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Assessment of Prehospital Hemorrhage and Airway Care Using a Simulation Model

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Background

Unintentional injury is the leading cause of death for most age groups in the United States and is the 4th leading cause of death for all age groups combined.¹ The availability and quality of prehospital trauma care can have a great impact on survival. Hemorrhage, for example, is a leading cause of trauma death prior to arrival at a hospital. It is estimated that 30–40% of trauma mortality is due to hemorrhagic shock, and hemorrhage plays a role in 33–56% of trauma fatalities that occur in the prehospital setting.^{2,3} Recognition of this fact has led to initiatives such as the Department of Homeland Security's "Stop the Bleed" campaign that encourages bystander action prior to the arrival of medical personnel.⁴ Equipping prehospital healthcare providers (PHPs) to succeed is essential to ensuring optimal patient outcomes.

The military has a wealth of experience with prehospital trauma care. Many United States military units have implemented training called "Tactical Combat Casualty Care" which aims to decrease mortality from potentially survivable combat injuries.⁵ One illustrative example of the efficacy of this training comes from data from the Army Rangers. Since 1998, all members of the 75th Ranger Regiment have undergone prehospital trauma care training. There is a particular emphasis on extremity hemorrhage, tension pneumothorax, and airway obstruction – medical emergencies that can often be rapidly stabilized with proper care. A retrospective review of almost ten years of combat casualties conducted by Kotwal et al.⁵ in 2011 revealed that this regiment has a decreased rate of soldiers who are killed in action and die of wounds compared to the rest of the Department of Defense. Notably, none of the regiment's deaths were from the three potentially survivable causes of death emphasized by the training program. This study gives credence to training all service members with a special emphasis on care of life-threatening injuries that can be managed with relatively simple maneuvers.

Our institutions have recently been involved in the development of simulation models to train military personnel. Historically, a large portion of military trauma care training utilized

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animal models, such as anesthetized goats. Animal models face inherent challenges such as animal safety and care. A polytrauma simulation model, dubbed “Frank-N-Stein”, was therefore developed. Sweet et al. compared the use of an animal model to use of this simulation model in the training of 590 combat medics, and they found no difference in the assessment performance based on the type of model used in the training.⁶

The purpose of our study was to evaluate the applicability of critical skills training focused on the treatment of potentially survivable injuries and assessment using a simulation model in the civilian population. The initial step in this investigation was to assess the baseline proficiency of PHPs utilizing a simulation model.

Methods

This prospective cohort study was conducted with PHPs (both nurses and paramedics) employed by North Memorial Health (Robbinsdale, MN) undergoing their annual skills training in January and February of 2016. The study size was therefore determined by convenience sampling. Study approval was granted by the Institutional Review Board of North Memorial Health. Providers from ground and flight crews were represented. Each participant was asked to provide care to a patient suffering from injuries after a grain bin explosion. The PHPs were provided a stocked equipment bag and were asked to provide interventions as they would in the field. An assistant to the PHP was present but could only assist as directed by the PHP. The providers had previously received all institutionally-required skills training, including education in Massive Hemorrhage, Airway, Respiration, Circulation, Head, and Hypothermia (MARCH) principles.

The first module assessed performance on hemorrhage control measures in the setting of a groin wound and lower limb amputation. It involved a live actor wearing the Frank-N-Stein model. The model consists of multiple elements. The upper portion is a cut suit that a live actor can wear (Strategic Operations, San Diego, CA). The lower portion of the model simulated groin hemorrhage and a traumatic amputation (Trauma F/X[®] HEMO, Kforce Government Solutions, Inc., Fairfax, VA). Hemorrhage occurred through both the groin wound and the stump of the amputated limb via a mechanical pump with bleeding rates set using the manikin’s software, as established by the manufacturer in collaboration with the U.S. Army Institute of Surgical Research. This composite simulation model can be utilized to demonstrate other injuries such as bowel evisceration and airway obstruction. For the purpose of the first module, we analyzed only the six measures related to hemorrhage control (Table 1). These measures were developed based on standards of care from military training experience as well as standard guidelines established by North Memorial Health for their PHPs.

The second module involved airway management. The participating PHP was brought from the setting of the hemorrhage control module to the transport vehicle (either a helicopter or ambulance dependent on the participant’s usual mode of transport). A simulation mannequin (SimMan[®] 3G, Laerdal Medical, Wappingers Falls, NY) was present, and the PHP was informed that the patient had stopped communicating. A direct laryngoscope (DL) was present, but the batteries had been installed incorrectly and thus the light did not function.

The alternative advanced airways available for use were a video laryngoscope (VL) and supraglottic airways (SGA) (King, Ambu, Ballerup, Denmark; i-gel®, Intersurgical Ltd, Berkshire, UK).

The evaluation tool was adapted from an instrument (the Medical Simulation Combat Casualty Training Consortium Assessment Instrument) previously developed and validated at the University of Minnesota to assess performance in polytrauma scenarios.⁷ The tool included eight items with global rating scales used to generate the participant's global rater score (Table 2). The total point scale ranged from 5 to 40. In addition to awarding an overall score of performance, task completion was also noted for participant education and feedback as well as to inform the scoring on the evaluation tool. Multiple tasks were tracked including the hemorrhage control measures detailed in Table 1 as well as tasks related to airway management (i.e. successful airway placement, achievement of bilateral chest rise after airway placement). The total blood volume loss was measured by the quantity of simulated blood lost from the model reservoir. The model contains sensors that stop blood flow when the appropriate pressure is applied (i.e. by direct pressure, wound packing, tourniquet application). There was one tourniquet available to the participants. Of note, if the hemorrhage was not controlled within ten minutes, the hemorrhage was stopped by remote means, and the PHP was directed to move on to the next module. The participants were evaluated by two trained judges. The judges were paramedics who had undergone training for rating the performance of military medics in hemorrhage control, and each had four years of experience in evaluating military prehospital providers. The evaluation tool utilized had previously been rigorously tested to determine its inter-rater reliability.⁷

In addition, the participants completed surveys before and after training reporting their comfort level with the key skills tested (namely, tourniquet use, wound packing, endotracheal intubation, and SGA placement). The PHPs ranked their comfort level on a scale from 1 to 5 (1 = "weak" and 5 = "confident").

Data analysis was conducted using SPSS Statistics 23 (IBM, Inc., Somers, NY) and the R statistical software package (R Foundation for Statistical Computing, Vienna, Austria). Binomial logistic regression was implemented to assess the relationship between the PHP's background (profession, years of prehospital experience, and past military experience) and the successful performance of the six hemorrhage control measures. Total blood volume loss and global rater score were compared using Pearson correlation testing. Chi-square testing was used to assess changes in comfort level between pre- and post-training. Participants with missing, duplicate, or otherwise inadequate data for a particular measure were excluded from analysis for that measure.

Results

Demographics

There were 95 participants, including both nurses (n = 45) and paramedics (n = 50) (Table 3). The range of prehospital experience was 1 to 39 years; the mean was 15.9 ± 8.3 years. The majority of participants (93%) did not have previous military training. A pre-assessment survey revealed that 17% (n=16) of the participants had placed a tourniquet while on-duty in

the prior six months. Furthermore, 64% of the PHPs had placed an endotracheal tube in the prior six months however only 29% of the PHPs had placed a SGA.

Hemorrhage Control Performance

Successful performance of the outlined measures ranged from 38.9% to 88.4% of participants (Table 1). The participants performed the best on prompt tourniquet application (successful performance by 88.4%) and placement of wound packing (80.4%). The poorest performance was seen in initiation of hemorrhage control within one minute (38.9%) and control of hemorrhage within ten minutes (52.2%).

Using binomial logistic regression, we assessed the performance of the hemorrhage control measures in relation to the participants' background, including profession (nurse versus paramedic), years of prehospital experience, and past military experience (Table 4). The analysis revealed that profession was a significant predictor of consideration of a blood transfusion before a fluid bolus ($p=0.011$) and consideration of tranexamic acid ($p=0.016$). In addition, previous military training impacted the performance of the same two measures with p values of 0.033 and 0.028, respectively. Paramedics were less likely to consider a blood transfusion before a fluid bolus (odds ratio [confidence interval], 0.305 [0.123–0.760]) as well as being less likely to consider tranexamic acid (0.315 [0.123–0.804]). Participants with previous military training were less likely to perform the same two measures (0.083 [0.008–0.813] and 0.073 [0.007–0.075], respectively).

The median total blood volume loss in the scenario was 1700 milliliters (IQR, 1043–2000). The mean global rater score was 25.0 ± 7.4 . The global rater score did negatively correlate with the total blood volume loss when evaluated with Pearson correlation testing ($r = -0.59$, $n = 88$, $p = 1.93 \times 10^{-9}$), providing additional support to the validity of the evaluation tool utilized in this study (Figure 1).

Airway Management Performance

Seven participants were excluded from analysis for this module due to incomplete data. After forced failure of DL, 58% of the PHPs elected to use VL for endotracheal intubation while the remaining 42% chose to utilize a SGA. Regardless of alternate advanced airway selected, 86% of the participants obtained bilateral chest rise in the simulation mannequin after airway placement. Sixty-four percent of PHPs secured the airway on the first VL or SGA attempt (Table 5). The selection of VL versus SGA and number of attempts to successful airway placement were similar between nurses and paramedics.

Participant Confidence

Comfort levels reported by the PHPs improved after training for each of the skills of inquiry (Figure 2). The participants' confidence rating for wound packing after training was significantly different from baseline ($p=0.0292$).

Discussion

Simulation model training is an important component in the education of healthcare professionals. Many studies have reported on the efficacy of simulation models.^{8–10} The military has also had growing interest in the utilization of simulation models.^{6,8} To optimize efficacy and enhance feasibility, prehospital trauma training should also focus on improved simulation models. Given the key role that trauma care plays for medics in the armed forces as well as civilian prehospital healthcare providers (i.e. paramedics, emergency medical technicians), it was a natural progression to move from the military population to test the relevance of the polytrauma simulation model in the training of civilian PHPs.

A key finding in our study was the deficiencies in the readiness of PHPs in hemorrhage control measures with less than two-thirds of participants successfully performing four of the six measures. This finding suggests need for improvement in the initial training of PHPs in addition to the potential initiation of remediation training when insufficient skills are identified. In 2014, the American College of Surgeons Committee on Trauma published guidelines for the prehospital care of external hemorrhage.¹¹ In their review, the recommendation best supported by the literature was the use of tourniquets for the control of significant extremity hemorrhage. There is growing adoption of tourniquet use in civilian practice, and evidence exists of the safe and appropriate use of tourniquets in the prehospital civilian setting.^{12,13} Notable gaps in the literature were appreciated in regards to topical hemostatic agents although such measures are regularly employed in military operations.¹⁴ Many of the recent studies related to prehospital care of traumatic hemorrhage focus on the resuscitation product.^{15–18} In addition to these efforts, given our experience in the assessment of PHPs, it is necessary to continue to develop and to validate improved training methods and simulation models.

We found that paramedics were less likely than nurses to consider the use of a blood transfusion before a fluid bolus in the setting of life-threatening hemorrhage (OR 0.305 [0.123–0.760]). Paramedics were also less likely to consider tranexamic acid (OR 0.315 [0.123–0.804]). The reason for this is unclear. A potential explanation could be a difference in training methods at some point in their careers. Also, 80% of the nurses were flight nurses. There could be a distinction in training based on flight versus ground crews. Our other significant finding was that participants who reported previous training in the military (namely tourniquet training) were less likely to consider a blood transfusion before a fluid bolus (OR 0.083 [0.008–0.0813]) as well as tranexamic acid (OR 0.073 [0.007–0.075]). We do not have additional data on the extent of military experience for the 7 participants who reported previous military tourniquet training therefore it is difficult to ascertain what may have contributed to this difference.

The difficulty of the airway management module was intentionally augmented to assess the participants' decision-making and fluidity with various airway adjuncts. Ultimately, 86% of the PHPs were able to secure an airway successfully as evidenced by bilateral chest rise in the mannequin. We did not assess the PHPs ability to place an endotracheal tube utilizing DL. Ideally, successful airway placement using DL or other airway adjuncts should approach 100%.

There are limitations to the current study. We did not have a control group to compare hemorrhage control performance on the model to the traditional PHP training and assessment. Furthermore, although skills in hemorrhage control are crucial for any PHP to develop and to maintain, extremity hemorrhage accounts for fewer prehospital deaths in the civilian population than is appreciated in the military.¹⁹ An emphasis on extremity hemorrhage, therefore, perhaps has a different training priority in civilian versus military populations. The coverage area for the PHPs participating in this study however does include a significant portion of agricultural land, and agricultural work carries the risk of limb injury and traumatic amputation.^{20–22} In addition, although the scenario was created as realistically as possible, we cannot determine with certainty that participant performance in our simulation scenario is comparable to how the participant would perform in the field. The Hawthorne effect concerns research participation, the consequent awareness of being studied, and possible impact on behavior.²³ Although this effect cannot be completely eliminated in simulation scenarios, attempts to mitigate observation bias included the creation of a realistic prehospital environment and deliberate instruction of PHPs to provide interventions as they would in the field.

Conclusion

PHPs are on the frontline of trauma care, and we must equip them to succeed. Given the military's recent successes in training to prevent death from potentially survivable combat injuries, there is a great opportunity to translate these efforts to the civilian population through improved training for our PHPs.

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FIGURE 1. Correlation of global rater score and total blood volume loss ($r = -0.59$, $n = 88$, $p = 1.93 \times 10^{-9}$).

FIGURE 2.

Participant reported comfort level with skills rated on a scale of 1 (“weak”) to 5 (“confident”), before and after modules. * $p < 0.05$. SGA, supraglottic airway.

TABLE 1

Successful performance of hemorrhage control measures.

Measure	n (total [*])	% of total
Hemorrhage control initiation within one minute	37 (95)	38.9
Application of a tourniquet within two minutes	84 (95)	88.4
Placement of wound packing	74 (92)	80.4
Hemorrhage control within ten minutes	48 (92)	52.2
Consideration/administration of packed red blood cells	55 (94)	58.5
Consideration/administration of tranexamic acid	58 (93)	62.4

^{*} This number represents the number of participants with complete data for given measure.

TABLE 2

Evaluation tool used to generate the global rater score.

1. Handling Equipment and Supplies				
(1) Clumsy, chose wrong tools, struggled with bags	(2)	(3) Hesitant, usually chose correct tools, basically had the correct bags	(4)	(5) Confident, chose correct tools, efficient with bags
2. Smoothness, Economy of Motion				
(1) Many unnecessary moves, frequent start and stop, restless hands	(2)	(3) Some unnecessary moves, reasonably efficient, somewhat calm hands	(4)	(5) Few or no unnecessary moves, efficient, calm and confident hands
3. Controlled Pace				
(1) All rushed or slow, pace unrelated to task	(2)	(3) Mixture of paces, pace somewhat related to task	(4)	(5) Quick when required, slow when needed, pace related to task
4. Controlled Force				
(1) Too aggressive/tentative, force unrelated to task	(2)	(3) Mixture of force, force somewhat related to task	(4)	(5) Forceful when needed, gentle when needed, force related to task
5. Thinking Like a Medic				
(1) Poor sequence of tasks, rarely verified results, no reassessment	(2)	(3) Ok sequence of tasks, some verification of results, some reassessment	(4)	(5) Optimum sequence, always verified results, constant reassessment
6. Working Under Stress				
(1) Poor error recovery, couldn't improvise, many breaks in focus	(2)	(3) Some error recovery, some ability to improvise, few breaks in focus	(4)	(5) Excellent error recovery, high ability to improvise, rare breaks in focus
7. Leadership				
(1) Poor communicator, awareness, and use of assets; indecisive	(2)	(3) Adequate communicator, awareness, and use of assets; adequate leader	(4)	(5) Excellent communicator, awareness, and use of assets; decisive
8. Communication with Patient				
(1) No reassurance, instructions, or chatter	(2)	(3) Moderate reassurance, instructions, and chatter	(4)	(5) Continuous reassurance, instructions, and chatter

TABLE 3

Background of study participants (n=95).

	n (%) or mean $\pm$ SD
Profession	
Nurse	45 (47.4)
Air	36 (37.9)
Ground	9 (9.5)
Paramedic	50 (52.6)
Air	28 (29.5)
Ground	22 (23.2)
Prehospital experience (years)	15.9 $\pm$ 8.3
Previous military tourniquet training	
Yes	7 (7.4)
No	88 (92.6)

TABLE 4

Results of logistic regression analyzing association of participant background to performance.

Participant background	Hemorrhage control measure	p value	OR ^a (95% CI)
Profession (paramedic ^b vs nurse)	Hemorrhage control attempt within 1 minute	0.395	
	Tourniquet application within 2 minutes	0.599	
	Placement of wound packing	0.827	
	Hemorrhage control within 10 minutes	0.576	
	Blood transfusion considered before fluid bolus	0.011	0.305 (0.123–0.760)
	Tranexamic acid considered	0.016	0.315 (0.123–0.804)
Years of prehospital experience	Hemorrhage control attempt within 1 minute	0.948	
	Tourniquet application within 2 minutes	0.984	
	Placement of wound packing	0.694	
	Hemorrhage control within 10 minutes	0.549	
	Blood transfusion considered before fluid bolus	0.703	
	Tranexamic acid considered	0.520	
Previous military tourniquet training (yes ^b vs no)	Hemorrhage control attempt within 1 minute	0.991	
	Tourniquet application within 2 minutes	0.992	
	Placement of wound packing	0.668	
	Hemorrhage control within 10 minutes	0.182	
	Blood transfusion considered before fluid bolus	0.033	0.083 (0.008–0.813)
	Tranexamic acid considered	0.028	0.073 (0.007–0.075)

^aReported for significant findings in logistic regression.^bReference group.

OR, odds ratio. CI, confidence interval.

TABLE 5

Number of attempts until airway secured (n=88).

Attempts	n (%)
1	56 (63.6)
2	18 (20.5)
3	12 (13.6)
4	2 (2.3)

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