

Evaluation of tourniquet application in a simulated tactical environment

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ABSTRACT

BACKGROUND: Application of a tourniquet in a tactical environment is implemented in two ways: the so-called self-aid, which is the application of a tourniquet by the injured, and the so-called buddy aid, which is the application of a tourniquet by the person provide aid. This study aimed to test the quality of tourniquet use in a simulated situation, close quarter battle.

METHODS: The study involved 24 injured operators and 72 operators in the whole simulation, implying 12 sections of six individuals. To validate the application of tourniquets, the recommendations of the Committee of Tactical Combat Care of the Injured were used, and ultrasound with Doppler function was employed to assess the hemodynamic effect of applying tourniquets.

RESULTS: Native flow was observed in 15 operators; in three people, a trace flow was noticed, whereas in six people, a full flow was observed. No significant difference was found between the qualities of tourniquet application by the operators themselves compared with those of tourniquet application by another person. The median distance of tourniquet application from the armpit was 9.5 cm for self-aid and buddy aid. In 16 participants the outer arrangement of tourniquets was observed, and in only eight participants tourniquets were correctly located on the internal part of the arm. In 18 participants, tourniquets were not correctly prepared for use in the tactical environment, whereas in only six participants, they were correctly prepared. Most operators with a negative ultrasound flow revealed negative distal observed pulse (DOP). Positive DOP occurred in the majority of operators with full ultrasound flow.

CONCLUSION: The application of tourniquets poses a challenge even in case of specialized units; therefore, there is a need to provide regular training for implementing that procedure.

Keywords: Care under fire; hemorrhage; tactical field care; tourniquet.

INTRODUCTION

Tourniquets may be used in the tactical environment during one of three phases.

The time and quality of provided assessments influence life or death dilemma and decide on the success of the conducted mission and its effectiveness.^[1]

In Phase I or the so-called care under fire (CUF), the priority is to take the fire initiative and execution of tactical and operational objectives. In this phase, known as the death zone, it is practically impossible to apply advanced emergency procedures, and stopping bleeding is limited to tourniquet application by the victim, known as the so-called self-aid, or by the operator who is in the vicinity, known as the so-called buddy aid (if it is possible depending on the tactical situation). It

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should be noted that 60% of deaths on the battlefield is associated with massive hemorrhage from the limbs in this phase. Phase II or the so-called tactical field care is defined as the seemingly safe zone. The trauma examination undertaken according to the MARCHE (M-massive bleeding, A-airway, R- respiratory management, C-circulation, H-hypothermia, E-everything else) scheme provides the possibility of changing tourniquets to hemostatic dressings. However, if the examination leads to the identification of an active bleeding source, it should be stopped in the first place with tourniquets.

In Phase III or the so-called tactical evacuation, the priority is to transport injured people to a field hospital with surgical protection as soon as possible.^[1]

Any use of tourniquets when not subjected to CUF is dictated by the inability to control bleeding by other means (bandages, gaze, etc.).^[2]

Types of Tourniquets

Combat Application Tourniquet (CAT)

CAT is a part of the individual medical package of each soldier who is involved in Polish Military Contingents. CAT comprises the Velcro tape having a width of 4 cm, inside which there is another tape constituting the “stringer mechanism.” At the distal end, there is a double buckle through which the pare needs to be threaded, two holes in each situation of buddy aid type (assistance provided by other people) and one hole in the situation when the victim assists itself. Application of tourniquets in the tactical environment is not easy, particularly when the operator is required to obey the discipline of light or sound. As a result of the training course according to the program Tactical Combat Casualty Care, each operator should acquire the so-called muscle memory to quickly apply the tourniquet as soon as bleeding appears. Muscle memory refers to the automaticity of the action that is implemented, devoid of any hesitation. CAT, available in both the right and left hands of the operator, should be placed on a tactical vest. Proper preparation for action means threading the Velcro tape through one hole, so that it is ready for the so-called self-aid.

Application of tourniquet. Tourniquets should always be applied in the way that the rod and strap are placed on the inside part of the leg. Such actions are crucial during the evacuation process because they protect against possible undoing of tourniquets.^[3,4]

Special Operations Forces Tactical Tourniquet-Wide (SOFTT-W)

SOFTT-W is currently the second most common tourniquet among individual equipment of the operators. The advantage of this tourniquet is its durable material. The tourniquet and buckle in “stringer mechanism” are made of steel, which allow generating high-force pressure on blood vessels. As in the case of CAT, SOFTT-W must be located within both the

left and right hands of the operator to make “self-application” possible. Tourniquets should also be placed on each of the inner part of the leg.^[5]

Hemostatic Effect

The use of tourniquets in each phase of assistance in the tactical environment should be associated with stopping bleeding. Tourniquets should be applied as high as possible on the limb in the CUF zone. Obtaining the hemostatic effect is associated with the closure of the artery light through the external compressive force of tourniquets. The operators, as a result of the learning process, should use tourniquets in such a way that the compression force stops the bleeding and eliminates pulse in the distal parts of the leg (upper limb, radial artery; lower limb, popliteal artery).^[4,5]

The research reviews the value and need of training for acquiring/sustaining skills in tourniquet application among military professionals.

MATERIALS AND METHODS

This study was based on the data gathered during the VI All-Polish Competition in Tactical Medicine “Paramedic 2013.” The competition participants were assessed using a questionnaire that comprised 10 questions concerning knowledge and assessment of providing immediate assistance in combat emergency situations, bleeding, and airway patency. The questionnaire was based on the literature in the field, collecting data on the tourniquet application and methods of airway management. The five enclosed questions regarding bleeding managements included issues concerning self-aid and buddy aid. The questions were related to the type of aid, limb chosen to provide aid, and technical aspects of applying the tourniquet such as the positioning of the tourniquet and distance between the wound and tourniquet. Database and statistical calculations were performed using the computer software Statistica version 10 (StatSoft Poland, Tibco Statistica Inc.). 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 Shapiro–Wilk test. Regarding qualitative variables, Pearson’s chi-square test was performed to compare the proportion of indicators used for one population, and chi-square test of maximum likelihood and Fisher’s exact test were performed to compare the association of the two populations. To assess the association between ultrasound flow and DOP, the chi-square independence test of maximum likelihood was used. The significance level for all tests was set at α values of 0.05.

The survey that assessed the effectiveness of tourniquets was conducted in the practice station called “tourniquets” during the VI All-Polish Competition Tactical Medicine Paramedic 2013” and was filled out by the judging panel.

Except for the subjective assessment of professionals judges of the event, employees of Warsaw Military Institute, and Medical University of Poznań concerning the tourniquet placement; the blood flow in vessels of distal extremities was measured using ultrasonography (USG; NanoMaxx Portable Ultrasound Machine SonoSite). For vascular imaging, a probe and the Power Doppler function were employed. After assembling the tourniquet (upper/lower extremity), Doppler echocardiography was used to examine the absence of blood flow in the arteries in the distal parts of the limbs. Full flow or microflow was a proof of incorrect tourniquet application. The lack of blood flow was a proof of correct tourniquet application (Fig. 1 and Fig. 2).

Scenario of the Simulation Task

The task aimed to investigate the tactical environment and interior of the building by six operator teams. The tactical situations required from operators to move in the so-called car (a short distance one behind the other) around the building. The interior of the rooms was heavily obscured; thus,

the operators used a fixed light source at the entrance. After entering the section of the building fire, contact was initiated, which resulted in two operators being injured in the upper limb at the elbow height. The first of the operators was still under fire and he applied the tourniquet by himself. The other tourniquet was placed after the enemy was neutralized by his colleagues. In this scenario, only one officer, a representative of the Ministry of Justice used its knees to pre-stop the source of bleeding.

Testing the Quality of Tourniquet Application in CUF

The study involved 24 operators who applied tourniquets and 72 in total participating in the tactical events (Table 1). Twelve operators implemented the so-called self-aid, wherein they applied a tourniquet themselves, and the remaining 12 operators had the tourniquet placed by other rescuer (buddy aid).

USG

In 15 operators, negative ultrasound flow was observed, and



Figure 1. Radial artery with a lack of blood flow using Doppler echocardiography.



Figure 2. Radial artery with micro blood flow using Doppler echocardiography.

Table 1. Sociodemographic data of the investigated group and the tactical experienced before the study

Investigated group of participants	(n=72)
Age	
a) 20–25 years	a) 4
b) 26–30 years	b) 36
c) 31–35 years	c) 18
d) >36 years	d) 14
Years of service	
a) 0–4 years	a) 21
b) 5–9 years	b) 22
c) 10–14 years	c) 24
d) >14 years	d) 5
When was your last participation in TCCC course?	
a) 1 year ago	a) 20
b) 2 years ago	b) 15
c) 3 years ago	c) 9
d) >4 years ago	d) 20
e) Never	e) 8
Have you ever experienced delivering first aid in tactical conditions?	
a) Yes, during the implementation of the tactical order	a) 16
b) Yes, but in situation not connected to implementing an order	b) 0
c) I have but in a non-tactical condition	c) 27
d) I have never experienced delivering first aid	d) 29

Table 2. Data for ultrasound flow

USG	All	Self-aid	Buddy aid
Negative	15	8	7
Trace	3	2	1
Full flow	6	2	4
Total	24	12	12

USG: Ultrasonography.

in three people, trace ultrasound flow was observed. Only six operators revealed full ultrasound flow (Table 2). The differences in proportion are statistically significant (chi-square, 9.75; df, 1; $p=0.007$).

There were more operators providing buddy aid (four people) than the operators employing self-aid (two people) whose ultrasound showed full blood flow. There were more buddy aid operators with negative ultrasound flow and trace ultrasound flow than self-aid operators (by one person) (Table 1). Comparison of ultrasound flow relative to the type of assistance provided showed no statistically significant difference between self-aid and buddy aid in ultrasound flows (chi-square, 1.09; df, 2; $p=0.58$).

Negative Doppler flow [distal observed pulse (DOP)] was observed in 18 operators, and positive DOP was observed only in six operators. The differences in proportion are statistically significant (chi-square, 6; df, 1; $p=0.01$).

The number of self-aid and buddy aid operators in whom DOP was negative (nine persons) and positive (three persons) was the same (Table 3). There was no statistical significance in case of DOP comparison and the type of assistance provided: participant implementing self-aid or buddy aid (Fisher's exact test; $p=1.0$).

Distance of the Tourniquet From the Armpit

For all operators, the average distance of the tourniquet from the armpit was 9.7 ± 3.6 cm (self-aid operators, 10.3 ± 3.6 cm; buddy aid operators, 9.2 ± 3.7 cm). The minimum distance of the tourniquet from the armpit was 2 cm and maximum was 17 cm. The median value indicates that in approximately half of the operators' distance of the tourniquet from the armpit was <9.5 cm and that in others it was >9.5 cm. The lower quartile indicates that 25% operators showed that the distance of the tourniquet from the armpit was <7.5 cm, and the upper quartile indicated that in 25% of the operators, the distance was >12 cm (Fig. 3).

For all operators, the distance of the tourniquet from the armpit had a normal distribution ($W=0.97245$; $p=0.72753$). Most operators (10 persons) presented with the distance of the tourniquet from the armpit ranging from 7.5 to 10 cm.

Only two operators presented with a proper distance of the tourniquet from the armpit (<5 cm). In 14 operators, the distance of the tourniquet from the armpit ranged from 5 to 10 cm. In eight operators, the distance was >10 cm.

Tourniquet

In 16 operators, the tourniquet was externally applied, and only in eight operators, the tourniquet was internally applied. The differences in proportion are not statistically significant (chi-square, 2.67; df, 1; $p=0.102471$).

Tourniquets were internally applied by more operators using buddy aid (six people) than those using self-aid (two people). However, tourniquets were externally applied by more operators using self-aid" (10 people) than those using buddy aid (six people). Comparison of tourniquet placement when the type of assistance provided was taken into account, showed no statistically significant difference between self-aid and buddy aid (Fisher's exact test; $p=0.19303$).

Preparation of Tourniquets

In 18 operators, tourniquets were incorrectly prepared (negative) (Fig. 4). There was determined a statistical relationship between the correctly and incorrectly prepared tourniquets (chi-square, 6; df, 1; $p=0.014306$).

Tourniquets were correctly prepared (positive) by more operators using buddy aid (four persons) than those using self-

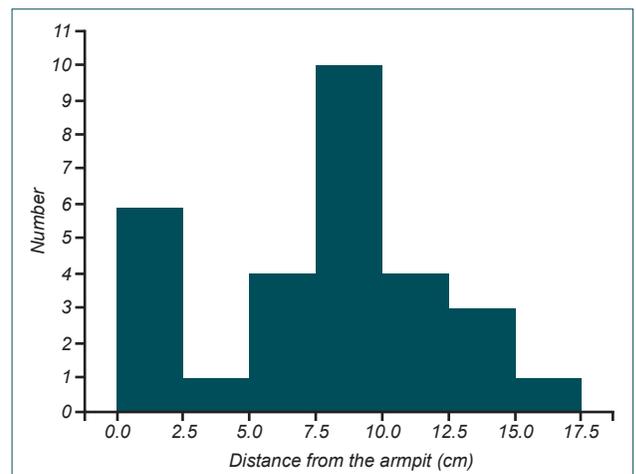


Figure 3. Histogram of tourniquet distance from the armpit for all operators.

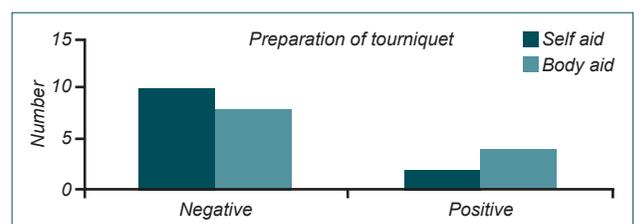


Figure 4. Preparation of the tourniquet and the type of assistance provided.

-aid (two persons). Tourniquets were incorrectly prepared (negative) by more operators using self-aid (10 persons) than those using buddy aid (eight persons). Comparison of tourniquet preparation in the terms of assistance provided showed no statistically significant difference between self-aid and buddy aid (Fisher's exact test; $p=0.64041$).

Forces

Most operators were from Ministry of Internal Affairs (MIA; 19 people). Two operators were from Ministry of Justice (MJ), two from the Shooter Group, and one from Ministry of National Defence (MND; Table 4). The differences in proportion are statistically significant (chi-square, 37.67; df, 3; $p=0.00$).

More MIA operators used buddy aid (10 persons) than those using self-aid (nine people). No MND operator used buddy aid. The same number (1 each) of MJ and Shooter Group operators used self-aid and buddy aid. Comparison of forces in the terms of the type of assistance provided showed no statistically significant difference between self-aid and buddy aid (chi-square, 1.43; df, 3; $p=0.69$).

Tourniquet Type

Most operators (19 participants) chose CAT, whereas three other operators used SOFTT-W. One operator used CAT and then approximately 3 cm above that type of a tourniquet applied on other one, SOFTT-W. One operator used an improvised tourniquet. The differences in types of used tourniquets are statistically significant (chi-square, 38; df, 3; $p=0.00$).

More operators used CAT for self-aid (10 people) than those who used CAT for buddy aid (nine people). In addition, more operators used SOFTT-W for self-aid (two persons) than those who used SOFTT-W for buddy aid (one person). None of the operators providing self-aid decided to place an improvised tourniquet or firstly used CAT tourniquet and then SOFTT-W tourniquet. Comparison of the type of tourniquet to that of assistance provided showed no statistically significant difference between self-aid and buddy aid (chi-square, 3.17; df, 3; $p=0.36687$).

Dependence Between USG and DOP Flow

There was a statistically significant association between USG and DOP flows (chi-square, 14.24; df, 2; $p=0.00081$).

Most operators with negative ultrasound flow had negative DOP. Most operators with full ultrasound flow had positive DOP (Table 5).

DISCUSSION

This study clearly proved that tourniquet application was a demanding procedure, requiring constant training. Tourniquet application is an important ability to possess as activ-

Table 3. DOP and type of assistance provided

DOP	All	Self-aid	Buddy aid
Negative	18	9	9
Position	6	3	3
Total	24	12	12

DOP: Distal observed pulse.

Table 4. Representatives of given forces

Forces	All	Self-aid	Buddy aid
Ministry of Internal Affairs	19	9	10
Ministry of Justice	2	1	1
Ministry of National Defence	1	1	0
Shooter	2	1	1
Total	24	12	12

Table 5. Two-way table

USG	Distal observed pulse		Line in total
	Negative	Position	
Negative	14	1	15
Trace	3	0	3
Full flow	1	5	6
Total	18	6	24

USG: Ultrasonography.

ities conducted on the battlefield, owing to their nature, are associated with life-threatening injuries such as hemorrhages. To improve the techniques of providing assistance and to minimize situations that may pose a direct threat to life, military and medical personnel constantly analyzes previously recorded accidents and incidents in the field of combat medicine. Corresponding analysis was performed in the study conducted by members of the medical corps of Israel Defense Forces during years 2002–2009. There were more than 4.5 thousand soldiers, of which approximately 850 were fatal. Soldiers living in a war zone are exposed to several types of injuries, majority of which are accompanied by major bleeding.^[6] Many publications have emphasized that hemorrhage remains the leading cause of death on the battlefield.^[7,8] The Committee of Tactical Combat Care of the Injured indicated hemorrhages to be a cause of approximately 60% of so-called avoidable deaths. Therefore, it is important to train medical and military personnel in the field of rapid response and the provision of necessary assistance to victims exposed to blood loss.^[6,8] In addition, our study proves the difficulty of

tourniquet application even by experienced combat participants. Although the military is constantly developing new uniforms for their soldiers to ensure the greatest possible body protection, protection cannot be provided for hands or feet without depleting effectiveness and mobility, leaving those areas highly vulnerable to any damage.^[7,9] This is a reason for the need of an extensive and regular training to perfect the ability of tourniquet application among soldiers because each of them is equipped with a tactical stasis in case of this type of injury. Moreover, the effectiveness and circumstances of the use of tourniquets often depends on the application efficiency.^[7,8,10,11] Walters et al.^[12] confirmed the equal effectiveness of CAT, Emergency & Military Tourniquet, and SOFTT by using Doppler auscultation at the popliteal artery. However, except for the equipment effectiveness, a rescuer's skills are a valid factor. Therefore, repeated training regarding its usage is important. That is the reason behind the need of designing training concerning tourniquets application. In our study, tactical stasis bands were used by most security services in the world. Thus, the tourniquets are often the subject of testing and analysis. The conducted experiments with various types of tourniquets demonstrated the advantages of CAT over other tourniquets, with the main advantages highlighted by the users being its high efficiency and the application speed.^[4,13] To determine the factors that influence the effectiveness of stasis, both CAT and other tourniquets, were evaluated in terms of pulse disappearance and diminished blood flow using Doppler ultrasound function,^[2,8,14] similar to our study. For these tests, researchers from Ankara involved 145 people who applied the band under ultrasound control. CAT proved to be the most efficient among all hemorrhage controlling techniques.^[4] Walters et al. tested the effectiveness of seventh self-applied types of bands. They summarized that three of seven examined tourniquets completely inhibited the blood flow, and other generally available bands should not be used, even if there is a chance that it may cause more damages. Among the winning stasis were the ones used in our study; CAT and SOFTT.^[15] Appropriate location plays an essential role. Uniforms equipped with special pockets for quick and uncomplicated access to the stasis significantly reduce the time required for self-use.^[16,17] The tourniquet was used only after other methods of bleeding control failed. It presented tourniquet application when providing assistance to a soldier in the danger zone even when under fire.^[11,13] The use of a personal first aid kit also increases the effectiveness of established tourniquets.^[18] There is no doubt that despite disadvantages of tourniquet use, tourniquets greatly increase the chances of survival of victims.^[10,17,18,19]

The use of tourniquets is not exclusively reserved for military institutions. Because of the easy and quick access to specialist care, in case of massive hemorrhage in case of civil casualties, assistance is provided in stages, the last of which is the tourniquet application.^[20,21] During the bombing attack in Boston, two explosives filled with bearing balls were detonated, killing three people and injuring 264. Eservices

decided to apply tourniquets for 27 victims in a form of improvised bands.^[20,22,23]

Conclusions

- There is no noticeable difference in the effectiveness of self-applied tourniquets and that of tourniquets applied with the help of another person; therefore, people knowing the application technique are able to correctly use tourniquets in both situations.
- Doppler outcomes revealed incorrect results in terms of technically appropriately fitted tourniquets. Therefore, there is a need for involving that tourniquet application technique in future training.
- There is a need to ensure regular training in case of tourniquet use to maintain the correct application procedure, particularly for units that have tourniquets at their disposal.

Conflict of interest: None declared.

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DENEYSEL ÇALIŞMA - ÖZET

Bir simülasyon taktik ortamında turnike uygulamasının değerlendirilmesi

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AMAÇ: Taktiksel ortamda turnike uygulaması iki şekilde yürütülmüştür: "kendi kendine yardım" denilen yaralının kendisine turnike uygulaması ve "arkadaş yardımı" denilen bir yardımcının turnike uygulaması. Bu çalışmanın amacı bir yakın harp simülasyon ortamında turnike kullanımının kalitesini test etmektir.

GEREÇ VE YÖNTEM: Çalışmaya 24 "yaralı" ve tüm simülasyon çalışmasında 72 uygulayıcı, altışarlı 12 bölüm şeklinde katıldı. Turnike uygulamalarını valide etmek için Yaralıların Taktiksel Savaş Ortamında Tedavisi Komitesi'nin önerilerinden yararlanılmış turnike uygulamasının hemodinamik etkisini değerlendirmek için Doppler ultrason kullanıldı.

BULGULAR: Sonuçlar 15 uygulayıcıda kan akımı durdurulmuş, üç hastada çok az kan akımı ve altı kişide kısıtlamasız kan akımı olduğunu göstermiştir. Kişilerin kendine veya başka biri tarafından uygulanan turnike prosedürlerinin kaliteleri arasında herhangi bir anlamlı farklılık yoktu. Turnike ile koltuk altı arasındaki ortalama mesafe kendi kendine veya başkasının uyguladığı turnikelerde 9.5 cm idi. On altı olguda turnikenin kol dışından bağlandığı, yalnızca sekiz olguda doğru biçimde kol içinden bağlandığı gözlenmiştir. On sekiz olguda taktiksel ortamda turnike doğru yerleştirilmemiş, yalnızca altı olguda doğru yerleştirilmiştir. Ultrasonda negatif akım görülen uygulayıcıların çoğunda DOP de negatifti. Ultrasonda tam kesintisiz akımın görüldüğü uygulayıcıların çoğunda pozitif DOP saptanmıştır.

TARTIŞMA: Turnikelerin uygulanması uzmanlaşmış birimlerde bile zorluk yarattığından bu işlemin uygulanmasına yönelik düzenli eğitim verilmesi gerekir.

Anahtar sözcükler: Ateş altında tıbbi bakım; kanama; taktiksel alan tedavisi; turnike.

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