Tourniquet Training Program Assessed by a New Performance Score

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Abbreviations:
CAT: Combat Application Tourniquet
EMT: Emergency and Medical Tourniquet
MTF: Medical Treatment Facility
SOFTT: Special Operation Forces Tactical Tourniquet

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Abstract

Introduction: Application of a tourniquet is the cornerstone in management of combat-related extremity hemorrhages. Continuous and appropriate training is required to use tourniquets correctly.

Hypothesis: The aim of this study was to analyze the impact of a refresher training session, conducted directly in the theater of military operations, on the performance of tourniquet use.

Methods: During their deployment (October 2015-April 2016) in the Central African Republic, a first simulation session evaluated soldiers from two combats platoons for the application of the SOFFT (Special Operation Forces Tactical Tourniquet; Tactical Medical Solutions; Anderson, South California USA) tourniquet. After randomization, a R (+) group underwent a refresher training session, while a R (−) group did not. Two months later, a second simulation session was conducted for both groups: R (+) and R (−). A dedicated score (one to seven points), including delay and effectiveness, evaluated the soldiers' performance for tourniquet application.

Results: Twenty-six subjects were included in the R (+) group and 24 in the R (−) group. Between the two assessments, the score improved for 61.5% of subjects of the R (+) group and 37.5% subjects of the R (−) group (P = .09). More particularly, the performance score increased from 4.2 (SD = 1.4) to 5.5 (SD = 0.9; P = .002) in subjects of the R (+) group whose last training for tourniquet application was over six months prior.

Conclusion: A refresher tourniquet training session, conducted directly in a combat zone, is especially effective for soldiers whose last training session was over six months prior. A dedicated score can assess appropriately the performance of tourniquet training.

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Introduction

Background

Hemorrhage is the leading cause of death in combat in modern conflicts. Moreover, extremity hemorrhages have been considered a cause of preventable death in combat.[1] The wide-spread use of tourniquets and their systematic availability for each combatant has led to a sharp decrease in avoidable deaths in combat settings.[2,3] Thus, tourniquet pre-deployment training is a major concern for Armed Forces.[4–6] Indeed, the tourniquet's effectiveness is very high in laboratory conditions, but it decreases significantly in simulation and stress conditions.[7–9] Numerous studies have highlighted the importance of training to improve users' ability to apply a tourniquet.[10,11]

Importance

It is unclear whether a refresher tourniquet training session conducted in a combat zone (in addition to the standard pre-deployment training program) improves the performance of tourniquet application.

Goals of the Investigation

The purpose of this study was to assess the impact of a refresher tourniquet training session, during simulation sessions, conducted directly in the theater of military operations. A dedicated score of performance was designed for the tourniquet applications evaluation.

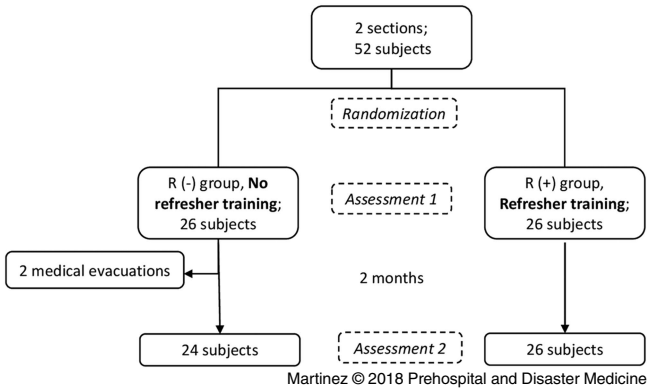

Figure 1. Study Flow Chart.

It was hypothesized that this dedicated training could improve the tourniquet application performance, measured with this score improvement.

Materials and Methods

Study Design and Setting

A monocentric, controlled, and single-blind prospective experimental study was conducted on healthy volunteers at the ROLE 2 Medical Treatment Facility (MTF) of M'Poko Camp, in Bangui, Central African Republic, from October 2015 through April 2016.

Selection of Participants

Fifty-two French soldiers were enrolled to participate in the study. They were from two combat platoons (26 subjects in each platoon) simultaneously engaged in the Central African Republic, as part of Operation SANGARIS.[12] Any military personnel belonging to one of the two participating platoons were included, after giving their informed consent.

Exclusion criteria were refusal to participate in the study, a medical history of arterial or venous thrombosis in the lower limbs, history of venous insufficiency, wounds or infections, injuries, or recent lower limbs trauma.

Both platoons were divided into two groups using simple randomization by flipping a coin, one undergoing the refresher training (R (+) group), and one without any refresher training (R (−) group). Two subjects in the R (−) group were considered as lost to follow-up, after their aeromedical evacuation toward France before the study's completion (Figure 1).

Before being included in the study, the last tourniquet placement training for all the subjects was performed in France, before their arrival in the Central African Republic.

Materials

The SOFTT model (Special Operation Forces Tactical Tourniquet; Tactical Medical Solutions; Anderson, South California USA) tourniquet was used for the study, currently available for all combatants in their French combat first aid kit. A Sonosite M-Turbo (Sonosite Inc.; Bothell, Washington USA) portable ultrasound device was used to test the popliteal arterial Doppler flow interruption after tourniquet application.

All participants, fully equipped for combat, first underwent a simulation-based assessment. The models for tourniquet application testing were three males, independent of the subjects of the study, and healthy volunteers from the Role 2 MTF. They weren't allowed to give feedback to those being tested.

The simulation sessions were conducted following the steps below:

a) Collection of demographic data (first assessment only).
b) Short briefing: "*You are engaged in a patrol mission, your buddy has just been injured in the leg, he is bleeding profusely, you will have to put a tourniquet in place.*"
c) Stopwatch start at the examiner's signal: "*It's up to you!*"
d) Assessment of the tourniquet performance included two points: the global time for placement (measured by the stopwatch, until the participant shouted "*Ok, tourniquet placed!*") and the effectiveness (assessed by the detection of a popliteal arterial Doppler flow interruption, by an experienced examiner).
e) Personalized debriefing of the actions performed during the session.

Immediately after the first assessment, an official instructor conducted refresher training for tactical tourniquet application to the R (+) group. During two months, no other courses were delivered for the subjects included in the study. Two months after the first assessment, both R (+) and R (−) groups were called back and underwent a second assessment, under the same conditions (Figure 1).

Methods and Measurements

The following data were collected during the assessments.

Demographic Data—Age, gender, military rank, date of enlistment, and date of last tourniquet training were collected. The time delay between the last tactical tourniquet training and the first assessment was calculated. According to the French Military Medical Service doctrine, pre-deployment training includes a dedicated course for tourniquet training in the six months before deployment.

Measures During Simulation Sessions—Each simulation session included an assessment of the following items:

- Pre-positioning and preparation of the tourniquet. The tourniquet was noted as pre-positioned if it was immediately available on the tactical jacket and prepared if the buckle was already engaged.
- Effectiveness. The tourniquet was deemed effective if the popliteal artery color Doppler flux was abolished. Two lengths of time were graded: "On-hand" time, measuring the elapsed time between the stopwatch start and the tourniquet grip; and "Global time" for tourniquet application, measuring the time between the stopwatch start and the end of tourniquet application.

Qualitative Assessment of Performance Score—To reflect the overall performance of the tourniquet, a composite score was developed, integrating and weighting several qualitative and quantitative items. A panel of experts in the field participated in a consensus meeting. All these experts held local or national roles in tourniquet training programs. Each item, empirically determined, was graduated according to its relative importance for management of extremity hemorrhage. The possible values ranged from zero (zero performance) to seven (best performance). Table 1 gives the details of the performance score. For recognizable reason, effectiveness was considered as the most important factor and was

	Variable	Points
Effectiveness	Yes	3
	No	0
Total Placement Time	<40 seconds	2
	40–80 seconds	1
	> 80 seconds	0
Tourniquet Pre-Positioning	Yes	1
	No	0
Tourniquet Preparation	Yes	1
	No	0

Table 1. Performance Score

rated as three points or zero point. The speed at which the tourniquet is placed is decisive for the survival of the war casualties.[13] Based on published studies about tourniquet performance, a total placement time shorter than 40 seconds was considered as "ideal" and rated at two points, comprised between 40 to 80 seconds as "acceptable" and rated at one point, and insufficient longer than 80 seconds as "insufficient" and rated at zero points.[10,14–16] Finally, to increase the speed of the tourniquet placement, it is important to consider the device access. One study has shown that the manner of storing the tourniquet affects the catching time.[14] Thus, criteria pre-positioning and preparation were considered as described above and rated each criterion at one or zero points.

Key Outcomes

The primary outcome was the improvement of the performance score between the two assessment sessions. The secondary outcomes were the time and effectiveness of tourniquet application.

Analysis

Given the primary outcome of the study, no data were available in the literature concerning the primary outcome; thus, it wasn't possible to determine an a priori sample size and chose a convenience sample determined by the possibility of delivering consistent training and evaluation.

Continuous data were summarized using medians and interquartile ranges (IQRs) or means and standard deviation (SD), depending on the distribution of the variable; categorical data were presented as absolute numbers and percentages. Comparison tests were performed using Student's *t*-test for continuous variables and χ^2 tests for categorical variables when the applicable conditions were fulfilled. If necessary, non-parametric tests were performed (Wilcoxon-Mann-Whitney test and Fisher exact test, respectively). The significance threshold was set at .05.

Ethical Considerations

This study received approval from a local Ethics Committee (*Comité d'Ethique de la Recherche en Anesthésie et Réanimation*; SFAR; Paris, France) under the number IRB 00010254. All participants were informed and gave their written consent to participate in the study.

Results

Characteristics of Study Sample

The two groups were similar, except for the time between the last tourniquet placement training and the first assessment, with a median time of 10.8 months (IQR: 4.3-13.3) for the R (+) group and 2.3 months (IQR: 2.3-2.3) for the R (–) group; $P < .0001$ (Table 2). No eligible soldier refused to participate in the study.

Main Results

The mean performance score between the two assessments increased from 4.2 (SD = 1.4) to 5.2 (SD = 1.0) for the R (+) group ($P = .009$), in comparison to the R (–) group 4.2 (SD = 1.8) at Assessment 1 and 4.3 (SD = 1.3) at Assessment 2 ($P = .79$; Table 3).

There was significant improvement in the mean performance score of the R (+) group whose last refresher training was more than six months old, the standard time delay scheduled in official pre-deployment training. There was no such improvement in the R (–) group (Table 4).

Analysis of the Performance Score Improvement Between Assessments

Soldiers whose most-recent refresher training occurred more than six months prior were more likely to improve their performance score between the two assessments ($P = .04$). The number of subjects who improved their performance score between the two assessments was 16 in the R (+) group and nine in the R (–) group, although below the significance threshold ($P = .09$; Table 5).

No complications were observed among participants, including among simulation actors (no complications following the tourniquet application).

Discussion

A refresher tourniquet training session did not improve the performance score for all participants. Nevertheless, the performance score was significantly higher for soldiers who underwent local refresher training at Assessment 2 (Table 3).

Improvement of the Performance Score

A dedicated performance score was designed to include all parameters describing correct tourniquet application. The mean performance score increased between both assessments in the R (+) group and didn't in the R (–) group. This outcome is not directly comparable with results from published data since the performance score was designed specifically for this study. To the best of the authors' knowledge, no previous study has reported such a score to explore tourniquet application performance. These results emphasize the results of Kragh, et al highlighting the best way to assess the tourniquet trainings. They showed that trainee learning curves vary according to the chosen metric, and the use of many metrics allows to assess training in a more comprehensive way.[17] Indeed, they compared the learning curves of six characteristics (effectiveness, pulse stop, blood loss, laying time, number of turns of the tourniquet, and pressure exerted) when repeatedly applying a tourniquet to a manikin. According to the criterion analyzed, the learning curve varied widely. Among other findings, authors have emphasized the interest of composite criteria to evaluate accurately the acquisition of this skill. Indeed, the score provides a better capability to show a performance improvement instead of a single criterion such as the effectiveness.

The performance score provides a pedagogic tool for the tourniquet training. This study, applying the four-levels scale

		R(+) Group	R(−) Group	P
Military Rank **Number**	Enlisted Men	23	19	.45
	Officers	3	5	
Age **(years) Median (IQRs)**		25.4 (24.0-28.0)	26.6 (23.8-28.1)	.7
Time **Median (IQRs)**	Date of the study – enlistment (years)	4.2 (3.0-6.9)	5.7 (2.7-7.6)	.5
	Date of the study – last refresher training (months)	10.8 (4.3-13.3)	2.3 (2.3-2.3)	< .0001

Table 2. Participants Characteristics According to the Randomization Group (R+ / R-), n = 50
Note: The "Time" measure expresses the delay between:
- Enlistment in the French army and the date of the study (expressed in years)
- The last refresher training for tourniquet application, in France, before the deployment of the subjects and the date of the study (expressed in months)

		Assessment 1	Assessment 2	P
Performance Score **Mean (SD)**	R (+) Group	4.2 (1.4)	5.2 (1.0)	.009
	R (−) Group	4.2 (1.8)	4.3 (1.3)	.79
Effectiveness **Number**	R (+) Group	11	15	.14
	R (−) Group	11	10	.5
"Global" Time **(seconds) Mean (SD)**	R (+) Group	58.1 (16.5)	45.5 (11.8)	.03
	R (−) Group	58.5 (14.8)	57.3 (18.7)	.81
"Hands-On" Time (seconds) **Mean (SD)**	R (+) Group	10 (10.2)	6.3 (3.3)	.15
	R (−) Group	6.8 (5.1)	7.6 (6.1)	.82
Pre-Positioning **Number**	R (+) Group	25	26	1.0
	R (−) Group	21	24	.23
Preparation **Number**	R (+) Group	26	26	1.0
	R (−) Group	23	23	1.0

Table 3. Data Measured at Assessment 1 and 2 According to the Randomization Group (R+/R-), n = 50

described by Kirkpatrick, corresponds to the second level.[18] The third level and, even more, the fourth level seem difficult to reach because they need an evaluation in real-life settings. The third level might be obtained by applying the performance score during a high-fidelity simulation session during an unexpected exercise. This could be the better way to approximate real-life and evaluate the knowledge transfer.

Effectiveness

The mean effectiveness rate for tourniquet placement was only 44% at Assessment 1 and 50% at Assessment 2. In an experimental study for the tourniquet placement by inexperienced subjects, the effectiveness rate was 44% in the group of participants who received a single period of short instruction.[19] The appropriateness of the placement was judged on a combination of subjective criteria such as correct anatomical location, adequate tightness, and properly secured windlass and straps. In an Israeli army study, the SOFTT tourniquet was successfully placed in 62% of the cases. Effectiveness assessment included abolition of the distal pulse (palpation and Doppler flow) and tourniquet stability.[20] In this study, participants were not equipped for combat, unlike the study participants. Schreckengaust, et al also explored the beneficial effect of tourniquet training. This prospective study analyzed the SOFTT tourniquet application in repeated simulation sessions for 89 US soldiers.[10] Two simulation sessions were performed four days apart. Participants received a refresher course before each simulation session. The effectiveness was recorded by *dorsalis pedis* Doppler flow elimination. The effectiveness percentage improved from 30% to 43% between the two sessions. In this study, the criterion for the tourniquet applications effectiveness was the popliteal arterial Doppler flow interruption. Numerous experimental studies have adopted this same assessment criterion.[21–23] However, in a real-life scenario, the only criterion for effectiveness is the stop of bleeding. Thus, it is difficult to compare

	Assessment 1	Assessment 2	P
R (+) Group			
<6 months **mean (SD)**	4.3 (SD = 1.4)	4.4 (SD = 0.7)	.84
> 6 months **mean (SD)**	4.2 (SD = 1.4)	5.5 (SD = 0.9)	.002
R (–) Group			
<6 months **mean (SD)**	4.4 (SD = 1.4)	4.4 (SD = 1.4)	1.0
> 6 months **mean (SD)**	2.5 (SD = 0.7)	4.0 (SD = 1.4)	.3

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Table 4. Mean Performance Score According to the Group and the Time Elapsed Since the Last Refresher Training

Performance Score Improvement		Yes number	No number	P
Group	R (+)	16	10	.09
	R (–)	9	15	
Time Since Last Refresher Training	<6 months	12	19	.04
	> 6 months	13	6	
Age	< 25 years	9	11	.56
	> 25 years	16	14	
Time Since Enlistment	< 5 years	12	14	.57
	>5 years	13	11	
Rank	Officers	5	3	.70
	Enlisted	20	22	

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Table 5. Performance Score Improvement Analysis

the effectiveness results with those of other studies from real-life combat settings.

The type of tourniquet can also influence the effectiveness. Numerous studies have compared SOFTT, CAT (Combat Application Tourniquet; Phil Durango LLC; Golden, Colorado USA), and EMT (Emergency and Medical Tourniquet; Delfi Medical Innovations; Vancouver, British Columbia, Canada) tourniquets.[16,20,24] Because of its characteristics (fragile pneumatic tourniquet and bulkier compared to SOFTT, not adapted for operational combat settings), the EMT seems to be preferred for secondary management; for example, during the evacuation to hospital. Nevertheless, the SOFTT was used because it's the official tourniquet in the French Army.

Participants were all combatants and not professional health care providers. However, the professional category (physicians, paramedics, or combatants) may be associated with differences in performance for the tactical tourniquet.[8,19,20] A higher level of skill in first aid improves the effectiveness of the tourniquet.[8]

Preparation and Pre-Positioning

The preparation of the tourniquet involved engaging the tightening strap and removing the tourniquet from its packaging. Only one subject in the R (–) group and in the two assessments did not take this precaution before beginning the exercise. The pre-positioning involved a tourniquet hung directly on the combat equipment, making it more easily accessible. At Assessment 1, four subjects did not meet this pre-positioning criterion, whereas all did so at Assessment 2. In the tactical tourniquet training programs, soldiers are trained to both pre-position and prepare. Higgs, et al have demonstrated that access modalities of the tourniquet might influence the time taken to apply it.[14] This study compared the differences in CAT placement time between American and Australian soldiers. The Australian Defense Force uniform uses buttons to secure the pocket, whereas the US uniform uses a hook and loop fastener system. The US personnel removed their tourniquets in a shorter time (median 2.5 seconds) than the Australians (median 5.72 seconds; $P < .0001$).

Time for Tourniquet Application

Here, the global tourniquet application time for the entire team was 58.3 seconds at Assessment 1 and 51.4 seconds at Assessment 2. Mean lower limb SOFTT application times from published data range from 26 to 59 seconds.[10,16,20,25] However,

few studies provided details about the measurement of time for tourniquet placement. In this study, stopwatches started before the participant caught the tourniquet in his hands. Therefore, the global time for tourniquet application included the time of catching, positioning, and tightening the tourniquet. Considering only studies using the same timing modalities, this duration varies from 48 to 55 seconds, comparable with the data from this study.[10,15,26] Analyzing each group separately, time for tourniquet application decreased significantly between the two assessments in the R (+) group but did not in the R (−) group. Schreckengaust, et al previously described the average duration for tourniquet application decreasing 55 to 50 seconds between both assessments.[10]

Time Since the Last Refresher Training

A significant difference was observed in the time between the study and the last tourniquet refresher training between the two groups: 10.8 months in the R (+) group versus 2.3 months in the R (−) group; $P < .0001$. The combat section randomized into the R (+) group could not undergo the refresher training session usually included in the operational pre-deployment because of a rapid and unexpected surge in Operation SANGARIS. In this study, a post-refresher training interval greater than six months was associated with increased effectiveness of the refresher training and with a significant improvement of the performance score. The pre-deployment training is a major factor associated with a rapid and effective tourniquet application.[10,11,19,24,25] To the best of the authors' knowledge, this study is the first to precisely highlight the influence of such a long delay on the learning of the tourniquet's use. This notion has been suggested by the work of Higgs, et al[14] In addition to measuring the tourniquet "hands-on" time of the American and Australian soldiers, the authors also measured the time of tourniquet application. This study was carried out in simulation, in the theater of military operations. The "hands-on" time of the Australian soldiers was longer than that observed among the American soldiers. Paradoxically, the global time for tourniquet application was significantly shorter (41.4 Seconds) for the Australian soldiers compared with American soldiers (58.9 seconds; $P = .0037$). The authors interpreted this result by the differences in training that had benefited the two groups of soldiers. In fact, American soldiers have received only initial training and then an annual refresher training, while Australian soldiers have benefited from two refresher training periods: before and immediately after their deployment in the theater of military operations.

Kragh, et al found no significant association between the post-training time interval and the tactical tourniquet application effectiveness.[27] However, the study period was less than three weeks, and no study has ever explored the performance change over a longer period.

Assessment in a Combat Zone

Several other studies have evaluated the impact of training on tourniquet use.[10,11,22,26] The originality of this work was to conduct this evaluation in a combat zone, directly during the deployment in a military operation. This distinction is important. Firstly, the goal of the tourniquet training is to improve its appropriated use for management of combat casualties presenting with extremity hemorrhages. Thus, it is appropriate to conduct this work directly where soldiers can potentially benefit the most from its use. Secondly, several studies have shown a strong psychological effect of military operations that can influence the performance of soldiers.[28,29] Conducting this work during a military operation included this factor.

Limitations

Number of Participants

One of the main limitations of the study is the lack of power in relation to the limited number of participants. This lack of power may partly explain the absence of difference in performance score improvements observed between the two groups. The number of subjects needed could not be estimated given the outcome of the study. However, it should be emphasized that this study was carried out in a combat zone and was therefore subject to operational imperatives. It limited *de facto* the number of subjects available for inclusion during the study period. Therefore, it remains uncertain if this training assessment is applicable for a large majority of soldiers.

Experimental Model

In the study, healthy volunteer actors simulated fake combat casualties. Thus, the participants stopped tightening the tourniquet when they felt that it was enough, with no obvious sign to determine effectiveness. Under real-life conditions, the tourniquet is tightened until the bleeding stops. Thus, the tightening of the tourniquet could have been stopped prematurely. Moreover, the pressure generated by the tourniquet is painful for the victim. It is possible that the fear of hurting the fake victim may have limited the effectiveness of the SOFTT application.[30] Finally, a screaming and bleeding simulation manikin could have been more appropriated. But in the setting of military operation, devices dedicated to simulation training were unavailable. Furthermore, the study did not include any combat simulation details like blood, or other simulated components of a combat environment. Therefore, the stress-level might be lower compared to real combat situations. Innovative and dedicated tools, such as serious games,[31,32] could improve this training and be particularly effective in case of unexpected deployment with shortened operational preparation.

Performance Score

Authors acknowledge that the performance score is novel and unique. It was designed according to previously published data but was not statistically validated.

Conclusion

In the study, there was no significant difference in the improvement of tourniquet application performance scores between two groups of soldiers, with or without a refresher training session, conducted directly in the theater of military operations. Conversely, results suggest that in-theatre refresher training is particularly useful for soldiers who are deployed unexpectedly. Authors acknowledged a six months maximum delay since the last training session to maintain adequate skills for the use of tourniquets. The benefits of the refresher training session observed in the study, as well as the significant failure rate of tactical tourniquet application in combat setting, highlight the critical nature of tactical tourniquet training programs.

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