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Clinical and Anatomical Characteristics of Abdominal Blast Injuries

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ABSTRACT

BACKGROUND: A significant feature of military operations is the widespread use of unmanned aerial vehicles to carry explosive devices, ensuring their targeted delivery and impact at different levels of the human axial skeleton. This factor significantly impacts the anatomy and topography of blast injuries. This is evidenced by a greater diversity of injury patterns compared to previous scenarios, wherein contact mine (contact) blast injuries resulting in lower extremity damage were more prevalent. Consequently, investigating the injuring effects of abdominal blasts is of significant relevance.

AIM: The work aimed to determine the incidence of abdominal blast injuries and analyze their clinical and anatomical characteristics using available experimental findings on the mechanogenesis of this type of combat injury.

METHODS: The study focused on the clinical and anatomical characteristics of abdominal blast injuries. A comparative analysis of the clinical progression of traumatic syndrome and surgical outcomes between two patient groups was conducted. The main and control groups included 52 wounded patients with blast injuries and 65 patients with shrapnel wounds, respectively. The study groups were comparable in injury severity and baseline condition, with the abdomen being the primary localization of injuries in all cases.

RESULTS: Clinical and anatomical signs of primary blast injury effects were found in 10.3% of patients with abdominal shrapnel wounds. The study found that brisance and shock-wave injuries accounted for 46% of cases in the control group and 100% in the main group. The overall complication rate was 48.1% and 38.5% in the main and control groups ($p > 0.05$) respectively, with significant differences ($p = 0.07$) in Clavien–Dindo grades III–IV between the groups.

CONCLUSION: Primary blast injury effects have a significant negative impact on traumatic syndrome progression in patients with abdominal blast injuries. This includes a higher incidence of pulmonary and soft tissue infections and an increased risk of intestinal perforations caused by intestinal anastomotic leaks and acute ulcers.

Keywords: blast injuries; abdominal shrapnel wounds; intestinal perforations; primary blast injuring effects; mine injury; acoustic barotrauma; traumatic syndrome; sepsis.

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Клинико-анатомические особенности взрывных поражений с ведущим повреждением органов живота

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АННОТАЦИЯ

Обоснование. Важная особенность современных боевых действий — широкое использование в качестве носителей взрывных устройств беспилотных летательных аппаратов, обеспечивающих их адресную доставку и срабатывание на разном уровне относительно осевого скелета человека. Это, несомненно, повлияло на анатомо-топографическую структуру взрывных повреждений. Она стала более разнообразной по сравнению с предшествующими вооруженными конфликтами, где преобладала классическая (контактная) минная травма с разрушением нижних конечностей. Исходя из этого, изучение особенностей воздействия поражающих факторов взрыва на организм пострадавших с ведущим повреждением живота весьма актуально.

Цель — определить частоту взрывных поражений с ведущим повреждением органов живота и проанализировать их клинико-анатомические особенности с учетом экспериментальных данных о механогенезе данного вида боевой травмы.

Методы. Изучены клинико-анатомические особенности повреждений у раненых с взрывным поражением живота. Проведен сравнительный анализ течения травматической болезни и результатов хирургического лечения двух групп пациентов. В основную группу включены 52 раненых с взрывным поражением, контрольную группу составили 65 пациентов с осколочными ранениями. Исследуемые группы пациентов были сопоставимы по тяжести повреждений и исходному состоянию, при этом ведущей локализацией повреждений во всех случаях был живот.

Результаты. Клинико-анатомические признаки воздействия первичных факторов взрыва выявлены у 10,3% пациентов с осколочными ранениями живота. Повреждения в результате бризантного и ударно-волнового механизма отмечены у 46 и 100% соответственно раненых основной группы. Общая частота осложнений составила 48,1% в основной группе и 38,5% — в контрольной (p >0,05), при этом выявлена тенденция к статистически значимым (p=0,07) различиям в отношении осложнений III–IV степени по Clavien–Dindo.

Заключение. Первичные факторы взрывной травмы оказывают существенное негативное влияние на течение травматической болезни при взрывном поражении живота, что проявляется увеличением частоты инфекционных осложнений со стороны легких и мягких тканей конечностей, а также тенденцией к более частому развитию перфораций кишечного тракта вследствие несостоятельности межкишечных анастомозов и острых язв.

Ключевые слова: взрывные поражения; осколочные ранения живота; перфорации кишечного тракта; первичные факторы взрывной травмы; минная травма; акубаротравма; травматическая болезнь; сепсис.

Как цитировать

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BACKGROUND

A distinctive feature of recent armed conflicts has been the widespread use of explosive munitions, which has influenced the pattern of combat trauma [1, 2]. Over several decades, the proportion of blast injuries has steadily increased, becoming one of the leading causes of sanitary and irreversible losses [3, 4]. Blast injuries are characterized by the multifactorial nature of their damaging effects on the body, manifested by extensive tissue alteration and a wide range of homeostatic disorders. Thus, blast injuries are considered one of the most severe types of combat trauma [1, 5, 6].

A crucial aspect of modern warfare is the extensive use of unmanned aerial vehicles as carriers of explosive devices, enabling targeted delivery and detonation at various levels relative to the axial skeleton [7, 8]. This has altered the anatomic and topographic pattern of blast injuries. They have become more diverse compared with previous armed conflicts, wherein classical (contact) mine injuries with predominant destruction of the lower limbs persisted [2, 9]. Therefore, studying the specific impact of blast injury factors in casualties with predominant abdominal involvement is highly relevant.

Notably, abdominal injuries caused by explosions are often considered solely within the context of the monofactorial action of wounding fragments [6, 10]. However, according to contemporary concepts of combat trauma semiotics, this interpretation is incorrect, as it corresponds to the criteria for firearm-related fragment wounds rather than blast injuries, whose characteristic feature is the impact of primary (specific) blast factors—primarily the shock wave and its derivatives [2, 7]. Thus, in some cases, firearm-induced abdominal wounds solely caused by fragments of explosive munitions are mistakenly classified as blast injuries. Moreover, in true blast injuries, the signs of exposure to the blast shock wave often remain overlooked by specialists, who mainly focus on fragment-induced damage [5, 9]. These circumstances distort statistical data on the structure of combat trauma and create prerequisites for inadequate clinical assessment of casualties and tactical errors in implementing diagnostic and therapeutic measures [6, 9].

A key prerequisite for the development of blast injuries is the victim's presence within the radius of action of the primary blast factors [2, 4]. In experimental studies, the evaluation of this criterion presents little difficulty; however, in real combat settings it is an extremely challenging task, as the exact power of the explosive device and distance to the epicenter of the blast are generally unknown [7, 9]. Consequently, the diagnosis of abdominal blast injury is difficult, and their prompt detection is the top priority. Equally important for substantiating treatment strategies is determining the anatomic and topographic characteristics of blast injury. Although evaluation of the zone of primary tissue loss and alteration resulting from high-explosive and blast effects is not problematic, the identification of the nature and extent of distant injuries remains unclear [6, 7]. The difficulty lies in the multifactorial nature of their pathogenesis (shock-wave impact, inertial mechanisms, cavitation, air embolism, etc.) and in the gradual development of pathomorphological changes in tissues and prolonged subclinical presentation [8, 11, 12]. Thus, an objective assessment of the full spectrum of injuries in abdominal blast injury requires a comprehensive approach with the implementation of additional diagnostic algorithms and a clear understanding of the injury mechanism and morphofunctional characteristics of blast trauma.

The distant damaging effect of the primary blast factors on the abdominal organs, as exemplified by mine injuries, was first described in the late 20th century. This issue was significantly studied by Russian specialists through the synthesis of medical support experience from combat operations in Afghanistan [2, 9]. However, the advancement of explosive munitions and widespread use of unmanned aerial vehicles for their targeted delivery indicate the relevance of further investigations into the specifics of this combat condition. Moreover, currently available studies lack systematized data on the prevalence of blast injuries with predominant abdominal involvement in modern armed conflicts and on the clinical and anatomical characteristics of this type of combat trauma.

This study aimed to determine the incidence of blast injuries with predominant abdominal involvement and analyze their clinical and anatomical characteristics in relation to the mechanism of this type of combat injury.

METHODS

The primary clinical material included medical records of 507 patients with penetrating abdominal gunshot wounds who were admitted for specialized surgical care 2–12 days after injury. In all cases, the wounds were caused by fragments of explosive munitions, with the leading sites of injury being the abdominal and retroperitoneal cavities.

The main objective of the first stage of the study was to analyze the clinical and anatomical characteristics of injuries in blast trauma with predominant abdominal involvement. Fifty-two patients (mean age: 38.2 ± 4.9 years) whose injury patterns corresponded to blast trauma (main group [MG]) were selected from the total cohort. The limited informativeness and ambiguity of the data obtained during earlier stages of medical evacuation required the identification

of clinical and anatomical signs of the impact of primary blast factors, which were considered the key diagnostic criteria for blast trauma.

As a fundamental basis, the concept (model) of the mechanogenesis of mine–blast injury developed by the Department of Operative Surgery and Topographic Anatomy of the S.M. Kirov Military Medical Academy was applied [2]. Its main provisions were extrapolated to the previously presented clinical group of patients to establish causal relationships between the observed injuries and presumed primary blast factors. Two principal biophysical mechanisms of blast injury formation were considered: brisant (crushing) action and blast-wave impact. The consequences of the former mechanism included traumatic amputations of extremities and/or extensive tissue destruction. The manifestations of the latter mechanism encompassed a broader spectrum of injuries caused by direct blast-wave (high-explosive) impact on body tissues and the blast-wind effect. Notably, blast-wave impact is attributed to primary mechanisms, whereas the blast wind is considered a tertiary mechanism of blast injury. However, a reliable differentiation between the origins of injuries caused by the abovementioned mechanisms is possible only in experimental settings. Furthermore, the blast-wind effect is specific to blast injuries, and its severity, similar to that of the blast-wave impact, depends on the characteristics of the blast wave [2, 7]. Therefore, for the selection of patients in the MG, alterations of blast-wave and blast-wind origin were combined into a common category of injuries caused by blast-wave exposure, which involved a wide spectrum of clinical manifestations—from classical blast barotrauma to visceral ruptures and the formation of distant contusion foci.

At the second stage of the study, the clinical course of traumatic syndrome in blast injuries with predominant abdominal involvement and the treatment outcomes in this type of combat trauma were examined. A comparative analysis of the results of surgical treatment in the two groups of patients was conducted. The MG included patients with blast injuries, namely, abdominal fragment wounds accompanied by signs of exposure to specific (primary) blast factors. The control group (CG) comprised 65 patients (mean age: 36.7 ± 4.2 years) with a monofactorial mechanism of injury, such as abdominal fragment wounds caused by firearms. To increase the reliability of the comparative analysis, pseudorandomization was applied to ensure comparability of the study groups regarding the nature of abdominal fragment wounds, severity of combat trauma, and patients' condition [13]. The main inclusion criterion for the CG was the penetrating character of fragment wounds of the abdomen with multiple internal organ injuries.

The groups were comparable in terms of the main clinical characteristics (Table 1). They predominantly comprised young and middle-aged patients with combined fragment wounds, with the predominant localization of injuries within the abdominal and/or retroperitoneal cavity.

Evaluation of the nature of injuries and patients' condition according to the Military Gunshot Wound Injury and Military Condition in Specialized Centers scales yielded high scores, corresponding to severe and extremely severe grades in their qualitative classification. At the time of admission, most patients in both groups showed signs of peritonitis, whereas abdominal sepsis was diagnosed in 36.5% and 33.8% of cases, respectively.

In the structure of combined fragment wounds, lower- and upper-extremity injuries predominated; however, the abdomen was the leading localization regarding prognosis and its impact on surgical strategy in all cases (Fig. 1).

All patients sustained penetrating abdominal fragment injuries, with the most common target organs being the small and large intestines (Fig. 2). Notably, injuries to two or more organs were diagnosed in 83% of patients in the MG and 100% of those in the CG.

The presented data indicate that the study groups were homogeneous with respect to all previously described clinical

Table 1. Age and clinical characteristics of patients in both groups (p >0,05)

Parameter	Main group	Control group
Mean age, years	38.2 ± 4.9	36.7 ± 4.2
Type of fragment wounds: isolated/combined, %	9/91	6/94
Mean MGWI scale score:		
– abdomen	8.5 ± 2	9.7 ± 2.5
– total score	13.8 ± 2.5	12.4 ± 2
Mean MCPS scale score	67 ± 6.3	62 ± 7.4
Peritonitis, %	63.5	66.2
Sepsis, %	36.5	33.8
Mean SOFA* score	7.8 ± 1.5	7.1 ± 1

Note: MGWI scale, Military Gunshot Wound Injury scale; MCPS scale, Military Condition in Specialized Centers scale; SOFA, Sequential Organ Failure Assessment.
*For patients with sepsis at admission.

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criteria, except for the impact of primary blast factors, which was observed only in patients in the MG.

Statistical analysis was performed using GraphPad Prism 8 and IBM SPSS Statistics 27. Comparisons were conducted using Fisher's exact test for categorical variables and Student's *t* test for continuous variables. The significance of differences was assessed using Student's *t* test. In cases of non-normal distribution, the Mann–Whitney test was applied. A *p* value of <0.05 was considered statistically significant.

RESULTS AND DISCUSSION

Comprehensive analysis of anamnesis and clinical data and evaluation of the anatomic and topographic characteristics of the injuries identified signs of exposure to primary blast factors in 52 wounded patients who were included in the MG, as previously indicated. Thus, the incidence of blast injury among patients with fragment-induced penetrating abdominal wounds was 10.3%. In the remaining 89.7% of cases, injuries resulted from the action of secondary blast factors, including munition fragments, corresponding to typical gunshot trauma.

When assessing the role of blast-specific mechanisms of injury formation, signs of brisant action were noted in 24 patients, accounting for 46% of the MG. The direct consequences included traumatic amputations of the upper and lower extremities, which were observed in 14 and 10 cases, respectively (Table 2). In addition, three patients sustained large abdominal wall defects caused by massive tissue destruction following a close-range explosion (Fig. 3).

The blast-wave effect of munitions was diagnosed in all patients of the MG. Its manifestations were highly diverse. Within the framework of distributional analysis, they were categorized by topographic–anatomical principle into abdominal organ injuries and non-abdominal injuries. Among the latter, the most common findings were blast barotrauma and pulmonary contusion, often accompanied by hemothorax and/or pneumothorax (Table 3).

Certain challenges were associated with determining the genesis of abdominal injuries, as in all patients, they had a multifactorial nature and could have resulted from fragment wounds, blast-wave impact, or a combination of these mechanisms. To differentiate them, criteria such as fragment localization, wound tract direction, and the morphological characteristics of the injuries were applied.

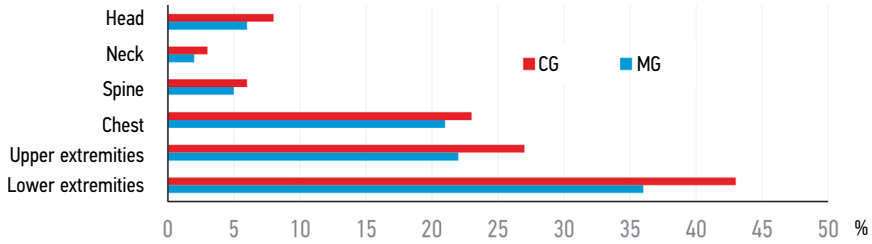


Fig. 1. Distribution of combined fragment wounds of the abdomen ($p > 0.05$). CG, control group; MG, main group (used in subsequent figures).

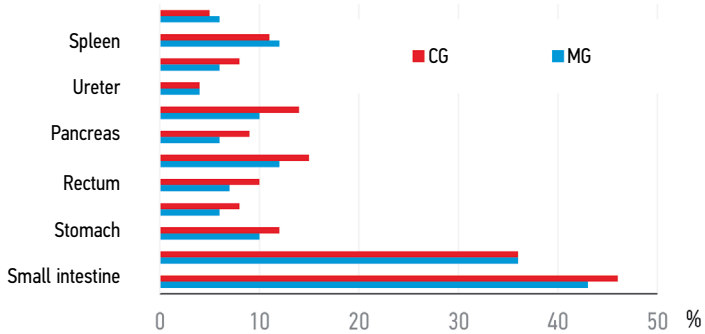


Fig. 2. Distribution of fragment wounds of the abdomen (p >0,05).

Table 2. Distribution of injuries resulting from the brisant effect in injured patients of the main group

Type of injury	*n*	%
Traumatic amputation (destruction) of the upper extremity:	14	26.9
– hand	6	11.5
– forearm	4	7.7
– upper arm	4	7.7
Traumatic amputation (destruction) of the lower extremity:	10	19.2
– foot	4	7.7
– lower leg	4	7.7
– thigh	2	3.8
Destruction of abdominal wall tissues	3	5.8

An interesting pattern was found in the comparative analysis of mechanisms of alteration with reference to specific organs. Hollow organ injuries were significantly more often caused by secondary blast factors (projectiles). Moreover, differences in the frequency of fragment wounds versus blast-wave effects in parenchymal organ injuries did not reach statistical significance (Table 4). Owing to the polymorphic nature of modern blast trauma, the findings do not claim absolute validity; however, they illustrate the substantial role of the brisant mechanism in the pathogenesis of abdominal blast injuries.

The most characteristic pathomorphological changes in parenchymal organs under the influence of blast-wave mechanisms were capsule disruptions with formation of subcapsular and intraparenchymal hematomas. In one wounded patient, this resulted in a two-stage splenic rupture with massive hemorrhage (Fig. 4). Among hollow organ injuries of brisant origin, contusion foci in the walls of the small and large intestines and their mesentery predominated, which were accompanied by hematoma formation (Fig. 5).

When analyzing the specifics of surgical treatment, the operative interventions showed to be diverse, reflecting the combined nature of injuries with multi-organ involvement. Furthermore, the distribution of the main stages of abdominal operations was comparable between the two groups. However, the need for limb amputations and thoracic procedures was significantly higher in the MG, which was associated with the impact of primary blast injury factors (Table 5).

The severe character of multi-organ injuries, combined with pronounced infectious and inflammatory changes in the abdominal cavity, warranted the implementation of an open-abdomen strategy with repeated programmed revisions in 61.5% of MG patients and 56.9% of CG patients. The main indications for its use were the prevention of abdominal compartment syndrome, repeated macroscopic assessment (second look), and control of the infectious focus (source control) (Fig. 6). A specialized peritonitis progression risk scale was applied to refine the latter criterion [14].

Vacuum-assisted or vacuum-instillation laparostomy was used as a temporary abdominal closure technique within the framework of infection source control (Fig. 7).

The overall complication rate was 48.1% in the MG and 38.5% in the CG ($p > 0.05$). Analysis of complication distribution according to the Clavien–Dindo classification [15] demonstrated significant differences ($p = 0.07$) in the incidence of grade III and IV complications, which occurred in 28.8% and 15.5% of cases, respectively (Fig. 8). Moreover, more

Table 3. Distribution of non-abdominal injuries resulting from blast-wave exposure in injured patients of the main group

Type of injury	*n*	%
Blast barotrauma	34	65.4
Closed traumatic brain injury:	19	36.5
– cerebral contusion	11	21.2
– concussion	8	15.4
Pulmonary contusion: *	25	48.1
– hemothorax	11	21.2
– pneumothorax	6	11.5
– hemothorax + pneumothoraxc	8	15.4

Note: *A combination of two or more injuries was observed in 16 patients.

Table 4. Distribution of abdominal injuries depending on their mechanism in patients of the main group, *n* (%)

Parameter	Fragment wounds	High-explosive effect	*p*=
Parenchymal organs: *	17 (32.6)	9 (17.3)	0.0724
– spleen	6 (11.5)	3 (5.7)	0.3081
– liver	6 (11.5)	3 (5.7)	0.3064
– kidneys	5 (9.6)	2 (3.8)	0.2462
– pancreas	3 (5.7)	1 (1.9)	0.3183
Hollow organs: *	37 (71.2)	17 (32.7)	0.001
– stomach	5 (9.6)	2 (3.8)	0.2421
– duodenum	3 (5.8)	–	0.0831
– small intestine	24 (42.3)	11 (21.2)	0.01
– large intestine	19 (36.5)	7 (13.5)	0.01

Note: *Injuries in two or more organs were observed in combination in 46 patients.

than one complication was identified in 28 MG patients and 31 CG patients.

The most severe complication in terms of its impact on patient condition and clinical course of traumatic syndrome was peritonitis progression with abdominal sepsis: 11.5% in the MG and 6.2% in the CG ($p > 0.05$). The triggering mechanisms of this complication in all cases were intestinal tract perforations resulting from acute perforated ulcers of the small intestine and/or anastomotic leakage. Their incidence was 9.6% and 7.6% and 3.1% and 4.6% in the MG

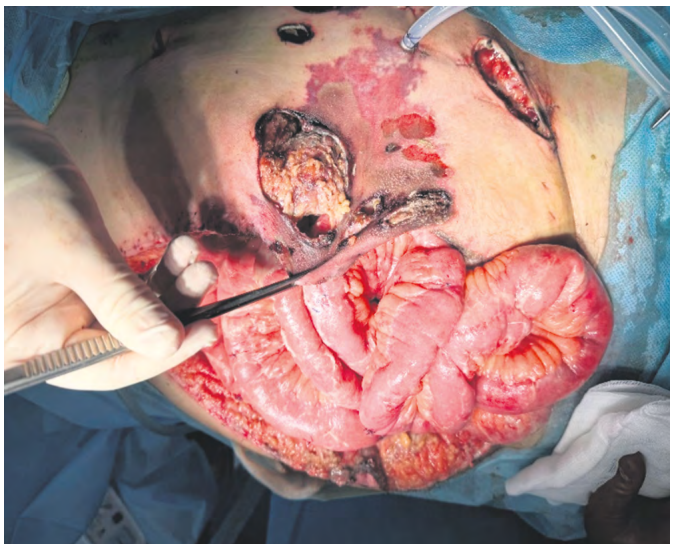
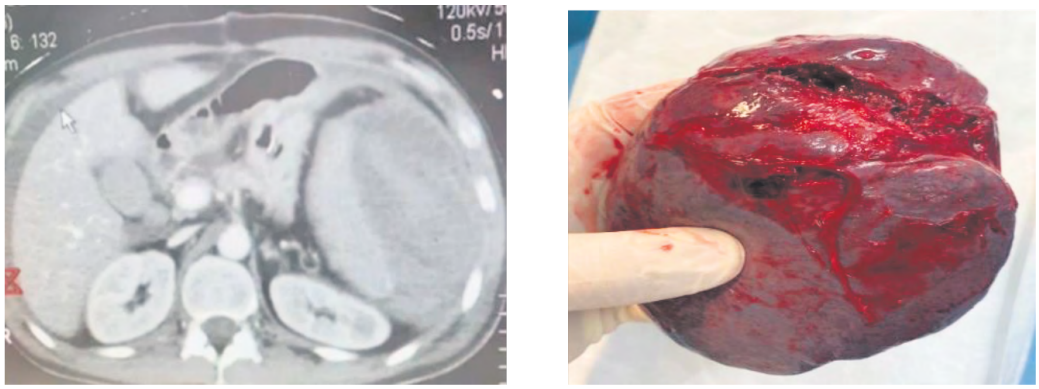
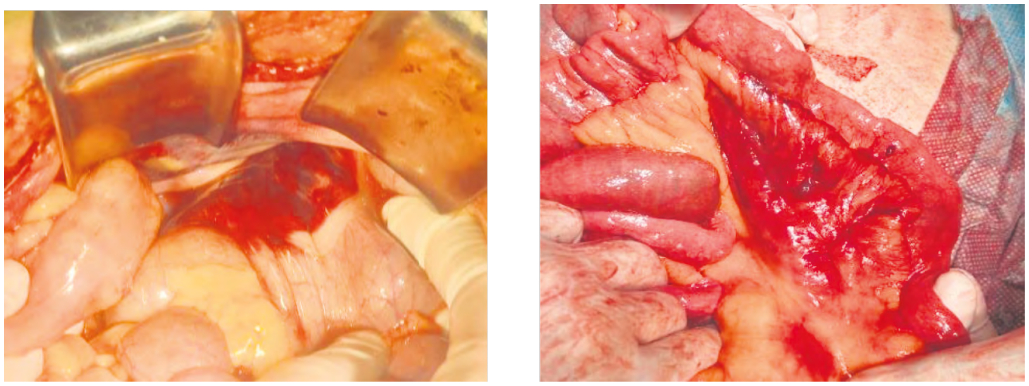


Fig. 3. Patient, 45 years old. Consequences of primary blast factors on the abdominal wall tissues: extensive defect with a perifocal zone of thermal burn.



a *b*

Fig. 4. Patient, 38 years old. Consequences of primary blast factors in the form of splenic rupture: *a*, abdominal computed tomography scan at admission; *b*, removed gross specimen.



a *b*

Fig. 5. Consequences of primary blast factors on hollow organs: *a*, 34-year-old patient with contusion focus in the wall of the sigmoid colon; *b*, 37-year-old patient with extensive hematoma of the small bowel mesentery.

Table 5. Distribution of the main types of surgical interventions, %

Type of operation	Main group	Control group	*p*
Abdominal operations*			
Resection and/or suturing of small bowel injuries	40.4	43.1	0.2032
Resection and/or suturing of large bowel injuries	36.5	35.4	0.0911
Formation of intestinal stoma	26.9	29.2	0.5643
Suturing of gastric injuries	13.4	10.8	0.1921
Suturing of duodenal injuries	5.8	7.7	0.8431
Obstructive rectal resection	5.8	4.6	0.4911
Drainage of the retroperitoneal space	23.1	18.5	0.0644
Resection and/or suturing of liver injuries	15.3	16.9	0.6133
Splenectomy	17.3	10.8	0.0324
Nephrectomy	7.7	9.2	0.9533
Resection of the bladder and/or ureter	3.8	3.1	0.7822
Suturing of inferior vena cava defect	–	1.5	0.3732
Suturing of superior mesenteric vessel defect	1.9	1.5	0.8724
Suturing (repair) of iliac vessel defect	3.8	1.5	0.2102
Amputations:			
– upper limbs	10 (19.2)	1 (1.5)	0.001
– lower limbs	14 (26.9)	2 (3.1)	0.001
Thoracic interventions:			
– pleural puncture	18 (34.6)	7 (10.7)	0.001
– thoracoscopic sanitation	7 (13.5)	2 (3.1)	0.0423

Note: *In 92% of patients in the MG and 94% in the CG, ⩾2 types of abdominal operations were performed.

and CG, respectively ($p > 0.05$). In the absence of these complications, peritonitis, which was diagnosed in >60% of patients in both groups upon admission, was successfully managed in all cases.

When analyzing non-abdominal complications, a significantly higher incidence of pneumonia and suppuration of soft tissues of the extremities was observed in patients in the MG, which was associated with the effects of primary blast injury factors. The incidence of these complications in the MG was 38.5% and 48.1%, compared with 21.5% and 26.2% in the CG, respectively ($p < 0.05$).

In-hospital mortality was 5.8% and 3.1% in both groups ($p > 0.05$). In all cases, the principal mechanism of thanatogenesis was multiple-organ failure progression in the setting of abdominal sepsis.

As previously noted, assessing the prevalence of blast injuries with predominant abdominal involvement in the context of the active use of modern explosive munitions is of considerable interest. However, such assessment is complicated by difficulties in differential diagnosis, determined by the polymorphic nature of injuries, severity of patient condition characteristic of this type of combat trauma, and lack of information about the circumstances of injury [2, 9]. Analysis of studies on this subject indicated that, in several cases, abdominal fragment gunshot wounds are classified as blast injuries without considering the contribution of primary blast mechanisms; therefore, the reported statistical indicators are often overestimated [6, 10]. Moreover, Wani et al. [5] and Minnullin [7] revealed the opposite tendency: a low rate of antemortem diagnosis of the full spectrum of blast injury sequelae, with abdominal organ injuries most frequently unrecognized.

Given the difficulties of clinical diagnosis of abdominal blast injuries, data from forensic medical examinations may be used as a reference point. Thus, the results of a large Russian study are of particular interest, wherein the structure of fatal trauma in a modern armed conflict was analyzed. Blast injuries accounted for 74.5% of all deaths, with abdominal and pelvic injuries identified in 31.1% and 13.6% of cases, respectively [4]. Most deaths were caused by fragment wounds; however, signs of gas-detonation effects were recorded in 28.7% of cases, indicating the role of primary mechanisms in the overall structure of thanatogenesis of blast trauma. Additionally, according to the vulnerability index for blast injury, the abdomen ranked third, following the head and neck [4].

The results of the present study demonstrate that the detection rate of blast injuries in fragment wounds with predominant abdominal involvement at the stage of specialized medical care was 10.3%. Thus, primary blast factors significantly affect the condition of every tenth patient with abdominal fragment injuries sustained in explosions, which should be considered when implementing diagnostic and therapeutic algorithms. The consequences of the brisant

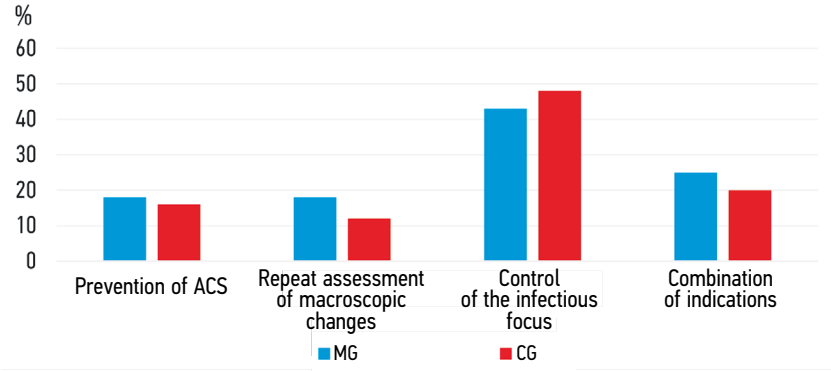


Fig. 6. Indications for implementing the open-abdomen strategy (p >0.05): ACS, abdominal compartment syndrome.

Fig. 7. Patient, 44 years old. Formation of a vacuum-instillation laparostomy.

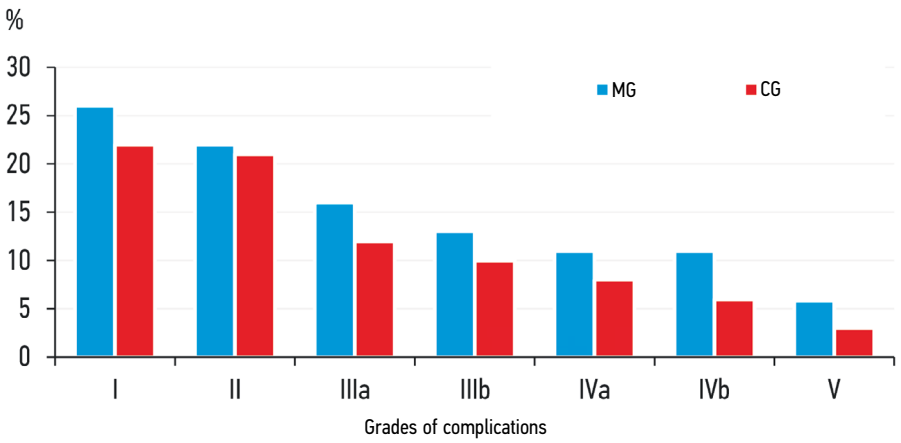


Fig. 8. Structure of complications according to the Clavien–Dindo classification.

mechanism of alteration are observable; however, according to Ritenour et al. [6] and Kovalov et al. [11], the diagnosis of injuries resulting from blast-wave exposure is associated with considerable challenges owing to the gradual development of pathomorphological changes and related functional disorders. This feature should be considered when selecting a surgical strategy. In particular, the presence of contusion injuries in abdominal organs, especially in the small and large intestines, should serve as an argument for performing second-look operations for the timely diagnosis of irreversible ischemic changes and as a counterargument to the creation of primary entero-enteric anastomoses.

The indicators presented in the current study demonstrate the considerable impact of primary blast injury factors on the clinical course of traumatic syndrome in abdominal blast injury. This is confirmed by the higher rate of complications in the MG than in the CG, despite comparable baseline injury severity and patient condition. Of particular note are pneumonias and infectious complications of the soft tissues of the extremities, which were significantly more common in patients exposed to the brisant and high-explosive effects of munitions. However, the higher incidence of intra-abdominal complications, primarily intestinal perforations, should not be overlooked. Differences in this parameter did not reach statistical significance, which may be associated with the relatively small sample size. Nevertheless, these findings indicate the negative influence of primary blast injury factors on intestinal circulation.

The findings of this study regarding the clinical and anatomical features of blast injuries with predominant abdominal involvement do not encompass the full spectrum of morphofunctional disturbances specific to this type of combat trauma. A promising direction in this context is considering the cavitation effect and air embolism as two of the most important yet insufficiently studied mechanisms of blast injury [2, 7]. Of particular interest is the assessment of the impact of these pathogenetic factors on the circulation of the abdominal and retroperitoneal organs.

CONCLUSION

Clinical and anatomical signs of blast injury in fragment wounds with predominant abdominal involvement were identified in 10.3% of patients at the stage of specialized medical care.

Primary blast factors induce a significant adverse effect on the clinical course of traumatic syndrome in abdominal blast trauma, primarily manifested by an increased frequency of infectious complications of the lungs and soft tissues of the extremities and by a tendency of more frequent intestinal perforations resulting from anastomotic leakage and acute ulcers.

Evaluation of the impact of primary blast factors on the body is critical in managing patients with abdominal fragment wounds, as these factors should be considered when selecting therapeutic strategies.

ADDITIONAL INFORMATION

Authors' contribution: A.A. Sazonov: data analysis, writing an article; P.N. Romashchenko: literature review, data analysis, final revision; N.A. Maistrenko: development of a general concept, research design, collection and processing of materials, writing an article; N.F. Fomin: development of a general concept, research design, review literature, collection and processing of materials, data analysis, making final corrections; I.A. Makarov, R.K. Aliyev: collection and processing of materials. The authors have approved the version for publication and have also agreed to be responsible for all aspects of the work, ensuring that issues relating to the accuracy and integrity of any part of it are properly considered and addressed.

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