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Learning how to stop external hemorrhage during a medical simulation using cadavers - a randomized trial.

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ABSTRACT

INTRODUCTION: Patients suffering from trauma are at risk of death from uncontrolled external bleeding, therefore witnesses to the incident and emergency medical services should promptly implement appropriate procedures, which requires prior training. The purpose of this study is to comparatively analyze the didactic effectiveness resulting from the use of cadavers – human-based unfixed preparations, and training devices, during practice-based teaching of medical students on how to stop external hemorrhage.

MATERIAL AND METHODS: Fifty-four medical students participated in the study. At the initial stage, training was provided including procedures for stopping external hemorrhages using hand maneuvers, tourniquets, and hemostatic dressings. Randomization was performed by selecting a study group (procedures performed on human unfixed specimens) and a control group (procedures performed on a training model). During the practical test, the time to perform the procedure until the hemorrhage was effectively stopped was evaluated. The students were also asked to perform a self-assessment of their skills, as well as to indicate their level of satisfaction with the training. Statistical analysis allowed to obtain correlations of variables, taking age, sex, height, body mass and hand sizes of the subjects into account.

RESULTS: The study group consisted of 35 women (64.81%) and 19 men (35.19%). Intergroup comparisons confirmed the absence of significant differences between groups in Mann-Whitney U tests for unrelated variables for the criterion of sex (p=0.403), age (p=0.081), height (p=0.472), body mass (p=0.883), hand width (p=0.653) and hand length (p=0.355). Group A performed the procedures on training models, while Group B performed the procedures on appropriately prepared cadavers. Direct manual compression was performed in an average of 2.85 seconds (group A) and 5.23 seconds (group B), wound packing in an average of 42.48 seconds (group A) and 50.97 seconds (group B), passing a tourniquet fastened into a loop in an average of 27.66 seconds (group A) and 26.01 seconds (group B), and an unfastened tourniquet over bleeding site in an average of 27.70 seconds (group A) and 29.14 seconds (group B). The manual wound compression procedure was performed significantly longer on the cadaver (p=0.005) than on the training model. The level of satisfaction and self-assessment after the training increased comparably in both groups.

CONCLUSIONS: Unfixed human-body-based preparations constitute an important part of medical student education. Simulations of external hemorrhage stopping allowed noticing prolonged procedure performance time in the case of cadaver-based exercises, especially regarding the procedure for manual wound compression. The results suggest that selected rescue procedures are more difficult to perform on human specimens, compared to training models, therefore cadaver-based training may prove more effective.

KEY WORDS: Hemorrhage, cadaver, training model, education, efficiency, simulation.

INTRODUCTION

Active external hemorrhages are among the most common causes of death in trauma patients. The European Resuscitation Council (ERC) guidelines identify intense blood extravasation as a reversible cause of cardiac arrest [1], hence an effective and efficient response by witnesses to the incident and emergency medical services is crucial to the survival of the injured. There are many ways to stop bleeding. The primary and also the fastest method to apply is direct compression, as well as the efficient application of a compression dressing [2]. For more serious hemorrhages, International Trauma Life Support (ITLS) guidelines recommend using appropriate equipment, including tourniquets or hemostatic dressings. Failure to control bleeding results in a decrease in the volume of blood circulating in the vessels, leading to organ hypoxia, which is known as hypovolemic shock [3]. Preventing this process is therefore a priority, therefore medical students should devote as much attention as possible during the course of their studies not only to learning theory, but also to developing practical skills.

In many countries, emergency medical personnel mainly includes paramedics, in addition to nurses and doctors [4], therefore it is extremely important to provide more teaching hours for representatives of these professions, used on simulations for practical learning how to stop external hemorrhage. Available training models provide common materials for learning basic medical techniques. The introduction of unfixed human specimens into medical simulation is not standard and currently is not a mandatory part of teaching medical students. Perfecting your skills on the cadaver gives you the opportunity to work with real human tissue, which allows you to perform procedures under near-real conditions.

The aim of this study is to evaluate the effectiveness of stopping external hemorrhage from upper extremities during classes for medical students. The authors attempted to indicate the correlation of selected biometric characteristics of the study participants with the time of task performance. The analysis included various techniques for stopping hemorrhage, including manual compression, as well as the use of dedicated medical supplies.

MATERIALS AND METHODS

Fifty-four medical students at the University of Siedlce participated in the study, which was conducted in June 2024, with the approval of the University of Siedlce Research Ethics Committee (No. 8/2024, dated June 14, 2024). The experiment was divided into 4 stages.

In stage one, the students were informed about the form of the study, informed consent was obtained from each participant to take part in the study, and the necessary documentation was completed, committing to due respect for human tissues and ethics. Each participant completed a questionnaire assessing their own skills and perceived level of stress related to using selected methods of stopping external hemorrhages. Biometric data were also extracted: age, sex, height, body mass and hand sizes. In order to verify measurements accurately, participants had a scale and a centimeter.

Stage two involved conducting hands-on training resembling procedures for stopping hemorrhages: direct compression, wound packing and the use of a CAT tourniquet (putting a looped tourniquet through the limb and direct fixation of the stretched tourniquet over the bleeding site). Each study participant had identical theoretical and practical instruction.

The third stage of the study included an assessment of practical skills and measurement of the time required to successfully stop a hemorrhage. Participants were divided by randomization (dice roll) into two subgroups of comparable numbers. The first, labeled A, performed the procedures on an upper limb training model, and the second (group B) performed the procedures on a cadaver with a prepared forearm wound. The dedicated training model had the ability to generate active external hemorrhage using artificial blood and dedicated pressure. In the case of an unfixed human specimen, a forearm wound of the same diameter as the training model's wound was prepared, and a set of pressurized artificial blood was connected to the brachial artery to simulate hemorrhage.

The fourth and final stage of the study involved completing a questionnaire assessing satisfaction with the completed task, as well as a reassessment of the skills and stress levels associated with performing the studied procedures. Statistical analysis was performed using spreadsheets and Past 3.20 software, setting statistical significance at the $p<0.05$ level.

RESULTS

Characteristics of the study group

Fifty-four medical students of the Faculty of Medical and Health Sciences at the University of Siedlce took part in the study. The study group consisted of 35 women (64.81%) and 19 men (35.19%). There were 31 emergency medical students, 61.29% of whom were female (n=19) and 39.71% male (n=12), 18 medical school students (medical doctor course), 61.11% of whom were female (n=11) and 38.89% male (n=7), and 5 nursing students, 100% of whom were female (n=5). The mean age was 21.41 years (SD ± 3.30), mean height was 172.24 cm (SD ± 9.22), body mass was 68.17 kg (SD ± 15.92), hand width was 8.07 cm (SD ± 0.98), and hand length was 17.24 cm (SD ± 1.23). The majority of participants lived in urban areas (n=29; 53.70%), while 25 residents were from rural areas (46.30%). Using randomization (dice roll – on-line version) 27 students were assigned to group A (training model) and B (cadaver). Intergroup comparisons confirmed the absence of significant differences between groups in Mann-Whitney U tests for unrelated variables for the criterion of sex (p=0.403), age (p=0.081), height (p=0.472), body mass (p=0.883), hand width (p=0.653) and hand length (p=0.355).

Time results

The average time required to successfully stop a hemorrhage on the training model (group A) by direct compression was 2.85 seconds (SD ± 1.05), while it was 5.23 seconds on the cadaver (group B) (SD ± 6.28). The minimum time in Group A was 1.58 seconds, while it was 2.17 seconds during the game in Group B, and the maximum time was 5.53 seconds (Group A) and 35.62 seconds (Group B), respectively.

Manual wound compression was significantly faster (p=0.005) on training models. A summary of the results is shown in Figure 1.

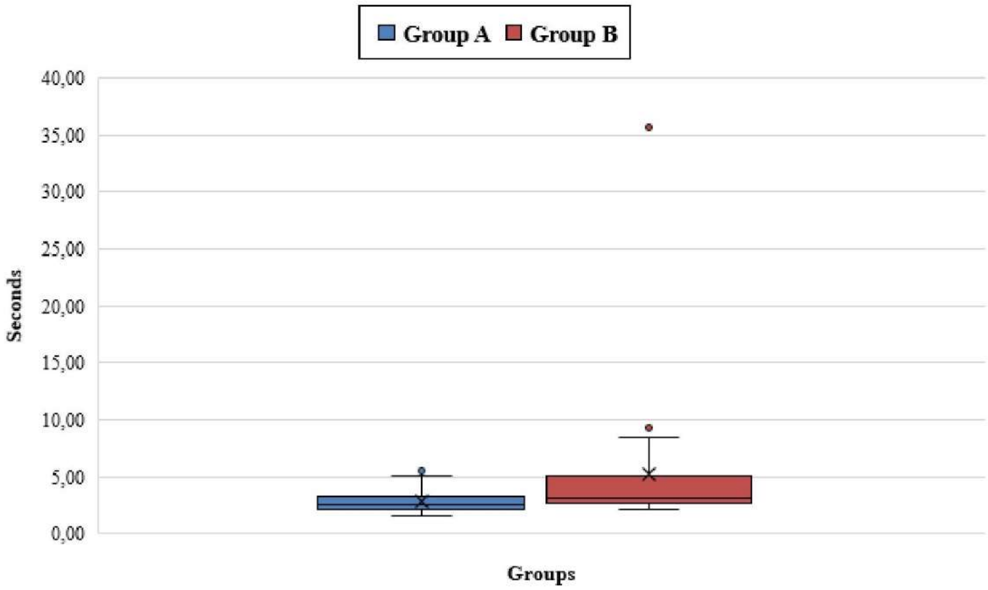

Figure 1. Comparison of times to stop hemorrhages by direct compression.

The wound packing procedure in group A took an average of 42.48 seconds (SD ± 19.98), while in group B it took as long as 50.97 seconds (SD ± 27.75), however, these differences were not statistically significant (p=0.373). The minimum time in Group A was 10.62 seconds, while it was 12.49 seconds in Group B. The maximum time in Group A equaled 113.38 seconds, and 121.92 seconds in Group B. A summary of the results is shown in Figure 2.

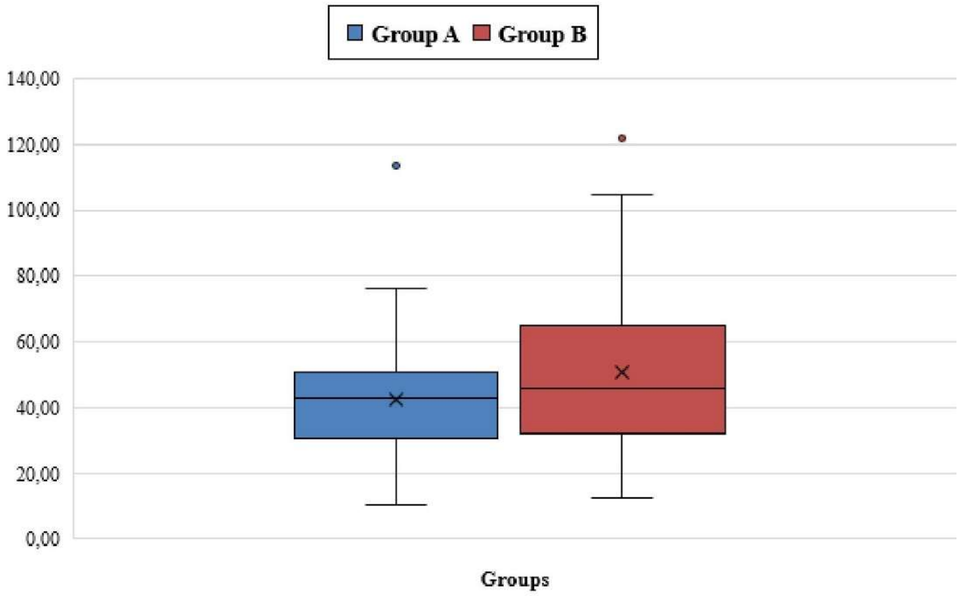

Figure 2. Comparison of times for stopping hemorrhages by wound packing.

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Students also stopped hemorrhages using CAT-type tourniquets by fixing them in two ways. The first of these was to put a band fastened in a loop through the entire length of the limb, which took an average of 27.66 seconds (SD ± 9.09) in Group A. Group B performed this procedure slightly faster, taking an average of 26.01 seconds (SD ± 7.73), but these were not statistically significant differences (p=0.704). It took a minimum of 13.82 seconds to pass a CAT-type tourniquet fastened in a loop in group A, and 14.62 seconds in group B. The maximum time was 50.84 seconds (group A) and 43.25 seconds (group B). A summary of the results is shown in Figure 3.

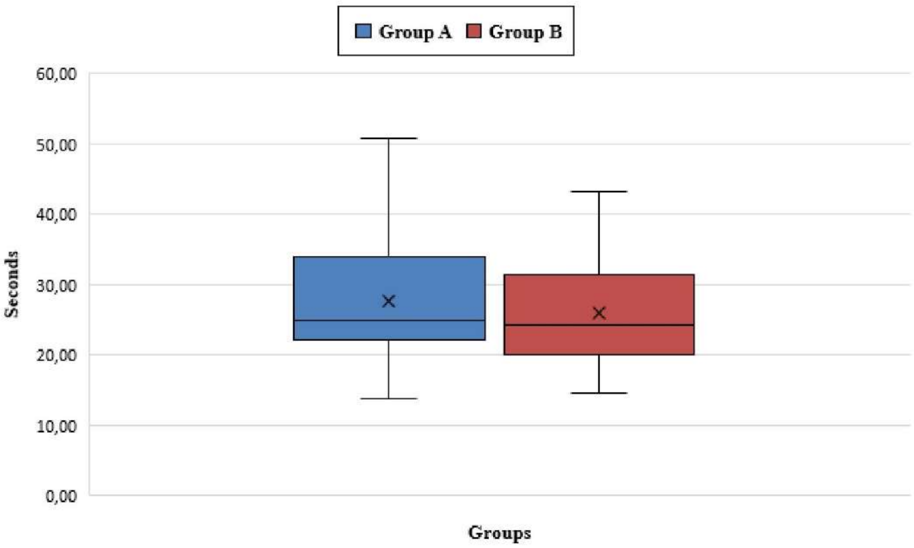

Figure 3. Comparison of hemorrhage stopping times with a CAT-type tourniquet (the method of passing the tourniquet fastened into a loop).

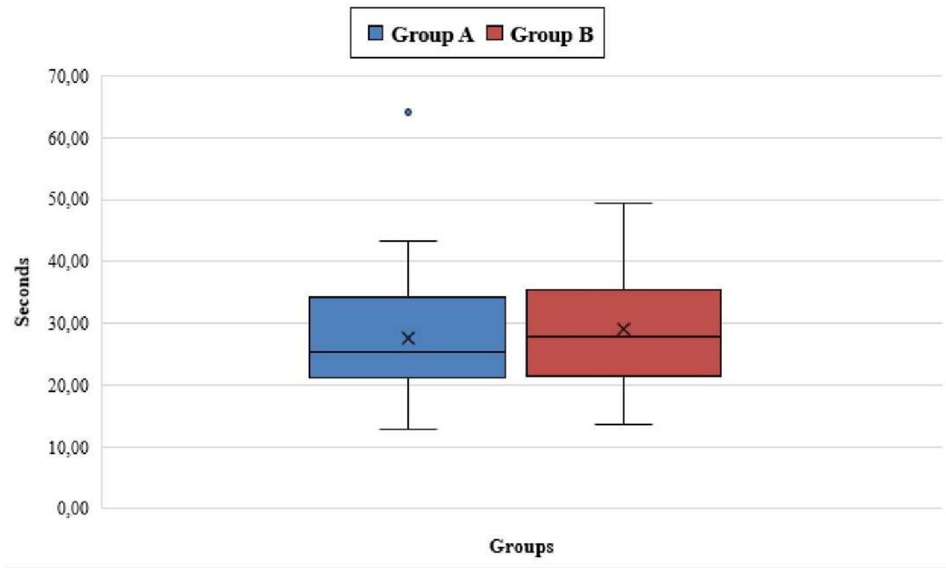

Figure 4. Comparison of hemorrhage stopping times with a CAT-type tourniquet (direct placement over the bleeding site).

The second way to perform the hemorrhage-stopping procedure with a tourniquet was to directly pass the unfastened tourniquet under the site of injury and fixate it above the bleeding site. The average time results were also found to be comparable, with Group A performing this procedure in 27.70 seconds (SD ± 10.19) and Group B in 29.14 seconds (SD ± 8.58). These were not statistically significant differences (p=0.584). This procedure took a minimum of 12.75 seconds in Group A and 13.56 seconds in Group B, while the maximum was 64.07 seconds and 49.41 seconds, respectively. A summary of the results is shown in Figure 4.

Self-assessment

In the first stage of the study, participants completed self-assessment questionnaires of their own skills in hemorrhage control, where they answered questions on a 7-point Likert scale. Students in the training model group scored an average of 4.56 points (SD ± 1.24), while those tested on the cadaver scored 4.55 points (SD ± 1.21). An intergroup comparison of survey results showed no statistically significant differences (p=0.667). After the study was completed, participants took a self-assessment of their skills by filling out the same questionnaire again. The mean scores in Group A were 5.06 points (SD ± 1.58), while those in Group B were 4.94 points (SD ± 1.97), which also showed no statistically significant deviations (p=0.494). A summary of the self-assessment results is shown in Figure 5.

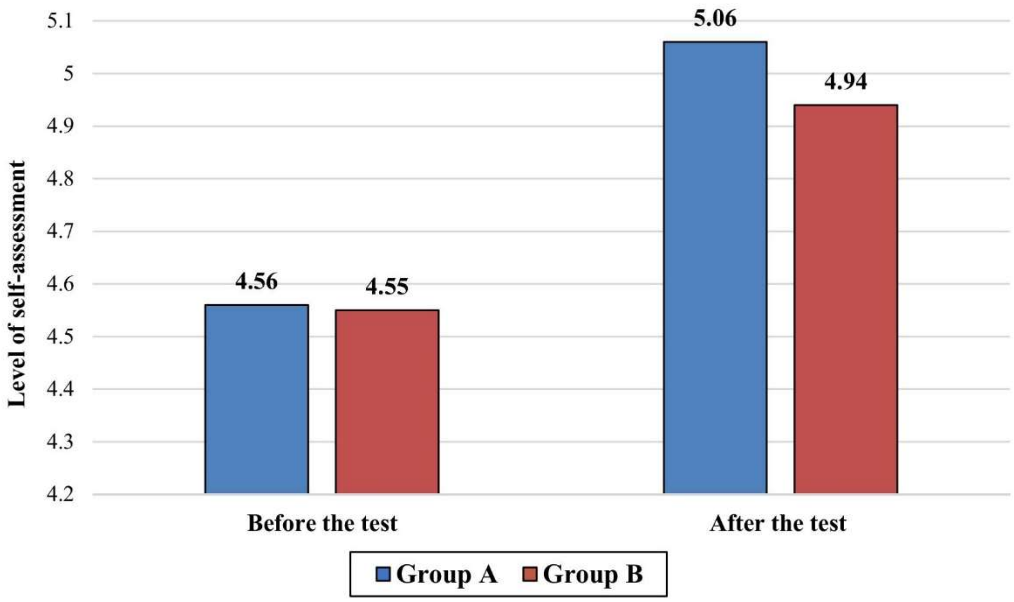

Figure 5. Comparison of the groups' self-assessment levels.

One of the items making up the self-assessment questionnaire were questions relating to the level of stress associated with the procedures performed. Before the practical part in group A, students felt stress at an average of 4.37 points (SD ± 1.47), which ranks between "difficult to determine / rather high” on a 7-point Likert scale, while in Group B: it was an average of 3.46 points (SD ± 1.21), located at "rather low- / difficult to determine” on the scale.

Performing all of the procedures studied enabled participants to significantly reduce the level of stress they felt. Group A ranked it at an average of 3.19 points (SD ± 1.53) labeling it it as "rather low", and Group B at an average of 2.20 points (SD ± 1.33) as “low”. A summary of the stress level results is shown in Figure 6.

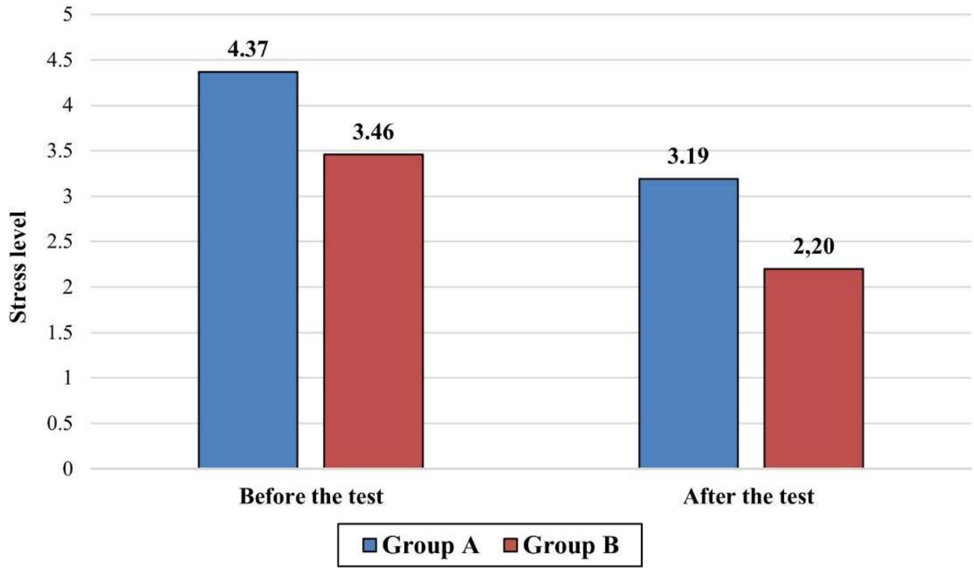

Figure 6. Comparison of perceived stress levels.

Satisfaction with training

In the final stage of the study, students completed a questionnaire assessing their perceived level of satisfaction with the procedures performed. A higher satisfaction level was observed in Group B (5.98; SD ± 1.10) than in Group A (5.69; SD ± 1.21), which indicated a borderline significant statistical result (p=0.054). The average scores of each group according to the procedure performed are included in Figure 7.

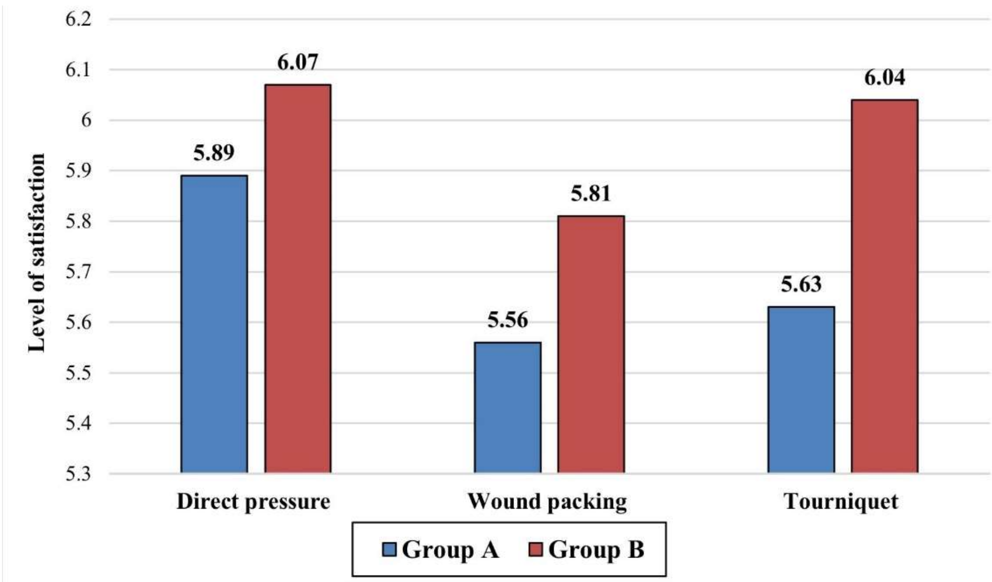

Figure 7. Comparison of satisfaction levels of groups according to the procedure performed.

DISCUSSION

Active external hemorrhages are one of the main reversible causes of cardiac arrest in trauma patients [5]. This means blood loss as low as 1.5 mL/kg b.w.m. in 20 minutes, or 150 mL/kg b.w.m. in one hour [6]. In cases of hemorrhage, the response of witnesses to the incident and emergency medical services must be quick and effective, which is why the European Resuscitation Council (ERC) guidelines and ITLS procedures point to various methods to stop bleeding [1,3]. The quickest and easiest way is direct pressure on the wound. It allows to stop further blood extravasation on a basic level and provide time to prepare dressings or equipment that will allow to properly secure and finally stop the hemorrhage.

The direct compression procedure was performed faster on the training model, taking an average time of 2.85 seconds (SD ± 1.05), while the group practicing on the cadaver took an average of 5.23 seconds (SD ± 6.28). One may notice that the group trained on the training model stopped the hemorrhage more quickly, however, it can be concluded that this group did not fully reflect the actual conditions offered by the unfixed human body. The training models are made of plastics, which means that they cannot fully convey the reality of working on real human tissue even when covered with a fluid that mimics blood.

A similar difference was observed in the next procedure, which was wound packing, performed in an average of 42.48 seconds (SD ± 19.98) in Group A, and as long as 50.97 seconds (SD ± 27.75) in Group B. As with direct compression, the training model can be considered an inferior material for practicing wound packing because it is made of cast plastic, while real tissues are flexible, making it often difficult to find the vessel rupture site.

Difficulties also occurred in case of tourniquets, whereas intergroup comparative analysis showed no statistically significant differences in the time it took to apply them. Group A applied the fastened tourniquet in an average of 27.66 seconds (SD ± 9.09), while Group B was slightly faster at 26.01 seconds (SD ± 7.73). The second way to perform this procedure was to put an unfastened tourniquet around the limb and fixating it 5-7 cm above the site of bleeding. The average time results were also found to be comparable, with Group A performing this procedure in 27.70 seconds (SD ± 10.19) and Group B in 29.14 seconds (SD ± 8.58). The authors noted divergent results for the first method of applying the tourniquet – this procedure was performed faster by group B. Nevertheless, the second method proved to be more time-consuming for that group. Such a difference may have been caused by the slippery feel of the skin, which hindered the ability to stably grip the limb, resulting in a longer time to put on the tourniquet at a later stage.

Enabling the improvement of skills related to stopping external hemorrhages on human specimens is associated with high costs and the requirement to prepare appropriate facilities, therefore it is not readily available to universities training medical students [7-11]. The above-average time results allow us to conclude that it is significantly more difficult to stop hemorrhage on real human tissues, which can translate into better preparation of students to work under real conditions at the scene.

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A comparative analysis of the results obtained from questionnaires, in which participants evaluated their own skills before and after taking on the tasks, showed an increase in the average self-assessment level in both groups. In group A, it was initially 4.56 points (SD ± 1.24) and increased to 5.06 pts (SD ± 1.58). Group B, on the other hand, initially identified the average level as 4.55 points (SD ± 1.21), and as 4.94 pts after the procedures (SD ± 1.97). It is worth noting that artificial materials are not able to replace human skin, so students practicing on training models may get the wrong impression about the speed and efficiency of their performance. This can be evidenced by a comparative analysis of the average results of perceived satisfaction with the procedures performed. Group A achieved its high level (5.69 points; SD ± 1.21), but Group B indicated a higher level (5.98 points; SD ± 1.10), confirming that the use of cadavers had a positive effect.

Similar results can be achieved when cadavers are used to teach other medical procedures. This was demonstrated, e.g., in a study by Bakalarski et al. (2019), who pointed out that training models may be inadequate when teaching pulmonary field auscultation [9]**.** Unfixed human preparations also constitute optimal material for learning to perform ultrasound, as demonstrated by Miller R. et al. (2016) [12]. The use of cadavers in medical education provides students with the opportunity to interact with a dead human body, allowing them to test their aptitude for a profession that involves death in some aspects [13,14].

The experience gained during such exercises is not only a valuable lesson in terms of practical learning to stop hemorrhages, but allows them to assess whether the chosen professional direction is right for them. The emotions that can accompany working on cadavers show the mental conditions of the participants in the classes, as also noted by Gryz P. (2023) in a study describing the example of two participants withdrawing due to emotional reasons [15].

The combination of the possibilities offered by the training models with the reflection of the physical conditions of the human body creates the most effective form of learning. Students experiencing the opportunity to repeatedly train and refine practical skills on training models, moving to cadavers later in their education, gain invaluable experience and awareness of working on human tissues, with the goal of acting effectively and efficiently in specific situations, such as stopping external hemorrhages. The authors recommend including unfixed human body preparations in the curriculum of medical students.

Study limitations - The study, due to its nature, was conducted on a rather small group of participants. Human tissues are quite malleable and susceptible to damage, which necessitated exercises using two upper limb preparations. Nevertheless, placing a tourniquet on human tissue several times causes deformation, which can affect the effectiveness of the procedures performed.

CONCLUSIONS

The effectiveness of the emergency procedures performed on cadavers and training models varies. It is reasonable to believe that the longer time required to stop hemorrhage simulated on human tissues is due to the difficulties encountered in real patient work. The authors therefore recommend implementing unfixed human body preparations in the teaching process at universities training medical students. Medical simulations, both on cadavers and training models, reduce the final stress level among participants, as well as raise the self-assessment and satisfaction scores. Further research is recommended to evaluate the effectiveness of selected didactic methods in teaching emergency procedures.

SUPPLEMENTARY INFORMATION

Funding: *No fund was received related to this study.*
Institutional Review Statement: *The study was conducted according to the guidelines of the Declaration of Helsinki.*
Informed Consent Statement: *Informed consent was obtained from all subjects involved in the study.*
Data Availability Statement: *The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.*
Conflicts of Interest: *The authors declare no conflicts of interest.*

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