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Should civilian pre-hospital emergency care provision include tourniquets for the management of uncontrolled traumatic haemorrhage?

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Review

Should civilian pre-hospital emergency care provision include tourniquets for the management of uncontrolled traumatic haemorrhage?

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Abstract

Introduction

Tourniquets are used extensively in military settings, where they have proven to be an effective means of managing uncontrolled external haemorrhage. This review aims to determine the value of tourniquets in the civilian pre-hospital setting.

Methods

A literature search was performed using the following electronic databases from inception to June 2014: MEDLINE, Academic Search Premier and the Cochrane Library. Additional searches were conducted in the Victoria University Library search engine. Key search terms included: pre-hospital, tourniquet, military, complications, failure, ischaemia, metabolic changes, history, and paramedics. Using the search terms outlined above, 236 articles were identified. With further examination 220 were excluded, leaving 16 for review (dated from 1974–2014). Of the 16 articles, two were determined to be relevant, published and peer reviewed case reports while the other 14 were peer reviewed and published studies.

Results

Tourniquet use for controlling major external haemorrhage is more accepted for military rather than civilian applications. Factors contributing to this include lack of education and training, variation and incidence of specific mechanisms of injury, complications such as ischaemia, decreased civilian scene times, and decreased civilian transport times to definitive care. Civilian research was inhibited by study numbers, with much of the data emanating from military research.

Conclusion

To date there is little evidence of tourniquet use in civilian environments, yet recent inclusion into clinical practice by ambulance services in the United Kingdom may yet provide valuable data through future studies. Tourniquet use in civilian environments is considered controversial due to complications and shortfalls. These factors contribute to user apprehension.

Keywords

pre-hospital, tourniquet, military, paramedics

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Introduction

Historically, haemorrhage from extremity injuries account for a significant percentage of preventable trauma deaths (1). The primary function of a tourniquet is to stop life-threatening and uncontrolled external haemorrhage. When appropriately applied, tourniquets occlude blood flow to distal tissue and arrest blood loss (2). This review aims to identify current military and civilian employment of tourniquets, complications arising from use, and controversies associated with their effectiveness.

Method

A literature search was performed using the following electronic databases from inception to June 2014: MEDLINE, Academic Search Premier and the Cochrane Library. Additional searches were conducted in the Victoria University Library search engine. Key search terms included: pre-hospital, tourniquet, military, complications, failure, ischaemia, metabolic changes, history, and paramedics.

Results

Using the search terms outlined above, 236 articles were identified during the initial search. Subsequent exclusions and summary search results are demonstrated in Figure 1.

Military studies

Haemorrhage and exsanguinations from extremity injury are major causes of morbidity and mortality in military conflict (3). For this reason, tourniquets are used extensively throughout military services worldwide. Emergency tourniquets are ideal in the combat setting as high velocity penetrating trauma and blast injuries are common, resulting in significant injuries to limbs and traumatic amputation of body parts. In this setting tourniquets can be applied rapidly by either the layperson/soldier or field

medic, thus creating potential for improved survival through timely application (4).

In the United Kingdom (UK), the military provide an acute awareness of the importance of uncontrolled (or 'catastrophic') haemorrhage (<C>) and have applied a modified trauma paradigm to the management of battlefield casualties. This management has evolved from the traditional model of Airway, Breathing, Circulation (ABC) to that of <C>ABC. This model highlights uncontrolled haemorrhage as a priority over airway and breathing assessment for the wounded soldier (4). It should be noted that military application of tourniquets is intended for under-fire emergency haemorrhage control or catastrophic bleeding, and that direct pressure and dressings remain the primary means of haemorrhage control.

Civilian studies

In contrast, there has been significant resistance to the introduction of tourniquet use for civilian applications, largely associated with the incidence of uncontrolled haemorrhage, and timely access to appropriate medical facilities. Uncertainty regarding the nature and incidence of complications resulting from tourniquet use has also contributed to underutilisation in situations that would otherwise be deemed appropriate. These include penetrating trauma, natural disaster and mass-casualty incident response, terrorist incidents, blast injuries, rural or remote incidents and geographies or populations with limited resources (5).

Pre-hospital emergency services and first responders consider tourniquet use as a last resort (6). A recent study identified a stigma attached to the use of tourniquets for civilian peripheral vascular injury, and an absence of any systemic use by pre-hospital emergency care providers globally (7). Overcoming the reluctance of civilian pre-hospital emergency care providers in utilising tourniquets where appropriate is likely to require both time and significant educational support to reduce the impact of existing cultural beliefs within paramedic practice.

Figure 1. Search results

Table 1. Identified military articles

Authors	Sample size Applications	Study design
Weppner J, Lang M, Sunday R, Debiasse N	1546	Experimental study (device)
Calkins M, Bentley T, Snow C, Costello M	15	Survey
Beekley AC, Sebesta JA, Blackburne LH, et al	165	Retrospective case series
Dayan L, Zinmann C, Norman D, Stahl S	5	Case reports
Kragh JF, Littrel ML, Jones JA, et al	498	Retrospective case series
Clasper J, Brown K, Hill P	113	Cohort study
Kragh J, Baer D, Walters T	1	Case report

Table 2. Identified civilian articles

Authors	Human studies	
	Sample size	Study design
Fludger S, Bell A	1	Case report
Guo J, Ma Y, Pi H, Wang J, Liu Y	20	Prospective interventional (healthy participants)
Haljamae HH, Enger EE	16	Prospective interventional
Kragh J, Littrel ML, Jones J, et al	498	Retrospective case series
Kragh JF, Walters TJ, Baer DG, et al	232	Prospective survey
Passos E, Dingley B, Smith A, et al	190	Retrospective case series
Townsend H, Goodman S, Schurman D, Hackel A, Brock-Utne J	11	Prospective interventional
	Animal studies	
Irving GA, Noakes TD	21	Interventional (porcine)

The use of tourniquets in the civilian setting requires consideration on an individual and situational basis. A cohort study on civilian arterial and extremity injuries reported tourniquet use (7). Of 190 patients who arrived to hospital with a suitable injury for application, only four had received pre-hospital tourniquets. Of these, all were improvised and not specifically designed for use as a tourniquet. In the four patients who received tourniquets in the pre-hospital setting, there were no deaths reported. Furthermore, none of these patients developed rhabdomyolysis or compartment syndrome, nor did they require blood transfusion. Additionally, results concluded that the six deaths that occurred in the 'no tourniquet' group occurred as a direct result of exsanguination (7).

A case report describing an aero-medical retrieval case from Queensland (Australia) in 2009 highlights the reluctance of tourniquet use by emergency service personnel in Australia. The patient discussed in this case was extracted from farm machinery with a partial amputation at knee level. He was then transported more than 25 km to hospital before receiving an improvised tourniquet. It was not until the patient was flown 3 hours to the nearest trauma centre that he received a

specifically designed tourniquet (8).

Complications associated with tourniquet use

A number of studies have highlighted complications that can occur from tourniquet use. Though the aim of tourniquet is to arrest blood flow, the end result can be tissue ischaemia (9). Circulatory arrest impacts both oxygenation and nutrient supply to the cells as well as preventing clearance of waste products. The subsequent metabolic changes can lead to permanent tissue destruction (10). Townsend et al also identified hypoxemia, hyperkalemia and acidosis as metabolic consequences of tourniquet ischaemia in his study on tourniquet release (9).

Other physiological changes associated with tourniquet use range from nerve paralysis and palsies to rhabdomyolysis, compartment syndrome and renal failure. Evidence also suggests an association between tourniquet use and increased vascular coagulation. When limb salvage fails or injuries are incompatible to salvage, amputation often becomes the only plausible option (11).

In another article, two 6-month studies from 2006 were compared (12). They explored 498 military patients who had undergone tourniquet treatment. The aims of this study were to identify complications. Results of this study included penetrating, blunt, crush, thermal or combination injuries, which were a result of explosion in 72% of cases. The most common complications identified include amputation, fasciotomy and thrombus formation. The authors found that minor morbidity was widespread, though often temporary. For example, majority of nerve palsies receded in 3 days. While the data indicates a high frequency of amputation, none of those were as a direct result of tourniquet application. The authors concluded that the risk of mortality outweighs the risk of complication (12).

In the past, tourniquet use has been linked to increased rates of infection. Clasper, Brown and Hill found this to be true when observing 22 soldiers who had received pre-hospital tourniquets (13). Of these patients, 50% were found to have developed an infection. The authors also acknowledged the limitations of this study only including participants with additional bone fracture that may contribute to these results. In saying this, they also found that the life-saving ability of the tourniquet far outweighed any risk of infection (13).

Research into tourniquet safe application time has varied significantly, and is limited in that most studies have been conducted in controlled orthopaedic environments and not in the pre-hospital setting (14). When ischaemic time is limited, changes are typically reversible. However, when left on for durations over 1.5 hours, tourniquet use was associated with increased incidence of degenerative and necrotic changes to muscle fibres and other tissue. Thus, metabolic complications have been shown to increase proportionally to time of ischaemia (10). In Comparison, Kragh et al described safe tourniquet times as being less than 2 hours (5). They also found that while the correlation between increased tourniquet time and metabolic changes was associated with higher rates of amputation and fasciotomy, it did not contribute to other morbidities or mortality (5).

Safe tourniquet time was examined in a series of case studies that reported both excessive pressure and prolonged ischaemia contribute to nerve damage (11). All five patients within this cohort study displayed signs of nerve complications thus supporting the notion that prolonged application time contributes to the prevalence of tourniquet complications (11).

The build-up of waste products during tourniquet ischaemia really comes into play when the tourniquet is released. Rapid post-ischaemic reactive hyperaemia occurs in an attempt to remove waste products and cell debris from the ischaemic tissue. This forces waste into circulation and can have a number of systemic effects (10). Townsend et al explored the systemic and metabolic effects of tourniquet release in 1996 (9). Eleven total knee replacement patients were fitted with tourniquets

under general anaesthesia. Findings revealed a rapid reduction in mean arterial pressure following release. This was attributed to a decrease in peripheral vascular resistance. However, these findings all normalised after a brief period of time. Specific changes included a short-term reduction in the partial pressure of oxygen and a significant elevation in the partial pressure of carbon dioxide lasting approximately 30 minutes. This was accompanied by increased lactate and potassium levels, decreased bicarbonate and therefore a decrease in pH (9). They also found that patients who are normally in good health cope well with tourniquet release, but in those with existing cardiopulmonary dysfunction, systemic and metabolic changes can be significant (9).

Dayan et al reported that while tourniquet placement is indicated in the field, removal should not occur outside of the hospital environment because of the physiological changes that occur in response to release (11). However, this notion also has implications on tourniquet safety time and prolonged application.

Mitigating the potential for complications

Managing or limiting the complications that can arise with tourniquet use can help to reduce apprehension surrounding their use. One method of interest is limb cooling. The benefits of limb cooling in ischaemia have been studied at length. Haljamae and Enger reported that the accumulation of dangerous metabolic waste products decreased as ischaemic time increased (10). They attributed this to the fact that the limb itself was cooling due to loss of perfusion causing a reduction in cellular metabolism. They determined that by inducing external hypothermia, safer tourniquet use with less irreversible damages was achievable (10).

The theory of protective hypothermia was supported in a study using porcine subjects in 1985 (15). The authors found that hypothermia has a protective role in tourniquet use, particularly when the application time was prolonged. In this instance, the authors aimed to ascertain the safety and efficiency of limb cooling during tourniquet application and to examine specific metabolic changes. Like the previous study, they found that induced hypothermia slows down metabolism and leads to a reduced inflammatory response. Additionally, they found that limb cooling during application led to a faster recovery period (15).

Irving and Noakes also reported a number of specific metabolic changes both during and after tourniquet release (15). This involved taking muscle biopsies from cooled subjects and comparing them to control limbs. Biopsies were taken before, during and after tourniquet application. During application there was a more pronounced reduction in glycogenolysis and hydrogen ion production in patients who had undergone limb cooling. This indicates a slower metabolism. The authors also found that cooled patients had a reduced potassium efflux upon tourniquet release indicating reduced muscle damage (15).

Research into the benefits of hypothermia was reinforced by a recent case report describing a patient who had successful limb salvage despite having a prolonged tourniquet application time of over 16 hours. This was attributed to patients in this study enduring temperatures of minus 15 degrees Celsius in the alpine regions of Afghanistan while engaged in military conflict (14).

While techniques such as hypothermia may be useful in managing patient outcome and limb salvage, a number of unavoidable factors require further investigation and quantification. These include patient age, damage to skeletal structures, ischaemic time and tissue damage (13).

Limitations of this study

This review is limited by the focus of many studies on military applications. This is likely a result of specific conflict-related mechanisms of injury resulting in high rates of mortality and morbidity, but also highlights the disparity between civilian and military use of tourniquets, which limits comparisons of effectiveness. The lack of civilian pre-hospital emergency care providers who included tourniquets in their clinical guidelines also limited the availability of data for analysis.

Another limitation was the absence of studies reporting prolonged tourniquet use. This is likely a result of ethical considerations, and the avoidance of potential injury. As a result, case studies reporting unavoidably prolonged application time were relied upon to identify potential complicating injury over time.

Tourniquet release provided some contradiction within studies, with recommendations varying from patient arrival and management in the emergency department to transient release at regular intervals to enable for reperfusion and metabolic clearance.

Conclusion

Tourniquets can potentially reduce mortality when used for specific conditions in the civilian pre-hospital setting. To minimise complications, application time should be monitored closely, particularly where a limb is considered to be potentially viable. Though used extensively in the military, tourniquets are not currently recognised as appropriate practice by pre-hospital emergency care providers generally. The recent introduction of tourniquets for the management of uncontrolled external haemorrhage in ambulance services in the UK is an exception that is likely to provide some evidence of the safety and effectiveness within future studies. It is recommended that the tourniquet should be considered as a useful adjunct in the pre-hospital setting for uncontrolled major external haemorrhage and where transport time to hospital (ie. surgical intervention) is prolonged.

Conflict of interest

The authors declare they have no competing interests. Each author of this paper has completed the ICMJE conflict of interest statement. Gavin Smith is an Associate Editor of the *Australasian Journal of Paramedicine*.

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