A Novel, Perfused-Cadaver Simulation Model for Tourniquet Training in Military Medics

Daniel Grabo, MD[1]; Travis Polk, MD[2]; Aaron Strumwasser, MD[2]; Kenji Inaba, MD[2]; Christopher Foran, MD[2]; Chase Luther, BS[3]; Michael Minneti, BS[3]; Shane Kronstedt, BS[4]; Alison Wilson, MD[1]; Demetrios Demetriades, MD, PhD[2]*

ABSTRACT

Background: Exsanguinating limb injury is a significant cause of preventable death on the battlefield and can be controlled with tourniquets. US Navy corpsmen rotating at the Navy Trauma Training Center receive instruction on tourniquets. We evaluated the effectiveness of traditional tourniquet instruction compared with a novel, perfused-cadaver, simulation model for tourniquet training. **Methods:** Corpsmen volunteering to participate were randomly assigned to one of two tourniquet training arms. Traditional training (TT) consisted of lectures, videos, and practice sessions. Perfused-cadaver training (PCT) included TT plus training using a regionally perfused cadaver. Corpsmen were evaluated on their ability to achieve hemorrhage control with tourniquet(s) using the perfused cadaver. Outcomes included (1) time to control hemorrhage, (2) correct placement of tourniquet(s), and (3) volume of simulated blood loss. Participants were asked about confidence in understanding indications and skills for tourniquets. **Results:** The 53 corpsmen enrolled in the study were randomly assigned as follows: 26 to the TT arm and 27 to the PCT arm. Corpsmen in the PCT group controlled bleeding with the first tourniquet more frequently (96% versus 83%; $p < .03$), were quicker to hemorrhage control (39 versus 45 seconds; $p < .01$), and lost less simulated blood (256mL versus 355mL; $p < .01$). There was a trend toward increased confidence in tourniquet application among all corpsmen. **Conclusions:** Using a perfused-cadaver training model, corpsmen placed tourniquets more rapidly and with less simulated-blood loss than their traditional training counterparts. They were more likely to control hemorrhage with first tourniquet placement and gain confidence in this procedure. Additional studies are indicated to identify components of effective simulation training for tourniquets.

Keywords: *tourniquet; tactical combat casualty care; military medics; perfused-cadaver training; high-fidelity simulation training*

Introduction

Exsanguinating limb injury is one of the most common causes of preventable death on the battlefield in the Global War on Terror.[1,2] Tourniquet use on the battlefield, however, is associated with improved hemorrhage control[3] and improved survival rates for combat casualties with major limb trauma when applied in the prehospital setting and in the absence of shock.[4] In addition, the use of tourniquets is not associated with limb loss or adverse outcomes, including nerve palsies.[3–5] Tourniquets are a critical component of the Tactical Combat Casualty Care (TCCC)[6] paradigm currently practiced by the US military. The application of tourniquets, moreover, is currently the most common field intervention performed during battlefield mass casualty events.[7]

With the effectiveness and low complication risk of tourniquet application firmly established, attention must turn to the existing training provided to our military personnel prior to combat deployment for this lifesaving intervention.[4] In a 2014 study, current training modalities used in the Combat Casualty Care Course for US Navy medical personnel still yielded inferior accuracy, time, and effectiveness of tourniquet application in simulated combat situations when compared with classroom settings.[8] In a recent review of tourniquet use by the military, Kragh and Dubick stated, "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."[9] There is a paucity of literature at this time evaluating training modalities for tourniquet application, yielding objective measurements that prove the efficacy of the training prior to deployment.

Students at the Navy Trauma Training Center (NTTC) at the Los Angeles County and University of Southern California (LAC+USC) Medical Center in Los Angeles receive training in lifesaving battlefield procedures, including tourniquet application. This is not a formal TCCC training course, but traditional instructional modalities for tourniquet education and training are used and include slide-based lectures that review indications, pertinent anatomy and technical instruction, a video presentation on proper application, and practice sessions in which the students place tourniquets on their training partner and themselves.

The purpose of the current study was to evaluate the addition of a novel, perfused-cadaver training model for providing superior predeployment training to US Navy corpsmen in the

*Correspondence to Daniel Grabo, MD, Division of Trauma, Acute Care Surgery, Surgical Critical Care, West Virginia University, Health Sciences Center South, PO Box 9238, Morgantown, WV 26506 *or* daniel.grabo@hsc.wvu.edu
[1]**Drs Grabo** and **Wilson** are at the Division of Trauma, Acute Care Surgery and Critical Care, West Virginia University, Morgantown, WV. [2]**Drs Polk, Strumwasser, Inaba, Foran,** and **Demetriades** are at the Division of Acute Care Surgery, Keck School of Medicine of University of Southern California, Los Angeles, CA. [3]**Messrs Luther** and **Minneti** are at the Keck School of Medicine of University of Southern CA. [4]**Mr Kronstedt** is at the Joint Special Operations Medical Training Center, Fort Bragg, NC.

application of tourniquets when compared with traditional instructional models alone. A secondary aim of this study was to evaluate the confidence of the trainees in their self-reported understanding of the indications for and technical abilities to apply tourniquets to exsanguinating limb injury after training.

Methods

This study was performed after approval by the Institutional Review Board at the Keck School of Medicine of USC and in accordance with the Keck School of Medicine of USC Fresh Tissue Dissection Laboratory (FTDL) policies. From January 2016 to November 2016, US Navy corpsmen rotating at NTTC were recruited to participate. Fifty-three corpsmen volunteered for the study. Demographic data were collected and included age, sex, experience (years), deployment history, and previous tourniquet experience in training and real-life situations. Each of the corpsmen was then randomly assigned to one of two limb-tourniquet instruction methods: traditional training (TT) alone or traditional training plus the addition of perfused-cadaver training (PCT).

In keeping with the curriculum at NTTC during the study period, the US Military standard-issue, Combat Application Tourniquet® (C-A-T) Generation 6 (C-A-T Resources; http://combattourniquet.com/) was used for all training and evaluation portions of this study. The TT arm included standardized lecture on indications and step-by-step instructions on the technique of limb tourniquet placement, using photographs, diagrams, and a demonstration video. In addition, under NTTC staff instruction, the corpsmen practiced tourniquet application on their training partners. In brief, the trainees would place tourniquets on themselves and their training partners. The PCT arm underwent the same TT, as well as hands-on practice of tourniquet application using the perfused cadaver. All tourniquet instruction was in accordance with TCCC guidelines and curriculum, as well as manufacturer instruction for the C-A-T Generation 6.

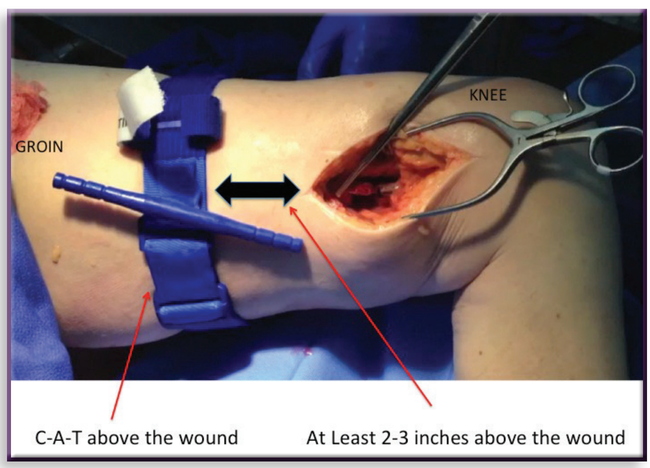
For the purposes of tourniquet instruction and testing, the NTTC staff used a novel, perfused-cadaver model (Minneti method)[10] for lower limb hemorrhage. The Minneti method of perfusion for cadavers was described by Carey et al.[10] and is commonly used in the FTDL for vascular procedure training on cadavers. All interventions occurred at and in accordance with the policies of the FTDL. All cadavers were fresh, never-frozen, nonembalmed human bodies. All cadavers were free of skin, bone, or soft-tissue abnormalities involving the lower extremities and were kept in refrigerated storage until 1 hour before training and evaluation, when they were allowed to warm to room temperature.

All cadavers were positioned supine on a standard dissection table for both training and evaluation. Cadaver age and weight were recorded. Bilateral groin dissections were performed and superficial femoral arteries (SFAs) were cannulated. A standardized wound was made on the medial thigh above the knee to include an injury to the distal SFA. A centrifugal perfusion pump and console (BPX-50 Bio-Pump and Bio Medicus Bio Console 550; Medtronic, http://www.medtronic.com) was connected to provide regional perfusion in the cadavers' SFAs. Revolutions per minute were set at 2,000 to deliver a nonpulsatile pressure within the vessel of 80–100mmHg. The perfusate consisted of red premium tempura paint (Dick Blick Art Material, https://www.dickblick.com/,) with salt and water. While nonpulsatile, this method allows tourniquet placement without tubing rupture associated with positive displacement pumps.

After the instruction and practice sessions (TT or PCT), each corpsman was brought to an unmarked and covered cadaver (with hospital gown and sheet). Once the gown and sheet were removed (to simulate injury and wound exposure) and extremity hemorrhage was identified, each of the corpsmen performed tourniquet application on the right and left lower extremity in separate timed events. The time taken to place the tourniquet(s) and stop the bleeding was recorded. After the tourniquet(s) was/were secured, a trauma surgeon blinded to the teaching method assessed the position of the tourniquet(s).

Correct application and positioning required that the tourniquet be applied in accordance with TCCC guidelines and manufacturer instructions and that the tourniquet be placed at least 2 to 3 inches (5–7.6cm) proximal to the wound (Figure 1). If needed, a second tourniquet was secured in the same way and placed above and immediately adjacent to the first tourniquet. Exact distance of the tourniquet from the most proximal wound edge was recorded. Total simulated blood loss was measured for each limb hemorrhage event. Cadaver arterial pressure was measured after each tourniquet application (range, 80–100mmHg).

FIGURE 1 *Application of Combat Application Tourniquet (C-A-T) Generation 6, per manufacturer instructions and Tactical Combat Casualty Care instruction for lower extremity placement. Tourniquet is placed proximal to the wound 2 to 3 inches (5–7.6cm). Wound exposed with self-retaining retractor for demonstration purposes only. The retractor was not used for training or evaluation purposes.*



The corpsmen were given surveys prior to tourniquet training (TT or PCT) and immediately after completion of testing. They were questioned regarding their confidence in understanding indications and technique for limb tourniquet application in a patient with extremity hemorrhage. A 5-point Likert scale (0 = no confidence to 4 = very confident) to rate their confidence was used.

The following outcomes were compared between the two study arms: (1) simulated hemorrhage control (yes or no), (2) time required to place the tourniquet(s) (time in seconds), (3) correct placement of the tourniquet(s) (measured as distance in centimeters from the wound apex), and (4) volume of simulated blood loss (measure in milliliters). In addition, survey responses for confidence (indications and technique) were compared between groups.

Statistical Methodology

Data were analyzed using OS X El Capitan 10.11.6/Microsoft Excel 15.24 (Microsoft Corp., www.microsoft.com). Univariate continuous data between two groups were compared by F-test for variance followed by an unpaired Student *t* test or Mann Whitney U test, where appropriate (comparison of baseline demographics and outcomes TT versus PCT). Categorical data were analyzed via χ^2 analysis where appropriate (for the Likert scale testing, each individual was their own control with improvement rated on a scale of 1 = improved or 0 = no improvement, depending on how they moved on a 5-point scale). Statistical significance was denoted at $p \leq .05$.

Results

During the study period, a total of 53 corpsmen were enrolled; 26 were randomly assigned to the TT arm and 27 to the PCT arm. Table 1 details the demographics of these groups. In general, both groups were predominately male, had approximately 8 years of military service, one combat deployment, and significant prior military medical training. However, the PCT arm had fewer TCCC-trained individuals, less prior cadaver training, and fewer real world tourniquet applications. A total of eight, fresh, nonembalmed cadavers were used for training and evaluation simulations (mean age, 72 years; mean weight, 64kg).

TABLE 1 *Demographics*

Demographic	Traditional Training (n = 26)	Cadaver Training (n = 27)	*p* Value
Age, y	29 (0.7)	29 (0.7)	.73
Male, %	92	83	.38
Military service, y	7.8 (0.6)	7.5 (0.7)	.69
Deployments, n (%)	1.2 (0.2)	1.1 (0.2)	.77
Experience prehospital provider (civilian), %	15	19	.76
Prior tourniquet training (military or civilian), %	96	93	.58
Taken TCCC course, %	100	82	.02*
Times taken TCCC course, n (%)	3.2 (0.3)	2.1 (0.3)	.01*
Taken PHTLS course, %	12	7.4	.61
Placed a tourniquet in practice environment, %	100	100	1.0
Tourniquets placed in practice environment, n (%)	73 (11)	40 (6.8)	.01*
Practice training mannequin model, %	100	100	1.0
Tourniquets placed on mannequin, n (%)	56 (9.4)	33 (6.5)	.05*
Practice training animal model, %	13	0	.07
Practice training cadaver model, %	23	3.7	.04*
Prior live casualty training, %	42	22	.12

Data arerepresented as mean (SEM) or percentages, where appropriate. TCCC, Tactical Combat Casualty Care; PHTLS, prehospital trauma life support. *Significant.

A total of 96 simulated leg hemorrhage scenarios were managed by 48 corpsmen. A total of 10 measurements for five corpsmen from the TT group were discarded because of perfusion system failure on a single day of testing. The failure was not the result of the tourniquets or corpsmen application of the tourniquets. None of the PCT group measurements required exclusion.

The PCT group was able to control simulated hemorrhage with one tourniquet more frequently than was the TT group (96.0% versus 83.0%; p = .03). Although the TT group required a second tourniquet to gain hemorrhage control more often than did the PCT group, there was no difference in the overall ability to control hemorrhage (97% versus 98%) with the addition of a second tourniquet (Figure 2). The PCT group took less time to achieve initial hemorrhage control (PCT: 39 seconds versus TT: 45 seconds; p = .01) and final hemorrhage control when compared with the TT group (PCT: 76 seconds versus TT: 99 seconds), when necessary (Figure 3).

When location of tourniquet placement was examined, corpsmen in both arms placed the tourniquet consistently proximal to the wound (PCT: 5.5 cm versus TT: 7.6 cm; p = .03).

FIGURE 2 *Successful hemorrhage control for TT and PCT groups is represented. Nearly all corpsmen were successful in controlling hemorrhage; the TT group needed to place a second tourniquet more often than did the PCT group. PCT, perfused-cadaver training; TT, traditional training.*

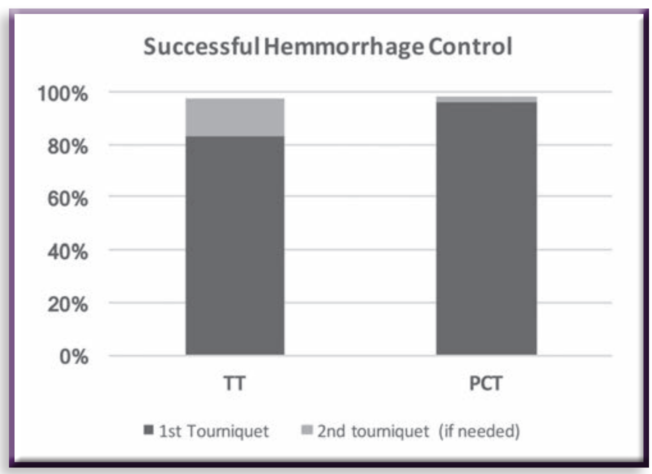
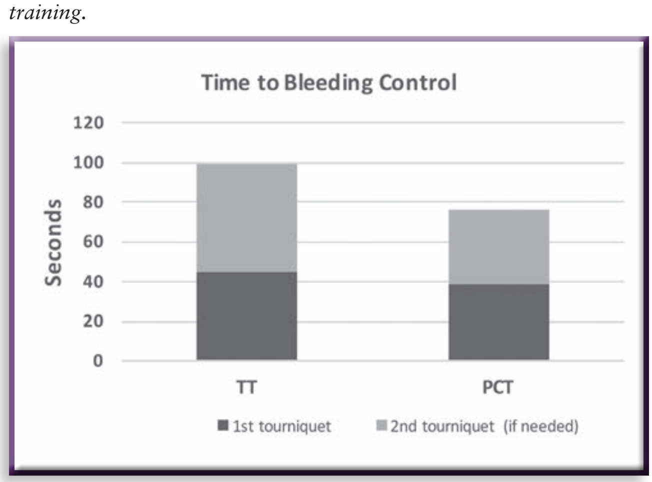


FIGURE 3 *Mean time to bleeding control was longer for the TT than for the PCT. PCT, perfused-cadaver training; TT, traditional training.*



Corpsmen in the PCT group lost significantly less simulated blood on the pressurized-cadaver hemorrhage model when compared with the TT group (PCT: 256mL versus TT: 355mL; p = .01; Figure 4). There was no variation noted in the perfused cadavers with regard to the measurements of pressure in the femoral artery occluded proximal to the injury by the tourniquet (TT: 95mmHg versus PCT: 92mmHg; p = .9.)

Corpsmen in both groups reported an increase in their self-reported confidence in understanding the indications for and technique of limb tourniquet application in extremity hemorrhage. A statistically significant trend of improvement among those trained in the PCT model was noted for improved confidence in the ability to place a tourniquet in extremity hemorrhage (p = .06; Figure 5). Please see Table 2 for detailed results description.

FIGURE 4 *Mean simulated blood loss was higher in the TT than the PCT. Standard error bars are shown as well. PCT, perfused-cadaver training; TT, traditional training.*

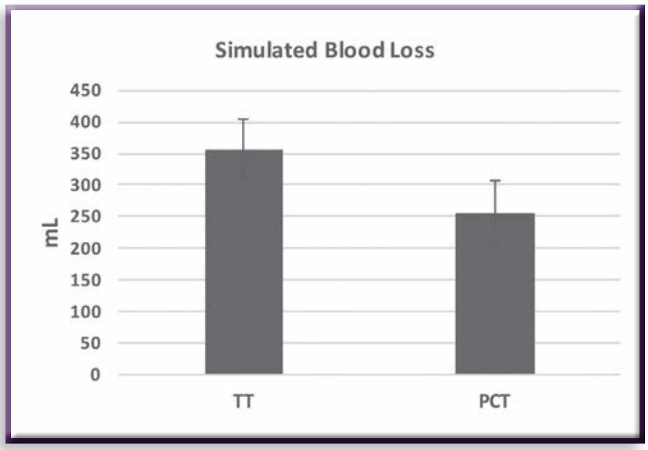


FIGURE 5 *Mean confidence scores as self-reported by the corpsmen using a survey and 5-point Likert scale (0 = no confidence to 4 = very confident). Scores are reported for pre- and post-training, indications and technique for extremity tourniquets. Standard error bars are shown. PCT, perfused-cadaver training; TT, traditional training.*

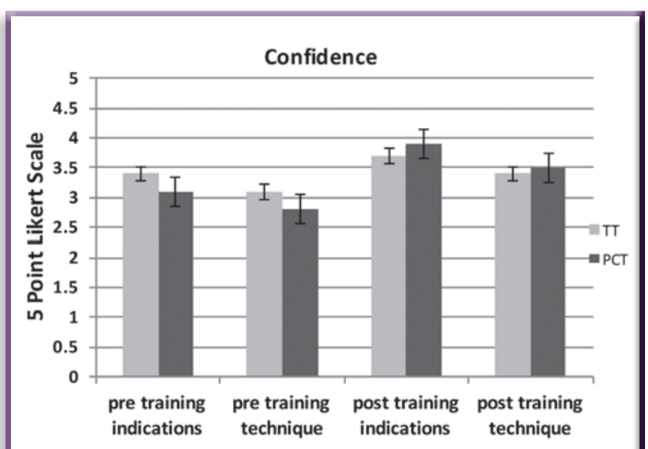


TABLE 2 *Outcome Measures*

Outcome	Traditional Training (n = 42 Measurements)	Cadaver Training (n = 54 Measurements)	*P* Value
Cadaver mean arterial pressure, mmHg	95 (1.7)	92 (2.7)	.98
Bleeding controlled with first tourniquet, %	83	96	.03*
Time to control of bleeding with first tourniquet, sec	45 (2.3)	39 (2.0)	.01*
Position of first tourniquet from apex of injury, cm	7.6 (0.7)	5.5 (0.2)	.03*
Achieved control with second tourniquet, %	86	50	.41
Time to control of bleeding with two tourniquets, sec	99 (1.9)	76 (1.4)	.12
Total simulated blood loss, mL	355 (30)	256 (21)	.01*

Data are represented as mean (SEM) or percentages, where appropriate. *Significant.

Discussion

The military medics or US Navy corpsmen in this study were a heterogeneous group of young people, mostly men (>80%). They were not new trainees; on average, they possessed almost 8 years of military experience and at least one combat deployment. Although they did not have much civilian tourniquet training, nearly all had previously received tourniquet training in the military (93%) and had taken TCCC training (>80%). The TT group had more experience in tourniquet training overall and on a cadaver-based model than did the PCT group. Neither group, however, had significant experience in real-life casualty tourniquet experience.

Despite this similar baseline background, the PCT group were better able to control bleeding with the first tourniquet in the perfused cadaver limb-hemorrhage model, although there was no difference in overall ability to control hemorrhage (when second tourniquet was used). In addition, the PCT group was quicker to control bleeding with the first tourniquet and lost less blood in their limb hemorrhage simulation scenarios. Corpsmen in both groups were accurate in the location of placement of the tourniquet. This is critically important when compressing a bleeding vessel that might have retracted proximally and allowing sufficient area in which to place a second tourniquet, if needed.

The results of this study indicate not only that the technical factors associated with limb tourniquet application improved with a perfused-cadaver training model but also that corpsmen in both groups had improved confidence in understanding the indications for and technique of limb tourniquet application for hemorrhage control. Those in the PCT arm, however, trended toward significant improvement in self-reported confidence in limb tourniquet application. The use of a simulated bleeding, fresh-tissue model that allows for vessel compression and real tissue manipulation may be a factor in improving the trainees' confidence in this lifesaving procedure. It has been established in the psychology literature, however, that self-estimation of confidence does not correlate directly with test performance and ability.[11] Self-evaluation instruments, such as the ones used in the current study, are best used for individual self-analysis and personal reflection.[12] As such, the corpsmen's self-reported confidence in knowledge or technique does not necessarily indicate actual knowledge or skills gained.

Cadaver-based training has been shown to be superior to traditional simulation and slide-based lecture in teaching lifesaving procedures. The emergency medicine residents in the Takeyesu et al. study[13] reported higher fidelity in the cadaver training model when compared with simulation for cricothyroidotomy and tube thoracostomy, as well as improved confidence when the cadaver training model was used. Furthermore, when training US Navy Corpsmen in needle decompression for tension pneumothorax, better results were had with the fresh-cadaver training model used by Grabo et al.[14] than with standard slide-based lectures when measuring accuracy of angiocatheter placement. Hart et al.[15] conducted a study of 559 Army Combat Medics in which the use of live tissue (goat) versus synthetic tissue model was evaluated for training in critical airway, breathing, and hemorrhage control procedures. Relevant to the study presented here, the group that was trained and tested on live tissue in the Hart et al. study, however, had fewer critical fails than the groups trained and tested on synthetic models.

Studies like those mentioned in the preceding paragraph lend support to the idea that high-fidelity and dynamic training models for procedural skills might be better teaching modalities. Previous work at LAC+USC has shown that the use of perfused, fresh cadaver simulation in a surgical training program was useful in replicating human-tissue handling.[10] Carden et al.[16] showed that dynamic simulation training using mannequins with ongoing hemorrhage for teaching temporary vascular shunt placement to general surgery residents was equivalent to cadaver training. The addition of dynamic hemorrhage simulation was thought to augment the trauma skills training. Human cadaver simulation with circulation in the major vessels is a novel concept for training trauma surgeons, especially as an alternative to a live animal model.[17]

The next generation of bleeding control interventions for limb hemorrhage likely involves developing standards in education and skill sets for tourniquet users.[9] The results of the current study suggest that the use of a human fresh cadaver with hemorrhage simulation is also applicable for high-fidelity, dynamic training and possible integration into the curriculum of Military Medics for lifesaving battlefield procedures. Additional opportunities exist for the development of predeployment and sustainment training for military surgical teams to perform damage-control surgical techniques on these high-fidelity, dynamic perfused cadavers for training and skills sustainment.

This study has several limitations. Although fresh, never-frozen, nonembalmed, perfused cadavers were used in this training model, this may not completely reproduce the anatomy, physiology, and tactile feedback of live patients. In general, age of the cadaver was older and muscle mass was lower than that of the average combat casualty. As such, the amount of pressure needed to compress the vessel would be less than in a more commonly encountered young male combat casualty. Unlike battlefield trauma, this study involved placing limb tourniquets in a highly controlled, sterile environment. Factors such as the battlefield environment, wounding patterns, patient movement and clothing, as well as multiple injuries could not be reproduced. To be consistent for the corpsmen who entered the study in the early phase, the C-A-T Generation 6 was used throughout the study despite C-A-T Generation 7 beginning production in late 2015 and becoming available at NTTC toward the mid to later part of the study. The primary difference between use of these devices is that the Generation 7 device is designed with a single-pass buckle. Kragh et al.[18] compared the Generation 6 to the prototype Generation 7 device in a small mannequin-based study in the spring of 2016 and concluded that the C-A-T Generation 7 performed better, was easier to use, and was preferred to the Generation 6 model. Their study, however, did not show statistically significant differences in effectiveness in bleeding control or time to bleeding control.[18] The most important limitation of the current study is the potential for bias introduced because the PCT group received more tourniquet training and was familiar with the testing model, having been exposed to it in their training. Although we readily acknowledge this as a potential for bias, this can also be viewed as a potential advantage of this model in that it provides more realistic, high-fidelity, and dynamic training that more closely imitates a real-life scenario.

Conclusion

US Navy corpsmen who received PCT were better trained in tourniquet application for lower limb hemorrhage than were their counterparts who received TT. The use of a perfused-cadaver model offers an exciting modality for training lifesaving procedures, such as tourniquets, with fresh tissue and simulated bleeding from compressible vessels. Additional studies are indicated to develop this model for its use in limb tourniquet and other lifesaving procedures for Military Medics and surgical teams.

Poster Presentation

This study was presented in poster form at the Annual Meeting of the American Association for the Surgery of Trauma, September 2017, Baltimore, Maryland.

Disclaimer

The views presented here are those of the authors and do not necessarily represent the views of the Department of the Navy or the Department of Defense.

Disclosures

The authors have no conflicts of interest and nothing to disclose.

Author Contributions

DG, TP, AS, KI, and CF contributed to the study design, data interpretation, and critical revision of the manuscript. CL contributed to data interpretation. MM, SK, AW, and DD contributed to critical revision of the manuscript.

References

1. **Holcomb JB, McMullin NR, Pearse L, et al.** Causes of death in U.S. Special Operations Forces in the global war on terrorism: 2001–2004. *Ann Surg*. 2007;245(6):986–991.
2. **Eastridge BJ, Mabry RL, Seguin P, et al.** Death on the battlefield (2001-2011): Implications for the future of combat casualty care. *J Trauma Acute Care Surg*. 2012;73(6 supplement 5):S431–437.
3. **Beekley AC, Sebesta JA, Blackbourne LH, et al.** Prehospital tourniquet use in Operation Iraqi Freedom: effect on hemorrhage control and outcomes. *J Trauma*. 2008;64(2 Suppl):S28–S37.
4. **Kragh JG, Walter TJ, Baer DG, et al.** Survival with emergency tourniquet use to stop bleeding in major limb trauma. *Ann Surg*. 2009;246(1):1–7.
5. **Kragh JF, Dubick MA, Aden JK, et al.** U.S. Military use of tourniquets from 2001 to 2010. *Prehosp Emerg Care*. 2014;19(2): 184–190.
6. **National Association of Emergency Medical Technicians**. TCCC for medical personnel guidelines and curriculum. http://www.naemt.org/education/TCCC/guidelines_curriculum.

7. **Schauer SG, April MD, Simon E, et al.** Prehospital interventions during mass-casualty events in Afghanistan: a case analysis. *Prehosp Disaster Med*. 2017;32(4):465–468.
8. **Schreckengaust R, Littlejohn L, Zarow GJ.** Effects of training and simulated combat stress on leg tourniquet application accuracy, time and effectiveness. *Mil Med*. 2014;179(2):114–120.
9. **Kragh JF, Dubick MA.** Battlefield tourniquets: lessons learned in moving current care toward a best care in an army medical department at war. *US Army Med Dep J*. 2016;April–September (2–16):29–36.
10. **Carey JN, Minneti M, Leland HA, et al.** Perfused fresh cadavers: method for application to surgical simulation. *Am J Surg*. 2015; 210(1):179–187.
11. **Kruger J, Dunning D.** Unskilled and unaware of it: how difficulties in recognizing one's own incompetence lead to inflated self-assessments. *J Pers Soc Psychol*.1999;77(6):1121–1134.
12. **Stewart J, O'Halloran C, Barton JR, et al.** Clarifying the concepts of confidence and competence to produce appropriate self-evaluation measurement scales. *Med Educ*. 2000;34(11):903–909.
13. **Takeyesu JK, Peak D, Stearns D.** Cadaver based training is superior to simulation training for cricothyroidotomy and tube thoracostomy. *Intern Emerg Med*. 2017;12(1):99–102.
14. **Grabo DJ, Inaba K, Hammer P, et al.** Optimal training for emergency needle thoracostomy placement by prehospital personnel: didactic teaching versus a cadaver-based training program. *J Trauma Acute Care Surg*. 2014;77(3 Suppl 2):S109–113.
15. **Hart D, Rush R, Rule G, et al.** Training and assessing critical airway, breathing, and hemorrhage control procedures for trauma care: live tissue versus synthetic models. *Acad Emerg Med*. 2018;25 (2):148–167.
16. **Carden AJ, Salcedo ES, Leshikar DE, et al.** Randomized controlled trial comparing dynamic simulation with static simulation in trauma. *J Trauma Acute Care Surg*. 2016;80(5):748–753.
17. **Aboud ET, Krisht AF, O'Keeffe T, et al.** Novel simulation for training trauma surgeons. *J Trauma*. 2011;71(6):1484–1490.
18. **Kragh JF, Moore VK, Aden JK, et al.** Short report comparing generation 6 versus prototype generation 7 combat application tourniquet in a manakin hemorrhage model. *J Spec Oper Med*. 2016;16(1):14–17.

The Special Operations Medical Association's Official Journal

JSOM

JOURNAL *of* SPECIAL OPERATIONS MEDICINE™

UNCONVENTIONAL WARFARE
UNCONVENTIONAL MEDICINE

Winter 2018
Volume 18, Edition 4

THE JOURNAL FOR OPERATIONAL MEDICINE AND TACTICAL CASUALTY CARE

Inside this Issue:

Dedicated to the Indomitable Spirit and Sacrifices of the SOF Medic

A Peer-Reviewed Journal That Brings Together the Global Interests of Special Operations' First Responders