols which involve the use of commercial tourniquet devices. Such protocols should include education on how to identify limb injuries with life threatening arterial hemorrhage where tourniquets will likely offer the greatest benefit over conventional techniques in addition to device-specific training.

The disparate and heterogeneous nature of the current published data on civilian limb tourniquet use paints an incomplete and unclear picture of their use and outcomes. To better understand civilian tourniquet use, coordinated study geared towards answering questions regarding safety, effectiveness, and situational concerns is needed. Comparative outcomes research specific to severe limb trauma and tourniquet use as well as multicenter registry data

should form the basis of this next step in studying the civilian use of tourniquets for limb hemorrhage.

## Conclusion

The rapid increase in the use of tourniquets for civilian limb hemorrhage control has occurred without a large amount or high quality of data. Adoption of a multicenter registry with standardized prospective data collection specific to limb trauma and tourniquet use can serve to improve the trauma community's understanding of the safety and effectiveness of tourniquet use in civilian trauma settings.

**Author Contributions**

All authors contributed to the acquisition and analysis of data and to the writing of this manuscript.

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Figure 1

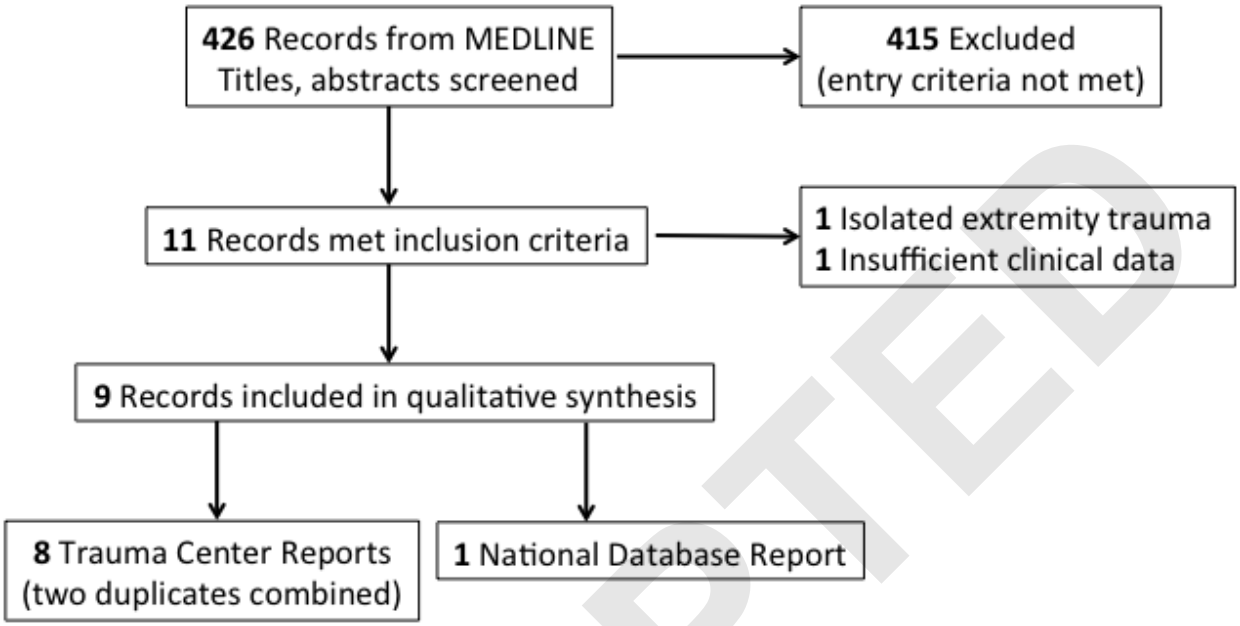

Figure 2

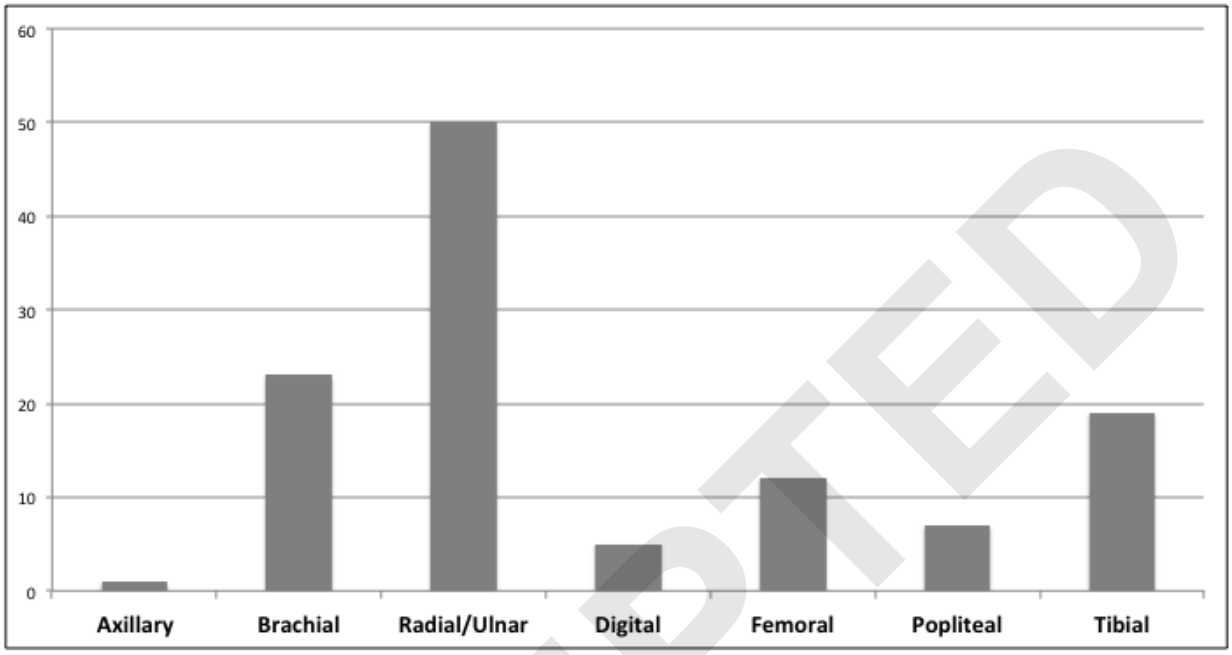

Table 1. Studies included and demographic data.

| Author | Publication Year | Data Years | Location(s) | N (% of total) | Age | Male | Blunt | Penetrating | Medical/ Other |
|---|---|---|---|---|---|---|---|---|---|
| Schroll, et al (10) | 2015 | 2010-2013 | Multiple* | 197 (27) | 39 | 169 | 71 | 111 | 15 |
| Inaba, et al (11) | 2015 | 2007-2014 | Los Angeles | 87 (12) | 35 | 79 | 29 | 58 | 0 |
| Ode, et al (12) | 2015 | 2012-2013 | Charlotte | 24 (3) | NR | NR | 8 | 11 | 5 |
| Kue, et al (13) | 2015 | 2005-2012 | Boston | 98 (13) | 39 | 82 | 9 | 66 | 23 |
| Scerbo, et al (17) | 2017 | 2008-2016 | Houston | 105 (35) | 33 | 92 | 52 | 52 | 1 |
| Leonard, et al (15) & Zeitlow, et al (16) | 2015-2016 | 2009-2014 | Minnesota & Wisconsin | 61 (8) | 35 | 48 | 31 | 23 | 7 |
| Total Trauma Center | 2015-2016 | 2005-2014 | | 719 | 36.4 | 590 (85) | 326 (45) | 342 (47) | 51 (8) |
| El Sayed, et al (18) | 2016 | 2011-2014 | NEMSIS | 2,048 | 44 | 1561 (76) | 1393 (68) | 603 (29) | 52 (2.5) |

* New Orleans, San Antonio, Los Angeles, Phoenix, Pittsburgh, Portland, Dallas, Richmond. NEMSIS – National Emergency Medical Services Information System, NR – Not Reported.

Table 2. Included studies with injury and tourniquet use information.

| Author | ISS | Extremity AIS | Shock/ Hypotension | Traumatic Amputation | Improvised | Upper Extremity | Lower Extremity | Tourniquet Time |
|---|---|---|---|---|---|---|---|---|
| Schroll, et al (10) | 11 | 2.3 | 37 | 15 | 40 | NR | NR | 48 |
| Inaba, et al (11) | 6 | NR | 11 | 9 | 7 | 62 | 25 | 103 |
| Ode, et al (12) | 9 | NR | 12 | NR | 3 | NR | NR | 72 |
| Kue, et al (13) | | NR | 16 | 4 | 98 | 53 | 45 | 15 |
| Scerbo, et al (14) | 9 | 3 | NR | 46 | 5 | 54 | 52 | 48* |
| Leonard, et al (15) & Zeitlow, et al (16) | 9 | 3 | 13 | 2 | 0 | 32 | 29 | 21 |
| Total Trauma Center | 9 | 3 | 89 (13) | 76 (11) | 153 (21) | 276 (55) | 222 (45) | 49 |
| El Sayed, et al (17) | NR | NR | NR | NR | NR | 811 (40) | 559 (27) | 33 |

*Estimated using transport time. ISS – Injury Severity Score, AIS – Abbreviated Injury Scale, NR – Not Reported.

Table 3. Included trauma center studies and outcome data.

| Author | ARTINJ | EFFECTIVE | Mortality | Amputation | All Complications | Compartment Syndrome | Nerve Deficit | Limb Infection |
|---|---|---|---|---|---|---|---|---|
| Schroll, et al (10) | NR | 175 | 6 | 9 | 64 | 17 | 12 | 17 |
| Inaba, et al (11) | 70 | NR | NR | 6 | 7 | 2 | NR | 2 |
| Ode, et al (12) | 16 | NR | 3 | NR | NR | NR | NR | NR |
| Kue, et al (13) | 11 | 87 | 10 | NR | NR | NR | 1 | NR |
| Scerbo, et al (14) | 101 | NR | 13 | 12 | NR | 5 | NR | NR |
| Leonard, et al (15) & Zeitlow, et al (16) | NR | 60 | 6 | 5 | 11 | 0 | 0 | 4 |
| Total Trauma Center | 198 (43) | 322 (90) | 38 (6) | 32 (5.3) | 82 (24) | 24 (4.0) | 13 (3.6) | 23 (4.0) |

INDIC – Indicated, ARTINJ – Arterial Injury, NR – Not Reported.