

Survey of the Indications for Use of Emergency Tourniquets

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ABSTRACT

Indications and evidence are limited, multiple and complex for emergency tourniquet use. Good recent outcomes challenge historically poor outcomes. Optimal tourniquet use in trauma care appears to depend on adequate devices, modern doctrine, refined training, speedy evacuation, and performance improvement. Challenges remain in estimation of blood loss volumes, lesion lethality, and casualty propensity to survive hemorrhage.

Summary Background Data: Evidence gaps persist regarding emergency tourniquet use indications in prehospital and emergency department settings as indication data are rarely reported. **Methods:** Data on emergency tourniquet use was analyzed from a large clinical study (NCT00517166 at ClinicalTrials.gov). The study included 728 casualties with 953 limbs with tourniquets. The median casualty age was 26 years (range, 4-70). We compared all other known datasets to this clinical study. **Results:** Tourniquet use was prehospital in 671 limbs (70%), hospital only in 104 limbs (11%), and both prehospital and hospital in 169 limbs (18%). Major hemorrhage was observed at or before the hospital in 487 (51%) limbs and minor hemorrhage was observed at the hospital in 463 limbs (49%). Anatomic lesions indicating tourniquets included open fractures (27%), amputations (26%), soft tissue wounds (20%), and vascular wounds (17%). Situations, as opposed to anatomic lesions, indicating tourniquets included bleeding from multiple sites other than limbs (24%), hospital mass casualty situations (1%), one multiple injury casualty needed an airway procedure, and one casualty had an impaled object. **Conclusions:** The current indication for emergency tourniquet use is any compressible limb wound that the applicator assesses as having possibly lethal hemorrhage. This indication has demonstrated good outcomes only when devices, training, doctrine, evacuation, and research have been optimal. Analysis of emergency tourniquet indications is complex and inadequately evidenced, and further study is prudent. Prehospital data reporting may fill knowledge gaps.

Objective: The purpose of this study is to report and analyze emergency tourniquet use indications to stop limb bleeding.

INTRODUCTION

For two millennia, the indication for emergency tourniquet use has been a most controversial first aid topic,¹⁻⁷ but recent tourniquet use in war has had favorable results in terms of hemorrhage control and major survival improvement with minor morbidity risk.⁸⁻¹² The most important issue regarding emergency tourniquet use is the decision of the applicator when or if to use one — in other words, what is the indication? Few studies offer much insight on tourniquet indications beyond clinician experience; so analysis has been limited. We completed a large clinical study at a combat support hospital in Baghdad, Iraq,¹¹⁻¹² and such recent reports with new evidence permit a fresh look at this controversial first-aid device. Proponents of Tactical Combat Casualty Care advocated that the indication for emergency tourniquet use was any compressible limb wound that the applicator assesses as having possibly lethal hemorrhage.¹³ However, there was no data on which to evidence that premise. The purpose of this study is to report and analyze tourniquet indications from that trial.

METHODS

The current report was designed to report indications

data for a clinical study, a performance improvement project on tourniquet use (NCT00517166 at ClinicalTrials.gov). This study was conducted under a protocol reviewed and approved by the Brooke Army Medical Center Institutional Review Board and was conducted in accordance with the approved protocol. The study setting was a combat support hospital (CSH) in Baghdad, Iraq. Tourniquet use during the study period was a standard prehospital hemorrhage control measure. Individual Soldier training is based on Tactical Combat Casualty Care as in Pre-Hospital Trauma Life Support teaching, see appendix.¹³ All deployed U.S. servicepersons are issued a tourniquet in their Individual and Vehicle First Aid Kits as well as medic assemblages, and they get tourniquet training with instructions to apply them as soon as possible to stop potentially lethal external limb bleeding. The study period was from 2006 to 2007 and included 728 casualties in three study portions with three different site investigators who studied 232, 267, and 225 casualties in each portion. The first and second portions have been reported regarding the mortality and morbidity, but little data on indications were included in those reports.^{11-12, 14}

Table 1: Emergency Tourniquet Indication Evidence

Evidence	Citation	General Level of Evidence
Anatomic Indication		
Traumatic amputation	9,10,11,20,24,25,66	Mid
Arterial disruption	9-11,20,23-25	Mid
Venous disruption	11	Low
Open fracture	9,11,13,20	Low
Soft-tissue injury	9,11,20,24	Low
Impaled object	9	Low
Neurologic injury	9	Low
Expanding hematoma	23	Low
Miscellaneous	11	Low
Situational indication		
Care under fire	8-11,14,15,24,25	Mid
Mass casualties	9,11	Low
Multiple-injury casualty	9,11,	Low
Darkness	9	Low

Table 2: Tourniquet Use Indications of Lakstein et al.⁹

- Failure to stop bleeding by direct pressure bandaging injury does not allow direct control of bleeding with a bandage, or objective factors
- Amputation
- Bleeding from multiple locations
- Protruding foreign body
- Need for immediate airway management or breathing control
- Under-fire situation
- Total darkness
- Mass casualty event

Indications are of two types — anatomic and situational (Tables 1 and 2³). Anatomic indications are tissue lesions with limb bleeding that risk death, such as a mid-thigh gunshot wound with femoral artery transection. Anatomic indications are defined medically and can be confirmed surgically. The investigators determined whether the bleeding was major or minor based on the wound, casualty appearance, and care provided. Anatomic injuries of the limb are categorized as amputation, open fracture, vascular injury, etc. Situational indications are predicaments in which applicators choose a tourniquet as the best treatment for reasons other than the lesion itself (e.g., care under fire on the battlefield)^{15, 16} and are defined and determined by rescuers. We also categorized the reason for use from our understanding of the applicator’s situation which included non-anatomic (non-lesion) reasons such as care under fire, mass casualties, and a multiply injured casualty.

Vascular lesions were defined conventionally similar to prior war studies in that visibly transected named arteries were recorded by surgeons. Also according to convention, the vascular lesion category included fractures with such lesions, but traumatic amputation was categorized different than vascular lesions since they were so severe. The soft tissue category did not include lesions with arterial injury. Also, the fracture category excluded arterial lesions and amputations (which routinely transected bone).

RESULTS

A total of 728 casualties (692 male [95%], 35 female [5%], one unknown) had 953 limbs with tourniquets of which 476 were left and 477 were right (50% each). Limbs included 679 lower extremities (71%) and 274 upper extremi-

ties (29%). Tourniquet use was prehospital only in 671 limbs (70%), hospital only in 104 limbs (11%), both prehospital and hospital in 169 limbs (18%), and unclear in 9 limbs (1%). Prehospital use with or without hospital use occurred in 840 limbs (88%). The median casualty age at presentation was 26 years (range, 4-70) (Figure 1). The nationalities of the casualties were mostly American and Iraqi but represented a broad array of 15 nations with subjects vulnerable to violence in and around Baghdad during the Operation Iraqi Freedom study period (Table 3). The median follow up was five days (range, 0.5-624) for the first 499 casualties and was seven days (range, 0.5-624) for the first 232 casualties; the final 225 casualties were not followed beyond discharge from the study site.

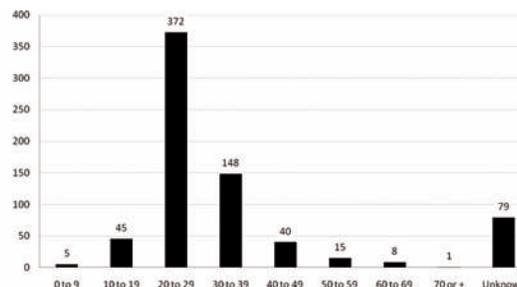


Figure 1: Title: Study Group Age Distribution.
Legend: The casualty count is the y-axis, and the age ranges in years is the x-axis. Of 728 casualties

Table 3: Casualty Counts by Nationality of Origin.

Casualty Nationality	N
American	362
Iraqi	343
British	4
Indian	3
Brazilian	2
Armenian	2
South African	2
Unknown	2
Polish	1
Nepali	1
Irish	1
Chilean	1
Jordanian	1
El Salvadoran	1
Kenyan	1
French	1

Indications for tourniquet use were examined in three ways by the investigators.

- First, regarding whether the reason to use the tourniquet was major hemorrhage or minor hemorrhage such as during care under fire or mass casualties. Major hemorrhage occurred in 487 (51%) limbs, while 463 limbs (49%) had minor hemorrhage. One casualty also had four limbs involved with coagulopathic hemorrhage during intensive care, and another casualty had one limb with an unclear indication.
- Second, 162 limbs had open fractures (27%), 156 had traumatic amputations (26%), 122 limbs involved soft tissue wounds (20%), 102 limbs had vascular wounds (17%), 65 limbs included other injuries (11%), two limbs were crushed, one limb

suffered an avulsion injury, and one limb had an unclear limb. This second look at anatomic injuries was a limited data set to the first 232 casualties and last 225 casualties as the interim period was absent such summary data.

- Third, we observed that 175 limbs (61%) had bleeding from multiple limb wounds, 64 limbs (39%) had single limb wounds, and one limb (1%) had unknown wound. Additionally, we had a record of only one limb in a multiple-injury casualty that needed an air way procedure, one limb with care under fire, one limb with an impaled object, and two limbs with unclear situations. This third look was limited to the last 228 casualties since that was the type of data collected. The investigators believed that situational data like care under fire was under-reported and such prehospital data was rarely given or available.

DISCUSSION

The main finding of the present study was that the current indication for emergency tourniquet use is any compressible limb wound that the applicator assesses as having possibly lethal hemorrhage. With this large dataset of the indications for emergency tourniquet use we filled the knowledge gap regarding the frequency of various indications.

Anatomic Indications

Open fractures were the most common indication in the present study at 27%. Open fractures can bleed much and long, even without an artery lesion,¹⁷⁻²⁰ and have ranged from 25% to 41% of the injured casualties with emergency tourniquet use in recent wars.^{9, 11, 21}

Traumatic amputations were the second most common indication in the present study at 26%. Traumatic amputations include artery and vein loss of varying degree and have ranged from 18% to 31% of the injured casualties with emergency tourniquet use in recent wars.^{9, 11, 21} Proximal amputations are more lethal than distal ones, and multiple amputations are more lethal than single ones.²²

Soft tissue wounds were the third most common indication in the present study at 20%. Soft-tissue injuries are generally less lethal than others; their frequency is generally thought to be low but in reality is high. Soft tissue wounds are a common indication for tourniquet use.^{11,23} Superficial injuries constituted 15% to 25% of recent tourniquet applications, apparently during care under fire.^{9-11,21,24-26} Even when a named vessel is not involved, wound volume, extent of tissue damage and injury severity have been associated with blood loss volume and mortality rates.²⁷⁻²⁸ The importance of soft-tissue injury, especially of muscle (which makes up 40% to 50% of cellular body tissue mass), is often underestimated in hemorrhagic shock because soft-tissue injury is less lethal than artery injury. Massive soft-tissue injuries can be associated with hyperkalemia (and hyponatremia) after resuscitation. Leaked cellular potassium can be later cleared with reperfusion into core circulation.²⁹ Soft-tissue injury has been added to models of lethal trauma, and such additions increase mortality prediction

accuracy although operational definitions of soft tissue injury differ.³⁰ Traumatized small vessels may clot off better than larger ones but may consume more coagulation factors and result in coagulopathy.³¹ Soft-tissue wounds can be associated with direct erythrocyte disruption and traumatic hemolysis, which have been shown to increase lethality of hemorrhagic shock by potentiating coagulopathy.³²

Vascular lesions were the fourth most common indication in the present study at 17%, and arterial injuries have ranged from only 8% to 28% of the injured casualties with emergency tourniquet use in recent wars.^{9,11,21} Vascular lesions may or may not in and of themselves present with clear or hard signs, and may only present with unclear or soft signs (Table 4). The hard and soft signs of vascular injury overlap substantially with both the other non-vascular injuries indicating tourniquet use, complications like compartment syndrome, and trauma care like pulselessness from tourniquet use.

The general appearance of the wound may influence

Table 4: Hard and Soft Signs of Arterial Injury⁶⁷

Physical Findings (Hard Signs) Indicating Operative Artery Exploration:

- Pulsatile bleeding
- Expanding hematoma
- Palpable thrill, audible bruit
- Evidence of regional ischemia
 - o Pallor
 - o Paresthesia
 - o Paralysis
 - o Pain
 - o Pulselessness
 - o Poikilothermy

Physical Findings (Soft Signs) Suggesting Further Evaluation:

- History of moderate hemorrhage
- Injury (fracture, dislocation, or penetrating wound) in proximity to a major artery
- Diminished but palpable pulse in an injured limb
- Peripheral nerve deficit

rescuers more than specific lesions or bleeding. Less visibly injured casualties were less likely to get tourniquets in the prehospital setting despite subsequently confirmed arterial injury or significant hemorrhage, and this is similar to a prior investigation from the study site.¹⁰ For recent casualties in Baghdad, some had a prehospital applicator use their first tourniquet outside of training, and few medics applied tourniquets to more than a few casualties.¹¹

Situational Indications

Uncontrolled hemorrhage has been the most common cause of death on the battlefield, and limb hemorrhage is a common preventable cause.³²⁻³⁵ In most studies care under fire is the most common situation for application of emergency tourniquets.^{9,24,25,36-40} Due to our methods and hospital base, the investigators believe they under-sampled care under fire because no one reported that prehospital data to them.

Mass casualty situations tax trauma systems and tourniquet use enables providers to attend safely and effectively to more casualties quickly.^{10,11,41} For example, 28 war casualties entered the CSH emergency department in a 25-minute span

after an explosion. All had limb injuries, three died early, eight had tourniquets, several had resuscitation procedures, and half required emergency surgery. Tourniquets helped providers triage, resuscitate, stabilize, and save 25 casualties.¹¹

One casualty each suffered from an impaled object, coagulopathic hemorrhage, and multiple-injuries. The last casualty may have required several simultaneous resuscitative procedures for best care.^{9,42} A casualty with a simple, rapid, severe arterial hemorrhage can have bleeding stopped more easily and can be resuscitated more easily than one with multiple, extensive hemorrhaging wounds.^{15,27,41,42}

Application of the Findings

The positive predictive value of clear findings (e.g., bright red blood spurting high with pulsations) from a simple lesion (e.g., a wrist wound where the radial artery is routinely palpable) observed acutely by an experienced clinician (r.g., vascular surgeon) under optimal lighting in safety may be high, but rarely in reality are such lesions or conditions so simple or optimal.⁴³ The exact type of vessel injury, severity, and location is difficult to ascertain without surgical exploration.⁴³ Soldiers or medics looking at a bloody limb may not be able to determine what tissues are injured^{8,25,41} or distinguish arterial from venous bleeding.⁴⁴ For example, in a simulated casualty with a simulated thigh wound, less than half of military student medics after basic training could recognize and appropriately treat life-threatening hemorrhage.⁴⁵

Venous bleeding presents a number of first aid problems. Low-pressure venous bleeding may not be as noticeable as arterial bleeding and go undetected longer, since vein anatomy precludes adequate lumen constriction and vessel contraction. Therefore veins retract little, resulting in continued bleeding if untreated. The capacity of observers to differentiate arterial and venous bleeding is limited, especially as time progresses after injury as anatomic, physiologic, and treatment effects mix together. Brief venous bleeding is rarely lethal or uncontrollable after limb elevation and compression.⁴⁶⁻⁴⁹ Experts noted a lack of evidence of efficacy for elevation and compression; so in tactical situations, these experts no longer recommend limb elevation and pressure point use.^{38,50,51} The investigators cannot say that tourniquet placement is mandatory in high-risk cases because lesser measures used by skilled persons may work quickly in some circumstances.

Difficulties in estimating blood loss volumes and predicting consequences complicate the decision to apply tourniquets in emergent situations. Casualties can bleed incrementally throughout care, particularly on the first day;^{10,16,18,52} but few observers see all prehospital, emergency department, operating room, intensive care unit, and ward blood loss that occurs.²⁶ Clothes, equipment, medical drapes, or blankets can obscure the casualty's bleeding.²⁶ Visual estimation of blood loss, even by surgeons, is too inaccurate to be clinically useful.⁵³⁻⁵⁵ Underestimation is more common than overestimation,^{53,56-58} especially with higher volumes of hemorrhage.^{53,57} This study offers a low-to-high need for tourniquet use based on bleeding, but situational indications can substantially increase user willingness (Table 5).

Table 5: Decision Matrix on Need for Tourniquet Use

Tourniquet Need	Bleeding		
	Rate	Color	Volume
Low	Slow	Dark	Small
Medium	Medium	Mixed	Medium
High	High	Bright	Large

Numerous aspects of arterial lesions affect hemorrhage. Extremity arterial lesions are generally more lethal than venous lesions, and higher arterial pressure can cause more rapid loss of blood volumes.⁴⁶ Proximal arterial lesions are more lethal than distal ones, probably because greater vessel caliber at a higher pressure permits larger volume and more rapid blood loss.^{16,17,22,59} Normal blood flow is proportional to the fourth power of the vessel radius. Flow is estimated by Poiseuille's law: $Q = (\Delta P \pi r^4) / (8 \eta l)$, where Q is the volumetric blood flow rate; ΔP is the driving pressure drop; π is a constant, approximately 3.14; r is the vessel radius; η is the dynamic viscosity; and l is the length of the vessel. This equation also helps explain how wide tourniquets, blood pressure cuffs, and Military Anti-shock Trousers stop flow at low pressures as l increases. Hemorrhage rate from a vessel leak is estimated initially by a derivation of Bernoulli's equation: $Q = A \sqrt{[(2 \Delta P) / \rho + v^2]}$, where the hemorrhage rate (Q) = the laceration area (A) times the square root of twice the transmural pressure change (ΔP) divided by the blood density (ρ) plus the velocity (v) squared.⁶⁰⁻⁶³

Stopping bleeding is a simple aim but a complex task. The overall goal is to maximize survival, and its corollary is to minimize morbidity — life over limb. The immediate aim is to stop the bleeding, which prevents the onset of hemorrhagic shock and thereby increases survival time.¹² Increased survival time allows better resuscitation and thus increases overall survival with minimized morbidity.^{11,12} The aims of tourniquet use in prior doctrine were unspecified but now include survival rate (survivor percentage of all casualties with tourniquet use), survival time (hours permitting resuscitation), hemorrhage control (stopping visible external bleeding), stopping the distal pulse (if there is a distal limb with a palpable pulse present), limb function preservation, and rescuer safety while under fire. Each aim has utility. Hemorrhage control, including tourniquet use in battle casualties, has been associated with shorter and less severe hemorrhage and shock, which decreased transfusion requirements and some sequelae.^{10,11,27}

Empirically, with the given training, doctrine, fielding, and performance improvement work, appliers in Operation Iraqi Freedom did a good — although imperfect — job of determining which limb-injured casualties were at risk for death from bleeding.^{10,11} In the first Baghdad survey, an 18% unindicated tourniquet use rate led to improved education and training.¹⁰ In a recent survey, only 5% of casualties had no situational or anatomic indication for the tourniquet use, and all 5% had prehospital tourniquets.¹¹ Furthermore, emergency department use was never seen to be unindicated.¹¹ However, there later were 2% of cases in which prehospital use was indicated, but no tourniquets were available or accessible before the casualties exsanguinated and died.¹¹

Study Limitations and Future Directions

The data in this study is limited in quantity and qual-

ity mostly due to war circumstances and the difficulty of doing an emergency performance improvement project at a busy CSH trauma center. When errors in resuscitation are studied and measured, they occur in almost every case although failure to observe or record relevant bedside information has been infrequently associated with adverse outcomes.⁶⁴ The team's experience is similar to that of this study, and this report provides a data collection sheet for use as an aid in making resuscitation decisions (Figure 2: Data Collection Sheet).

The visual anatomic indications for emergency tourniquet are intuitive but difficult in both practice and clinical study (Table 6). Furthermore, casualty propensity to survive hemorrhage currently appears complex and unpredictable.⁶⁵ Currently, no easy fix exists for the complex problem of limb hemorrhage control, resulting in an apparent need to balance multiple essentials of tourniquet best care until breakthrough ideas or technologies are developed (Table 7).

with Tiger Tourniquet, LLC, Tactical Medical Solutions, LLC, Combat Medical Solutions, Inc., Composite Resources Inc., Delfi Medical Innovations, Inc., North American Rescue Products LLC, H & H Associates, Inc., Creative & Effective Technologies, Inc., TEMS Solutions, LLC, Blackhawk Products Group, and Hemaclear. He has received honoraria for work for the Food and Drug Administration for device panel consultation. He has received honoraria for trustee work for the non-profit Musculoskeletal Transplant Foundation.

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Key words: hemorrhage, shock, resuscitation, first aid.

TOURNIQUET DATA COLLECTION SHEET

Patient Name:		ID #	Lived/Died:		Injury date:	Death date:	
Last Follow-up Date:		Age (years):	Sex: <input type="checkbox"/> M <input type="checkbox"/> F	Nationality:	Job:		
Limb Injury	Devices	Placement	Setting	Bleeding	Distal Pulse	Time On/Off	Duration of Use (min)
Left upper extremity (LUE), right (RUE), left lower extremity (LLE), right (RLE)	CAT (C) SOFTT (S) EMT (E) Other (O)	Arm (A) Forearm (FA) Thigh (T)	Hospital (H) Pre-hospital (PH)	Stopped (0) Decreased (-) Increased (+)	Absent (Abs), Present (Pres) Is distal pulse present during use?	Record on time/record off time to calculate duration of use in minutes.	
<input type="checkbox"/> LUE <input type="checkbox"/> RUE <input type="checkbox"/> LLE <input type="checkbox"/> RLE	<input type="checkbox"/> C <input type="checkbox"/> S <input type="checkbox"/> E <input type="checkbox"/> O	<input type="checkbox"/> A <input type="checkbox"/> FA <input type="checkbox"/> T	<input type="checkbox"/> H <input type="checkbox"/> PH	<input type="checkbox"/> 0 <input type="checkbox"/> - <input type="checkbox"/> +	<input type="checkbox"/> Abs <input type="checkbox"/> Pres	/	min
	<input type="checkbox"/> C <input type="checkbox"/> S <input type="checkbox"/> E <input type="checkbox"/> O	<input type="checkbox"/> A <input type="checkbox"/> FA <input type="checkbox"/> T	<input type="checkbox"/> H <input type="checkbox"/> PH	<input type="checkbox"/> 0 <input type="checkbox"/> - <input type="checkbox"/> +	<input type="checkbox"/> Abs <input type="checkbox"/> Pres	/	min
	<input type="checkbox"/> C <input type="checkbox"/> S <input type="checkbox"/> E <input type="checkbox"/> O	<input type="checkbox"/> A <input type="checkbox"/> FA <input type="checkbox"/> T	<input type="checkbox"/> H <input type="checkbox"/> PH	<input type="checkbox"/> 0 <input type="checkbox"/> - <input type="checkbox"/> +	<input type="checkbox"/> Abs <input type="checkbox"/> Pres	/	min
	<input type="checkbox"/> C <input type="checkbox"/> S <input type="checkbox"/> E <input type="checkbox"/> O	<input type="checkbox"/> A <input type="checkbox"/> FA <input type="checkbox"/> T	<input type="checkbox"/> H <input type="checkbox"/> PH	<input type="checkbox"/> 0 <input type="checkbox"/> - <input type="checkbox"/> +	<input type="checkbox"/> Abs <input type="checkbox"/> Pres	/	min

DRAW AND WRITE NOTES ON AND NEAR OUTLINE Front Right Back Right Explain trials of conversion to pressure dressing:

Was any vessel visibly injured? Yes No Vessel Name: _____

Nerve palsy was at the level of: Wound Tourniquet Unknown No palsy

Shock onset: None Before tourniquet use After tourniquet use Unknown

TK device make/type/Description Notes: CAT SOFTT EMT Improvised: from _____ Other make: _____

Side by side use? Yes: LUE RUE LLE RLE Why? _____ Response to more TKs: _____

Main Indication: Medical Tactical Unknown Tactical Indication: None Care under fire Darkness Unknown

Lesion notes: _____

Medical Indication: Mass casualties Multiply injured patient Exsanguination-failed countermeasures (e.g., pressure dressing)

Use intent: Arterial (routine) Only as venous tourniquet In case of re-bleed (purposefully loose—never tightened) Unknown

Placement: Proximal to wound (routine) Distal to a wound Atop wound Wound too proximal for tourniquet to fit normally proximal

Breakage Wear & tear Mishap Loose None Explain if not none: _____

Applicator level: Self Lay Soldier Medic Nurse Physician assistant Physician Unknown

Applicator name: _____ Notes on use: _____

POC: _____ Field Provider/Notes: _____ Patient Unit: _____

ER Provider: _____ Surgeon: _____ Admit Transfer Morgue Hospital Name: _____

Who indicated tourniquet(s)? Self Lay Medic Nurse Physician assistant Physician Surgeon Other Unknown

Explain fully if amputation was Injury emergency completion surgery Note why: _____

failed salvage (>24hr) reconstruction Note when: _____

Other notes on treatment: Limb exposed to ambient temperature Limb actively cooled Hemostatic dressing:

Reminder to clean tourniquet/dry/replace in treatment area; remove from use if unserviceable. Explain if unserviceable: _____

CONCLUSION

Indications for emergency tourniquet use are complex and have been rarely evidenced so these findings fill knowledge gaps. The current indication for emergency tourniquet use is any compressible limb wound that the applicator assesses the potential for lethal hemorrhage. In complex situations, it is difficult to tell how much a casualty bled. Optimal healthcare appears to depend upon adequate fielding of effective devices, modern doctrine, specific training, speedy evacuation, and refinements through performance improvement. Analysis of emergency tourniquet indications is complex and inadequately evidenced, so further study, particularly emphasizing prehospital data, is prudent.

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Table 6: Questions for Further Tourniquet-Related Study

1. How difficult is direct pressure normally or under fire? What is the quality and quantity of evidence that it is effective? What about limb elevation or pressure points?
 2. Should tourniquets be placed very proximal during care under fire so a proximal wound is not missed before the casualty is removed from danger before the survey for controllable hemorrhage is complete?
 3. How can emergency care researchers effectively gather meaningfully complete data?
 4. Which civilian situations are similar to military ones for considering emergency tourniquet use?
 5. What civilian situations are evidenced regarding tourniquet use?
 6. What data can be meaningfully collected regarding resuscitative tourniquet use in the prehospital or emergency room settings?
 7. What candidate procedures may be indicated during resuscitation with concurrent tourniquet use in a multiply injured casualty?
 8. What meaningful data can be collected during or after mass casualty situations?
 9. How can civilians adequately prepare for mass casualties without tourniquet experience, training, or doctrine?
 10. In the face of absent or inadequate tourniquet training and doctrine, how can civilian mass casualty situations be handled best?
 11. What present user or data needs are unmet regarding pressure dressing techniques and training? Pressure points? Limb elevation?
 12. What data are available to form guidelines regarding pressure dressings with or without novel hemostatic agents or tourniquet use?
 13. What data exist regarding conversion of tourniquet use to pressure dressing use?
 14. How does a circumferential pressure dressing differ from a venous tourniquet?
 15. What of the 'pop a clot' phenomena with normo-tensive resuscitation or over resuscitation with pressure dressing use?
 16. How well does a lay person put on pressure dressing even if trained? Complex cases.
 17. What is the failure rate of pressure dressings? Death rate? Morbidity rate?
 18. Might pressure dressings for open fractures be evidenced to save lives?
 19. How can one avoid a pressure dressing acting like a venous tourniquet yet still control hemorrhage? When or if does it matter?
 20. How exactly does one learn to put on a pressure dressing for mangled limbs?
 21. With massive wounds of soft tissue, how do providers put on a pressure dressing?
 22. Can a pressure dressing be placed safely under fire?
 23. How do we differentiate bleeding types (active, venous tourniquet, rebleeding, 'pop a clot', and drainage)?
 24. How do we teach such differentiation? Is it worthwhile?
 25. What are the consequences of under or over resuscitation of tourniquet casualties?
 26. How does one optimize resuscitation in austere environments?
 27. How does one best teach the bleeding limb imperatives to the uninitiated?
 28. How is that we determine which lesions have lethality?
 29. Can we better determine the lethality of lesions?
 30. How can we teach what lesions are lethal?
 31. What can policy makers do to improve tourniquet availability and improve doctrine and training?
 32. How can the lessons learned recently be communicated effectively?
 33. Can a health care system expect good results without implementing what may be essential?
 34. Do first aid hemostatics and tourniquet use affect each other?
 35. Are the experiences reported from Baghdad consistent over time?
 36. What are the associations among tourniquet use, survival, injury severity, and fasciotomy rates?
 37. Are the experiences of other US military services similar to the Army's?
 38. Are the experiences of other military forces similar to the US's?
 39. Is meaningful civilian data collection possible?
 40. What tourniquet guidelines are best for lay persons, medics, physicians, or executives?
 41. What device design items are of practical concern to manufacturers and users?
 42. What risks and benefits would tourniquets pose when incorporated into clothing or uniforms?
 43. Can we integrate an in-uniform tourniquet system into Future Force Warrior?
 44. What are the limits of what is anatomically amenable to tourniquet application?
 45. How do we assess for discontinuation of tourniquets once bleeding is controlled by other means?
 46. Before releasing any tourniquet on a patient who has been resuscitated for hemorrhagic shock, should a positive response exist to resuscitative efforts (i.e., a peripheral pulse normal in character and normal mentation if there is no traumatic brain injury)?
 47. What operational definitions of hemorrhagic shock are useful prehospital?
 48. Is the proper use of the tourniquet to only stop hemorrhage or to also stop the distal pulse? Are the two conditional?
 49. How exactly does one provider elevate and compress bleeding in a fractured or mangled extremity?
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Table 7: List of Possible Potential Breakthrough Ideas or Technologies

- Improved capacity to predict patient lesions that are lethal; e.g., genetic markers
 - Improved capacity to differentiate arterial from venous bleeding
 - Improved understanding of hemostatic devices or techniques (e.g., pressure points, limb elevation, pressure dressings, hemostatic devices)
 - Prehospital coagulators (perhaps ultrasonic, chemical, or thermal)
 - New hemostatic dressings, powders, liquids, foams, or sprays
 - New pressure dressings or devices; e.g., proximal lesion tamponade by balloons
 - Smart tourniquet (adjusts pressure; has timer, manometer, and pop-off valve)
 - Combinations of the above
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appendix

Tactical Combat Casualty Care Guidelines – Hemorrhage Control Excerpt 1 November 2010

Basic Management Plan for Care Under Fire

7. Stop *life-threatening* external hemorrhage if tactically feasible:
 - Direct casualty to control hemorrhage by self-aid if able.
 - Use a CoTCCC-recommended tourniquet for hemorrhage that is anatomically amenable to tourniquet application.
 - Apply the tourniquet proximal to the bleeding site, over the uniform, tighten, and move the casualty to cover.

Basic Management Plan for Tactical Field Care

4. Bleeding
 - a. Assess for unrecognized hemorrhage and control all sources of bleeding. If not already done, use a CoTCCC-recommended tourniquet to control life-threatening external hemorrhage that is anatomically amenable to tourniquet application or for any traumatic amputation. Apply directly to the skin 2-3 inches above wound.
 - b. For compressible hemorrhage not amenable to tourniquet use or as an adjunct to tourniquet removal (if evacuation time is anticipated to be longer than two hours), use Combat Gauze as the hemostatic agent of choice. Combat Gauze should be applied with at least 3 minutes of direct pressure. Before releasing any tourniquet on a casualty who has been resuscitated for hemorrhagic shock, ensure a positive response to resuscitation efforts (i.e., a peripheral pulse normal in character and normal mentation if there is no traumatic brain injury (TBI)).
 - c. Reassess prior tourniquet application. Expose wound and determine if tourniquet is needed. If so, move tourniquet from over uniform and apply directly to skin 2-3 inches above wound. If a tourniquet is not needed, use other techniques to control bleeding.

- d. When time and the tactical situation permit, a distal pulse check should be accomplished. If a distal pulse is still present, consider additional tightening of the tourniquet or the use of a second tourniquet, side-by-side and proximal to the first, to eliminate the distal pulse.
- e. Expose and clearly mark all tourniquet sites with the time of tourniquet application. Use an indelible marker.

Basic Management Plan for Tactical Evacuation Care

* The term “Tactical Evacuation” includes both Casualty Evacuation (CASEVAC) and Medical Evacuation (MEDEVAC) as defined in Joint Publication 4-02.

3. Bleeding

- a. Assess for unrecognized hemorrhage and control all sources of bleeding. If not already done, use a CoTCCC-recommended tourniquet to control life-threatening external hemorrhage that is anatomically amenable to tourniquet application or for any traumatic amputation. Apply directly to the skin 2-3 inches above wound.
- b. For compressible hemorrhage not amenable to tourniquet use or as an adjunct to tourniquet removal (if evacuation time is anticipated to be longer than two hours), use Combat Gauze as the hemostatic agent of choice. Combat Gauze should be applied with at least 3 minutes of direct pressure. Before releasing any tourniquet on a casualty who has been resuscitated for hemorrhagic shock, ensure a positive response to resuscitation efforts (i.e., a peripheral pulse normal in character and normal mentation if there is no TBI.)
- c. Reassess prior tourniquet application. Expose wound and determine if tourniquet is needed. If so, move tourniquet from over uniform and apply directly to skin 2-3 inches above wound. If a tourniquet is not needed, use other techniques to control bleeding.
- d. When time and the tactical situation permit, a distal pulse check should be accomplished. If a distal pulse is still present, consider additional tightening of the tourniquet or the use of a second tourniquet, side by side and proximal to the first, to eliminate the distal pulse.
- e. Expose and clearly mark all tourniquet sites with the time of tourniquet application. Use an indelible marker.



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