Battlefield Tourniquets: Lessons Learned in Moving Current Care Toward Best Care in an Army Medical Department at War

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Abstract

Bleeding prevention and control by tourniquet use by out-of-hospital caregivers is a major breakthrough in military medicine of current wars. The present review documents developments in tourniquet practices since 2001 among the US military services for aid in improving doctrine, policy, and especially care in wars to come. Tourniquets are an adjunct for resuscitation in self-care and buddy aid and today are issued to all military servicepersons who deploy into a combat zone. In the US Army, virtually every Soldier is trained in first aid tourniquet use; since 2009 they are instructed early and often to use them early and often. Despite substantial knowledge gains among the services in tourniquet use and resulting improvements in casualty survival, current evidence shows persistent difficulties in achieving best care with tourniquet use for individual trauma patients. Nevertheless, contemporary tourniquet use incorporates key lessons learned over the last 14 years of war that include: (1) tourniquet use reliably stops bleeding from limb wounds and prevents mortality in prehospital settings; and (2) brief tourniquet use appears to be safe. These 2 lessons have become so evident that civilian emergency medical systems have begun using them, albeit unevenly. Collection and interpretation of data of casualties with tourniquet use have showed that such intervention has lifesaving benefit through 2 mechanisms: control of both ongoing hemorrhage and shock severity. The next generation of interventions in bleeding control involves developing the skill sets, education, and standards of tourniquet users which may improve hemorrhage control in wars to come.

Tourniquets today have come far from where they were on September 11, 2001. When war came to the United States on 9-11, tourniquets were a means of last resort in bleeding control. Today, tourniquet use is a means of first aid. The scientific evolution of tourniquets among the US military services since 9-11 has had one main finding: tourniquet use provides a significant survival benefit.[1-5] However, little is known about that benefit: what is its size; who receives that benefit, and does it apply to both military and civilians?[6] Other gaps include how to optimize performance of tourniquet users.[3] A reminder of our current need to know such things may aid ongoing efforts of key leaders to maintain a scholarly focus within the US Army Medical Department so that it does not drift. "No drift" is a mantra of stewards of combat casualty care research so that the military goes to the next war without having to relearn lessons of past wars, i.e., without the need to improve caregiving to reach levels of the last war.[4]

In an effort to maintain a scholarly focus on improving first aid, the present update gives a basic understanding of the recent scientific evolution of tourniquets in the US military. The present review documents such lessons not only to improve doctrine and policy today, but also—and especially—to prevent such drift and thereby improve care in future wars. Furthermore, the lessons learned by the military may guide improvements in civilian first aid.

Update on Current Use of Tourniquets in the US Army

Tourniquet use in the military services today incorporates 4 key lessons learned over the last 14 years of war. The first lesson about tourniquet use the military learned in the current war was that we should not forget to focus on what we need to know; that is to say, what is not already in the lesson plans of medics. Although we have learned much recently, such as if surviving casualty percentages are compared between those with first tourniquet use after shock onset and those who are not in shock at first use, the fact remains that shock onset is associated with more mortality—as much as 80% to 92%.[2,7] However, such a difference is not a treatment effect of tourniquets, it is a difference in shock effect.[6] Such a need to know more about first aid is a still a well-established knowledge gap; tourniquet use provides a ready example of such gaps.[5,6] Some such gaps are discovered by trying to answer questions such as, what is the effect size of tourniquet treatment?[5]

A military survey reported in 2015 that tourniquet use was associated with worse shock and more transfusion requirements among hospital-admitted casualties, yet those who received tourniquets had survival rates similar to those of comparable, transfused casualties who did not receive tourniquets.[5,6] Does effectiveness vary by clinical setting (use out-of-hospital vs emergency department)? Surveys of military casualties have shown that first use of tourniquets in such settings is associated with improved survival if use is earlier; specifically, survival has been associated with prehospital application (89% vs 78% hospital, $P<.01$) and application before the onset of shock (96% vs 4% after).[2,7] But such surveys began at the emergency department, not at the time of indication which is a better, albeit harder, way of surveying the need for intervention.[2,6,7] Does effectiveness vary by condition of the casualty (degree of shock or injury severity)?[5,6] An evaluation of tourniquet use for patients treated at forward surgical (Role 2) facilities revealed an association with improved survival and reduced shock index on arrival; a 20% reduction of mortality was associated with each increase of 0.2 unit of shock index (odds ratio [OR], 1.27; 95% confidence interval [CI], 1.12-1.42) in tourniquet use vs nonuse (OR, 1.46; 95% CI, 1.37-1.56).[8] However, in this study the time-course of individuals casualties was not tracked for shock control as the data were not paired in 2 times for an individual; such cohort data are more like epidemiology of large groups rather than treatment of individual patients—the difference between public health of populations and health care of individuals.

What should first aid instructors teach about how and when to use tourniquets, for example, at a marathon bombing or at a shooting in a movie theater? Such questions are basic to how and when caregiving is needed.[5,6] Data gathered regarding improvised tourniquets has advanced rapidly since 2013, and improvised strap-and-windlass tourniquets have been shown to be more effective than those with no windlass, as a windlass allowed the user to gain mechanical advantage. However, improvised strap-and-windlass tourniquets fail to control hemorrhage often (ie, 32% of tests), even in a laboratory setting.[9,10] In a second laboratory study of improvised tourniquets, the commercial Combat Application Tourniquet (CAT) was a control for the US Army improvised tourniquet and a bandana-windlass tourniquet; CAT performed fastest ($P<.0001$, both), but both improvised techniques were not statistically different from each other. All time-of-application results in the commercial group were less than the minimums of either improvised group.[11] In a third laboratory study of improvised windlasses, effectiveness, windlass turn numbers, time to stop bleeding, the number of windlasses, and the under-tourniquet pressure were associated inversely with breakage.[12] The windlass type was associated with breakage; only chopsticks were without breakage at 2 windlasses. Of those windlass types that broke, 21% were chopsticks, 26% were pencils, and 53% were craft sticks; such data showed differential value of various items used together as one working windlass.[12] In a fourth laboratory study of a standard issue military tourniquet, tourniquet effectiveness rates were uniformly 100% irrespective of whether the windlass position was medial, lateral, anterior, or posterior.[13] Presently, much other information is lacking about what first aid instructors should teach about how and when to use tourniquets, and a focus on user development is needed if we are to optimize user performance.

The second lesson the military learned about tourniquet use was that its use provided a survival benefit while safety was also provided.[1,2] A tourniquet survey began in Baghdad was made in 3 sequential parts and observed casualties with tourniquet indications.[14] Altogether, the survey included 727 patients with 1,212 tourniquets used on 952 limbs.[2,7,10,14-17] This large survey was useful by dispelling theories that were wrong and confirming theories that were right.[2,17] The performance improvement aspect of the large survey was emphasized in the third time period surveyed which showed increased usage of tourniquets within the US military trauma system in Baghdad in 2007 (Figure 1).[17] This survey over 466 days showed that (1) the appropriate wound indication rose from 96% to 99%, (2) first usage before shock onset for individual casualties rose from 96% to 99%, and (3) the prehospital (first use before hospital) usage rose from 84% to 97%.[17] All of these changes were significant. A newly refined concept of bleeding control by tourniquet use emerged that indicated the patient's status regarding hemorrhagic shock at the time of first tourniquet use was the main determinant of survival. If shock onset had not occurred, tourniquet use was associated with high survival rates as documented by both a higher proportion of surviving patients and a longer duration of patient survival.[2] Much like emergency room thoracotomy, shock onset (as indicated by loss of a palpable peripheral pulse) before tourniquet use was associated with low survival rates.[2] Furthermore, minor morbidity during tourniquet use was empirically confirmed as few, temporary, and incomplete.[15] Such a refined understanding led to renewed efforts to use tourniquets early and often, and tourniquet trends showed good results such as improving survival (decreasing case fatality rates of all-causes) despite increasing injury severity.[5,6,8,15,17]

The third lesson about tourniquet use that the military learned in the current war was that the users' concepts

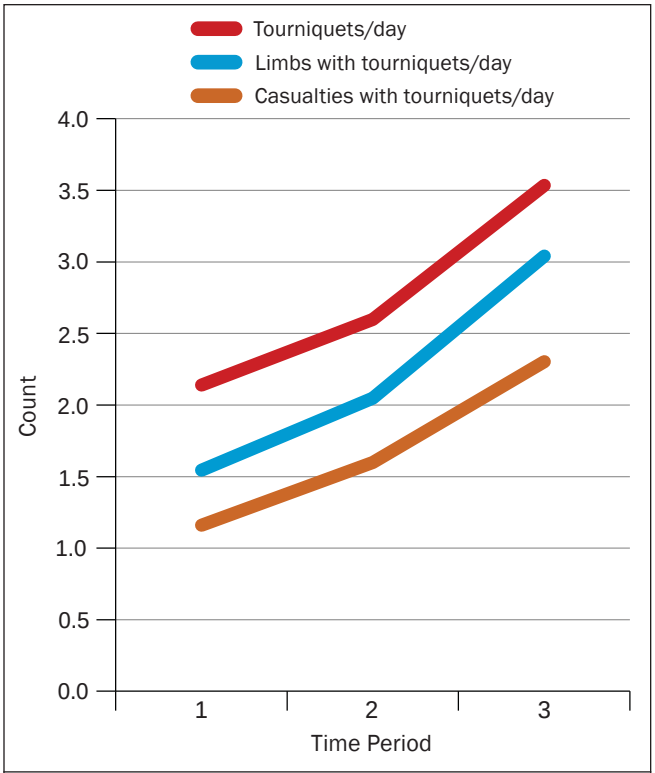

Figure 1. Improvement in use of tourniquets by time period in a Baghdad combat support hospital during 2006-2007. The time span is separated into 3 distinct, sequential periods: 1-Precondition; 2-Preparation; 3-Execution of the Surge. Data source: Kragh et al.[17]

of tourniquets changed. Early in the war, a tourniquet was a device, a materiel item issued within an individual's first aid kit. Since tourniquets were devices made of materials familiar to Soldiers like nylon webbing and a metal rod, early in the war Soldiers innately thought of them as a mechanical means of compressing limbs and underlying blood flow to control bleeding from wounds. Such mechanistic thinking was easy to teach and learn, as illustrated in Figure 2, and there was little action needed to develop user training (eg, learning curves, skill decay measurement, or differentiating user skillsets by experience level). Situational concerns were more apparent at the beginning of the war. For example, strategies concerning tourniquet use might change in an environment-dependent manner: Care Under Fire (tourniquets could be tried first) versus Tactical Field Care (tourniquets were to be tried last). Tourniquets applied in the field were often found later to be relatively loose by physicians, and the looseness problem was thought to be caused by the tourniquet user applying them too loose. However, the problem was eventually understood and explained better through research from Iowa.[19,20] Difficulty in achieving arterial compression was explained by civilian researchers who showed that persons with tourniquets applied changed over time during tourniquet use; the individual's limb changed.[19,20] A person who self-applied their tourniquet to their arm, for example, soon relaxed their arm muscles which altered the

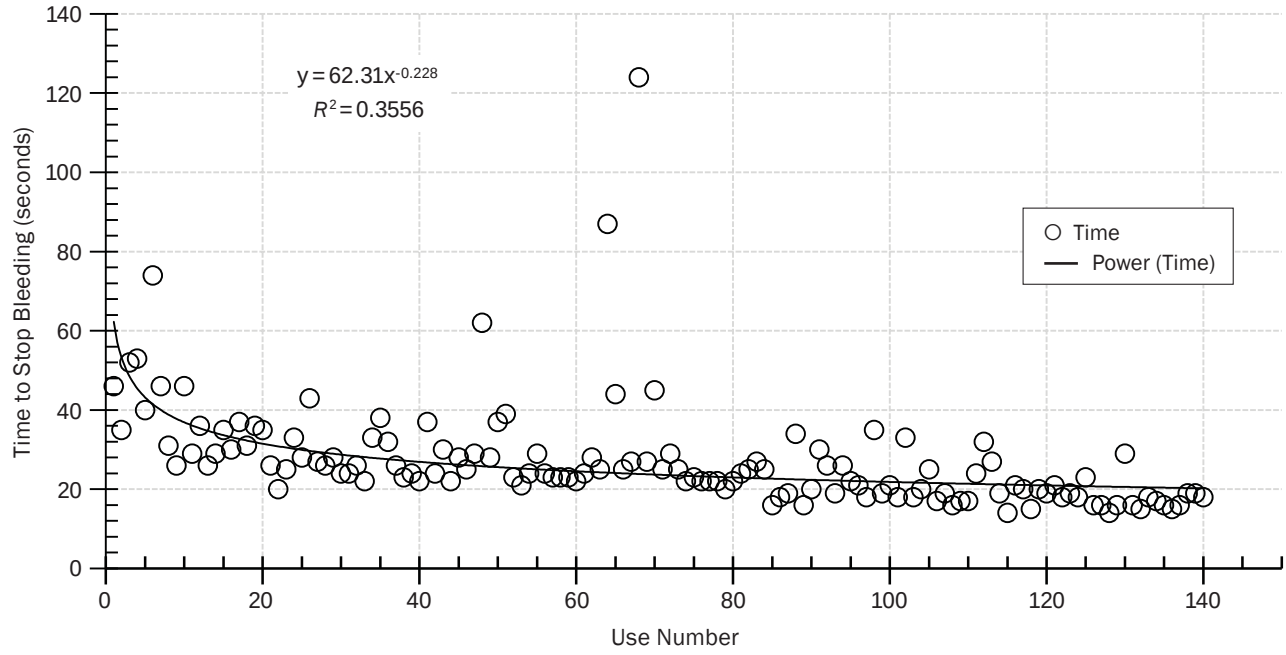

Figure 2. Learning curve for a user of a first aid tourniquet (on a manikin). For this subject, the data indicates that the user learned to achieve better bleeding control by becoming faster. The variance tended to decrease, but the maximum variance in use-to-use was in use number 68, surprisingly late and after almost half of the experience. This chart was generated for this article using data from Davinson et al.[18]

tourniquet effectiveness from arterial to venous control within minutes.[19,20] Further research showed that there was variance in applied pressures under tourniquets even of the same model applied by the same person.[19,20] More research showed that compression of the limb changed the underlying limb itself by extruding blood from all vessels and lymph from the lymphatic system.[19-21] Such fluid extrusion altered effectiveness of the tourniquet as its pressure applied to the skin dropped within minutes, which in turn allowed arterial flow to recur while venous flow remained blocked; a bad situation—a venous tourniquet. Moreover, the blood and lymph responses differed over time; the blood effects were faster and the lymph effect was slower.[19-21] From such science, refinements were subsequently made to caregiving guidelines to underscore the importance and to increase the frequency of users reassessing casualties with tourniquets.[22] Given such subtle science, a refined understanding occurred to change the tourniquet concept from mechanistic to probabilistic. That is to say, tourniquet use was not a simple, mechanistic, yes-no intervention. Rather, each use had a probability of success that could be partial, change over time, or be altered by the specific situation. The mechanistic concept changed to a tetrad concept wherein the 4 interrelated parts of the tetrad are a user, a patient, an intervention, and a situation, as shown by Figure 3. This new concept is dynamic as all elements can change, and such change means that empiric results are probabilistic and not purely mechanistic; empiric outcomes of tourniquet use indicate that the probability of better outcomes is associated with improvements in care delivered. In another example of improved caregiving from the large, 3-part Baghdad survey, the rate of limbs with only one tourniquet used increased from 66% to 74% to 89%; while tourniquet models themselves did not change, and while injury numbers and severity increased, improvements appeared to come from users as use, experience, and efficiency improved.[10] Such new knowledge involving best tourniquet practices is continuously and incrementally added. Given battlefield experience over a decade, knowledge of wear and tear of tourniquets has increased in part through scientific inquiries.[23-26] For one example, in a study of heat exposure, prolonged dry heat was not associated with change in tourniquet effectiveness rates ($P=.32$); when adjusted for the effects of user and model, the comparisons of time to effectiveness and total blood loss were statistically significant ($P<.0001$), but the comparison of pressure was not ($P=.0613$) as user effects appeared to affect outcomes while exposure did not.[18] The military changed its concept of the tourniquet to become a concept of dynamic interrelation among users-situations-patients-tourniquets.

What the military teaches Soldiers in tourniquet application is substantial in breadth and occasionally in depth. In an example of breadth, all new Army recruits learn tourniquets upon initial entry training, receive further detailed training during subsequent advanced individual training in a combat lifesaver course, and get predeployment refresher training. (and data to support why when available) gaps that remain. Another example of breadth: medics receive training in greater specificity for their more advanced skillset than other Soldiers, and they often are taught about troubleshooting difficult cases and converting tourniquets to pressure dressings. Specific information about what Soldiers are taught about tourniquet application is included in the Combat Lifesaver course.[27] Specific information that military medics are taught about tourniquet application is presented in Figure 4.

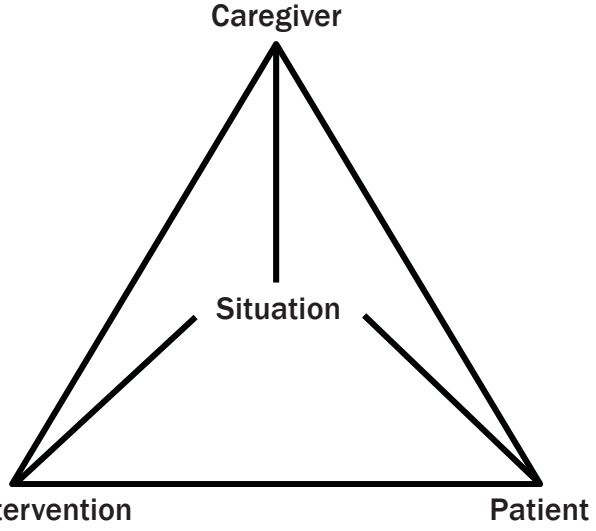

Figure 3. A new schema of tourniquet science developed recently includes the dynamic interaction among components of a tetrad that include a patient, a caregiver, an intervention, and a situation, represented schematically as a tetrad. Each item in the tetrad can change. The caregiver may also be the patient in self-applied tourniquet use. Each item is interrelated with the others. For example, if a casualty (patient) is wounded in a limb in combat, a Soldier (caregiver) provides first aid with tourniquet use (intervention) during Care Under Fire (situation). Soon after the end of active combat, the situation changes to Tactical Field Care (a new situation) wherein Soldiers are taught to convert the tourniquet use to use of a pressure dressing. The schema alters the perception of the challenges for looking just at the device (the tourniquet) to invite looking at each item and each interrelation. The tourniquet is a tool, and it its use is the intervention; deemphasizing other items makes the problem simpler than reality, an over-simplification which generates unintended problems such as under-emphasizing patient reassessment. The patient changes because of the intervention. The patient also changes over time and requires rechecking if the limb under the tourniquet gets smaller from applied pressure.

The fourth lesson the military learned about tourniquet use in the current war was that today, in developing the way ahead for military medicine, civilians may also improve their use of tourniquets. Such implementation gaps also apply to civilian first aid situations wherein similar risks occur (eg, external hemorrhage associated with penetrating trauma).[4,22] Such application led civilian medical authorities to reverse course and recommend tourniquet use.[28-30] An increasing number of clinical studies from civilian settings have been published since 2014 indicating that several of the military findings about tourniquet use are supported by comparable civilian findings such as lifesaving benefit and safety of use.[31-37] However, civilian adoption of tourniquet use is currently uneven.[38] Defense research in out-of-hospital use of tourniquets paved the way for civilian use, and both military and civilian investigators are considering extension of other interventions to control hemorrhage, such as prehospital use of pelvic binders. On the road from current care toward best care, the lessons that the military learned about what is necessary for a large trauma system to work well is also improving civilian caregiving.

Current Status of Tourniquet Use in all US Military Services in 2015

As a result of one of the longest wars in US history in which combat still continues, the military is keenly aware of existing knowledge gaps. Another important gap relevant to the military services presently being addressed by ongoing research is junctional hemorrhage, ie, bleeding from wounds at the torso-appendage junctions where limb tourniquets cannot fit.[39-42] Presently, there are few clinical trials, junctional case reports, or case series of hemostatic dressing use, but there are some laboratory and preclinical studies.[43-47] Additionally, the hydraulic or mechanical effects of wound packing in bleeding control are becoming better understood.[48,49] The principles of controlling hemorrhage early by mechanical methods appear to apply to all portions of the extremities: the limbs where limb tourniquets fit and junctional parts of extremities where junctional tourniquets fit. Furthermore, tourniquets have been proposed in prolonged field care for mitigation of reperfusion after limb crush syndrome, although limited experience is available for decision-making.[10,50-52] The topics of junctional bleeding and crush syndrome require further research to provide evidence of effectiveness and safety.

Tourniquets in 2015 are issued to all military service personnel who deploy into a combat zone. In the US Army, virtually every Soldier is trained in tourniquet use—early and often. For example, since 2009 all recruits (new enlisted Soldiers) irrespective of specialty

(1) To maintain firepower supremacy, only extremity bleeding should warrant any intervention during Care Under Fire.
   (a) Casualty blood sweeps are not recommended during this phase of care. The assessment takes a considerable amount of time to complete and leaves the care giver vulnerable to the enemy.
   (b) Visual inspection is not necessary until both the care provider and the casualty are behind cover.
   (c) When approaching the casualty, if blood is apparent on the shirt sleeve or the pant leg, that is all the proof necessary to warrant application of a tourniquet.

(2) When the tactical situation dictates, no intervention should be employed unless and until:
   (a) The unit can afford to have the provider drop out of the fire fight long enough to intervene.
   (b) Efforts to direct the self-aid/buddy aid have failed.

(3) Tourniquets are the only recommended treatment for extremity hemorrhage during this phase. (Remember: 30 seconds on the "X" is 25 seconds too many. Even if it take only a few seconds to apply a tourniquet, that is enough time for the enemy to take aim and fire on both you and the casualty.)
   (a) Intervention should take place under suitable cover or concealment. This may require that you initially move the casualty before placing a tourniquet.
   (b) The intervention should be tactically feasible as to avoid a circumstance where the care giver is an additional casualty.
   (c) For obvious life threatening extremity hemorrhage.
      1) You may not really know if hemorrhage is life threatening until Tactical Field Care phase when the wound can be exposed and evaluated.
      2) The suspicion of life threatening hemorrhage is the only required criteria during Care under Fire.

(4) All tourniquets placed during Care Under Fire should be Hasty Tourniquets.
   (a) Place over the clothing.
   (b) As high on the extremity as possible (without capturing the shoulder or the buttock).
      1) Rarely are combat wounds clean incisions perpendicular through the extremity.
      2) This placement is preferred during Care under Fire because of the inability to properly expose and assess the wound.
      3) High application ensures the tourniquet is placed completely above any possible damaged/injured tissue.
   (c) As tightly as possible (due to the limitations during this phase of care, pulse checks are not required).

(5) Hasty Tourniquets should be converted to an alternative form of hemorrhage control prior to evacuation, typically during the Tactical Field Care Phase.

Figure 4. Excerpt from student handout for US Army Medic: Tourniquet Use During Care under Fire.

have been trained in tourniquet use in Basic Combat Training (also known as Initial Entry Training) that includes a Combat Lifesaver Course in first aid skills. Soon thereafter in Advanced Individual Training, more tourniquet training is again provided. Further training may be given when Soldiers are assigned to their units, and refresher training occurs before deployments. Such a systematic and long-standing program has changed the US Army's first-aid culture. Before 2009, tourniquets were new, a new way of doing things; after 2009, they were old. Prior to 2009, such a culture change was made in miniature by individual units like the 75th Ranger Regiment and Special Operations Forces. After their success, leaders of other organizations used it as a template for expanding this critical knowledge to all Soldiers.[2]

Next Generation of Bleeding Control Interventions

Current evidence shows that user development is important to best performance in bleeding control interventions.[18,53,54] Moreover, an emphasis on the quality of training should be recognized, understood by key leaders, planned for in military units, and made a priority. Among all areas associated with improvement of tourniquet use (ie, Doctrine, Organization, Training, Material, Leadership, Personnel, Facilities [DOTMLPF]), training is today the quintessential item to be addressed for tourniquet use: optimal user development is the most likely of all factors to improve outcomes. The path from current care toward best care is challenging; may we journey with knowledge, hope, and determination.

References

1. Beekley AC, Sebesta JA, Blackbourne LH, et al, for the Combat Support Hospital Research Group. Prehospital tourniquet use in Operation Iraqi Freedom: effect on hemorrhage control and outcomes. *J Trauma*. 2008;64(suppl 2):S28-S37.
2. Kragh JF Jr, Walters TJ, Baer DG, Fox CJ, Wade CE, Salinas J, Holcomb JB. Survival with emergency tourniquet use to stop bleeding in major limb trauma. *Ann Surg.* 2009;249:1-7.
3. Markenson D, Ferguson JD, Chameides L, et al. Part 13: First aid: 2010 American Heart Association and American Red Cross International Consensus on First Aid Science With Treatment Recommendations. *Circulation.* 2010;122(16 suppl 2):S582-S605.
4. Rasmussen TE, Baer DG. No drift. *JAMA Surg.* 2014;149:221-222.
5. Kragh JF Jr, Nam JJ, Berry KA, et al. Transfusion for shock in US military war casualties with and without tourniquet use. *Ann Emerg Med*. 2015;65:290-296.
6. Kragh JF Jr, Aden JK III, Walters TJ, et al. In reply. *Ann Emerg Med*. 2015;66:340-341.
7. Kragh JF Jr, Littrel ML, Jones JA, Walters TJ, Baer DG, Wade CE, Holcomb JB. Battle casualty survival with emergency tourniquet use to stop limb bleeding. *J Emerg Med*. 2011;41:590-597.
8. Le TD, Kragh JF Jr, Gross KR, et al. Impact of tourniquet use on mortality and shock for patients arriving at U.S. Role 2 surgical facilities in Afghanistan. Poster presentation at: Military Health System Research Symposium; Fort Lauderdale, Florida; August 17-20, 2015.
9. Altamirano MP, Kragh JF Jr, Aden JK III, Dubick MA. Role of the windlass in improvised tourniquet use on a manikin hemorrhage model. *J Spec Oper Med*. 2015;15(2):42-46.
10. Kragh JF Jr, Walters TJ, Baer DG, Fox CJ, Wade CE, Salinas J, Holcomb JB. Practical use of emergency tourniquets to stop bleeding in major limb trauma. *J Trauma*. 2008;64(suppl 2):S38-S49; discussion S-50.
11. Lyles WE III, Kragh JF Jr, Aden JK, Dubick MA. Testing tourniquet use in a manikin model: two improvised techniques. *J Spec Oper Med*. 2015;15(4):21-26.
12. Kragh JF Jr, Wallum TE, Aden JK III, Dubick MA, Baer DG. Which improvised tourniquet windlasses work well and which ones won't?. *Wilderness Environ Med*. 2015;26(3):401-405.
13. Kragh JF Jr, Wallum TE, Aden JK III, Dubick MA, Baer DG. Emergency tourniquet effectiveness in four positions on the proximal thigh. *J Spec Oper Med*. 2014;14(1):26-29.
14. Kragh JF Jr, Walters TJ, Westmoreland T, et al. Tragedy into drama: an American history of tourniquet use in the current war. *J Spec Oper Med*. 2013;13(3):5-25.
15. Kragh JF Jr, O'Neill ML, Walters TJ, et al. Minor morbidity with emergency tourniquet use to stop bleeding in severe limb trauma: research, history, and reconciling advocates and abolitionists. *Mil Med*. 2011;176:817-823.
16. Kragh JF, O'Neill ML, Beebe DF, Fox CJ, Beekley A, Cain J, Parsons D, Mabry R, Blackbourne L. Survey of the indications for use of emergency tourniquets. *J Spec Oper Med*. 2011;11(1):30-38.
17. Kragh JF, Beebe DF, O'Neill ML, Beekley AC, Dubick MA, Baer DG, Blackbourne LH. Performance improvement in emergency tourniquet use during the Baghdad surge. *Am J Emerg Med*. 2013;31:873-875.
18. Davinson J, Kragh JF Jr, Aden J III, DeLorenzo R, Dubick M. Laboratory testing of emergency tourniquets exposed to prolonged heat. *J Spec Oper Med*. 2015;15(1):34-38.

19. Slaven SE, Wall PL, Rinker JH, Halub ME, Hopkins JW, Sahr SM, Buising CM. Initial tourniquet pressure does not affect tourniquet arterial occlusion pressure. *J Spec Oper Med*. 2015;15(1):39-49.

20. Slaven SE, Gildemaster Y, Rometti M, Hopkins JW, Sahr SM, Buising CM, Wall PL. Pattern of pressure loss under strap tourniquets immediately following application. Poster presentation at: 2014 Special Operations Medical Association Scientific Assembly; December 8-11, 2014; Tampa, Florida.

21. Wall PL, Coughlin O, Rometti M, et al. Tourniquet pressures: strap width and tensioning system widths. *J Spec Oper Med*. 2014;14(1):19-29.

22. Shackelford SA, Butler FK Jr, Kragh JF Jr, Stevens RA, Kotwal RS, Mabry RL, Bailey JA. Optimizing the use of limb tourniquets in tactical combat casualty care: TCCC Guidelines Change 14-02. *J Spec Oper Med*. 2015;15(1):17-31.

23. Kragh JF Jr. Use of tourniquets and their effects on limb function in the modern combat environment. *Foot Ankle Clin*. 2010;15:23-40.

24. Childers R, Tolentino JC, Leasiolagi J, Wiley N, Liebhardt D, Barbabella S, Kragh JF Jr. Tourniquets exposed to the Afghanistan combat environment have decreased efficacy and increased breakage compared to unexposed tourniquets. *Mil Med*. 2011;176:1400-1403.

25. Kragh JF Jr, O'Neill ML, Walters TJ, et al. The military emergency tourniquet program's lessons learned with devices and designs. *Mil Med*. 2011;176:1144-1152.

26. Kragh JF Jr, Burrows S, Wasner C, et al. Analysis of recovered tourniquets from casualties of Operation Enduring Freedom and Operation New Dawn. *Mil Med*. 2013;178:806-810.

27. US Army. *Combat Lifesaver Course: Student Self Study Manual, Subcourse ISo871.* ed C. Fort Sam Houston, TX: US Army Medical Department Center & School; September 2013.

28. Fox N, Rajani RR, Bokhari F, et al. Evaluation and management of penetrating lower extremity arterial trauma: an Eastern Association for the Surgery of Trauma practice management guideline. *J Trauma Acute Care Surg.* 2012;73(5 suppl 4):S315-S320.

29. Bulger EM, Snyder D, Schoelles K, et al. An evidence-based prehospital guideline for external hemorrhage control: American College of Surgeons Committee on Trauma. *Prehosp Emerg Care*. 2014;18:163-173.

30. Jacobs LM Jr. Joint Committee to Create a National Policy to Enhance Survivability from Mass Casualty Shooting Events: Hartford Consensus II. *J Am Coll Surg.* 2014;218:476-478.

31. Passos E, Dingley B, Smith A, et al. Tourniquet use for peripheral vascular injuries in the civilian setting. *Injury.* 2014;45:573-577.

32. Zietlow JM, Zietlow SP, Morris DS, Berns KS, Jenkins DH. Prehospital use of hemostatic bandages and tourniquets: translation from military experience to implementation in civilian trauma care. *J Spec Oper Med*. 2015;15(2):48-53.

33. Ode G, Studnek J, Seymour R, Bosse MJ, Hsu JR. Emergency tourniquets for civilians: can military lessons in extremity hemorrhage be translated?. *J Trauma Acute Care Surg.* 2015;79:586-591.

34. Schroll R, Smith A, McSwain NE Jr, et al. A multiinstitutional analysis of prehospital tourniquet use. *J Trauma Acute Care Surg.* 2015;79:10-14.

35. Inaba K, Siboni S, Resnick S, et al. Tourniquet use for civilian extremity trauma. *J Trauma Acute Care Surg.* 2015;79:232-237.

36. Meizoso JP, Valle EJ, Allen CJ, et al. Decreased mortality after prehospital interventions in severely injured trauma patients. *J Trauma Acute Care Surg.* 2015;79:227-231.

37. Alpert EA, Lipsky AM, Elie ND, Jaffe E. The contribution of on-call, volunteer first responders to mass-casualty terrorist attacks in Israel. *Am J Disaster Med.* 2014;10:35-39.

38. Haider AH, Piper LC, Zogg CK, et al. Military-to-civilian translation of battlefield innovations in operative trauma care. *Surgery.* 2015;158:1686-1695.

39. Tovmassian RV, Kragh JF Jr, Dubick MA, Baer DG, Blackbourne LH. Combat ready clamp medic technique. *J Spec Oper Med*. 2012;12(4):72-78.

40. Kragh JF Jr, Murphy C, Dubick MA, Baer DG, Johnson J, Blackbourne LH. New tourniquet device concepts for battlefield hemorrhage control. *US Army Med Dep J.* April-June 2011:38-48.

41. Kragh JF Jr, Mann-Salinas EA, Kotwal RS, et al. Laboratory assessment of out-of-hospital interventions to control junctional bleeding from the groin in a manikin model. *Am J Emerg Med*. 2013;31(8):1276-1278.

42. Kragh JF Jr, Parsons DL, Kotwal RS, et al. Testing of junctional tourniquets by military medics to control simulated groin hemorrhage. *J Spec Oper Med*. 2014;14(3):58-63.

43. Mann-Salinas EA, Kragh JF Jr, Dubick MA, Baer DG, Blackbourne LH. Assessment of users to control simulated junctional hemorrhage with the combat ready clamp (CRoC™). *Int J Burns Trauma*. 2013;3(1):49-54.

44. Kragh JF Jr, Dubick M, Aden J III, McKeague A, Rasmussen T, Baer D, Blackbourne L. U.S. military experience with junctional wounds in war from 2001 to 2010. *J Spec Oper Med.* 2013;13(4):76-84.

45. Kragh JF Jr, Johnson JE, Henkel CK, Dubick MA. Technique of axillary use of a combat ready clamp to stop junctional bleeding. *Am J Emerg Med*. 2013;31(8):1274-1276.

46. Johnson JE, Sims RK, Hamilton DJ, Kragh J. Safety and effectiveness evidence of SAM? Junctional tourniquet to control inguinal hemorrhage in a perfused cadaver model. *J Spec Oper Med*. 2014;14(2):21-25.

47. Klotz JK, Leo M, Anderson B, et al. First case report of SAM? Junctional tourniquet use in Afghanistan to control inguinal hemorrhage on the battlefield. *J Spec Oper Med*. 2014;14(2):1-5.

48. Kragh JF Jr, Steinbaugh J, Parsons DL, Mabry RL, Kheirabadi BS, Dubick MA. A manikin model for study of wound packing interventions to control out-of-hospital hemorrhage. *Am J Emerg Med*. 2014;32(9):1130-1131.

49. Kragh JF, Aden JK, Steinbaugh J, Bullard M, Dubick MA. Gauze vs XSTAT in wound packing for hemorrhage control. *Am J Emerg Med*. 2015;33(7):974-976.

50. Porter K, Greaves I. Crush injury and crush syndrome: a consensus statement: Keith Porter and Ian Greaves review the findings of a consensus meeting on crush injury and crush syndrome held in Birmingham on May 31 2001 and co-ordinated by the faculty of pre-hospital care of the Royal College of Surgeons of Edinburgh. *Emerg Nurse*. 2003;11:26-30.

51. Schwartz DS, Weisner Z, Badar J. Immediate lower extremity tourniquet application to delay onset of reperfusion injury after prolonged crush injury. *Prehosp Emerg Care*. 2015;19(4):544-547.

52. Kragh JF Jr, Baer DG, Walters TJ. Extended (16-hour) tourniquet application after combat wounds: a case report and review of the current literature. *J Orthop Trauma*. 2007;21:274-278.

53. Clumpner B, Polston R, Kragh JF Jr, et al. Single versus double routing of the band in the combat application tourniquet. *J Spec Oper Med*. 2013;13(1):34-41.

54. Polston RW, Clumpner BR, Kragh JF Jr, Jones JA, Dubick MA, Baer DG. No slackers in tourniquet use to stop bleeding. *J Spec Oper Med*. 2013;13(2):12-19.

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