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Role of procalcitonin in conversion osteosynthesis of combat injuries of the extremities

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Abstract

Objective. To determine the possibility of using the procalcitonin inflammation marker in clinical practice for conversion osteosynthesis of combat injuries of the extremities.

Materials and methods. An analysis of 174 injuries to long bones of the limbs sustained during modern combat operations due to Russia's full–scale invasion between 2022 and 2024 was conducted. All patients who participated in the study were military personnel who were treated at the Chernivtsi Regional Clinical Hospital at the stage of providing qualified medical care.

Results. It has been proven that the use of procalcitonin to predict the course of the traumatic process in patients with long bone fractures as a marker of the risk of inflammation is appropriate for deciding on the possibility and advisability of conversion. After conversion osteosynthesis, blood procalcitonin levels reliably decreased in patients with combat trauma to the extremities, indicating a reduced risk of infectious complications.

Conclusions. The use of blood procalcitonin level measurement is promising in clinical practice when converting the osteosynthesis method.

Keywords: combat trauma; long bones; markers of inflammation; infectious complications; fractures; treatment tactics.

Ukraine is currently defending itself against Russian aggression, which, having launched a full–scale invasion of our territory, has unleashed the largest war of the 21st century. Firearm and mine–blast injuries account for 57–93% of medical casualties [1]. During the anti–terrorist operation in eastern Ukraine, firearm injuries to the limbs accounted for the vast majority (54%) due to insufficient means of protection. In 60–65% of patients with firearm injuries to the limbs, soft tissue damage was found, primary soft tissue defects were noted in 21.3% of the wounded, 35–40% of them were accompanied by bone fractures, 2–3.9% injuries to major blood vessels, 11–18% to peripheral nerve trunks, and the frequency of combined injuries was 20.8–25%, burns 2–5%, and traumatic shock 8–10% [2].

The problem of treating gunshot fractures of long bones of the extremities remains relevant in modern traumatology and orthopedics, due to their high specific weight (from 35 to 56%) in the structure of combat surgical pathology, the significant severity, complexity, and labor intensity of providing medical care to the wounded during medical evacuation, the high frequency of complications, as well as unsatisfactory anatomical and especially functional results [3]. In the case of reconstructive interventions using autotransplantation of tissue complexes from distant parts of the body, transposition of tissue complexes to replace extensive defects in the covering tissues of the limbs, end surfaces of short stumps of the lower legs, defects in long bones, elimination of large scars, contractures, chronic ulcers, microsurgical suturing of peripheral nerves, major vessels, and restoration of tendons of the hand and fingers, there is a need for accurate and early diagnosis of infectious complications [4]. Among the latest publications on the early diagnosis of infectious complications, there are reports on the successful use of the procalcitonin (PCT) inflammation marker in clinical practice [5]. However, we did not find any publications in the available literature on the use of PCT for the early diagnosis of infectious complications in conversion osteosynthesis of combat injuries of the extremities, which prompted us to conduct this study.

The aim of the study was to determine the possibility of using the PCT inflammation marker in clinical practice in conversion osteosynthesis of combat injuries of the extremities.

Materials and methods

To achieve the research objective, 174 injuries to long bones of the limbs sustained during modern combat operations between 2022 and 2024 were analyzed. All patients who participated in the study were military personnel who were treated at the Chernivtsi Regional Clinical Hospital at the stage of providing qualified medical care after receiving full surgical care at the three previous stages of medical evacuation. They were divided into two groups. Group 1 included 93 patients who underwent

sequential osteosynthesis, accounting for 53.4% of the total sample, and group 2 included 81 patients who underwent single–stage transosseous external osteosynthesis, accounting for 46.6% of the total sample. All patients in the study groups were men, ranging in age from 22 to 49 years, with an average age of (30.5 ± 5.2) years. The study was conducted in accordance with the Helsinki Declaration with the approval of the Ethics Committee of the Ukrainian Scientific and Practical Center for Emergency Medical Care and Disaster Medicine of the Ministry of Health of Ukraine (protocol No. 11 of March 21, 2023). All patients involved in the study signed a voluntary informed consent form to participate in it. All patients who participated in the study were examined using laboratory, radiological, sonographic, and other diagnostic methods.

A nonparametric method was used for statistical processing. Given the large number of analyzed characteristics and the need to ensure uniformity of performance indicators, the method of calculating the polyarchic correlation coefficient proposed by K. Pearson was chosen to make a correct comparison. The calculated values of Pearson's probability criterion were compared with its critical values in Snedecor's tables using a 5% error margin and a degree of freedom k = 1, which is due to the influence of the disjunction law, as mentioned above ( ). The relationship between signs of bone damage in victims with combat trauma to the limbs, studied using this method, was analyzed both within groups and between groups, which made it possible to unify the results of statistical analysis and ensure a correct comparison using the laws of formal logic.

Results

To determine the potential of the PCT inflammation marker in the early diagnosis of infectious complications, its levels in the blood were measured on the 3rd and 14th days of treatment. These dates were chosen taking into account the fact that by the 3rd day of treatment, all patients had undergone primary stabilization of fractures in external fixation devices, and on the 14th day, conversion osteosynthesis was performed, and there was an urgent need to determine the readiness of the injured segment for a change in the osteosynthesis method and early diagnosis of infectious complications. A blood PCT level of less than 0.05 ng/ml is considered the reference level in scientific studies.

According to *Table 1*, 23.7% of patients in group 1 and 24.7% of patients in group 2 had normal and subnormal PCT levels up to 0.1 ng/mL. The rank distribution in both groups was identical. A moderate increase in PCT levels up to 1.0 ng/ml was found in 34.4% of patients in group 1, which corresponded to the second and third places in the rank distribution, and in 35.8% of patients in group 2, whose rank distribution was the same as in group 1. High PCT levels up to 2.0 ng/ml in group 1 were observed in 37.6% of patients, among whom patients with PCT levels of 1.1–1.5 ng/ml accounted for 26.9% and ranked first. In group 2, high PCT levels were observed in 34.5% of patients, but patients with PCT levels of 1.6–2.0 ng/mL predominated, accounting for 22.2% and ranking first. The least common in both study groups were patients with extremely high PCT levels, accounting for 4.3% in group 1 and 4.9% in group 2, ranking last in seventh place.

To determine the reliability of the obtained indicators, a polychoric analysis was performed using Pearson's method (*Table 2*).

Thus, through polychoric analysis, it was established that the indicators are within the confidence interval: χ^2 57.42 ≥ χ^2st 16.8 ($p \leq 0.01$).

According to the data *in Table 3,* there were some changes in the distribution of blood PCT levels in patients in the study groups on the 14th day of treatment. Thus, in group 1, after conversion of osteosynthesis, patients with normal and subnormal PCT levels were in the first and second places, accounting for 51.5% of patients. In group 2, normal and subnormal PCT levels were observed in 34.3% of patients, which is 1.5 times less than in group 1, and they were in third and fourth place. A moderate increase in PCT levels

Table 1. **PKT levels in the blood of patients in the study groups on the third day of treatment**

PCT level, ng/ml	Study group					
	1		Rank	2		rank
	abs.	%		abs.	%	
< 0.05	9	9.7	6	9	11.1	6
0.05 - 0.1	13	14	4	11	13.6	4
0.2 - 0.5	17	18.3	2	17	21	2
0.6 - 1.0	15	16.1	3	12	14.8	3
1.1 - 1.5	25	26.9	1	10	12.3	5
1.6 - 2.0	10	10.7	5	18	22.2	1
≥ 2.1	4	4.3	7	4	4.9	7
Overall …	93	100.0	-	81	100.0	-

Table 2. **Calculated values of the reliability of communication indicators**

Indicator	Value	Probability
Mutual connection φ^2	0.33	+
Polychoric correlation C	0.49	+
Pearson's chi-square test χ^2	57.42	+

Discussion

There remains a huge and growing need to change the subjective, qualitative, and often ineffective approach to combat limb trauma to a quantitative, evidence–based approach that is prognostic, prescriptive, and personalized. Establishing objective global standards for assessing infectious complications and developing algorithms to identify specific interventions that are truly beneficial will enable the development of individualized treatment strategies for patients who need them [6].

Table 3. **PCT levels in the blood of patients in the study groups on the 14th day of treatment**

PCT level, ng/ml	Study group					
	1		Rank	2		rank
	abs.	%		abs.	%	
< 0.05	26	27.9	1	14	17.3	3
0.05 - 0.1	22	23.6	2	13	16	4
0.2 - 0.5	17	18.3	3	19	23.4	2
0.6 - 1.0	14	15	4	20	24.7	1
1.1 - 1.5	8	8	5	8	9.9	5
1.6 - 2.0	5	5	6	4	4.9	6
≥ 2.1	1	1.1	7	3	3.7	7
Total …	93	100.0	-	81	100.0	-

Table 4. **Calculated values of the reliability of communication indicators**

Indicator	Value	Probability
Mutual connection φ^2	0.71	+
Polychoric correlation C	0.64	+
Pearson's chi-square test χ^2	123.54	+

to 1.0 ng/ml occurred in one–third of patients in group 1, which placed them in third and fourth place. Unlike group 1, in group 2, there were significantly more patients with a moderate increase in PCT levels – 48.1%, and they led the ranking, occupying the first and second places.

In 14.0% of patients in group 1, a significant increase in PCT levels to 2 ng/mL was observed. In the rank distribution, they occupied fifth and sixth places. In group 2, such an increase in PCT levels was found in 14.8% of patients, and their rank distribution was the same as in group 1. The least common in group 1 were patients with sharply elevated blood PCT levels ≥ 2.1 ng/mL, accounting for 1.1% and ranking last in seventh place. A similar situation was observed in group 2, but there were three times more patients with extremely high PCT levels, and their rank distribution was identical to that in group 1.

To determine the reliability of the obtained indicators, a polychoric analysis was also performed using Pearson's method (*Table 4*).

Thus, according to the results of the polychoric analysis, these indicators are within the confidence interval: χ^2 123.54 ≥ χ^2st 16.8 ($p \le 0.01$).

Early identification of patients at risk of developing post–traumatic complications is crucial for ensuring early appropriate treatment. Rapid and adequate treatment of infectious complications reduces mortality rates and improves clinical outcomes [7]. Studies of the prognostic value of a number of inflammatory markers have not resulted in a clear identification of a reliable marker [8]. This is particularly true for PCT, the measurement of which in serum has recently attracted interest as a potential and more accurate method for detecting bacterial infection in critically ill patients. PCT is a polypeptide consisting of 116 amino acids produced by C cells of the thyroid gland. In healthy individuals, serum PCT levels do not normally exceed 0.05 ng/mL. In response to bacterial endotoxins or proinflammatory cytokines such as interleukin–6 and tumor necrosis factor alpha, various cell types outside the thyroid gland produce PCT, leading to a 1000–fold increase in its levels. Such an increase in PCT levels occurs in severe inflammation, including systemic infection and particularly severe sepsis, with higher levels of this marker being associated specifically with severe sepsis [9]. Most importantly, a decrease in PCT levels is potentially associated with recovery. Given these unique characteristics and reliable kinetics, PCT is considered a promising biomarker. This has led to the assumption that measuring serum PCT levels may be a better method than measuring previously studied biomarkers for diagnosing sepsis, monitoring its course and severity, and guiding antibiotic therapy [10]. Since its first

description in 1993, many authors have reported a strong and generally consistent association between serum PCT levels and the subsequent clinical course of severe trauma. An early increase in PCT levels is associated with the severity of trauma and the extent of tissue damage. Patients with trauma and sepsis caused by systemic inflammatory response syndrome have elevated initial PCT levels. However, PCT levels are only slightly elevated in non–infectious systemic inflammatory response syndrome. Significantly elevated PCT levels correlate with a substantially increased risk of infectious complications [11]. According to the results of observational studies, in most patients with non–infectious systemic inflammatory response syndrome, the level of PCT mediated by the inflammatory process ranged from 0.3 to 0.8 ng/mL, while in patients with sepsis of any origin in the intensive care unit, they ranged from 4.5 to 12.0 ng/mL. In addition, a rapid decrease in PCT levels to normal values most often indicates recovery from systemic inflammation/infection. Therefore, under these circumstances, the initial peak blood PCT level can reliably differentiate between infectious and non–infectious systemic inflammatory response syndrome in trauma patients, demonstrating the advantages of PCT over other biomarkers such as C–reactive protein and interleukin–6 [12]. Since elevated PCT levels usually precede the onset of clinical symptoms, this allows infection to be detected earlier than with conventional standard methods. Four studies have failed to demonstrate a link between PCT levels and the development of sepsis. The variability in results may be due to inconsistencies in the interpretation of sepsis and the lack of a consensus "gold standard" for defining infection as such [13]. This could have led to the misclassification of potentially infected patients who had no clinical signs or whose bacterial cultures were negative as having systemic inflammation. P. Feng and co–authors [14] used only the PCT measurement to predict the development of infection. However, since the complexity of the immune response after trauma is influenced by factors specific to both the patient and the trauma, it may not be possible to adequately predict its clinical course based on a single parameter.

Conclusions

1. The use of the PCT inflammation marker is appropriate in the early diagnosis of infectious complications in patients with combat trauma to the extremities.

2. After conversion osteosynthesis, PCT levels decreased sharply, indicating its role in the early diagnosis of infectious complications in patients with combat trauma to the extremities.

3. The use of blood PCT level measurement is promising in clinical practice when converting the osteosynthesis method.

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Conflict of interest. None.

Consent to publish. All authors have read the final version of the article and agreed to its publication.

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