Developing "Herd Immunity" in a Civilian Community Through Incorporation of "Just-In-Time" Tourniquet Application Training

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Abbreviations:
AED: automated external defibrillator
C*A*T: Combat Application Tourniquet
JiT: Just-in-Time
POD: Point of Distribution

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Abstract

Introduction: Herd immunity, a concept normally applied in vaccinated populations, is a preventative measure to determine if a significant portion of a population can protect vulnerable individuals against a certain disease. Like vaccines, tourniquet education can be a form of herd immunity to protect vulnerable individuals in a population and prevent the loss of life from a peripheral hemorrhage. The authors have identified a deficiency in simple, quick, and effective hemorrhage control education. Therefore, to maximize herd immunity, the novel educational platform evaluates the efficacy of "Just-in-Time" (JiT) tourniquet application training.

Hypothesis/Problem: The authors hypothesize that the utilization of JiT training will be effective in promoting both competence and confidence for individuals to utilize tourniquets in response to a disaster environment.

Methods: This Institutional Review Board-approved study recruited medical students who were trained in hemorrhage control measures at a Level 1 Trauma Center. Tourniquet training sessions were held, and naïve civilians received tourniquet education. The subjects received a five- to ten-minute lesson on indications, contraindications, and application techniques of commercial and improvisational tourniquets. Participants subsequently applied a tourniquet to an instructor's arm to demonstrate proper tourniquet application for a brachial artery hemorrhage. Pre- and post-educational surveys were completed to test participant competency and confidence.

Results: Of the 104 subjects who completed the course, 97 had no prior training in hemorrhage control techniques, including commercial and improvisational tourniquet application. The mean pre-test score was 2.27/5.00 and the mean post-test score was 4.38/5.00, $P < .001$ ($n = 97$). When queried "How competent would you feel applying a tourniquet (commercial or improvisational) on an individual with a bleeding wound?" 92/97 felt confident (95%), one felt less confident, and four felt no difference in confidence levels ($P < .001$).

Conclusion: Just-in-Time training is an effective method in teaching naïve civilians proper tourniquet application. This platform could serve as an alternative to more extensive training programs and requires less time, costs, and resources. If a significant number of individuals in a local community can effectively apply a tourniquet in a disaster scenario, a "herd immunity" effect could be achieved to control peripheral hemorrhages.

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Introduction

The efficacy of tourniquets in hemorrhage control has been a subject of debate for centuries, with tourniquet use being noted as early as 326 BC by Greek armies, and perhaps much earlier than that.[1,2] However, recent advances in military medicine and validating research demonstrate that timely and proper application of tourniquets in peripheral hemorrhages can save lives. Past studies have reported up to 2,000 lives were saved as a result of wide-scale military adoption of tourniquets during the mid-2000s (ie, decreased number of preventable deaths secondary to extremity hemorrhage).[3,4] In the military setting, prehospital tourniquet use has been found to control severe hemorrhage without the presence of

any adverse events related to their use.[5–7] This has spurred an increased tourniquet usage in prehospital management of peripheral hemorrhages by civilian Emergency Medical Services (EMS) with similarly convincing data.[8]

As recent events indicate, active-shooter incidents have not abated, particularly within the United States (ie, Parkland, Florida 2018; Pittsburgh, Pennsylvania 2018).[9,10] Research conducted in the wake of the Boston Marathon bombing in 2013 (Massachusetts USA) noted a significant gap between the available prehospital hemorrhage control measures and their use in emergency situations, where such measures have been proven to save lives.[11] Thus, there is a growing need to not only make tourniquets available to the average civilian in public-access areas, but also to develop and disseminate the necessary education and training that will allow these civilians to apply a tourniquet competently and safely.[12]

As tourniquet application is not an intuitive process, proper training is essential to increase the likelihood of a positive outcome for civilian responders.[13–15] While some training programs may be more popular than others, standardized training can be difficult to achieve due to the differences in faculty commitment, length of training, content, and durable resources that are available from one community to another. The current crop of educational opportunities, regardless of time expenditure and/or costs, will primarily attract a segment of the civilian population who will attend because of personal obligations, occupational mandates, or altruistic sensibilities.[15] The question remains: will the current tourniquet training opportunities, with their inherent limitations, be attended by a critical mass of the community populace to be truly effective during a sudden, high-intensity disaster event? And is there a way to do the greatest good for the greatest number of people?

Amidst the concepts of infectious disease, there is one that has a significant degree of *gravitas*: Herd Immunity. This is defined as the vaccination of a critical mass of a community's population that will, in effect, maintain the current health status of the entire community in the event of an infectious disease outbreak or epidemic.[16] As a greater percentage of a community is vaccinated against a particular disease, the public health "umbrella" becomes sturdier and better suited to protect that community. The herd immunity effect can result in a lower rate of morbidity and mortality. Infectious disease studies have found that the herd immunity threshold (ie, the amount of individuals that need to be protected before herd immunity sets in) is approximately 87% for diseases like smallpox, and even lower at 45% for diseases like influenza.[17] Determining such a threshold for active-shooter training remains elusive, but it illustrates the importance of tourniquet training in a community in order to make it more resilient.

Extending "Herd Immunity" to a mass-casualty incident, community leaders and partners must determine whether their current educational offerings actually reach that threshold (ie, the critical mass of their population to create a "herd immunity" impact at the time of a critical incident). It is likely, given public automated external defibrillator (AED) data, that there is a significant segment of the population (possibly even the majority) who will not access anti-hemorrhage classes due to time, distance, costs, or ignorance.[18,19] Therefore, if one posits that the current educational platforms are not achieving the desired herd immunity effect, then consideration must be given to investigate alternative platforms that will be attractive to the remaining members of the community, while still being effective as an educational resource.

	N	%
Gender		
Female	55	56.7
Male	42	43.3
Degree Level		
Bachelor's Student	86	88.7
Master's Student	11	11.3
Any Health Care Experience?		
Yes	17	17.5
No	80	82.5
Age	**Years**	
Minimum	18	
Maximum	34	
Mean	22.06	
SD	2.94	

Table 1. Demographic Characteristics of Study Population

Hypothesis

An educational approach utilizing "Just-in-Time" (JiT) training can complement current tourniquet application training opportunities and achieve a potential herd immunity effect by producing a critical mass of individuals competent in hemorrhage control techniques.

Methods

This cross-sectional study of health care students from the University of Toledo (Toledo, Ohio USA) received approval from the Biomedical Sciences Institutional Review Board. Medical students were recruited and trained in anti-hemorrhage control by faculty from the Department of Emergency Medicine. They established training stations on the University campus for five days in August 2018 where under-graduate and first-year medical students had the opportunity to consent to participate. The medical students were deemed "civilians" for the purposes of the study because data collection occurred prior to the start of their first classes and they were therefore considered naïve about tourniquets and hemorrhage control. Participants were informed of study protocol (including anonymity) and those who agreed to participate were enrolled. Prior to the training, students provided data regarding their age, gender identity, educational background, and any history of prior tourniquet training. No personally identifiable information was collected. Participants were excluded from participation if they were younger than age 18 or if they had any kind of prior tourniquet or anti-hemorrhage training. A total of 104 participants were identified for participation. Of those, seven were excluded from the study due to prior experience in applying tourniquets or pressure dressings. The remaining 97 individuals participated in the study (Table 1).

Each participant completed a pre-training survey that included five questions designed to test the participant's knowledge of proper tourniquet application technique. The questions were reviewed by faculty to check for bias and accuracy. There was also a series of questions designed to evaluate the participant's reported level of confidence in applying a tourniquet (commercial and improvisational). The objective questions were presented with the answer choices of True, False, and Unsure. These questions were designed to test knowledge of the tourniquet's indications,

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	Mean	95% CI
Pre-Test Score	2.27	(2.00–2.54)
Post-Test Score	4.38[a]	(4.24–4.52)
	P <.001	(1.80–2.42)
How competent would you feel applying a tourniquet (CAT or improvisational) on an individual with a bleeding wound?		
Positive Ranks	92	
Negative Ranks	1	
Ties	4	
Z	8.414[b]	
	P <.001	

Table 2. Pre-/Post-Test Knowledge and Competency (n = 97)
Abbreviation: CAT, Combat Application Tourniquet.

[a] Indicates statistically significant increase in post-test score where p < .001, using paired samples t-test.

[b] Indicates statistically significant increase in perceived tourniquet application competency where p < .001, using Wilcoxon Signed Ranks test.

complications, and applications. The questions assessing confidence were answered using a six-point Likert scale, where a response of four and greater was considered a favorable response.

Researchers then gathered the willing passers-by into groups of three to five and began the brief five- to ten-minute training period where JiT training in tourniquet application was conducted. Four second-year medical students who were previously trained in tourniquet application conducted the training. Faculty co-researchers were available. Here, they displayed a Combat Application Tourniquet (C*A*T; CAT Resources, LLC; Rock Hill, South Carolina USA), described its components (strap/windlass), and reported the locations on the University campus where C*A*T are available. Participants were informed about the indications, limitations, and contraindications of tourniquet use, the proper positioning of the tourniquet, and potential tourniquet complications. A researcher then applied the C*A*T to the arm of another researcher with a simulated brachial artery hemorrhage. After the demonstration and after addressing any questions, the participants demonstrated the skill on the researcher's arm. Each participant was required to correctly apply the tourniquet before completing the training. Because the researcher's arms were used for demonstration purposes, participants were asked to tighten the windlass only one turn, but were informed that in a real-life scenario, the windlass should be turned as many times as possible to achieve maximum occlusion of the bleeding vessel.

The training concluded with a discussion of improvisational tourniquets. The researchers demonstrated how one might apply an improvised tourniquet using a necktie as a strap and a pair of scissors or a cell phone as the sturdy windlass. For example, once a strap such as a scarf or a tie is wrapped around an arm, a pair of scissors or a cell phone would be integrated into the strap and then torqued like a windlass to compress the hemorrhaging vessels further. The use of these types of tourniquets as last-ditch efforts when nothing else is available to control life-threatening hemorrhage was emphasized. Other possible options for improvisational tourniquets were described, and the differences between C*A*T and improvisational tourniquets were explained. Participants were given the opportunity to ask questions at any point in the training.

Following the training, participants were asked to complete a post-training survey. This survey contained the same questions that were answered pre-training, and the answers were compared using Statistical Package for the Social Sciences (SPSS) 24.0 (IBM Corporation; Armonk, New York USA).

The primary outcome was the change in objective competency scores by participants before and after the JiT training. Secondary outcomes included confidence in being able to use a tourniquet in a real-life scenario and reported confidence in ability to apply an improvisational tourniquet when a C*A*T is not available.

The paired samples t-test was used to statistically compare the pre-test and post-test scores. The Wilcoxon signed ranks test was used to statistically compare the perceived competence in applying a tourniquet on an individual with a bleeding wound. An alpha of 0.05 was used to determine statistical significance. Through sample size and power calculation, it was determined that a sample of 44 individuals would provide 90% power to detect a one-point difference between the pre-test and post-test scores.

Results

Of the 97 participants that received JiT training, the competency scores increased from an average score of 2.27 to 4.38 (Table 2), indicating the average participant scored 4.38 out of 5.00 in competency after receiving JiT training (+2.11 correct answers post-training; P <.001; Table 3). Perceived tourniquet application competency following the training increased for 92 (94.8%) of the participants (P <.001; Table 4).

Discussion

Ever since the Sandy Hook Elementary School Shooting in 2012 (Newtown, Connecticut USA), there has been a greater appreciation of the public as "first responders" and the necessity of providing them with the tools and the education to save lives.[20,21]

The aim of this study was to find another efficacious and efficient way to empower individuals with the knowledge and skills to save lives through hemorrhage control. The results of this research introduce two concepts that merit further consideration. First, JiT training is a feasible complement to the traditional educational programs that teach hemorrhage control measures. This is validated by the statistical improvement seen in the objective survey scores, as well as the subjects' confidence to apply a tourniquet in an actual event. Collectively, the results suggest JiT training is able to promote both increased competence and confidence in tourniquet application in a very short time frame. As a result, JiT training takes an important step in increasing the collective knowledge of the community in prehospital hemorrhage control, moving said community closer to a state of "herd immunity" and rendering it safer than before.

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How competent would you feel applying a tourniquet on an individual who has a bleeding wound?						
	Not at All	**2**	**3**	**4**	**5**	**Very**
Pre-Test	54 (55.7%)	14 (14.4%)	15 (15.5%)	6 (6.2%)	7 (7.2%)	1 (1.0%)
Post-Test	1 (1.0%)	0 (0.0%)	2 (2.1%)	11 (11.3%)	39 (40.2%)	44 (45.4%)
	Correct	**Incorrect**	**Victim has suffered an injury in the armpit and it is severely bleeding. Place a tourniquet in this area as soon as possible.**			
Pre-Test	20 (20.6%)	77 (79.4%)				
Post-Test	73 (75.3%)	24 (24.7%)				
	Correct	**Incorrect**	**The correct position to place a tourniquet is between the bleeding wound and the heart.**			
Pre-Test	61 (62.9%)	36 (37.1%)				
Post-Test	91 (93.8%)	6 (6.2%)				
	Correct	**Incorrect**	**Improvisational tourniquet is only indicated when there is no other option to stop a severe hemorrhage.**			
Pre-Test	45 (46.4%)	52 (53.6%)				
Post-Test	91 (93.8%)	6 (6.2%)				
	Correct	**Incorrect**	**If simple compression, covering, and wrapping are sufficient to stop the bleed, a tourniquet should still be applied.**			
Pre-Test	40 (41.2%)	57 (58.8%)				
Post-Test	83 (85.6%)	14 (14.4%)				
	Correct	**Incorrect**	**If the patient is screaming in pain, you should loosen the tourniquet to relieve the pain.**			
Pre-Test	53 (54.6%)	44 (45.4%)				
Post-Test	88 (90.7%)	9 (9.3%)				

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Table 3. Pre-/Post-Training Questions and Responses

After completing this training, do you feel like you can effectively apply compression to a bleeding wound?						
	Not at All	**2**	**3**	**4**	**5**	**Very**
	1 (1.0%)	1 (1.0%)	6 (6.2%)	9 (9.3%)	41 (42.3%)	39 (40.2%)
After completing this training, do you feel like you can effectively apply a tourniquet on an individual who has a bleeding wound?						
	Not at All	**2**	**3**	**4**	**5**	**Very**
	0 (0.0%)	0 (0.0%)	2 (2.1%)	11 (11.3%)	42 (43.3%)	42 (43.3%)
After completing this training, do you feel like you can effectively apply an improvisational tourniquet on an individual who has a bleeding wound?						
	Not at All	**2**	**3**	**4**	**5**	**Very**
	0 (0.0%)	2 (2.1%)	6 (6.2%)	20 (20.6%)	35 (36.1%)	34 (35.0%)
After completing this training, how competent would you feel applying a tourniquet (CAT or improvisational) on an individual who has a bleeding wound?						
	Not at All	**2**	**3**	**4**	**5**	**Very**
	0 (0.0%)	0 (0.0%)	4 (4.1%)	17 (17.5%)	34 (35.1%)	42 (43.3%)

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Table 4. Post-Training Competency Questions

In general, untrained people are hesitant to give specific medical help, such as a tourniquet, to people in-need.[12,22] This hesitance was further evidenced by low pre-test confidence scores reported in this study, but was also found in similar studies concerning AEDs.[18,19] Therefore, there is a need for an alternative educational paradigm which can complement the traditional educational opportunities by targeting members of the community who would not normally access the longer and more intensive platforms. The authors believe the two measures of success of JiT training evidenced herein support the notion that JiT training can be the means to provide quick, accessible, and successful education to individuals who would not otherwise pursue formal training modalities.

The second concept to be considered is that motivated and properly trained health care students can become a viable extension of a community's collective public health education and services.[23,24] The deployment of these students and their faculty at strategically-placed, public-access venues (ie, malls, schools, and offices) could be considered as a Point of Distribution (POD). Classically, the POD is an improvisational venue where community stakeholders may dispense essential items (eg, Meals-Ready-To-Eat [MREs], potable water, antibiotics, and vaccines) during an emergency or disaster.[25,26] In a sense, the item that is being distributed in a tourniquet POD is education. From such a model, one can see a simple and effective way to dispense JiT training using the idea of a POD. Implementing such a model would improve access to training and further strengthen the herd immunity concept.

Limitations

The authors have identified limitations to this study. First, the study dealt with a limited population, consisting only of

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under-graduate and graduate students. This was an intended outcome, as the authors' aim was to evaluate JiT training in the context of achieving herd immunity at The University of Toledo, where the study was conducted.

Second, the results of the training were limited by safety concerns. Trainees practiced applying tourniquets, but were not permitted to fully tighten the windlass in order to protect the researcher's arm from injury. As a result, participants were not able to personally experience turning the windlass to maximum tightness. The authors believe, however, that this limitation does not retract from the study, as the importance of full tightness was clearly explained by the trainers. This study was also able to overcome a weakness of other studies, which cited improper application as a common source of error.[9]

Finally, while this study demonstrates the efficacy of JiT tourniquet training, it fails to demonstrate that trained individuals would be competent to train other individuals and fails to assess their long-term retention of the anti-hemorrhage techniques that were taught. Future studies are planned to evaluate herd immunity from tourniquet application, by assessing the ability of JiT training recipients to teach their newfound skills to others, as well as to evaluate the retention of knowledge from the training over a longer period of time.

Conclusions

Just-in-Time training is an effective method in teaching naïve civilians proper tourniquet application. This platform could serve as an alternative to more extensive training programs that require more time, cost, and resources. By coupling this short and easily-dispensable training to complementary educational platforms in a given community, a "herd immunity" effect could be achieved to control peripheral hemorrhages in the prehospital setting.

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