Prehospital Use of Hemostatic Bandages and Tourniquets: Translation From Military Experience to Implementation in Civilian Trauma Care

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ABSTRACT

Background: While the military use of tourniquets and hemostatic gauze is well established, few data exist regarding civilian emergency medical services (EMS) systems experience. **Methods:** A retrospective review was performed of consecutive patients with prehospital tourniquet and hemostatic gauze application in a single ground and rotor-wing rural medical transport service. Standard EMS registry data were reviewed for each case. **Results:** During the study period, which included 203,301 Gold Cross Ambulance and 8,987 Mayo One Transport records, 125 patients were treated with tourniquets and/or hemostatic gauze in the prehospital setting. Specifically, 77 tourniquets were used for 73 patients and 62 hemostatic dressings were applied to 52 patients. Seven patients required both interventions. Mechanisms of injury (MOIs) for tourniquet use were blunt trauma (50%), penetrating wounds (43%), and uncontrolled hemodialysis fistula bleeding (7%). Tourniquet placement was equitably distributed between upper and lower extremities, as well as proximal and distal locations. Mean tourniquet time was 27 minutes, with 98.7% success. Hemostatic bandage MOIs were blunt trauma (50%), penetrating wounds (35%), and other MOIs (15%). Hemostatic bandage application was head and neck (50%), extremities (36%), and torso (14%), with a 95% success rate. Training for both interventions was computer-based and hands-on, with maintained proficiency of >95% after 2 years. **Conclusion:** Civilian prehospital use of tourniquets and hemostatic gauze is feasible and effective at achieving hemostasis. Online and practical training programs result in proficiency of skills, which can be maintained despite infrequent use.

KEYWORDS: *dressing, hemostatic; tourniquet; trauma care, prehospital civilian*

Introduction

Uncontrolled hemorrhage is a leading cause of prehospital mortality in military trauma and the second leading cause after civilian trauma.[1–3] While the use of emergency tourniquets and hemostatic gauze in military populations has been thoroughly documented, the same cannot be said for civilian populations.[4] Despite the effectiveness of tourniquets and hemostatic gauze in military populations and the recommendation from Advanced Trauma Life Support,[5] the use of tourniquets and hemostatic gauze in the civilian emergency medical services (EMS) community is not widespread.[6,7] Mayo Clinic's prehospital providers, Gold Cross Ambulance and Mayo One Medical Transport, were trained to use tourniquets (beginning in 2009) and hemostatic agents (in 2011) via computer-based didactic training with hands-on practice, in an effort to use these agents for improved patient outcomes.

The purpose of this project was to determine if the success for tourniquets (Combat Application Tourniquet [CAT®]; Composite Resources Inc.; http://combattourniquet.com) and hemostatic gauze (QuikClot Combat Gauze®; Z-Medica LLC; www.z-medica.com/healthcare/Products) in the military could be translated to civilian use. While these interventions are effective in a military population that is predominantly composed of young men with few comorbidities, it is unknown if they would be as effective in a civilian population composed of all ages, both sexes, and individuals with multiple comorbidities. Based on the training completed by Gold Cross and Mayo One Medical Transport, the effectiveness and proficiency was also reviewed in conjunction with the retrospective study.

Methods

Setting

The Gold Cross Ambulance and the Mayo One Medical Transport service provide medical transportation within the tri-state area of Iowa, Minnesota, and Wisconsin. In a typical year, Gold Cross provides 60,000 ground transports with 60 ambulances in 12 locations, while Mayo One provides 2,000 air transports with four helicopters in three sites (Eau Claire, Wisconsin; and Mankato and

Rochester in Minnesota). Combined, they employ 400 total team members (350 paramedics and 50 flight team members).

Study Design

This was a retrospective review of consecutive patients with prehospital tourniquets and hemostatic gauze applications using a single service ground and rotor-wing rural program. The study period was from 20 June 2009 to 1 January 2014, for tourniquet use, and 4 November 4 2011 to 1 January 2014 for hemostatic agent use. All patients transported during this time who required either a tourniquet and/or hemostatic gauze were included in the study. No experimental interventions were performed. The study was approved by the Mayo Clinic institutional review board.

Data Management

The records of patients to be included in the study were located by a query of the electronic transport-record database during the study time frames. This query included 203,301 Gold Cross Ambulance and 8,987 Mayo One Transport charts. The following data points were used in the search: run number, date of service, ground or air transport, city of origin, destination city, transport outcome (transported, care turned over to an air service, or resuscitation terminated in the field), and the tourniquet and hemostatic dressing intervention. The abstraction form was created based on the known information collected within prehospital charts used by Mayo One and Gold Cross and followed the same order that information was presented in these charts. All personal identifiers were removed prior to data abstraction, in compliance with patient confidentiality standards. Data points included standard demographics and details of the patients' presentation. Using explicit criteria, this review collected specific details of tourniquet and hemostatic gauze use, including application information, effectiveness, and complications, as well as all available laboratory and comorbidity information. The criteria for tourniquet success were based on effectiveness in stopping arterial bleeding (pulsating quality). Hemostatic agent use leading to effective hemostasis was defined as the cessation of clinically observable bleeding. If any of the above criteria were missing from a patient's chart, that specific patient encounter was not included in the study.

Results

Of the 125 patients, 6 (5%) were <16 years old and 23 (18%) were >65 years old; the remainder were between 16 and 65 years old. Also, approximately 20% of patients (12 treated with a tourniquet and 12 with hemostatic gauze) were in shock upon arrival, according to the shock index (SI).

Tourniquet

In the tourniquet population, the majority of patients were male, with a mean age of 42 years, who were transported from the scene of injury via ground transport (Table 1). The locations of injuries are summarized in Figure 1; injuries were equally distributed between upper and lower extremities. The mechanisms of injury (MOIs) included a mix of penetrating and blunt injury (Table 2). Of note, 7% of patients requiring a tourniquet developed uncontrollable hemodialysis-fistula bleeding—a patient condition previously unrecognized by most trauma surgeons.

Table 1 *Patient Population Demographics*

	Tourniquet	Hemostatic Gauze
Patients, n	73	52
Sex, male	60 (82%)	37 (71%)
Age, mean y (range)	42 (1–83)	49 (16–93)
Ground, n	59 (81%)	36 (69%)
Air, n	14 (19%)	16 (31%)
Scene, n	62 (85%)	39 (75%)
Interfacility, n	11 (15%)	13 (25%)

Figure 1 *Tourniquet injury location.*

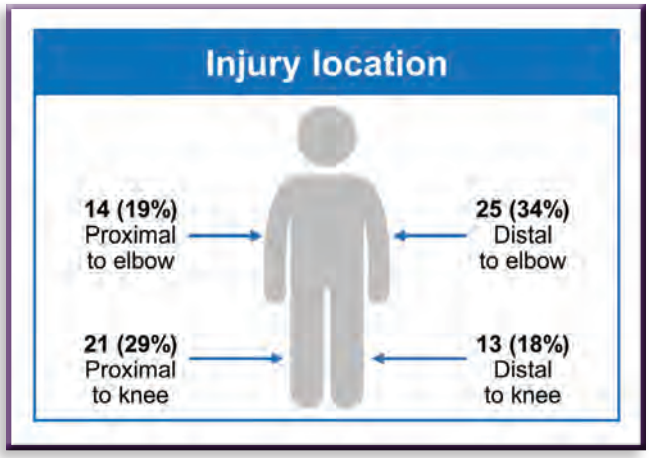


Table 2 *Mechanism of Injury*

Mechanism, n	Tourniquet	Hemostatic Gauze
Blunt	27 (37%)	15 (29%)
Laceration	21 (29%)	12 (23%)
Stab wound	7 (10%)	5 (10%)
Hemodialysis	5 (7%)	1 (2%)
Fall	3 (4%)	11 (21%)
Gunshot wound	3 (4%)	1 (2%)
Other	7 (10%)	7 (13%)

Table 3 shows various time frames associated with the study. Injury-to-intervention time was defined as time from 911 call to on-scene arrival. The transport time was defined as time from departure from scene or facility to arrival at the destination center. Intervention-in-use time was defined as the time from when a tourniquet or hemostatic gauze was placed until arrival at the destination center.

Table 3 *Timeframe for Tourniquet and Hemostatic Gauze Use*

Time, min	Tourniquet	Hemostatic Gauze
Injury to intervention, median (range)	8 (2–95)	17 (1–198)
Transport, median (range)	9 (1–74)	12 (3–162)
Intervention in use, median (range)	19 (1–145)	21 (2–181)

Table 4 *Tourniquet and Hemostatic Gauze Use and Success*

	Tourniquet, n (%)	Hemostatic Gauze, n (%)
Prior to our arrival	16 (22)	0 (0)
On scene	52 (71)	46 (88)
En route	5 (7)	6 (12)
Successful hemostasis	76 (99)	59 (95)

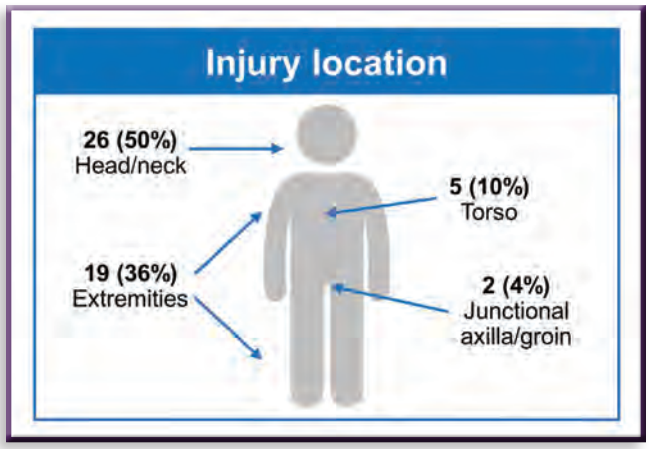
Table 4 explains who placed the tourniquet and when it was placed, as well as if the agent was successful. If a tourniquet was placed prior to our arrival (PTA), it was either by another EMS team, firefighter, law enforcement officer, another hospital, or bystander. The majority of tourniquets (71%) were placed on scene.

Overall, 98.7% (76 of 77) of the CAT tourniquets were successful in stopping arterial bleeding. While 77 tourniquets were used for 73 patients, only one was used on the same extremity, due to incorrect application of the first tourniquet at an outside emergency department (ED). The other patients who required more than one tourniquet only needed one tourniquet per injury location. Of note, once a tourniquet was placed, our protocol is to leave it in place until arrival at the ED or operating room (OR). All three improvised tourniquets used PTA were unsuccessful.

Hemostatic Gauze

In the hemostatic gauze study group, the majority were male patients (mean age, 49 years) who were transported from the scene of injury via ground transport (Table 1). Half of the wounds involved the head and neck, with the other 50% involving the rest of the body (Figure 2). Only four patients had a junctional injury (two neck and two axilla/groin) requiring hemostatic gauze. While

Figure 2 *Hemostatic gauze injury location.*



junctional hemorrhage is common in battlefield injuries, they are relatively rare in civilian injuries. There was a wide variety of MOIs, with the "other" category including postoperative axillary hemorrhage, tonsillar hemorrhage, and vaginal hemorrhage (Table 2).

Table 3 describes the time frames associated with hemostatic gauze use, and the definitions are the same as with tourniquet use. As seen in Table 4, no hemostatic dressings were applied PTA because, at the time of the study, no other prehospital program in the tri-state area carried hemostatic dressings. The majority (88%) were placed on scene.

Hemostatic gauze was highly successful at stopping bleeding, with 59 of 62 injuries (95%) achieving hemostasis. A total of 62 hemostatic dressings were used for the 52 patients, as eight patients required more than one roll, but only one roll was needed per wound location. According to our prehospital protocol, hemostatic gauze was only applied after standard compression bandages were unsuccessful. As for the three (5%) that were unsuccessful, one injury occurred to the scalp, face, and extremity, respectively.

Combined Tourniquet and Hemostatic Gauze Use

Interestingly, in seven instances, a patient required both a tourniquet and hemostatic gauze. Four patients had successful simultaneous placement without issue. Two patients had a tourniquet placed properly PTA of our prehospital personnel, with initial success in stopping arterial bleeding, but were augmented 12 and 48 minutes later with hemostatic gauze to control venous bleeding. One use of hemostatic gauze was initially unsuccessful; however, a tourniquet was applied successfully afterwards, with resulting hemostasis.

One prehospital death occurred during our experience. This patient had a hemodialysis shunt malfunction in his left upper extremity with massive hemorrhage. Upon

arrival of EMS, cardiopulmonary resuscitation was in progress by firefighters on scene. A tourniquet was placed by our EMS personnel and achieved hemostasis, however, the patient never regained spontaneous circulation and expired in the field.

Discussion

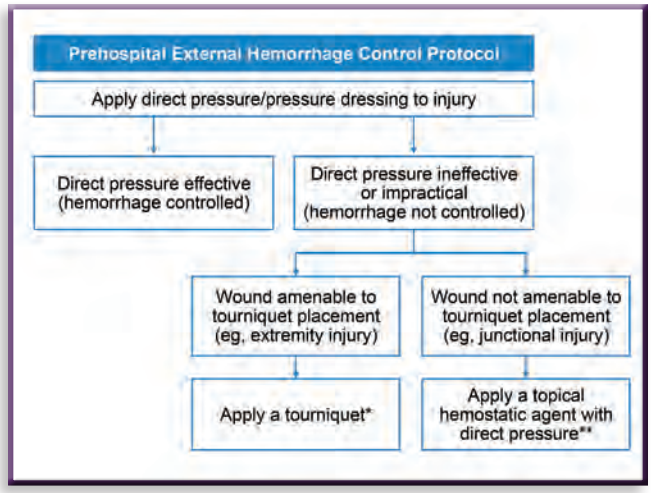
Tourniquets have a long and complicated history. The use of tourniquets dates back to 1517, when bandages were used proximal to wounds to help control bleeding.[8] However, over time, the fact that most major external hemorrhage can be controlled with direct pressure, as well as the increased recognition of the morbidity associated with tourniquets, led to decreased use. Some of the major morbidity results of tourniquet use, including permanent nerve, muscle, vascular, and soft tissue injury, significant pain, and improper application of improvised, ineffective tourniquets, led to emergency medical authorities discouraging their use.[9,10]

The key to the re-emergence of tourniquet use has been the development of commercial tourniquets and training for providers in their appropriate use, leading to a decrease in the morbidity and mortality associated with historical tourniquet use. Military experience has shown tourniquets and hemostatic agents to be safe and effective, significantly decreasing mortality from extremity hemorrhage.[11] Currently, all military personnel in theater, not just the unit medics, carry tourniquets and/or hemostatic agents and are trained to use these products.[11] From the largest military experience database present, which included 499 combat individuals, Kragh et al. found that tourniquet use was strongly associated with survival when shock was absent. The use of tourniquets on the battlefield contributed to improved hemorrhage control and survival. Tourniquet use caused no loss of limbs, and morbidity attributable to the tourniquet was minor.[12]

In the UK Armed Forces, QuikClot Combat Gauze is issued to military medical technicians for use on external injuries when conventional gauze field dressings have failed.[13] Similarly, a study from the Israeli Defense Force highlighted the importance and effectiveness of QuikClot Combat Gauze in the prehospital treatment of combat casualties.[14] While previous-generation products by QuikClot have had side effects, including partial-thickness burns due to a consequential exothermic reaction from product activation, the third generation product is heat free.[15] Furthermore, its mechanism of action has improved, as it is a kaolin (clay) impregnated bandage that enhances clotting and platelet function, as well as absorbance.

As seen in this study, all three improvised tourniquets (belts) were unsuccessful. Furthermore, the one commercial tourniquet failure was due to improper placement. However, when the misplaced tourniquet was replaced with a properly placed one, external hemorrhage was controlled. The proper use of these agents produces good outcomes, as seen in experimental studies that showed 100% effectiveness in human volunteers.[16] A CAT should be placed 2–3 inches above the wound location and tightened to occlude arterial blood flow. Furthermore, the tourniquet should not be removed until the patient arrives at an ED or OR. QuikClot Combat Gauze should be placed on or in the wound and held with direct pressure for 3 minutes. It should also not be removed until arrival at an ED or OR. The majority of external hemorrhages can and will be controlled by applying a stepwise approach (Figure 3[17]).

Figure 3 *Protocol for prehospital external hemorrhage control.*



The recent Hartford Consensus conference has encouraged wider civilian use of tourniquets for management of hemorrhage in active shooter situations.[18] Junctional zones, such as the groin, axilla, neck, and perineum, present a particular problem to medical personnel when trying to control the hemorrhaging wound and are clearly inappropriate for tourniquets.[4] Bulger et al. recommended the use of topical hemostatic agents, in combination with direct pressure, for the control of significant hemorrhage in the prehospital setting, in anatomic areas where tourniquets cannot be applied and where sustained direct pressure alone is ineffective or impractical.[17]

Based on the military's success with tourniquets and hemostatic bandages, our prehospital personnel began using tourniquets and hemostatic gauze as adjuncts for hemorrhage control. To date, this study is the first report of their use in the civilian population, which clearly differs significantly from the military population. The mean age of the Active Duty Force is 28.7 years and 85.4% of this population is male,[19] compared with

a mean civilian age of 37.2 years, with 49.1% of the population being male.[20] Despite these differences, we have shown the tourniquet and hemostatic gauze were both safe and effective within this population.

Based on our experience, with 11.2% of cases (14 of 125) requiring multiple tourniquets or hemostatic agents, each prehospital vehicle in our system currently carries two tourniquets and two hemostatic dressings. The cost for one CAT is $33.25[21] and for one QuikClot Combat Gauze is $41.31.[22] Thus, having two of each per transport vehicle is adequate without adding excessive expense or taking up disproportionate space in otherwise fully loaded vehicles.

Training

To achieve and maximize effectiveness, training is vital. Training played a crucial role in our study for both the tourniquet and hemostatic gauze. In our system, tourniquet training includes computer-based didactic training with hands-on practice, which was initiated 1 month prior to implementation in June 2009. Subsequent skills testing within 6 months of implementation showed proficiency of 98.5% (326 of 331 providers). For those providers who failed this skill testing, immediate remedial training was completed. The follow-up skills testing within 2 years showed a maintenance of proficiency at 98% (350 of 357 providers).

The training for the hemostatic gauze was similar to tourniquet training. The computer-based and hands-on training 1 month prior to implementation was deployed, but subsequent skills testing within 12 months only showed proficiency of 90% (338 of 375 providers). Nonetheless, with revisions of the guidelines and training manual, the proficiency improved to >95% and has been maintained.

A major outcome of this retrospective study is the training for and implementation of tourniquets and hemostatic dressings with law enforcement and firefighter units. As seen in our results, 22% of tourniquets were placed prior to the arrival of EMS personnel. Of those, 98.7% of the commercial tourniquets were successful, while the three improvised tourniquets (belts) were unsuccessful. Additionally, with 7% of the tourniquets being used for hemodialysis-shunt hemorrhages, it may be beneficial for hemodialysis units and/or hemodialysis patients to carry tourniquets, with the proper training to help prevent exsanguination in the case of major shunt hemorrhage.

Limitations to this study include its retrospective nature and small sample size. While the numbers are small, ours is the first and largest civilian report of tourniquet and hemostatic agent use. The realities of prehospital care often preclude a complete documentation of the circumstances surrounding procedures or clinical decision-making rationale. Thus, explanations as to why a tourniquet was placed first or why a wound was augmented with hemostatic dressings are sometimes unclear. Also, in the majority of cases, the patients' medical histories were unknown and thus undocumented. For example, the anticoagulation status was only known in 7.3% of patients (11 of 150), which could impact morbidity and mortality in patients with external hemorrhage. Finally, being a retrospective review, follow-up with patients in regard to outcomes and morbidity was limited due to the distribution of patients throughout the state: only 40% of the patients were initially transported to our trauma center.

Our report provides a foundation for further investigation in civilian tourniquet and hemostatic gauze use. Inpatient follow-up from our statewide trauma data system is ongoing. Other needs include prospective studies with larger population sizes to determine effectiveness, and morbidity and mortality rates in varied civilian populations.

Conclusion

The use of tourniquets and hemostatic gauze in prehospital civilian care is safe and highly effective, with success rates of 98.7% and 95%, respectively. Furthermore, training and subsequent proficiency of skills are maintained despite infrequent use of only about two times per month. Our single-system experience can be applied to other prehospital care programs, including other first responders. Our experience has shown that hemodialysis units may wish to stock tourniquets and hemostatic gauze for emergency use in this heretofore unrecognized vulnerable patient population.

Disclosures

The authors have nothing to disclose.

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