The Journal of Emergency Medicine, Vol. 54, No. 3, pp. 307–314, 2018
Published by Elsevier Inc.
0736-4679/$ - see front matter

https://doi.org/10.1016/j.jemermed.2017.09.011

Brief Report

THE TOURNIQUET GAP: A PILOT STUDY OF THE INTUITIVE PLACEMENT OF THREE TOURNIQUET TYPES BY LAYPERSONS

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☐ Abstract—Background: The "Stop the Bleed" campaign in the United States advocates for nonmedical personnel to be trained in basic hemorrhage control and that "bleeding control kits" be available in high-risk areas. However, it is not clear which tourniquets are most effective in the hands of laypersons. Objectives: The objective of this pilot study was to determine which tourniquet type was the most intuitive for a layperson to apply correctly. Methods: This project is a randomized study derived from a "Stop the Bleed" education initiative conducted between September 2016 and March 2017. Novice tourniquet users were randomized to apply one of three commercially available tourniquets (Combat Action Tourniquet [CAT; North American Rescue, LLC, Greer, SC], Ratcheting Medical Tourniquet [RMT; m2 Inc., Winooski, VT], or Stretch Wrap and Tuck Tourniquet [SWAT-T; TEMS Solutions, LLC, Salida, CO]) in a controlled setting. Individuals with formal medical certification, prior military service, or prior training with tourniquets were excluded. The primary outcome of this study was successful tourniquet placement. Results: Of 236 possible participants, 198 met the eligibility criteria. Demographics were similar across groups. The rates of successful tourniquet application for the CAT, RMT, and SWAT-T were 16.9%, 23.4%, and 10.6%, respectively (*p* = 0.149). The most common causes of application failure were: inadequate tightness (74.1%), improper placement technique (44.4%), and incorrect positioning (16.7%). Conclusion: Our pilot study on the intuitive nature of applying commercially available tourniquets found unacceptably high rates of failure. Large-scale community education efforts and manufacturer improvements of tourniquet usability by the lay public must be made before the widespread dissemination of tourniquets will have a significant public health effect. Published by Elsevier Inc.

☐ Keywords—Stop the Bleed; layperson tourniquet use; intuitive tourniquet; first aid training; tourniquet training

INTRODUCTION

Background

In October of 2015, the White House launched its "Stop the Bleed" initiative to address the concerns for the alarming number of mass shooting incidents plaguing the United States (1). The Federal Bureau of Investigation in cooperation with Texas State University published a report in 2013 on the study of active shooter events in the United States demonstrating a concerning rise from 2000 to the year 2013 (2). Between 2000 and 2013, there were 160 active shooter events, with 1043 victims killed or wounded. The findings in this study suggest that the duration of most active shooter incidents is so short that in most cases they are over prior to the arrival of any police or medical first responders. Also, most of these crime scenes are not determined to be safe for medical

Received: 19 June 2017; Final submission received: 4 September 2017;
Accepted: 14 September 2017

responders to enter until long after the violence has occurred, leaving shooting victims without any medical attention for prolonged periods. These delays to treatment may have led to lives lost that could have been saved if medical care had been more readily available. The report clearly illustrated the increasing threat to the public, and after a meeting of medical experts within the trauma community, the resulting Hartford Consensus called for new protective and response measures within the community to respond to this rising threat (3).

The Hartford Consensus convened after the tragic events at Sandy Hook Elementary School, where 27 people were shot and killed at a U.S. elementary school, with 20 of the victims being children. They concluded it was unreasonable to believe that medical first responders can arrive in a timely enough fashion to respond, and therefore, bystanders need to be capable of rendering emergency first aid to save lives (3). Other researchers have shown bystander first aid has the potential to save lives in more everyday events as well. Ashour et al. identified that appropriate bystander actions at the scene of motor vehicle collisions would have resulted in a 4.5% increased survival based on deaths from preventable causes (4). According to the Fatal Injury Reports from the Centers for Disease Control's Web-based Injury Statistics Query and Reporting System, the death rate for motor vehicle collisions in the United States in 2014 was 10.58 per 100,000 (33,736 individuals) (5). Bystander action in these scenarios would translate into over 1500 lives saved annually in the United States alone. The lessons learned from the military experience with tourniquet use and safety has already successfully translated to civilian prehospital medicine practice (6,7).

The "Stop the Bleed" campaign focuses on two major components: training of the general public in hemorrhage control to include the use of tourniquets, and to make hemorrhage control supplies readily available in public spaces (1). This model has successfully been implemented for out-of-hospital cardiac arrest with multiple levels of legislation at national, state, and county levels addressing both cardiopulmonary resuscitation training and the placement of automated electronic defibrillator devices in public spaces (8–13). In addition to improved national readiness, this training will prepare citizens for the more likely events they may experience within their community.

When considering the number of public spaces needing hemorrhage control supplies, the cost, effectiveness, and the ability for laypersons to use the devices should be the key components to selecting materials. The elastic band tourniquets cost less than one-third the cost of the traditional strap and windlass tourniquet. The cost difference between materials when expanded to many thousands of locations (over 8000 public schools in Texas alone) is in the millions of dollars. These costs are a significant factor in the planning of any large-scale public health intervention.

Study Objectives

This study is part of a larger project that included evaluating behavioral factors impacting the use of tourniquets by the public and the effectiveness of a brief educational intervention on the placement of tourniquets. This project was also an important community engagement and educational initiative that will improve community resiliency. We envision that this project will answer important clinical questions but also serve to involve and improve the community directly. In this study, we sought to investigate which tourniquets are the most intuitive to use by laypersons prior to any training of its use.

METHODS

Study Design

The study was a prospective randomized study evaluating the ability of laypersons to place commercial tourniquets on a mannequin. The University of Texas Health Science Center San Antonio Institutional Review Board approved this study and was found to meet criteria for Not Regulated Research, as a community outreach project.

Study Setting and Population

Investigators recruited participants through the University of Texas San Antonio student interest groups, the Southwest Regional Trauma Advisory Council community education committee, and through personal connections within the San Antonio community. There were 236 participants that voluntarily applied for the class at multiple venues within Bexar County and Frio County, Texas. Sites included a community health fair, two elementary schools, community group meetings, the University of Texas at San Antonio student interest groups, San Antonio Airport personnel public safety training, and a local musician's group rehearsal class.

Data collection occurred over 7 months from September 2016 to March 2017. Volunteers completed a prestudy questionnaire to determine eligibility. We collected comfort levels and attitudes about tourniquets with the prestudy questionnaire. A participant was excluded for age younger than 17 years, history of prior military service, a history of any formal medical training resulting in medical certification (such as emergency medical technician, physician, nurse), or a history of previous formal tourniquet training.

Figure 1. Study tourniquets used. (A) Ratcheting Medical Tourniquet (RMT); (B) Combat Application Tourniquet (CAT); (C) Stretch Wrap and Tuck Tourniquet (SWAT-T).

Study Protocol

Each participant was randomized, using an online randomization generator, into one of 12 possible study arms. They included tourniquet type (Combat Action Tourniquet [CAT; North American Rescue, LLC, Greer, SC; retail cost $29.99], Ratcheting Medical Tourniquet [RMT; m2 Inc., Winooski, VT; retail cost $37.95], or Stretch Wrap and Tuck Tourniquet [SWAT-T; TEMS Solutions, LLC, Salida, CO; retail cost $10.54]), mannequin type (adult [Rescue Randy; Simulaids, Inc., Saugerties, NY] or child [Model S152, Gaumard Scientific, Inc., Miami, FL]), and location (upper extremity or lower extremity). The tourniquets selected represented three different classes of commercially available tourniquets, strap and windlass, strap and ratchet, and elastic band wrap (Figure 1). Randomization occurred upon arrival to the class and was performed prior to determining study eligibility criteria. All participants were allowed to fully participate in the study and class, but data were collected only for those meeting eligibility criteria. After the completion of the precourse questionnaire, each participant was asked to place a tourniquet on the bleeding extremity to which they were randomly assigned. They were provided the following scenario: "This person has an injury that has continued to bleed despite direct pressure on the wound. It has been determined they need a tourniquet. A tourniquet has been pulled from the public access bleeding control kit and someone hands it to you. Please place the tourniquet so that it will stop the bleeding. Please let me know when you believe your placement is complete." The researcher would then hand the participant their designated tourniquet and start a timer. The timer would be stopped once the participant reported being done placing the tourniquet. The tourniquet placement would then be assessed for correct position, placement technique, and adequate tightness. Each mannequin was marked with a simple piece of moulage to identify the bleeding area. Correct position included any location on the injured limb proximal to the wound. Correct placement technique was observed if the participant used the device in a reasonable manner as compared with manufacturer-provided instructions. Adequate tightness was present if the researcher was unable to slide a finger under the tourniquet. No instructions were provided to the participant and no feedback was provided until after the timer had stopped. After the exercise, the researcher would provide feedback on the correct placement.

When participants completed the testing phase of the event, they received a brief 20-min period of instruction on hemorrhage control techniques to include indications for tourniquet use followed by hands-on instruction with tourniquet application on both adult and child-size practice mannequins. All participants were able to demonstrate proper tourniquet use with each of the three styles of tourniquet tested prior to leaving the event. Participants were asked to complete a postevent questionnaire readdressing comfort levels and attitudes about tourniquets after training.

Statistical Analysis

We used Microsoft Excel (Microsoft Corporation, Redmond, WA) to manage the data and SAS JMP (SAS Institute Inc., Cary, NC) for statistical analyses. We used Random.org (www.random.org/lists) to provide group randomization. Descriptive statistics were produced for analysis of demographics, and chi-squared (or Fisher's exact) tests were conducted to determine differences between the groups. Wilcoxon/Kruskal-Wallis tests were performed on age and time data not meeting assumptions of normality. Although this study is a pilot, a power analysis was performed during design, and the sample size was designed to show a difference of 20% between groups. Statistical significance was defined as $p < 0.05$, and 95% confidence intervals (CI) were obtained when appropriate.

RESULTS

Characteristics of Study Participants

Of 236 possible participants, 198 met the eligibility criteria and 195 completed the study (Figure 2). We found no statistically significant differences in baseline demographics between the three tourniquet groups (Table 1).

Main Results

The overall success rate for tourniquet placement was 16.9%. The rates of successful tourniquet application

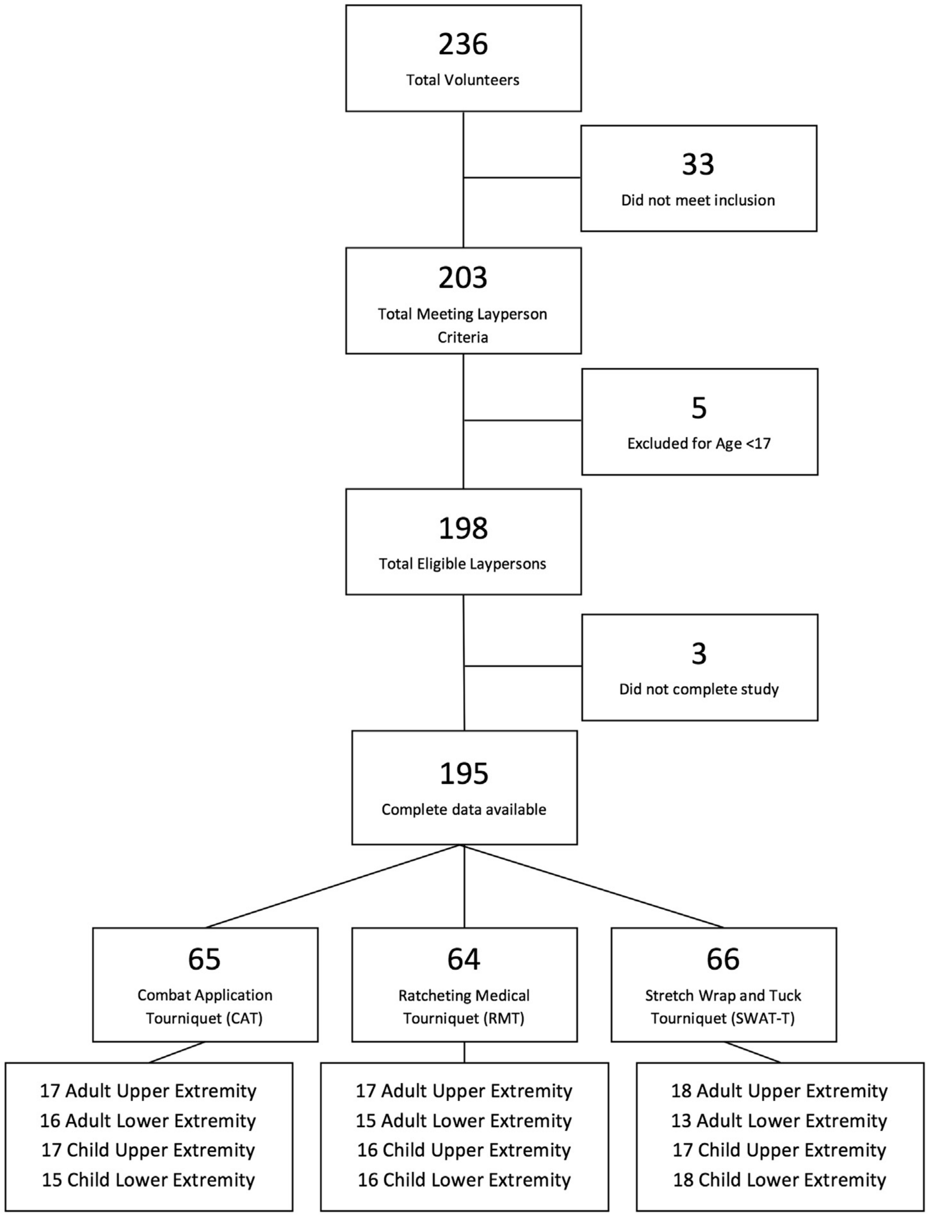

Figure 2. Study enrollment diagram. There were 235 class volunteers; 37 did not meet inclusion criteria. Of the 198 eligible laypersons, 195 had complete data for analysis. Participants were randomly assigned to one of three tourniquet types and assigned to Adult or Child mannequin as well as upper or lower extremity.

for the RMT, SWAT-T, and CAT were 23.4%, 10.6%, and 16.9%, respectively ($p = 0.149$) (Table 2). The most common causes of application failure were: inadequate tightness (74.1% [120/162]), improper placement technique (44.4% [72/162]), and incorrect positioning (16.7% [27/162]) (Table 3). These causes of failure were common to all three tourniquet devices. Additionally, we observed multiple common errors specific to each tourniquet, with the most common being failure to use windlass with the CAT, not tightening the strap prior to using the ratchet with the RMT, and the SWAT-T was tied into knots rather than wrapping as directed (Table 3).

When comparing application time, the SWAT-T (38.7 s, 95% CI 43–34.5 s) was significantly faster than the CAT (47.6 s, 95% CI 52–43.3 s) and the RMT (60.3 s, 95% CI 69.4–51.3 s) ($p < 0.001$) (Table 2). However, the speed was not associated with placement success ($p = 0.401$).

A subgroup analysis looking at success rates based on the extremity (upper extremity vs. lower extremity) and

Table 1. Patient Demographics

	Total	RMT	CAT	SWAT-T	*p*-Value
Age (n)	n = 194	n = 64	n = 64	n = 66	0.539*
Years (95% CI)	33.82 (32–36)	32.58 (29–36)	34.45 (31–38)	34.45 (31–38)	
Sex (n)	n = 193	n = 63	n = 65	n = 65	0.372†
Male	29.5% (57)	33.3% (21)	32.3% (21)	23.1% (15)	
Female	70.5% (136)	66.7% (42)	67.7% (44)	76.9% (50)	
Race (n)	n = 195	n = 64	n = 65	n = 66	0.233†
Asian	4.6% (9)	9.4% (6)	1.5% (1)	3.0% (2)	
Black	18.5% (36)	20.3% (13)	21.5% (14)	13.6% (9)	
Hispanic	44.6% (87)	35.9% (23)	46.2% (30)	51.5% (34)	
White	32.3% (63)	34.4% (22)	30.8% (20)	31.8% (21)	
Education (n)	n = 194	n = 64	n = 65	n = 65	0.503†
Grade school	0.5% (1)	1.6% (1)	0.0% (0)	0.0% (0)	
High school	10.8% (21)	12.5% (8)	7.7% (5)	12.3% (8)	
Some college or current student	50.5% (98)	50.0% (32)	47.7% (31)	53.9% (35)	
College	28.9% (56)	31.3% (20)	33.8% (22)	21.5% (14)	
Postgraduate	9.3% (18)	4.7% (3)	10.8% (7)	12.3% (8)	
Income (n)	n = 190	n = 63	n = 63	n = 64	0.913†
< $25,000	44.2% (84)	44.4% (28)	42.9% (27)	45.3% (29)	
$25,000–$49,999	18.9% (36)	23.8% (15)	15.9% (10)	17.2% (11)	
$50,000–$100,000	27.4% (52)	23.8% (15)	30.2% (19)	28.1% (18)	
> 100,000	9.5% (18)	7.9% (5)	11.1% (7)	9.4% (6)	

CAT = Combat Action Tourniquet; RMT = Ratcheting Medical Tourniquet; SWAT-T = Stretch Wrap and Tuck Tourniquet.
p-Values: *Kruskal-Wallis test; †chi-squared test.

patient type (adult vs. child) showed no statistically significant differences. Upper-extremity success rate was 16.7%, vs. lower extremity at 17.2% ($p = 1.0$), and adult mannequin success rate was 18.8%, vs. child at 15.2% ($p = 0.568$). There was a statistically significant difference between groups when looking specifically at adult upper extremity, with the RMT having the highest rate of success, 29.4% ($p = 0.037$) (Table 4).

DISCUSSION

We found that only 16.9% of laypersons could place a commercially available tourniquet correctly without prior training. We noted some differences between the devices but the differences were not statistically significant. Additionally, we found no significant associations between individual demographics such as age, education, sex, or socioeconomic status and the ability to correctly place a tourniquet. This study focused only on laypersons, as it may be many years until an adequate percentage of individuals in this country have been trained on hemorrhage control and tourniquet use as evidenced by our rate of bystander cardiopulmonary resuscitation in out-of-hospital cardiac arrest (9). Additionally, we attempted to gain a representative sample of individuals from key identified high-risk areas for mass casualty incident: schools/universities, public spaces, and businesses, by testing in many different locations (3).

We found that there were a significant number of participants who had difficulty operating the ratchet on the RMT (24%, 16/67). Many reported never seeing a ratchet and were unfamiliar with its use. The ratchet is a common style found for many ski, snowboard, and rollerblading boots. We believe if these devices were tested in a different region of the country where these ratchets are more commonly used, the success rate for the RMT may have been higher. This suggests local assessment of devices may be beneficial prior to the planning of an implementation strategy.

In addition to evaluating laypersons' ability to place the tourniquets, we ensured that all participants in the event were comfortable and capable of tourniquet application and general hemorrhage control principles prior to leaving the event. We utilized education principles for trauma care as described by previous authors (14–18).

Our findings are similar to prior studies by Goolsby et al., who showed layperson success with the CAT Tourniquet at 21% when tested without prior training.

Table 2. Successful Placement by Tourniquet Type and Application Time by Tourniquet Type

Tourniquet Type	Successful Placement	Application Time (95% CI)
CAT (n = 65)	16.9% (11)	47.7 s (43.3–52.0)
RMT (n = 64)	23.4% (15)	60.3 s (51.3–69.4)
SWAT-T (n = 66)	10.6% (7)	38.7 s (34.5–43.0)
Total (n = 195)	16.9% (33)	48.8 s (45.1–52.5)
p-Value	0.149*	0.001†

CI = confidence interval; CAT = Combat Action Tourniquet; RMT = Ratcheting Medical Tourniquet; SWAT-T = Stretch Wrap and Tuck Tourniquet.
p-Values: *chi-squared test; †Kruskal-Wallis test.

Table 3. Causes for Placement Failure and Specific Difficulties Identified with Devices

	CAT (n = 54)	RMT (n = 49)	SWAT-T (n = 59)	Total (n = 162)	*p*-Value
Causes for placement failure					
Incorrect position	18.5% (10)	14.3% (7)	16.9% (10)	16.7% (27)	0.845
Device too loose	68.5% (37)	79.6% (39)	74.6% (44)	74.1% (120)	0.438
Not all steps completed	50.0% (27)	34.7% (17)	47.5% (28)	44.4% (72)	0.249
Subjects requested to stop early	0	2.0% (1)	0	0.6% (1)	0.313
Observed device problems					
Did not tighten strap	15.3% (6)	12.5% (5)		9.1% (11)	
Did not secure windlass	7.7% (3)			2.5% (3)	
Did not use windlass	56.4% (22)			18.1% (22)	
Did not unfold from packaging configuration	7.7% (3)			2.5% (3)	
Did not tighten windlass sufficiently	7.7% (3)			2.5% (3)	
Tied in a knot	2.6% (1)		78.6% (33)	28.1% (34)	
Did not know how to use ratchet		30% (12)		9.9% (12)	
Did not use ratchet		17.5% (7)		5.9% (7)	
Used ratchet prior to tightening strap		32.5% (13)		10.7% (13)	
Loose wrap			7.1% (3)	2.5% (3)	
Positioned incorrectly	7.7% (3)	17.5% (7)	14.3% (6)	13.2% (16)	
Other	12.8% (5)	2.5% (1)	7.1% (3)	7.4% (9)	
Total difficulties observed	46	45	45	136	

CAT = Combat Action Tourniquet; RMT = Ratcheting Medical Tourniquet; SWAT-T = Stretch Wrap and Tuck Tourniquet.

Whereas their study had slightly higher success rates than ours, they also tested in and around the Washington, DC area, suggesting a different regional demographic (19).

We believe that even after appropriate training within the community, correct placement by bystanders will not likely exceed 55% given the current models of tourniquets. Baruch et al. showed military personnel who had been trained on the CAT tourniquet use within the last 1–2 weeks, when re-tested, could correctly place them only about 55% of the time (20).

Goolsby et al. have demonstrated that by adding a photo instruction card with the device, it doubled layperson success rates (19). They also found that by color-coding the device, it improved the success slightly more (44% to 51%), although this was not statistically significant (21). Work with public automated external defibrillators and Narcan injection pens (Adapt Pharma Inc., Radnor, PA) have demonstrated the importance of both visual and verbal instructions in the successful application of lifesaving treatments in the hands of laypersons (22–25). Many of these tourniquets, although easy to use, are not intuitive to use. This study adds evidence to current professional opinions that further design improvements are needed to enable a majority of laypersons attempting to assist in a medical emergency to be successful (26). Additionally, it cannot be overstated the importance of some form of medical training with these devices to improve their success as Goolsby et al. demonstrated (21).

Study Limitations

Our study has limitations. First, to meet the needs of our diverse community, we wanted to teach lifesaving skills for adults and children. We used both pediatric (approximately 8-year-old) and adult mannequins for tourniquet placement. We noted no statistically significant difference between the devices based on mannequin type or extremity, but there was a trend noted that might have influenced the overall success rates. This study was powered to show a 20% overall difference between the three tourniquets and was not sufficiently powered to show smaller differences or small differences within the subgroups.

Table 4. Subgroup Analysis of Successful Placement by Tourniquet Type

	Total	CAT	RMT	SWAT-T	*p*-Value
Adult upper extremity (n = 52)	13.5% (7)	11.8% (2/17)	29.4% (5/17)	0% (0/18)	*0.037
Adult lower extremity (n = 44)	25% (11)	25% (4/16)	33.3% (5/15)	15.4% (2/13)	0.55
Child upper extremity (n = 50)	20% (10)	17.7% (3/17)	18.8% (3/16)	23.5% (4/17)	0.901
Child lower extremity (n = 49)	10.2% (5)	13.3% (2/15)	12.5% (2/16)	5.6% (1/18)	0.713

CAT = Combat Action Tourniquet; RMT = Ratcheting Medical Tourniquet; SWAT-T = Stretch Wrap and Tuck Tourniquet.
* Indicates statistical significance.

Second, our study was limited to adults. We had several high school and middle school students attend our classes, but they were excluded from the testing. A significant body of research has shown that teaching younger students may have a much larger impact than adults on community preparedness (27,28). Future efforts should look at tourniquets in the hands of layperson teenagers as well.

Third, our study was not blinded, and the assessment of correct placement was determined by multiple researchers who had been trained on the successful placement criteria. As there was no inter-rater reliability evaluation, this may have been a source of potential bias.

Finally, we tested in multiple different environments and venues. The various testing sites may have influenced the success of the participants. We made every effort to ensure that testing was performed in a private location where no other participants could observe, to avoid peer observational pressure and observational learning from other participants.

CONCLUSION

Our pilot study on the intuitive nature of applying commercially available tourniquets found unacceptably high rates of failure. Large-scale community education efforts and manufacturer improvements in tourniquet usability by the lay public must be made before the widespread dissemination of tourniquets will have a significant public health effect.

Acknowledgements—We would like to thank the San Antonio Fire Department, the Office of the Medical Director for the San Antonio Fire Department, and all the “Stop the Bleed” trainers for their contribution to this community outreach effort.

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ARTICLE SUMMARY

1. Why is this topic important?

The "Stop The Bleed" campaign is a national effort to educate the lay public on how to control life-threatening bleeding and provide hemorrhage-control supplies in public spaces. No one has examined the usability of current hemorrhage control devices utilized by military/emergency medical services/police when used by the lay public nor asked the question if a hemorrhage control device for the lay public should be different from those for military and public safety officers.

2. What does this study attempt to show?

This study shows that in addition to educational efforts, current tourniquet designs need to be more intuitive for them to have a large-scale effect if placed in public spaces.

3. What are the key findings?

The average untrained layperson will place a tourniquet correctly only 16.9% of the time.

4. How is patient care impacted?

Without further education and tourniquet improvements, large-scale distribution of current tourniquets will have a limited public health impact.