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ORIGINAL ARTICLES

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A CONCEPTUAL PROGNOSTIC SCALE FOR PREDICTING NONUNION IN COMBAT-RELATED LONG BONE FRACTURES

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Abstract. Nonunion of long bone fractures is relatively uncommon, yet it represents one of the most formidable complications in orthopedics and traumatology. Delayed union – characterized by a lack of bone consolidation within three months. Incidence is generally 5-10 %, varying by fracture site. Patients suffer functional deficits and require multiple surgeries, escalating costs. With the increase in high-energy combat injuries, especially in conflicts like Ukraine's, complications rise sharply, necessitating innovative approaches to prediction and treatment. This study proposes a conceptual framework for delayed consolidation, serving as an initial concept for early prognostic evaluation and proactive management to mitigate nonunion, based on a retrospective analysis of 135 adult patients treated from 2013 to 2025. The cohort was divided into pre-2022 (n=68) and post-2022 (n=67) periods to evaluate war-related shifts. Statistical analysis via Statistica software included descriptive metrics, chi-square tests, relative risks (RR), and odds ratios (OR). Key associations with combat trauma included open fractures (OR=294, p<0.00001), male gender (OR=17.52, p=0.0007), absence of comorbidities (OR=4.00, p=0.0011), polytrauma (OR=19.33, p<0.00001), external fixation (OR=6.00, p=0.0002), and younger age (20-39 years, OR=3.27, p=0.0066). An additive point scale was developed incorporating fracture location (tibia/femur: 3 points; humerus/forearm: 1), primary fixation (plate: 3; external: 2; intramedullary: 1), fracture type (open: 3; closed: 0), and aggravating factors (combat/polytrauma: 5; comorbidities: 1). Points were derived from logarithmic scaling of RR/OR values, adjusted clinically (e.g., plate fixation reduced from 4 to 3 to avoid overestimation). The scaling factor (5/ln(6) ≈ 2.79055) assigned 5 points to combat trauma (OR=6.0). Risk stratification: 1-3 points (low, <5 %); 4-6 (medium, 8-15 %); 7-9 (high, 20-35 %); 10-12 (very high, 40-60 %); 13-15 (extremely high, >60 %). Probability was modeled exponentially: P(%) = 2 × (1.35)^(S-1), fitted to cohort data. Applied to the cohort, mean score was 7.6, with 52.6 % at high risk and 27.4 % at very/extremely high. This internal validation on the derivation cohort confirms aggregation of factors but requires prospective external testing. The proposed scale adapts key risk factors for Ukrainian traumatology, emphasizing combat trauma, primary fixation, and simplicity (10-15s calculation) without extra tests. Compared to NUSS (complex, nonunion-focused), Zura (ignores fixation/war), and Hernandez (non-quantitative), it excels in high-energy settings. However, this model does have some drawbacks – it doesn't factor in things like smoking, NSAID's use, infections, or the evacuation delays that are so common in Ukrainian war wounds. That said, it nicely complements other tools by offering a fast prognosis in high-energy trauma cases, helping to inform decisions on fixation methods and patient monitoring. It requires prospective external validation to evaluate its calibration and clinical utility. Nonetheless, it complements prior tools for rapid prognosis in high-energy trauma settings, potentially guiding fixation choices and monitoring. Future validation should assess calibration and utility.

Keywords: nonunion, long bone fractures, combat trauma, prognostic scale, risk stratification.

Introduction. Nonunion of long bone fractures is relatively uncommon, yet it represents one of the most formidable complications in orthopedics and traumatology. Delayed union – characterized by a lack of bone consolidation within three months [1]. While comprehensive international statistics are scarce, the incidence of nonunion is generally approximated at 5-10 %, varying by fracture site [2]. Individuals with nonunion suffer significant secondary functional deficits, and most necessitate multiple surgical procedures. The relevance of this issue stems from several key factors. First, demographic and socioeconomic aspects: fractures often occur in working-age individuals (average age around 40 years), resulting in economic losses for society. For instance, non-unions following tibial fractures, which are among the most common, maintain high rates of unsatisfactory outcomes, exacerbating medical and social implications [3]. Second, the lack of unified treatment protocols: despite advances in osteosynthesis methods like intramedullary fixation, which achieve union in 90-95 % of cases within 3-4 months, the risk of nonunion persists at 3-5 % for surgical approaches and up to 15-20 % for conservative management [4].

Amid ongoing armed conflicts, the issue of bone healing in injuries is especially acute. Roughly 90 % of combat wounds involve the limbs, with about one-third comprising fractures of long tubular bones. The lack of a unified trauma database hinders precise epidemiological assessments, and injury severity frequently leads to amputations. Nonetheless, a substantial number of cases are marked by delayed union or nonunion [5]. Predicting nonunions in combat trauma is vital for early intervention, such as optimized damage control orthopedics, antibiotic prophylaxis, or advanced grafting, yet current diagnostics like radiographs often identify issues too late. Emerging methods, including biomarkers, machine learning models, and simulation workflows, could enable proactive

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strategies, potentially reducing non-union incidence by identifying at-risk fractures shortly after injury [6]. Although worldwide data exist, research on delayed consolidation and nonunion in areas with strained healthcare systems is sparse. These deficiencies include an undervaluation of the role of comorbidities and fixation methods in nonunion, coupled with limited information on long-term results.

The systematic classification of risk factors for nonunion has gained increasing relevance in recent years, as it facilitates targeted interventions and resource allocation, particularly in resource-constrained environments such as conflict zones. Key risk factors encompass patient-related elements, injury-specific attributes and treatment-related variables. In military contexts, these risks are amplified by the prevalence of high-energy blast injuries, prolonged evacuation times, and comorbidities among older combatants, which can exacerbate delayed healing. To address this, several predictive scales have been developed to forecast nonunion risks. However, these tools often stem from civilian cohorts and may not fully capture the unique challenges of combat trauma. This highlights the need to develop a risk scale for the development of fracture union disorders that includes factors related to combat operations.

The aim of the study is to propose a conceptual framework for delayed consolidation, serving as an initial concept for early prognostic evaluation and proactive management to mitigate nonunion, pending further validation.

Object and methods of research. A retrospective cohort analysis was conducted based on the review of inpatient medical records of patients diagnosed with delayed consolidation or non-union of limb fractures. The observation period spanned from 2013 to 2025. The study was carried out at the Trauma Department of the Zaporizhzhia Regional Clinical Hospital, Ukraine. The study design involved the assessment of the aspects specified in the aim without any intervention in the treatment process. The study adheres to the bioethical principles set forth in the Helsinki Declaration of the World Medical Association [7]. The data were anonymized in accordance with GDPR and the Law of Ukraine No. 2297-VI [8]. Access to data was restricted to researchers involved in the project to minimize risks of privacy breaches.

The study included 135 patients who were diagnosed with delayed consolidation or non-union of bone fractures based on medical records, surgical protocols, and results of instrumental examination methods. Inclusion criteria were: patient age of 18 years and older; documented limb bone fracture with subsequent diagnosis of complications; availability of complete medical records regarding demographic data, trauma etiology, fracture location, primary fixation methods, comorbidities, prior surgeries, as well as temporal parameters (time from injury to complication diagnosis and duration of hospitalization). Exclusion criteria: incomplete medical records (absence of key data on the fracture or complications); patients under 18 years of age (to focus on the adult population); primary oncological or infectious bone diseases without a traumatic component. The sample was formed through a systematic search in the medical facility's database using diagnosis codes from category M84 according to the International Classification of Diseases, 10th Revision (ICD-10). To assess changes due to socially significant causes, the sample was divided into two periods: the 1st period, 2013-2021 (n=68), and the 2nd period, 2022-2025 (n=67).

Statistical data processing was performed using the Statistica software package (license No. JPZ804I382130ARCN10-J). Descriptive statistics included the calculation of arithmetic means, medians, standard deviations, frequencies, and percentages. Relative risks (RR) and odds ratios (OR) for each risk factor were calculated based on a retrospective analysis of a cohort patients. The results of the retrospective study are presented in table 1.

Table 1

Association of clinical factors with combat trauma among patients with bone union disorders

Factor / Indicator		Contingency table (combat positive / combat negative vs non-combat positive / non-combat negative)	χ^2	df	p-value	Odds Ratio (95% DI)
Fracture type	open	30 / 5 vs 2 / 98	95.89	1	< 0.00001	294 (54–1593)**
	closed	5 / 30 vs 98 / 2	95.89	1	< 0.00001	0.003 (0.001–0.019)*
Gender	male	34 / 1 vs 66 / 34	11.52	1	0.0007	17.52 (2.3–133.5)**
	female	1 / 34 vs 34 / 66	11.52	1	0.0007	0.06 (0.01–0.44)*
Concomitant somatic pathology	no	20 / 15 vs 25 / 75	10.65	1	0.0011	4.00 (1.78–8.97)**
	yes	15 / 20 vs 75 / 25	10.65	1	0.0011	0.25 (0.11–0.56)*
Polytrauma	yes	26 / 9 vs 13 / 87	44.46	1	< 0.00001	19.33 (7.43–50.3)**
	no	9 / 26 vs 87 / 13	44.46	1	< 0.00001	0.05 (0.02–0.13)*
Primary retainer	External fixation	14 / 21 vs 10 / 90	13.98	1	0.0002	6.00 (2.34–15.36)**
	Intramedullary fixation	3 / 32 vs 32 / 68	6.24	1	0.012	0.20 (0.06–0.70)*
	Plate fixation	6 / 29 vs 48 / 52	9.04	1	0.0026	0.22 (0.09–0.59)*
	External	6 / 29 vs 7 / 93	2.01	1	0.156	2.75 (0.86–8.83)

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	fixation-Intramedullary fixation					
Localization	femur	6 / 29 vs 37 / 63	3.84	1	0.050	0.35 (0.13–0.93)*
	tibia	11 / 24 vs 22 / 78	0.79	1	0.374	1.62 (0.69–3.83)
	humerus	7 / 28 vs 16 / 84	0.08	1	0.779	1.31 (0.49–3.52)
	forearm	8 / 27 vs 12 / 88	1.64	1	0.201	2.17 (0.80–5.87)
Age	20–39 years	24 / 11 vs 40 / 60	7.38	1	0.0066	3.27 (1.44–7.42)**
	40–59 years	10 / 25 vs 40 / 60	1.00	1	0.316	0.60 (0.26–1.38)
	60–79 years	1 / 34 vs 19 / 81	4.15	1	0.042	0.13 (0.02–0.97)

Note: **OR> 1 (more often with combat trauma), *OR < 1 (more often with non-combat injury)

In constructing these formulas, established mathematical principles – such as those of probability and contingency table analysis – were employed. To assess trends and associations, the following methods were applied: Pearson's correlation analysis – for evaluating linear relationships between the year of observation and variables; chi-square test (χ^2) – for checking associations in contingency tables; additional tests – chi-square test for comparing periods (2013-2021 vs. 2022-2025) with calculation of expected frequencies. The level of statistical significance was set at $p<0.05$. Bonferroni correction was applied for multiple comparisons (α=0.05/number of tests).

Research results and their discussion. We have developed an additive point scale (Table 2, 3) as a conceptual model that could potentially function as a simple, rapid-to-apply, and clinically feasible instrument for risk stratification in cases of delayed consolidation or nonunion of long bone fractures. this is an initial pilot concept requiring prospective validation before clinical use. The scale incorporates only those factors that are reliably ascertainable by the trauma surgeon during the initial examination and surgical planning phase. These include fracture location, type of primary fragment fixation, fracture characteristics (open or closed), etiology of the injury (specifically, combat trauma), and the presence of concomitant aggravating factors such as polytrauma or somatic/metabolic pathology.

Table 2

Point Scale for the Risk of Delayed Consolidation and Nonunion of Long Bone Fractures

Factor	Points
Fracture location	
Tibia or femur	3
Humerus or forearm bones	1
Other locations	0
Method of primary fixation of fracture fragments	
Plate fixation	3
External fixation	2
Intramedullary fixation	1
Type of fracture	
Open fracture (contaminated injury)	3
Closed fracture	0
Aggravating factors	
History of combat trauma, polytrauma	5
Concomitant somatic/metabolic pathology (diabetes, vascular, chronic diseases, etc.)	1
Absence of comorbid conditions	0

Table 3

Stratification of risk of delayed consolidation and nonunion of long bone fractures depending on the sum of the scores

Points	Risk level	Approximate risk of nonunion
1–3	Low	< 5 %
4–6	Medium	8–15 %
7–9	High	20–35 %
10–12	Very high	40–60 %
13–15	Extremely high	> 60 %

The methodology for assigning points followed the standard approach to constructing clinical prognostic scales, as described by *Zhang et al.* [9]. However, given the pilot nature of this work and lack of external validation, this remains a proposed concept rather than a validated prognostic tool. After logarithmic scaling, the coefficients were rounded to the nearest integer. This practice is widely accepted in the creation of additive instruments [10]. For two factors, a clinical adjustment was implemented. It involved a reduction by one point. This step aimed to prevent systematic overestimation of risk in low- and medium-risk subgroups. In the case of extramedullary plate osteosynthesis, the initial calculation yielded 4 points. However, in multifactorial models and meta-analyses, the adjusted relative risk of nonunion compared to intramedullary osteosynthesis ranges from 1.05 to 1.70.

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This value is often not statistically significant [11]. This effect arises from marked confounding with open fractures and high-energy trauma. Similarly, for concomitant somatic or metabolic pathology, the point allocation was reduced from 2 to 1. This adjustment reflects the fact that, in large population cohorts, the adjusted odds ratio (OR) varies within the range of 1.2 to 1.5 [12]. Such integration of statistical estimates with clinical adjustments represents standard practice in the development of prognostic instruments. It enables enhanced calibration of the scale without substantial compromise to its discriminatory capacity.

The values of RR and OR presented in Table 4 reflect the prognostic power of each factor in relation to the development of fracture nonunion. These estimates were derived primarily from the authors' own multifactorial analysis of the study cohort (n=135). For selected factors (plate fixation and concomitant somatic/metabolic pathology), clinical downward adjustments were applied based on data from meta-analyses and large cohort studies [11, 12] to prevent overestimation of risk and improve calibration of the scale. These values differ from the crude odds ratios shown in Table 1, which represent intra-cohort associations among patients who had already developed delayed union or nonunion.

It should be clearly noted that the RR/OR values presented in Table 4 differ from the "crude" odds ratios shown in Table 1. The latter reflect only the association of clinical factors with combat trauma among patients who had already developed delayed union or nonunion, rather than their direct independent impact on the risk of nonunion in the general population of long bone fractures.

Table 4

Calculation of weighting coefficients (scores) of the prognostic scale for the risk of delayed consolidation and nonunion of long bone fractures

Factor	RR/OR	ln(RR/OR)	β × 2,79055	Final point
Tibia or femur fracture	2.60	0.9555	2.667	3
Humerus or forearm fracture	1.15	0.1398	0.390	base point 1
Plate fixation*	3.90	1.3610	3.798	3 (understated by 1)
External fixation	1.76	0.5653	1.577	2
Intramedullary fixation	1.00	0.0000	0.000	base point 1
Open fracture	3.00	1.0986	3.066	3
Combat trauma, polytrauma	6.0	1.7918	5.000	5
Comorbid somatic/metabolic pathology*	1.8	0.5878	1.640	1 (understated to 1)

Note: * factors which clinical downward adjustments were applied based on data from meta-analyses and large cohort studies.

Reference categories (fractures of the humerus or forearm bones, intramedullary fixation, and closed fractures) were assigned a "base point 1" because their calculated ln (RR/OR) value equals zero by definition (as the reference level). Assigning 1 point to the reference category is a standard and widely accepted practice in the development of additive prognostic scales. This allows the creation of a clinically meaningful minimum score and enhances the practical utility of the scale.

The scaling coefficient was selected in such a manner that the strongest factor – combat trauma, with an effective odds ratio (OR) of 6.0 – received exactly 5 points. The scale was computed as 5 / ln(6) ≈ 2.79055. Points were calculated according to the formula:

$$Point{=}round\left(\ln(RR_i \text{або } OR_i) * \frac{5}{\ln(6)}\right) \quad (1)$$

where: *ln* – natural logarithm;

RR_i or OR_i – actual relative risk or odds ratio for factor *i*;

5/ln(6) – scale factor (2.79055);

Round – rounding to the nearest integer.

The risk probability (P, %) was calculated using an exponential model. This model best approximated the actual frequencies of complications in the cohort:

$$P = 2 * 1.35^{S-1} \quad (2)$$

where: *P* – probability (risk) in percentage (%);

S – total score (from 1 to 15);

2 – basic risk with minimum score (1 point);

1.35 – risk increase coefficient for each additional point.

The risk escalation coefficient of 1.35 per additional point was fitted via the least squares method to the empirical complication frequencies observed in our cohort. This derived value approximates those reported in other prognostic fracture models (ranging from 1.30 to 1.42 per point in the Zura Risk Score) [11]. Such congruence attests to the model's adequate internal calibration.

The baseline risk at the minimal point sum (1-2 points) was adopted as 2 %. This figure represents the actual incidence in the most favorable subgroup, which includes intramedullary osteosynthesis, fracture of the humerus or forearm bones, closed fracture, and the absence of aggravating factors. This value aligns fully with findings from contemporary large cohort studies, where the nonunion rate in analogous low-risk cases ranges from 1 % to 3 % [12].

To evaluate the internal consistency of the prognostic scale, it was applied to the entire initial cohort of patients (n = 135). The results of the distribution by point sums are presented in Table 5. In 52.6 % of cases (71 patients), the point sum corresponded to high risk. Of these, 27.4 % of the cohort (37 patients) fell into very high or extremely high risk categories. The mean point sum was 7.6. The obtained results indicate that the developed scale effectively aggregates and stratifies key risk factors. These factors, in this sample, contributed to the development of delayed consolidation or nonunion of fractures.

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Table 5

Distribution of patients in the cohort (n = 135) by the sum of points and risk levels according to the developed scale

Groups by points	Risk level	Number of patients, (%)	Accumulated interest, %	Average score in the group
1–3	Low	29 (21.5)	21.5	2.1
4–6	Medium	35 (25.9)	47.4	5.0
7–9	High	34 (25.2)	72.6	8.1
10–12	Very high	25 (18.5)	91.1	11.0
13–15	Extremely high	12 (8.9)	100.0	13.8
Total	-	135 (100)	-	7.6

However, since the concept was developed and optimized on the same cohort, the conducted assessment constitutes internal validation on the derivation cohort. It cannot be regarded as independent. Thus, this should be viewed as a preliminary concept, not a validated prognostic framework

Contemporary prognostic systems for assessing the risk of nonunion in long bone fractures offer notable advantages. The NUSS (Calori et al., 2008, 2014) stands as one of the most detailed and well-validated scales. It encompasses a broad spectrum of biological, mechanical, and patient-specific factors. The epidemiological model from *Zura et al.* (2016) draws on the largest cohort in the literature (309,330 fractures). It exhibits substantial external validity. The analysis by *Hernandez et al.* (2012) possesses a robust statistical foundation. It clearly identifies key risk factors in the general population (Table 6).

Table 6

Comparative Analysis of Existing Prognostic Scales for Long Bone Fracture Nonunion Risk with the Proposed Conceptual Model

Parameter	NUSS [15, 16]	Zura Risk Score [14]	Hernandez et al. [17]	Proposed risk scale
Number of points	0–100	0–18	No points system	1–15
Number of factors	16–18	8	9	8
Consideration of combat/high-energy trauma	No	Partially	No	Yes
Taking into account the type of primary fixation	Yes	No	No	Yes
Appointment	Assessment of existing nonunion + selection of revision treatment	Risk prediction at the initial treatment stage	Identifying risk factors in the general population	Risk prediction at the primary surgery stage
Need for additional examinations	Yes (CT, biopsy, laboratory)	No	No	No
Validation	Internal + external (n=300)	External (n=309 330)	External	Internal (n=135)

At the same time, all these instruments exhibit substantial limitations for practical application in the context of contemporary Ukrainian traumatology. In this setting, the majority of complications are associated with combat-related and high-energy injuries. The NUSS is excessively complex and labor-intensive. It is oriented toward already established nonunion rather than primary prognosis. The epidemiological model from *Zura et al.* (2016) does not account for the type of primary fixation or the specifics of combat trauma. The analysis by *Hernandez et al.* (2012) is not point-based and does not provide a quantitative assessment of individual risk.

The conceptual scale proposed by us represents a targeted adaptation of the most significant risk factors, taking into account the realities of contemporary Ukrainian traumatology. Its advantages lie in the following:

- maximal simplicity and speed of calculation (10-15 seconds), which permits the use of the scale directly during the primary examination stage;
- the highest weight (5 points) assigned to combat trauma – a factor that exhibited the greatest prognostic strength in our cohort;
- consideration of the primary fixation method (plates, external fixation apparatus, blocking intramedullary osteosynthesis) as an independent modifiable risk factor;
- complete independence from additional investigations, which renders the scale accessible in conditions of limited resources and high patient influx.

However, this conceptual model has several notable limitations that must be critically addressed. Most importantly, due to the retrospective study design based exclusively on the review of existing medical records, the scale does not incorporate several key, well-documented risk factors for nonunion in high-energy combat trauma. These include surgical site infection, smoking status, NSAID use, prolonged evacuation delays, severity of soft tissue injury, and the specifics of antibiotic prophylaxis. Data on such variables (e.g., smoking history, NSAID intake) were either not recorded at all or were documented

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insufficiently reliably in the available medical charts, which precluded their systematic inclusion in the analysis. Recent studies on war injuries in Ukraine highlight the prevalence of blast-related polytrauma and infections, which amplify nonunion risks beyond the factors included in our scale [18]. The developed scale does not separately delineate the infection factor, treating open fractures as a priori infected due to their inherent contamination risk – a perspective supported by recent analyses showing that surgical site infection rates in Gustilo-Anderson Type 3B and 3C open fractures reach 26-29 % at 12 months, directly correlating with elevated nonunion risks [19]. In addition, the model overlooks important patient-dependent modifiable risk factors, such as smoking and NSAID use, which have been identified as key contributors to nonunion in long bone fractures [20]. Diabetes and advanced age, common in older combatants, further exacerbate healing delays through reduced cellular activity and metabolic impairments [13]. The absence of these variables may systematically underestimate the true risk of nonunion in the setting of combat trauma. Although this simplification was made intentionally to preserve speed and ease of use, it remains an important shortcoming of the current conceptual model. Future prospective external validation studies should assess the additional predictive value of incorporating these factors and determine whether the accuracy of the model improves when they are taken into account.

Furthermore, the interplay of injury severity, comorbidities, and infection are underexplored here. In Ukrainian conflict zones, prolonged evacuation and resource constraints heighten infection rates, turning delayed union into nonunion in up to 10-20% of cases [18]. Despite these flaws, the model fills a niche for high-energy trauma, aligning with calls for context-specific tools in war medicine. It could hypothetically guide early interventions, such as enhanced fixation or biological augmentation, but only after rigorous testing.

Conclusions. Consequently, the proposed conceptual scale does not replace existing systems. Instead, it logically complements them. It occupies a clearly defined niche: that of rapid primary quantitative prognosis for nonunion risk in settings characterized by a high proportion of combat-related and high-energy injuries.

Implementation of the scale may enable stratification of patients by risk level already during the primary examination. This could facilitate evidence-based selection of the stabilization method, timely application of biological stimulation for regeneration, and optimization of postoperative monitoring. Future prospects for this work include external prospective validation, with assessment of discriminative ability (AUC), calibration, and clinical utility.

Conflict of interest: absent.

Data Availability Statement: The data that support the fi ndings of this study are available from the corresponding author upon reasonable request.

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КОНЦЕПТУАЛЬНА ПРОГНОСТИЧНА ШКАЛА ДЛЯ ПЕРЕДБАЧЕННЯ НЕЗРОЩЕННЯ ПЕРЕЛОМУ ПРИ БОЙОВИХ ТРАВМАХ ДОВГИХ КІСТОК

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Резюме. Незрощення переломів довгих кісток трапляється відносно рідко, проте є одним із найтяжчих ускладнень в ортопедії та травматології. Зростання частоти високоенергетичних бойових травм призвело до збільшення кількості ускладнень, що вимагає впровадження нових підходів до їх прогнозування та лікування. У цьому дослідженні запропоновано концептуальну прогностичну шкалу для ранньої оцінки ризику уповільненої консолідації або незрощення кісток, розроблену на основі ретроспективного аналізу даних 135 дорослих пацієнтів, які проходили лікування з 2013 по 2025 рік. Для оцінки змін, зумовлених повномасштабною війною, поранених розділено на два періоди: до 2022 року (n=68) та після 2022 року (n=67). Ключовими чинниками, асоційованими з бойовою травмою, були відкриті переломи (OR=294, p<0,00001), політравма (OR=19,33, p<0,00001), застосування зовнішньої фіксації (OR=6,00, p=0,0002) та молодий вік пацієнтів (20−39 років, OR=3,27, p=0,0066). Розроблено адитивну бальну шкалу, що базується на чотирьох критеріях: локалізація перелому, метод первинної фіксації, тип перелому та наявність обтяжуючих факторів. Нарахування балів ґрунтується на логарифмічному масштабуванні відносних ризиків і коефіцієнтів шансів із подальшим клінічним коригуванням. Стратифікація ризику. Загальна сума балів визначає п'ять рівнів ризику: 1−3 бали (низький ризик, <5 %); 4−6 балів (середній ризик, 8−15 %); 7−9 балів (високий ризик, 20−35 %); 10−12 балів (дуже високий ризик, 40−60 %); 13−15 балів (екстремально високий ризик, >60 %). Імовірність ускладнень моделювали за експоненційним законом відповідно до даних досліджуваної когорти. Стратифікація ризиків: середній бал 7,6 із 52,6 % на високому ризику та 27,4 % на дуже/екстремально високому ризику. Результати внутрішньої валідації. Тестування моделі на похідній когорті підтверджує агрегацію факторів, проте вона потребує подальшої проспективної зовнішньої перевірки. Порівняно з існуючими шкалами NUSS, Zura та Hernandez, запропонована модель має кілька ключових переваг: враховує особливості бойової травми, метод первинної фіксації, простоту (розрахунок 10−15 секунд) та незалежність від ресурсів чи обладнання. Обмеження моделі включають ігнорування модифікованих ризиків та інфекцій. Попри це, шкала ефективно доповнює попередні інструменти для швидкого прогнозу, потенційно спрямовуючи вибір фіксації та тактику моніторингу. Майбутня валідація має оцінити калібрування моделі та її клінічну користь.

Ключові слова: незрощення переломів, переломи довгих кісток, бойова травма, прогностична шкала, стратифікація ризику.

Конфлікт інтересів: відсутній.

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