ORIGINAL ARTICLE

CONTENTS

Blastotrauma: Concept and development of the blast trauma severity scale (BTSS) for explosion-related injuries

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ABSTRACT

Aim: This study set out to develop and substantiate the concept of blastotrauma as a distinct category of traumatic pathology, to introduce the Blast Trauma Severity Scale (BTSS) for evaluating the severity of explosion-related injuries, and to show how the scale can be applied clinically in patients with combat-related trauma.

Materials and Methods: The study followed a retrospective observational design, drawing on archived clinical records of patients with combat-related injuries treated between 2023 and 2025. A total of 70 patients with blast and explosion-associated trauma qualified for inclusion. To enable consistent severity grading, the Blast Trauma Severity Scale (BTSS) was developed around five domains: soft tissue injury, bone injury, neurovascular injury, internal organ injury, and physiological response.

Results: The study introduces blastotrauma as a complex pattern of morphological and physiological damage arising when explosive energy is transferred to human tissues. The BTSS delivers an integrated severity score from 0 to 20 points, organised into four grades. Assessment can be further refined by appending the dominant blast-injury mechanism descriptor (P/S/T/Q). Applying the scale to the study cohort confirmed that consistent, standardized stratification of blast injuries is achievable in clinical practice.

Conclusions: The blastotrauma concept and the BTSS classification offer a practical framework for standardized description of explosion-related injuries, clinical stratification of patients, and continued research in trauma and military medicine.

KEY WORDS: combat trauma, military medicine, wound assessment

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INTRODUCTION

Modern armed conflicts have seen the extensive deployment of explosive devices, resulting in a large number of blast-related injuries. Such injuries are inherently complex, as they arise through several simultaneous mechanisms, including the pressure wave, fragmentation, blast wind displacement, and secondary environmental factors [1–3]. In clinical settings, they rarely present in isolation; combined injury patterns are the norm, resulting in diverse morphological changes and systemic disturbances. When explosive energy is transferred to human tissues, the resulting damage involves multiple organs and systems: barotrauma, fragment wounds, bone fractures, extensive soft tissue loss, internal organ injury, and systemic physiological compromise are all well documented [4–6]. This injury profile differs substantially from classical mechanical trauma, which necessitates classification and severity assessment approaches tailored specifically to blast injuries.

Injury severity in traumatology is commonly assessed using tools such as the Abbreviated Injury Scale (AIS) and the Injury Severity Score (ISS). However, these systems were developed for general trauma contexts and do not capture the specific mechanisms and pathophysiological features that define blast injuries [7–9].

Blast injuries have traditionally been grouped into four mechanisms: primary injuries from the pressure wave; secondary injuries caused by fragments; tertiary injuries from blast wind displacement of the body; and quaternary injuries such as burns and inhalation damage [2, 10–12]. When these forces act together, the resulting injury patterns are too complex for conventional scoring systems to adequately reflect. Given the distinctive mechanisms and specific clinical features of explosion-related trauma, treating these injuries as a separate category of traumatic pathology is well justified. Against this background, the present study pro-

poses the term "blastotrauma" to describe the complex injury spectrum produced by the transfer of explosive energy to human tissues. Without a unified severity assessment system, comparison of outcomes across studies of blast injury is difficult, and the development of standardised treatment protocols remains limited. To address this gap, the present study introduces the Blast Trauma Severity Scale (BTSS), a classification designed to improve consistency in the description of blast-related injuries and to support clearer clinical stratification of patients.

AIM

The study aimed to develop and substantiate the concept of blastotrauma as a distinct category of traumatic pathology, to introduce the Blast Trauma Severity Scale (BTSS) for grading the severity of explosion-related injuries, and to demonstrate its practical clinical application in a cohort of patients with combat-related trauma.

MATERIALS AND METHODS

The study used a retrospective observational design, analysing archived clinical records of patients who sustained combat-related injuries and received treatment between 2023 and 2025.

Data were obtained from electronic medical registries of patients with combat-related trauma. Each record contained information on the date of admission, mechanism of injury, clinical diagnosis, injury localisation, and therapeutic interventions performed.

Over the study period, 359 patients with combat-related injuries were recorded in the registry. From this cohort, 70 patients were identified whose records contained sufficient clinical detail to characterise injury type and severity and to apply the proposed classification system.

INCLUSION CRITERIA

Inclusion required all of the following:

1. presence of trauma sustained as a result of combat-related events;
2. availability of clinical information describing the injury;
3. sufficient data for the assessment of injury severity.

EXCLUSION CRITERIA

Patients were excluded if they had:

1. incomplete clinical data;
2. absence of information describing the injuries;
3. duplicated records within the registry.

TRAUMA SEVERITY ASSESSMENT

To bring consistency to blast injury evaluation, the Blast Trauma Severity Scale (BTSS) was developed. The scale covers morphological damage—soft tissue injuries, bone injuries, neurovascular injuries, and internal organ injuries—together with physiological disturbances, integrating both into a single assessment.

Each of the five domains is scored from 0 to 4 points, giving a maximum cumulative total of 20 points.

The total score maps onto four severity grades:

- Grade I (0-4 points) - mild injury;
- Grade II (5-8 points) - moderate injury;
- Grade III (9-13 points) - severe injury;
- Grade IV (14-20 points) - critical injury.

STATISTICAL ANALYSIS

Standard descriptive statistical methods were applied. Quantitative variables are reported as absolute values and relative frequencies (%). The analysis was designed to evaluate whether the proposed BTSS could be applied consistently and meaningfully to a real clinical cohort.

ETHICS

All work was carried out in compliance with the ethical principles of the Declaration of Helsinki of the World Medical Association for research involving human subjects. The study protocol was reviewed and approved by the Commission on Bioethical Expertise and Ethics of Scientific Research at Bogomolets National Medical University.

Because the study design was retrospective and relied entirely on archived clinical records, all patient data were fully de-identified and anonymised prior to analysis. No additional informed consent was required, as the study did not involve new interventions, prospective data collection, or the use of identifiable patient information beyond routine clinical documentation obtained during standard patient care.

RESULTS

CONCEPT OF BLASTOTRAUMA

Explosion-related injuries constitute a distinct and complex form of traumatic pathology arising from the transfer of explosive energy to human tissues. What distinguishes them from ordinary mechanical trauma is the concurrent action of multiple injury mechanisms, which together produce complex morphological and physiological damage patterns [1–3].

Four principal mechanisms are recognised: primary injuries from the blast wave; secondary injuries caused

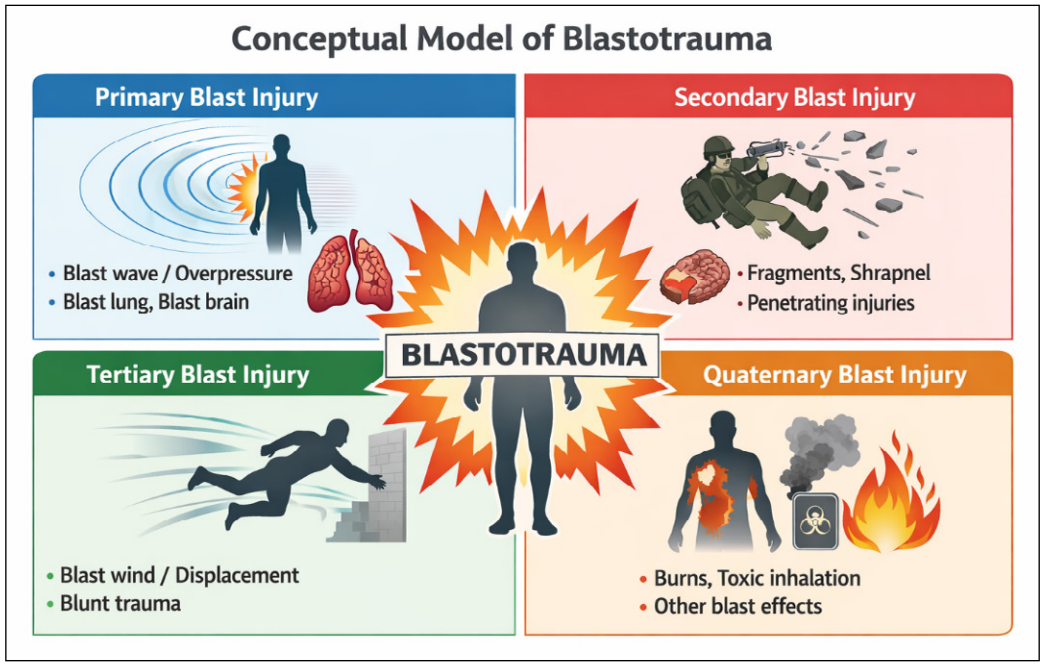

Fig. 1. Conceptual model of blastotrauma formation
Picture taken by the authors

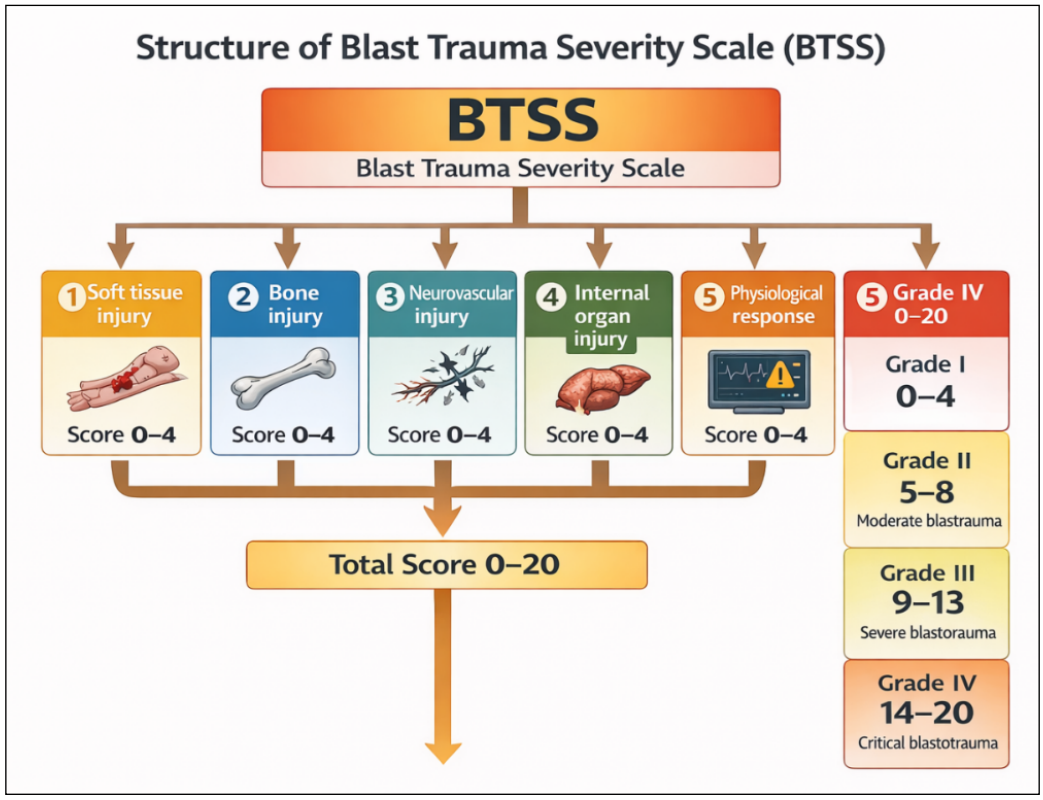

Fig. 2. Structure of the Blast Trauma Severity Scale (BTSS)
Picture taken by the authors

by fragments and debris; tertiary injuries resulting from body displacement by blast wind; and quaternary injuries, including burns, inhalation damage, and other environmental effects [2, 10–12].

Acting in combination, these mechanisms can produce virtually any combination of barotrauma, fragment wounds, bone fractures, extensive soft tissue defects, internal organ damage, and systemic physiological disturbance—a spectrum far broader than that observed in conventional trauma.

Given these specific mechanisms and the distinctive clinical presentation of explosion-related trauma, classifying such injuries as a separate category of traumatic pathology is well justified. The present study therefore introduces the term blastotrauma to denote the complex injury pattern produced when explosive energy interacts with human tissues through multiple simultaneous mechanisms.

Blastotrauma may accordingly be defined as a complex injury pattern arising from the interaction of multiple blast injury mechanisms, characterised by

Table 1. Blast Trauma Severity Scale (BTSS)

Domain	Score	Description
Soft tissue injury	0	No soft tissue injury
	1	Superficial wound
	2	Moderate soft tissue defect
	3	Extensive soft tissue damage
	4	Massive tissue destruction
Bone injury	0	No fracture
	1	Simple fracture
	2	Comminuted fracture
	3	Segmental fracture
	4	Critical bone defect
Neurovascular injury	0	No neurovascular injury
	1	Suspected injury
	2	Confirmed nerve injury
	3	Vascular injury
	4	Combined neurovascular injury
Internal organ injury	0	No internal organ injury
	1	Mild injury
	2	Moderate injury
	3	Severe injury
	4	Critical organ injury
Physiological response	0	Stable condition
	1	Mild physiological disturbance
	2	Moderate physiological disturbance
	3	Severe physiological compromise
	4	Critical physiological instability

Notes: Grade I - Mild blastotrauma (0-4); Grade II - Moderate blastotrauma (5-8); Grade III - Severe blastotrauma (9-13); Grade IV - Critical blastotrauma (14-20)

Source: compiled by the authors of this study

the coexistence of local morphological damage and a systemic physiological response.

Fig. 1 presents the conceptual model of blastotrauma formation.

BLAST TRAUMA SEVERITY SCALE (BTSS)

The Blast Trauma Severity Scale (BTSS) was developed to standardize the assessment of blast-related injuries. Rather than treating morphological damage and physiological disturbance as separate considerations, the scale combines both into a unified, integrated assessment.

The BTSS includes five domains:

1. soft tissue injury;
2. bone injury;
3. neurovascular injury;
4. internal organ injury;
5. physiological response.

Each domain is scored on a 0–4 scale, where 0 indicates the absence of the finding and 4 represents the most severe presentation. The scores across all five domains are summed, yielding a maximum possible total of 20 points.

Four severity grades are defined on the basis of the cumulative score:

- Grade I (0-4 points) - mild blastotrauma;
- Grade II (5-8 points) - moderate blastotrauma;
- Grade III (9-13 points) - severe blastotrauma;
- Grade IV (14-20 points) - critical blastotrauma.

To retain pathogenetic information about the blast event, the numerical score is supplemented with a descriptor identifying the dominant injury mechanism:

- P - primary blast injury;
- S - secondary blast injury;
- T - tertiary blast injury;
- Q - quaternary blast injury.

The combined notation brings both dimensions togeth-

Table 2. The dominant blast mechanism descriptors

Descriptor	Mechanism
P	Primary blast injury (blast wave)
S	Secondary blast injury (fragments and debris)
T	Tertiary blast injury (body displacement)
Q	Quaternary blast injury (burns, inhalation and other effects)

Source: compiled by the authors of this study

Table 3. Clinical characteristics of patients with combat-related blast and explosion-associated injuries

Variable	Value
Number of patients	70
Study period	2023–2025
Mechanism of injury	Blast and explosion-associated combat trauma
Combined injuries	Majority of patients
Soft tissue injuries	Frequently observed
Bone fractures	Common
Neurovascular injuries	Observed in part of patients
Internal organ injuries	Present in severe trauma cases
Physiological instability	Observed in severe trauma

Note: Data are presented as general characteristics of the studied cohort based on retrospective clinical records
Source: compiled by the authors of this study

Table 4. Distribution of patients according to Blast Trauma Severity Scale (BTSS) grades (n = 70)

BTSS Grade	Score Range	Severity of blastotrauma	Number of patients
Grade I	0–4	Mild blastotrauma	12
Grade II	5–8	Moderate blastotrauma	24
Grade III	9–13	Severe blastotrauma	22
Grade IV	14–20	Critical blastotrauma	12

Note: Severity grading is based on the cumulative score of the Blast Trauma Severity Scale (BTSS)
Source: compiled by the authors of this study

er in a single expression—for instance, S / 9 / Grade III indicates a secondary blast mechanism with a score of 9, classifying the injury as severe blastotrauma.

The full scoring structure of the BTSS is set out in Table 1.

MECHANISM DESCRIPTOR

Each BTSS score should be paired with the descriptor of the dominant blast mechanism (Table 2).

The structural overview of the BTSS is illustrated in Fig. 2.

CLINICAL CHARACTERISTICS OF PATIENTS

The cohort comprised 70 patients with combat-related blast and explosion-associated injuries treated during 2023–2025.

The injury profile was dominated by combined trauma involving varied combinations of soft tissue injuries, bone fractures, and internal organ damage.

The most common injury components were:

1. soft tissue injuries and defects;
2. fractures of long bones;
3. fragment-related wounds;
4. neurovascular injuries;
5. internal organ injuries.

Systemic physiological disturbances—most notably haemodynamic instability and respiratory compromise–were documented in a substantial proportion of patients.

The general characteristics of the study cohort are summarised in Table 3.

DISTRIBUTION OF PATIENTS ACCORDING TO BTSS GRADES

All 70 patients were assessed using the Blast Trauma Severity Scale (BTSS).

The distribution of injury severity across the cohort is presented in Table 4.

Table 5. Comparison of trauma severity scoring systems and the proposed BTSS classification

Characteristic	Abbreviated Injury Scale (AIS)	Injury Severity Score (ISS)	Trauma Score / TRISS	BTSS (proposed)
Type of assessment	Anatomical injury scale	Anatomical severity score	Physiological + anatomical prediction model	Integrated morphological and physiological assessment
Primary purpose	Classification of individual injuries	Overall trauma severity assessment	Prediction of survival probability	Assessment of blast-related trauma severity
Consideration of injury mechanism	No	No	Limited	Yes (P/S/T/Q descriptor)
Evaluation of soft tissue injury	Limited	Indirect	Limited	Direct assessment
Evaluation of bone injury	Yes	Yes	Indirect	Direct assessment
Evaluation of neurovascular injury	Limited	Limited	Limited	Direct assessment
Evaluation of internal organ injury	Yes	Yes	Yes	Direct assessment
Evaluation of physiological response	No	No	Yes	Yes
Applicability to blast injuries	Limited	Limited	Limited	Specifically designed for blastotrauma
Clinical simplicity	Moderate	Moderate	Complex	Simple

Source: compiled by the authors of this study

The use of the BTSS allowed clear stratification of all patients by injury severity. Patients with localised soft tissue injuries and limited fractures in the absence of significant physiological disturbance were typically assigned to Grade I or II. Those presenting with multiple fractures, extensive soft tissue damage, internal organ involvement, or neurovascular injury were classified as Grade III. Patients with massive combined injuries, marked physiological instability, or polytrauma were placed in Grade IV, corresponding to critical blastotrauma.

Appending the mechanism descriptor (P/S/T/Q) to the severity score integrates pathogenetic characterization of the blast event directly into the injury classification.

The BTSS can therefore support:

1. standardized assessment of blast injury severity;
2. clinical stratification of patients;
3. comparison of results between studies;
4. optimization of treatment planning.

DISCUSSION

Explosion-related injuries rank among the most complex forms of traumatic pathology, given the simultaneous action of multiple injury mechanisms and the resulting wide variability in clinical presentation. In contemporary armed conflicts, explosive devices are a leading cause of combat trauma, accounting for a growing proportion of patients with combined blast injuries [1–3, 17–20].

Blast injuries are defined by the concurrent action of several distinct mechanisms—the pressure wave, fragment wounds, blast wind displacement, and secondary environmental effects [2, 10–12]. When these forces combine, the resulting morphological and physiological injury patterns differ markedly from those observed in conventional mechanical trauma [21]. Against this background, the present study introduces the concept of blastotrauma as a distinct category of traumatic pathology. The concept reflects the complex nature of damage produced when explosive energy is transferred to human tissues through the simultaneous interaction of multiple blast injury mechanisms. A persistent challenge in traumatology is the lack of a severity assessment system specifically designed for blast injuries. Clinicians currently rely on instruments such as the Abbreviated Injury Scale (AIS) and the Injury Severity Score (ISS) [13–16], both of which were developed for general trauma and were not intended to capture the specific mechanisms of blast injuries [7–9].

Table 5 compares the most widely used trauma scoring systems with the proposed BTSS.

The BTSS introduced here bridges this gap by combining the evaluation of morphological damage with the assessment of systemic physiological responses in a single instrument. This integrated approach provides a more comprehensive picture of trauma severity than traditional scoring systems, which rely primarily on anatomical injury criteria. A notable strength of the scale is the P/S/T/Q mechanism descriptor: it preserves pathogenetic information about the blast event while simultaneously enabling severity-based patient stratification—an advantage not offered by existing general trauma scales.

In the study cohort, the BTSS successfully stratified blast injuries according to severity. The scale

demonstrates clear potential for standardised injury description, cross-study comparison of outcomes, and more structured clinical management of patients with blast trauma.

Certain limitations of this study must be acknowledged. The retrospective design and relatively small cohort size limit the generalisability of the findings. Prospective validation of the BTSS in larger and more diverse patient populations is required before wider clinical adoption can be recommended.

Despite these limitations, the blastotrauma concept and the BTSS classification represent an important initial step towards a standardised framework for describing and quantifying explosion-related injuries in both clinical and research settings.

CONCLUSIONS

1. Explosion-related injuries arise from a complex combination of injury mechanisms and produce a characteristic spectrum of morphological and physiological changes sufficiently distinct to justify recognition as a separate category of traumatic pathology, for which the term blastotrauma is proposed.
2. The study proposes a working definition of blastotrauma: a complex injury pattern produced when explosive energy is transferred to human tissues through the simultaneous interaction of multiple blast injury mechanisms.
3. The Blast Trauma Severity Scale (BTSS) introduced here integrates assessment of morphological damage and systemic physiological disturbances into a single instrument, enabling standardized grading of blast injury severity.
4. Pairing the BTSS numerical score with a dominant mechanism descriptor (P/S/T/Q) links severity grading to the pathogenetic characteristics of the blast event, adding clinical context that existing scales do not provide.
5. The BTSS classification is suitable for clinical stratification of patients with blast injuries, standardized documentation of injury patterns, and as a research instrument in trauma and military medicine.

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CONFLICT OF INTEREST
The Authors declare no conflict of interest

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