Preliminary Investigation of Civilian Clinician Perspectives & Just-in-Time Guidance for Tourniquet Use to "Stop the Bleed"

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Preliminary Investigation of Civilian Clinician Perspectives & Just-in-Time Guidance for

Tourniquet Use to “Stop the Bleed”

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ABSTRACT

Objective: The American College of Surgeons (ACS) encourages clinicians to provide training to laypeople on tourniquet application. It is unclear whether clinicians are confident in their abilities and equipped with adequate knowledge, skills, and resources. This study aimed to determine surgical trainee knowledge and attitudes regarding tourniquet application and compare the effectiveness of instructions. Methods: Thirty surgical trainees performed a tourniquet application simulation using a Combat Application Tourniquet and one of the three instructions sets developed by ACS, Department of Homeland Security, and the tourniquet manufacturer. Participants reported tourniquet knowledge, attitudes and confidence and discussed the instructions. One instruction set was updated and compared to the original set with 20 new trainees. Results: Participants with ACS instructions passed the greatest number of steps (p < 0.01) and completed the task significantly faster compared to those with manufacturer instructions (p < 0.01). Participants (80%) reported favorable views toward tourniquets but 30-60% did not align with ACS tourniquet guidelines. Focus group participants suggested revisions to the ACS instructions. Comparing the original and revised version of these instructions resulted in no significant improvements. Conclusions: ACS instructions provide guidance; however, improvements to tourniquet instruction are needed for success in controlling exsanguinating hemorrhage.
INTRODUCTION

Controlling exsanguinating hemorrhage is a critical pre-hospital step to managing trauma victims in military and civilian environments. Hemorrhage is the cause of up to 40% of trauma-related mortality, with 33% to 56% occurring as pre-hospital deaths.\textsuperscript{1,2} Extremity tourniquet application prior to the onset of hemorrhagic shock can increase survival rates.\textsuperscript{3-5} The Hartford Consensus started campaigns by the United States Department of Homeland Security (DHS) and American College of Surgeons (ACS) to use tourniquets as part of the \textit{Stop the Bleed} initiative.\textsuperscript{6,7} Both ACS and DHS encourage layperson education in tourniquet application to save the lives of hemorrhaging trauma victims. Additional initiatives such as \texttrademark\textsuperscript{TM} in the United Kingdom support these efforts internationally and have similar campaigns to train medical professionals and laypeople on proper tourniquet use.\textsuperscript{8}

Historically, medical practitioners have supported limited use of tourniquets to stop hemorrhage due to concerns for distal tissue ischemia.\textsuperscript{9} In addition, lack of standardized tourniquet application training for laypeople has resulted in an inadequate number of individuals equipped to perform this life-saving task. With the current shift toward tourniquet application support in the medical community, exposure and training is expected for medical professionals and laypeople.

Just-in-time instructions can enable untrained individuals to successfully complete a task and provide refresher cues to trained individuals during infrequent and emergent situations. Our team identified shortcomings in current just-in-time information for tourniquet application.\textsuperscript{10,11} We anticipated that if these instructions failed to guide surgical trainees through proper tourniquet application, they would be less likely to achieve success in the lay population.
Therefore, this multi-phase study aimed to: (1) determine clinician knowledge and attitudes regarding tourniquet application, and (2) compare the effectiveness of instructions for the purpose of just-in-time guidance.

METHODS

Participants and setting

Two convenience samples of surgical trainees (i.e. general surgery residents [postgraduate year 1], medical students, and research trainees [postgraduate researchers with a medical degree]) were recruited from the same population one training year apart (Figure 1) for participation at an academic quaternary medical center in the Midwest. Trainees were recruited during an educational event held twice a year that tested their clinical knowledge and surgical skills. Evaluations took place in 2017: January (Phase I-A) and February (Phase I-B) with the first sample, and July (Phase II) with the second sample. The study focused on tourniquet use in a trauma simulation as one of several educational assessment stations developed for the event.12 This study was approved by the Institutional Review Board.

Instrumentation and instruction sets

This educational simulation used a commercially-available tourniquet, Combat Application Tourniquet-Generation 7 (CAT-7. C•A•T Resources, LLC; Rock Hill, SC). The tourniquet was comprised of a constricting band with a single-routing buckle, a windlass, a clip to secure the windlass, and a Velcro windlass strap to ensure the windlass remained secure inside the clip and allowed for time notation.11 A manikin lower limb with a simulated open fracture
and resultant uncontrolled hemorrhage provided a consistent model for a patient that would require a tourniquet (Figure 2).

In Phase I, three publically- or commercially-available instruction sets developed by ACS, DHS, and CAT Resources were used for the first phase of this study. Only the steps specific for tourniquet use and placement were studied in this evaluation; steps prior to tourniquet use such as direct pressure were excluded (Table 1). The ACS instructions were subsequently modified per findings from Phase I-A testing and Phase I-B focus group discussion (Figure 3). In Phase II, the modified ACS (ACS-2.0) instructions were compared to the original ACS instructions (ACS-1.0).

**Participant recruitment and randomization**

This study includes the results from one of eighteen 7-minute stations completed during each surgical skills event in January and July of 2017. In January 2017, 30 participants were randomized to the three different instruction sets by gender and level of education/role. In July, 20 participants were randomized to two different instruction sets using the same parameters. Additionally, a subset (n=12) of the surgical resident participants from January received further instruction on tourniquet application in February where they placed a tourniquet on a simulated emergent patient and participated in a focus group to identify opportunities for instructional improvement.
Data collection

Phase I-A

In January, participants completed a baseline questionnaire about their perceptions of, knowledge with, and previous experience with tourniquets (Appendix). Participants then completed the simulated task. When entering the room for the task, trainees were briefed on the incident, provided with verbal instructions, and could ask any task-related questions they had prior to starting their task. Participants were not informed of the study purpose, which was to evaluate the impact of the instruction sets on performance. The simulation set-up consisted of a mannequin limb with a lower leg hemorrhage (Figure 2). Next to the limb were a CAT-7 tourniquet, an instruction set, and a marker to write down the time. Participants were randomized to one of the three instruction sets and allotted 3 minutes to complete the tourniquet application to qualify as successful application but were asked to verbally indicate task completion.

Phase I-B

In February, a convenience subset sample of Phase I-A participants attended a focus group where they provided feedback on the instructions. Prior to the focus group, participants received didactic training from an experienced trauma surgeon on tourniquet application with indicators of success and performed a simulated trauma case requiring tourniquet application. During the focus group, participants reviewed each of the instruction sets used in the Phase I-A task and identified positive and negative aspects of the instructions that could be improved for use as just-in-time guidance and for layperson use.
Human Factors Heuristics and Instructional Revision

Human Factors experts completed a heuristics analysis to compare the three instruction types. The ACS instructions were revised, as participants with this set had the best initial tourniquet application performance and it received positive feedback in the focus group. Modifications were made to the ACS instructions by combining results from usability testing, human factors heuristic analysis, and qualitative feedback focusing on potential failure modes. The revisions were tested during Phase II under the same protocol as Phase I-A with new participants six months later.

Phase II

In July, participants completed the same baseline questionnaire as Phase I-A participants (Appendix). The same prompt and simulation setup were used for this evaluation of instructions. Participants were randomized to one of the two instruction sets—the original version that resulted in the best performance and received the best feedback during the focus group in phase I-B (ACS-1.0), and the revised version (ACS-2.0)—and allotted 3 minutes to complete the tourniquet application and verbally indicate task completion.

Tourniquet Application Steps and Evaluation

Two human factors researchers conducted the set-up, introduction, and evaluation of the tourniquet applications in Phase I and II. While a participant performed the application, one researcher observed for tourniquet application steps and recorded completion time. Using the Combat Medic Advanced Skills Training book and the manufacturer-provided instructions on tourniquet application (C•A•T Resources, LLC; Rock Hill, SC), ten steps for tourniquet
application were identified (Table 1).\footnote{11} Participants were graded Pass/Fail based on each step completion with the provided instruction set.

**Statistical analysis**

Descriptive statistics were performed to compare participant groups and failure rates based on instruction type provided. Chi-squared analyses were used to compare failed steps by training level. Performance time and percentage of failed steps were compared across instruction type groups using ANOVA and results reported in the following format: $F(\text{degrees of freedom})=F$-statistic, $p$-value, with Tukey post-hoc analyses. All analyses were conducted at an alpha=0.05 level.

**RESULTS**

**Clinician Knowledge and Attitudes**

While 62% of all surgical trainee participants from Phases I and II had previous training, 16% indicated they had no familiarity with applying tourniquets and 22% indicated they were not at all confident in their ability to apply a tourniquet (Figure 5). None of the participants opposed the use of tourniquets in the prehospital setting with 85% favoring the use of tourniquets for prehospital bleeding control. More than half (62%) preferred commercial tourniquets (Figure 6); however, they did not perform significantly better than those that preferred the other hemorrhage control options.

Although 71% of participating trainees would advise a bystander not to remove the tourniquet, 20% would advise a bystander to loosen the tourniquet every 30 minutes. To determine successful application, 92% reported they would check to ensure bleeding was
stopped and 49% reported they would check the distal pulse. Less than half of the participants indicated they would tighten the tourniquet (39%), reapply the tourniquet (35%) or apply second tourniquet (41%) if the bleeding had not stopped.

**Performance with Just-in-Time Instructions**

**Phase I**

There were 30 participants (17 male) during Phase I. Thirteen (43.3%) participants had prior training in tourniquet use.

**Performance Time**

Participants completed the tourniquet task within a mean (SD) of 101 (40) seconds (min=35 seconds, max=180 seconds) (Table 2). Individuals that reached the three-minute cut-off (n=5) were finished with the task but had not yet verbalized completion. Across instruction types, participants with the ACS instruction set had the fastest average completion time at 70 (33) seconds followed by DHS at 105 (41) and CAT-7 at 137 (37). A 3 (instruction types: ACS, DHS, CAT-7) by 2 (training: trained, untrained) ANOVA on completion time showed a significant effect of instructions, $F(2, 25)=7.13, p<0.01$, but no effect of training, $F(1, 25)=7.13, p=0.31$. Specifically, the ACS-group had significantly shorter average application times compared to the CAT-7 group ($p<0.01$).

**Failed Steps**

The combined failure rate across the 10 steps for instruction type (ACS, DHS, CAT-7) by level of training (Trained, Untrained) ANOVA showed that instruction type was significant, $F(2, 25)=6.18, p<0.01$. Participants using the ACS instructions had a significantly lower percentage of failed steps compared to participants using the CAT-7 manufacturer instructions, $p<0.01$ and
participants using the DHS instructions, $p=0.02$. For each step individually, the percentage of surgical trainees that failed the step did not differ significantly ($p>0.05$).

**Heuristics Comparison across Instruction Sets**

The heuristic analysis of the instructions explained how instruction set improvements may further differentiate performance such as the non-significant performance differences shown in Figure 7. The instructions are broken up by tasks in Figure 4 for this comparative analysis.

The first two steps were based on the tightness of the tourniquet after application, distinguishing between the tightness of the Velcro strap before the windlass crank was used (step 1) and the tightness following the windlass crank (step 2). These two steps were measured objectively by the researcher at the end of the task before removing the tourniquet. For step 1, passing was when less than three fingertips fit in between the strap and the manikin limb, which came from the CAT-7 manufacturer instructions. For step 2, the researcher felt for a tightly secured tourniquet.

Step 3 pertained to placement above the wound. While two instruction sets (CAT-7 and DHS) indicated placement should be 2-3 inches above the wound, this step was only determined a failure if it was on or below the wound. The CAT-7 instructions stated the tourniquet should be placed “above the wound,” while the DHS instructions stated it should be placed “closer to the torso”. Only one participant applied the tourniquet on or below the wound. No instruction set specifically had error prevention integrated into their design.

Steps 4-6 indicated how the tourniquet was secured following tightening (step 4—inserting the windlass into the clip, step 5—securing the extra portion of the Velcro strap, and step 6—applying the Velcro windlass strap and indicating time on the clipped windlass). The ACS instructions only indicated step 4 in a visual picture of the windlass inserted into the clip
with the word “secure”. There was no indication of using the extra strap or the Velcro to further secure the windlass in the instructions. The CAT-7 instructions explained each of the steps in the text; however, only steps 4 and 6 are portrayed in the pictures and step 5 is not pictorially indicated in the instructions. The DHS instruction stated that the user should “clip and secure the rod [windlass] with the clasp or the Velcro strap.” The ‘or’ statement is at odds with how the task is supposed to be carried out by securing the rod using the clasp followed by the Velcro strap.

Step 7 addressed twisting the tourniquet windlass. While it was not an indication of the tightness or success in stopping an uncontrollable hemorrhage, it was a way to determine if users knew to twist the windlass to tighten. The DHS and CAT-7 instructions stated that users should “twist the rod” and the ACS and CAT-7 instructions had arrows indicating the windlass should be twisted. All participants completed at least one twist of the windlass, indicating a pass of this step.

Steps 8 and 9 related to the manner in which the tourniquet is applied. The instructions for the CAT-7 indicated application differences for applying the tourniquet with one or two hands. During one-handed application, instructions indicate the tourniquet should be applied with the tourniquet strap threaded and crossing the wound, placing it between the wound and the torso. In two-handed application, the user is instructed to rethread the tourniquet strap above the wound. The other two instruction sets did not have any indication of how to apply the tourniquet. This was also the step with the highest failure rates. Many participants incorrectly re-threaded the tourniquet instead of crossing the wound. The instructions are not clear in indicating that the one-handed application instructions are ideal for most situations (not just one-handed self-application). The instructions imply that use of two-handed application is intended for self-application when a user cannot reach down to their leg to apply a threaded tourniquet strap over
their wound before securing. The manual dexterity required to re-thread the strap is time-consuming and unnecessary when the threaded tourniquet can be moved up the limb, over the wound, and placed between the wound and the heart.

The last step (step 10) measured was writing down the tourniquet application time. This step had the greatest difference across instruction sets. The ACS instructions most clearly depicted the time written on the tourniquet. It was a very simple pictorial design that included the pen to indicate writing. The CAT-7 instructions in contrast only referred to writing down the time of tourniquet application in the written portion of the instructions. The DHS instructions had the word “time” visible on the picture of the tourniquet; however, there was no picture demonstrating or text indication that time should be written on the tourniquet. While this is not an essential step in saving the life of an exsanguinating patient, it can aid in limb recovery and demonstrates the necessity of instructional clarity.

Phase I-B

Feedback during focus group

The feedback provided from Phase I-B participants supported the heuristic comparison and varied by instructional set. The instruction set developed by ACS received overwhelmingly positive feedback and was the preferred set of the group. Participants favored the ACS instruction set due to its use of colored, detailed images and minimal, yet succinct verbiage. The other two instruction sets were less favorable due to their use of excessive verbiage (CAT), lack of instructional flow (DHS), and poor clarity (CAT and DHS). Participants also noted that non-medical, lay users may lack anatomical knowledge that could be useful to successful tourniquet application (e.g. placing tourniquet between wound and heart).
ACS Instruction Revision

Revisions (Figure 3) were made to the ACS instructions to provide more contextual information (an extension of a torso) to the users to indicate during step 3 (Table 1) that the tourniquet should be applied between the wound and the torso (heart). An arrow was added to indicate the Velcro should follow the wrapping (step 5, Table 1). The secure step was updated to show the securing of the time strap following the placement of the rod into the clip (step 6, Table 1).

Phase II

Twenty surgical trainee residents (14 males) participated in Phase II. Four (20%) of the participants had prior training in tourniquet use. None of the participants from Phase II had previously participated in Phase I.

Performance Time

Participants completed the tourniquet task within a mean (SD) of 81.25 (24.12) seconds (Table 2). Between instruction types, participants with the ACS-1.0 instruction set competed the task in 89.30 (28.08) seconds and participants with the ACS-2.0 instructions in 73.20 (17.15) seconds. A 2 (instruction type: ACS-1.0, ACS-2.0) by 2 (training: trained, untrained) ANOVA on completion time was not significant (p>0.05), nor was the effect of training (p>0.05), or the interaction between training and instruction type (p>0.05).

Failed Steps

The combined failure rate across the 8 steps (Figure 7) for instruction type (ACS-1.0, ACS-2.0) by level of training (Trained, Untrained) ANOVA was not significant (p>0.05), nor was the effect of training (p>0.05), nor the interaction between training and instruction type (p>0.05).
Participant failure rates at each step of the tourniquet application did not statistically differ across instruction sets. Steps 1 and 5 were not included because it was not anticipated that the instructions would impact these steps. Performance on the tourniquet placement (step 3) did not change with revision (Figure 8); however, performance on this step was nearly perfect before the revision (Phase I-A). Failure rates remained high for wound crossing and tourniquet re-threading. Neither the ACS-1.0 nor ACS-2.0 instruction sets clearly indicated that the strap should not be rethreaded and that the user should cross the wound during application. While not statistically significant, more participants failed to write the time of tourniquet placement with the revised instructions despite no change in instructions for step 10.

DISCUSSION

Until recently, tourniquet use was not favored by medical professionals due to the risk of limb loss following prolonged ischemia.9 Extensive military tourniquet experience along with increased concern for intentional mass casualty events have instigated changes in care standards to favor tourniquet application.6,14,15 Military studies have demonstrated that even after several hours of a tourniquet applied to an individual limb, tissues deprived of blood can still heal without the need for amputation.1,16-18 Although the civilian literature is sparse, similar results have been noted.2,4,19 With the Stop the Bleed Campaign6,7 surgeons ahave been called to action to use and advocate for the use of tourniquets, as well as encouraged to train laypeople. Since medical professionals need to be trained and are expected to train others, we focused on the use of just-in-time instructions to facilitate tourniquet application with surgical trainees.

Despite support by the ACS, current surgical trainees are unaware of many aspects of tourniquet application. Over 20% of participating trainees indicated they did not favor or outright
opposed the use of a tourniquet for stopping an uncontrolled extremity hemorrhage. When surgical trainees that indicated they would use a tourniquet, there were still high failure rates to determine successful application (checking the distal pulse and visually checking that active bleeding stopped) and to identify actions to take if bleeding had not stopped (adding an additional tourniquet above the current one). While participants were medically trained individuals and had a higher level understanding of the circulation system and anatomy, a majority were novice tourniquet users. It is important to note that lay users may require further information or cues in just-in-time guidance to successfully apply a tourniquet. Some of these themes were elucidated during the focus group, as the surgical trainees provided insight on what they thought laypeople would need to know. One example of this is the addition of the torso drawing (Figure 3) in the new ACS-2.0 instructions. While the surgical trainees did not feel like they needed this, they anticipated laypeople would benefit from the further clarification of proper tourniquet location.

The three instruction sets used in the first phase of this study were very distinct from one another. Although CAT-7 manufacturer instructions were not specifically intended for just-in-time use, it might still be used in this setting if no previous knowledge or additional instruction was available. The ACS instructions were provided pictorial instructions with minimal cues or keywords. The DHS instruction set used a combination of pictures and words; however, it lacked an organized, linear flow, which made several key steps confusing to users. Our work has demonstrated a lack of consistency and standards in the terms used across tourniquet application materials. As general acceptance of tourniquet use continues to grow and education of laypeople commences nationally and internationally, advances toward standards and consistency in terminology and instruction are essential.
Key human factors assessments were used to create the new instructions by revising the leading instruction set by ACS. Based on the heuristic analysis, surgical trainee performance, and the focus group feedback during Phase I, the researchers updated the instructions to increase the probability of guiding laypeople through tourniquet application. These instructions aimed to address major shortcomings identified in the ACS instruction set; however, this was an initial pilot with minor revisions. The first revision goal was to highlight the placement of a tourniquet—between the wound and the torso (heart). The image was extended to clearly show a torso. Even before this update, most of the surgical trainees placed the tourniquet in the correct place. Therefore, it was difficult to test the impact of the instructions for this user group as indicated by the lack of significant difference between participants that received ACS-1.0 and ACS-2.0. Future studies will need to include non-medically trained users to evaluate the effectiveness of the instructions in guiding lay users in this step. The revised ACS instructions also included two steps in the securing process to clarify that the time strap needed to be attached with Velcro after the windlass rod was clipped. This was not a critical step but could help ensure the tourniquet was not loosened prior to the arrival of further medical assistance. The last change made to the ACS instruction set was to provide post-application cues. Two instructions were added, telling users not to remove tourniquet and to apply a second tourniquet closer to the torso (heart) if bleeding had not stopped. This was not measured in the evaluation of the revised ACS instructions as, like the other instruction revisions, this change was targeted at laypeople.

Limitations

This study examined the usability of various just-in-time instruction sets in guiding a user through tourniquet application. While this is not a replacement for normal training, it should be considered a source to refresh knowledge and skill during an application. No direct comparisons
were made by gender. Male and female participants were recruited to be representative of the surgical trainee population. Most important to note, no layperson users were included in this study.

The importance of each step to overall task success was not taken into account and our simulator was not advanced enough to determine if bleeding was controlled. The study focused on use of one type of tourniquet. Further, only formative testing of the minor revisions to the ACS instructions was carried out. Additionally, performance with the task was rated by two consistent human factors researchers. While they did not have the clinical or military experience with tourniquet application, they have experience in evaluating the effectiveness of instructions and through collaboration with clinical and military authors (MS, WF) were able to confidently assess performance of tourniquet application steps in this simulation.

Next Steps

While usability goals for devices are to be self-explanatory with no additional instructions, this is not always attainable. For tasks completed infrequently—such as tourniquet application—concise instructions can provide the needed guidance to save a life successfully. In order to be helpful to the user, this instruction must be easy to use, task-oriented, and contain task-critical steps. Next steps involve further refinement of just-in-time guidance instructions that include layperson usability and higher fidelity trainers for clinical success evaluations.

CONCLUSIONS

The knowledge, attitudes and practice of tourniquet application among surgical trainees are inconsistent and may not be satisfactory. This indicates a potential need for tourniquet application training among medical personnel to improve knowledge and attitude.
Standardization and incorporation of tourniquet application training and just-in-time instructions may be useful in eliminating preventable death from uncontrolled bleeding. Instruction sets in their current form fail to aid users in achieving ideal performance for every step in tourniquet application. Small changes to the leading instruction set, as part of a pilot formative test and directed by human factors experts, did not indicate improvement in tourniquet application among medically-trained persons. Further just-in-time instructional improvements by clinical and human factors experts are necessary for improved tourniquet application and increased possibility of saving a life after traumatic hemorrhage throughout general civilian populations.
REFERENCES


**Figure 1. Study Procedures: Participants and Materials**

Phase I

- Simulation by Surgical Trainees
  - January 2017; n=30 (10/instruction set)
  - ACS vs DH5 vs CAT-7: Steps 1-10
  - Focus group by subset of Surgical Trainees
  - February 2017; n=12

Phase II

- Simulation by Surgical Trainees
  - July 2017; n=20
  - ACS 1.0 vs ACS 2.0: Steps 2-4 & 6-10

Update of ACS from 1.0 to 2.0

This figure displays the phases of the study. Sample 1 performed a simulation and a focus group in Phase I. Sample 2 performed a simulation with ACS-1.0 vs ACS-2.0 in Phase II.
Figure 2. Mannequin lower leg with hemorrhage.

This is the lower limb of the mannequin with hemorrhage used for tourniquet application simulation.
Figure 3. Original vs. Revised ACS Instruction Sets

In the first step on the left, we added the "& Velcro" to the instructions and more of the victim's body for context. There was no change made to the second box from the left "Wind". For the third box the number "1" was inserted near the existing error and then a Velcro strap with an arrow and the number "2" were added to indicate securing the Velcro after the windlass rod was secured.
**Figure 4.** Comparison of instructions based on tasks

<table>
<thead>
<tr>
<th>Tasks</th>
<th>ACS</th>
<th>CAT-7</th>
<th>DHS</th>
<th>Steps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross Wound/Rethread</td>
<td><img src="acs.png" alt="Image" /></td>
<td><img src="cat7.png" alt="Image" /></td>
<td><img src="dhs.png" alt="Image" /></td>
<td>3, 8, 9</td>
</tr>
<tr>
<td>Strap</td>
<td><img src="acs.png" alt="Image" /></td>
<td><img src="cat7.png" alt="Image" /></td>
<td><img src="dhs.png" alt="Image" /></td>
<td>2</td>
</tr>
<tr>
<td>Crank</td>
<td><img src="acs.png" alt="Image" /></td>
<td><img src="cat7.png" alt="Image" /></td>
<td><img src="dhs.png" alt="Image" /></td>
<td>1, 7</td>
</tr>
<tr>
<td>Secure</td>
<td><img src="acs.png" alt="Image" /></td>
<td><img src="cat7.png" alt="Image" /></td>
<td><img src="dhs.png" alt="Image" /></td>
<td>4, 5, 6</td>
</tr>
</tbody>
</table>

This figure displays the how the three instruction sets instruct users to complete the tasks of tourniquet application and how they were evaluated based on the steps in Table 1.
Figure 5. Surgical Trainee Attitudes on Tourniquet Application

- **Tourniquet (TQ) preference**
  - Elastic: 62%
  - Improvised: 28%
  - Commercial: 11%
  - None: 18%

- **Familiarity applying TQs**
  - Not at all familiar: 19%
  - Slightly familiar: 17%
  - Somewhat familiar: 38%
  - Moderately familiar: 27%

- **Confidence applying TQs**
  - Not at all confident: 22%
  - Slightly confident: 26%
  - Somewhat confident: 36%
  - Moderately confident: 16%

- **Feelings about TQ use in prehospital setting**
  - Oppose: 14%
  - Slightly oppose: 25%
  - Neither favor nor oppose: 61%
  - Slightly favor: 11%
  - Favor: 7%
**Figure 6. Knowledge on when to Remove Tourniquet**

This pie chart shows surgical trainee response breakdown for when they would advise tourniquet removal.

- **73%**: Keep the TQ in place until medical assistance arrives
- **19%**: Loose TQ slightly every 30 mintues; remove it completely after 4 hours
- **6%**: Oppose the TQ; apply pressure only
- **2%**: Remove TQ safely after 1 hour
Figure 7. Percentage of participants that failed steps 1-10 by instruction set

This graph displays the percentage of participants that failed steps 1-10 as described in Table 1. Ten participants represented for each version of the ACS instruction set.
Figure 8. Percentage of participants that failed steps by instruction set in Phase 2

This graph displays the percentage of participants that failed steps 2-4, 6-10 as described in Table 1. Ten participants represented for each version ACS instruction set. Steps 1 and 5 were not included in evaluation during Phase II, as it was not anticipated that the instructions would impact these steps.
Table 1. Explanation of Identified Tourniquet Steps

<table>
<thead>
<tr>
<th>Step</th>
<th>Evaluation Type</th>
<th>Pass Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Subjective</td>
<td>Tightness of the Windless</td>
</tr>
<tr>
<td>2</td>
<td>Subjective</td>
<td>Less than 3 fingers fit under secured strap</td>
</tr>
<tr>
<td>3</td>
<td>Objective</td>
<td>Tourniquet placement above wound</td>
</tr>
<tr>
<td>4</td>
<td>Objective</td>
<td>Windless secured</td>
</tr>
<tr>
<td>5</td>
<td>Objective</td>
<td>Extra Strap secured in Clip</td>
</tr>
<tr>
<td>6</td>
<td>Objective</td>
<td>Time strap secured over Clip</td>
</tr>
<tr>
<td>7</td>
<td>Observation</td>
<td>Windless/Rod Twisted</td>
</tr>
<tr>
<td>8</td>
<td>Observation</td>
<td>Did not cross the wound when applying Tourniquet</td>
</tr>
<tr>
<td>9</td>
<td>Observation</td>
<td>Re-thread the Tourniquet</td>
</tr>
<tr>
<td>10</td>
<td>Objective</td>
<td>Notation of Time or Tourniquet in use</td>
</tr>
</tbody>
</table>

The steps are not presented in task-based order in the table, but grouped by measurement type (objective/subjective) and by which observer graded the items. Steps 1-6 were recorded by one human factors researcher after the task and steps 7-10 were recorded by the second human factors researcher during the task.
Table 2. Performance across the different instruction sets.

<table>
<thead>
<tr>
<th>Performance</th>
<th>Phase I</th>
<th></th>
<th>Phase II</th>
<th></th>
<th>Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ACS N=10</td>
<td>DHS N=10</td>
<td>CAT-7 N=10</td>
<td>Statistic</td>
<td>ACS-1.0 N=10</td>
</tr>
<tr>
<td>Mean(SD) completion time (Seconds)</td>
<td>70 (33)</td>
<td>105 (41)</td>
<td>137 (33)</td>
<td>p&lt;0.01^a</td>
<td>89.3 (28.1)</td>
</tr>
<tr>
<td>Mean Number of Errors across all steps*</td>
<td>4.3 (2.1)</td>
<td>4.6 (1.9)</td>
<td>5.3 (1.8)</td>
<td>p&gt;0.05^a</td>
<td>1.8 (1.0)*</td>
</tr>
<tr>
<td>Mean number of Errors across all steps, but 1 and 5</td>
<td>3 (1.4)</td>
<td></td>
<td></td>
<td></td>
<td>1.8 (1.0)</td>
</tr>
</tbody>
</table>

This table displays the mean(SD) completion time and mean(SD) errors across instruction sets in a) Phase I, b) Phase II and c) a comparison for ACS between Phase I and Phase II.*Note: for Phase II, all steps excluded steps 1 and 5 for both ACS-1.0 and ACS-2.0.