EXPERIMENTAL STUDY

Cadaver as an educational tool increasing the effectiveness of Combat Application Tourniquet use in extremity injuries

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ABSTRACT

BACKGROUND: One of the most frequent life-threatening emergencies is extremity haemorrhage. In such cases, patient survival depends on a fast on-scene intervention. Thus, both the potential witnesses and medical emergency staff should have the ability to control haemorrhages. However, simulator-based courses do not fully reflect the structures and physiology of the human body. Therefore, invasive procedure training in trauma patients is limited. The present study aims to evaluate the effectiveness of cadavers as educational tools during a training course in extremity haemorrhage control with the use of the Combat Application Tourniquet (CAT).

METHODS: This study was conducted among 31 paramedic students, who applied a tourniquet to the upper extremity of an unembalmed (fresh) human cadaver with simulated bleeding. Two time measurements were performed, the latter being preceded by a short CAT application training on a human cadaver.

RESULTS: The mean time needed to stop the simulated bleeding in the first attempt was 38.33 seconds (SD±35.14). After the training, the mean time decreased to 20.58 seconds (SD±5.77). A statistically significant difference was observed between these two values (p=0.004).

CONCLUSION: This study demonstrated that training conducted on human cadavers led to a significant improvement in the effectiveness of CAT use. Cadavers constitute a high-quality educational tool that, after adequate preparation, allows for practicing invasive medical procedures, such as extremity haemorrhage control.

Keywords: Amputation; cadaver; CAT; education; trauma.

INTRODUCTION

Paramedics working on an accident scene face many challenges, such as emergency interventions in trauma patients.[1] These procedures need to be performed professionally and fast, which requires proper training.[2,3] However, differing on-scene conditions prevent any consistent education in emergency medicine. Even the most advanced computer programs and simulators do not fully reflect the structures and physiology of the human body. Therefore, invasive procedure training in trauma patients is limited.[4] The highest-quality education can be obtained when a student manually performs a physical examination and any invasive procedures in real-life conditions under the supervision of his/her teacher. This can be achieved with the use of unembalmed (fresh) cadavers.

Modern education strives towards maximising the realism of exercises performed by students, and human cadavers are the best material to reflect the real course of medical procedures. There are many studies in the subject literature demonstrating that students feel a significant increase in their satisfaction and comfort level performing invasive procedures after a cadaver-based training course.[5,6] There is an extensive range of medical procedures that can be trained on human cadavers. These include orthopaedic and dental procedures, intravenous cannulation, surgical methods for airway management, and intraosseous infusion. One of the greatest limitations in using human cadavers for educational purposes is their short durability and the lack of active bleeding upon tissue dissection. Still, cadavers constitute a valuable educational tool as they allow for teaching a given procedure in a regular way.

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This is important as medical students never have the possibility of repeating the same invasive procedure in the same patient so that the teacher can verify their effectiveness.

Polish law introduces many restrictions on the use of corpses for experimental purposes. Despite the widespread use in this country of human bodies for teaching purposes, their preparation and traumatization are used. For this purpose, human corpses brought from other countries are used, where the law allows donors to sign a contract to transfer their body after death for experimental and scientific purposes.

Emergency medical service (EMS) teams in Poland and other countries in the world are mainly composed of paramedics. Their task is to provide medical treatment to individuals who have suffered a sudden illness or been in an accident and transport them to definitive care units.[7] The most frequent injuries in trauma victims are extremity injuries and haemorrhages.[8] Injuries causing external bleeding may be lethal, but efficient on-scene care may minimise the risk of death. However, this requires proper training and proficiency in applying medical procedures and handling medical equipment.[9] In the course of their university education, paramedics rarely have the opportunity to independently treat patients with active bleeding using tourniquets.

A tourniquet that is most commonly used by emergency services in Poland (both EMS and Fire Service) is the Combat Application Tourniquet (CAT).[8] Depending on the situation and the type of injury, tourniquets should be applied over the casualty's clothing as high up the extremity as possible or directly to the skin. The effectiveness of stopping the bleeding with a tourniquet depends on the skills acquired by the paramedic. The use of haemostatic dressings and tactical tourniquets helps to control bleeding and enables the transfer of the victim to the hospital. This is particularly important in emergency situations like natural and man-made disasters and mass accidents as it allows for saving a considerable number of casualties.[10]

The present study aims to evaluate the effectiveness of cadavers as educational tools during a training course in extremity haemorrhage control with the use of the CAT.

MATERIALS AND METHODS

Study Group

The study group consisted of paramedic students (n=31) at a university in central Poland who had practised CAT application in a simulation laboratory and successfully performed the procedure on medical manikins in accordance with the educational standards adopted.

Fourteen days before the experiment, the exam was conducted according to the OSCE (Objective Structured Clinical Examination) standard. Two stations were prepared then using the Trauma CPR phantom. The first simulation required CAT use on the upper limb and the second - on the lower limb. The assessment of the time of the procedure was performed and a checklist containing, among others:

1- safety assessment;
2- use of nitrile gloves;
3- diagnosis of injury;
4- choosing the right technique to stop the bleeding;
5- an indication of the correct location of the CAT;
6- correct tightening of Velcro tape;
7- correct tightening of the tape;
8- a re-evaluation of bleeding;
9- in the absence of an effect - the use of a second CAT band (high location);
10- a re-evaluation of bleeding.

The lack of any checklist was treated as a fatal error. Time measurement was made only when the first CAT was set up. The mean time needed to stop the simulated bleeding on the phantom was T0=18.19 seconds (SD±3.40). The results are presented in Figure 1.

Before this study, none of the students applied a tourniquet to a live patient, which allowed for excluding this confounding factor from the analysis. In estimating the sample size power for the infinite population, a 50% fraction size and a 5% significance level were assumed ($p<0.05$). The number of the test group (n=31) allowed for an acceptable error of 18%.

Material

The study materials were human cadavers provided by FDA certified American suppliers who complied with very restrictive procedures. All the cadavers were tested for HIV, HBV, HCV and syphilis, and due to low preservation temperatures, they were practically biologically inactive and safe. The fresh-frozen unembalmed cadavers were thawed in a dissect-

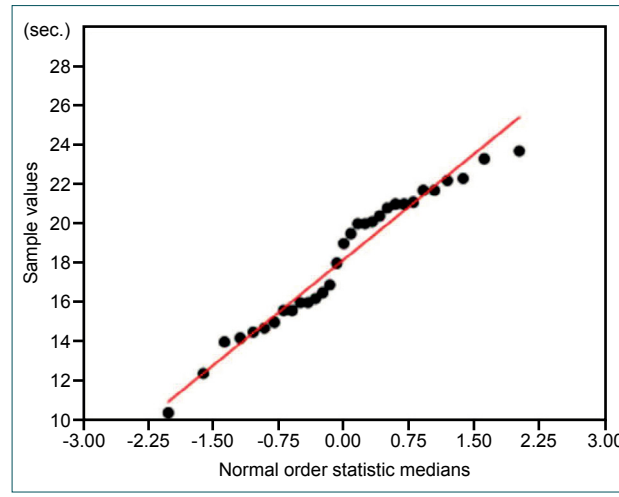

Figure 1. Distribution of variables – setting-up CAT on a phantom.

ing room 24 hours before this study to restore their realistic appearance and tissue flexibility.

Methods

The cadavers were adequately prepared for the purpose of this study. First, proximal forearm amputation was performed. Then, the extremity vessels were cleared of all remaining blood to exclude the presence of any embolic material. Next, the subclavian artery was dissected and a catheter was inserted into it to provide constant controlled fluid pressure to the brachial artery BP=140 mmHg (Fig. 2). Surgical thread was used to ligate the radial and ulnar arteries in the stump so that they would not move during repeated attempts at tourniquet tightening (Fig. 3).

The first part of this study consisted of measuring the time needed to effectively apply the CAT to the amputated upper extremity. The order in which the task was completed was randomly selected by the randomization program. Each time, the tourniquet was staged and arranged in the same way to standardise the measurement conditions (Fig. 4). The time was measured until the simulated arterial bleeding was stopped. After the first measurement, the students were provided with a short 20-minute refresher training with a demonstration of the procedure on an unembalmed cadaver. The content of the training was analogous to the lecture conducted in simulation conditions. The teacher additionally showed the structure of anatomical structures (vessels, bones, soft tissues) of the upper limb stump of the cadaver. This allowed students to better understand the physiology of amputation hemorrhage.

The results obtained in the second attempt were subject to statistical analysis (Wilcoxon test for paired variables).

This study was approved by the Bioethics Committee. The funding was obtained from the Ministry of Science and Higher Education under project no. 37 titled "The Best of the Best 3.0".

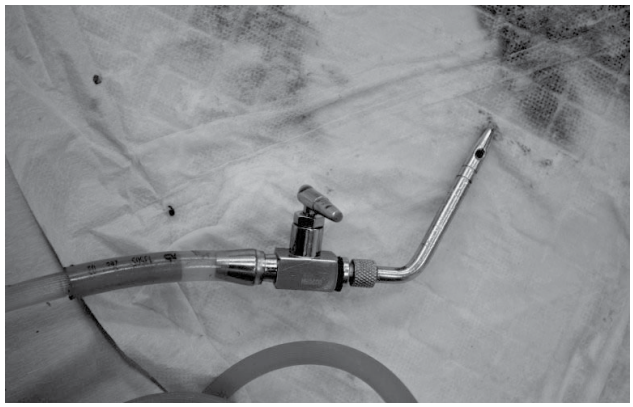

Figure 2. Catheter inserted into the artery.

Figure 3. Upper extremity stump with artery ligature.

RESULTS

Characteristics of the Study Group

This study included 31 undergraduate paramedic students, 32.26% of whom were women (n=10) and 67.74% men (n=21). The mean age was 21.58 (SD±3.23). Each student received a positive mark and the entire group presented a similar level of skill in this respect. The mean time needed to stop the simulated bleeding on the phantom was T0=18.19 seconds (SD±3.40). There was no correlation between the result and sex (rho-Spearman: -0.160; p=0.366) or age (rho-Spearman: -0.170; p=0.338).

The First Measurement

Working at a screened work station, each student placed a staged CAT tourniquet on the amputated upper extremity and tightened it until the bleeding stopped (Fig. 3). Students performed all the elements of the checklist (numbers from 1 to 8), and the differences were only in the time of the procedure (Fig. 5). The mean time needed to stop the simulated bleeding was T1=38.33 seconds (SD±35.14). There was no correlation between the result and sex (rho-Spearman: 0.100; p=0.591) or age (rho-Spearman: -0.074; p=0.693).

The Second Measurement

Before the second attempt, the students participated in a 20-minute demonstration of how to properly apply the tour-

Figure 4. CAT being tightened on the amputated upper extremity.

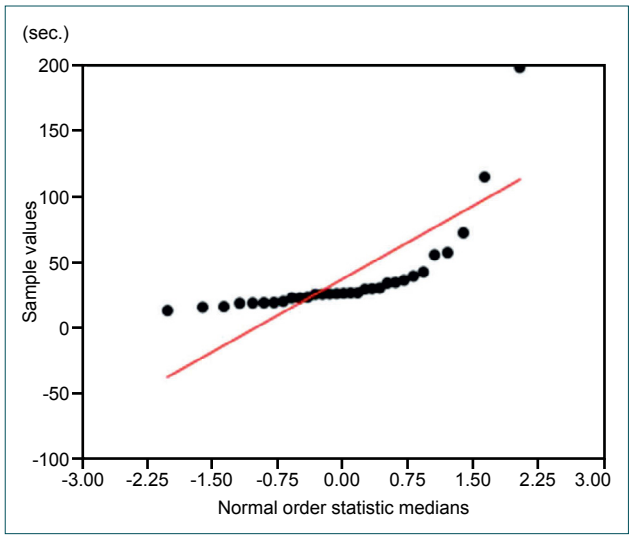

Figure 5. Distribution of variables – setting-up CAT in the first measurement on cadaver.

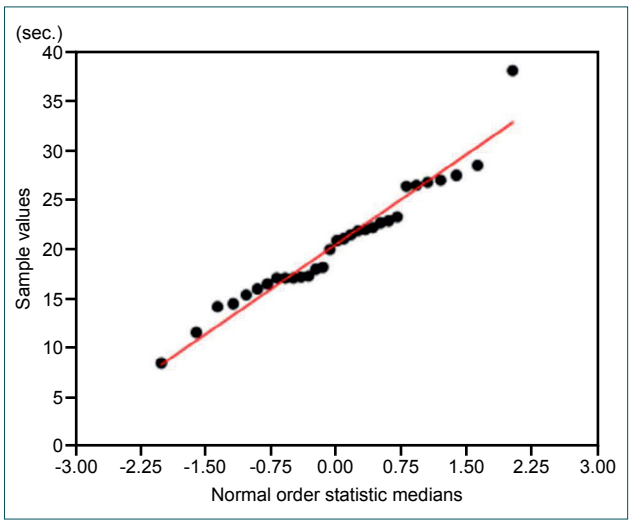

Figure 6. Distribution of variables - setting up CAT in the second measurement on cadaver.

niquet. The subjects discussed included anatomic structures and problems related to the tourniquet material being soaked with blood and slipping on the wet skin of the stump. The second measurement was performed in the same order, yielding the mean time of T2=20.58 seconds (SD±5.77). There was no correlation (Fig. 6) between results and sex (rho-Spearman: -0.114; p=0.542) or age (rho-Spearman: 0.228; p=0.218).

Comparative Analysis

One-way analysis of variance for ANOVA showed significant intergroup differences in T0, T1 and T2 measurements (df=2; F=8.520; p=0.000), as shown in Figure 7. Post-hoc tests were performed to determine the specific relationships. The Wilcoxon test for paired variables was used, demonstrating a statistically significant difference between the two measurements (T1=38.33 sec. vs. T2-20.58 sec.; p=0.004). The final result on cadavers was also compared with measurements

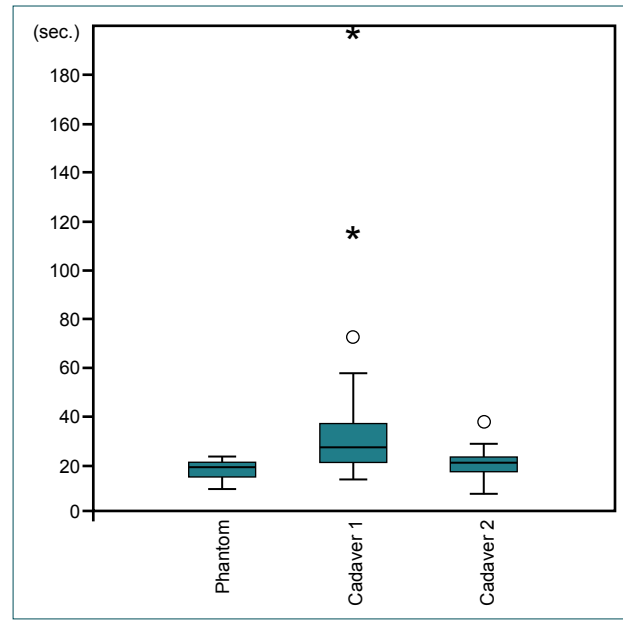

Figure 7. Average results of all time measurements of CAT use.

on the phantom, obtaining a statistically significant benefit of training on human preparations (T2=20.58 sec. vs. T0=18.19 sec.; Wilcoxon: p=0.002).

DISCUSSION

Life-threatening injuries and haemorrhages are a frequent problem encountered in the battlefield and emergency medical settings.[11] With extremity haemorrhages, immediate pressure placed on the artery and tourniquet application constitutes a lifesaving procedure.[12] However, this procedure requires excellent skills from the medical staff that have to control the bleeding rapidly and efficiently on the scene. In many countries, EMS teams consist of paramedics and nurses but do not include a physician.[13] Also, medical programme curricula and ways of teaching vary across the world. The training process is usually based on model and manikin simulator use. Vocational training does not usually provide future paramedics with the opportunity to independently perform invasive life-saving procedures in a patient (e.g., bleeding control, thoracentesis).

Currently, medical schools and universities use state-of-the-art simulators, which allow for practising invasive procedures in a training room. However, the level of realism of a manikin depends on the technology it features and thus its price. Animal models constitute an alternative to manikin simulators. However, they are only suitable for selected procedures and their value as an educational tool in treating trauma patients remains to be determined.[14] A sought-after material commonly used in the teaching of anatomy is human cadavers. The increasing popularity of this educational tool in university settings allows for education based on natural cadaveric models which perfectly mirror the structures of the human body. There is evidence suggesting a considerably higher level of

students' satisfaction and the realism of medical procedures during classes based on fresh frozen cadaver use compared to different types of manikins.[15,16] Cadavers are also used to evaluate the effectiveness of different techniques and devices used to stop bleeding from extremities and pelvis minor.[17]

The present study attempted to evaluate the effectiveness of CAT application to the upper extremity following traumatic amputation. For that purpose, adequately prepared fresh-frozen cadavers were used. The technique of CAT application consisted of a single routing of the band through the buckle as there are arguments demonstrating the superiority of this mode over a double routing.[18]

Although each of the students were practically prepared to perform the procedure on a simulator, the results varied, the mean time being 38.33 seconds (SD±35.14). The subject literature lacks sufficient comparative data on the effectiveness of tourniquet application measured in seconds. Therefore, the authors find it difficult to interpret the results of the first measurement. The second measurement was performed after a short demonstration of the procedure given by an instructor. Notably, only 20 minutes of training allowed the students to stop the bleeding with the CAT in a significantly shorter time, i.e., 20.58 seconds (SD±5.77), compared to the first attempt (T1 vs. T2; p=0.004). The brachial artery physiological blood flow in an adult is about 1250 ml/min. In the second measurement, the time needed to stop the bleeding was shorter by 17.75 seconds, which roughly translates to 370 ml of blood saved. For a trauma patient in shock, losing this amount of blood may have a significant impact on circulatory function.

The use of cadavers in the teaching of extremity haemorrhage control yielded positive results as indicated by the improved quality of the procedure performed by the students after a short training on a human cadaver. Adequate preparation of the cadaver allowed for multiple attempts at CAT application and standardisation of the study conditions. Results obtained by other authors demonstrate that there also other benefits to be gained in the education process, such as the development of interdisciplinary cooperation among students of different medical programmes who practice their skills on fresh cadavers.[19]

The authors note the result, which indicates that the time of establishing a CAT on a phantom (T0=18.19 sec.) turned out to be much shorter than after training on cadaverach (T2=20.58 sec.). This proves that training on human preparations is more demanding and better reflects real conditions than simulating a phantom.[20] However, it is important to address certain ethical questions when using fresh cadavers in the teaching process. About 45% of anatomy educators do not know or are uncertain about the origins of the cadavers used in their classes.[21] Therefore, the authors of the present study met all formal and ethical requirements to implement the project with full respect towards the human cadavers used. Further studies are necessary to evaluate the effectiveness of using cadavers in the teaching of invasive emergency procedures.

Study Limitations

The authors decided to use only the upper extremity as the effectiveness of applying tourniquet cuffs narrower than 8 cm to lower limbs is questionable.[22] The human cadavers was adequately prepared for this study (vessel ligation, catheterisation) to prevent any damage to the natural tissue from repeated attempts at tourniquet application. Due to the limited durability of cadavers, similar methods are also used in central venous access training.[23]

Conclusions

This study demonstrated that training conducted on human cadavers led to a significant improvement in the effectiveness of CAT use. Cadavers constitute a high-quality educational tool that, after adequate preparation, allows for practicing invasive medical procedures, such as extremity haemorrhage control.

Lessons for Practice: Training conducted on human cadavers led to a significant improvement in the effectiveness of CAT use, and in addition, adequate preparation of the cadaver allows for multiple attempts at CAT application and standardisation of the study conditions.

Ethics Committee Approval: Approved by the local ethics committee.

Peer-review: Internally peer-reviewed.

Authorship Contributions: Concept: P.L.; Design: P.L., A.C.; Supervision: P.L., A.C., T.Z.; Resource: P.L.; Materials: P.L.; Data: P.L.; Analysis: P.L., A.C., T.Z.; Literature search: P.L., A.C., T.Z.; Writing: P.L.; Critical revision: P.L., A.C., T.Z.

Conflict of Interest: None declared.

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DENEYSEL ÇALIŞMA - *ÖZET*

Ekstremite yaralanmalarında Combat Application Tourniquet (CAT) kullanımının etkinliğini artıracak bir eğitim aracı olarak kadavra kullanımı

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AMAÇ: En sık yaşamı tehdit eden acil durumlardan biri ekstremite kanamasıdır. Bu gibi durumlarda hastanın hayatta kalması, olay yerinde hızlı müdahaleye bağlıdır. Bu nedenle, hem potansiyel tanıklar hem de tıbbi acil durum personeli kanamaları kontrol etme yeteneğine sahip olmalıdır. Ancak simülatör temelli kurslar, insan vücudunun yapılarını ve fizyolojisini tam olarak yansıtmamaktadır. Bu nedenle, travma hastalarında invaziv prosedür eğitimi sınırlıdır. Bu çalışmanın amacı, ekstremite kanama kontrolünde Combat Application Tourniquet (CAT) kullanımının eğitimi sırasında bir eğitim aracı olarak kadavra kullanımının etkinliğini değerlendirmektir.

GEREÇ VE YÖNTEM: Çalışma simüle edilmiş kanamalı, taze bir insan kadavrasının üst ekstremitesine turnike uygulayan 31 sağlık görevlisi öğrencisi arasında gerçekleştirildi. İki kez ölçüm yapıldı, ikincisinden önce bir insan kadavrası üzerinde kısa bir CAT uygulama eğitimi verildi.

BULGULAR: İlk denemede simüle edilmiş kanamayı durdurmak için gereken ortalama süre 38.33 saniyeydi (SD±35.14). Eğitim sonrası ortalama süre 20.58 saniyeye düştü (SD±5.77). Bu iki değer arasında istatistiksel olarak anlamlı bir fark gözlendi (p=0.004).

TARTIŞMA: Çalışma, insan kadavraları üzerinde yapılan eğitimde CAT kullanımının, etkinlikte önemli bir iyileşme sağladığını göstermiştir. Kadavralar, yeterli hazırlığın ardından, ekstremite kanama kontrolü gibi invaziv tıbbi prosedürlerin uygulanmasına izin veren yüksek kaliteli birer eğitim araçlarıdır.

Anahtar sözcükler: Ampütasyon; CAT; eğitim; kadavra; travma.

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