Limb Tourniquet Configuration

Preliminary Investigation of Problems and Principles

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ABSTRACT

Background: A tourniquet's readiness during emergencies depends on how it is configured. We investigated configuration so ways of improving readiness can be developed. **Methods:** This study was conducted at the Institute of Surgical Research in 2018 as sequential investigations by one user of Combat Application Tourniquets (C-A-Ts) in a band-and-rod design. **Results:** Each tourniquet comes packaged with paper instructions for use, which include directions on how to configure it in preparation for caregiving. The paper and video instructions for use omit tensioning of the tourniquet in configuration, and the video misconfigured a time strap over the rod. In first-aid classrooms, we saw unwitting learners troubleshoot that misconfiguration. Problems with configuration were also seen in caregiving and with tourniquets stowed in kits. In deliberate practice, we self-applied a tourniquet to a thigh. In configuration after each of 100 uses, tourniquet elongation due to tensioning averaged 2.4 in was important for restoring the tourniquet to its full length. During configuration, if the C-A-T's stabilization plate slid along the band, out of position, the user slid the plate back into position. In various ways of testing other C-A-Ts, elongations averaged from 0.4 in to 0.9 in, depending on whether the tourniquet was self-applied or applied to a firm manikin. Elongation increments accrued as the tourniquet's band flattened. Configuration time averaged 22 seconds, and accrued experience improved the compactness of configuration. **Conclusion:** People are too often unreliable at putting C-A-Ts into the optimal configuration for use. That ready-to-use configuration includes the tourniquet being at its full length, having the stabilization plate positioned correctly along the band, and having the strap fastened to its clip of origin. When used, tourniquets had normal, small elongations in part due to band flattening. This tourniquet study showed the importance of optimal configuration to first-aid readiness practices.

KEYWORDS: *Combat Application Tourniquet; tourniquet configuration; limb tourniquet; Stop the Bleed; medical device; combat injury first aid; tourniquet band flattening; tourniquet elongation; use instruction; resuscitation; emergency*

Introduction

In caregiving, we learned that better performance of tourniquet configurations improved hospital preparedness, such as to receive groups of casualties.[1] After cleaning and inspecting used tourniquets, selected ones were configured to restock resuscitation bays.[2,3] These tourniquets, of a band-and-rod design, had the band circumferentially around the limb. Bands poorly tensioned during configuration were shorter and needed extra turns of the rod to compress limbs, thereby slowing attempts to stop the bleeding. While bleeding continued, inadequate tightening resulted in more force needed to turn the rod and more time to complete the turns. Extra force also increased risk of tourniquet damage. At first, we incorrectly thought more turns resulted from the band loosening, but turns simply removed slack left over after poor tensioning. Because tensioning was supposed to remove leftover slack, we learned to restore length by tensioning better during configuration. Tensioning also flattened out the wavy, scrunched-up portions of the band. Such portions were thicker and impeded efforts to pull the band through the narrow slit of the buckle. Caregiving was made easier by fixing these problems.

We saw other misconfiguration problems in first-time use of a tourniquet[4] and in teaching tourniquet use, such as in Stop the Bleed classes. Such misconfigurations stowed in first-aid kits may risk preventable death by delaying and complicating caregiving.[5] One-handed self-application is the worst-case scenario: The wounded person is bleeding, stressed, impaired,[6] and challenged to detect misconfiguration, undo the error, and complete the application. Users erred systematically in preparing and stowing tourniquets. We gave feedback about the importance of configuration to readiness practices.[5]

At the Institute of Surgical Research, we serially check the bleeding-control kits, which are kept in unlocked, wall-mounted boxes. In 2018, we corrected a tourniquet misconfiguration. Someone had unwrapped a Combat Application Tourniquet (C-A-T; C-A-T Resources Inc.; http://combattourniquet.com/) and left its band out of the buckle. That misconfiguration remains a whodunit. Because people struggled

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to configure tourniquets, we decided to sleuth the case of configuration. The current study investigated C-A-T configuration to develop ways to improve readiness of individuals, organizations, and their tourniquets.

Methods

This study was conducted within the protocol guidelines at the Institute of Surgical Research in 2018. The design comprised sequential classroom investigations and investigations of C-A-T (generation 7) mechanics while being used. With a tape measure with markings to one-sixteenth of 1 in, a tourniquet expert checked the length of tourniquets from one end to the other as laid flat on a table. Descriptive statistics (mean ± standard deviation) were used to analyze the data and present results. Least squares regression was used to show the tension effect on tourniquet length. Paired *t* tests were performed to determine the significance of length change. Analyses were performed by using Excel 2003 (Microsoft, www.microsoft.com).

Results

Configuration Problems With Instructions for Use

Tourniquets come packaged individually with instructions for use (IFU). The C-A-T's paper IFU include "Storing the C-A-T in the Quick Launch Configuration" in written steps and drawings.[7] These instructions are incomplete because they omit tensioning before the first shown step. At the bottom of this IFU page, the side for configuration, three C-A-Ts in different colors are pictured. However, all three show the time strap secured across to the opposite clip, trapping the rod underneath the strap. That visual cue contradicts the drawn instructions for storage.

That strap error in configuration was repeated in the video IFU[8] (now off-line) which depicted a "Ready to Go" textbox and stated "Place the time strap over the rod." The audio stated, "Place the time strap over the rod to complete the configuration. Now your C-A-T is in the quick-launch configuration and ready to be put away."[7] The video specified securing the time strap to the incorrect clip. The correct clip would have the time strap secured to the clip from which the strap originates: The strap is to fasten back onto its clip of origin. The incorrect clip has the strap over the rod, which incorrectly blocks a gap between the clips. Blocking the rod from exiting or entering the clips keeps it inside or outside, respectively. The strap folded back to its clip of origin keeps the gap open to rod traffic. The strap is to be folded back onto its clip of origin—*not over the rod*. The difference is that this misconfiguration risks a preventable death in the worst-case scenario. The viewers may learn this misconfiguration and think it is the best practice when, instead, it is the worst. The correct configuration optimizes preparation (Appendix 1).

On January 9, 2019, four other videos (arm, self-aid; arm, buddy aid; leg, self-aid; leg, buddy aid) at the bottom of the www.combattourniquet.com website started with a black C-A-T apparently in the quick-launch configuration, and showed the three differently colored C-A-Ts in the incorrect configuration for storage by having the time strap again secured across to the incorrect clip. In both paper and video forms of instruction, the photogenic and sleekly streamlined images of the strap misplaced were visual cues that may nudge people to inadvertently misconfigure their tourniquet.

Configuration Problems in Classrooms

Configuration problems occurred during teaching tourniquet use to student medics in a block of instruction in hemorrhage control. We recognized a problem resulting when two skills were taught inefficiently out of order. We made that same mistake previously and had fixed it by reversing the order to put configuration before use (Appendixes 1–3, Figure 1). The new order was more efficient and easier for learners in their first tourniquet experience. We added nothing and removed a problem and its consequences.

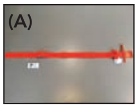
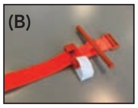
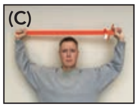
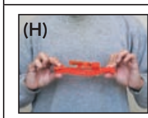
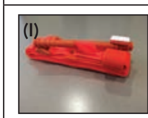
In the classroom, an instructor demonstrated tourniquet use in steps that were concurrently mimicked by each learner with their own tourniquet. The lesson included naming the parts, demonstrating application once and, finally, removal. The class then began a break, so learners rolled up their tourniquet and shoved it in their pocket. After repeated uses and repeated misconfigurations by rollup, the instructor called out learners for erring. Impromptu remediation unexpectedly disrupted the classwork. The avoidable consequences included remediation, time loss, instruction delay, and redevelopment of muscle memory. Afterward, we and the course director discussed the problem and its prevention: After learners are taught configuration, they break, and first use follows. By priming configuration, first-use teaching is unburdened. By reversing the order of skills taught, each configuration performed provides a better opportunity for prompt feedback to hone the skill.

In classes for the Stop the Bleed program,[9] we found that people frequently had problems with configuration. Unwitting learners often had to start by fixing a tourniquet misconfiguration. Such troubleshooting was neither planned nor taught. Inadvertently, these learners' first impression of the tourniquet was literally messed up. We felt compelled before class to routinely check the tourniquets in each training kit. Our checks revealed a diverse array of configurations: correct, almost correct, and messy. One organization's kits often held tourniquets as misconfigured in the video IFU. As we discussed our observations and experiences with other instructors, their knowledge of configuration and consequences of misconfiguration varied widely. Few instructors said that they had perused the paper IFU. Many instructors were previously unaware of, but immediately realized when told, the importance of configuration to avoid forcing learners to troubleshoot their first use. We fixed misconfigurations on the spot, showed others how to identify and fix them, used the IFU to spotlight key points, and discussed configuration awareness.

Deliberate Practice in Configuration and Tourniquet Use

The tourniquet expert applied his practice tourniquet to his thigh and made three turns of the rod when tightening. The tourniquet length was measured after each of 100 uses to determine if accrual of uses changed the length. Measurement was taken twice—before and after tensioning (Figure 1C). Both measurements were trended to see if poor tensioning also may have affected tourniquet length. Before the next use, the tourniquet was configured. In 100 uses and configurations, the tourniquet did not stretch like pulled taffy, as a few instructors had thought (Figure 2). However, there was substantial length change due to tensioning (mean change, 2.4 in). The change in length was important because it underscored that tensioning was essential to proper configuration and demonstrated the magnitude of length restoration. During configuration, if the

FIGURE 1 *Pointers on the technique of configuration.*

(A) 	Lay the tourniquet flat and straighten it by pulling it lengthwise so its band-and-rod design is clear. Look for evidence of use, mud, blood, writing, wear, deformation, or breakage. Unclip the rod to free it. Untwist rod turns so the inner band is untwisted where it goes through the rod's opening. Look there for a tear at the edges of the inner band. Flip the tourniquet over to check the downward side. Fold up the paper instructions for use (IFU).
(B) 	Pinch the free end of the time strap, lengthen it, fold it in half, and adhere its loop fasteners to the hook fasteners on the strap's clip of origin. The strap edge and its clip edge are to be stacked flush. This is a step of configuration because it prevents delay in troubleshooting a loose strap that errantly fastens elsewhere.
(C) 	Grip the red-tip end of the band and the other end at the buckle. Lift the tourniquet. Pull the ends apart for 4 seconds with firm, steady force to restore length. Note the end-feel of tension while slips restore length, and firm up that feel. This tensioning step is needed to restore length and to check the mechanical integrity of the tourniquet.
(D) 	Check that the band is not twisted, so it passes its red tip flatly through the buckle slit. Pull the tip so 8.5 in of the band has gone through the slit. Check the distance with fist widths. For example, the person shown has a fist atop the band at the red tip, then moves that fist adjacently to finish estimating the distance as two fist widths.
(E) 	At the slit in the buckle, fold the band. Folding the band orients its fastener surface back toward itself near the red tip. Lightly touch the surface back onto itself so that it self-adheres. Shape the band into a round loop. A light touch eases compact folding. A heavy touch stiffens the band, which risks a bulky configuration.
(F) 	Roll the loop to orient the rod, clips, and buckle upward. Center the buckle so it is just to your right of 12 o'clock. Put your left and right thumbs inside the loop on its left and right side. Just past the clips, start to fold the loop over a thumb. Diametrically opposite, start another fold the loop over the other thumb at the red tip.
(G) 	Put your left index fingertip under 12 o'clock to hold up the loop there. Over that fingertip, drape both ends of the band down to form an apex in the loop so it folds in half. The loop now forms an inverted V whose two stems are double layers of the flattening loop.
(H) 	Keep the band edges neatly aligned to stack them. The rod, clips, and buckle are facing upward. The red tip is downward and ideally projects just a bit, making peel back faster and easier. The buckle does not go past its nearby fold in the band. The strap remains folded and fastened to its clip of origin. The tourniquet is streamlined and compact.
(I) 	Secure the rod by putting one end of it into a clip. That rod end is near the band fold but does not hang past. This is called the quick-launch configuration, which is ready for one-handed use. This configuration also enables the IFU to be replaced between the clips, because this was how the tourniquet was packaged. Using the IFU in this way centers the rod, which aids streamlining. This configuration is the routine way to stow tourniquets in kits.

C-A-T's stabilization plate had slid along the band to become out of position, the user slid the plate back into position.

No tourniquet breakage or substantial wear occurred. We dismantled the tourniquet seeking hidden problems, but none was found. The inner band had mild deformation in a few short, curved creases where the rod twisted the fabric (Figure 3).

Results Before and After Tensioning in Configuration but Without Tourniquet Use

We tested if tourniquet length changed before first use, because tensioning may elongate a tourniquet right out of its wrapper. The expert measured the length of 30 unwrapped tourniquets before and after tensioning. Length increased little (mean, 0.4 in; Figure 4).

When laying out each tourniquet fresh from its wrapper, we noticed that as the band was pulled lightly to straighten and flatten it atop the tape measure and table, it flattened. However, when our hands released the pull, each tourniquet recoiled in tiny, sliding movements as the red tip skidded incrementally to shorten the band. Shortening happened as folds in the band reformed. The folds—formed by configuration and held while wrapped—flattened almost completely when pulled during layout, but release led to the folds partially reforming. This refolding showed stretched length was, in part, an illusion. Tourniquets did flatten out but did not stretch like pulled taffy.

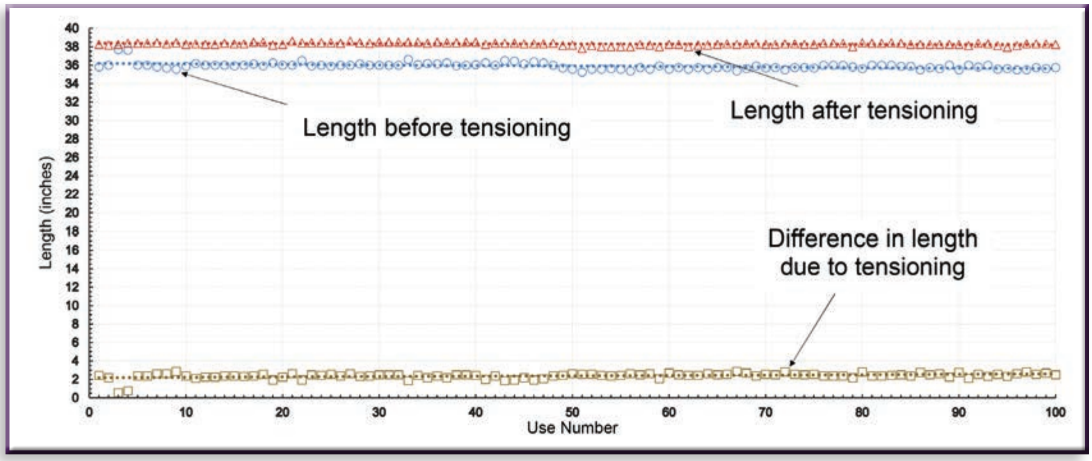
Configuration time averaged 22 seconds (range, 16–28 seconds). Accrued experience improved compactness. The ideal shape of configuration made the side view of the band look flattened like a grilled sandwich made with compressed Italian bread—a teeny panini (Figure 1H).

Results of Tensioning in Configuration and a First Use

We checked if length changed from unpacking through first use. The expert tested another 30 tourniquets, each used once. Length changes from unpacking through postuse tensioning were moderate (mean, 0.9 in; Figure 5).

Configured bands remained folded at both ends of the tourniquet. The ends were 7 in apart. Among six folds, four were 7 in apart and the other two folds were 2 in away from a fold at the buckle. When laid flat, each fold nearly flattened, yet rested in a residually smaller fold. Residual folds are examples of shape memory, a type of structural property where the form of the band tends to keep a degree of its prior shape despite a change in arrangement. In this case, that change was laying out the band.

FIGURE 2 *Results in practicing with one tourniquet used and configured 100 times.*



The length before tensioning (blue open circle) changed negligibly with repeated use and configuration [length = (–0.0017 × use number) + 38.388; R^2 = 0.1126]. Similarly, the length after tensioning (red open triangle) also changed negligibly with repetitions [length = (–0.0058 × use number) + 36.201; R^2 = 0.2135]. However, the length difference (olive open square) from before to after tensioning was substantial (2.4 ± 0.33 in; strains, 6.7% ± .96%). That difference also changed negligibly with repetitions [length = (0.004 × use number) + 2.187; R^2 = 0.1254). Regression results are shown as a dotted line in the color of its marker. Tensioning restored length of the band to its normal trend line.

FIGURE 3 *The practice tourniquet disassembled.*

This band-and-rod tourniquet was disassembled after 100 practice uses and configurations. The inner band is laid in the foreground. The inner band is laid double side by side. Normally, it runs double but stacked from the red tip to the other end where it folds within the buckle to return to its origin. The inner band show patterns of creases which looked like foam-crested waves. These waves formed where the rod twisted the inner band. The rod opening twisted the inner band widthwise so the stress and strain oriented transversely, not lengthwise. At the crest of each wave, a thin rim of lighter blue color indicated focally significant stress in the fabric threads, a process called stress whitening, which occurs when stress is created at a polymeric surface by forces like twisting. The rim of stress whitening is not a reflection of light off the material. Whitening is a refraction of light in the material. Just as foam bubbles refract light atop surf crests, the microbubbles formed within the stressed polymer refract light. The reflection and refraction are categorically different, independent, and, in this case, present adjacently. The creases of the inner band were not hidden; they were seen through a 1.5-in opening in the self-adhering band's top layer. Although the inner band runs within the outer band, the opening is where the inner band passes once through the rod as two stacked layers. These creases in the inner band resisted flattening because they retained shape memory.

Results With Tensioning in Configurations and 10 Uses

Because lengths changed with first use, we sought to know if changes would trend differently over 10 uses. The expert tested three new tourniquets, each used 10 times on a firm manikin. Measurements were made before and after tensioning. When graphed, length increased in a power-law trend. However, each elongation due to a tensioning was, again, small (mean, 0.4 in; Figure 6), plateauing by the eighth use.

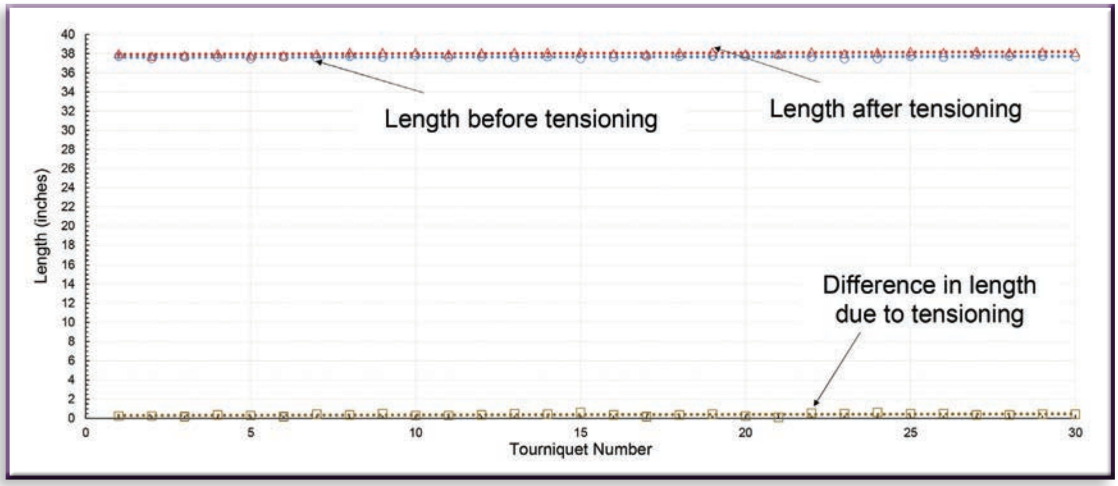
With accruing uses, fold heights decreased as band lengths increased commensurately. The loss of shape memory in the band was associated with length increases by mechanism, magnitude, direction, and temporality. Losses in shape memory caused increases in length.

Discussion

The major finding of this study was that people, including the tourniquet maker and first-aid instructors, sometimes do not know or cannot detail or perform the optimal C-A-T configuration. The tensioning action, a key step in configuration, is one way people can err. Tensioning affected preparation by allowing users to restore length to a tourniquet, assess its integrity mechanically, and flatten its band before later steps in configuration. However, we found little awareness of the importance of tensioning among first-aid instructors (Table 1). Properly tensioning the band fully restores length. In conversations with instructors, we also found that how we thought of length increases affected our diction (e.g., "stretch out") describing the phenomenon, which, in turn, reciprocally affected how we perceived the phenomenon. Interestingly, people often mixed up "stretch out" for "length restoration," the former implying abnormality, whereas the latter was normal with proper tensioning. Word choices matter. Having the optimal configuration for use matters for application speed, ease of use, and avoiding user confusion—all of which affect clinical effectiveness by how much blood is lost. Anyone who takes a C-A-T out of its plastic wrapper before placing it into a kit, such as for training, first aid, or bleeding control, should at least know its optimal configuration by sight. In fact, configuration is a skill in the set of tourniquet skills.

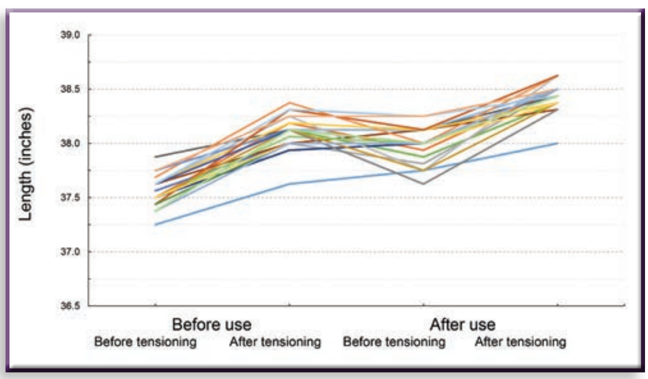
The first minor finding was that tourniquets elongated for multiple reasons, including use, tensioning, and band flattening. The tourniquet did not "stretch out" from its full length because of 100 uses, but tensioning in configuration restored

FIGURE 4 *Results of the tensioning step in configuring 30 freshly unpackaged tourniquets.*



The lengths before tensioning (blue open circle) varied little (37.7 ± 0.1 in; length = 0.0099 × tourniquet number + 37.899; R^2 = 0.4363). Similarly, length after tensioning (red open triangle) also varied little [38.1 ± .01 in; length = (0.0038 × tourniquet number) + 37.609; R^2 = 0.0975]. The difference (olive open square) from before to after tensioning was small and varied little [0.4 ± 0.13 in; strains, 1.0% ± 0.34%; length = (0.006 × tourniquet number) + 0.2898; R^2 = 0.1697]. Such small differences were not noticed until the tape measure was used. Elongation was not from overuse but before any use. The mean differences, 0.4 in and 2.4 in, between the results in this figure and those in Figure 2, respectively, appeared to be from the different compressibility between of the firm manikin used for this figure and the human thigh used for practice in Figure 2. The inner band traveled more with the actual thigh than with the manikin.

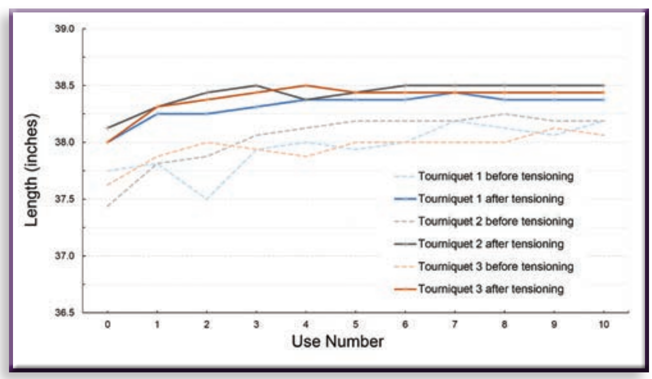
FIGURE 5 *Results among 30 tourniquets before and after tensioning and again after a use.*



The mean length change (0.9 ± 0.16 in; strains, 2.3% ± 0.43%) from unpackaged and before any use (37.6 ± 0.14 in) to the end state posttuse after tensioning (38.4 ± 0.12 in; p <.001) was small and varied little. Although these actions of use and tensioning lengthened tourniquets by a statistically significant amount, no problem resulted. The minimum change was approximately 0.6 in (strain, 1.5%), which meant that elongation was the norm. Before the tape measure was used, changes were just noticeable differences, in part because we were intently looking for them. With this new insight of length changes, the magnitude of the elongating effect appeared to be accrued from three apparent causes. Tensioning a used, shortened tourniquet while performing configuration had a large effect size (2.4 in). Elongation during first use accompanied by tensioning before and after use had a moderate effect size (0.9 in). From the length results in practicing with one tourniquet used 100 times (Figure 2), later use, such as after use 8, had an effect size close to zero.

its length. Furthermore, when measured through the first several uses, each tourniquet had a small elongation resulting from all three causes, and tensioning contributed most. These three reasons all caused the tourniquet to reach its full length, which was a trend line as a power law. We found that small elongations were the norm with the first several uses, were not associated with failure, and were not a sign of overuse. We learned to expect small elongations as a sign of proper use, good tensioning, and suitable flattening.

FIGURE 6 *Results before use, before and after tensioning, and after 10 uses.*



Three tourniquets were measured before their first use and after 10 uses. Length was measured twice: before tensioning (dashed lines) and after tensioning (solid lines). For each tourniquet, its length results increased in what looked like a power law [e.g., for tourniquet 3 (orange lines), length = (38.145 × use number$^{0.004}$); R^2 = 0.6831), which fit the data better than a straight line. An effect of tensioning on length was noticed. Among the 33 changes in length due to tensioning among the three tourniquets (n = 3 tourniquets; n =11 assessments; n = 10 uses plus a preuse measurement [use 0]), elongations were small again (0.4 ± 0.13 in; strains, 1.0% ± .35%). An effect of use on length was also noticed. The mean length change (0.8 ± 0.22 in) of the tourniquet from the unpackaged, pretensioning state (use 0, 37.6 ± 0.16 in) to the end state after tensioning (38.4 ± 0.06 in; p <.001) was reliably positive with little variation. The minimum elongation of a device was 0.6 in again, which meant that such small elongations were consistently the norm over the first several uses. The association between repeated use and elongation was front loaded, because elongations only occurred in the first several uses and not later. The opposite evidence appeared to negate the implication from the instruction slides in both of its dual premises: Accrual of uses stopped accruing elongations, and accrual of uses was not associated with failure.

The second minor finding was about mechanical loads. When forces like tension are applied to structures like tourniquets, loads cause internal stresses and strains. A tourniquet has several components, including a rod, but parts like a band may bear more stress and strain than others, like the time strap,

TABLE 1 *Knowledge Developed for Instruction, Practice, Preparation, and Caregiving Using Combat Application Tourniquets*

Optimal tourniquet configuration improves outcomes, like a Soldier's readiness.
Configuration affected readiness of tourniquets, kits, training, users, and organizations.
Preparing a tourniquet by configuration is a skill.
Awareness of configuration as a skill is currently limited yet improvable.
To perform configuration well, useful feedback given promptly can aid learners.
Configuration can be honed in deliberate practice to take, on average, approximately 22 seconds.
Misconfigurations in kits impair interoperability among potential users.
Contrasting written and video IFU may show discrepancies.
For clarity among IFU versions, each is to be individually identifiable (e.g., coded).
The strap put to the wrong clip impairs fast application, one-handed use, and readiness.
To configure the strap: fasten it back onto its clip of origin—*not over the rod*.
Instructions are improvable. A mistaken step is removable and replaceable.
When instructing configuration, warn learners that current IFUs skip a tensioning step.
When instructing configuration, band tensioning should be shown and emphasized.
Tensioning the band is essential to configuration because it restores tourniquet length.
Instructors can be efficient by wisely ordering that tourniquet skills be taught to learners.
Handling a tourniquet can begin with its unwrapping, IFU removal, and band unrouting.
Parts naming can be performed while handling a tourniquet. Correct naming improves communication.
Good diction improves learning, caregiving, dispatching, and talking to patients.
Some tourniquet configurations were prepared poorly.
It is easy to err because preparations are manmade.
People must manage equipment correctly.
For configuration, prior preparation prevents piss-poor performance.
Learners in the basic STB class are not ready to learn configuration.
Soldiers and instructor candidates for STB are supposed to learn configuration.
The STB instructor course is to teach participants to instruct configuration to others.
Medics and instructors for the STB program should be able to teach configuration.
The instructors for the STB program are to harmonize diction so everyone communicates better.
The instructors for the STB program should learn what tourniquet components do.
The new instructors are to identify, fix, and discuss misconfigurations.
The advanced beginner instructors are to assist learners in troubleshooting.
The competent instructors teach configuration awareness and spotlight points with IFU.
Proficient instructors teach configuration and troubleshooting to candidate instructors.
Expert instructors monitor classes and programs in support of instructor development.
In making and learning from our many errors in tourniquet practice, we became expert.
Instructors and course directors should avoid extrapolating content beyond slide scripts.
Course directors should be familiar with several types of instructions for use.
Stewards are to periodically revise messaging, course content, and lesson materials.
Steward neatness and care of configuration shall set the example for others to follow.
Do not rely on worn-out tourniquets for care, because they are in poor condition for use.
Do not use worn-out tourniquets in care. Use is harder and risks failure.
New tourniquets well prepared are easier to use than worn-out or misconfigured ones.
Tourniquets are normally elongated a bit by their first several uses.
Doctrinal developers may consider different configurations for various kits, users, and contexts.

IFU, instructions for use; STB, Stop the Bleed.

which is lightly loaded in holding the rod in a clip. Repeated loads may cause a component to sustain accumulated effects, such as by formation of a craze (a fine crack), crack propagation, fatigue fracture, or breakage. In this study, none of these was observed in the band. Also, we did not observe any deformation like when taffy is pulled. However, strain in the inner band was seen. Although rarely noted by users or instructors, the inner band is essential because it loads the outer band. In simulation, we have loaded several tourniquets 100 or more times, and rarely have we had breakage. When it occurs, it is rarely catastrophic because the tourniquet does not become ineffective. Breakage usually occurs at a small part, like at an edge of the stabilization plate near one of its three slits allowing the band to pass. Passes of the band through these slits hold the tourniquet flatly on the patient. Such minor breakage can make tourniquets wobbly and harder to use, but they may remain effective in the hands of users. Other problems like wearing out of hook-and-loop fasteners may also risk making tourniquets harder to use. In our experience, catastrophic damage required extraordinary problems like prolonged exposure to sunlight or abuse of tourniquets, which indicated poor practices, like leaving slack in the band.[10,11] Instruction can emphasize that worn-out tourniquets are harder to use and may risk failure. Those are two good reasons not to rely on worn-out tourniquets. The first and second minor findings resonate because excessively repeated loading is the reason why instructors should blame overuse, not the tool.

The third minor finding comprised several errors in our work and in that of others. A focus on the tourniquet as a tool is apt to have an inexperienced user attribute problems in use to the tool itself. That attribution is intuitive, easy, natural, and occasionally wrong. "Poor workmen blame their tools" is a proverb describing how inexperienced users are apt to attribute a problem to the tool instead of inexperience. If the tool is truly faulty, that is one thing, but otherwise a user may err in assigning blame or credit.[12,13] Although small elongation of the tourniquet is thought to be bad, it still did occur—normally. With this new understanding, we can now explain it. Also, we have learned to detect other postcompletion errors like misconfiguration as situations where learner intuition may be manifestly inaccurate. In addition, instructors often erred in saying that North American Rescue is the manufacturer. C-A-T Resources is the manufacturer.[7,8] The former is a distributor.

The limitations of this study evolve from its design being based in an exploration of a new topic in first aid. The findings are limited within the scope of study and may not apply widely.

Directions for research include surveying readiness of users or instructors in performing the skill of configuration. Also of interest is whether configuration practice reduces incidence of the postcompletion errors of forgetting to configure the tourniquet, whether degrees of firmness in actual limbs or manikins affect the learning of users, and whether the aims of speed versus ease are at cross-purposes in quick-launch and one-handed configurations.

Conclusion

Too often instructors and potential users are unready to put a C-A-T in its optimal configuration for use. That ready-to-use configuration includes the tourniquet being restored to full length, having the stabilization plate correctly positioned along the band, and having the time strap fastened to its clip of origin. When used, tourniquets had normal, small elongations in the first several uses, in part due to band flattening and proper tensioning. This tourniquet study showed the importance of optimal configuration to first-aid readiness.

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(continues on page 42)

APPENDIX 1: Skill Sheet for C-A-T Configuration

Storing the C-A-T in the Quick-Launch Configuration

1. Inspect the tourniquet for serviceability. Unclip the rod. Untwist it and the inner band.
2. Fold the time strap in half and fasten it to its clip of origin.
3. Grip each end of the band and pull the ends with firm force to restore length.
4. Pass the red tip through the buckle slit so 8.5 in of the band goes through the slit.
5. At the slit, fold the band so it self-adheres from the slit to the red tip.
6. Shape the band into a round loop.
7. Roll the loop to get the rod, clips, and buckle upward. Center the buckle. Flatten the loop.
8. Drape down both ends of the flattened loop to fold it in half.
9. Neatly align the band edges to stack them neatly.
10. Secure the rod by putting one end of it into a clip.

Assessment Aids

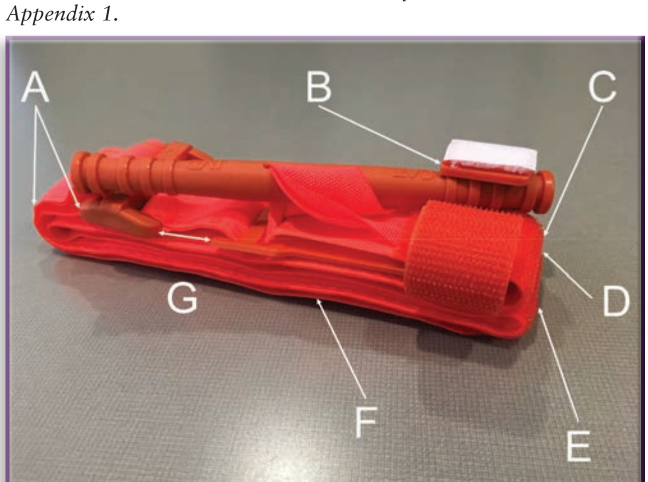
A. The buckle does not hang past its nearby fold in the band.
B. The time-strap edges are stacked squarely atop the corners of its clip of origin.
C. No rod end hangs past a fold in the band at either end.
D. The two layers of the band have folds stacked neatly atop each other.
E. The red tip is downward and projects just a bit past the fold so tip peel back is easier.
F. The side edges of the band are stacked neatly.
G. For the buckle-plate gap, configured C-A-Ts average 0.75 in.

Notes: Length × width × height: 7.5 in × 1.5 in × 1.5 in. A tape measure aids assessment: The average band distance from the slit to the red tip (at its straight edge) is 8.5 in.

If a tourniquet passes postuse checks, it can be reused, such as in training. Quick-launch configuration and one-handed configuration are two names for one setup.

This configuration permits the instructions for use (IFU), a folded paper, to be replaced between and under the clips, which was how the tourniquet was packaged. It is the routine way to stow a tourniquet in medical kits. The IFU centers the rod lengthwise, which streamlines configuration. IFU is to be present for stowage but distracts laypeople in class.

APPENDIX FIGURE 1 *Letter labels correspond to the lettered list in Appendix 1.*



APPENDIX 2: First Contact of a Learner With a Tourniquet

Note: This script guides an instructor and presumes one learner

- This is the Combat Application Tourniquet, the C-A-T.
- Unwrap it. This type of tourniquet design is called band-and-rod.
- Give me the wrapper.
- Take out the instructions for use. They're also known as the paper IFU. Give it to me.
- Pull the red tip and peel back the self-adhering band from itself.
- The Velcro will peel back to make a sound like from ripping a cloth.
- Unroute the band from the buckle by pulling the band out of the slit.
- Pull the tourniquet out to its full length.
- Lie it flat on the table.
- This is the red tip.
- This is the self-adhering band.
- Omni-Tape brand has its hook-and-loop fasteners together. The surface can stick to itself.
- This is the buckle. It has a slit to route the band through.
- This is the rod. It has the role of a crank in the type of machine called a windlass.
- These are two rod clips. Either can hold the rod and keep it from turning loose.
- This is the TIME strap. It is white, but in the current black C-A-T, it is gray.
- This is the stabilization plate.
- The inner band runs inside the self-adhering band.
- The inner band is stacked in two plies to go through the rod and to run full length end to end.
- When the tourniquet encircles a limb, you pull the self-adhering band to pull its slack out.
- Turning the rod tightens the inner band, which has the role of rope in a classic windlass.
- The rod goes into a clip, and the time strap goes over both clips to keep the rod inside.
- You write the time of application here on the time strap, which has "TIME:" printed on it.
- Let's go through the instructions for use (read aloud all steps, discuss all images, use a ruler).
- How many fist widths is 8.5 in for you (fist, palm-down, ruler at knuckles [MCPJs])?
- How many finger widths is 2–3 in (extend, palm-down, flat hand, first knuckles [PIPJs])?
- Now let's configure the tourniquet so it's ready to go. You do yours while I do mine.
- This is for the quick-launch configuration, also known as the one-handed configuration.
- Lay the tourniquet flat lengthwise.
- Look for wear or tear, deformation, breakage, mud, blood, writing, or evidence of use.
- Pinch the time strap at its free end, lengthen it, fold it, and fasten it to its clip of origin.
- The strap edge lays flush at the corners of its clip of origin. The gap between the clips is open.
- Unclip the rod to set it free, then untwist its turns. Untwisting the rod untwists the inner band.
- Flip the tourniquet over to check its downward side, too.
- Lift the tourniquet. With each hand, grip both ends of the band—red tip and buckle.

- Pull the band for 4 seconds with firm, steady force: Tensioning restores full length.
- Note the end feel of tension. The slips you note restore length to firm up the feel.
- If the tourniquet passes all postuse checks, it can be used, such as for training.
- Ensure that the band is untwisted so its red tip passes flatly through the slit in the buckle.
- Pull the tip so 8.5 in of band comes out of the slit. Check distance with your fist widths.
- At the slit, fold the band. Lightly touch the Velcro to itself so the band self-adheres.
- Shape this band loop to be round. The loop is double layered from the red tip to the buckle.
- Rotate the loop to get the rod, clips, and buckle upward.
- Center the buckle so it is just to your right of 12 o'clock.
- Just past the clips, start a fold in the band. Hold this fold. A thumb inside the loop will do.
- The other fold is on the other side at the red tip. Hold that fold, too.
- Put your index fingertip under high noon to hold up the loop there.
- Over the fingertip, fold the loop in half. Align and stack edges. The tourniquet is flattened.
- Secure the rod by putting one end into a clip.
- The time strap remains fastened to its clip of origin.
- The rod, clips, and buckle are upward. The buckle is near an end.
- Downward, the red tip is at an end to project just a bit, making peel back faster and easier.
- This is called the quick-launch configuration. This is good for one-handed use.
- This is how a tourniquet is packaged. It's the routine way to stow a tourniquet in a medical kit.
- You keep this, your practice tourniquet. Here's your IFU. Refer to it. Save it. It is online.
- What is our first question or comment?

MCPJ, metacarpophalangeal joint; PIPJ, proximal interphalangeal joint.

APPENDIX 3: Annotated Glossary

directions for use – The term "directions for use" provides directions under which the practitioner or layman (e.g., patient or unlicensed health care provider), as appropriate, can use the device safely and for the purposes for which it is intended. Directions for use also include indications for use and appropriate contraindications, warnings, precautions and adverse reaction information (https://www.fda.gov/RegulatoryInformation/Guidances/ucm081368.htm, Accessed 12-Oct-18).

instructions for use – information provided by the manufacturer to inform the device user of the medical device's intended purpose and proper use and of any precautions to be taken (http://www.imdrf.org/docs/ghtf/final/sg1/technical-docs/ghtf-sg1-n70-2011-label-instruction-use-medical-devices-110916.pdf, Accessed 18-Sep-18). The regulators like the FDA may use alternative terms like *directions for use*. We use the IFU phrase to apply not only to items reviewed by the regulators like the FDA but also for other items such as used by training like in the Stop The Bleed program. The IFU phrase is more general than directions for use. IFU encompasses care, teaching, research, and executive functions like regulation. Many learners and instructors are both unfamiliar with and surprised by some IFU types. Here are some types of IFU for the C-A-T:

1. Paper IFU as product insert. Sponsor-made (the device sponsor is often its maker).
2. Video IFU Quick-launch way to configure the tourniquet. Maker. 1:13 (1 min, 13 sec).
3. Video IFU Arm Self, the way to self-apply the tourniquet to one's own arm. Maker. 2:01.
4. Video IFU Leg Self, the way to self-apply the tourniquet to one's own leg. Maker. 1:51.
5. Video IFU Arm Buddy, way to apply the tourniquet to another person's arm. Maker. 1:55.
6. Video IFU Leg Buddy, way to apply the tourniquet to another person's leg. Maker. 1:13.
7. Slides IFU Stop The Bleed Bleeding Control Basic Course (v 1.0) self-application.

postuse checks – Include band tensioning, visual inspection of components, and operational check in handling. Pneumatic devices are inflated for underwater testing of air leaks in the bladder or tubes. If a tourniquet passes postuse checks, it can be cleaned, dried, configured, and reused such as in practice. For tourniquets which are single-use devices, reuse is off-label under the supervision of a physician. Since postuse checks can precede another use, postuse and preuse usage may be interchangeable.