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Staged surgical strategy for the management of combat-related duodenal injuries according to level of care

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Objective – to assess the impact of an enhanced staged surgical management algorithm, stratified by levels of care, on postoperative complications and mortality in combat-related duodenal injuries.

Materials and methods. This prospective study included 51 military personnel with gunshot-induced duodenal injuries. Patients were assigned to an experimental group (n=28) treated according to a newly developed algorithm and to a control group (n=23) managed with a conventional approach. The groups were comparable with respect to age, injury mechanism, duodenal injury severity, overall injury severity, and peritonitis characteristics. Both parametric and nonparametric methods were used in the statistical analyses.

Results. Isolated duodenal injuries accounted for 13.7% of cases, while multiple injuries were present in 86.3%. In the experimental group, 82.1% of patients received staged care across levels II, III, and IV, with complex reconstructive and combined surgical interventions such as duodenal diverticulization with gastroenteroanastomosis, pancreaticoduodenectomy, and percutaneous transhepatic cholecystostomy (biliary decompression) primarily performed at level IV care following stabilization. In the control group, the staged model was implemented in only 26.1% of cases, while in the remaining cases, the main volume of surgical intervention was performed at level II care. A length of stay of less than 1 day at level II care was observed in 94% of the experimental group, compared with 5% of the control group (p=0.001). The experimental group demonstrated significantly lower rates of duodenal suture failure (7.1% vs. 52.2%, p=0.001), peritonitis (17.9% vs. 47.8%, p=0.022), sepsis (17.9% vs. 60.9%, p=0.002), and relaparotomies for recurrent peritonitis (14.2% vs. 60.9%, p=0.007). Mortality was 13.4% in the experimental group and 39.1% in the control group (p=0.043). The mean hospital stay was significantly shorter in the experimental group (18.2±7.1 days) compared to the control group (29.3±8.1 days; p<0.001).

Conclusions. The enhanced staged surgical management algorithm for combat-related duodenal injuries significantly decreases the incidence of severe postoperative complications, relaparotomy rates, length of hospital stay, and mortality.

Keywords
duodenum, combat injury, damage control surgery, staged surgical strategy, combined abdominal trauma, peritonitis, suture failure, mortality.

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Duodenal injuries represent some of the most complex and prognostically challenging types of abdominal trauma, particularly in combat settings. This complexity arises from the organ's deep anatomical position and its close anatomical and functional associations with the pancreas, biliary tract, and major blood vessels. Despite prompt surgical intervention, duodenal injuries are frequently accompanied by a high rate of postoperative complications, such as suture failure, recurrent peritonitis, sepsis, and multiple organ failure [1, 7, 9].

The current literature indicates that isolated duodenal injuries are relatively uncommon, accounting for only 10–20% of cases; the majority of patients present with combined injuries. Duodenal injury is most frequently associated with concurrent injuries to the liver, spleen, small intestine, pancreas, and thoracic organs, which significantly complicates both

diagnosis and the selection of optimal surgical strategies. The concurrence of duodenal and pancreatic injuries is recognized as a significant factor contributing to adverse postoperative outcomes [7, 11, 20].

A further complicating factor is the high incidence of early intra-abdominal contamination. Bile leaks and peritonitis develop in the initial stages of duodenal injury, and any delay in controlling contamination sources accelerates the progression of infectious and inflammatory complications as well as the systemic inflammatory response. Therefore, timely surgical intervention, appropriate determination of intervention scope, and effective patient routing across levels of care are critical considerations [10, 18].

Current guidelines for managing abdominal trauma and duodenopancreatic injuries advocate for the application of damage control surgery principles, with clearly defined treatment stages. However, implementing these principles in combat environments remains challenging, and standardized protocols for staged surgical management that account for the resources available at each level of care are not widely adopted. This situation can result in either excessively aggressive early interventions or delays in achieving adequate control of injury and contamination [6, 16, 19].

Consequently, identifying optimal organizational and tactical strategies to reduce postoperative complications and mortality in patients with duodenal injuries remains a key priority. Assessment of a staged surgical management algorithm, which enables adaptation of the scope and type of surgical intervention based on the patient's clinical status and available medical resources, is consistent with current approaches to the management of severe abdominal trauma [5, 6, 8, 13].

Objective – to assess the impact of an enhanced staged surgical management algorithm, stratified by levels of care, on postoperative complications and mortality in combat-related duodenal injuries.

Materials and methods

This prospective study involved 51 male military personnel who sustained duodenal injuries from shrapnel (46 cases, 90.2 %) or bullets (5 cases, 9.8 %) during active duty between 2014 and 2025. The research was conducted at the National Military Medical Clinical Center of the «Main Military Clinical Hospital» and the Military Medical Center of the Southern Region.

Based on treatment strategies, wounded individuals were divided into two groups. The experimental group comprised 28 patients (54.9 %) who received care in accordance with the developed algorithm. The control group included 23 patients (45.1 %) who received standard medical care without the proposed recommendations.

The developed algorithm required strict adherence to the prescribed volume and sequence of medical care at specific levels of medical support. It incorporated principles of damage control surgery and advanced surgical approaches (Fig. 1).

Level II care

Diagnostic procedures

- Assessment of the general condition of wounded individuals.
- Determination of blood group and Rh factor, performance of necessary laboratory tests.
- Assessment of the nature, size, and localization of gunshot entrance and exit wounds.
- Emergency ultrasound examination within the scope of the FAST protocol.
- Abdominal X-ray in two projections; if the equipment is available and the wounded individual is stable, computed tomography.
- Laparocentesis using the «wandering catheter» method or Tupfer revision of the abdominal cavity.
- Diagnostic video-assisted laparoscopy – according to indications and if appropriate equipment is available.

Surgical management

- Suturing of the duodenal injury.
- In case of duodenal perforation or rupture, clipping of the edges of the damaged area with mandatory decompression of the stomach.
- Bleeding control by suturing, ligation, or coagulation of blood vessels.
- Gauze tamponade of the abdominal cavity (tamponade with hemostatic gauze or a combination of methods).

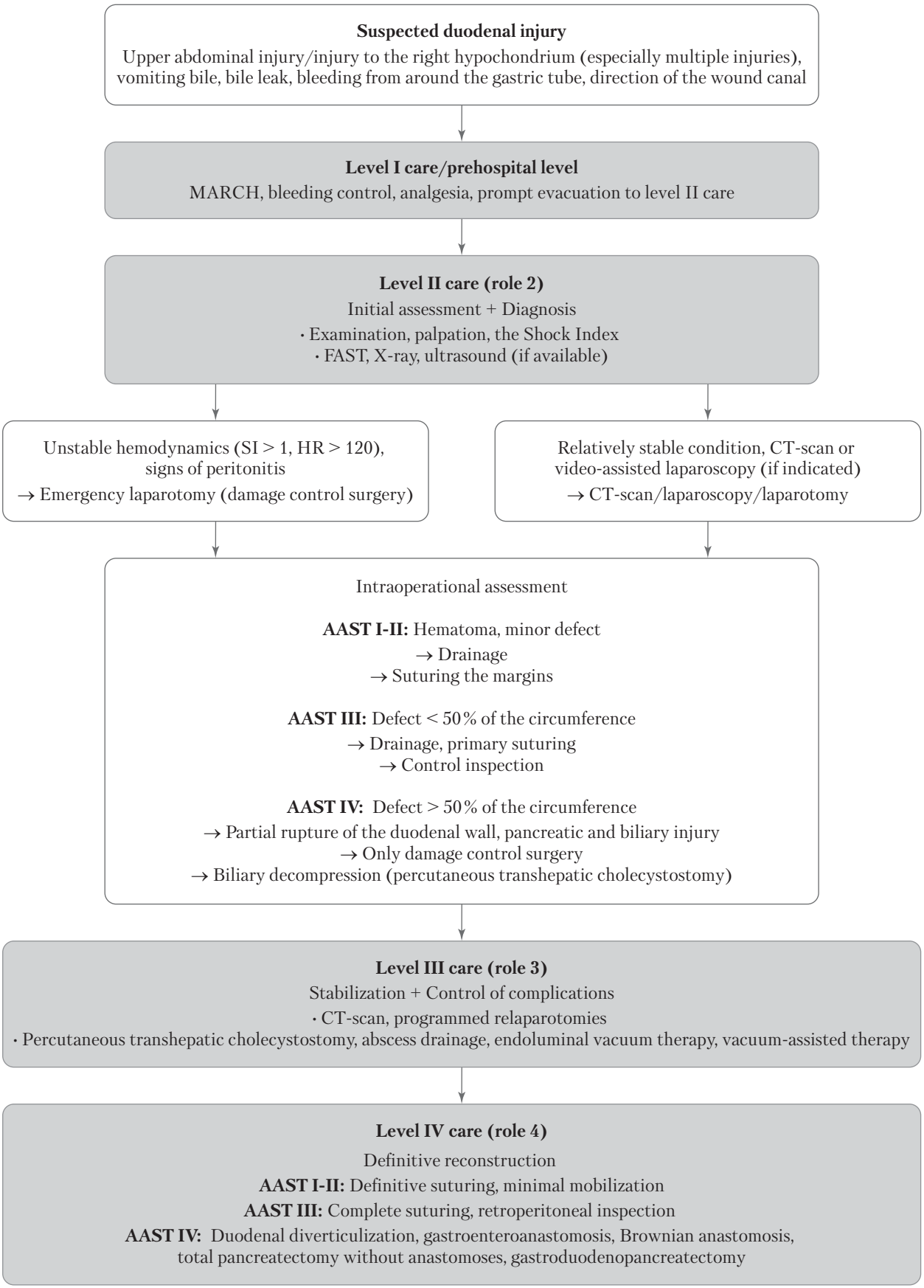
Level III care

Diagnostic procedures

- Assessment of the general condition of wounded individuals after evacuation.
- Laboratory tests.
- Comprehensive ultrasound examination of the abdominal organs.
- X-ray of the abdomen and other anatomical areas – according to indications.
- Multi-spiral computed tomography.
- Video-assisted endoscopic examinations in the required volume.
- Diagnostic video-assisted laparoscopy – according to indications.

Surgical management

At level III, care for duodenal injuries focuses on stabilization. This stage involves correcting vital



MARCH – algorithm for pre-medical and tactical medical care; SI – shock index; HR – heart rate; CT – computed tomography

Figure 1. **Diagnostic and treatment algorithm for medical support in cases of combat-related duodenal injury**.

functions and conducting further examinations using all available technical resources, followed by evacuation to level IV care. When indicated, programmed relaparotomy is performed according to damage control surgery principles. This procedure includes complete hemostasis and ultrasound-guided percutaneous transhepatic cholecystostomy.

Level IV care

Diagnostic procedures

- Assessment of the general condition of wounded individuals after evacuation to level IV care.
- Comprehensive laboratory tests.
- Ultrasound examination of the abdominal organs.
- X-ray of the abdomen and other anatomical areas – according to indications.
- Multi-spiral computed tomography.
- Full-scale video-assisted endoscopic examinations (ERCP-endoscopic retrograde cholangiopancreatography, fibrogastroduodenoscopy).
- Diagnostic and dynamic video-assisted laparoscopy (second look).

Surgical management

At level IV care, the third phase of damage control surgery is initiated. If necessary, this phase may be divided into multiple staged interventions until the final surgical objective is achieved.

The scope of surgical intervention may include:

- Duodenal diverticulization with the disconnection of the passage of gastric contents by forming a precolonic gastroenteroanastomosis with an interintestinal anastomosis according to Brown (the length of the lead loop is 40–50 cm).
- In case of destruction of the pyloroduodenal junction with damage to the D1 segment, formation of a duodenal stump using one of the appropriate methods, antrumectomy with the formation of a gastroenteroanastomosis on a long loop with a Brownian anastomosis.
- In case of damage to the D2 segment of the III–IV grade, pancreaticoduodenal resection or duodenectomy with external drainage of the common bile duct and pancreatic ducts without the formation of anastomoses.
- Indications for total pancreatectomy are massive gunshot injuries of the duodenum according to Moore III–IV, the development of pancreatic necrosis, and complications in the form of recurrent erosive bleeding.
- In case of damage to the D3–D4 segments, the formation of a duodenojejunal anastomosis is allowed with the recommended passage of a fully perforated microirrigator through the cystic duct and duodenojejunal anastomosis into the diverting loop of the small intestine.
- In case of failure of the duodenal sutures, the use of the EndoVac system is effective.

In cases of intra-abdominal abscess formation (subdiaphragmatic or subhepatic) at level IV care, ultrasound-guided percutaneous drainage is routinely performed.

A key component of the algorithm is mandatory external decompression of the biliary tract, primarily achieved through percutaneous transhepatic cholecystostomy (PTC) or choledochal drainage as described by Pikovsky.

The severity of duodenal injuries was assessed according to the classification of the American Association for the Surgery of Trauma (AAST Organ Injury Scale) [14]: grade I – hematoma, superficial injury; grade II – hematoma > 1 segment or partial defect; grade III – rupture < 50 % of the circumference; grade IV – rupture ≥ 50 % of the circumference, papilla damage; grade V – massive destruction, devascularization.

To assess the severity of peritonitis, the Mannheim Peritonitis Index (MPI) was used [12].

The severity of the combined injury was assessed using the New Injury Severity Score (NISS) scale, with patients further stratified by severity [2, 21]. The study was conducted in compliance with modern bioethical requirements. All study participants or their authorized representatives signed an informed consent to participate in the study. Protocol No. 163 received approval from the local ethical commission of the Central Council for Military Medicine on 07.11.2022 at Bogomolets National Medical University.

Statistical analysis was conducted using IBM SPSS Statistics version 22.0.

For comparing two independent samples, the Student's t-test was used for normally distributed variables, and the Mann-Whitney U test was used for non-normally distributed variables. For dependent samples, the Wilcoxon T and Wilcoxon W tests were employed. Qualitative differences were assessed using the Chi-square test or Fisher's exact test.

Statistical significance was set at $p < 0.05$ for rejection of the null hypothesis of variable equality.

Results

The study groups were comparable with respect to basic baseline characteristics (Table 1).

The mean age of wounded individuals in the experimental group was 37.6 ± 9.7 years, while in the control group it was 39.6 ± 10.7 years; this difference was not statistically significant ($p = 0.494$).

Table 1. **Baseline characteristics of wounded individuals and specific features of duodenal injuries**

Parameter	Experimental group (n = 28)	Control group (n = 23)	Total (n =51)
Age, years (M ± SD)	37.6 ± 9.7	39.6 ± 10.7	38.5 ± 10.1
Body Mass Index, kg/m^2 (M ± SD)	24.5 ± 2.9	24.4 ± 1.3	24.5 ± 2.2
Wound			
Shrapnel	26 (92.3 %)	20 (87.0 %)	46 (90.2 %)
Bullet	2 (7.7 %)	3 (13.0 %)	5 (9.8 %)
Isolated	5 (17.9 %)	5 (21.7 %)	10 (19.6 %)
Combined	23 (82.1 %)	18 (78.3 %)	41 (80.4 %)
Severity of duodenal injuries as classified by AAST			
Grade I	7 (25.0 %)	5 (21.7 %)	12 (23.5 %)
Grade II	5 (17.9 %)	8 (34.8 %)	13 (25.5 %)
Grade III	13 (46.4 %)	8 (34.8 %)	21 (41.2 %)
Grade IV	3 (10.7 %)	2 (8.7 %)	5 (9.8 %)
Duodenal segment involved in the injury			
D1 (pars superior)	6 (21.4 %)	4 (17.4 %)	10 (19.6 %)
D2 (pars descendens)	16 (57.1 %)*	14 (60.9 %)	30 (58.8 %)
D3 (pars horizontalis)	5 (17.9 %)	4 (17.4 %)	9 (17.6 %)
D4 (pars ascendens)	1 (3.6 %)	1 (4.3 %)	2 (3.9 %)

Note. * Three patients sustained injuries to the papilla of Vater.
The difference between compared and experimental group is statistically significant for all parameters (p > 0.05).

Similarly, there was no significant difference in body mass index between the groups (24.5 ± 2.9 vs. 24.4 ± 1.3 kg/m^2; p = 0.972).

Shrapnel wounds were the predominant injury type in both groups, accounting for 92.3 % in the experimental group and 87.0 % in the control group; this difference was not statistically significant (p = 0.481). The incidence of isolated and combined wounds was also comparable between the groups (p = 0.728), with combined injuries comprising over 78 % in both groups.

The distribution of duodenal injury severity, as classified by the AAST scale, did not differ significantly between the groups (p = 0.584). Grade II and III injuries accounted for the majority of cases, at 64.3 % in the experimental group and 69.6 % in the control group. These findings indicate a predominance of moderate and severe injury morphology characteristics.

In both groups, the D2 segment was most frequently affected, with rates of 57.1 % in the experimental group and 60.9 % in the control group; this difference was not statistically significant (p = 0.984). Lesions of segments D1, D3, and D4 were less common and similarly distributed between the groups. Three patients sustained injuries to the papilla of Vater.

Among the 51 wounded individuals, only 7 (13.7 %) presented with isolated duodenal injury. The remaining patients had duodenal injuries in combination with trauma to other organs and anatomical structures (Table 2).

The organs most frequently affected concurrently with the duodenum included the diaphragm and liver (33.3 % each), the spleen (35.3 %), chest organs (33.3 %), the small intestine (27.5 %), and the pancreas (25.5 %). Colon injuries occurred in 19.6 % of cases, kidney injuries in 15.7 %, and major blood vessel injuries in 11.8 %. Bladder injuries were documented in 3.9 % of patients. There were no statistically significant differences between the groups regarding the frequency of injury to individual organs (p > 0.05 for all).

The number of additional organs and structures of the abdominal cavity and extraperitoneal space affected (excluding duodenal injury) ranged from 0 to 6 (Fig. 2).

The distribution of wounded individuals by the number of combined injuries did not differ significantly between the groups (p = 0.573).

The mean injury severity score (NISS) for the total cohort was 21.8 ± 9.3 (range: 4–42), indicating predominantly severe and critical injuries. No statistically significant differences were observed

Table 2. **Associated injuries to organs and structures concurrent with duodenal trauma**

Organs and structures	Experimental group (n = 28)	Control group (n = 23)	Total (n =51)
Diaphragm	9 (32.1 %)	8 (34.8 %)	17 (33.3 %)
Liver	8 (28.6 %)	9 (39.1 %)	17 (33.3 %)
Pancreas	7 (25.0 %)	6 (26.1 %)	13 (25.5 %)
Spleen	7 (25.0 %)	11 (47.8 %)	18 (35.3 %)
Stomach	6 (21.4 %)	6 (26.1 %)	12 (23.5 %)
Small intestine	7 (25.0 %)	7 (30.4 %)	14 (27.5 %)
Large intestine	6 (21.4 %)	4 (17.4 %)	10 (19.6 %)
Chest	12 (42.9 %)	5 (21.7 %)	17 (33.3 %)
Kidney	4 (14.3 %)	4 (17.4 %)	8 (15.7 %)
Urinary bladder	2 (7.1 %)	0 (0.0 %)	2 (3.9 %)
Major blood vessels	2 (7.1 %)	4 (17.4 %)	6 (11.8 %)

Note. The difference between compared and experimental group is statistically significant for all parameters (p > 0.05).

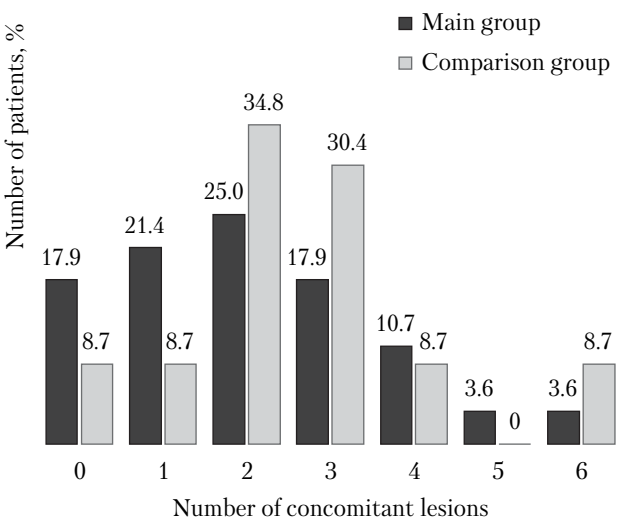


Figure 2. **Distribution of wounded individuals in the study groups according to the number of concomitant lesions in the abdominal cavity and extraperitoneal space, excluding duodenal lesions**

between the groups in mean NISS values: 22.1 ± 8.3 in the experimental group and 21.3 ± 10.6 in the control group (p = 0.762).

Comparative analysis of injury severity structure did not demonstrate statistically significant differences between the groups (p = 0.652). In both groups, patients with severe (NISS 16–24) and critical injuries (NISS ≥ 25) comprised the majority, together representing 70.6 % of the total sample. Unsurvivable injuries (NISS ≥ 40) were identified in three patients (5.9 %) (Table 3).

At the initial assessment at designated levels of care, bile leaks were observed in 21 patients (41.1 %): 10 (35.7 %) in the experimental group and 11 (47.8 %) in the control group. No statistically significant difference was identified between the groups (p = 0.509).

Among patients with bile leaks, the volume of bile loss from the wound was up to 100 ml in 6 cases (28.6 %), 100–200 ml in 2 cases (9.5 %), 200–500 ml in 9 cases (42.9 %), and up to 1000 ml in 4 cases (19.0 %). There was no statistically significant difference between the groups for this indicator (p = 0.176).

Hemorrhagic shock was diagnosed in 21 patients (75.0 %) in the experimental group and 15 patients (65.2 %) in the control group (p = 0.218).

Peritonitis was diagnosed in all patients, with localized peritonitis in 7 cases (13.7 %) and generalized (diffuse) peritonitis in 44 cases (86.3 %). Biliary peritonitis was the predominant type based on exudate characteristics (88.2 %), while fecal peritonitis was identified in 6 cases (11.8 %).

The mean MPI in the total cohort was 19.8 ± 5.6 (range: 10–34). According to MPI grading, mild peritonitis was present in 28 patients (54.9 %), moderate to severe in 22 patients (43.1 %), and severe in only 1 patient (2.0 %). Comparative analysis showed no statistically significant differences between the groups in peritonitis prevalence, exudate characteristics, or mean MPI value (p > 0.05 for all), indicating comparable initial severity of intra-abdominal infection in both groups (Table 4).

The surgical interventions were designed to address the complications of duodenal injury as well

Table 3. **Characteristics of patient groups by injury severity as classified by NISS**

Parameter	Experimental group (n = 28)	Control group (n = 23)	Total (n =51)
NISS score (M ± SD)	22.1 ± 8.3	21.3 ± 10.6	21.8 ± 9.3
Injury severity by NISS			
Minor	4 (14.3 %)	2 (8.7 %)	6 (11.8 %)
Moderate	2 (7.1 %)	4 (17.4 %)	6 (11.8 %)
Severe	8 (28.6 %)	7 (30.4 %)	15 (29.4 %)
Critical	13 (46.4 %)	8 (34.8 %)	21 (41.2 %)
Unsurvivable	1 (3.6 %)	2 (8.7 %)	3 (5.9 %)

Note. The difference between compared and experimental group is statistically significant for all parameters (p > 0.05).

Table 4. **Characteristics of patient groups based on peritonitis and MPI indicators**

Parameter	Experimental group (n = 28)	Control group (n = 23)	Total (n =51)
Localization			
Localized	4 (14.3 %)	3 (13.0 %)	7 (13.7 %)
Generalized	24 (85.7 %)	20 (87.0 %)	44 (86.3 %)
Content			
Biliary	26 (92.9 %)	19 (82.6 %)	45 (88.2 %)
Fecal	2 (7.1 %)	4 (17.4 %)	6 (11.8 %)
MPI score (M ± SD)	19.3 ± 4.7	20.4 ± 6.6	19.8 ± 5.6
MPI categories			
Mild	16 (57.1 %)	12 (52.2 %)	28 (54.9 %)
Moderate	12 (42.9 %)	10 (43.5 %)	22 (43.1 %)
Severe	0	1 (4.3 %)	1 (2.0 %)

Note. The difference between compared and experimental group is statistically significant for all parameters (p > 0.05).

as associated pathological conditions resulting from the trauma.

Due to the staged approach to treatment, multiple surgical interventions were performed on a single patient at various levels of care. Table 5 presents the range of surgical interventions performed in each group, by evacuation stage.

Surgical interventions to address the complications of duodenal injury were primarily conducted during stage II. Specialized and delayed interventions were performed at stage IV, whereas procedures for concomitant injuries were carried out during the early stages of treatment.

The number of surgical interventions per patient, excluding planned relaparotomies, ranged from 0 to 7 (Fig. 3).

There was no statistically significant difference between the groups in the distribution of wounded individuals by the number of surgical interventions (p = 0.301).

Analysis of the distribution of wounded individuals by the level of care at which primary surgical interventions were performed demonstrated substantial differences between the groups. In the experimental group, the majority of patients (82.1 %) underwent surgical interventions at the II, III, and IV levels of care, indicating the use of multi-level treatment strategies. Conversely, in the control group, this approach was implemented in only 26.1 % of cases. In the control group, 73.9 % of wounded individuals underwent all major surgical interventions at level II care, whereas only 14.3 % of patients in the experimental group did so (Table 6).

In the experimental group, a staged surgical approach was more frequently employed, with the major interventions transferred to specialized levels of care. In contrast, the control group primarily concentrated on the major surgical procedures at level II. Since both groups exhibited comparable initial injury severity, these differences are significant for subsequent

Table 5. **Classification of surgical interventions by levels of care**

Type of surgery	Experimental group (n = 28)			Control group (n = 23)			p
	Evacuation stage			Evacuation stage			
	II	III	IV	II	III	IV	
Eliminating the complications of duodenal injury							
Duodenal suturing	26 (92.9 %)	2 (7.1 %)	0	23 (100.0 %)	0	0	1
Duodenal diverticulization	1 (3.6 %)						0.360
Gastroenteroanastomosis after duodenal diverticulization	0	0	1 (17.9 %)	0	0	0	0.360
Duodenal diverticulization + gastroenteroanastomosis	2 (7.1 %)	0	4 (14.3 %)	0	0	1 (4.3 %)	0.078
Pancreatoduodenal resection	0	0	4 (14. %)	0	0	2 (8.7 %)	0.538
Pancreatectomy	0	0	1 (3.6 %)	0	0	0	0.360
Resection of the tail of the pancreas	0	0	4 (14.3 %)	5 (21.7 %)	0	0	0.487
Biliary decompression	6 (21.4 %)	1 (3.6 %)	21 (75.0 %)	0	0	1 (4.3 %)	< 0.0001
Ultrasound-guided percutaneous transhepatic cholecystostomy	5 (17.9 %)	1 (3.6 %)	18 (64.3 %)	0	0	0	< 0.0001
Drainage of the common bile duct by Pikovsky method	1 (3.6 %)	0	3 (10.7 %)	0	0	1 (4.3 %)	0.235
Eliminating concomitant injuries							
Liver suturing	8 (28.6 %)	0	0	9 (39.1 %)	0	0	0.426
Stomach suturing	5 (17.9 %)	1 (3.6 %)	0	6 (26.1 %)	0	0	0.696
Diaphragm defect repair	9 (32.1 %)	0	0	8 (34.8 %)	0	0	0.842
Splenectomy	7 (25.0 %)	0	0	11 (47.8 %)	0	0	0.090
Small bowel resection with anastomosis	3 (17.9 %)	2 (7.1 %)		7 (30.4 %)	0	0	0.292
Obstructive resection of the small intestine with clip placement	2 (7.1 %)	0	0	0	0	0	0.191
Entero-enterostomy after obstructive resection	0	0	2 (7.1 %)	0	0	0	0.191
Obstructive colon resection with clip placement	6 (21.4 %)	0	0	4 (17.4 %)	0	0	0.718
Ileotransversostomy after damage control colectomy	0	0	2 (7.1 %)	0	0	1 (4.3 %)	0.673
Final colostomy after damage control surgery	0	0	4 (14.3 %)	0	0	3 (13.0 %)	0.898
Kidney surgeries	4 (14.3 %)	0	0	4 (17.4 %)	0	0	0.782
Suturing	3 (10.7 %)	0	0	2 (8.7 %)	0	0	
Resection	1 (3.6 %)	0	0	1 (4.35 %)	0	0	
Nephrectomy	0	0	0	1 (4.35 %)	0	0	
Bladder defect repair	2 (7.1 %)	0	0	0	0	0	0.191

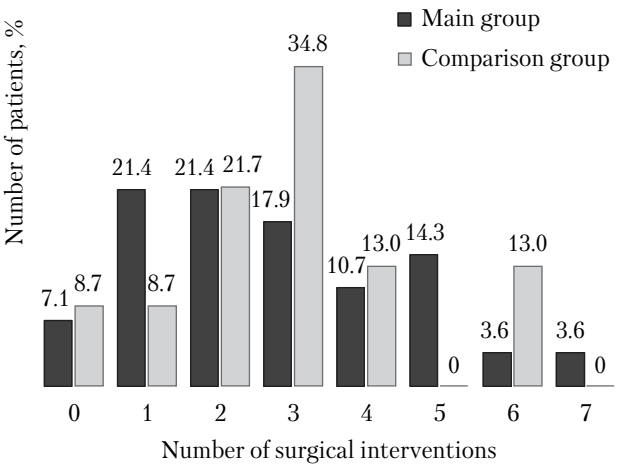


Figure 3. **Distribution of wounded individuals across groups by the number of surgical interventions, excluding suturing or clipping of the duodenum**

Table 6. **Distribution of wounded individuals by level of care at which major surgical interventions were performed**

Stage of operation	Experimental group (n = 28)	Control group (n = 23)	Total (n =51)
II	4 (14.3 %)	17 (73.9 %)	21 (41.2 %)
II–III	1 (3.6 %)	0 (0.0 %)	1 (2.0 %)
II–III–IV	23 (82.1 %)	6 (26.1 %)	29 (56.8 %)

Note. All wounded individuals were subsequently evacuated to level IV care. The table presents the stage at which the major surgical intervention occurred. Relaparotomies for postoperative complications performed at level IV care were excluded from this analysis.

Table 7. **Postoperative complications, need for relaparotomy, mortality, and length of hospital stay in patients with duodenal injuries**

Complications	Experimental group (n = 28)	Control group (n = 23)	p	Total (n = 51)
Mortality	4 (13.4 %)	9 (39.1 %)	0.043	13 (25.5 %)
Failure of duodenal sutures	2 (7.1 %)	12 (52.2 %)	0.001	14 (27.5 %)
Peritonitis	5 (17.9 %)	11 (47.8 %)	0.022	16 (31.4 %)
Eventration	1 (3.6 %)	7 (30.4 %)	0.007	8 (15.7 %)
Sepsis	5 (17.9 %)	14 (60.9 %)	0.002	19 (37.3 %)
Abscess	7 (25.0 %)	11 (47.8 %)	0.090	18 (35.3 %)
Wound suppuration	14 (50.0 %)	16 (69.6 %)	0.158	30 (58.8 %)
Pancreatic necrosis	4 (14.3 %)	7 (30.4 %)	0.092	11 (22.9 %)
Erosive bleeding	2 (7.1 %)	4 (17.4 %)	0.258	6 (11.8 %)
Stricture of the hepatocholedochus	1 (3.6 %)	0 (0.0 %)	0.360	1 (2.0 %)
Multiple organ failure	4 (14.3 %)	9 (39.1 %)	0.043	13 (25.5 %)
Fistula	6 (21.4 %)	14 (60.9 %)	0.004	20 (39.2 %)
Biliary	2 (7.1 %)	6 (26.1 %)	0.064	8 (15.7 %)
Pancreatic	4 (14.3 %)	7 (30.4 %)	0.092	11 (22.9 %)
Nosocomial pneumonia	10 (35.7 %)	12 (52.2 %)	0.238	22 (43.1 %)
Number of patients who underwent relaparotomy for recurrent peritonitis	4 (14.2 %)	14 (60.9 %)	0.007	28 (54.9 %)
Number of relaparotomies for peritonitis				
1	2 (7.1 %)	2 (8.7 %)		4 (7.8 %)
2	1 (3.6 %)	4 (17.4 %)	0.078	5 (9.8 %)
3	1 (3.6 %)	3 (13.0 %)		4 (7.8 %)
4	0 (0.0 %)	2 (8.7 %)		2 (3.9 %)
Length of hospital stay	18.2 ± 7.1	29.3 ± 8.1	< 0.001	23.2 ± 9.3

analysis of how organizational strategies influence complication rates and treatment outcomes.

In the experimental group, 16 patients remained at the first stage of medical evacuation for less than 1 day, while 1 patient remained for more than 1 day. In the control group, only 1 patient stayed less than 1 day at this stage, whereas the remainder stayed for more than 1 day ($p = 0.001$).

Analysis of postoperative complication patterns demonstrated a significantly lower incidence of surgical and septic complications in the experimental group (Table 7).

The experimental group exhibited a mortality rate of 13.4 %, which was statistically significantly lower than the 39.1 % observed in the control group ($p = 0.043$).

Duodenal suture failure occurred in 7.1 % of patients in the experimental group compared to 52.2 % in the control group ($p = 0.001$). It was associated with a significantly lower incidence of peritonitis in the experimental group (17.9 % vs. 47.8 %, $p = 0.022$). Additionally, the frequency of relaparotomies due to recurrent peritonitis was significantly lower in the experimental group (14.2 % vs. 60.9 %, $p = 0.007$).

Eventration (3.6 % vs. 30.4 %, $p = 0.007$), sepsis (17.9 % vs. 60.9 %, $p = 0.002$), and multiple organ failure (14.3 % vs. 39.1 %, $p = 0.043$) were all significantly less frequent in the experimental group. Fistula formation also occurred significantly less often in the experimental group (21.4 % vs. 60.9 %, $p = 0.004$).

Complications, including intra-abdominal abscesses, postoperative wound suppuration, pancreatic necrosis, erosive bleeding, and nosocomial pneumonia, were more frequently observed in the control group; however, these differences were not statistically significant ($p > 0.05$).

The hospital stay was significantly shorter in the experimental group than in the control group (18.2 ± 7.1 days vs. 29.3 ± 8.1 days, $p < 0.001$).

Discussion

Combat-related duodenal injuries represent some of the most severe forms of abdominal trauma, primarily due to the organ's anatomical and functional characteristics, as well as the high incidence of combined injuries and early contamination of the abdominal cavity. In this study, isolated duodenal injuries accounted for only 13.7 % of cases, whereas 86.3 % had combined injuries, frequently affecting multiple organs and structures. This distribution aligns with contemporary data from both combat and civilian trauma series, where isolated duodenal injuries typically account for 10–20 % of cases, and combined thoracoabdominal injuries predominate [1, 7, 9, 15].

Accurate interpretation of the results depends on the homogeneity of the experimental and control groups with respect to key baseline characteristics, including age, body mass index, injury mechanism, duodenal injury severity (AAST scale), lesion localization, and overall injury severity (NISS). The mean NISS score was 21.8 ± 9.3, with no significant intergroup differences ($p = 0.762$), and the distribution across injury severity categories was comparable. Therefore, observed differences in treatment outcomes can be attributed to variations in medical care tactics and organization, rather than initial patient heterogeneity.

The predominance of D2 segment injuries (approximately 60 % in each group) aligns with current anatomical and clinical understanding, reflecting the segment's fixed position and its proximity to the pancreas and biliary tract. This localization contributes to the high incidence of duodenopancreatic injuries and complicates early surgical management of contamination and biliary leaks [4, 11, 20]. In this study, pancreatic involvement occurred in 25.5 % of cases, consistent with current literature and directly associated with increased risk of suture failure and recurrent peritonitis.

The severity of patients' clinical condition upon admission was evidenced by a high frequency of systemic trauma manifestations: bile leaks occurred in 42.9 % of cases, hemorrhagic shock in 65–80 %, and signs of peritonitis in all patients. Generalized biliary peritonitis was predominant, with a mean MPI score of 19.8 ± 5.6, indicating mild to moderately severe peritonitis in most cases [10, 18]. The lack of intergroup differences in peritonitis characteristics further supports the comparability of initial condition severity.

The primary finding of this study is the confirmation of the critical importance of organized and staged surgical management of duodenal injuries. In the experimental group, most patients (82.1 %) received staged surgical treatment across levels II, III, and IV, consistent with multilevel strategies and the damage control surgery concept. Conversely, in the control group, this approach was applied in only 26.1 % of cases, with 73.9 % of patients undergoing major surgical interventions at level II care.

These differences indicate not only variations in patient routing but also fundamentally distinct strategies for managing contamination, biliary leaks, and physiological instability. Performing extensive surgical procedures at the early stage in cases of severe combined trauma, as seen in the control group, restricts the application of damage control

surgery and contradicts current recommendations for duodenal injury management. In contrast, the staged approach in the experimental group allowed for the deferral of complex reconstructive procedures until after patient stabilization, with these interventions performed in specialized level IV medical facilities, in accordance with international guidelines [6, 16, 19]. The disparity in duration of stay at level II care is notable: 94 % of experimental group patients stayed for less than 1 day, whereas 95 % of control group patients stayed for more than 1 day ($p = 0.001$). Given the presence of active contamination and biliary leaks associated with duodenal injuries, such a delay in early treatment has a significant impact on clinical outcomes.

Recent studies have demonstrated that prolonged hospitalization of patients with duodenal injuries in settings with limited diagnostic and surgical resources is linked to worsening peritonitis, increased bacterial burden, and higher risks of suture failure and septic complications [8, 16, 19]. The findings of this study are consistent with these observations and support the conclusion that reducing the duration of stay at level II is a key component of the improved surgical management algorithm, contributing to better clinical outcomes in the experimental group.

Although the number of surgical interventions per patient did not differ significantly between the groups, the distribution of surgical procedures across treatment stages varied. In the experimental group, complex reconstructive and combined interventions (duodenal diverticulization, gastroenteroanastomosis, and pancreaticoduodenal resections) as well as biliary decompression were more frequently performed at level IV care after patient stabilization. This approach aligns with current recommendations from the World Society for Emergency Surgery (WSES) and the Eastern Association for the Surgery of Trauma (EAST), both of which advise against performing complex reconstructions during periods of physiological instability [6, 13].

The experimental group undergoing PTC demonstrated a significantly higher frequency of biliary decompression ($p < 0.0001$). According to recent literature, adequate biliary decompression is an essential factor in preventing duodenal suture failure, recurrent peritonitis, and septic complications, particularly in cases involving D2 segment damage and concurrent pancreatic trauma [5, 8, 11]. This aspect of the treatment algorithm likely contributed to the markedly lower incidence of duodenal suture failure observed in the experimental group (7.1 % vs. 52.2 %; $p = 0.001$).

The reduction in suture failure rates in the algorithm group led to lower incidences of recurrent peritonitis, sepsis, eventration, multiple organ failure, and the need for relaparotomy. The proportion of patients requiring relaparotomy for recurrent peritonitis was four times lower in the experimental group (14.2 % vs. 60.9 %; $p = 0.007$), and multiple relaparotomies were more frequently observed in the control group. According to recent meta-analyses, this sequence of complications is the primary predictor of mortality in duodenal injuries [16, 17].

The integral indicator of the improved algorithm's effectiveness was a significant reduction in mortality in the experimental group compared with the control group (13.4 % vs. 39.1 %, $p = 0.043$). Given the comparable initial injury severity between the groups, these findings indicate that the staged, algorithm-based approach, rather than the initial intervention's aggressiveness, is the key determinant of prognosis in combat-related duodenal injuries.

In summary, these findings support the current understanding that effective treatment of duodenal injuries relies on prompt contamination control, early minimally invasive interventions, and the execution of complex reconstructive procedures following patient stabilization. The improved staged surgical management algorithm applied in the experimental group significantly reduced the incidence of severe complications, length of hospital stay, and mortality, underscoring its practical relevance for the management of combat-related injuries.

Conclusions

In 86.3 % of cases, combat-related duodenal traumas present as combined injuries. They are associated with a severe systemic response, as evidenced by elevated NISS scores 21.8 ± 9.3, peritonitis in all patients, and a high incidence of bile contamination (88.2 %).

The implementation of an improved staged surgical management algorithm, incorporating early evacuation and major surgical interventions at specialized medical facilities, significantly enhances treatment outcomes. This approach reduces duodenal suture failure from 52.2 % to 7.1 %, recurrent peritonitis from 47.8 % to 17.9 %, sepsis from 60.9 % to 17.9 %, and the need for relaparotomy from 60.9 % to 14.2 %.

The staged surgical management algorithm results in a substantial reduction in mortality (from 39.1 % to 13.4 %) and shortens inpatient treatment duration. These findings underscore the critical importance of organizational and tactical strategies in managing combat-related duodenal injuries and support the adoption of this approach in military surgical practice.

Declaration of interests

The authors declare that they have no conflicts of interest.

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Authors contributions

I. P. Khomenko: concept and design, the first and second critical revisions of the manuscript; P. O. Shkliarevych: data collection, analysis and interpretation, statistical analysis, and drafting the manuscript.

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Поетапна хірургічна тактика лікування бойових ушкоджень дванадцятипалої кишки з урахуванням рівнів медичного забезпечення

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Мета — оцінити вплив удосконалення алгоритму поетапної хірургічної тактики лікування бойових ушкоджень дванадцятипалої кишки (ДПК) з урахуванням рівнів медичного забезпечення на частоту післяопераційних ускладнень і летальність.

Матеріали та методи. У проспективне дослідження було залучено 51 військовика з вогнепальними пораненнями ДПК. Пацієнтів розподілили на дві групи: основну групу (n = 28), в якій лікування здійснювали за розробленим алгоритмом, і групу порівняння (n = 23), в якій застосовували стандартну тактику. Групи були порівнянними за віком, механізмом поранення, тяжкістю ушкоджень ДПК, тяжкістю поєднаної травми та характеристиками перитоніту. Статистичний аналіз проводили з використанням параметричних і непараметричних методів.

Результати. Ізольовані ушкодження ДПК мали місце в 13,7 % випадків, поєднані — у 86,3 %. В основній групі в більшості пацієнтів (82,1 %) хірургічне лікування проведено поетапно із залученням II—III—IV рівнів медичного забезпечення та виконанням складних реконструктивних і комбінованих втручань — дивертикулізації ДПК із гастроентероанастомозом, панкреатодуоденальної резекції, декомпресії жовчних шляхів (черезшкірної черезпечінкової холецистостомії) переважно на IV рівні після стабілізації стану пацієнтів. У групі порівняння така модель була реалізована лише в 26,1 % випадків, тоді як у решти поранених основний обсяг оперативного втручання виконували на II рівні. Перебування на II рівні понад однієї доби зареєстрували в 94 % пацієнтів основної групи та 5 % осіб із групи порівняння (p = 0,001). Частота неспроможності швів ДПК була значно нижчою в основній групі (7,1 і 52,2 %, p = 0,001), а також частота перитоніту (17,9 та 47,8 %, p = 0,022), сепсису (17,9 і 60,9 %, p = 0,002) та релапаротомій з приводу рецидивного перитоніту (14,2 і 60,9 %, p = 0,007). Летальність становила 13,4 % в основній групі та 39,1 % у групі порівняння (p = 0,043). Тривалість стаціонарного лікування була вірогідно меншою в основній групі ((18,2 ± 7,1) і (29,3 ± 8,1) доби, p < 0,001).

Висновки. Удосконалений алгоритм поетапної хірургічної допомоги при бойових пораненнях ДПК дає змогу вірогідно знизити частоту тяжких післяопераційних ускладнень, потребу в релапаротоміях, тривалість стаціонарного лікування та летальність.

Ключові слова: двенадцятипала кишка, бойова травма, тактика хірургії контролю ушкоджень, поетапна хірургічна тактика, поєднана абдомінальна травма, перитоніт, неспроможність швів, летальність.

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