Травма

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Assessment of the effectiveness and risks of using tourniquets in the Armed Forces of Ukraine during hostilities in Ukraine

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Abstract. ***Background.*** *Massive bleeding remains one of the leading causes of death among military personnel in armed conflicts, which leads to a constant need to improve the means of temporary bleeding control. The combat application tourniquet continues to be the standard in tactical medicine due to its proven clinical effectiveness, high speed of application and reliability during hostilities. Its use significantly reduces mortality in injuries with critical bleeding from the extremities, especially at the pre-hospital stage of medical care. The purpose was to analyze the impact of using tourniquets by military personnel in cases of massive/critical bleedings, traumatic amputations of limbs, and to assess the timeliness of the conversion in the world and in Ukraine. Particular attention is paid to the rationale for the expediency and inexpediency of using tourniquets, the duration of application, as well as the study of possible complications associated with their excessive or untimely use during intense hostilities and delays in evacuating the wounded.* ***Materials and methods.*** *The work was carried out through a systematic review, meta-analysis, content analysis of articles in the scientometric databases Scopus, PubMed, ResearchGate. The literature search was carried out using the following keywords: "tourniquet", "stop the bleeding". The study included descriptions of clinical cases of applying tourniquets by the servicemen of the Armed Forces of Ukraine, retrospective analyses and literature reviews. After reviewing the articles and reading their full texts, 8 sources were selected. The search covered the period from 2012 to 2025. The study was conducted based on one surgical hospital (Role 2) in April-May 2024 and April-May 2025. The use of means to temporary stop critical bleeding, its appropriateness, duration and risks of complications were analyzed in 135 servicemen who were in the combat zone.* ***Results and conclusions.*** *The duration of hemostasis in most cases (60.0 in 2025 %, an increase by 10 % vs. 2024) exceeds 2 hours, and the duration of tourniquet use exceeding 3 hours (compared to 2024, the frequency has increased by 5.0 % in 2025) indicates a prolonged evacuation of the wounded as a result of intense hostilities, which, in turn, increases the risk of ischemic complications and requires careful clinical monitoring. In 70.0 % of cases, one tourniquet is enough to stop the bleeding, while in 30.0 %, two or more tourniquets are required, which indicates the more severe nature of the wounds caused by the modernization and increased destructive power of modern weapons. Ischemic complications are recorded in almost half of the cases, the main reason for which is the prolonged application of a tourniquet.*

Keywords: *tourniquet; massive/critical bleeding; ischemic complications; military personnel of the Armed Forces of Ukraine*

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Introduction

Bleeding is one of the most noticeable and dangerous manifestations of trauma, which can lead to rapid critical blood loss and death if timely assistance is not provided. Methods of stopping bleeding have been known to mankind since ancient times. One of the first written sources describing methods to control bleeding is the surgical papyri of Ancient Egypt. In particular, the Edwin Smith Papyrus, dated approximately 1600 BC, contains detailed descriptions of wounds and methods of treating them, including direct pressure on the wound, applying ligatures (bandages), and sutures to close damaged tissues [1].

These early techniques laid the foundation for the further development of surgery and medicine in general. Over time, humanity has improved methods to control bleeding, adding new tools and techniques, such as tourniquets, hemostatic agents, and modern surgical technologies. However, the basic principles established in ancient times remain relevant today: timely detection of the source of bleeding and its effective cessation during combat operations are key to saving the life of a soldier [2, 3].

These methods have become particularly relevant in the context of military conflicts, disasters, and full-scale war in Ukraine, where the speed and accuracy of applying bleeding control measures can determine the fate of both civilians and military personnel [4].

The loss of personnel due to massive bleeding in military conflicts has always called for major improvements. A revolutionary breakthrough in this area was the creation in 2004 of the combat application tourniquet (CAT) for the US Special Operations Forces, designed by Ted Westmoreland. By 2005, this tourniquet had been adapted for the needs of regular armed forces units. Since its introduction, the CAT has undergone a number of design modifications reflecting the evolution of requirements for its functionality, ergonomics, and safety of use. Today, the eighth generation of the device (Generation 8) is in use, which meets modern tactical and medical standards [5].

Between 2001 and 2010, J.F. Kragh Jr conducted research on the use of tourniquets in the US Armed Forces. The author found that during this period, its frequency increased from 4.0 to 40.0 %, which was due to the modernization of weapons and changes in the nature of combat operations [6].

During military operations, the IDF Medical Corps applied tourniquets in cases of critical bleeding, resulting in a survival rate of 87.8 % due to the rapid use of tourniquets for any injury and type of weapon used, provided that the soldier has the skills to apply a tourniquet to the wounded limb to stop critical bleeding in combat conditions. During evacuation, 25.7 % of military personnel underwent conversion, of which 2.2 % failed to stop massive bleeding and a new tourniquet/tourniquet was applied, and 8.8 % of military personnel underwent fasciotomy. The overall complication rate (neurological, with or without vascular damage) was 11.7 % of all wounded soldiers [7].

One of the key factors contributing to improved survival rates was a significant reduction in the average evacuation time from combat zones — from 4.6 hours in 2014 to 2.6 hours in 2023 [8].

The timely and correct use of tourniquets, timely evacuation, and conversion of tourniquets are relevant and directly affect the survival rate among the Armed Forces of Ukraine personnel due to Russia's long-term war against Ukraine.

The purpose was to analyze the effectiveness of the use of tourniquets by military personnel in cases of massive/critical bleeding, traumatic limb amputations, and to assess the timeliness of conversion in the world and Ukraine. Particular attention is paid to justifying the advisability and inadvisability of using a tourniquet, the duration of its application, and studying possible complications associated with its excessive or untimely use during intense combat operations and delays in the evacuation of the wounded.

Materials and methods

The work was performed by systematic review, meta-analysis, and content analysis of articles from the scientometric databases Scopus, PubMed, and ResearchGate. The literature search was conducted using the keywords: "tourniquet", "stop the bleeding". The work included descriptions of clinical cases of tourniquet application by the Armed Forces of Ukraine personnel, retrospective analyses, and literature reviews. This review included eight articles. The search covered the period from 2012 to 2025. The study was conducted at a single surgical hospital (Role 2) during April-May 2024 and April-May 2025. The total number of military personnel included in the study was 135. The following methods were used in the work: bibliosemantic method and content analysis, comparative analysis, systematization of the researched material, and statistical analysis.

Results

In April-May 2024 and April-May 2025, the study was conducted on the use of temporary hemostatic agents in 135 military personnel who were in the combat zone. It analyzed the effectiveness of tourniquets, taking into account the duration of their application, the anatomical location of gunshot wounds, the methods of applying hemostatic agents, and the frequency of conversion. Particular attention was paid to assessing the risk of developing ischemic complications, which made it possible to comprehensively evaluate not only the effectiveness but also the safety of modern approaches to temporarily stopping massive bleeding. Separately, cases of unjustified use of tourniquets or untimely conversion in combat conditions and tactical medicine were analyzed.

The results of the study indicate the predominant use of the CAT as the primary means of temporarily stopping critical bleeding, which was used in 92.0 % of cases (90.0 % in 2024). Such a high frequency is due to the clinically proven effectiveness of this device in massive bleeding, especially in conditions of limited time, resources, and high stress. The design features of the CAT ensure its quick and effective application in the field, with reliable fixation and the ability to accurately dose the compression pressure on the affected area. This allows not only to achieve hemostasis in a timely manner, but also to maintain it until qualified medical care is provided, which significantly reduces the risk of developing severe forms of hemorrhagic shock and increases the overall survival rate of victims.

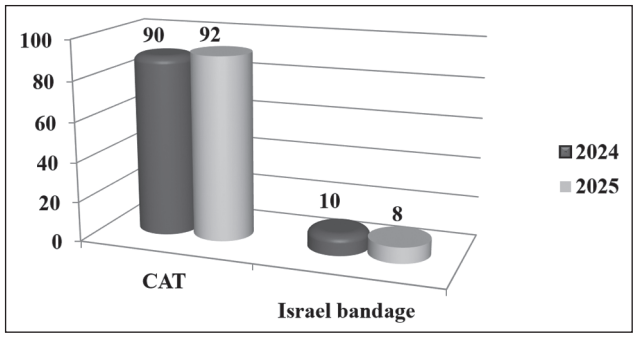

Figure 1. Distribution of temporary bleeding control measures among military personnel in the combat zone during April-May 2024/2025, %

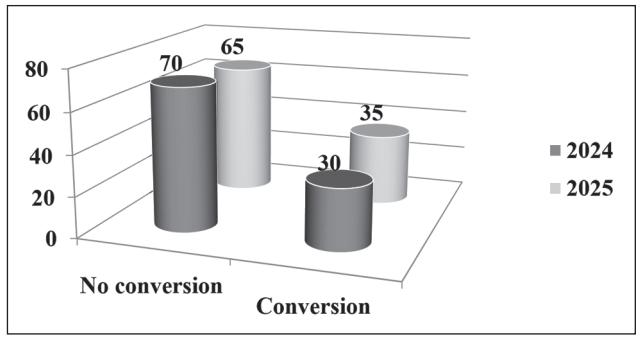

Figure 2. Distribution of conversions among military personnel who were in the combat zone during April-May 2024/2025, %

The Israel tourniquet was used in 8.0 % of cases (10.0 % in 2024), mainly for wounds with moderate bleeding that did not pose an immediate threat of severe hemorrhagic shock. In such cases, the compression pressure of the bandage was sufficient to reliably stop the bleeding (Fig. 1).

An analysis of the duration of using temporary measures to stop massive bleeding showed that in 40.0 % of cases (50.0 % in 2024), they were used for 1–2 hours; in 45.0 % of cases (40.0 % in 2024), for 2 to 3 hours; in 15.0 % of cases (10.0 % in 2024), the duration exceeded 3 hours. Concurrent compression times, especially those exceeding three hours, are associated with an increased risk of ischemic complications and require careful monitoring of the affected limb at all stages of medical evacuation.

Regarding the conditions for applying tourniquets, in 45.0 % of cases (40.0 % in 2024), fixation was performed as part of self-help, indicating a sufficient level of training of personnel to independently provide tactical pre-hospital care in combat conditions. In the remaining 55.0 % of cases (60.0 % in 2024), tourniquets were applied by comrades or combat medics, which emphasizes the importance of teamwork and quality medical care on the battlefield.

The research showed that most bleedings were localized in the lower extremities — 70.0 % of cases (75.0 % in 2024), while upper extremity injuries were treated in 30.0 % of cases (25.0 % in 2024). The technique for applying tourniquets varied depending on the clinical situation: in 55.0 % of cases (40.0 % in 2024), it was fixed as close as possible to the source of bleeding with complete compression, while in 45.0 % of cases (60.0 % in 2024), the hemostatic device was placed 5–8 cm above the injury site.

The choice of application technique was essential for assessing the risk of vascular and neurological complications and directly influenced further treatment, both conservative and surgical. In 35.0 % of cases (30.0 % in 2024), the tourniquet was converted — replaced with tamponade (alternative methods) to partially or completely restore peripheral blood flow. This approach helped reduce the risk of ischemic complications, in particular tissue necrosis or prolonged compression syndrome. At the same time, in 65.0 % of cases (70.0 % in 2024), conversion was not performed, which was probably due to the severity of the traumatic injury, the risk of recurrent bleeding, or the instability of the general condition of patients, or tactical conditions did not allow it to be performed (Fig. 2).

An analysis of the tourniquet effectiveness for temporarily stopping massive bleeding showed that in the vast majority of clinical cases — 70.0 % (65.0 % in 2024) — applying a single tourniquet was sufficient to achieve adequate hemostasis. In 25.0 % (30.0 % in 2024) of cases, two tourniquets were required, which may indicate a larger area of injury or insufficient effectiveness of a single bleeding control device. In 5.0 % (similar to 5.0 % in 2024) of cases, three tourniquets were required, indicating the exceptional severity of the blast injury and the extremely critical condition of the patients (Fig. 3).

Irreversible limb ischemia caused by critical regional blood supply disruption, the development of necrotic changes in soft tissues, and the need for subsequent amputation are among the most serious complications associated with the use of tourniquets. The main factors associated

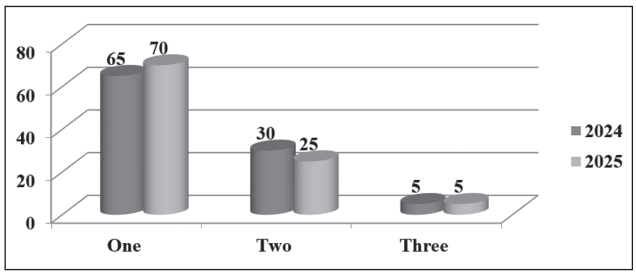

Figure 3. Distribution of the number of tourniquets applied among military personnel who were in the combat zone during April-May 2024/2025, %

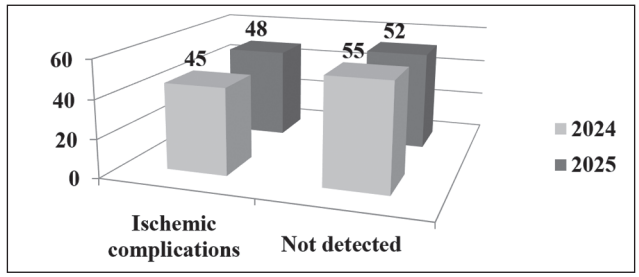

Figure 4. Distribution of complications associated with the use of tourniquets among military personnel in the combat zone during April-May 2024/2025, %

with their development were duration of ischemia and excessive compression pressure caused by incorrect application of the tourniquet.

Ischemic complications were found in 48.0 % of cases (45.0 % in 2024), indicating a high risk of irreversible changes if tourniquet application protocols are not followed. At the same time, in 52.0 % (55.0 % in 2024) of cases, such complications weren't observed in the victims, which indicates the potential effectiveness of the chosen application technique, rational choice of temporary hemostasis tactics, and proper clinical monitoring of the condition of the ischemic limb (Fig. 4).

One of the pressing issues in modern pre-hospital tactical care is the inappropriate use of tourniquets, which was recorded in 35.0 % of cases (30.0 % in 2024). Applying a tourniquet without clear clinical indications can lead to serious complications, including ischemic damage to limb tissues, and complicate further treatment of the victim.

The data obtained underscore the relevance of improving the system of training military personnel in the field of tactical pre-hospital care. In particular, deepening theoretical knowledge and regularly practicing skills regarding the indications, techniques, and rationale for using tourniquets are necessary measures to reduce the frequency of their unjustified use, which, in turn, will help reduce the frequency of complications (Table 1).

The research analyzed clinical cases of tactical pre-hospital care provided to military personnel in combat conditions, including self-help, mutual assistance among comrades, and the actions of combat medics. The effectiveness of stopping critical bleeding was assessed taking into account the ope-rational situation, the nature of combat injuries, and the compliance of the measures taken and the measures implemented with modern tactical medicine protocols (in particular, TCCC — Tactical Combat Casualty Care). Particular attention was paid to the quality of tourniquet application, the time to achieve hemostasis, and the frequency of complications associated with the use of bleeding control measures.

Clinical case 1

A 40-year-old male soldier of the Ukrainian Army suffered a mine-blast injury to the lower limb as a result of detonation on an anti-personnel mine (Fig. 5). At the stage of self-help/mutual assistance directly on the battlefield, a tourniquet was quickly applied in accordance with TCCC protocols to temporarily stop critical arterial bleeding. Thanks to the rapid evacuation of the victim, the tourniquet was removed 60 minutes after application, which reduced the risk of ischemic complications.

During the Role 2 medical evacuation stage, a set of measures was implemented to stabilize the general condition of the wounded. Infusion therapy was performed to restore and maintain adequate hemodynamics, as well as detoxification therapy to reduce endogenous intoxication. Analgesia was administered to effectively control pain, and antibacterial and anti-inflammatory drugs were prescribed to prevent infectious and inflammatory complications.

In the context of massive blood loss, fresh frozen plasma was transfused as component support for the hemostasis system. Due to severe traumatic injuries to the right lower limb, primary surgical treatment was performed in the form of amputation at the level of the lower third of the tibia. The therapeutic and diagnostic measures taken stabilized vital signs, allowing for further evacuation of the wounded under medical triage conditions.

Table 1. Comparative characteristics of the use of temporary bleeding control measures by military personnel in the combat zone (April-May 2024/2025), %

Parameter		2024	2025
Means of temporarily stopping bleeding, %	CAT Israel bandage	90 10	92 8
Time to stop bleeding, hours	1–2 2–3 > 3	50.0 40.0 10.0	40.0 45.0 15.0
Who imposed	Self-help Mutual aid	40.0 60.0	45.0 55.0
Localization of damage	Lower limbs Upper limbs	75.0 25.0	70.0 30.0
Height of tourniquet placement	High/tight 5–8 cm above the wound	40.0 60.0	55.0 45.0
Conversion	Not conducted Conducted	70.0 30.0	65.0 35.0
Number of tourniquets	1 2 3	65.0 30.0 5.0	70.0 25.0 5.0
Complications	Irreversible ischemia No complications	45.0 55.0	48.0 52.0
Inappropriate use		30.0	35.0

Figure 5. Explosive trauma with avulsion of the right lower limb from the lower third of the tibia. Multiple gunshot shrapnel blind wounds of both tibias. Grade II hemorrhagic shock

Figure 6. Explosive trauma with avulsion of the left lower limb from the middle third of the tibia. Multiple gunshot shrapnel blind wounds of the right popliteal region and thigh with massive soft tissue defect. Grade II hemorrhagic shock

Clinical case 2

A 29-year-old male soldier of the Ukrainian Army suffered a severe injury as a result of artillery fire (Fig. 6). In the field, the victim temporarily stopped critical bleeding by applying a tourniquet as a self-help measure. The first tourniquet was applied to the lower third of the thigh, which provided partial hemostasis. To strengthen control over bleeding, a second tourniquet was applied to the upper third of the thigh. The total time of tourniquet application was 40 minutes, which corresponded to a safe time interval in order to minimize the risk of developing ischemic complications.

At the Role 2 stage, a set of intensive care measures was carried out to stabilize the general condition of the wounded and prevent the development of complications. In order to correct hypovolemia and maintain systemic hemodynamics, infusion therapy with crystalloids was initiated. Effective analgesia was used to adequately control pain. Antibiotic prophylaxis was administered to reduce the risk of infectious complications, and anti-inflammatory therapy was prescribed. In addition, a transfusion of fresh frozen plasma was performed. Subsequently, surgical treatment was conducted for amputation of the left lower limb at the level of the middle third of the tibia, as well as for multiple gunshot and shrapnel wounds. Thanks to timely surgical intervention and adequate stabilization, the patient was prepared for further medical evacuation and successfully transferred to the next stage.

Clinical case 3

A 32-year-old male soldier of the Ukrainian Army suffered a gunshot wound to his right upper limb as a result of artillery fire. A tourniquet was applied to temporarily stop critical bleeding in a mutual aid situation. Due to a delay in medical evacuation, the tourniquet remained on the limb for 12 hours, which significantly exceeded the recommended maximum period of use. As a result of prolonged ischemia, irreversible ischemic damage to the soft tissues of the right upper limb developed (Fig. 7).

Figure 7. Firearm shrapnel blind wound of the right forearm in the middle third with a firearm fracture of the ulna. Tourniquet syndrome (12 hours). Irreversible ischemia of the right upper limb

At the Role 2 stage, a set of measures was taken to stabilize the patient's hemodynamic status and prepare him for further surgical treatment. Infusion therapy with crystalloid solutions was performed to correct hypovolemia and maintain systemic hemodynamics. Adequate analgesia was used to control severe pain. A course of antibiotic therapy was started to prevent infectious and inflammatory complications. Due to the presence of clinical signs of critical ischemia of the upper limb, fasciotomy was performed to assess the viability of muscle tissue. Subsequently, primary surgical treatment was conducted in the form of amputation of the right upper limb at the level of the upper third of the shoulder. Thanks to the timely implementation of therapeutic measures, the patient's general condition was stabilized, which made it possible to transfer him to the next stage of medical evacuation.

Clinical case 4

A 40-year-old male soldier of the Ukrainian Ground Forces was wounded as a result of artillery fire (Fig. 8). To temporarily stop massive bleeding, a tourniquet was applied within the limits of mutual assistance for 30 minutes, which ensured effective control of bleeding until evacuation without the development of ischemic complications.

At the Role 2 medical evacuation, intensive care was provided to stabilize the general condition of the wounded soldier. Infusion therapy was performed to correct hemodynamic disturbances, detoxification measures were carried out, and adequate analgesia was provided for effective pain control. Prevention of infectious complications was implemented through early administration of antibacterial and anti-inflammatory therapy. Subsequently, surgical treatment was performed for amputation. The therapeutic measures taken stabilized the patient's condition and ensured his further evacuation to the next level of medical care.

Figure 8. Explosive trauma with avulsion of the right lower limb from the lower third of the thigh. Multiple gunshot shrapnel blind wounds of the left lower limb

Conclusions

1. The CAT remains the primary means of temporarily stopping critical bleeding in military personnel due to its high effectiveness, speed of application, and reliability in combat/field conditions.

2. In most cases (60.0 % in 2025, a 10% increase vs. 2024), the duration of hemostasis exceeds 2 hours; applying tourniquets for more than 3 hours (the frequency has increased by 5.0 % vs. 2024) indicates a prolonged evacuation of the wounded as a result of intense combat operations, which, in turn, increases the risk of ischemic complications and requires careful clinical monitoring.

3. Compared to 2024, the number of cases of tourniquet self-application by military personnel increased by 5.0 % in 2025, indicating an improvement in their first aid training. However, in most cases (55.0 in 2025 vs. 60.0 % in 2024), tourniquets were applied by comrades or combat medics, which also confirms the importance of coordinated teamwork during injuries.

4. Most bleedings are localized in the lower extremities (70.0 in 2025 vs. 75.0 % in 2024). To stop them, tourniquets are most often applied as high as possible on the limb and at a distance of 5–8 cm above the injury site, which affects the risk of developing vascular-neurological complications and amputations.

5. Tourniquet conversion is performed in only one third of cases, indicating the need for a balanced approach to reduce the risk of ischemic complications, including necrosis and prolonged compression syndrome.

6. In most cases (70.0 in 2025 vs. 65.0 % in 2024), one tourniquet was sufficient to stop bleeding. At the same time, in 30.0 % (2025) compared to 35.0 % of cases (2024), two or more tourniquets were used, indicating more severe injuries.

7. In almost half of the cases (48.0 in 2025 vs. 45.0 % in 2024), ischemic complications developed, the main cause of which remain excessive duration of tourniquet application.

8. A significant proportion of cases of unjustified tourniquet use (35.0 % in 2025 compared to 30.0 % in 2024) highlights the need to improve the level of training of military personnel in tactical medicine, especially with regard to indications and application techniques.

Prospects for further research. To continue research into the safety of tourniquet use depending on the correct choice of device, application technique, and regular clinical monitoring, which should become a priority in the training of combat medics and personnel.

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Authors' contribution. V.V. Chorna — concept and design of the study, data collection and analysis, responsibility for statistical analysis, writing the article, critical review, final approval of the article; A.M. Hrynzovskyi — data collection and analysis, responsibility; S.I. Kalashchenko, S.Yu. Nesterova, L.B. Lototska — concept and design of the study, critical review, final approval of the article; A.M. Hubar — critical review, final approval of the article.

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Оцінка ефективності та ризиків застосування турнікетів у ЗСУ під час бойових дій в Україні

Резюме. ***Актуальність.*** Масивні кровотечі залишаються однією з провідних причин смертності військовослужбовців у збройних конфліктах, що зумовлює постійну потребу у вдосконаленні засобів тимчасової зупинки кровотечі. Турнікет типу CAT (combat application tourniquet) продовжує залишатися стандартом тактичної медицини завдяки доведеній клінічній ефективності, високій швидкості накладання та надійності в умовах бойових дій. Його використання суттєво знижує летальність при травмах із критичними кровотечами з кінцівок, особливо на догоспітальному етапі надання медичної допомоги. ***Мета:*** проаналізувати вплив застосування турнікетів (джгутів) військовослужбовцями у випадках масивної/критичної кровотечі, травматичних ампутацій кінцівок, а також оцінити своєчасність проведення конверсії у світі та Україні. ***Матеріали та методи.*** Роботу виконано шляхом систематичного огляду, метааналізу, контент-аналізу статей у наукометричних базах Scopus, PubMed, ResearchGate. Пошук літератури здійснювався з використанням ключових слів «tourniquet», «stop the bleeding». У дослідження були включені описи клінічних випадків накладання турнікетів (джгутів) військовослужбовцями ЗСУ, ретроспективні аналізи та огляди літератури. Після проведення огляду статей та ознайомлення з їх повними текстами відібрано 8 джерел. Пошук даних виконано за період 2012–2025 рр. Дослідження проводили на базі одного хірургічного госпіталя (Role 2) у квітні — травні 2024 року та квітні — травні 2025 року. Проаналізовано застосування засобів тимчасової зупинки критичних кровотеч, їх доцільність, тривалість та ризики ускладнень у 135 військовослужбовців, які перебували в зоні бойових дій. ***Результати та висновки.*** Тривалість накладання засобів гемостазу в більшості випадків (60,0 % у 2025 р., зростання на 10 % порівняно з 2024 р.) перевищує 2 години, а застосування турнікетів понад 3 години (збільшення частоти на 5,0 % у 2025 р. проти 2024 р.) свідчить про тривалу евакуацію поранених унаслідок інтенсивних бойових дій, що, у свою чергу, підвищує ризик ішемічних ускладнень та вимагає ретельного клінічного моніторингу. У 70,0 % випадків для зупинки кровотечі достатньо одного турнікета, тоді як у 30,0 % виникає потреба у застосуванні двох і більше, що свідчить про тяжчий характер поранень, зумовлений модернізацією та підвищеною вражаючою здатністю сучасного озброєння. Ішемічні ускладнення фіксуються майже в половині випадків, головною причиною є тривале накладання турнікета.

Ключові слова: турнікет (джгут); масивна/критична кровотеча; ішемічні ускладнення; військовослужбовці ЗСУ