

ORIGINAL ARTICLE

ASSESSMENT OF THE TOURNIQUETS APPLICATION TIME, EFFECTIVENESS AND SIMPLICITY

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Summary

BACKGROUND: Damaged arteries bleeding can cause a life-threatening condition and it is one of the main causes of death which can be prevented both on the battlefield and in the civilian environment. In case when severe external bleeding in a limb cannot be controlled by direct pressure a tourniquet should be used. The purpose of this study was to test four different types of tourniquets and to determine which type of tourniquet is effective to be used in the Army of the Czech Republic.

METHODS: Four different types of tourniquets were tested: SOFTT, C-A-T Generation 6, C-A-T Generation 7 and the CZ Tactical tourniquet. 59 students of military medicine (35 males and 24 females) from the Faculty of Military Health Sciences volunteered for the study. Each student applied all four types of tourniquets by self-application on the non-dominant upper arm. 20 students applied all four types of tourniquets on the arm as a buddy aid. Tourniquets order was determined by randomization. Time to placement, effectiveness and a subjective assessment of the application were recorded.

RESULTS: The C-A-T 7 tourniquet was the fastest applicable one, with 52, 5% of students being able to apply it up to 30 seconds. In the range of 31-60 seconds, 66, 1% of the C-A-T 6 and 54, 2% the CZ Tactical tourniquets were applied. On the contrary, the SOFTT tourniquet, as the only one, 5, 1% exceeded the application time of 2 minutes. The C-A-T 7, the C-A-T 6 and the CZ Tactical tourniquets were more effective (95%, 95% and 86%, respectively) compared with the SOFTT (56%). The correct application was found in men in 89% of the cases, while in women in 74% of the cases. A higher rate of failure was recorded for women in all types of the tourniquets. Average subjective students' score was in the tourniquet SOFTT 3, 46 (assessment between neutral and difficult), the other tourniquets were assessed between easy and very easy (C-A-T 6 1.63, CZ Tactical tourniquet 1.46 and C-A-T 7 1.34).

CONCLUSIONS: The C-A-T 7 tourniquet was best evaluated, followed by the CZ Tactical tourniquet, the C-A-T 6 and the SOFTT. A significant difference between C-A-T 7, CZ Tactical tourniquet and C-A-T 6 on one side and SOFTT on the other side and a significant difference between male and female correct tourniquet application was found out.

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TRIAL REGISTRATION: The trial was approved by the IRB of the Faculty of Military Health Sciences of the University of Defence, Czech Republic (No. MO 4330/2017-2994 HK).

Key words: Tourniquet; SOFTT; C-A-T; CZ Tactical tourniquet; time of application; effectiveness; subjective assessment of the application simplicity; self-application; buddy application

Background

Damaged arteries bleeding can cause a life-threatening condition and it is one of the main causes of death which can be prevented both on the battlefield and in the civilian environment (1, 2, 3). Firstly, the direct pressure is used to manage external limb bleeding, however, it may not be effective enough and a tight compression bandage directly over the wound may not stop arterial bleeding completely as well. Therefore, the 2015 European recommended procedures for resuscitation (4) in the chapter on first aid state in case when severe external bleeding in a limb cannot be controlled by direct pressure a tourniquet should be used.

In the military environment tourniquets in field conditions have been used to stop severe external limb bleeding for centuries (5, 6). The principle “It is better to lose a limb than life” was promoted, for example, by Dominique Jean Larrey during the Battle of Borodino (1812). Experience gained particularly during the operations of Allied Forces in Iraq and Afghanistan resulted in resurgence in tourniquets use. Only 2 % of soldiers with severe bleeding died in these countries in comparison with 7 % in Vietnam partially also due to using tourniquets many times and transporting the wounded to doctors very quickly. Consequently, using tourniquets to stop limb bleeding has resulted in a significant decrease of soldiers’ mortality in armed conflicts (7, 8). In the Czech Armed Forces (hereafter ACR), tourniquets are handed out to all soldiers who are deployed in the battle zone. A success of tourniquets as a lifesaving measure depends particularly on two factors. The first one is the tourniquet itself, its quality, material, structure and easy application. The other factor is training. Every user has to have corresponding knowledge and skills in which situations and which way to use the tourniquet.

The academic staff of the Department of Military Medical Service Organization and Management at the Faculty of Military Health Sciences of the University of Defence carries out a field training of the students. In 2017, within this training, an analysis of skills in using selected types of tourniquets was carried out. The aim of the analysis was to compare the set parameters of the effective application of the tourniquets from the perspective of not only an objective observation but also a subjective assessment.

Methods

The observational study was composed of data collected during training military medicine students in the military training area Brezina. The aim of the first training was to find out how well the students would handle tourniquets without the trainer’s or data collector’s intervention. The training was attended by 59 students of military medicine (35 males and 24 females). The training participants were instructed by the physicians about the purpose of the training, the procedures to be done (to tighten the tourniquet until they thought it was sufficient to stop the pulse) and possible complications. The experiment was carried out with approval from the ethics committee of the Faculty of Military Health Sciences of the University of Defence, Hradec Kralove, Czech Republic. All students gave an informed consent to participate in the study.

Four different types of tourniquets were used to control external limb bleeding. The first one was SOFTT¹ Generation 2, the others were C-A-T² Generation 6 and C-A-T Generation 7 and the fourth type was the CZ Tactical tourniquet (CZ TT)³. Each participant applied all four types of tourniquets by self-application on the non-dominant

¹ Special Operations Forces Tactical Tourniquet SOFTT, producer – a company Tactical Medical Solutions, available at <https://www.tacmedsolutions.com/SOF-Tactical-Tourniquet>, cit. 2018-05-07.

² Combat Application Tourniquet C-A-T, producer – a company C-A-T Composite Resources, LLC., available at <http://www.combattourniquet.com/>, cit. 2018-05-08.

³ Producer – a company E.S.P. Euro Security products, FMA MIC tourniquet

upper arm. 20 students (12 males and 8 females) applied all four types of tourniquets on the arm as a buddy aid. Tourniquets order was determined by randomization.

The following parameters within the training were assessed: time to placement of the tourniquet, effectiveness of setting the tourniquet and a subjective assessment of the application technique simplicity by the students themselves. Differences between a self-application and a buddy-application and differences between male and female were observed as well.

Time of the tourniquet placement was measured in seconds and a time limit was not set. Due to the usability of the results for the overall evaluation we converted the measured times into five levels defined by thirty-second intervals. The speed of tourniquet applications was rated according to the following time scale: (1) < 30 seconds, (2) 31-60 seconds, (3) 61-90 seconds, (4) 91-120 seconds, (5) >120 seconds. The effectiveness of the tourniquet setting was determined by absence of peripheral pulse. The pulse elimination was checked palpably on arteria radialis and in an auscultatory way by stethoscope in the elbow socket. The elimination of pulse was recorded as a success (coded as 1) or a failure (coded as 5). The subjective assessment was performed in the following way. Each student described the simplicity of the tourniquet application using the scale 1-5, when number 1 meant the easiest and number 5 the most difficult manageability.

During the training, the students wore a battledress uniform and means of ballistic protection (a vest, a helmet) and they were equipped with a gun (an automatic gun). The tourniquets were applied on the battledress uniform. Within both situations (self-aid and buddy aid), measurements were carried out in a lying position and under the same conditions. Totally 316 application attempts were carried out.

The available data were statistically analyzed using the t-test for continuous variables and chi-square test for categorical variables (IBM SPSS Statistics 25 Software). Quantitative parameters were presented as means, median values, and standard deviations; qualitative parameters were presented as numbers and percentages. Normality of distribution of a quantitative variable was assessed using Kolmogorov-Smirnov and Shapiro-Wilk test, for the data not normally distributed we used log transformation. The data were analyzed using mixed ANOVA, with post hoc Bonferroni pairwise comparisons to localize significant differences among tourniquet products. Regarding qualitative variables, Pearson's chi-square, Kruskal-Wallis and Mann-Whitney U tests were performed. The significance level for all tests was set at values of 0.05.

Results

Time of Application

The best pulse elimination time for the C-A-T 7 was 14 seconds, for the CZ TT it was 18 seconds, for the C-A-T 6 and the SOFTT 20 seconds. The longest tourniquet application time regardless the effectiveness lasted 1 minute 4 seconds for the C-A-T 7, 1 minute 12 seconds for the C-A-T 6, 1 minute 38 seconds for the CZ TT and 2 minutes 41 seconds for the SOFTT. Average time of the self-applied tourniquet took for the C-A-T 7 31 seconds, the C-A-T 6 35 seconds, the CZ TT 40 seconds and the SOFTT 64 seconds. (Table 1)

Table 1. Time of tourniquet's application

	SOFTT	CAT6	CAT7	CZ TT	Total
N	59	59	59	59	236
Mean	1:03,53	0:35,39	0:31,04	0:40,35	0:42,48
Median	0:58,00	0:35,00	0:30,00	0:34,00	0:35,00
Std. Deviation	0:32,42	0:09,40	0:10,06	0:17,23	0:23,23

Source: Own

The C-A-T 7, the C-A-T 6 and the CZ TT arm applications were much faster (31 ± 10 sec, 35 ± 9 sec and 40 ± 17 sec, respectively) as compared with the SOFTT, which on average took much more time to place (64 ± 32 sec). The differences in proportion were statistically verified by ANOVA and Post Hoc Bonferroni tests. Generally, application time differs significantly (ANOVA, $s=0$). However, comparing the results for the individual tourniquets significant difference can be seen between the group of the C-A-T 6, C-A-T 7, CZ TT and the SOFTT only, not inside of the mentioned group (Bonferonni, test, $s>0,05$).

The values show that the C-A-T 7 tourniquet is the fastest applicable one, with 52, 5% of students being able to apply it up to 30 seconds. In the range of 31-60 seconds, 66, 1% of the C-A-T 6 and 54, 2% the CZ TT were applied. On the contrary, the SOFTT tourniquet, as the only one, 5, 1% exceeded the application time of 2 minutes. (Table 2)

Table 2. Frequency of tourniquet's application by thirty-second intervals

	SOFTT		CAT6		CAT7		CZ TT	
	Frequency	Percent	Frequency	Percent	Frequency	Percent	Frequency	Percent
1 (<30 sec)	9	15,3	18	30,5	31	52,5	17	28,8
2 (31-60 sec)	22	37,3	39	66,1	27	45,8	32	54,2
3 (61-90 sec)	17	28,8	2	3,4	1	1,7	9	15,3
4 (91-120 sec)	8	13,6					1	1,7
5 (>120 sec)	3	5,1						

Source: Own

Time of application decreased in buddy application in all types of tourniquets. Average time of the buddy applied tourniquet took for the C-A-T 7 and the CZ TT 28 seconds, the C-A-T 6 30 seconds and the SOFTT 44 seconds.

Effectiveness

The C-A-T 7, the C-A-T 6 and the CZ TT arm application failure rate was lower than the SOFTT when self-application was used. Almost 2/3 of application failure rate were caused by the SOFTT, the other types of the tourniquets did not exceed 8%, respectively 20%. (Figure 1)

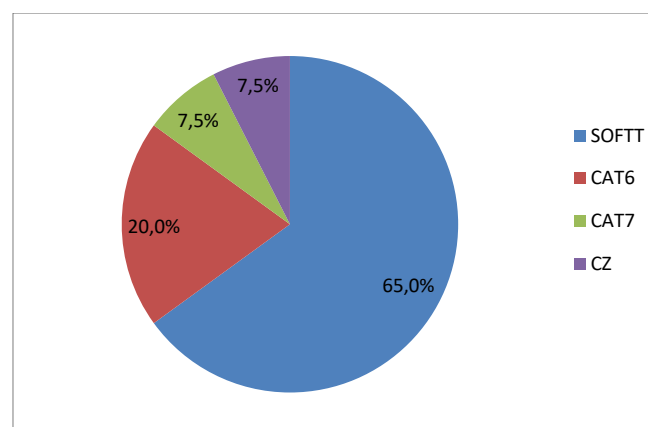


Figure 1. Percentage share of failure tourniquets applications

Percentage of pulse elimination indicate, that the C-A-T 7, the C-A-T 6 and the CZ TT were more effective (95%, 95% and 86%, respectively) compared with the SOFTT (56%).

The Independent-sample Kruskal-Wallis test for all tourniquets efficiency showed significant differences ($s=0$) among them. The same test was performed for only the C-A-T 6, the C-A-T 7, and the CZ TT. Based on the significance value ($s=0,267$) it is possible to confirm tourniquet efficiency distribution similarity.

Average time of the effectively self-applied tourniquet was for the C-A-T 7 31 seconds, for the C-A-T 6 35 seconds, the CZ TT 40 seconds and the SOFTT 48 seconds.

Efficacy results were compared based on gender. The correct application (absence of pulse) was found in men in 89% of the cases, while in women in 74% of the cases. A higher rate of failure was recorded for women in all types of the tourniquets. (Figure 2)

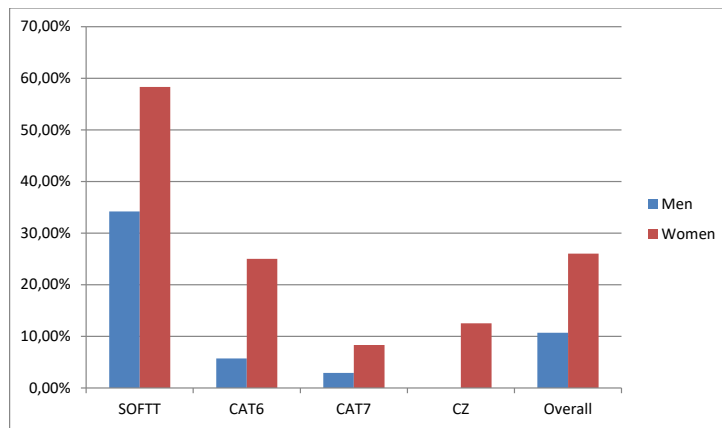


Figure 2. Failure rates (%) of tourniquet application based on gender

The results of the tourniquets efficiency usage by gender were evaluated by Mann-Whitney U test (2 samples). There was a significant difference between men and women ($s=0,002$).

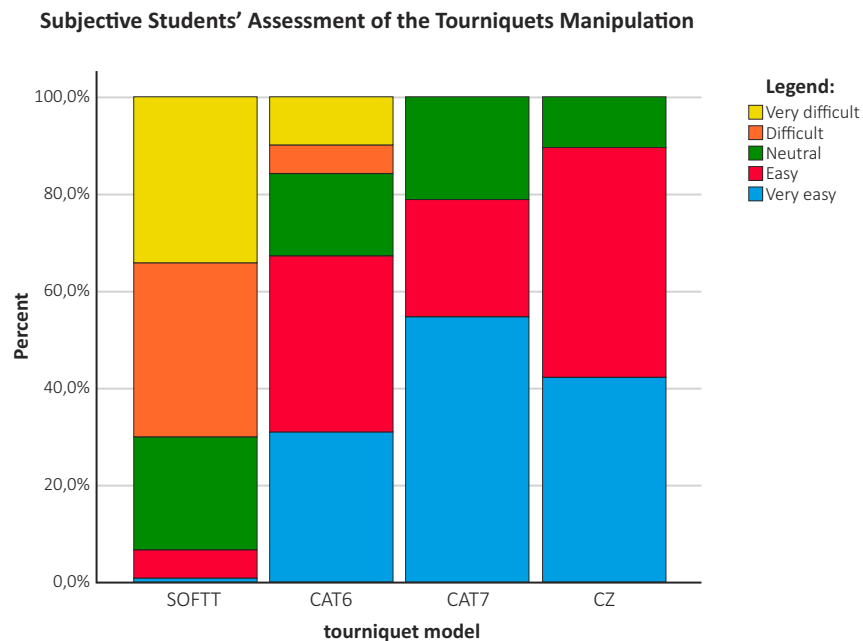


Figure 3. Subjective Students' Assessment of the Tourniquets Manipulation

Simplicity of Application

Easy of the use was assessed by each student using a Likert scale with a range of 5 numbers: (1) very easy, (2) easy, (3) neutral, (4) difficult, (5) very difficult.

Average subjective students' score was in the tourniquet SOFTT 3, 46 (assessment between neutral and difficult), the other tourniquets were assessed between easy and very easy (C-A-T 6 1.63, CZ TT 1.46 and C-A-T 7 1.34). In the tourniquets C-A-T 7 and CZ TT none of the subjective assessments was mentioned as difficult or very difficult. (Figure 3)

For the final evaluation, the sum of the results of the three assessed parameters was performed. The results were averaged to achieve a more accurate balance. The C-A-T 7 had the highest assessment score, followed by the CZ TT, the C-A-T 6 and the SOFTT (4.6 ± 0.6 , 4.0 ± 1.0 , 2.1 ± 1.0 , respectively). (Table 3)

Table 3. Overall tourniquets assesment

	SOFTT	CAT6	CAT7	CZ TT
Time to application	2,56 \pm 1,07	1,73 \pm 0,52	1,49 \pm 0,54	1,90 \pm 0,71
Effectiveness	2,83 \pm 2,01	1,47 \pm 1,31	1,20 \pm 0,89	1,20 \pm 0,89
Application simplicity	3,46 \pm 1,09	1,63 \pm 0,83	1,34 \pm 0,61	1,46 \pm 0,57
Mean	2,9492	1,6102	1,3446	1,5198
Median	2,6667	1,3333	1,3333	1,3333
Std. Deviation	1,16759	0,71426	0,46718	0,47654

Source: Own

Discussion

Different outcomes could be found out in the application on the lower extremities. The thigh is potentially the hardest site at which to achieve occlusion because of circumference. In the lower limb noticeably bigger pressure is necessary to close the blood flow which is related to a larger limb circumference. It is likely that due to the variability in girth of the thigh they might have seen more differentiation among the tourniquets. However, any tests on the lower extremities were not carried out.

The cause of the lower success rate in the effective application of some of the tourniquets in comparison with the others could have been missing training of the tourniquet application. Although the students had gained theoretical knowledge of the tourniquets application, they had insufficient practical experience with their use. Only a quarter of the students reported the experience with the practical use of the tourniquets. In students with previous practical experience the application was effective in 68 % cases while in students who applied the tourniquet for the first time only in 53 % cases. Our findings were similar to the studies in the prehospital setting that have shown that those with training are able to correctly apply a tourniquet more often than those without reported training (9, 10, 11, 12, 16). Schreckengaust et al. (13) has shown in their study the important role of training in fast, accurate and effective application of prehospital tourniquet and simulated combat.

A relatively lower success rate compared to real-life studies could be explained by the fact that on non-injured patients could not be seen bleeding to assess the usefulness of the tourniquet application. In order to minimize bias, no interference was made by the physicians while the students applied the tourniquets.

Correct application could be affected by the width of tourniquets as well. The C-A-T 6, the C-A-T 7 and the CZ TT (3, 8 cm) are wider than the SOFTT (2, 7 cm). As pressure is the ratio of force to the area over which that force is distributed, the wider form has mechanical advantage, which may in part explain why the C-A-T 6, the C-A-T 7 and the CZ TT outperformed the SOFTT (14).

A difference between male and female correct tourniquet application was found out. An application success was more frequent in a group of men. Out of the total number of the tests, the number of misapplied tourniquets was 11 % in males while in females the number was more than doubled – 26 %.

Average application time was ≤ 40 seconds for the C-A-T 6, the C-A-T 7 and the CZ TT tourniquet and 64 seconds for the SOFTT. Men were faster than women, but no significant difference was found. Our findings were similar to Wall et al. (17).

Contrary to Sanak et al (18), our outcomes of the buddy-aid tourniquet application were generally better than the self-aid application. Our results may have been biased by the order of the application, because the buddy application of tourniquets has always been tested after the self-application.

The overall assessment results correspond to the similar comparative studies (14, 15). The most significant criterion for the total assessment of the tourniquets application skills is the rate of effectiveness of the tourniquet setting, it means if the pulsation on the limb was stopped or not.

Limitations

It should be noted that the tests were conducted under field conditions, but we did not try to simulate a gunfire or other battlefield threats. The students were tested in a military training area without the visual, auditory and emotional stress which is typically associated with a real-world casualty incident. However, they wore a battledress uniform and means of ballistic protection, they were equipped with a gun.

The tourniquet applications were carried out under the very good conditions (summer, drought, daylight, temperature about 25 degrees). It is almost sure that the outcomes would be a bit worse under the unfavourable conditions.

A non-dominant upper arm (usually the left arm) was chosen for the tests. The self-aid tourniquet application on the dominant arm (in a right-hander the tourniquet application by the left hand on the right arm) would probably bring worse outcomes.

Potential challenging environmental conditions and regular first responder training in tourniquet application remain to be evaluated.

Additionally, tourniquets qualities testing will also be required to ensure the correct technical parameters exposed to climate extremes.

Conclusion

The C-A-T 7 tourniquet was best evaluated, followed by the CZ TT, the C-A-T 6 and the SOFTT. A significant difference between C-A-T 7, CZ TT and C-A-T 6 on one side and SOFTT on the other side was found.

Marginal differences were noticed among the tourniquets in the first three places in all tested parameters. Consequently, the final order is an outcome of this one-shot analysis along with the statistical analysis of the acquired data. The last place belongs to the SOFTT Tourniquet Generation 2.

The C-A-T 6, C-A-T 7 and the CZ TT were more effectively applied by medical students than the SOFTT tourniquet. Self-aid and buddy aid had no impact on the failure rate – the same failure rate was noticed for either self-aid or buddy aid applications.

A significant difference between male and female correct tourniquet application was found out.

All types of the tested tourniquets are usable in field conditions and meet the function which they were constructed for.

Declarations

- Ethics approval and consent to participate

The trial was approved by the IRB of the Faculty of Military Health Sciences of the University of Defence, Czech Republic (No. MO 4330/2017-2994 HK).

- Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

- Competing interests

The authors declare that they have no competing interests in this section.

- Authors' contributions

The individual contributions of authors to the manuscript are the same.

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