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LIMB COMPLICATIONS FOLLOWING PRE-HOSPITAL TOURNIQUET USE

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Abstract

It has been stated that the application of a pre-hospital tourniquet could prevent 7% of combat deaths, however their widespread use has been questioned due to the potential risk from prolonged ischaemia. We reviewed members of the UK Armed Forces who sustained severe limb-threatening injuries in Iraq and Afghanistan, and performed a matched cohort study based on the presence or absence of pre-hospital tourniquet application. When a pre-hospital tourniquet had been applied, 19/22 patients had a least one complication compared to 15/22 where no tourniquet had been applied [p=0.13]. There were 10 limbs with at least one major complication in the pre-hospital tourniquet group but only four in the group with no tourniquet [p=0.045].

The significant difference in the incidence of major complications is a concern, particularly as the difference was mainly due to a deep infection rate of 32% vs. 4.5%. Although a number of variables could have influenced these small groups, such as choice of fracture fixation implant and method and timing of wound closure, the use of a matched cohort study design with a statistical significance level of $p < 0.05$, suggests the use of a pre-hospital tourniquet as a factor. Although the use of pre-hospital tourniquets cannot be decried as a result of this study, the need to continually prospectively review their use to determine their risk/benefit ratio remains.

Introduction

Haemorrhage from the limbs is a significant and potentially avoidable cause of preventable deaths in conflict [1,2]. Properly applied tourniquets can be an effective means of controlling haemorrhage, and Walters, quoting the United States (US) experience in both Vietnam and Somalia, has stated that they could prevent 7% of combat deaths [3]. Both the US and United Kingdom (UK) armed forces have embraced this concept and the Combat Application Tourniquet (CAT) has been introduced for use in the pre-hospital environment to control life-threatening haemorrhage. The widespread introduction of the CAT has resulted in a 20-fold increase in the use of such devices [4]. However, concern has been expressed that the more liberal use of tourniquets may increase the morbidity of the severe limb wounds seen in conflict due to the resulting temporary ischaemia [5]. In particular, injuries associated with an open fracture are associated with a significant complication rate, and risk of later amputation [6]. The aim of this study was to investigate if the pre-hospital application of a tourniquet resulted in an increase in morbidity following significant ballistic limb injury.

Methods

We have previously reviewed members of the UK Armed Forces who sustained life and limb threatening injuries in Iraq and Afghanistan [6]. The database for soldiers injured on operational tour, the Joint Theatre Trauma Register (JTTR), commenced in December 2003 and all patients with an Abbreviated Injury Score (AIS) > 1 in the lower limb category up until May 2008 were identified. An AIS = 1 equates to minor wounds only that will not endanger life, and would not include any patient with a significant extremity injury. Tourniquets should only be applied to limbs with significant haemorrhage and all will have an AIS ≥ 2.

The trauma audit and clinical records of these patients were reviewed by two of the authors (JCC & KVB), including the notes from the UK Field Hospital where the initial assessment and surgery was performed, and their in-patient notes from Selly Oak Hospital, Birmingham, where definitive surgery was carried out. In addition, the operating surgeons involved were contacted if necessary. Basic demographic data collected included patient age, sex, mechanism of injury and date and timings of injury. Specific patterns of injury were documented, including the extent of tissue damage and description at first surgery, presence of limb ischaemia and/or systemic hypotension and presence of a vascular injury. The use of a prehospital tourniquet is specifically recorded on the JTTR, and this was confirmed by reviewing the notes. Tourniquet time was recorded.

A cohort study was then performed based on the presence or absence of a pre-hospital tourniquet in lower limb injuries where there was a fracture, in order to minimise heterogeneity and focus on a group in which tourniquets were most likely to have been applied and in which complications were most likely. Lower limb injuries with a fracture were selected and patient details and all details of treatment and outcome after initial surgery were deleted. An experienced military orthopaedic surgeon blinded to the study (PH) matched each casualty from the pre-hospital tourniquet group with a casualty from the pre-hospital non-tourniquet group; all data was anonymised and identifiable by JTTR number only. Although the exact details of the matching were left to the surgeon, each casualty was only used once and matched for anatomical location, severity of the bony injury, initial surgical management, Injury Severity Score and Mangled Extremity Severity Score [7] as much as possible.

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Pair	MOI	Bone Involved	Age	MESS	ISS	Time to Debridement [Hours]	Tourniquet Time [Mins]	Complications
ONE	IED	Tibia	31	7	10	>3	70	Deep wound infection & flap failure
	IED	Tibia	23	6	10	3	N/A	None
TWO	GSW	Distal Femur	26	5	16	<3	60	Superficial Wound Infection
	GSW	Femur	22	6	16	3	N/A	Deep wound infection needing debridement
THREE	GSW	Fibula	26	4	5	3	145	Superficial Wound Infection & Failed Split Skin Graft
	GSW	Distal Fibula	25	4	4	<3	N/A	None

Table 1: Examples of the matching process – 3 casualties who had a tourniquet applied with their matched pair. The highlighted complication was not available to the matching surgeon. MOI – Mechanism of injury; IED - Improvised Explosive Device; GSW - Gunshot Wound; MESS - Mangled Extremity Severity Score; ISS - Injury Severity Score; N/A – Not applicable

Three matched pairs are given as examples in Table 1.

Following matching, all recorded complications were identified; major complications [defined as a complication requiring surgical treatment] that could significantly affect the outcome were also compared separately. Fishers' Exact test was used to compare the two groups with significance set at p<0.05.

Results

During the study period JTTR recorded 113 significant limb injuries. Of these, 15 had a primary amputation - 13 as part of damage control surgery and two that were deemed anatomically unreconstructable - leaving a potential study group of 98 limbs. Of these, 65 were lower limb injuries with a fracture present which were selected as our study group. In addition there were 26 upper limb injuries with a fracture present and seven significant vascular injuries without a fracture present.

Of the 65 limbs in the study group, 23 had definitely had a pre-hospital tourniquet applied, and 35 definitely had not. In seven cases, the presence or absence of a pre-hospital tourniquet could not be absolutely confirmed and these were excluded. It was not possible to match one of the injured limbs on which a tourniquet had been used due to the extent and location of the injuries and this too was excluded from further analysis.

	Pre-hospital Tourniquet Applied [n=22]	No Pre-hospital Tourniquet Applied [n=22]
Mean Age [Range]	26.6 [19 - 37]	25.7 [19 - 37]
Mean/Median Follow up [months]	14.3/12	19.2/14
Median ISS	10	10
Number with ISS over 15	10	9
Median MESS	5	5
Explosive Mechanism of Injury	7 [31.8%]	14 [63.6%]
Time to initial surgery >6 hours from injury	4	4
Bone Involved: Femur	6	7
Patella	1	1
Tibia	10	11
Isolated fibula	1	1
Ankle + Hindfoot	2	1
Hindfoot/Midfoot	2	1

Table 2: Demographics of the two groups – those who had a pre-hospital tourniquet applied and a matched cohort that did not. ISS – Injury Severity Score; MESS – Mangled Extremity Severity Score.

Complication	Pre-hospital Tourniquet Applied [n=22]	No Pre-hospital Tourniquet Applied [n=22]	Significance
Total Number of Limbs with any complication	19	15	p=0.13
Superficial Wound Infection	11	11	NS
Major Complications	10	4	p=0.045
Failed salvage [amputation required]	3	3	NS
Deep Infection *including* [osteomyelitis]	7 [4]	1 [0]	p<0.05
Flap Failure	1	0	NS

Table 3: Complications in those who had tourniquets applied and those who did not. NS – Not significant

Demographic details of the 2 groups are shown in Table 2 which also includes details of the injury severity and relevant timings. For three of the 22 pre-hospital tourniquets it was impossible to determine accurately the applied tourniquet time due to uncertainty about the times of injury and application. For the remainder, the tourniquets were applied for a median of 60 minutes [range 19 – 150 mins]. Three were applied for greater than the currently recommended maximum time of 120 minutes.

Table 3 lists the major and minor limb complications identified in the two groups. In the pre-hospital tourniquet group 19/22 limbs had a least one complication compared to 15/22 in the no-tourniquet group [p=0.13]. There were 10 limbs with at least one major complication in the pre-hospital tourniquet group and four in the group with no tourniquet [p=0.045].

Discussion

The use of tourniquets in the conflict environment has always been questioned [2,5,8,9]. The debate centres on their ability to improve survival after major haemorrhage versus the potential risk of limb loss from prolonged ischaemia.

Haemorrhage is the leading cause of death following military trauma [1], and recent developments in military resuscitation have placed the control of catastrophic haemorrhage above that of the management of the airway or breathing [9]. This has lead to the introduction of novel haemostatic agents, and the re-issuing of tourniquets to all soldiers in both the US [10] and UK [4] armed forces.

Although it has been acknowledged that tourniquet use can be associated with morbidity [4], a recent prospective study demonstrated improved survival when a tourniquet was applied, and reported that no limb was lost solely from tourniquet use [10]. The outcome after limb salvage however is multifactorial, as scoring systems which consider other factors including age and the degree of soft tissue injury and bony injury demonstrate [7].

The prospective study by Kragh et al focused on early limb loss, with a median follow-up of only seven days [10]. However, early outcome cannot be viewed in isolation when considering limb salvage. Non-union, osteomyelitis and chronic pain are all factors that may lead to late amputation following early limb salvage, and any study should consider these as well.

Although this is a retrospective study, much of the data was obtained from a prospectively collected database, where information on the use of tourniquets is specifically collected and recorded. Even within this, we only considered patients in whom it was certain that a tourniquet had been applied or not; if there was any doubt, the casualty was excluded from further analysis. This data has been previously used to document the short-term complications of tourniquet use [4]. In order to use as an homogenous group as possible we analysed only lower limb injuries with a fracture present, which we felt were the most likely both to have a tourniquet applied, and to be at greater risk of complications. In addition there were 26 upper limb injuries with a fracture present, but only four had a pre-hospital tourniquet applied, which would have created difficulties in matching, and seven significant vascular injuries without a fracture.

Given the strong evidence that tourniquets save lives, a randomised trial would be unethical. In a standard retrospective study it is likely that there would be considerable bias if simple comparison was made between the two groups as it is likely that those casualties with more severe injuries would have required a tourniquet, but those with a more severe injury are also likely to have worse outcomes and experience more complications. To minimise this potential bias we used a cohort study, and Table 1 confirms that these were similar casualties.

The median ISS in both groups was 10, and nearly half of the patients had an ISS greater than 15, confirming that the casualties had sustained significant injuries. The median MESS score was five, which approaches the score where amputation should be considered [7] and again confirms the severity of these limb injuries. Although the results may be affected by the length of follow-up, the higher complication rate was seen in the group with the shorter follow-up. This is unlikely to be a source of bias.

The most common complication was superficial infection, occurring in 50% and there was no difference in the incidence between the two groups. This marked infection rate is due to the nature of military wounds, which are highly contaminated and associated with significant bone and soft tissue injury; a 35% incidence of infectious episodes following limbs wounds has been reported from a large series of US combat wounds [11]. Our increased infection rate probably reflects the fact that we only studied wounds with an associated fracture. We have previously documented an increased incidence of complications following extremity vascular injury, when associated with a fracture [6].

The significant difference in the incidence of major complications after tourniquet use is a concern, particularly as the difference was mainly due to a deep infection rate of 32% vs. 4.5%. Although there are a number of variables which could have influenced outcomes and complications in these small groups, such as choice of implant for fracture fixation and the method and timing of wound closure, the use of a cohort study design and statistically significant results at the level of $p=0.05$, suggests that the use of a pre-hospital tourniquet was a factor. This is likely to be due to the ischaemia time, and would be consistent with literature documenting a higher infection rate following vascular injury resulting in temporary ischaemia [12].

The only notable difference between the two groups was the mechanism of injury; those with no pre-hospital tourniquet applied were twice as likely to have been injured by an explosive mechanism rather than fragments or bullets. The reason for this difference, which approaches but does not reach statistical significance [$p=0.07$] in this small study is uncertain, but could be a source of bias and merits further study.

Conclusions

Ultimately the use of the tourniquet may have saved lives, and did not increase the amputation rate in this small study, and so despite the increased deep infection rate the use of pre-hospital tourniquets cannot be decried as a result of this study.

There remains a need to continually prospectively review their use, to determine the risk/benefit ratio. We recommend that this study is repeated when a larger number of patients and longer follow-up is available, and that the mechanism of injury is specifically matched between the two groups.

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