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D.A. Krishtafor, O.V. Kravets, O.M. Klygunenko, Yu.O. Ploshchenko, V.A. Sedinkin
Dnipro State Medical University, Dnipro, Ukraine

Oliguria caused by dehydration in combat trauma (case series)

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Abstract. ***Background.*** *A combat gunshot wound is significantly different from a civilian trauma. It is characterized by the prevalence of penetrating injuries, which increases the volume of blood loss at the pre-hospital stage, and the destruction of large masses of muscle tissue (rhabdomyolysis), which leads to acute kidney injury. Moreover, combat trauma occurs in conditions of chronic background stress as a result of severe emotional and physical strain, uncomfortable weather conditions, and deprivation of sleep, drinking and food. So, such a phenomenon as voluntary dehydration is common among soldiers in combat conditions. In wounded, oliguria is often considered a result of acute kidney injury, but it can also be a symptom of severe dehydration. The purpose of our work was to analyze three clinical cases of oliguria caused by dehydration in wounded with combat trauma to better understand the severity of the condition of such victims and to improve medical aid for them.* ***Materials and methods.*** *The article describes three cases of men aged 35, 50 and 44 years with combat gunshot wounds to the extremities, who were admitted to the tertiary care hospital on the second day after the injury with oliguria (0.18–0.19 ml/kg/hr) and high creatinine (333 to 457 μmol/L).* ***Results.*** *All three patients were conscious, breathing spontaneously, had stable hemodynamics, and moderate anemia after pre-hospital blood transfusions. Focused ultrasound study revealed hyperdynamic left ventricle and small inferior vena cava with complete inspiratory collapse, which suggested hypovolemia. Upon further investigation of the medical history, patients admitted not drinking any liquid for one to two days prior to injury. Tissue hydrophilicity test was conducted which showed severe dehydration in all three cases. Infusion volume was calculated using P.I. Shelestiuk nomogram (modified by O.V. Kravets et al.) and amounted to 60 ml/kg of balanced crystalloid solutions. Upon starting rehydration, diuresis was restored within two hours and amounted to 0.7–2.1 ml/kg/h in all three patients. Creatinine levels normalized in 2–4 days. Patients were transferred to another hospital in a moderate condition in 4–5 days.* ***Conclusions.*** *Oliguria is a frequent complication of combat gunshot injury. Although it is most often associated with acute kidney injury from rhabdomyolysis, it should also be considered that in a combat environment, soldiers' access to water may be limited and the injury may be accompanied by dehydration. In the cases presented, the differential diagnosis of the causes of oliguria in the wounded made it possible to detect signs of severe dehydration, abstain from the inappropriate use of saluretics, quickly compensate for the fluid deficit, and to avoid the development of kidney damage and the need for renal replacement therapy.*
Keywords: *combat trauma; dehydration; rhabdomyolysis; voluntary dehydration*

Introduction

According to the United Nations (UN) reports, from the beginning of the conflict in Ukraine on April 6, 2014, to January 31, 2022, more than 13,250 people were killed (including 3,107 civilians), and more than 31,200 were injured (including more than 7,000 civilians) [1]. For comparison, 3,238 people died in road traffic accidents in Ukraine in 2021, and 29,738 were injured [2]. From February 24, 2022, to June 7, 2024, the UN confirmed the death of 11,126 civilians, and another 21,863 were injured. The real figures are probably considerably higher, as the receipt of information from some locations where intense hostilities have been going on has been delayed and many reports are still pending corroboration [3].

A combat gunshot wound is significantly different from a civilian multiple trauma. A combat trauma is characterized

Для кореспонденції: Кріштафор Дар'я Артурівна, кандидат медичних наук, асистент кафедри анестезіології, інтенсивної терапії та медицини невідкладних станів ФПО, Дніпровський державний медичний університет, вул. Вернадського, 9, м. Дніпро, 49044, Україна; e-mail: shredderine@gmail.com; тел.: +380 (66) 407-84-84
For correspondence: Daria Krishtafor, PhD in Medicine, Assistant at the Department of Anesthesiology, Intensive Care and Emergency Medicine, Faculty of Postgraduate Education, Dnipro State Medical University, Vernadsky st., 9, Dnipro, 49044, Ukraine; e-mail: shredderine@gmail.com; phone: +380 (66) 407-84-84
Full list of authors' information is available at the end of the article.

Table 1. P.I. Shelestiuk nomogram (modified by O.V. Kravets et al.) [25]

Degree of dehydration	Resorption time, min	Amount of fluid, ml/kg/day	Daily amount of fluid for a patient weighing 70 kg
1	40–30	25–40	1,750–2,800
2	29–15	40–60	2,800–4,200
3	15–5	60–80	4,200–5,600

by the prevalence of penetrating injuries, which increases the volume of blood loss at the pre-hospital stage and often requires urgent surgical stopping of bleeding [4, 5]. High-energy projectiles cause the destruction of large masses of muscle tissue (rhabdomyolysis), which leads to the leakage of the intracellular contents of myocytes into the bloodstream and an increase in plasma levels of creatine kinase and myoglobin. The iron-containing part of myoglobin reacts with urine glycoproteins and forms an insoluble complex that causes obstruction of renal tubules [6]. As a result, the most common systemic complication of rhabdomyolysis is acute kidney injury (AKI). It occurs with a frequency of 10 to 55 % and is associated with a poor prognosis, especially in the presence of multiple organ failure [7]. In the past years of the conflict in Ukraine, signs of AKI were observed in 37.9 % of wounded who were admitted to the intensive care units [8].

In addition to the nature of the trauma itself, combat injury is also distinguished by the background where it occurs. Combat conditions are characterized by chronic background stress as a result of severe emotional and physical strain, uncomfortable weather conditions, deprivation of sleep, drinking and food [9]. Even if a soldier has free access to water, in stressful conditions the sense of thirst may be inadequate. As a result, such a phenomenon as voluntary dehydration is frequent among combatants [10–12].

The most common clinical manifestations of dehydration are thirst, dry skin and mucous membranes, dark urine or oliguria. In laboratory studies, hemoconcentration with increased levels of hemoglobin and hematocrit is noted [13, 14]. On the contrary, blood loss is characterized by hemodilution and anemia [15]. Calculation methods for determining deficit of the water [16] or circulating blood volume [17] using the hematocrit level are based on this. Accordingly, when dehydration and posthemorrhagic anemia are combined in one patient, the hemoglobin and hematocrit levels will not correspond to the severity of either dehydration or blood loss.

Hemodynamic instability develops with a loss of about 5 % of body weight due to dehydration or with a blood loss of about 30 % of circulating blood volume, which for a man weighing 80 kg will be 4,000 ml of fluid and 1,680 ml of blood, respectively [5, 13]. Up to this point, there is a hidden hypovolemia, which is important to diagnose in order to timely start restoring the fluid or blood volume [18].

Bedside echocardiography plays an important role in the diagnosis of hidden hypovolemia. This is a non-invasive study method that every anesthesiologist can master at the basic level. It allows to carry out a qualitative assessment of the myocardium contractile function and to create an idea of the state of pre- and afterload in a patient [19]. A sign of severe hypovolemia is the "kissing" of the left ventricular papillary muscles, when the left ventricular cavity completely collapses at the end of systole. This phenomenon is characterized as a hyperdynamic left ventricle [20]. Another sign of hypovolemia that is quickly diagnosed by ultrasonography (US) is the inferior vena cava (IVC) diameter variability. A small IVC (less than 17–21 mm according to various authors) with an inspirational collapse of more than 50 % in patients with spontaneous breathing indicates a low (below 5 mm Hg) central venous pressure [21, 22]. Complete IVC collapse during inspiration indicates an intravascular fluid deficiency [23].

In Ukraine, to assess the degree of dehydration, a tissue hydrophilicity test (THT) according to P.I. Shelestiuk (also known as McClure tissue hydrophilicity test in Western literature) is routinely used. After disinfecting the skin, 0.25 ml of 0.9% sodium chloride solution is injected intradermally into the front surface of the forearm; the degree of dehydration is calculated by the time until the complete resorption of the formed "lemon peel" (Table 1) [24, 25].

25 % of the calculated infusion volume is administered in the first hour of treatment, the next 25 % — in the following two hours, the last 50 % — until the end of the first day of treatment [25]. Thus, in the first hour of treatment, the infusion rate reaches 1,400 ml/h.

Treatment for rhabdomyolysis also involves aggressive infusion therapy with balanced crystalloid solutions. But at the same time, the rate of infusion is 200–1,000 ml/h depending on the severity of rhabdomyolysis, and its total volume is 2–3 times daily need (i.e. 50–90 ml/kg). In addition, with oliguria due to rhabdomyolysis, it is recommended to add saluretics to the therapy, which is contraindicated in case of dehydration [7, 26].

Thus, given the multiplicity of possible causes of oliguria in combat trauma, their differential diagnosis is of great importance for choosing the correct treatment.

The aim of our work was to analyze three clinical cases of oliguria caused by dehydration in wounded with combat trauma to better understand the severity of the condition of such victims and to improve medical aid for them.

Clinical case 1

Patient K., a 35-year-old man, was taken to the tertiary care hospital on the second day after the injury with a diagnosis of blast injury, open fracture of the left femur, shrapnel wounds to the neck, left shoulder, and left hand. Primary surgical treatment of wounds, fixation of the fracture with an external fixation device, antibiotic administration, transfusions and fluid therapy were performed at the previous stages of treatment.

Upon admission, the general condition was serious, stable. Glasgow coma scale (GCS) score 15. Spontaneous breathing through natural airways was adequate. Blood pressure (BP) 130/80 mm Hg without sympathomimetics, heart rate (HR) 82 bpm, body temperature 37.1 °C. Hemoglobin level of 86 g/L, hematocrit of 26.0 %. Infusion, antibiotics, venous thromboembolism (VTE) and stress ulcer prophylaxis were prescribed [27, 28].

In the first 6 hours of treatment, despite the infusion of balanced crystalloid solutions at a rate of 200–400 ml/h, the patient had oliguria (diuresis of 0.18 ml/kg/h). Because of the stable hemodynamics, an adequate volume of transfusion in the previous stages of evacuation, no signs of active bleeding, hyperazotemia (serum urea level of 21.0 mmol/L, creatinine of 457 μmol/L), an increase in the serum creatine kinase level up to 8,128 U/L, AKI was suspected. A renal US was performed, which did not reveal any signs of kidney damage or impaired renal blood flow. Focused echocardiographic examination showed signs of hyperdynamism (left ventricular cavity collapse in systole) and low central venous pressure (IVC diameter of 7 mm with full inspiratory collapse), suggesting hypovolemia.

The patient's medical history has been clarified again. He denied kidney disease. Upon further investigation, it was found that the patient had hardly consumed any liquid during the two days before the injury. THT was conducted; the time of papule resorption was equal to 5 minutes, which corresponded to a severe degree of dehydration.

The calculated infusion volume was 60 ml/kg (5,400 ml) of balanced crystalloid solutions, which were administered according to the protocol [25]: 25 % in the first hour of treatment, the next 25 % — in the following two hours, the last 50 % — until the end of the first day of treatment. In addition, the patient was allowed to drink without restrictions. Upon starting rehydration, diuresis has restored within two hours and amounted to 0.7–2.1 ml/kg/h (4,000 ml per day).

Hemoglobin on the first day of treatment decreased to 77 g/L, hematocrit to 23.7 %, urea level to 18.3 mmol/L, creatinine to 321 μmol/L, creatine kinase to 4,250 U/L. On the third day, the level of urea was 12.7 mmol/L, creatinine was 171 μmol/L, creatine kinase was 2,817 U/L. In the next days, positive clinical and laboratory dynamics was observed. The patient was transferred to the orthopedics department in a moderate condition on the 4th day of treatment.

Clinical case 2

Patient B., a 50-year-old man, was brought to the tertiary care hospital on the second day after the injury with the diagnosis of blast injury, gunshot shrapnel blind non-penetrating wounds of the chest, lumbar area, left buttock, open fracture of the right scapula, right-sided pneumothorax, shrapnel wound of the left lower limb with damage to the superficial femoral artery, open fracture of the left femur. Primary surgical treatment of wounds, thoracostomy, fixation of the fractures with external fixation devices, reconstruction of the left superficial femoral artery "end-to-end", fasciotomy of the left leg, antibiotic administration, transfusions and fluid therapy were performed at the previous stages of treatment.

Upon admission, the general condition was serious, stable. GCS score 15. Spontaneous breathing through natural airways, adequate. BP 130/70 mm Hg without sympathomimetics, HR 99 bpm, body temperature 37.0 °C. Hemoglobin level of 97 g/L, hematocrit of 28.9 %. Infusion, antibiotics, VTE and stress ulcer prophylaxis were prescribed.

Despite balanced crystalloid solutions infusion at a rate of 200–400 ml/h, in the first 6 hours, the patient had oliguria (diuresis of 0.19 ml/kg/h). The volume of infusion and transfusion at the previous stages of evacuation was adequate, there were no signs of active bleeding, and hemodynamics remained stable. A blood chemistry test revealed an increase in serum urea to 18.0 mmol/L, creatinine to 378 μmol/L, myoglobin to 1,317 μg/L, and creatine kinase to 10,249 U/L. AKI was suspected. A renal US was performed, with no signs of kidney damage or impaired renal blood flow. Focused echocardiographic examination showed evidence of left ventricular hyperdynamism and complete inspiratory IVC collapse, suggesting hypovolemia.

The patient's medical history has been clarified. He denied kidney disease. During a more detailed investigation, the patient noted that he had not consumed liquid during 24 hours before the injury. THT was conducted; the time of papule resorption was 7 minutes, which corresponded to a severe level of dehydration.

The calculated infusion volume was 60 ml/kg (5,400 ml) of balanced crystalloid solutions, which were administered according to the protocol [25]. The patient was also allowed to drink without restrictions. Against the background of rehydration, diuresis was restored within two hours and amounted to 1 ml/kg/h (2,300 ml per day).

After the first day of treatment, hemoglobin decreased to 80 g/L, hematocrit to 24.4 %, urea level to 17.3 mmol/L, creatinine to 128 μmol/L, creatine kinase to 3,628 U/L. In the next days, positive dynamics was observed. The patient was transferred to the next evacuation phase in a state of moderate severity on the 5th day of treatment.

Clinical case 3

Patient K., a 44-year-old man, was brought to the tertiary care hospital on the second day after the injury with a diagnosis of blast injury, open fractures of the right humerus and both bones of the left forearm, shrapnel wound of the chest, contusion of the right lung, right-sided hemopneumothorax. Primary surgical treatment of wounds, thoracostomy, fixation of the fractures with external fixation devices, antibiotic administration, transfusions and fluid therapy were performed at the previous stages of treatment.

Upon admission, the general condition was serious, stable. GCS score 15. Spontaneous breathing through natural airways, adequate. Blood pressure 120/80 mm Hg without sympathomimetics, heart rate 88 bpm, body temperature 36.8 °C. Hemoglobin level of 89 g/L, hematocrit of 27.8 %. Infusion, antibiotics, VTE and stress ulcer prophylaxis were prescribed.

In the first 6 hours of treatment, despite the infusion of balanced crystalloid solutions at a rate of 200–400 ml/h, the patient had oliguria (diuresis of 0.31 ml/kg/h). Hemodynamics remained stable, there were no signs of active bleeding. The amount of replenishment of blood loss in the previous stages of evacuation was adequate. Due to oliguria, hyperazotemia (blood serum urea increased to 22.9 mmol/L, creatinine to 333 μmol/L) and signs of rhabdomyolysis (blood serum myoglobin elevated to 1,566.5 μg/L, creatine kinase to 7,138 U/L), AKI was suspected. No signs of kidney damage or impaired renal blood flow were detected during renal US. Focused echocardiographic examination showed evidence of the left ventricular hyperdynamism and complete inspiratory IVC collapse, suggesting hypovolemia.

The patient's medical history has been clarified again. He denied kidney disease, but noted that practically had not consumed any liquid during 24 hours preceding the injury. THT was performed and was equal to 12 minutes, which corresponded to a severe level of dehydration.

The calculated infusion volume was 60 ml/kg (4,800 ml) of balanced crystalloid solutions, which were administered according to the protocol [25]. In addition, the patient was allowed to drink without restrictions. Against the background of rehydration, diuresis was restored within two hours and amounted to 1.5–2.1 ml/kg/h (3,500 ml per day).

In 12 hours, the amount of hemoglobin decreased to 71 g/L, hematocrit to 21.8 %, urea level to 9.3 mmol/L, creatinine to 92 μmol/L, creatine kinase to 4,617 U/L. In the future, positive dynamics was observed. The patient was transferred to the next evacuation phase in a state of moderate severity on the 5th day of treatment.

Discussion

The described cases demonstrate the complexity of the combined effect of blood loss, rhabdomyolysis and dehydration on the patient's condition.

In all three cases, the victims had severe blast injuries with massive blood loss. Accordingly, the main attention was paid to the injury, blood loss and the adequacy of its replenishment both during the history collection and the condition assessment. Adequate volume and composition of infusion-transfusion therapy at the pre-hospital stage; absence of signs of hemodynamic instability; post-hemorrhagic anemia, which masked dehydration; the very nature of the injury, which implies rhabdomyolysis and the risk of kidney damage; the presence of biochemical markers of rhabdomyolysis and hyperazotemia in the blood — all these factors created conditions for oliguria to be considered a sign of AKI, and not hypovolemia. At the same time, hemoconcentration due to dehydration masked the real degree of posthemorrhagic anemia.

Renal US and focused echocardiographic examination helped exclude renal causes of oliguria and revealed signs of hypovolemia, which were confirmed by anamnestic data and THT results. This allowed to choose the correct tactics of fluid therapy and abstain from the inappropriate use of saluretics, thanks to which it was possible to quickly compensate for the fluid deficit, avoid the development of kidney damage and the potential need for renal replacement therapy.

Conclusions

Oliguria is a frequent complication of combat gunshot injury. Although it is most often associated with acute kidney injury from rhabdomyolysis, it should also be considered that in a combat environment, a soldier's access to water may be limited and the injury may be accompanied by dehydration. In the cases presented by us, the differential diagnosis of the causes of oliguria made it possible to detect signs of severe dehydration, to abstain from the inappropriate use of saluretics, to quickly compensate for the fluid deficit, and to avoid the development of kidney damage and the need for renal replacement therapy.

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Information about authors

Daria Krishtafor, PhD in Medicine, Assistant at the Department of Anesthesiology, Intensive Care and Emergency Medicine, Faculty of Postgraduate Education, Dnipro State Medical University, Dnipro, Ukraine; e-mail: shredderine@gmail.com; phone: +380 (66) 407-84-84; http://orcid.org/0000-0003-0942-4099

Olha Kravets, MD, DSc, PhD, Professor, Head of the Department of Anesthesiology, Intensive Care and Emergency Medicine, Faculty of Postgraduate Education, Dnipro State Medical University, Dnipro, Ukraine; e-mail: 535951@ukr.net, 602@dmu.edu.ua; https://orcid.org/0000-0003-1340-3290

Olena Klygunenko, MD, DSc, PhD, Professor, Department of Anesthesiology, Intensive Care and Emergency Medicine, Faculty of Postgraduate Education, Dnipro State Medical University, Dnipro, Ukraine; e-mail: klygunenko@gmail.com; https://orcid.org/0000-0001-8470-4790

Yuliia Ploshchenko, PhD in Medicine, Associate Professor, Department of Anesthesiology, Intensive Care and Emergency Medicine, Faculty of Postgraduate Education, Dnipro State Medical University, Dnipro, Ukraine; e-mail: ploshchenkoyulia@gmail.com; phone: +380 (67) 921-00-16; https://orcid.org/0000-0003-0538-0164

Vladyslav A. Sedinkin, PhD in Medicine, Associate Professor, Department of Anesthesiology, Intensive Care and Emergency Medicine, Faculty of Postgraduate Education, Dnipro State Medical University, Dnipro, Ukraine; e-mail: dnepr_vlad@ukr.net; https://orcid.org/0000-0002-8894-1598

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Кріштафор Д.А., Кравець О.В., Клигуненко О.М., Площенко Ю.О., Седінкін В.А.
Дніпровський державний медичний університет, м. Дніпро, Україна

Олігурія на тлі дегідратації при бойовій травмі (серія випадків)

Резюме. ***Актуальність.*** Бойова вогнепальна травма значно відрізняється від травми мирного часу. Для бойового поранення характерне превалювання проникних ушкоджень, що збільшує об'єм крововтрати на догоспітальному етапі, та руйнування великих масивів м'язової тканини (рабдоміоліз), яке призводить до гострого ураження нирок. Крім того, бойова травма відбувається в умовах хронічного фонового стресу внаслідок тяжких емоційних і фізичних навантажень, некомфортних погодних умов, позбавлення сну, пиття та їжі. Тому серед солдат в бойових умовах поширене таке явище, як «добровільна дегідратація». У поранених олігурію часто розглядають як результат гострого пошкодження нирок, але вона також може бути симптомом тяжкої дегідратації. ***Метою*** нашої роботи було проаналізувати три клінічних випадки олігурії, спричиненої зневодненням, у поранених із бойовою травмою для покращення розуміння тяжкості стану таких постраждалих і удосконалення надання їм медичної допомоги. ***Матеріали та методи.*** У статті описана динаміка стану трьох чоловіків 35, 50 та 44 років із бойовими вогнепальними пораненнями кінцівок, які надійшли до стаціонару III рівня на другу добу після поранення з олігурією (0,18–0,19 мл/кг/год) і високим рівнем креатиніну (від 333 до 457 мкмоль/л). ***Результати.*** Усі пацієнти були в свідомості, дихали спонтанно, мали стабільну гемодинаміку та помірну анемію після гемотрансфузії на догоспітальному етапі. При сфокусованому ультразвуковому дослідженні виявлені гіпердинамія лівого шлуночка й маленька нижня порожниста вена з повним інспіраторним колапсом, що свідчило про гіповолемію. При уточненні анамнезу пацієнти зазначили, що не вживали рідини протягом 1–2 діб до моменту травми. Була проведена проба на гідрофільність тканин, яка показала тяжку дегідратацію в усіх випадках. Об'єм інфузії, розрахований за номограмою П.І. Шелестюка (у модифікації О.В. Кравець та ін.), становив 60 мл/кг збалансованих кристалоїдних розчинів. Після початку регідратації діурез відновився протягом двох годин і становив 0,7–2,1 мл/кг/год у всіх трьох пацієнтів. Рівень креатиніну нормалізувався через 2–4 дні. Через 4–5 днів постраждалі в стані середньої тяжкості були переведені з відділення інтенсивної терапії до профільного відділення або на наступний етап евакуації. ***Висновки.*** Олігурія є частим ускладненням бойової вогнепальної травми. Хоча найчастіше вона пов'язана з гострим пошкодженням нирок внаслідок рабдоміолізу, слід також враховувати, що в бойових умовах доступ солдат до води може бути обмеженим і травма може супроводжуватися дегідратацією. У представлених нами випадках диференційна діагностика причин олігурії в поранених дозволила виявити ознаки тяжкої дегідратації, відмовитися від недоцільного застосування салуретиків, швидко компенсувати дефіцит рідини та уникнути розвитку пошкодження нирок і потреби в замісній нирковій терапії.

Ключові слова: бойова травма; дегідратація; рабдоміоліз; «добровільна дегідратація»
