

Battle Casualty Survival With Emergency Tourniquet Use To Stop Limb Bleeding

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Background: In spite of recent positive reports of the use of emergency tourniquets from studies conducted at US combat support hospitals in Iraq, these devices are still considered controversial by some providers. We recently reported major lifesaving benefits and minor morbidity risks with emergency tourniquet use to stop bleeding in major limb trauma (1,2). Our goal was see if our preliminary findings would hold true as the war progressed and tourniquets continued to be used. The fielding of tourniquets during the current war and the number of casualties permitted us to study and continue to evaluate performance. Improving prehospital hemorrhage control is vital to military and civilian trauma care and we continue our efforts to fill knowledge gaps regarding first aid of limb-injured patients. There is no consensus on tourniquet use in civilian trauma, but adequate collection of military data may help to change this.

Study Objectives: Specifically, our objective was to assess morbidity and mortality associated with tourniquet use.

Design and Setting: The current report was designed to test the consistency of the findings of our previous reports on emergency tourniquet use (1,2). The design was an observational study of patient care; there was no experiment or intervention. Before the study began we predetermined the data of interest, e.g., possible tourniquet morbidity. The study was approved by our institutional review board as part of an ongoing prospective performance improvement project on tourniquet use (NCT00517166 at ClinicalTrials.gov). The informed consent waiver was approved.

The setting was a military hospital in support of combat and related security work where casualties including civilians were admitted directly or transferred from forward surgical teams. Prehospital tourniquets were applied by people with a wide range of medical skills and included casualties themselves, lay bystanders, soldiers, medics, nurses and doctors. Tourniquets are part of standard prehospital care to stop bleeding in combat and are often used before pressure dressings during care under fire. All deployed US servicepersons get tourniquet training with instructions to apply them as soon as possible to stop potentially lethal external limb bleeding; the soldiers were taught how to use the tourniquets simplified from Tactical Combat Casualty Care in Pre-Hospital Trauma Life Support. The aim of tourniquet use is to prevent hemorrhagic shock and save lives while minimizing morbidity. Casualties were transferred to other hospitals for definitive care.

Patients and Methods: All patients at the combat support hospital who had a tourniquet of any type used in their emergent health care were included in the study. Patients with tourniquets ready at the bedside, purposefully left loose, or whose first applied tourniquet was in the hospital operating room were excluded. Detainees and prisoners of war are restricted from research by military policies and were also excluded.

The study period was one year made of two consecutive six-month time periods. The primary investigator (first author), an orthopaedic surgeon with extensive experience with emergency tourniquet use, was the site investigator for the first time period; the second author, a registered nurse new to tourniquets, was the site investigator for the second time period. The nurse was a founding member of a deployed research team. Hospital providers were replaced at the same time as the investigators.

Results: The total study population was 499 (232 in the previous study and 267 in the current study). In all, 862 tourniquets were applied on 651 limbs. Survival was 87% for both study periods. Morbidity rates for palsies at the level of the tourniquet were 1.7% for study 1 and 1.5% study 2, major limb shortening was 0.4% for both. Survival was associated with prehospital application (89% v. 78% hospital, $p<0.01$) and application before the onset of shock (96% v. 4% after).

The two study periods were similar for the number of patients, deaths, palsies at the level of the tourniquet, and limbs with major shortening so the data were consistent, and therefore we pooled data for further analysis. The study group consisted of 499 patients from 13 nations, and included 257 Iraqis and 226 Americans. There were 479 males and 20 females, 16 children and 5 elderly patients. The average age was 29 years. Follow up averaged 36 days.

Of all 651 limbs (499 patients), 635 (483 patients) had indicated tourniquet use. There were 16 limbs (15 patients) that had tourniquets

applied but did not have a medical or tactical indication. Of the 15 patients, one Iraqi had a right biceps brachii soft tissue injury, but had a tourniquet applied prehospital to the left upper extremity. The tourniquet was removed in the ED; it had been used for 25 minutes. The patient had no morbidity from the tourniquet, and this use was unindicated medically (a pressure dressing sufficed) and misplaced (wrong limb). For this one patient the tourniquet was indicated for care under fire. Fourteen patients had 15 tourniquets for 15 soft tissue injuries that were converted to pressure dressings in the ED, and no tactical indication was present prehospital for these 14 patients. A prehospital pressure dressing would have sufficed for the fifteen wounds. Of the 16 unindicated tourniquets the maximum tourniquet duration was 2 hours, and none of the 16 limbs had morbidity.

All patients except one had emergency tourniquet use that was appropriate. All were aimed at being an arterial tourniquet except the one patient that had a purposeful venous tourniquet. This one patient had open type 3B tibia and fibula shaft fractures and a medically indicated tourniquet used inappropriately as a venous tourniquet in the ED. The patient also had 40% body surface area burns. No complications other than blood loss were attributable to inappropriate use, and tourniquet replacements or corrections were made on the spot.

Misuse occurred in 13 cases including the patient described above who had a tourniquet on a wrong limb. We fixed these problems with improved training, device design refinements, and more device testing and maintenance procedures.

Ten patients who came to our hospital during the study period had isolated limb exsanguination amenable to tourniquet application, but tourniquets were either unavailable (none at scene), inaccessible (packed away and found after the patient died), or not placed in time after extrication from vehicles or after transport before the patient died. Cause of death in all ten patients was exsanguination from limb injuries. In contrast to the 10 casualties without tourniquets, the 499 casualties with tourniquets had 16 of the 65 deaths from isolated limb exsanguination often with tourniquets used after shock onset (19 had severe [AIS 3 to 6] head wounds, 15 had severe abdominal wounds, 7 had severe chest wounds, 4 had severe burns, and 2 had 2 or more equally severe body regions injured). From the ten patients without tourniquets (0% survival) and the 499 with tourniquets (87% survival), we measured the mortality rate of patients that exsanguinated from isolated limb injuries at 2% (10/519).

The results of the tourniquet use with shock present v. when shock was absent were consistent in the two time periods so we pooled the data. Patients had a 500% (429/476 v. 4/22, lived/died) better survival rate when tourniquets were applied before shock onset rather than after. Tourniquet use in the absence of shock was associated with survival ($p<0.001$), and prehospital use was associated with survival ($p=0.015$). Prehospital use was associated with shock absence and ED use was associated with shock presence ($p<0.001$). Survival was associated with use both before shock onset (96% before v. 4% after, 477/499 v. 22/499) and prehospital (89% prehospital v. 78% hospital, 374/422 v. 59/76, $p=0.015$).

Conclusions: This study shows consistent lifesaving benefits and low risk of emergency tourniquets to stop bleeding in major limb trauma..

Tourniquet use is important as first aid is lifesaving on the battlefield but controversial in civilian trauma, and recent military experiences are referents of lessons learned. This study shows that battle casualty survival rates remain high with emergency tourniquet use to stop limb bleeding while morbidity rates remain low in comparison with prior reports. The key finding is that evidence indicates that when used for the right patient at the right time in the right way, emergency tourniquets save lives. Patient care is impacted in that tourniquet use for limb hemorrhage control on the battlefield increases survival time permitting more effective resuscitation and yielding higher survival rates.

1. Kragh JF Jr, Walters TJ, Baer DG, et al. Practical use of emergency tourniquets to stop bleeding in major limb trauma. *J Trauma*. 2008;64:S38-S50.

2. Kragh JF, Walters TJ, Baer DG, et al. Survival with emergency tourniquet use to stop bleeding in major limb trauma *Ann Surg*. 249(1):1-7, 2009.