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Research Article

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Predicting the Development of Venous Thromboembolic Complications in Combat Burn Injury

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BACKGROUND Venous thromboembolic complications (VTEC) are an urgent problem of modern military medicine and require constant improvement of methods for their prediction, prevention, diagnosis and treatment.

AIM to study the incidence of VTEC in casualties with combat burn injury and evaluate the possibility of predicting their development.

MATERIAL AND METHODS An analysis of treatment outcomes of 47 casualties with combat burn injury in the period from 2022 to September 2024 was carried out. All the patients were men, average age 27.3±3.1 years. The average severity of injuries on the Injury Severity Score (ISS) scale was 12.4±1.7 points.

Depending on the severity of the injuries received, the casualties were divided into 2 groups. Group I included 21 (44.7%) wounded with ISS ⩽6; group II included 26 (55.3%) with ISS>6.

For casualties of group I, pharmacoprophylaxis of VTEC was carried out only in 2 cases; mechanical types of prophylaxis were not used. All casualties of group II were prescribed anticoagulant therapy in preventive and therapeutic dosages, mechanoprophylaxis — in the absence of contraindications.

To identify significant prognostic signs of VTEC development, multiple regression analysis was used, and ROC analysis was used to assess the ability of independent prognostic factors.

RESULTS Combined thermomechanical injuries were diagnosed in 25 (53.2%) wounded, isolated burn injury — in 22 (46.8%). Deep burns were detected in 19 (40.4%), of which 5 (26.3%) were in group I, 14 (73.7%) were in group II ($p<0.001$); thermal inhalation injury — in 10 (38.5%) patients of group II. With ISS⩽6 (group I), venous thrombosis did not develop; with ISS⩽6 (group II), a significant increase in VTEC was noted to 42.3% ($\chi^2=9.4$; $p<0.002$). Pulmonary embolism (PE) was present in 1 (2.1%) wounded person of group II.

Multiple regression analysis showed that of all the studied signs, only the severity of injuries on the ISS scale turned out to be a reliable prognostic indicator of the development of VTEC ($p=0.000085$). The area under the ROC curve was 0.829.

CONCLUSION 1. The incidence of VTEC in casualties with combat burn injury is 23.4%, PE — 2.1%.

2. The number of points on the Injury Severity Score is a reliable predictor of the development of VTEC ($p=0.000085$) and, according to the results of ROC analysis, has a good predictive ability for assessing the likelihood of developing VTEC in combat burn injury.

Keywords: burn, thrombosis, wound, prognosis, prevention, thromboembolism

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b.s. — body surface area
CI — confidence interval
DVT — deep vein thrombosis
ISS — Injury Severity Score
PE — pulmonary embolism
USAS — ultrasound angioscanning
VTEC — venous thromboembolic complications

INTRODUCTION

A feature of modern wars is the active use of various explosive ordnance by the parties; the incidence of burns from their explosions varies from 15 to 25% [1]. Thermal injuries account for 5 to 20% of the overall structure of combat trauma with a mortality rate of about 4% [2]. An analysis of the structure of US medical losses during the wars in Iraq and Afghanistan in 2002–2019 showed that in most cases (77.5%) burns were observed in ground forces, 19.4% in the Marine Corps, 2.1% in the Navy, and 1% in the Air Force. Serious burn injuries were detected in 48.1% of victims (ISS=9–15), severe in 26.1% (ISS=16–24), critical ones in 25.8% (ISS⩾25) [3]; thermal inhalation injuries were diagnosed in 10% of them [4].

Despite the absence of studies in the modern scientific literature describing the incidence of venous thromboembolic complications (VTEC) in combat burn trauma, the results of screening duplex ultrasound examination of blood vessels show that in the civilian population, the incidence of deep vein thrombosis (DVT) in thermal trauma varies from 6 to 23% [5, 6], and pulmonary embolism (PE) develops in 8–8.1% [7, 8]. According to autopsy data, DVT is diagnosed in 60%; and PE is diagnosed in 10.7–25.3%, and is the direct cause of death in 0.8–5.9% of cases [9–11].

An important component of combat burn injury is thermal inhalation damage [12], in which early pulmonary changes usually manifest as pulmonary edema caused by the chemical effects of smoke, inhalation pneumonitis, the development of pulmonary microembolism, acute respiratory distress syndrome, and atelectasis on the 2nd–5th day after injury. Delayed pulmonary complications that develop 5 days after receiving a burn include severe pulmonary embolism and pneumonia [13].

The high incidence of DVT and PE shows the need to improve the prevention, diagnosis and treatment of VTEC in burn injuries. Informing doctors about the risk of developing VTEC and timely treatment and diagnostic measures will allow the victims to return to their work duties in the shortest possible time [14].

The aim of the study was to study the incidence of VTEC in victims with combat burn injuries, and to assess the possibility of predicting their development.

MATERIAL AND METHODS

The analysis of treatment outcomes of 47 victims with burn injuries who were treated at the Main Military Clinical Hospital of the National Guard Troops from 2022 to September 2024 was conducted.

Study design: prospective cohort study. In accordance with the STROBE guidelines [15], the study flow chart was drawn up and shown in Fig. 1.

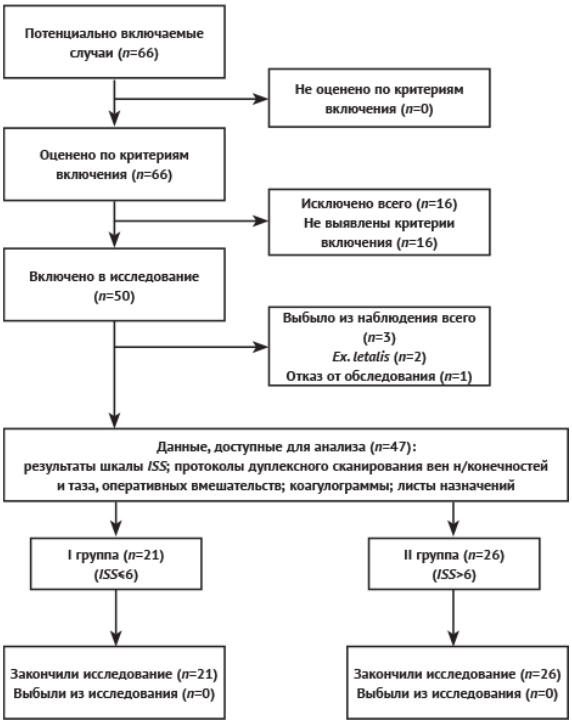

Fig. 1. Flow chart of the prospective cohort study

The inclusion criteria for the study were the presence of a burn injury received while performing combat missions and the performance of ultrasound angioscanning (USAS) of the veins of the extremities upon admission to the hospital.

Exclusion criteria from the study were a fatal outcome not related to the development of VTEC, and the victim's refusal of the prescribed examination and therapy.

All patients were men, mean age 27.3±3.1 years. Average severity of injuries according to the ISS (Injury Severity Score) was 12.4±1.7 points. After providing medical assistance in the area where combat missions were being carried out, the victims were evacuated to the hospital by air or rail transport.

As a result of the analysis of the treatment outcomes of about 7,000 wounded during the counter-terrorist operation in the North Caucasus (from 1994 to 2013), it was found that VTEC developed with a severity of injuries corresponding to 6 or more points on the ISS [16]. In this connection, a hypothesis was formulated that the incidence of VTEC depends on the severity of the injuries sustained.

In our study, the burn victims were divided into two groups depending on the injuries sustained. Group I included 21 wounded (44.7%) with the ISS of no more than 6, Group II included 26 (55.3%) with the ISS of more than 6. The groups were comparable in age, gender and burn localization. Before receiving a burn injury, the victims of both groups had no history of chronic cardiovascular diseases or VTEC.

Depending on the presence of risk factors for the development of VTEC, upon admission to the stage of providing specialized medical care, the victims underwent USAS of the veins of the upper extremities and the inferior vena cava system. Subsequently, the examination was performed according to indications, with an interval of 7-10 days. In isolated thermal trauma, the scanning was conducted on patients with a burn area of ⩾ 10% of the body surface area (b.s.). In the presence of extensive burns in the projection of the vascular-nerve bundles, in order to minimize pain, USAS was performed during dressings under general anesthesia. In the case of treating burn wounds using the method of “in one’s own liquid environment” [17], developed by the winner of the Russian National Guard Prize in Science and Technology, V.A. Menzul, USAS was carried out through applied film dressings.

The examination was performed using high- and expert-class ultrasound equipment (Esaote MyLab X7, Esaote MyLab X8, Italy; Philips CX50, Netherlands) with high frequency linear transducers with a frequency of 3–11, 4–15, 3–12, and convex transducers with a frequency of 1–8 MHz. The velocity characteristics of blood flow in the veins of the upper, lower extremities and pelvis were assessed; the presence and nature of thrombotic masses, vascular damage, and the localization of foreign bodies (fragments, bullets, and other wounding elements) were identified. When performing USAS, the recommendations of the Association of Phlebologists of Russia for ultrasound examination of the veins of the lower extremities were used [18].

If PE was suspected, the victims underwent computed tomography of the chest organs with intravenous contrast on a Siemens SOMATOM go. Top 128-slice CT scanner.

The study of the hemostasis system included the determination of activated partial thromboplastin time, prothrombin time, fibrinogen, antithrombin III and D-dimer (as indicated).

In victims of Group I, pharmacoprophylaxis of VTEC with low-molecular-weight heparins was carried out only in cases of combined wounds with the presence of wounds in the projection of the main vessels (n=2); mechanical types of prophylaxis were not used.

All victims of Group II were prescribed anticoagulant therapy with heparins of various molecular weights in prophylactic and therapeutic doses, or a factor Xa inhibitor (rivaroxaban 10 mg once daily) for the purpose of preventing and treating VTEC [19]. In the case of development of hemorrhagic complications, as well as the risk of bleeding from the gastrointestinal tract, pharmacoprophylaxis of VTEC was not carried out. In the absence of burns and wounds on the lower extremities, mechanical methods were used to accelerate venous blood flow - elastic bandages and intermittent pneumatic compression.

Statistical processing of the obtained results was performed using the functions of Microsoft Excel tables and Statistica 10.0 software application. The conformity of the features to the normal distribution law was determined using the Shapiro-Wilk test. The

hypothesis of equality of mean values was tested using Student's t-test. Calculation of absolute and relative frequencies (percentages, probabilities, odds) and confidence intervals (CI) were performed using the Epi Info™ statistical software. To analyze the differences in frequencies, the χ^2 (chi-square) test with Yates correction and Fisher's exact test were used.

Multiple regression analysis was used to identify statistically significant prognostic features of VTEC development. The dependent (explained) variable was the number of cases of VTEC among all victims with thermal injury; the independent (explanatory) variables were the total area of burns, the area of deep burns, the presence of thermal damage to the lower extremities, thermal inhalation trauma, combined injuries, the number of points of the injuries received according to the ISS scale, age, number of days in the intensive care unit, and the implementation of pharmacoprophylaxis.

To test the ability of independent prognostic factors, the receiver operating characteristic (ROC) analysis was used, and ROC curves were constructed. For quantitative assessment of the informativeness of a factor, a comparative analysis of the area under the ROC curve (AUC) was used. It was considered that the area coefficient of the curve lying in the range of 0.9–1 should be considered as an indicator of the highest informativeness of the studied factor, in the range of 0.8–0.9 — good informativeness, in the range of 0.7–0.8 — satisfactory, in the range of 0.6–0.7 — mediocre, and below 0.6 — an uninformative factor [20]. Differences were considered statistically significant at $p<0.05$.

RESULTS

Servicemen with burn injuries were evacuated to the hospital after receiving medical care in the areas of combat clashes. The time of admission to the specialized medical care stage for victims of both groups did not differ statistically significantly, and averaged 3.5±1.1 days. The duration of hospitalization in Group I was 32.4±3.7 bed-days, in Group II – 102.8±5.3 bed-days ($p<0.001$).

Thermomechanical combination injuries were diagnosed in 25 victims (53.2%), including 10 (40%) in Group I, and 15 (60%) in Group II; isolated burn injury in 22 (46.8%). The burn area varied from 0.5 to 90% of the b.s., deep burns were detected in 19 victims (40.4%), of which 5 (26.3%) were in Group I and 14 (73.7%) were in Group II ($p<0.001$). Thermal inhalation injury was not observed in Group I, but was found in 10 (38.5%) victims of Group II.

13 (50%) patients of Group II underwent treatment in the intensive care and resuscitation center. The treatment duration varied from 2 to 37 days and averaged 18.5±2.3 days.

The localization of the identified venous thromboses is presented in Table 1.

Table 1

Localization of venous thrombosis in victims with burn injuries

	Group I (n=21, ISS≤6)	Group II (n=26, ISS>6)	Total
Internal jugular vein	–	1	1
Brachial vein	–	2	2
Proximal deep vein thrombosis	–	2	2
Distal deep vein thrombosis	–	6	6
Total	0 (0%)	11 (42.3%)	11 (23.4%)

In accordance with the recommendations of Russian experts on the prevention, diagnosis and treatment of DVT, distal vein thrombosis of the lower extremities included DVT of the shin that did not extend to the popliteal vein, proximal one – the presence of thrombotic masses in the popliteal, femoral, iliac veins or inferior vena cava, regardless of the presence of vein thrombosis in the shin [21].

The analysis of the results presented in Table 1 showed that in victims with burn injuries with the severity of damage according to the ISS scale of no more than 6 (Group I), venous thrombosis did not develop; when the ISS was more than 6 (Group II), a statistically significant increase in VTEC to 42.3% was noted ($\chi2=9.4$; $p<0.002$). Thus, a statistically significant relationship was found between the severity of injuries and the incidence of VTEC.

In Group II, occlusive thrombosis was detected in 6, parietal thrombosis in 3, proximal DVT with

flotation in 1, and brachial venous thrombosis with flotation in 1 victim. Considering the size of the floating part of the thrombus (in the common femoral vein - up to 3 cm, in the brachial vein - up to 3.5 cm), surgical methods for preventing VTEC were not used. Thromboembolism of small branches of the right pulmonary artery was diagnosed in 1 (2.1%) wounded person of Group II with occlusive venous thrombosis in the shin.

The time periods for the development of venous thrombosis in victims with burn injuries are presented in Table 2. As can be seen from Table 2, in period I of traumatic disease (the period of disruption of vital functions, 4–12 hours), thrombosis was not detected in the wounded; in period II (the period of relative stabilization of vital functions) — it was diagnosed in 1; in period III (the period of maximum probability of complications) - in 3, and in period IV (the period of complete stabilization of vital functions) - in 11 victims. It was established that in period IV, venous thrombosis was diagnosed within 2–2.5 victims. It was established that in period IV, venous thrombosis was diagnosed within 2–2.5 months after getting a burn, which suggests a similarity in the pathogenetic development of VTEC in victims with burn trauma and combat gunshot trauma in a modern armed conflict [22], and requires that such patients undergo the necessary diagnostic and preventive measures throughout their entire stay in the hospital.

Table 2

Time of development of venous thrombosis in victims with burn injuries

Period	*n (%)*
Period I (4–12 hours)	0
Period II (12–48 hours)	1 (9.1)
Period III (3rd–10th day)	3 (27.3)
Period IV (11th day and more)	7 (63.6)
Total:	11 (100)

The results of multiple regression analysis showed that of all the studied factors, only the severity of injuries according to the ISS scale turned out to be a statistically significant prognostic feature of the development of VTEC (p=0.000085). The absence of a statistically significant level of significance for the independent factor of "administration of pharmacoprophylaxis" shows that the prophylactic anticoagulant therapy administered to the victims of Group II was insufficient and requires adjustment.

The results of the ROC analysis for the severity of injuries according to the ISS scale are presented in Fig. 2.

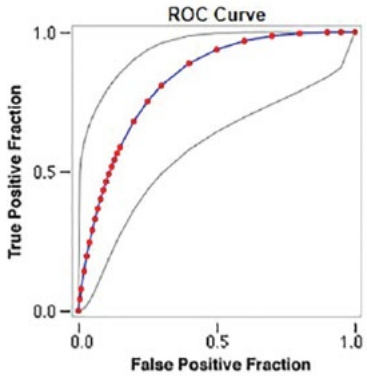

Fig. 2. ROC curve for injury severity according to the ISS scale

In Figure 2, the 95% confidence interval for the ROC curve is marked with gray lines. The area under the ROC curve (AUC) was 0.829, indicating good prognostic ability of the ISS scale for assessing the likelihood of developing VTEC in combat burn injury.

DISCUSSION

The difference between combat burn injury and domestic burn injury is the younger age of the victims (26±7 and 41±19 years); long, on average 6 days, evacuation to a specialized burn center (6±5 and 1±5); higher ISS compared to domestic burns (9±11 and 5±8); and a higher incidence of thermal inhalation injuries (13 and 8%). The burn area does not differ statistically significantly, while the mortality rate for domestic burn injuries is higher (7.1%) than for combat burns (3.8%). It should be noted that civilian patients have a higher Baux score (burn area as a percentage + patient age) [23, 24].

Victims of thermal injuries have numerous risk factors for the development of VTEC. In this

country, the most significant works on the study of prevention and treatment for venous thrombosis and pulmonary embolism in burn injuries in the civilian population were published by specialists of the N.V. Sklifosovsky Research Institute for Emergency Medicine [25, 26]. The conducted research has shown that the risk of developing VTEC statistically significantly increases by 1.02 times for every 1% increase in the area of the burn injury [8]. Independent risk factors also include increased body mass index [8], the presence of infectious complications of the burn wound [27], lower extremity burns [28], total burn area, the presence of a catheter in the central vein and veins of the lower extremities, pneumonia and increased D-dimer levels in the blood [29, 30], as well as the presence of deep burns, treatment in the intensive care unit, mechanical ventilation, surgical interventions [31], red blood cell transfusion [32], prolonged bed rest [33], history of alcohol abuse [8], belonging to the black race, the area of skin lesions of at least 20%, and the presence of VTEC in the anamnesis [34]. At the same time, the findings of other studies have shown that age, gender, body mass index, and degree of burn are not always risk factors for VTEC [35]. Considering that the listed risk factors were studied in the civilian population, and military personnel represent a more homogeneous group of people by age with a minimum number of severe chronic diseases, further study of the significance and possibility of using the listed risk factors in wounded military personnel with burn injury is necessary.

Currently, effective methods and scales for predicting the risk of developing VTEC in burn injuries have been developed, allowing for informed decisions regarding the strategy of preventive measures [36, 37]. However, the volume of calculations performed and the need to useadditional equipment in the presence of time constraints during periods of mass influx of wounded make the routine use of such methods and scales difficult.

The principles of simplicity and ease of using methods for predicting the development of VTEC in the wounded show the need to use a single statistically significant indicator to determine the probability of developing such complications, that, according to the results of the study, is the number of points on the Injury Severity Score, and the calculation of which allows the specialists to decide within a few seconds on the advisability of prescribing preventive measures to a specific victim.

CONCLUSION

Thermal injuries in modern warfare are accompanied by the development of VTEC, the maximum number of which is diagnosed during the first two weeks after receiving a burn injury, and require a comprehensive approach to their prediction, prevention and treatment.

FINDINGS

1. The incidence of venous thromboembolic complications in victims with combat burn injury is 23.4%, pulmonary embolism - 2.1%.
2. The number of points on the Injury Severity Score is a statistically significant prognostic sign of the development of venous thromboembolic complications (p=0.000085), and, according to the results of ROC analysis, has a good prognostic ability to assess the likelihood of developing venous thromboembolic complications in combat burn injuries.
3. To effectively prevent venous thromboembolic complications in high-risk victims with combined burn injuries, it is necessary to use an individual approach when administering anticoagulant prophylaxis until complete restoration of motor activity.

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