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Staged surgical strategy for the management of combat-related duodenal injuries

Comparative analysis of sleeve gastrectomy with transit bipartition versus single anastomosis sleeve ileal bypass in morbidly obese patients with type 2 diabetes mellitus

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ORIGINAL RESEARCH

ОРИГІНАЛЬНІ ДОСЛІДЖЕННЯ

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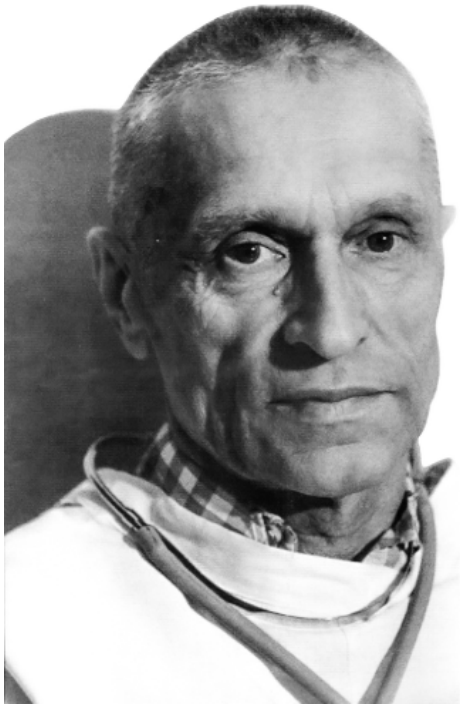
Mykola Amosov: engineer, surgeon, and world-class thinker

Mykola Mykhailovych Amosov (1913—2002) was an outstanding Ukrainian surgeon, cardiac surgeon, world-class scientist and innovator. Born into a poor peasant family, he developed an early interest in both technology and medicine, ultimately obtaining degrees in engineering and medicine. During World War II, Amosov served as a leading surgeon in a front-line hospital, where he improved methods for treating gunshot wounds and established the basis for his PhD research. After the war, he worked in Bryansk and Kyiv, quickly becoming a leading specialist in thoracic surgery. Amosov founded the first department of thoracic surgery in Ukraine, introduced an artificial blood circulation device, performed pioneering heart operations, and developed innovative valve prostheses. As director of the Institute of Cardiovascular Surgery, he elevated the institution to a leading position in Europe. Concurrently, he headed the department of biocybernetics, contributed to the modeling of physiological and mental processes, and developed the first autonomous robots. Mykola Amosov died in 2002, leaving a substantial scientific and humanistic legacy.



Mykola Mykhailovych Amosov was born on December 6, 1913, in the village of Olkhovo, Olkhovo Volost, Cherepovets County, Novgorod Province, into a poor peasant family. His mother, Yelyzaveta Kyrylivna, worked throughout her life as a midwife at a medical center in Vilkhovo. His father participated in World War I and returned from German captivity in 1919. After some time, his father left the family, and from then on, his mother became his primary support. After completing the eighth grade, Amosov attended a woodworking technical school and, upon graduating in 1932, worked for three years as a mechanic at a power plant in a lumber mill. During this period, he developed an interest in designing various mechanisms and innovative devices. Lacking technical knowledge, Amosov enrolled in the All-Union Correspondence Industrial Institute. He further pursued his academic ambitions by entering the Arkhangelsk Medical Institute, where he completed a two-year program in his first year. He advanced rapidly, finishing the second year and proceeding directly to the third year, which provided his initial exposure to clinical medicine, including patient care. From his fourth year, Amosov began teaching at the paramedic school and studied a wide range of disciplines, including ophthalmology. He graduated from the medical institute with honours, receiving only two grades of «four». In August 1939, Amosov began his surgical career in a traumatology clinic. In February 1940, he passed his final exams and defended his diploma project with excellence at the All-Union Correspondence Industrial Institute, receiving an engineering diploma. Amosov became a certified doctor and engineer almost simultaneously.

Amosov worked at an interdistrict hospital in Cherepovets, where he served as the interim head of the surgical department, overseeing 50 beds. Over time, his responsibilities expanded to include teaching anatomy and physiology at the paramedic school. Under his leadership, the surgical department experienced notable progress, with patients undergoing planned operations. Remarkably, during his year of service in Cherepovets, there were no patient fatalities.

At the beginning of World War II, Amosov was appointed as the head of the surgical department and leading surgeon at the field mobile hospital No 2266, holding the rank of military doctor of the third rank.

Faced with a high volume of wounded soldiers, he worked daily from eight in the morning until two the following morning. As Amosov later recalled, «if they had said earlier that such a thing was possible, I would not have believed that it was possible to withstand such a load».

While stationed at the front, Amosov systematically acquired expertise in treating gunshot fractures of the limbs and introduced modifications to existing medical techniques. Notably, he enhanced the surgical approach for gunshot injuries to the knee joint, and this innovation became the foundation of his PhD research, «Primary treatment of knee joint wounds», which he wrote daily during his limited rest periods between operations. Beginning in March 1943, the hospital expanded its focus to include the treatment of chest injuries, during which Amosov again implemented novel, proprietary methods.

By undertaking considerable personal risk, Amosov initiated lung resection procedures, a practice that would later contribute to his international recognition. In early January 1944, he reached a significant personal milestone when he married Lydiia Denysenko, a senior nurse and junior lieutenant.

After his demobilization in December 1946, Amosov assumed the position of head of the main operating room at the M. V. Sklifosovsky Institute. However, despite his strong aspiration to continue surgical practice, he was not permitted to perform operations. Dissatisfied with these limitations, he chose to resign from the position.

In February 1947, Amosov received an invitation to take up the position of regional surgeon and head of the surgical department at Bryansk Regional Hospital. His wife, Lydiia, was appointed as the senior operating room nurse. Reflecting on his own experiences, Amosov stated, «The Bryansk years – from 1947 to 1952 – were the brightest in my life. There, I felt surgical happiness, friendship with my subordinates. Later, this was no longer the case». As a former front-line surgeon, he also remarked, «The war made me a surgeon. But Bryansk made me a real surgeon».

In November 1951, a major surgical conference took place in Kyiv. By that time, Amosov had performed hundreds of operations for pulmonary pathology and had completed a draft of his doctoral dissertation. After his presentation, Amosov received an invitation from Alexander Samoilovych Mamolat, director of the Scientific Research Institute of Tuberculosis named after Academician F. G. Yanovsky, to join the institute. The move to Kyiv was expedited because Mykola Mikhailovich's wife had entered the Kyiv Medical Institute.

In November 1952, Mykola Amosov and his wife, Lidiia, moved to Kyiv. Amosov was appointed to lead a newly established thoracic surgery clinic. He defended his doctoral dissertation entitled «Pneumonectomy and lung resection in tuberculosis».

Subsequently, the rector of the Kyiv Medical Institute, Terentii Yakovlevych Kalinichenko, invited Amosov to head the Department of Surgery within the Sanitary and Hygienic Faculty. While students appreciated Amosov's lectures, his commitment to rigorous academic standards occasionally resulted in unsatisfactory exam scores for some. At that time, none of the clinic employees had seen or performed the surgical interventions introduced by Amosov. Interest in cardiac surgery was growing rapidly, and in 1955, he performed a commissurotomy for mitral stenosis under local anesthesia. Recognizing the necessity of endotracheal anesthesia combined with artificial lung ventilation, Amosov was compelled to acquire expertise in anesthesiology. In 1955, through his tireless organizational efforts, Amosov founded the first department of thoracic surgery in Ukraine at the Kyiv Institute of Advanced Training of Doctors, which he headed. The department of anesthesiology was later separated from this unit. The year 1956 marked a significant personal milestone for Amosov with the birth of his long-awaited daughter, Katia, on February 8. In the autumn of 1957, Amosov was delegated to the International Surgical Congress in Mexico. The most consequential aspect of this trip was his observation of an operation utilizing an artificial circulatory system. Amosov recognized that the advancement of cardiac surgery depended on the adoption of modern general anesthesia techniques and artificial circulatory systems. In Kharkiv, an artificial circulatory system was designed at one of the local factories. By the end of 1958, the first attempt to use this system in the operating room was made, with success achieved on the third attempt.

In 1958, Amosov published his seminal work, «Essays on Thoracic Surgery», which became an essential reference for both thoracic and general surgeons.

In 1959, Amosov maintained an exceptionally demanding schedule, performing 150 to 200 operations annually, preparing lectures for cadets, participating in surgical society meetings, supervising student dissertation defenses, and delivering presentations at conferences, congresses, and conventions.

In 1962, Amosov spent one month in the USA studying advancements in cardiac surgery. It marked the beginning of his specialization in this field. In 1963, he first performed the mitral valve prosthesis procedure for heart defects.

In 1965, Amosov reported his experience with the successful implantation of hemispherical heart valve prostheses in patients with small left ventricles, for whom spherical prostheses could not be used. That

same year, he became the first in the world to design and implement an antithrombotic heart valve prosthesis. Amosov developed a number of innovative surgical techniques for treating heart defects.

At the end of 1969, Amosov was elected a full member of the Academy of Sciences of Ukraine. In 1976, a significant event took place in his professional life. The clinic under his leadership moved to a new building with 350 beds, necessitating an increase in surgical interventions. In 1982, the clinic performed 2,000 operations, including 600 procedures utilizing an artificial blood circulation apparatus.

In 1983, the cardiac surgery clinic of the Kyiv Research Institute (RI) of Tuberculosis and Thoracic Surgery was reorganized as the Kyiv Research Institute of Cardiovascular Surgery of the Ministry of Health of Ukraine. In 1993, it became the Institute of Cardiovascular Surgery of the Academy of Medical Sciences of Ukraine, now known as the National Institute of Cardiovascular Surgery named after M. M. Amosov of the National Academy of Medical Sciences of Ukraine. Naturally, Amosov was appointed as the first director of the newly established R&D Institute.

Beginning in 1984, Amosov experienced health problems and was diagnosed with heart block. In January 1986, he received a pacemaker in Kaunas. On December 6, 1988, upon reaching his 75th birthday, Amosov made a difficult decision to resign from his position as director of the R&D Institute of Cardiovascular Surgery.

In addition to his surgical work, Amosov focused on contemporary issues in biological, medical, and psychological cybernetics. From 1959 to 1990, he headed the Department of Biological Cybernetics at the Institute of Cybernetics of the National Academy of Sciences of Ukraine. Under his leadership, fundamental research was conducted on heart self-regulation systems, the development of machine diagnostic methods for heart diseases, the creation of a physiological model of the «internal environment of the human organism», computer modeling of basic mental functions, and some socio-psychological mechanisms of human behaviour. These contributions received national and international recognition. During the 1960s and 1970s, he also participated in the research and design of artificial intelligence systems. Together with colleagues at the Institute of Cybernetics, he developed the world's first autonomous robots controlled by an artificial neural network.

In 1996, the progression of Amosov's aortic valve defect became evident. However, he continued to work at the computer. In 1999, following a decline in his health, Amosov underwent surgery performed by Professor Reiner Körfer in Germany, during which a biological aortic valve was implanted, and two coronary artery shunts were placed. After the operation, Amosov resumed his professional activities and continued to write. However, age-related diseases progressed, particularly ischemic heart disease, which led to a myocardial infarction and his death on December 12, 2002, at the age of 90. He was buried at Baikove Cemetery in Kyiv.

References

1. 160 years of the National Medical University named after O. O. Bogomolets. NMU named after O. O. Bogomolets; Edited by E. G. Goncharuk. Kyiv: Stolittya; 2001. 368 p.
2. Ioffe OYu, Dibrova YuA, Tsiura YuP, Stetsenko OP, Tarasiuk TV, et al. From the Past to the Future Through the Present: History of the Department of General Surgery No. 2. Kyiv: Medprint; 2024. 312 p.
3. Vilensky Yu.H., Ioffe O.Yu., Kryzhanovskyi Ya.Y., et al., compilers. Mykola Mykhailovych Amosov. A Life That Entered History: Memories, Reflections, Encounters. Kyiv: Medprint; 2023. 272 p.

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Микола Амосов: інженер, хірург і мислитель світового рівня

Ю. П. Цюра, М. С. Кривопустов

Національний медичний університет імені О. О. Богомольця, Київ

Микола Михайлович Амосов (1913—2002) — видатний український хірург, кардіохірург, учений і новатор світового рівня. Народився в бідній селянській родині, рано захопився технікою та медициною, отримавши одночасно дипломи інженера й лікаря. Під час Другої світової війни працював провідним хірургом фронтового шпиталю, де вдосконалив методи лікування вогнепальних поранень і заклав основу своєї кандидатської дисертації. Після війни працював у Брянську та Києві, швидко ставши провідним фахівцем із торакальної хірургії. Амосов створив першу в Україні кафедру грудної хірургії, запровадив апарат штучного кровообігу, виконав одні з перших у світі операцій на серці та розробив унікальні клапанні протези. Як директор Інституту серцево-судинної хірургії він перетворив його на провідний європейський центр. Паралельно очолював відділ біокібернетики в інституті кібернетики, займався моделюванням фізіологічних і психічних процесів, створенням перших автономних роботів. Помер у 2002 році, залишивши величезний науковий і гуманістичний спадок.

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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).

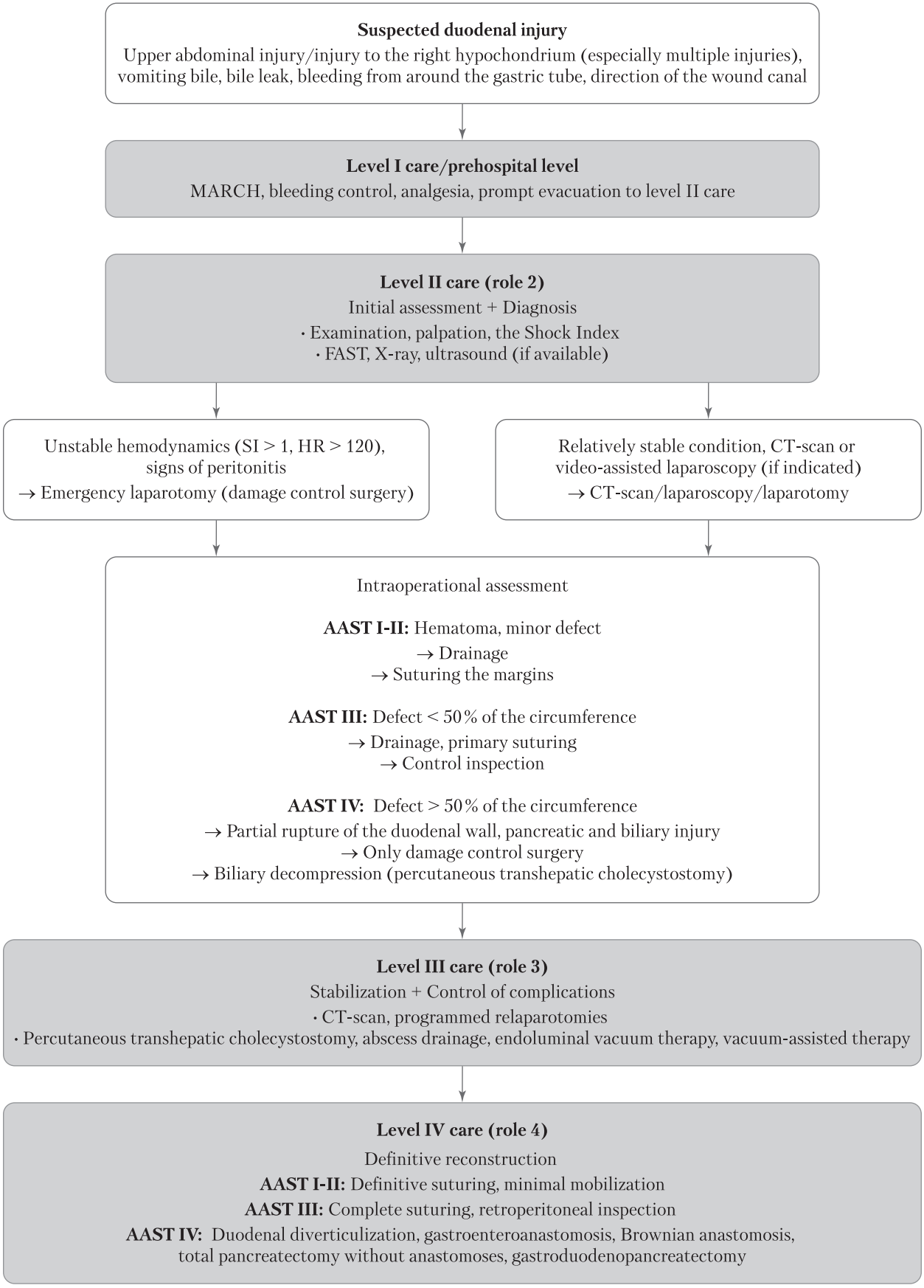
Level III care

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).

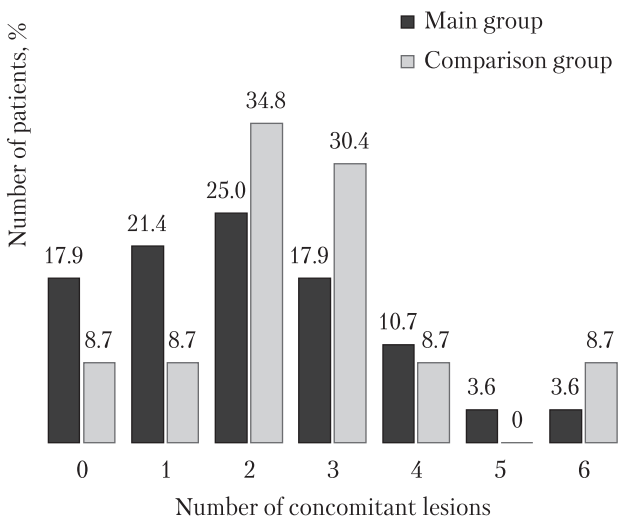


Figure 2. **Distribution of wounded individuals in the study groups according to the number of concomitant lesions in the abdominal cavity and extraperitoneal space, excluding duodenal lesions**

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

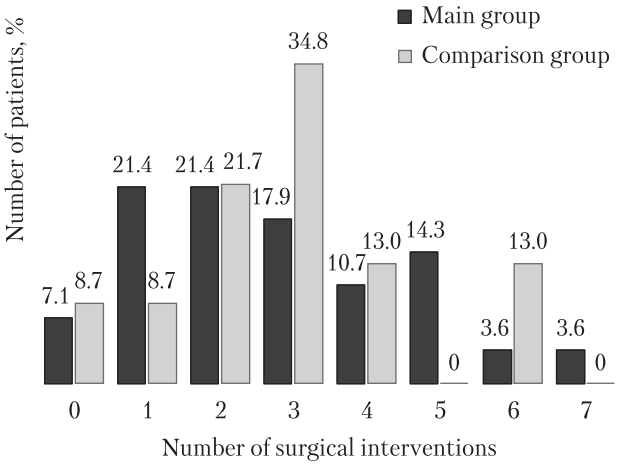


Figure 3. **Distribution of wounded individuals across groups by the number of surgical interventions, excluding suturing or clipping of the duodenum**

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.

References

1. Aiolfi A, Matsushima K, Chang G, Bardes J, Strumwasser A, Lam L, Inaba K, Demetriades D. Surgical Trends in the Management of Duodenal Injury. J Gastrointest Surg. 2019 Feb;23(2):264-269. doi: 10.1007/s11605-018-3964-x.
2. Balogh ZJ, Varga E, Tomka J, Süveges G, Tóth L, Simonka JA. The new injury severity score is a better predictor of extended hospitalization and intensive care unit admission than the injury severity score in patients with multiple orthopaedic injuries. J Orthop Trauma. 2003 Aug;17(7):508-12. doi: 10.1097/00005131-200308000-00006.
3. Bolaji T, Ratnasekera A, Ferrada P. Management of the complex duodenal injury. Am J Surg. 2023 Apr;225(4):639-644. doi: 10.1016/j.amjsurg.2022.12.016.
4. Butano V, Napolitano MA, Pat V, Wahrenbrock T, Lin P, Quintana MT, Kartiko S, Sarani B, Estroff JM. Contemporary Management of Traumatic Duodenal Injuries. Am Surg. 2023 Apr;89(4):1254-1257. doi: 10.1177/0003134821995054. Epub 2021 Feb 17. PMID: 33596103.
5. Choron RL, Teichman AL, Bargoud CG, Sciarretta JD, Smith RN, Hanos DS, Afif IN, Beard JH, Dhillon NK, Zhang A, Ghneim M, Devasahayam RJ, Gunter OL, Smith AA, Sun BL, Cao CS, Reynolds JK, Hilt LA, Holena DN, Chang G, Jonikas M, Echeverria K, Fung NS, Anderson A, Fitzgerald CA, Dumas RP, Levin JH, Trankiem CT, Yoon JJ, Blank J, Hazelton J, McLaughlin CJ, Al-Aref R, Kirsch JM, Howard DS, Scantling DR, Dellonte K, Vella M, Hopkins B, Shell CH, Udekwu PO, Wong EG, Joseph BA, Lieberman H, Ramsey W, Stewart C, Alvarez C, Berne JD, Nahmias J, Puente I, Patton JH Jr, Rakitin I, Perea LL, Pulido OR, Ahmed H, Keating J, Kodadek LM, Wade J, Henry R, Schreiber MA, Benjamin AJ, Khan A, Mann LK, Mentzer CJ, Mousafeiris V, Mulita F, Reid-Gruner S, Sais E, Marks J, Foote C, Palacio CH, Argandykov D, Kaafarani H, Coyle S, Macor M, Manderski MTB, Narayan M, Seamon MJ. Outcomes among trauma patients with duodenal leak following primary versus complex repair of duodenal injuries: An Eastern Association for the Surgery of Trauma multicenter trial. J Trauma Acute Care Surg. 2023 Jul 1;95(1):151-159. doi: 10.1097/TA.0000000000003972. Epub 2023 Apr 19. PMID: 37072889.
6. Coccolini F, Kobayashi L, Kluger Y, Moore EE, Ansaloni L, Biffl W, Leppaniemi A, Augustin G, Reva V, Wani I, Kirkpatrick A, Abu-Zidan F, Cicuttin E, Fraga GP, Ordonez C, Pikoulis E, Sibilla MG, Maier R, Matsumura Y, Masiakos PT, Khokha V, Mefire AC, Ivatury R, Favi F, Manchev V, Sartelli M, Machado F, Matsumoto J, Chiarugi M, Arvieux C, Catena F, Coimbra R; WSES-AAST Expert Panel. Duodeno-pancreatic and extrahepatic biliary tree trauma: WSES-AAST guidelines. World J Emerg Surg. 2019 Dec 11;14:56. doi: 10.1186/s13017-019-0278-6. PMID: 31867050; PMCID: PMC6907251.
7. Diggs LP, Gregory S, Choron RL. Review of Traumatic Duodenal Injuries: Etiology, Diagnosis, and Management. Am Surg. 2023 May;89(5):1989-1996. doi: 10.1177/00031348211065091.
8. Ferrada P, Wolfe L, Duchesne J, et. al. Management of duodenal trauma: A retrospective review from the Panamerican Trauma Society. J Trauma Acute Care Surg. 2019 Mar;86(3):392-396. doi: 10.1097/TA.0000000000002157.
9. García Santos E, Soto Sánchez A, Verde JM, Marini CP, Asensio JA, Petrone P. Duodenal injuries due to trauma: Review of the literature. Cir Esp. 2015 Feb;93(2):68-74. English, Spanish. doi: 10.1016/j.ciresp.2014.08.004.
10. Gupta S, Zingade A, Baviskar M, Vakil RB. Efficacy of the Mannheim Peritonitis Index (MPI) in Predicting Postoperative Outcomes in Patients With Perforation Peritonitis. Cureus. 2025 Apr 29;17(4):e83193. doi: 10.7759/cureus.83193.
11. Lin BC, Fang JF, Wong YC, Liu NJ. Blunt pancreatic trauma and pseudocyst: management of major pancreatic duct injury. Injury. 2007 May;38(5):588-93. doi: 10.1016/j.injury.2006.11.017. Epub 2007 Feb 15. PMID: 17306266.
12. Linder MM, Wacha H, Feldmann U, Wesch G, Streifensand RA, Gundlach E. Der Mannheimer Peritonitis-Index. Ein Instrument zur intraoperativen Prognose der Peritonitis [The Mannheim peritonitis index. An instrument for the intraoperative prognosis of peritonitis]. Chirurg. 1987 Feb;58(2):84-92. German. PMID: 3568820.].
13. Malhotra A, Biffl WL, Moore EE, Schreiber M, Albrecht RA, Cohen M, Croce M, Karmy-Jones R, Namias N, Rowell S, Shatz DV, Brasel KJ. Western Trauma Association Critical Decisions in Trauma: Diagnosis and management of duodenal injuries. J Trauma Acute Care Surg. 2015 Dec;79(6):1096-101. doi: 10.1097/TA.0000000000000870. PMID: 26680146.
14. Moore EE, Cogbill TH, Malangoni MA, Jurkovich GJ, Champion HR, Gennarelli TA, McAninch JW, Pachter HL, Shackford SR, Trafton PG. Organ injury scaling, II: Pancreas, duodenum, small bowel, colon, and rectum. J Trauma. 1990 Nov;30(11):1427-9. PMID: 2231822.
15. Obadiel YA, Albrashi AA, Saeed MA, Jowah HM. Incidence and Management of Duodenal Trauma in a War Setting: Insights From a Military Hospital in Yemen. Cureus. 2025 Jan 12;17(1):e77323. doi: 10.7759/cureus.77323.
16. Ordoñez CA, Parra MW, Millán M, et.al. Damage control in penetrating duodenal trauma: less is better – the sequel. Colomb Med (Cali). 2021 May 3;52(2):e4104509. doi: 10.25100/cm.v52i2.4509.
17. Osler T, Baker SP, Long W. A modification of the injury severity score that both improves accuracy and simplifies scoring. J Trauma. 1997 Dec;43(6):922-5; discussion 925-6. doi: 10.1097/00005373-199712000-00009.
18. Sartelli M, Chichom-Mefire A, Labricciosa FM, et.al. The management of intra-abdominal infections from a global perspective: 2017 WSES guidelines for management of intra-abdominal infections. World J Emerg Surg. 2017 Jul 10;12:29. doi: 10.1186/s13017-017-0141-6. Erratum in: World J Emerg Surg. 2017 Aug 2;12:36. doi: 10.1186/s13017-017-0148-z.
19. Smyth L, Bendinelli C, Lee N, Reeds MG, Loh EJ, Amico F, Balogh ZJ, Di Saverio S, Weber D, Ten Broek RP, Abu-Zidan FM, Campanelli G, Beka SG, Chiarugi M, Shelat VG, Tan E, Moore E, Bonavina L, Latifi R, Hecker A, Khan J, Coimbra R, Tebala GD, Søreide K, Wani I, Inaba K, Kirkpatrick AW, Koike K, Sganga G, Biffl WL, Chiara O, Scalea TM, Fraga GP, Peitzman AB, Catena F. WSES guidelines on blunt and penetrating bowel injury: diagnosis, investigations, and treatment. World J Emerg Surg. 2022 Mar 4;17(1):13. doi: 10.1186/s13017-022-00418-y. PMID: 35246190; PMCID: PMC8896237.
20. Søreide K, Weiser TG, Parks RW. Clinical update on management of pancreatic trauma. HPB (Oxford). 2018 Dec;20(12):1099-1108. doi: 10.1016/j.hpb.2018.05.009.
21. Weale RD, Kong VY, Bekker W, Bruce JL, Oosthuizen GV, Laing GL, Clarke DL. Primary repair of duodenal injuries: a retrospective cohort study from a major trauma centre in South Africa. Scand J Surg. 2019 Dec;108(4):280-284. doi: 10.1177/1457496918822620.

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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Personalized treatment algorithm for acute anal fissures: comparison with traditional symptomatic therapy

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Objective – to evaluate the clinical efficacy of a personalized treatment algorithm for acute anal fissures based on a fissure chronicity risk scale compared with standard symptomatic therapy.

Materials and methods. This prospective non-randomized comparative study included 175 patients with acute anal fissure treated at the proctology department of Kyiv City Clinical Hospital № 18 between 2021 and 2024. The mean patient age was 39.29 ± 12.98 years. The study group received individualized treatment based on chronicity risk assessment, while the control group received standard symptomatic treatment. Efficacy was assessed by the rate of complete healing at week 4, pain dynamics on the VAS scale, and the incidence of chronicity.

Results. The personalized treatment protocol resulted in a higher rate of complete healing compared to standard therapy (81.63 % versus 41.56 %, $p < 0.001$). The incidence of chronicity of anal fissures was lower in the study group (4.08 %) than in the control group (23.38 %). Patients in the study group achieved pain reduction of more than 50 % faster than those in the control group (6.1 ± 2.3 versus 12.8 ± 3.5 days). Side effects were observed in both groups, including local redness (11 % and 14 %), temporary incontinence (7 % and 0 %), and headache (0 % and 3 %).

Conclusions. The personalized protocol for managing acute anal fissures shows higher efficacy and significantly improved clinical outcomes compared to standard conservative therapy. Implementation of this approach in clinical practice accelerates healing, reduces chronicity rates, and lowers early recurrence. Therefore, adoption of the proposed protocol is recommended.

Keywords
minimally invasive proctology, combined pathology, anal fissure, hemorrhoids, scar deformities, perianal scar.

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Anal fissure represents the second most prevalent disease of the anorectal region, accounting for 10 % to 15 % of visits to a proctologist [9, 12, 14]. An acute anal fissure is defined as a linear defect of the anoderm, typically accompanied by severe pain. This condition often leads to anal sphincter spasm due to irritation of its fibers, resulting in ischemia. This pathological cycle constitutes the key pathogenetic mechanism. Prolonged ischemia usually causes the development of a chronic anal fissure [5, 9, 12, 14].

Although this pathology is quite common, optimal management tactics remain limited. Current recommendations for acute anal fissure management generally endorse the same methods, but the application process, specific indications, effectiveness evaluation, and criteria for therapy escalation are insufficiently defined. The primary therapeutic goals are to alleviate anal sphincter spasm and restore adequate blood supply. Delayed therapy escalation or inadequate therapy are associated with an increased risk of chronicity [2, 8, 13, 17]. It should be noted that predictors of an unfavourable course of acute anal fissure include pain intensity, symptom duration for more than 4 weeks, severe spasm, and concomitant functional disorders. At present, no guidelines support individualized treatment approaches.

According to the recommendations, standard conservative therapy includes stool regulation through a high-fiber diet, maintenance of water balance, sitz baths, and application of local anesthetic ointments. These measures promote healing in approximately 60 % of patients with acute anal fissures [2, 13, 17].

Early administration of topical calcium channel blockers or nitrates significantly accelerates healing and reduces the risk of chronic fissure development. However, these methods may be insufficient for patients at high risk of poor outcomes.

Therefore, there is a need to develop a personalized treatment protocol that incorporates clinical predictors of unfavourable outcomes and facilitates the rational selection of therapeutic strategies.

Objective – to evaluate the clinical efficacy of a personalized algorithm for the treatment of acute anal fissures based on a fissure chronicity risk scale compared to standard symptomatic therapy.

Materials and methods

This prospective non-randomized comparative study was conducted from 2021 to 2024 and included 175 patients with acute anal fissures. Depending on the management approach, patients were divided into two groups. The study group (n = 98) received treatment according to the chronicity risk scale (Table 1), and the control group (n = 77) received standard conservative therapy.

The fissure chronicity risk (FCR) scale was used to stratify the risk of chronicity of acute anal fissures. This scale includes five independent clinical factors with established pathogenetic significance:

Table 1. **Personalized fissure chronicity risk scale**

Criterion	Points
Symptoms lasting > 4 weeks	1
Pain on the VAS > 7	1
Pronounced anal sphincter spasm	1
Nocturnal pain	1
History of fissure recurrence	1

Interpretation:
0 – standard therapy,
1–2 – topical calcium channel blockers,
≥ 3 – botulinum toxin injections (30–50 U).

Table 2. **Internal validation of fissure chronicity risk scale in our sample**

Score	Chronic cases after treatment
0 (n = 14)	0
1 (n = 23)	1 (4.3 %)
2 (n = 31)	1 (3.2 %)
≥ 3 (n = 30)	2 (6.7 %)

symptoms persisting for more than four weeks, intense pain syndrome (> 7 on the Visual Analogue Scale (VAS)), severe sphincter spasm, presence of nocturnal pain, and a history of anal fissure recurrence. These indicators present the principal mechanisms underlying chronicity: anoderm ischemia, neuromuscular regulation disorders, and reduced reparative potential. Each criterion was assigned one point, as all indicators have comparable independent prognostic value and reflect distinct aspects of the pathophysiology. The total FCR score was used to stratify patients and guide therapeutic escalation decisions. To confirm the predictive utility of the FCR scale, an internal validation analysis was conducted. Patients were grouped according to their initial FCR score, and the frequency of chronicity after treatment was recorded (Table 2). The observed distribution demonstrates a progressive increase in chronicity among patients with higher FCR scores, thereby supporting the scale's internal validity and justifying treatment escalation in the subgroup with scores ≥ 3.

Symptoms lasting more than four weeks were interpreted as evidence of fibrotic changes at the fissure margins and persistent ischemia. A pain intensity VAS > 7 was used to assess the severity of neurogenic spasm in the internal anal sphincter. Severe sphincter spasm was identified as the primary mechanism sustaining ischemia and hindering tissue repair. Nocturnal pain was considered indicative of damage extending beyond defecation and was associated with more pronounced ischemia. A history of previous relapses suggested structural vulnerability of the anoderm and an increased risk of defect recurrence. Each of these five factors was assessed as equally influential in determining the likelihood of chronicity and was therefore assigned a weight of one point. The total FCR score was used to evaluate the overall risk and to guide decisions regarding therapeutic escalation.

Patients with 0 points received standard symptomatic therapy, while those with 1–2 points were additionally prescribed topical calcium channel blockers to reduce internal sphincter tone. Patients with a total score of ≥ 3 were considered a high-risk group in whom the pathogenetic cycle of «pain-spasm-ischemia» had already formed and required a more intensive effect on the sphincter apparatus. In such cases, botulinum toxin injection was selected as the preferred method, providing reversible chemical sphincterotomy, significantly improving blood supply to the anoderm, and facilitating effective fissure healing.

Topical calcium channel blockers were used in patients with an FCR score of 1–2. Nifedipine 0.2 % ointment was applied 2–3 times a day in

a thin layer along the anal canal (≈1 cm from the anal ring) for 14 days. The choice between nifedipine and diltiazem was based on the tolerability of previous treatments and individual patient sensitivity. Both drugs are regarded as equally effective in reducing intrasphincteric pressure.

Patients with an FCR score of ≥ 3 received botulinum toxin type A (Botox®, Allergan) injections. The drug was administered at a dose of 20–30 units, evenly distributed in the internal anal sphincter. Injections were performed at two sites, corresponding to the 3 and 9 o'clock positions on the conventional clock face, to a depth of approximately 3–4 mm. This approach ensured a uniform reduction in sphincter pressure and minimized the risk of local excessive relaxation. The injection was performed under sterile conditions, without anesthesia or with minimal local anesthesia if necessary.

Inclusion criteria were as follows: diagnosis of acute anal fissure (symptom duration ≤ 6 weeks), patient age 18–65 years, a follow-up period of at least 6 months, and provision of signed informed consent.

Exclusion criteria were as follows: diagnosis of chronic anal fissure (symptom duration ≥ 6 weeks), pregnancy, inflammatory bowel diseases, HIV, specific proctitis, previous calcium channel blocker or botulinum toxin therapy, and atypical anal fissures.

The clinical characteristics of the patients included in the study are presented in Table 3. Both groups were statistically homogeneous at the baseline with respect to age, sex, duration of symptoms, initial pain syndrome, severity of spasm, and distribution of high-risk patients according to the FCR scale (all $p > 0.2$).

Table 3. **Clinical characteristics of patients**

Indicator	Study group (n = 98)	Control group (n = 77)
Age, years	37.83 ± 11.62	41.16 ± 14.39
Men	43 (43.9 %)	35 (45.5 %)
Duration of symptoms, days	8.7 ± 2.4	9.1 ± 2.6
VAS (baseline)	7.1 ± 1.2	7.0 ± 1.3
Severe spasm	37,8 %	33,8 %
FCR ≥ 3	30,6 %	28,6 %
Concomitant anorectal diseases, %	65.3 %	72.7 %
History of constipation or diarrhea	43.9 %	45.5 %
History of acute anal fissure	23.3 %	24.3 %

All $p > 0.05$.

Additionally, possible confounding factors such as concomitant anorectal diseases, defecation disorders (constipation or diarrhea), and previous episodes of acute anal fissures did not differ significantly between groups ($p = 0.28$; $p = 0.83$; $p = 0.85$, respectively). These findings confirm the clinical homogeneity of the study samples at the time of inclusion.

Treatment efficacy was assessed based on the following criteria: complete epithelialization at week 4, pain syndrome dynamics, frequency of progression to chronic fissure, and early recurrence of fissure. However, a preliminary assessment was performed on day 14 to determine the need for therapy escalation. In cases where clinical improvement was ≥ 30 %, patients who received standard therapy alone were additionally prescribed calcium channel blockers; those receiving calcium channel blockers were escalated to Botox therapy; and those on Botox were considered for lateral internal sphincterotomy (LIS), although this intervention was not included in the present study.

The follow-up period lasted at least 6 months. The median follow-up was 7 months (range: 6–12 months), allowing assessment of both early and delayed chronicity.

Statistical analysis was performed using MedStat software. Quantitative variables are presented as mean ± standard deviation (M ± SD), and categorical variables are presented as frequencies and their percentage distributions (n, %). Normality of quantitative data was assessed both graphically and using descriptive statistics.

Student's t-test was used to compare the means of two independent groups. Categorical variables were analyzed using Pearson's χ^2-test, and Fisher's exact test was employed when expected frequencies in the cells were < 5. Differences in proportions of complete epithelialization were assessed using the χ^2 test, with relative risk (RR) and its 95 % confidence interval (CI) also calculated.

The dynamics of pain syndrome were analyzed using Student's t-test for independent samples. The frequency of progression from acute to chronic fissures was assessed by comparing proportions (χ^2), with calculation of RR and odds ratio (OR). Statistical significance was defined as $p < 0.05$. No correction for multiple comparisons was applied, as the study had a predefined primary endpoint.

Results

Baseline characteristics of both groups were homogeneous with respect to age, sex, initial pain syndrome intensity, duration of clinical manifestations, and severity of internal anal sphincter spasm (see Table 3).

At week 4, a significantly higher frequency of complete epithelialization was observed in patients treated according to a personalized protocol, with 80 patients (81.63 %) achieving this outcome. In contrast, only 32 patients (41.56 %) receiving standard therapy achieved healing at the same time point, representing nearly half the rate noted in the personalized protocol group. These findings indicate that a personalized management protocol based on risk assessment for anal fissure chronicity improves healing effectiveness within a month, which is statistically significant ($p < 0.001$).

Given that the primary complaint is severe pain during defecation, it is essential to assess treatment effectiveness using an analog pain scale. Patients recorded pain intensity daily. To standardize the assessment, the number of days with a pain reduction exceeding 50 % was calculated. In the study group, this indicator was 6.1 ± 2.3 days, compared to 12.8 ± 3.5 days in the control group ($p < 0.001$). This statistically significant difference suggests that addressing anal sphincter spasm and ischemia is more effective than solely providing local analgesia. Early pain relief also prevents the development of defecation-related fear and reduces the risk of early recurrence of anal fissures.

During the first week of treatment, a reduction in anal sphincter spasm was observed in 71.43 % (70 patients) of the study group and 28.57 % (22 patients) of the control group ($p < 0.001$). These results indicate that the absence of persistent tonic spasm facilitates faster healing and epithelialization.

In both groups, some patients required therapy escalation. Therefore, we conducted the initial assessment of its necessity on day 14. In the personalized protocol group, 9 patients (9.18 %) required escalation, with 5 receiving calcium channel blockers and 4 receiving botulinum toxin injections. In the control group, 21 patients (27.27 %) required escalation. It should be noted that surgical intervention was indicated for 1 patient (1.09 %) in the study group and 9 patients (11.69 %) in the control group. These indicators are critical because they increase treatment costs, risk of side effects and complications, and prolong the patient's incapacity.

Assessment of chronicity risk is essential in our study. A reduction in its score of ≥ 1 point on day 14 was observed in 68 (69.39 %) patients in the study group and 21 (27.27 %) patients in the control group. At the same time, only 4.08 % (4 patients) of the study group developed chronic anal fissures, compared with 23.38 % (18 patients) in the control group $p < 0.001$. These findings confirm that timely intervention in the pathogenetic cycle is crucial for preventing chronicity. Chronic fissures require longer, more complex treatment and can significantly impair quality of life.

A comparative analysis demonstrated significant advantages of the personalized treatment algorithm over standard therapy for most clinical endpoints (Table 4). The probability of complete healing was almost twice as high with the personalized algorithm (RR 1.96), and the chances of treatment success were more than 6 times higher (OR 6.25). The incidence of chronicity was markedly lower in the personalized group (4.08 % vs. 23.38 %), with an RR of 0.17 (95 % CI 0.06–0.49). A trend toward reduced risk of early recurrence was observed (RR 0.22), although the 95 % CI partially overlapped 1. Improvements in pathogenetic markers, specifically reduction in sphincter spasm and a decrease in FCR ≥ 1 point, occurred significantly more often in the personalized group (RR 2.50 and RR 2.54, respectively). The personalized approach also reduced the need for therapy escalation (RR 0.34 (95 % CI 0.16–0.69)) and surgical intervention (RR 0.09 (95 % CI 0.01–0.67)).

Table 4. **Therapy effectiveness indicators**

Indicator	Study group (n = 98)	Control group (n = 77)	p	RR (95 % CI)	OR (95 % CI)
Complete healing at week 4	80 (81.6 %)	32 (41.6 %)	< 0.001	1.96 (1.48–2.60)	6.24 (3.16–12.38)
Time to ≥ 50 % pain reduction, days	6.1 ± 2.3	12.8 ± 3.5	< 0.001	–	–
Chronicity	4 (4.1 %)	18 (23.4 %)	< 0.001	0.17 (0.06–0.49)	0.14 (0.04–0.43)
Early recurrence of fissure	2 (2.0 %)	7 (9.1 %)	0.036	0.22 (0.05–1.05)	0.21 (0.04–1.03)
Reduction of sphincter spasm on day 7	70 (71.4 %)	22 (28.6 %)	< 0.001	2.50 (1.72–3.64)	6.25 (3.23–12.10)
Reduction of FCR ≥ 1 point by day 14	68 (69.4 %)	21 (27.3 %)	< 0.001	2.54 (1.73–3.75)	6.04 (3.12–11.70)
Need for therapy escalation (Botox/medication)	9 (9.2 %)	21 (27.3 %)	0.002	0.34 (0.16–0.69)	0.27 (0.12–0.63)
Need for surgical intervention (LIS)	1 (1.0 %)	9 (11.7 %)	0.004	0.09 (0.01–0.67)	0.08 (0.01–0.63)

During treatment, patients reported side effects in the form of local reactions to topical agents and headaches (Figure). However, the most notable, yet anticipated and manageable, adverse event was temporary anal gas incontinence, which occurred in 7 patients (7.14 %) after botulinum toxin injections in the study group. This mild, transient anal incontinence, primarily manifested by gas incontinence, was reversible and disappeared within 1–3 weeks without treatment. This effect is consistent with the expected temporary decrease in internal sphincter tone, which underlies the therapeutic action of botulinum toxin.

In summary, the data indicate that the personalized protocol offers a clear advantage over conservative therapy. This superiority is reflected in greater reductions in spasm, pain, and chronicity, thereby supporting the pathogenetic validity of the algorithm.

Discussion

Most associations, including the American Society of Colon and Rectal Surgeons (ASCRS) and Association of Coloproctology of Great Britain and Ireland (ACPGBI), recommend conservative therapy (stool regulation, sitz baths, topical nitrates, calcium channel blockers, botulinum toxin), but do not offer a clear quantitative stratification of patients or an escalation algorithm [4, 5]. Our approach seeks to address this gap by systematizing actions and creating a precise algorithm for acute fissure treatment. Although international recommendations and meta-analyses provide a list of remedies, they lack specific guidance on the sequence and techniques for their use [1—3, 6, 8, 9, 15]. We offer an easy-to-use scale to assess fissure chronicity, enabling individualized treatment strategies. Importantly, the study groups did not have statistically significant differences in any of the key clinical or potentially confounding variables, including concomitant anorectal pathology, defecation disorders, and a history of acute anal fissures. Therefore, the observed treatment effects are unlikely to be attributable to differences in baseline patient characteristics.

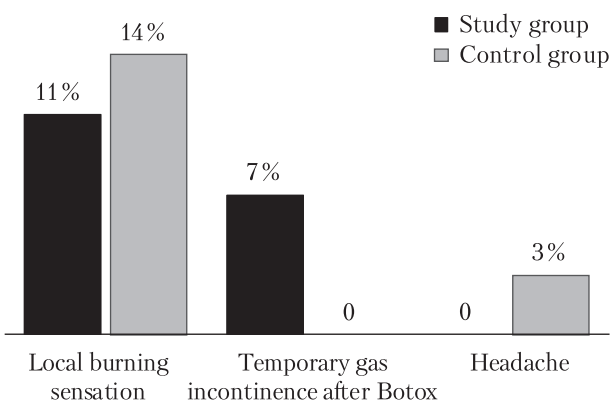

Figure. **Side effects observed in the study and control groups**

Our findings are consistent with existing literature regarding the effectiveness of topical calcium channel blockers. Several studies and clinical guidelines support the administration of topical calcium channel blockers and nitrates for the treatment of acute anal fissures. A randomized study by Momayez Sanat et al. demonstrated that nifedipine achieved higher remission rates and faster pain relief than diltiazem in patients with acute anal fissures [11]. Another randomized study found that 0.5 % nifedipine was more effective and better tolerated than 0.2 % glyceryl trinitrate in the treatment of acute fissures [1]. Although debate persists regarding the relative effectiveness of nitrates versus calcium channel blockers, meta-analyses by Sahebally et al. confirm that calcium channel blockers are both more effective and better tolerated [1, 8, 12, 15]. In our study, only calcium channel blockers were administered to patients with moderate risk (1–2 points on the FCR scale), while topical nitrate-based agents were not used. It can be assumed that, in this subgroup, the use of calcium channel blockers contributed to the high healing rate due to the rapid relief of anal sphincter spasm. These findings suggest that calcium channel blockers may be the first-line escalation for patients with moderate risk.

There is scientific debate regarding the use of botulinum toxin in the treatment of anal fissures, including questions about its effectiveness, optimal injection site, and appropriate dosage [12, 16, 17]. Most randomized controlled trials investigating botulinum toxin have focused on chronic anal fissures, where the drug serves as an alternative or adjunct to lateral internal sphincterotomy. The current ASCRS and ACPGBI guidelines do not consider botulinum toxin as a standard treatment for acute anal fissures, a position shaped by the historical context of the available evidence. Most of the existing randomized studies and meta-analyses on which these recommendations are based addressed the treatment of chronic fissures, as this was the main clinical problem requiring an alternative to surgical intervention [4, 5]. Botulinum toxin was practically excluded from studies of the acute phase, limiting its representation in the recommendations [7, 14]. The rationale for using botulinum toxin in acute anal fissures is its capacity to directly target the principal pathogenetic mechanism: pronounced tonic spasm of the internal anal sphincter, which influences anoderm ischemia and tissue repair rates.

Unlike chronic fissures, in which pathomorphological changes are established, reducing sphincter tone during the acute phase can rapidly restore blood supply at a critical time, when complete healing without surgery remains possible. Notably, the use of botulinum toxin in the acute phase, specifically for high-risk patients, has been minimally explored in the literature, making this approach a novel contribution to the field. The present findings demonstrate that targeted administration of botulinum toxin during the acute phase can substantially decrease the incidence of chronicity and reduce the need for surgical intervention.

In our study, botulinum therapy was administered exclusively in high-risk patients (FCR ≥ 3) or those unresponsive to previous therapeutic stages. The findings confirm that an FCR score of ≥ 3 identifies patients with a high probability of acute anal fissures progressing to chronicity. The presence of prolonged symptoms, severe pain, sphincter spasm, nocturnal pain, and recurrent episodes indicates a pathological cycle of «pain-spasm-ischemia» that does not respond to standard conservative therapy. In these cases, topical calcium channel blockers provide insufficient antispasmodic effects, failing to restore blood supply to the anoderm and stop disease progression. Thus, the use of botulinum toxin in high-risk patients is not an additional option, but an essential component of a treatment strategy aimed at preventing chronic fissure development. These results are particularly significant given the low chronicity rate observed in the study group. Early administration of botulinum toxin in a clearly defined high-risk category may help avoid the need for lateral internal sphincterotomy. The use of botulinum toxin during the acute phase in patients at elevated risk of chronicity aligns with and enhances current guidelines, thereby improving management for this clinically vulnerable population.

Under standard therapy, the rate of progression from acute to chronic anal fissures was consistent with international statistics and amounted to 23.38 %. This therapy includes dietary modifications, combination ointments, sitz baths, and symptomatic laxatives [1–3, 6, 8, 10]. Typically, pain reduction and partial remission occur as part of the natural disease course, without interfering with the chronicity risk assessment and the development of a structured treatment algorithm. In contrast to conventional practice, which is often chaotic or overly conservative in the early stages, the proposed algorithm enables clinicians to select the most effective method for each patient immediately. The assessment on day 14 plays a crucial role in preventing the prolongation of ineffective therapy, a primary contributor to chronicity in clinical practice. This approach advances the management of acute fissures toward personalized medicine by basing decisions on a formalized patient risk profile. The obtained RR and OR values demonstrate that the personalized algorithm not only accelerates healing but also modulates key pathogenetic mechanisms, including spasm, ischemia, and the risk of chronicity. The FCR and sphincter spasm indicators are particularly significant, as OR values exceeding 6 suggest a strong effect of the algorithm in disrupting the pathological cycle of «pain-spasm-ischemia-chronicity». Low RRs for chronicity and the need for LIS confirm that early risk stratification can prevent progression to chronic forms and reduce the need for surgical intervention. Thus, the personalized approach demonstrates both symptomatic and substantial pathogenetic efficacy, distinguishing it from standard therapy.

However, this study has several limitations. First, the non-randomized design does not eliminate the possibility of systematic errors, despite comparable baseline characteristics across groups. Second, the findings are limited to data from a single center. Third, the study group included several treatment methods, depending on risk level, which complicates direct comparison. Consequently, further evaluation through additional randomized studies is warranted.

Conclusions

This study demonstrates that a personalized approach based on risk assessment for anal fissure chronicity can significantly improve treatment effectiveness compared to standard practice regimens. The proposed algorithm facilitates rational therapy selection and reduces the need for surgical intervention. These findings provide a foundation for further randomized studies and multicenter validation of the chronicity risk assessment scale, which has the potential to change management strategies for acute anal fissures.

Declaration of interests

The author declares that there is no conflict of interest.

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Ethics approval and written informed consent statements

The study was conducted in accordance with the Declaration of Helsinki.

All patients provided informed consent.

References

1. Akıncı O, Abdulrahman SMF, Güngör Ö, Yüceyar NS, Perek A, Ertürk MS. Randomised Comparison of the Effect of 0.2 % Glyceryl Trinitrate and 0.5 % Topical Nifedipine in Acute Anal Fissure Treatment. Turk J Colorectal Dis. 2020 Dec 25;30(4):246-252. doi: 10.4274/tjcd.galenos.2020.2020-4-2.
2. Arroyo A, Montes E, Calderón T, Blesa I, Elía M, Salgado G, García-Armengol J, de-la-Portilla F. Treatment algorithm for anal fissure. Consensus document of the Spanish Association of Coloproctology and the Coloproctology Division of the Spanish Association of Surgeons. Cir Esp (Engl Ed). 2018 May;96(5):260-267. doi: 10.1016/j.ciresp.2018.02.007.
3. Brisinda G, Cadeddu F, Brandara F, Marniga G, Maria G. Randomized clinical trial comparing botulinum toxin injections with 0.2 per cent nitroglycerin ointment for chronic anal fissure. Br J Surg. 2007 Feb;94(2):162-7. doi: 10.1002/bjs.5514.
4. Cross KLR, Brown SR, Kleijnen J, Bunce J, Paul M, Pilkington S, et al. The Association of Coloproctology of Great Britain and Ireland guideline on the management of anal fissure. Colorectal Dis. 2023;25:2423-2457. doi: 10.1111/codi.16762.
5. Davids JS, Hawkins AT, Bhama AR, Feinberg AE, Grieco MJ, Lightner AL, Feingold DL, Paquette IM; Clinical Practice Guidelines Committee of the American Society of Colon and Rectal Surgeons. The ASCRS Clinical Practice Guidelines for the Management of Anal Fissures. Dis Colon Rectum. 2023 Feb 1;66(2):190-199. doi: 10.1097/DCR.0000000000002664.
6. Gardner IH, Siddharthan RV, Tsikitis VL. Benign anorectal disease: hemorrhoids, fissures, and fistulas. Ann Gastroenterol. 2020 Jan-Feb;33(1):9-18. doi: 10.20524/aog.2019.0438.
7. Gerbasi L, Ashurst JV. Anal Fissures. StatPearls [Internet]. 2025 Sep 15. Treasure Island (FL): StatPearls Publishing; 2025–. PMID: 30252319.
8. Higuero T. Update on the management of anal fissure. J Visc Surg. 2015 Apr;152(suppl. 2):S37-43. doi: 10.1016/j.jviscsurg.2014.07.007.
9. Lohsiriwat V. Anorectal emergencies. World J Gastroenterol. 2016 Jul 14;22(26):5867-78. doi: 10.3748/wjg.v22.i26.5867.
10. Mert T. The importance of topical metronidazole in the treatment of acute anal fissure: a double-blind randomized study. Ann Coloproctol. 2023 Apr;39(2):131-138. doi: 10.3393/ac.2021.00675.0096.
11. Momayez Sanat Z, Mohammadi Ganjaroudi N, Mansouri M. The Effect of Topical Nifedipine versus Diltiazem on the Acute Anal Fissure. Middle East J Dig Dis. 2023 Apr;15(2):121-125. doi: 10.34172/mejdd.2023.330.
12. Nelson RL, Thomas K, Morgan J, Jones A. Non-surgical therapy for anal fissure. Cochrane Database Syst Rev. 2012;(2):CD003431. doi: 10.1002/14651858.CD003431.pub3.
13. Newman M, Collie M. Anal fissure: diagnosis, management, and referral in primary care. Br J Gen Pract. 2019 Aug;69(685):409-410. doi: 10.3399/bjgp19X704957.
14. Schlichtemeier S, Engel A. Anal fissure. Aust Prescr. 2016;39(1):14-17. doi: 10.18773/austprescr.2016.007.
15. Shahid MH, Javed S, Javed S, Khan AZ, Kaiser A, Mithany RH. Comparative Efficacy of Topical Metronidazole and Glyceryl Trinitrate Versus Glyceryl Trinitrate Alone in Acute Anal Fissure. Cureus. 2022 Nov;14(11):e31812. doi: 10.7759/cureus.31812.
16. Thippeswamy KM, Gruber M, Abdelaziz H, Abdel-Dayem M. Efficacy and safety of botulinum toxin injection in chronic symptomatic anal fissure: a systematic review and meta-analysis. Tech Coloproctol. 2025 Jan 9;29(1):44. doi: 10.1007/s10151-024-03087-y.
17. Vitton V, Bouchard D, Guingand M, Higuero T. Treatment of anal fissures: Results from a national survey on French practice. Clin Res Hepatol Gastroenterol. 2022 Apr;46(4):101821. doi: 10.1016/j.clinre.2021.101821.

Персоналізований алгоритм лікування гострої анальної тріщини: порівняння з традиційною симптоматичною терапією

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Мета — оцінити клінічну ефективність персоналізованого алгоритму лікування гострої анальної тріщини з використанням шкали ризику хронізації тріщини порівняно із стандартною симптоматичною терапією.

Матеріали та методи. Проведено проспективне нерандомізоване порівняльне дослідження за участю 175 пацієнтів із діагнозом «гостра анальна тріщина», які проходили лікування в проктологічному відділенні КНП «Київська міська клінічна лікарня №18» протягом 2021—2024 рр. Середній вік пацієнтів становив (39,29 ± 12,98) року. Пацієнти дослідної групи отримували індивідуальне лікування відповідно до оцінки рівня ризику хронізації, пацієнти групи контролю — рутинне симптоматичне лікування. Оцінку ефективності проводили за частотою повного загоєння на 4-й тиждень, динамікою болю за візуальною аналоговою шкалою та частотою хронізації.

Результати. У пацієнтів, які отримували лікування згідно з персоналізованим протоколом, частота повного загоєння була вищою порівняно з тими, хто отримував стандартну терапію (81,63 і 41,56 % відповідно, $p < 0,001$). Частота хронізації анальної тріщини у дослідній групі становила 4,08 %, у контрольній групі — 23,38 %. Зменшення болю більше ніж на 50 % швидше досягалося в пацієнтів дослідної групи (через (6,1 ± 2,3) та (12,8 ± 3,5) дня). Побічні дії зареєстровано в дослідній та контрольній групах: місцеве почервоніння (11 і 14 % відповідно), тимчасову інконтиненцію (7 та 0 %), головний біль (0 і 3 %).

Висновки. Запропонований персоналізований протокол ведення пацієнтів із гострою анальною тріщиною продемонстрував вищу ефективність і значно кращі клінічні результати порівняно зі стандартною консервативною терапією. Його використання в клінічній практиці прискорює загоєння гострої тріщини, зменшує частоту хронізації та раннього рецидиву. Тому запропонований підхід доцільно впровадити в клінічну практику.

Ключові слова: малоінвазивна проктологія, поєднана патологія, анальна тріщина, геморой, рубцеві деформації, перианальний рубець.

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Short-term hemodynamic effects of splenic blood flow modulation after partial splenic artery embolization for secondary prevention of esophageal variceal bleeding

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Partial splenic artery embolization (PSE) is used in the management of portal hypertension to reduce splenic inflow. However, its hemodynamic impact in the secondary prophylaxis of esophageal variceal bleeding requires additional investigation.

Objective – to assess changes in splenic hemodynamics after PSE for secondary prevention of variceal bleeding.

Materials and methods. The study included 90 patients (mean age 49.5 years) with a history of variceal bleeding and splenomegaly (mean volume 781.6 cm^3). Splenic hemodynamics were evaluated using Doppler ultrasound at baseline and 1 month after PSE. Splenic volume and complications were monitored for up to 12 months.

Results. One month after PSE, splenic artery diameter decreased from 5.77 ± 1.20 to 4.72 ± 1.14 mm ($p < 0.001$). Peak systolic velocity declined (152.92 ± 50.35 to 89.77 ± 34.28 cm/s, $p < 0.001$), and end-diastolic velocity decreased (56.76 ± 21.93 to 38.18 ± 15.59 cm/s, $p < 0.001$). Both resistance (0.63 ± 0.08 to 0.58 ± 0.13, $p < 0.05$) and pulsatility indices (1.07 ± 0.24 to 0.95 ± 0.27, $p < 0.01$) reduced significantly. Splenic volume initially increased to 831.7 cm^3 due to edema but significantly decreased to 504.2 ± 209.8 cm^3 by month 6 ($p < 0.001$), with this reduction sustained through month 12. Post-embolization syndrome was managed conservatively in 99% of cases; one instance of splenic abscess occurred. Conversely, the sclerotherapy comparison group showed increased splenic volume.

Conclusions. PSE induces significant short-term attenuation of splenic arterial inflow and venous outflow, followed by a substantial reduction in splenic volume. It is an effective adjunct for secondary prophylaxis with a predictable safety profile. Future comparative studies using unified hemodynamic protocols are required.

Keywords
portal hypertension, esophageal varices, secondary prophylaxis, partial splenic artery embolization, Doppler ultrasound, splenic vein.

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Partial splenic artery embolization (PSE) induces predictable and clinically significant alterations in splenic and portal hemodynamics, which underlie its therapeutic efficacy in patients with portal hypertension complicated by splenomegaly and hypersplenism [2]. Immediately after embolization, a marked reduction in arterial inflow to the spleen is observed, resulting in a significant decrease in splenic perfusion. Doppler ultrasound assessment typically demonstrates reduced peak systolic velocity (PSV) and mean flow velocity in the splenic artery, accompanied by an increase in the resistive index (RI). These changes reflect an effective mechanical limitation of splenic arterial inflow and redistribution of blood volume within the splanchnic circulation. At the venous level, PSE leads to a progressive decrease in splenic venous outflow, which contributes to a reduction in portal venous inflow. Several studies have reported a subsequent decline in portal vein diameter and flow velocity, indicating partial decompression of the portal system. This hemodynamic unloading is considered one of the principal mechanisms by which PSE reduces portal pressure and lowers the risk of variceal bleeding. The extent

of these hemodynamic changes correlates with the embolized splenic volume. Patients undergoing embolization of 50–70 % of the splenic parenchyma exhibit a more pronounced reduction in splenic artery flow and portal venous inflow compared to those with limited embolization, while maintaining an acceptable safety profile [5]. Excessive embolization, however, may result in substantial ischemic changes without providing further hemodynamic benefit.

In the subacute and long-term periods, partial restoration of splenic blood flow is commonly observed due to the development of collateral arterial circulation. Nevertheless, Doppler parameters usually remain significantly lower than baseline values, suggesting sustained modulation rather than complete normalization of splenic hemodynamics. This persistent reduction in splenic inflow explains the durable improvement in hypersplenism parameters, particularly platelet and leukocyte counts.

From a pathophysiological perspective, PSE does not eliminate portal hypertension but instead modifies one of its major contributors–the hyperdynamic splenic circulation. By reducing splenic arterial inflow, PSE decreases splenic sequestration and portal venous inflow, thereby exerting a dual beneficial effect on both systemic hematologic parameters and portal hemodynamics.

Objective – to assess short-term changes in splenic arterial and venous hemodynamics following partial splenic artery embolization performed for secondary prevention of esophageal variceal bleeding.

Materials and methods

Study design and patients

This prospective observational study included 90 patients who underwent PSE as a part of secondary prevention of esophageal variceal bleeding. All patients had a documented history of at least one episode of variceal hemorrhage prior to enrollment, with the number of bleeding episodes ranging from one to seven.

The study cohort consisted of 38 women and 52 men, with a mean age of 49.5 years. Splenomegaly was present in all patients, with baseline splenic volume exceeding 300 cm^3 in every case. The mean baseline splenic volume was 781.6 cm^3, as assessed at the pre-intervention time point (0 months).

Doppler ultrasound assessment

Doppler ultrasound flowmetry was used to assess splenic arterial and venous hemodynamics before intervention and during follow-up. Examinations were performed by experienced operators using standardized protocols. The splenic artery was evaluated at the proximal segment, with measurements including vessel diameter, peak systolic velocity, end-diastolic velocity, time-averaged mean velocity, RI, and pulsatility index (PI). Volumetric blood flow was calculated based on vessel diameter and mean flow velocity (Fig. 1).

The splenic vein was assessed at the hilum or proximal segment, with measurements including vessel diameter, maximal and time-averaged mean flow velocities, and calculated volumetric blood flow.

Baseline Doppler measurements were obtained prior to embolization (0 months), and follow-up assessments were performed at 1 month after the procedure. Additional volumetric and clinical follow-up was conducted up to 12 months post-intervention.

Partial splenic artery embolization technique

Partial splenic artery embolization was performed using a reductional technique under fluoroscopic guidance (Fig. 2, 3). Selective catheterization of the splenic artery was achieved via standard transfemoral access. Embolization was targeted to achieve

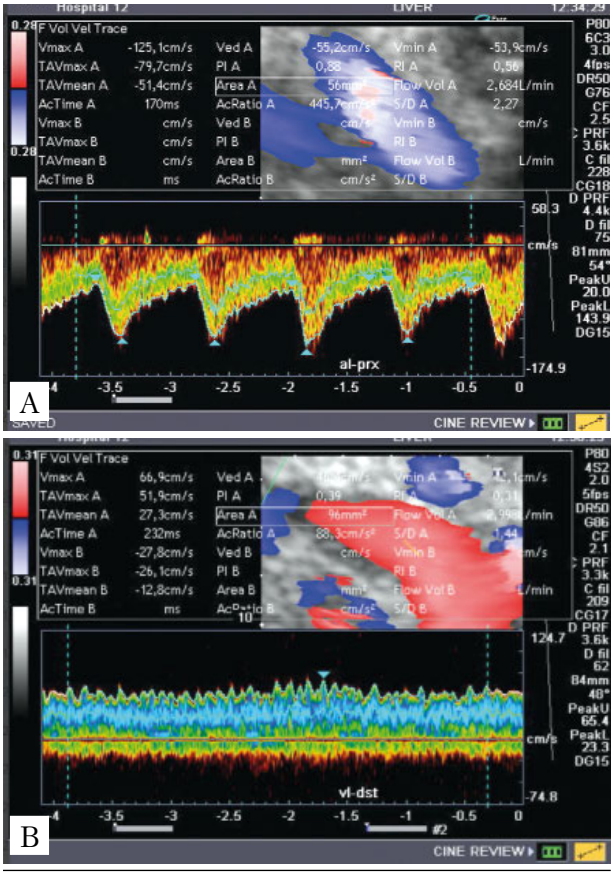

Figure 1. **Doppler ultrasound flowmetry assessment: A. Splenic artery (AL) B. Splenic vein (VL). The image demonstrates the spectral Doppler waveform and the calculation of volumetric blood flow parameters in the splanchnic circulation**

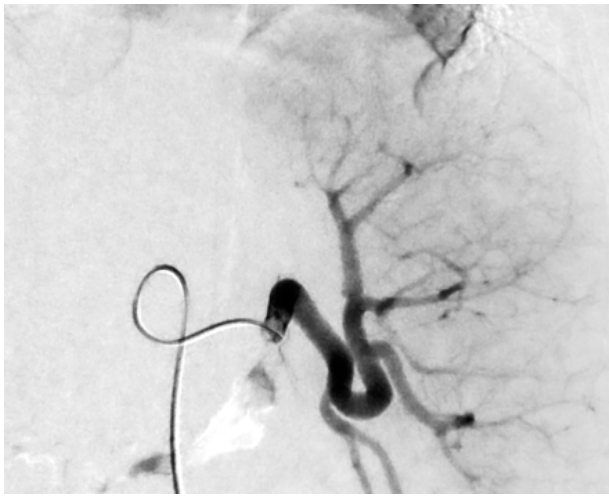

Figure 2. **Selective angiography of the splenic artery. The catheter is positioned in the proximal segment of the vessel prior to embolization**

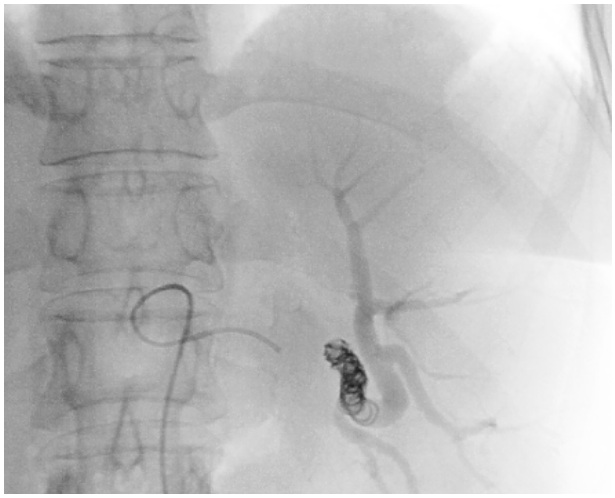

Figure 3. **Angiographic result of partial splenic artery embolization. The image demonstrates the placement of embolization coils in the splenic artery, resulting in reduced distal perfusion**

partial devascularization of the splenic parenchyma while preserving a functioning splenic remnant. The extent of embolization was determined based on angiographic findings and clinical indications.

The extent of embolization was determined based on angiographic findings and clinical indications.

Outcome measures

The primary outcomes of the study were short-term changes in splenic arterial inflow and splenic venous outflow parameters assessed by Doppler ultrasound at 1 month after embolization. Secondary outcomes included changes in splenic volume during follow-up and the incidence of post-embolization syndrome.

Statistical analysis

Continuous variables are presented as mean ± standard deviation. Paired comparisons between baseline and follow-up measurements were performed using appropriate statistical tests. A p-value of < 0.05 was considered statistically significant.

Results

The data presented in Table demonstrate a pronounced hemodynamic effect of reductional PSE on the major vessels of the portal circulation.

At the arterial level, significant changes in splenic artery morphology and flow parameters were observed as early as 30 days after the intervention. Systolic and diastolic splenic artery flow velocities and the effective vessel diameter decreased significantly from baseline values ($p < 0.001$; see Table).

Doppler-derived impedance parameters changed accordingly. Both the PI and RI showed significant reductions, reflecting attenuation of splenic arterial flow intensity following embolization (see Table).

Table. **Changes in splenic artery and vein Doppler parameters after partial splenic artery embolization**

Parameter	Before intervention	1 month after PSE	p
Splenic artery			
Diameter, mm	5.77 ± 1.20	4.72 ± 1.14	< 0.001
Peak systolic velocity, cm/s	152.92 ± 50.35	89.77 ± 34.28	< 0.001
End-diastolic velocity, cm/s	56.76 ± 21.93	38.18 ± 15.59	< 0.001
RI	0.63 ± 0.08	0.58 ± 0.13	< 0.05
PI	1.07 ± 0.24	0.95 ± 0.27	< 0.01
Splenic vein			
Diameter, mm	9.09 ± 2.57	7.15 ± 2.30	< 0.001
Maximal flow velocity, cm/s	34.08 ± 15.04	21.53 ± 7.87	< 0.001

The reduction in arterial inflow to the spleen was followed by a corresponding decrease in venous outflow. As shown in Table, splenic vein hemodynamic parameters demonstrated a statistically significant ($p < 0.001$) and sustained decline throughout the postoperative observation period.

Maximal splenic vein flow velocity decreased from 34.08 cm/s to 21.53 cm/s (–37 %), while time-averaged mean velocity declined from 27.96 cm/s to 17.62 cm/s (–37 %). Simultaneously, a reduction in splenic vein diameter was observed, resulting in a marked decrease in calculated splenic venous volumetric flow from 1.19 L/min to 0.39 L/min (–67.2 %).

For comparison, in the endoscopic sclerotherapy group, in which ultrasound examination was performed using a limited protocol without Doppler flowmetry for vascular velocity assessment, an increase in splenic vein diameter was observed at 1 month after the procedure.

At 1-month follow-up, splenic vein diameter after PSE (7.15 ± 2.30 mm) was numerically smaller than that observed after endoscopic sclerotherapy (8.63 ± 2.79 mm and 9.88 ± 1.45 mm).

As an integral consequence of reduced splenic arterial inflow and venous outflow, dynamic changes in splenic volume and the functioning parenchymal fraction were observed. Splenic volume increased from 781.6 cm^3 prior to embolization to 831.7 cm^3 at 1 month of follow-up. Subsequently, a consistent downward trend was noted up to the 12-month control point, with a statistically significant reduction observed from the 6-month follow-up onward ($p < 0.001$). The transient early increase in splenic volume was attributed to parenchymal edema associated with embolization-induced infarctions and the infarcted areas themselves. During further follow-up, infarct evolution and replacement by fibrous tissue led to a gradual reduction in splenic volume, typically observed between 6 and 12 months after the procedure.

Clinically, splenic infarctions were accompanied by transient fever ranging from 37.5°C to 38.7°C and left upper quadrant pain radiating to the left clavicle, shoulder, or scapular region. These manifestations were interpreted as post-embolization syndrome (PES). In 99 % of cases, PES was successfully managed with nonsteroidal anti-inflammatory drugs in combination with antibiotic prophylaxis administered for 7–12 days. The occurrence of splenic infarctions and PES was not regarded as a postoperative complication, as exclusion of a portion of the functioning splenic parenchyma represents the intended mechanism of PSE. Inadequate antibiotic prophylaxis was associated with secondary infection of splenic infarcts and abscess formation in one patient.

Discussion

In patients treated with endoscopic sclerotherapy, an increase in splenic volume was observed during short-term follow-up without evidence of splenic infarction. Mean splenic volume increased from 724.2 ± 242.6 cm^3 at baseline to 750.8 ± 165.1 cm^3 at 1 month after the procedure. This pattern differed from that observed after PSE.

The observed increase in splenic volume after sclerotherapy may reflect the progression of unfavorable portal hemodynamic changes associated with impaired venous outflow. However, given that ultrasound assessment in the sclerotherapy group was performed using a limited protocol without Doppler flowmetry, this observation should be interpreted with caution. This limitation highlights the need for further studies using a unified hemodynamic assessment protocol across patient groups managed with different secondary prophylaxis strategies.

Although direct studies evaluating splenic hemodynamic changes after endoscopic sclerotherapy are scarce, the relationship between portal hypertension, venous congestion, and splenomegaly is well established in the literature [1, 2, 5, 11]. Endoscopic sclerotherapy effectively controls variceal bleeding at the local level but does not directly modify splanchnic inflow or splenic venous return. As a result, portal venous congestion and splenic enlargement may persist or progress, depending on baseline liver function and collateral circulation patterns [3, 7].

In contrast, PSE has been shown to reduce splenic arterial inflow and splenic venous return, thereby modulating portal hemodynamics [1, 4, 6]. In our cohort, early Doppler flowmetry demonstrated a pronounced reduction in splenic artery velocities and effective vessel caliber at 1 month after PSE. This arterial inflow reduction was paralleled by a concordant decline in splenic venous velocity and diameter, supporting a mechanistic chain whereby reduced splenic arterial inflow leads to decreased splenic venous return and, consequently, a lower portal inflow burden.

From a pathophysiological standpoint, PSE should not be viewed as eliminating portal hypertension but rather as targeting one of its major modifiable components–excessive splanchnic (splenic) inflow–with a plausible downstream effect on portal venous loading. Because direct portal pressure measurements (e.g., hepatic venous pressure gradient) were not performed in the present study, any inference regarding portal pressure reduction should be regarded as hypothesis-generating and requires confirmation in future studies employing standardized pressure-based endpoints [2, 5, 8].

A clinically relevant observation in our study was the dynamic volumetric response of the spleen

after PSE. An initial increase in splenic volume at 1 month was followed by a sustained downward trend with a significant reduction at later follow-up intervals. This pattern is consistent with post-embolization parenchymal edema and infarction evolution, followed by fibrosis and contraction of non-functioning splenic tissue. It supports the concept that the therapeutic effect of PSE is achieved through controlled reduction of functional splenic parenchyma and redistribution of splenic inflow rather than immediate organ shrinkage.

Importantly, the concept of splenic inflow reduction for portal decompression is not limited to endovascular techniques. Tutchenko and colleagues described laparoscopic and laparoscopic-assisted surgical approaches aimed at reducing portal inflow, including clipping or ligation of the splenic artery, often combined with interventions on left gastric vessels, in patients with portal hypertension complicated by variceal bleeding [10]. These authors interpreted splenic artery clipping or ligation as producing a direct, moderate portodecompressive effect by decreasing arterial inflow to the spleen and reducing venous runoff toward the portal vein. More recently, Tutchenko et al. compared splenectomy and selective splenic artery ligation during porto-azygos disconnection and emphasized that splenic flow-reduction strategies are associated with measurable changes in portal system parameters, while also carrying distinct risk profiles for thrombosis, infection, and infarction [9].

Taken together, our short-term Doppler findings support the concept that PSE induces an early and coordinated reduction in both splenic arterial inflow and splenic venous return, changes that are mechanistically consistent with a dicrease in portal inflow burden. Comparison with endoscopic sclerotherapy suggests fundamentally different hemodynamic consequences of these treatment strategies. However, definitive conclusions regarding their relative impact on portal pressure and long-term outcomes require prospective, head-to-head studies with harmonized imaging protocols and pressure-based validation.

Conclusions

Partial splenic artery embolization performed for secondary prevention of esophageal variceal bleeding is associated with significant short-term attenuation of splenic arterial inflow, as evidenced by reductions in splenic artery diameter, systolic and diastolic flow velocities, and Doppler impedance indices.

The reduction of splenic arterial inflow after embolization is accompanied by a concordant decrease in splenic venous outflow, including significant reductions in splenic vein diameter and flow velocity, indicating decreased venous return from the spleen.

These coordinated arterial and venous hemodynamic changes suggest that PSE modulates splenic contribution to portal circulation by reducing portal inflow load. However, direct portal pressure measurements were not performed, and the effect on portal pressure requires further validation.

Splenic volume demonstrates a characteristic short-term increase following embolization, followed by a sustained downward trend with significant reduction during mid-term follow-up, reflecting post-embolization parenchymal changes and controlled reduction of functional splenic tissue.

In contrast, endoscopic sclerotherapy is associated with an increase in splenic volume and splenic vein diameter during short-term follow-up, highlighting fundamentally different hemodynamic consequences compared with splenic inflow–modulating strategies.

The findings support PSE as a hemodynamically active intervention that extends beyond local variceal control; however, comparative assessment of secondary prophylaxis strategies requires future prospective studies using unified hemodynamic assessment protocols and pressure-based validation.

Declaration of interests

The authors have no conflicts of interest to declare.

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Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all patients prior to inclusion.

Ethics approval and written, informed consent statements

The study was conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all patients prior to inclusion.

The assessment and use of all clinical data were approved and permitted by the ethics committee of Bogomolets National Medical University before the study. The study protocol conformed to the ethical guidelines of the «World Medical Association (WMA) Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects» adopted by the 18th WMA General Assembly, Helsinki, Finland, June 1964, and amended by the 59th WMA General Assembly, Seoul, South Korea, October 2008. Written informed consent was obtained from all individual participants included in the study.

Authors contributions

S. M. Kozlov: work concept and design, data collection and analysis, responsibility for statistical analysis, and writing the manuscript.

I. V. Kolosovych: work concept and design, critical review, and final approval of the manuscript.

References

1. Helaly AZ, Al-Warraky MS, El-Azab GI, et al. Portal and splanchnic hemodynamics after partial splenic embolization in cirrhotic patients with hypersplenism. APMIS. 2015;123(12):1032-9. doi: 10.1111/apm.12470.
2. Iwakiri Y. Pathophysiology of portal hypertension. Clin Liver Dis. 2014 May;18(2):281-91. doi: 10.1016/j.cld.2013.12.001. Epub 2014 Feb 25. PMID: 24679494; PMCID: PMC3971388.
3. Korula J, Ralls P. The effects of chronic endoscopic variceal sclerotherapy on portal pressure in cirrhotics. Gastroenterology. 1991;101(3):800-5. doi: 10.1016/0016-5085(91)90542-s.
4. Kotani K, Kawada N. Recent Advances in the Pathogenesis and Clinical Evaluation of Portal Hypertension in Chronic Liver Disease. Gut Liver. 2024 Jan 15;18(1):27-39. doi: 10.5009/gnl230072. Epub 2023 Oct 16. PMID: 37842727; PMCID: PMC10791512.
5. Mukaiya M, Hirata K, Yamashiro K, et al. Changes in portal hemodynamics and hepatic function after partial splenic embolization (PSE) and percutaneous transhepatic obliteration (PTO). Cancer Chemother Pharmacol. 1994;33 Suppl:S37-41. doi: 10.1007/BF00686666.
6. Saeki M, Hidaka H, Nakazawa T, et al. The impact of partial splenic embolization on portal hypertensive gastropathy in cirrhotic patients with portal hypertension. J Clin Med. 2023;12(7):2662. doi: 10.3390/jcm12072662.
7. Shigefuku R, Takahashi H, Watanabe T, Hattori N, Ikeda H, Matsunaga K, Ehira T, Suzuki T, Matsumoto N, Okuse C, Iwasa M, Nakagawa H, Itoh F, Suzuki M. Effects of endoscopic injection sclerotherapy for esophagogastric varices on portal hemodynamics and liver function. BMC Gastroenterol. 2022 Jul 21;22(1):350. doi: 10.1186/s12876-022-02422-7. PMID: 35864442; PMCID: PMC9306194.
8. Srinivas S, Yeluru A, Berman ZT, et al. Partial splenic artery embolization to treat portal hypertension. Dig Dis Interv. 2022;6(3):208-216. doi: 10.1055/s-0042-1757762.
9. Tutchenko MI, Rudyk DV, Chub SL, et al. Clinical and pathophysiological aspects of splenectomy and selective splenic artery ligation in patients with decompensated portal hypertension. The Odesa Medical Journal. 2024;4(189):34-9. doi: 10.32782/2226-2008-2024-4-6.. Ukrainian
10. Tutchenko MI, Rudyk DV, Klyuzko IV, Besedinskyi MS, Chub SL, Sirenko OA. Treatment of portal hypertension complicated by variceal bleeding. Emergency Medicine. 2024 May 17;20(3):180-5. https://doi.org/10.22141/2224-0586.20.3.2024.1690. Ukrainian.
11. Yoshida H, Shimizu T, Yoshioka M, et al. The role of the spleen in portal hypertension. J Nippon Med Sch. 2023;90(1):20-25. doi: 10.1272/jnms.JNMS.2023_90-104.

Безпосередні гемодинамічні результати корекції селезінкового кровоплину після емболізації селезінкової артерії при вторинній профілактиці кровотеч із варикозно розширених вен стравоходу

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Парціальну емболізацію селезінкової артерії (ПЕСА) використовують при портальній гіпертензії для зменшення селезінкового артеріального притоку. Її гемодинамічний вплив у контексті вторинної профілактики кровотеч із варикозно розширених вен стравоходу потребує уточнення.

Мета — оцінити зміни селезінкової гемодинаміки після ПЕСА, виконаної для вторинної профілактики варикозних кровотеч.

Матеріали та методи. У дослідження було залучено 90 пацієнтів (середній вік – 49,5 року) з анамнезом варикозних кровотеч і спленомегалією (середній об'єм – 781,6 см^3). Селезінкову гемодинаміку оцінювали за допомогою допплерівського ультразвукового дослідження (УЗД) до ПЕСА та через 1 місяць. Моніторинг об'єму селезінки та ускладнень проводили протягом 12 міс.

Результати. Через 1 міс після ПЕСА діаметр селезінкової артерії зменшився з (5,77 ± 1,20) до (4,72 ± 1,14) мм ($p < 0,001$). Пікова систолічна швидкість знизилася з (152,92 ± 50,35) до (89,77 ± 34,28) см/с ($p < 0,001$), кінцева діастолічна швидкість – з (56,76 ± 21,93) до (38,18 ± 15,59) см/с ($p < 0,001$), індекс резистентності – з 0,63 ± 0,08 до 0,58 ± 0,13 ($p < 0,05$), індекс пульсації – з 1,07 ± 0,24 до 0,95 ± 0,27 ($p < 0,01$). Об'єм селезінки спочатку збільшився до 831,7 см^3 (набряк), але до 6-го місяця статистично значущо зменшився до (504,2 ± 209,8) см^3 ($p < 0,001$) зі збереженням ефекту до 12-го місяця. Постемболізаційний синдром лікували консервативно в 99 % випадків. Зареєстровано один випадок абсцесу селезінки. У групі порівняння (склеротерапія) відзначено збільшення об'єму селезінки.

Висновки. Парціальна емболізація селезінкової артерії сприяє значному короткостроковому зниженню селезінкового артеріального притоку та венозного відтоку з подальшим суттєвим зменшенням об'єму органа. Це ефективний допоміжний метод вторинної профілактики з прогнозованим профілем безпечності. Необхідно провести порівняльні дослідження з уніфікованими гемодинамічними протоколами.

Ключові слова: портальна гіпертензія, варикозні вени стравоходу, вторинна профілактика, парціальна емболізація селезінкової артерії, допплерографія, селезінкова вена.

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Comparative analysis of sleeve gastrectomy with transit bipartition versus single anastomosis sleeve ileal bypass in morbidly obese patients with type 2 diabetes mellitus: a retrospective cohort study

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Objective – to compare the effectiveness of sleeve gastrectomy (SG) + transit bipartition (TB) and the novel metabolic procedure, sleeve gastrectomy with single anastomosis sleeve ileal bypass (SASI), in the treatment of morbidly obese patients with type 2 diabetes mellitus (T2DM).

Materials and methods. A retrospective cohort study was conducted among morbidly obese patients with T2DM who underwent bariatric surgical procedures, specifically SG+TB and SASI, between September 2013 and December 2024 at the study hospital. Exclusion criteria included a history of previous bariatric surgery, upper laparotomy, severe comorbidities (ASA III–IV), and psychological instability. A total of 33 patients who underwent metabolic surgery for T2DM were divided into two groups: Group I underwent SG+TB, and Group II underwent the SASI operation. The mean age of patients was 42.6 years (range: 26 to 64 years), with a mean preoperative weight of 107.5 kg (range: 92.0–189.5 kg), a mean preoperative body mass index of 43.2 kg/m^2 (range: 36.7–65.0 kg/m^2), and a mean excess weight of 50.8 kg (range: 28–106 kg). The average duration of metabolic disease before surgery was 7.5 years (range: 3–21 years). The mean preoperative glycaemia was 11.8 mmol/L (range: 6.5 to 23 mmol/L), and the mean glycated hemoglobin (HbA1c) was 7.6 % (range: 6.5–13.2 %). The primary outcomes were the percentage of excess weight loss (%EWL), resolution of diabetes, and improvement of comorbidities. The secondary outcome was postoperative nutritional status.

Results. A cohort of 33 patients had a follow-up period of 12 to 48 months. After the Santoro operation, excess weight loss (EWL) was 72 % at 6 months, 88 % at 1 year, 92 % at 2 years, and 86 % at 4 years. After the SASI operation, EWL was 76 % at 6 months, 89 % at 1 year, 93 % at 2 years, and 82 % at 4 years. Complete resolution of diabetes occurred in all patients within the first 6 months postoperatively. Mean postoperative glycemic and HbA1c levels normalized at 1 year postoperatively. Disease control was defined as achieving normal HbA1c levels (< 6 %). Among insulin-dependent patients, 76 % achieved disease control during the 12- to 48-month follow-up. Patients receiving oral treatment reduced HbA1c to < 6 % in 100 % of cases at 1 year postoperatively and in 89 % of cases over the subsequent 5 years. Two years postoperatively, the mean total protein concentration was 7.7 ± 1.7 g/dL in Group I and 7.2 ± 1.5 g/dL in Group II ($p > 0.1$). The mean albumin concentration was 4.1 ± 0.6 g/dL in Group I and 4.0 ± 0.8 g/dL in Group II. The mean daily bowel movement frequency was 1.6 ± 1.8 in both groups.

Conclusions. The novel procedure – single anastomosis sleeve ileal bypass – demonstrates effectiveness as a less invasive surgical treatment for morbid obesity and T2DM. It is expedient to conduct further investigations to evaluate the efficacy of this method and to establish clear indications and contradictions for SASI.

Keywords
sleeve gastrectomy with transit bipartition, Santoro operation, single anastomosis sleeve ileal bypass, SASI, morbidly obese patients, type 2 diabetes mellitus.

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Bariatric procedures, including biliopancreatic diversion (BPD) and duodenal switch, are effective treatments for diabetes mellitus. However, after BPD, many patients experience severe malabsorption symptoms [38, 41]. To address these complications, S. Santoro et al. [36, 37] proposed sleeve gastrectomy (SG) with transit bipartition (TB) as a metabolic intervention for obesity. TB involves creating a gastroileal anastomosis in the antrum after SG, which maintains nutrient transit through the duodenum, prevents the formation of blind loops, and minimizes malabsorption. The stomach retains two outflow pathways, and a lateral entero-enteroanastomosis connects both segments 80 cm proximal to the cecum. After this operation, 86% patients with type 2 diabetes achieved remission [37]. SG + TB is similar to BPD with duodenal switch (BPD + DS), but the malabsorption component is significantly reduced as the duodenum and jejunum are not excluded [36]. In the past decade, minor operations such as mini gastric bypass and single-anastomosis duodenoileal bypass with sleeve gastrectomy (SADI-S) have gained popularity [2, 5, 34, 35].

Objective – to compare the effectiveness of sleeve gastrectomy + transit bipartition and the novel metabolic procedure, sleeve gastrectomy with single anastomosis sleeve ileal bypass, in the treatment of morbidly obese patients with type 2 diabetes mellitus.

Materials and methods

A retrospective cohort study was conducted among morbidly obese patients with type 2 diabetes mellitus (T2DM) who underwent bariatric surgical procedures, specifically SG + TB and SASI, between September 2013 and January 2014 at the study hospital. The study protocol received approval from the Odesa National Medical University ethical committee. All patients included in the study were between 25 and 65 years of age.

Exclusion criteria comprised a history of previous bariatric surgery, upper laparotomy, severe comorbidities (ASA III–IV), and psychological instability. Informed consent was obtained from all patients after a detailed explanation of operative and postoperative procedures as well as potential complications. The preoperative evaluation comprised a comprehensive medical history and laboratory investigations, including blood glucose, glycated hemoglobin (HbA1c), lipid profile, and thyroid function tests. In addition, all patients underwent routine gastroscopy and abdominal ultrasound to exclude gallstones and to assess hepatic steatosis.

A total of 33 patients who underwent metabolic surgery for T2DM were divided into two groups: Group I underwent SG + TB, and Group II underwent the SASI operation. The mean age was 42.6 years (range: 26 to 64 years), with 23 women and 10 men. The mean preoperative weight was 107.5 kg (range: 92.0–189.5 kg), the mean preoperative body mass index was 43.2 kg/m^2 (range: 36.7–65.0 kg/m^2), and the mean excess weight was 50.8 kg (range: 28–106 kg). The average duration of metabolic disease before surgery was 7.5 years (range: 3–21 years). In only two patients was the disease controlled with dietary modification, while 14 patients received oral agents and 17 patients received insulin therapy. The mean preoperative glycemia was 11.8 mmol/L (range: 7.2 to 23 mmol/L), and the mean glycated hemoglobin (HbA1c) was 7.6% (range: 6.5–15.2%). The mean C-peptide was 2.4 ng/mL (range: 0.8–6.9), and the mean homeostasis model assessment (HOMA) value was 7.6 (range: 3.8–25.2). Hypertriglyceridemia was detected in 20 patients, hypercholesterolemia in 30 patients, obstructive sleep apnea in 22 patients, and hypertension in 25 patients.

Operative techniques for SASI and Santoro procedures

Both operations were performed under general anesthesia. Pneumoperitoneum was established using a Veress needle. The first 10 mm trocar was inserted approximately 15–20 cm below the xiphoid process and 3 cm to the left of the midline. Four additional ports were placed under direct vision at the same sites as for sleeve gastrectomy. The omental bursa was opened, and the greater omentum was sectioned using a Ligasure or ENSEAL device. Dissection proceeded toward the gastroesophageal junction. The left crus was mobilized from its attachments. Posterior attachments connecting the stomach and pancreas were carefully divided. A 36 French bougie was passed into the stomach to facilitate gastric tube placement. The stomach was transected using a linear stapler with a staple height of 4.1 mm, beginning at the greater curvature 4 to 5 cm from the pylorus and extending to the angle of His. In cases of bleeding from the stapling line, additional seromuscular running sutures were placed.

The second stage of the operation was performed with the patient in the Trendelenburg position. The Santoro operation, consisting of sleeve gastrectomy with transit bipartition, was performed. Subsequently, a gastroileal anastomosis was created, followed by a lateral-lateral ileo-ileal anastomosis 100 cm proximal to the ileocecal valve, using a laparoscopic linear stapler with a 45 mm cartridge and a staple height of 4.1 mm. Running sutures were used to close the mesenteric borders to prevent

internal hernias. At the conclusion of the procedure, the segment between both anastomoses was interrupted using a linear stapler with a white cartridge. A closed suction drain was placed after both operations. The SASI operation involves creating a single gastroileal anastomosis. The ileocecal junction was identified, and 250 cm of ileum was measured proximally. The selected loop was ascended after division of the greater omentum and stapled isoperistaltically side-to-side to the anterior wall of the gastric antrum. Gastroileal anastomosis was created using a linear stapler with a 45 mm cartridge and a staple height of 4.1 mm. The anastomosis was tested for watertightness using a methylene blue test. The staple defect was closed with 3/0 V-lock sutures.

Postoperative care

Ambulation and administration of clear liquids commenced 12 to 24 hours postoperatively. Thromboprophylaxis with enoxaparin 40 mg once daily was initiated on the first postoperative day and continued for up to 3 weeks. A proton pump inhibitor was administered for 2 months postoperatively. A low-calorie, protein-rich liquid diet was maintained during the first month. Patients were encouraged to begin physical activity in the first postoperative week. Outpatient follow-up was conducted monthly. A complete blood count was ordered every 3 to 6 months, and gastroscopy was scheduled every 6 to 12 months.

Assessments

The primary outcomes included the percentage of excess weight loss (%EWL), resolution of diabetes, and improvement of comorbidities. The %EWL was calculated as follows:

$$\frac{\text{Preoperative weight} - \text{Follow-up weight}}{\text{Preoperative excess weight}} \times 100\%.$$

Resolution of diabetes was defined as a fasting glucose level < 6.06 mmol/L or an HbA1c level $< 6\%$ without hypoglycemic medication, whereas improvement was defined as a reduction of at least 25% in fasting plasma glucose and at least 1% in HbA1c level. Resolution of comorbidities was defined as disease control without medication. Secondary outcomes included postoperative complications and postoperative nutritional status.

Statistical analysis

Data were analyzed using IBM SPSS v. 21.0. Descriptive and inferential statistics were conducted using both parametric and non-parametric procedures, as appropriate. Comparison of variables was performed using chi-square tests for trend analysis. All tests were two-tailed, and results with $p < 0.05$ were considered statistically significant.

Results

A total of 33 patients underwent metabolic surgery for T2DM during the study period. Sleeve gastrectomy with transit bipartition (Santoro operation) was performed in 12 patients (Group I), and SASI in 21 patients (Group II). No statistically significant differences were observed between the two groups (Table 1).

The duration of operative laparoscopic procedures ranged from 92 to 180 minutes. The mean operative time for the Santoro operation was significantly longer than for SASI (158 ± 28 min vs. 112 ± 16 min, $p < 0.05$). No serious intraoperative complications or mortality occurred in either group. Two cases of postoperative bleeding from the staple line of the stomach were observed (one in each group). One patient was treated conservatively, while another required laparoscopic exploration 12 hours postoperatively and hemostasis by suturing the bleeding points at the staple line. One case of pulmonary embolism was seen in Group II and was managed conservatively. In Group I, one patient developed complete intestinal obstruction due to an internal hernia 3 months postoperatively and underwent successful laparoscopic reoperation.

Table 1. **Clinical characteristics of the two patient groups**

Parameter	Group I (n = 12)	Group II (n = 21)
Mean age, years	42 (26–58)	45 (27–64)
Men/women	4/8	9/12
Preoperative weight, kg	104 (92–158)	108 (96–190)
Preoperative body mass index, kg/m^2	42 (37–58)	43 (38–65)
Preoperative excess weight, kg	49 (28–99)	53 (32–106)
Preoperative glycaemia, mmol/L	10 (7–21)	14 (10–23)
Preoperative HbA1C, %	7.2 (6.5–11.6)	7.9 (7.0–12.2)
Hypertriglyceridemia	7	19
Sleep apnea	8	14
Hypertension	9	18
Preoperative treatment		
Diet control	1	1
Oral Antidiabetic	6	8
Insulin therapy	6	11

Note. Quantitative indicators are presented as mean (min–max). All $p > 0.05$.

Table 2. **Preoperative and postoperative glycemic and lipid profiles in patients after Santoro (Group I) and SASI (Group II) operations**

Parameter	Preoperatively		6 months postoperatively		1 year postoperatively		2 years postoperatively	
	Group I (n = 12)	Group II (n = 21)	Group I (n = 12)	Group II (n = 21)	Group I (n = 12)	Group II (n = 21)	Group I (n = 10)	Group II (n = 18)
HbA1c, %	7.2 ± 1.8	7.9 ± 2.0	5.4 ± 0.8	5.6 ± 1.0	5.6 ± 0.7	5.8 ± 0.8	5.5 ± 0.8	5.6 ± 0.8
HOMA	7.4 ± 1.6	7.8 ± 1.8	1.1 ± 0.6	1.1 ± 0.7	1.2 ± 0.8	1.3 ± 0.7	–	–
Triglycerides, mmol/L	2.7 ± 0.7	2.6 ± 0.9	1.1 ± 0.6	1.2 ± 0.8	1.2 ± 0.7	1.3 ± 0.9	1.2 ± 0.7	1.4 ± 0.8
Cholesterol, mmol/L	6.9 ± 1.8	6.8 ± 2.0	3.9 ± 1.2	4.2 ± 1.4	3.1 ± 1.1	3.6 ± 1.3	3.2 ± 1.4	3.5 ± 1.5

Twelve months after surgery, one patient in Group I (Santoro operation) was diagnosed with a marginal ulcer on gastroscopy, which responded well to medical treatment. The mean hospital stay was 7.2 days (range: 6–9 days) in Group I and 5.6 days (range: 5–8 days) in Group II ($p < 0.05$).

Follow-up in 33 patients ranged from 6 to 48 months. After the Santoro operation, excess weight loss (EWL) was 72 % at 6 months, 88 % at 1 year, 92 % at 2 years, and 86 % at 4 years. After the SASI operation, excess weight loss was 76 % at 6 months, 89 % at 1 year, 93 % at 2 years, and 82 % at 4 years. There were no statistically significant differences in %EWL between the two groups ($p > 0.05$). All patients experienced complete resolution of diabetes within the first 6 months postoperatively.

Mean postoperative glycemic and HbA1c levels normalized in the first postoperative year (Table 2). Disease control was defined as achieving normal HbA1c levels (< 6 %). Among insulin-dependent patients, 79 % achieved disease control during the 12- to 48-month follow-up. Patients on oral therapy reduced HbA1c to < 6 % in 100 % of cases in the first postoperative year and in 89 % of cases over the subsequent 4 years. Of the 17 patients who were insulin-dependent preoperatively, after 12–48 months, six required only oral therapy, and seven discontinued medication entirely. The effectiveness of diabetes control was equivalent between the two operations (see Table 2).

Both patient groups demonstrated significant improvements in lipid profiles. By the end of the first postoperative year, 90 % of patients exhibited normal total cholesterol levels, and 85 % had normal triglyceride levels. Mean follow-up values remained stable (see Table 2). Hypertension resolved in 21 patients, with 6 cases in Group I and 15 cases in Group II. No statistically significant differences were observed in the normalization of comorbidities between the two groups.

Postoperatively, the mean total protein concentration was 8.0 ± 1.1 g/dL in Group I and 7.8 ± 1.2 g/dL in Group II ($p > 0.1$). The mean albumin concentration was 4.1 ± 0.5 g/dL in Group I and 4.0 ± 1.0 g/dL in Group II. Two patients in Group II had symptoms of bile reflux. The mean daily bowel movement frequency was 1.6 ± 1.8 in both groups (Table 3).

Table 3. **Biochemical profiles pre- and postoperatively in patients after Santoro and SASI operations**

Parameter	Preoperatively		6 months postoperatively		12 months postoperatively	
	Group I (n = 12)	Group II (n = 21)	Group I (n = 12)	Group II (n = 21)	Group I (n = 12)	Group II (n = 20)
Albumin, g/dL	3.9 ± 0.7	4.0 ± 0.8	4.3 ± 0.4	4.1 ± 0.9	4.1 ± 0.5	4.0 ± 0.6
Protein, g/dL	7.6 ± 1.4	7.2 ± 1.5	8.0 ± 1.7	7.8 ± 1.6	7.9 ± 1.6	7.6 ± 0.9
ALT U/L	69.0 ± 20.4	72.0 ± 18.6	36.0 ± 12.5	38.0 ± 15.0	34.0 ± 0.9	33.0 ± 1.1
Gamma-GT, U/L	34.0 ± 12.5	32.0 ± 15.0	24.0 ± 10.5	25.0 ± 12.2	22.0 ± 15.2	26.0 ± 18.2
Iron, μmol/L	15.0 ± 3.6	14.0 ± 13.9	23.0 ± 11.2	21.0 ± 12.8	24.0 ± 12.5	23.0 ± 15.0
Hemoglobin, g/dL	12.5 ± 1.4	11.2 ± 1.6	12.9 ± 1.6	12.2 ± 1.8	12.8 ± 0.9	12.6 ± 1.2
Platelet count, $\times 10^3$/μL	230.0 ± 30.2	246.0 ± 32.2	300.0 ± 30.4	310.0 ± 36.2	320.0 ± 25.7	300.0 ± 24.6

Discussion

Contemporary human diets are typically high in calories, low in fiber, and extensively processed through cooking and refining, resulting in rapid food absorption. This absorption often occurs in the proximal bowel, thereby reducing the functional workload of the distal bowel and diminishing the secretion of glucagon-like peptide-1 (GLP-1) and peptide YY (PYY). Consequently, diabetic and obese patients exhibit reduced GLP-1 production [16, 23, 31].

Specific bariatric procedures involve excision of segments of the digestive tract, which can lead to mucosal atrophy and subsequent bacterial proliferation. This process may facilitate bacterial translocation to the portal system, increasing the risk of hepatic failure [3, 7, 13]. Such complications can exacerbate preexisting hepatic conditions, particularly in patients with nonalcoholic fatty liver disease [1].

The SASI operation is a novel bariatric operation that combines the principles of sleeve gastrectomy with transit bipartition (SG + TB) [19].

The modification of SG + TB aimed to simplify the surgical procedure and decrease the potential complication rate. Reducing the number of intestinal anastomoses is expected to lower the risk of postoperative leaks and anastomotic strictures. Moreover, preserving the mesentery's integrity minimizes the likelihood of postoperative obstructions.

Intestinal obstruction was observed in one patient after the Santoro operation. In contrast, no cases of intestinal obstruction were reported in Group II after the SASI operation.

After sleeve gastrectomy, ghrelin secretion decreases because the hormone is primarily produced by cells in the gastric fundus [26], which is removed during the surgical procedure.

GLP-1 is a more potent incretin than GIP in both diabetic and obese individuals and in healthy individuals. GLP-1 more effectively suppresses glucagon secretion [17] and sustains a robust late phase of insulin release. Furthermore, the secretion of GLP-1 and PYY, which signals the ingestion of substantial amounts of food, promotes satiety, slows gastric emptying, and contributes to meal termination [9, 19, 22].

Nowadays, food absorption primarily occurs in the proximal bowel. Enhanced glucose-dependent insulinotropic polypeptide (GIP) secretion directly associates overnutrition with both general obesity [24] and, specifically, with visceral obesity [28]. Anti-GIP antibodies and GIP-receptor blockers have demonstrated efficacy in treating obesity [10, 25]. GLP-1 analogues, but not blockers, can help treat both obesity and diabetes [11, 32, 33].

Evidence indicates that restriction and malabsorption are not the primary factors responsible for the positive outcome of modern bariatric procedures. Instead, neurohormonal changes induced by these procedures play a significant role in their success [2].

Large meta-analyses have demonstrated that bariatric procedures resulting in substantial weight loss and metabolic improvement are those that reduce foregut exposure to food and enhance food transit to the hindgut [30]. If a small segment of the proximal bowel is excluded, as in the Roux-en-Y gastric bypass, successful outcomes depend on gastric volume restriction [12]. In contrast, if a large proximal segment is excluded, as in the BPD, restriction is unnecessary for metabolic benefits and weight loss, but malabsorption becomes a significant concern [8].

S. Santoro et al. [37] proposed a new procedure that avoids ileal exclusion and uses a minor surgical technique. SG + TB amplifies the nutritive stimulation of the distal gut while simultaneously diminishing the exposure of the proximal bowel to nutrients, without completely deactivating the duodenum and jejunum. The food transit to the ileum is preferential, as shown by S. Santoro et al. [36, 37].

Simultaneously, a smaller portion of the meal passes through the duodenum, which decreases but does not eliminate nutritive overstimulation of the proximal bowel.

The incomplete exclusion of the proximal bowel reduces the risk of malabsorption-related complications. Unlike BPD, the Santoro operation does not result in hypoalbuminemia [36].

SG + TB significantly reduces meal size and overeating, thereby leading to a substantial decrease in fat consumption by changing taste preferences [39]. Notably, TB is highly effective in treating both obesity and metabolic syndrome.

After the SASI operation, patients do not overeat due to an early sensation of gastric fullness and a hypothalamic-generated satiety response triggered by nutrient absorption primarily in the distal bowel [19].

Intense stimulation of the distal bowel further decreases the proximal bowel activity. Additionally, distal gut hormones are steatogenic and slow gastric emptying [18].

Both SG + TB and SASI procedures resulted in adequate initial weight loss. The restrictive component in both operations is sleeve gastrectomy, while the gastro-ileal bypass induces neuroendocrine modulation.

Excess weight loss after the Santoro operation was 72 % at 6 months, 88 % at 1 year, and 92 % at 2 years. Comparable results were observed after SASI: EWL of 76 % at 6 months, 89 % at 1 year,

and 93 % at 2 years. No significant differences in weight loss were found between the two groups ($p > 0.1$). S. Santoro et al. [36, 37] reported similar outcomes: after 6 months, 72.2 ± 17.3 %; after 1 year, 91 ± 19.6 %; and after 2 years, 94.1 ± 21 %.

Another potential mechanism contributing to the observed metabolic improvement after SG + TB is an increased stimulation of distal gut endocrine cells by bile acids, as bile acids are known to stimulate GLP-1 and PYY secretion [29, 32].

SG + TB and a BPD + DS share significant anatomical similarities. However, BPD + DS is designed to induce malabsorption, while SG + TB aims to avoid malabsorption and maintain neuroendocrine effects [36]. The SASI operation in this study operates via the exact mechanism as the Santoro operation.

The treatment of T2DM after the Santoro operation demonstrated high effectiveness. Extended follow-up showed complete remission of T2DM in 86 % of patients [36, 37].

Both bariatric operations demonstrated effectiveness in treating T2DM in this study.

HbA1c normalization was comparable between the two patient groups (see Table 1). No significant differences in HbA1c levels were observed between patients after the Santoro operation and SASI during follow-up from 6 months to 2 years.

Biochemical tests showed that both operations were equally effective in resolving T2DM (see Table 2). Comorbidity resolution was also comparable between the two patient groups. Respiratory problems, including sleep apnea, improved substantially within the first 3 months. All eight patients in Group I and 12 of the 14 patients in Group II experienced resolution of respiratory issues. Hypertension no longer required medication in 6 patients from Group I and in 12 of the 18 patients from Group II.

Both surgical procedures were equally effective in treating comorbidities. No incidents of diarrhea or flatulence were reported in patients after either the Santoro surgery or SASI. Bile reflux symptoms were observed in two patients after SASI, which were managed successfully with conservative treatment.

In summary, the Santoro and SASI procedures demonstrate comparable effects on excessive weight, metabolic disturbances, and complication frequency. However, SASI is notably simpler, requires less operative time, minimizes the risk of bowel obstruction, and can be performed with a single anastomosis.

There is a current trend in bariatric and metabolic surgery toward less invasive surgical procedures, such as mini-gastric bypass and sleeve gastrectomy with single anastomosis duodenoileal bypass (SADI-S) [2, 34, 35]. Both the immediate and long-term outcomes of these procedures are considered acceptable.

Based on this approach and supporting clinical results, SASI can be introduced into surgical practice as a minor and effective procedure.

Conclusions

The novel procedure – single anastomosis sleeve ileal bypass – demonstrates effectiveness as a less invasive surgical treatment for morbid obesity and T2DM.

It is expedient to conduct further investigations to evaluate the efficacy of this method and to establish clear indications and contradictions for SASI.

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Declaration of interests

The authors declare no conflicts of interest relevant to this manuscript.

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Ethics approval and written informed consent statements

This study was conducted in accordance with the Declaration of Helsinki and was approved by the ethics committee of Odessa National Medical University. Written informed consent was obtained from all patients prior to their participation in the study.

Authors contributions

V. V. Grubnik: study concept and design, critical revision of the manuscript, supervision; O. V. Medvedev: clinical procedures, patient follow-up, data analysis, manuscript drafting and revision; V. V. Grubnyk: data collection, literature review, manuscript drafting.

References

1. Beymer C, Kowdley KK, Larson A, et al. Prevalence and predictors of asymptomatic liver disease in patients undergoing gastric bypass surgery. Arch. Surg. 2003;138:1240–1244. doi: 10.1001/archsurg.138.11.1240.
2. Buchwald H, Estok R, Fahrbach K, Banel D, Jensen MD, Pories WJ, Bantle JP, Sledge I. Weight and type 2 diabetes after bariatric surgery: systematic review and meta-analysis. Am J Med. 2009 Mar;122(3):248-256.e5. doi: 10.1016/j.amjmed.2008.09.041. PMID: 19272486.
3. Castillo J, Fábrega E, Escalante CF, Sanjuan JC, Herrera L, Hernánz F, Martino E, Casafont F, Gómez Fleitas M. Liver transplantation in a case of steatohepatitis and subacute hepatic failure after biliopancreatic diversion for morbid obesity. Obes Surg. 2001 Oct;11(5):640-2. doi: 10.1381/09608920160557174. PMID: 11594111.
4. Chu D, He Y, Li N, Zhang H, Zhang H, Li C, Deng Z, Chen Y, Han X, Li Y, Wei T. Immunohistochemical distribution of glucagon-like peptide 1 in the digestive system of different aquatic vertebrates. Anat Histol Embryol. 2020 Jan;49(1):31-37. doi: 10.1111/ahe.12479. Epub 2019 Oct 1. PMID: 31571240.
5. Gagner M. Laparoscopic revisional surgery after malabsorptive procedures in Bariatric surgery, more specifically after duodenal switch. Surg Laparosc. Endosc. Percutan Tech. 2010;20:344–347. doi: 10.1097/SLE.0b013e3181f5aa05.

6. Gudzune KA, Huizinga MM, Chang HY, Asamoah V, Gadgil M, Clark JM. Screening and diagnosis of micronutrient deficiencies before and after bariatric surgery. Obes Surg. 2013 Oct;23(10):1581-9. doi: 10.1007/s11695-013-0919-x. PMID: 23515975; PMCID: PMC3740071.
7. Haber GB, Heaton KW, Murphy D, Burroughs LF. Depletion and disruption of dietary fibre. Effects on satiety, plasma-glucose, and serum-insulin. Lancet. 1977 Oct 1;2(8040):679-82. doi: 10.1016/s0140-6736(77)90494-9. PMID: 71495.
8. Hess DS, Hess DW, Oakley RS. The biliopancreatic diversion with the duodenal switch: results beyond 10 years. Obes Surg. 2005 Mar;15(3):408-16. doi: 10.1381/0960892053576695. PMID: 15826478.
9. Higa K, Ho T, Tercero F, Yunus T, Boone KB. Laparoscopic Roux-en-Y gastric bypass: 10-year follow-up. Surg Obes Relat Dis. 2011 Jul-Aug;7(4):516-25. doi: 10.1016/j.soard.2010.10.019. Epub 2010 Nov 26. PMID: 21333610.
10. Irwin N, Flatt PR. Evidence for beneficial effects of compromised gastric inhibitory polypeptide action in obesity-related diabetes and possible therapeutic implications. Diabetologia. 2009;52:1724–1731. doi: 10.1007/s00125-009-1422-8.
11. Jenkins DJ, Wolever TM, Taylor RH, Ghafari H, Jenkins AL, Barker H, Jenkins MJ. Rate of digestion of foods and postprandial glycaemia in normal and diabetic subjects. Br Med J. 1980 Jul 5;281(6232):14-7. doi: 10.1136/bmj.281.6232.14. PMID: 7407477; PMCID: PMC1713732.
12. Karamanakos SN, Vagenas K, Kalfarentzos F, Alexandrides TK. Weight loss, appetite suppression, and changes in fasting and postprandial ghrelin and peptide-YY levels after Roux-en-Y gastric bypass and sleeve gastrectomy: a prospective, double blind study. Ann Surg. 2008;247:401–407. doi: 10.1097/SLA.0b013e318156f012.
13. Lee WJ, Almulaifi AM, Tsou JJ, et al. Duodenal-jejunal bypass with sleeve gastrectomy versus the sleeve gastrectomy procedure alone: the role of duodenal exclusion. Surg Obes Relat Dis. 2015;11(4):765–70. doi: 10.1016/j.soard.2014.12.017.
14. Lee WJ, Lee YC, Ser KH, Chen SC, Chen JC, Su YH. Revisional surgery for laparoscopic minigastric bypass. Surg Obes Relat Dis. 2011 Jul-Aug;7(4):486-91. doi: 10.1016/j.soard.2010.10.012. Epub 2010 Oct 30. PMID: 21159561.
15. Lugari R, Dei Cas A, Ugolotti D, et al. Evidence for early impairment of glucagon-like peptide 1-induced insulin secretion in human type 2 (non insulin dependent) diabetes. Horm Metab Res. 2002;34:150–154. doi: 10.1055/s-2002-23199.
16. Lugari R, Dei Cas A, Ugolotti D, et al. Evidence for early impairment of glucagon-like peptide 1-induced insulin secretion in human type 2 (non-insulin-dependent) diabetes. Horm. Metab. Res. 2002;34:150–154. doi: 10.1055/s-2002-23199.
17. Lund A, Vilsbøll T, Bagger JI, et al. The separate and combined impact of the intestinal hormones, GIP, GLP-1 and GLP-2, on glucagon secretion in type 2 diabetes. Am J Physiol Endocrinol Metab. 2011;300:E1038-E1046. doi: 10.1152/ajpendo.00665.2010.
18. Lustig RH. The neuroendocrinology of obesity. Endocrinol Metab Clin North Am. 2001 Sep;30(3):765-85. doi: 10.1016/s0889-8529(05)70211-5. PMID: 11571940.
19. Mahdy T, Al Wahedi A, Schou C. Efficacy of single anastomosis sleeve ileal (SASI) bypass for type-2 diabetic morbid obese patients: Gastric bipartition, a new metabolic surgery procedure. A retrospective cohort study. Int J Surg. 2016;34:28–34. doi: 10.1016/j.ijsu.2016.08.018.
20. Manasyan A, Cannata B, Ross E, Lasky S, Stanton EW, Malkoff N, Collier Z, Johnson MB, Gillenwater TJ. The Emerging Role of GLP-1 Agonists in Burn Care: What Do We Know? J Burn Care Res. 2025 Mar 4;46(2):481-486. doi: 10.1093/jbcr/irae189. PMID: 39405180.
21. Mason EE. Ileal transposition and enteroglucagon/GLP-1 in obesity (and diabetic?) surgery. Obes Surg. 1999;9:223–228. doi: 10.1381/096089299765553070.
22. Mentis N, Vardarli I, Köthe LD, Holst JJ, Deacon CF, Theodorakis M, Meier JJ, Nauck MA. GIP does not potentiate the antidiabetic effects of GLP-1 in hyperglycemic patients with type 2 diabetes. Diabetes. 2011 Apr;60(4):1270-6. doi: 10.2337/db10-1332. Epub 2011 Feb 17. PMID: 21330636; PMCID: PMC3064100.
23. Mithieux G. Influence of diabetes surgery on a gut-brain-liver axis regulating food intake and internal glucose production. Nutr. Hosp. 2013;28:109–114. doi: 10.3305/nh.2013.28.sup2.6721.
24. Miyawaki K, Yamada Y, Ban N, Ihara Y, Tsukiyama K, Zhou H, Fujimoto S, Oku A, Tsuda K, Toyokuni S, Hiai H, Mizunoya W, Fushiki T, Holst JJ, Makino M, Tashita A, Kobara Y, Tsubamoto Y, Jinnouchi T, Jomori T, Seino Y. Inhibition of gastric inhibitory polypeptide signaling prevents obesity. Nat Med. 2002 Jul;8(7):738-42. doi: 10.1038/nm727. Epub 2002 Jun 17. PMID: 12068290.
25. Montgomery IA, Irwin N, Flatt PR. Active immunization against (Pro)GIP improves metabolic status in high-fat-fed mice. Diabetes Obes Metab. 2010;12:744–751. doi: 10.1111/j.1463-1326.2010.01228.x.
26. Muccioli G, Tschöp M, Papotti M, Deghenghi R, Heiman M, Ghigo E. Neuroendocrine and peripheral activities of ghrelin: implications in metabolism and obesity. Eur J Pharmacol. 2002 Apr 12;440(2-3):235-54. doi: 10.1016/s0014-2999(02)01432-2. PMID: 12007539.
27. Naslund E, Gryback P, Hellstrom PM, et al. Gastrointestinal hormones and gastric emptying 20 years after jejunoileal bypass for massive obesity. Int J Obes Relat Metab Disord. 1997;21:387–392. doi: 10.1038/sj.ijo.0800418.
28. Oben J, Morgan L, Fletcher J, et al. Effect of the entero-pancreatic hormones, gastric inhibitory polypeptide and glucagon-like polypeptide-1(7-36) amide, on fatty acid synthesis in explants of rat adipose tissue. J Endocrinol. 1991;130:267–272. doi: 10.1677/joe.0.1300267.
29. Plaisancié P, Dumoulin V, Chayvialle JA, Cuber JC. Luminal glucagon-like peptide-1(7-36) amide-releasing factors in the isolated vascularly perfused rat colon. J Endocrinol. 1995 Jun;145(3):521-6. doi: 10.1677/joe.0.1450521. PMID: 7636436.
30. Ranganath LR, Beety JM, Morgan LM, et al. Attenuated GLP-1 secretion in obesity: cause or consequence? Gut. 1996;38:916–919. doi: 10.1136/gut.38.6.916.
31. Ranganath LR, Beety JM, Morgan LM, et al. Attenuated GLP-1 secretion in obesity: cause or consequence? Gut. 1996;38:916–919. doi: 10.1136/gut.38.6.916.
32. Roberts RE, Glicksman C, Alagband-Zadeh J, et al. The relationship between postprandial bile acid concentration, GLP-1, PYY and ghrelin. Clin Endocrinol. 2011;74:67–72. doi: 10.1111/j.1365-2265.2010.03886.x.
33. Rubino F, Forgione A, Cummings DE, Vix M, Gnuli D, Mingrone G, Castagneto M, Marescaux J. The mechanism of diabetes control after gastrointestinal bypass surgery reveals a role of the proximal small intestine in the pathophysiology of type 2 diabetes. Ann Surg. 2006 Nov;244(5):741-9. doi: 10.1097/01.sla.0000224726.61448.1b. PMID: 17060767; PMCID: PMC1856597.
34. Rutledge R. The mini-gastric bypass: experience with the first 1,274 cases. Obes Surg. 2001 Jun;11(3):276-80. doi: 10.1381/096089201321336584. PMID: 11433900.
35. Sánchez-Pernaute A, Herrera MA, Pérez-Aguirre ME, Talavera P, Cabrerizo L, Matía P, Díez-Valladares L, Barabash A, Martín-Antona E, García-Botella A, Garcia-Almenta EM, Torres A. Single anastomosis duodeno-ileal bypass with sleeve gastrectomy (SADI-S). One to three-year follow-up. Obes Surg. 2010 Dec;20(12):1720-6. doi: 10.1007/s11695-010-0247-3. PMID: 20798995.
36. Santoro, S. From bariatric to pure metabolic surgery: new concepts on the rise. Ann. Surg. 2015;262:e79–e80. doi: 10.1097/SLA.0000000000000590.
37. Santoro S, Velhote MC, Malzoni CE, Milleo FQ, Klajner S, Campos FG. Preliminary results from digestive adaptation: a new surgical proposal for treating obesity, based on physiology and evolution. Sao Paulo Med J. 2006 Jul 6;124(4):192-7. doi: 10.1590/s1516-31802006000400004. PMID: 17086299; PMCID: PMC11065371.
38. Suárez Llanos JP, Fuentes Ferrer M, Alvarez-Sala-Walther L, García Bray B, Medina González L, Bretón Lesmes I, Moreno Esteban B. Protein malnutrition after gastric bypass incidence versus comparison biliopancreatic diversion. Nutr Hosp. 2015 Jul 1;32(1):80-6. doi: 10.3305/nh.2015.32.1.8963. PMID: 26262700.
39. Tang-Christensen M, Vrang N, Larsen PJ. Glucagon-like peptide containing pathways in the regulation of feeding behaviour. Int J Obes Relat Metab Disord. 2001;25(suppl 5):S42–S47. doi: 10.1038/sj.ijo.0801912.
40. Wisen O, Johansson C. Gastrointestinal function in obesity: motility, secretion and absorption following a liquid meal test. Metabolism. 1992;41:390–395. doi: 10.1016/0026-0495(92)90073-J.
41. Yska JP, van Roon EN, de Boer A, Leufkens HG, Wilffert B, de Heide LJ, de Vries F, Lalmohamed A. Remission of Type 2 Diabetes Mellitus in Patients After Different Types of Bariatric Surgery: A Population-Based Cohort Study in the United Kingdom. JAMA Surg. 2015 Dec;150(12):1126-33. doi: 10.1001/jamasurg.2015.2398. PMID: 26422580.

Порівняльний аналіз рукавної резекції шлунка з транзитною біпартицією та одноанастомозного ілеального шунтування після рукавної гастректомії у пацієнтів із морбідним ожирінням і цукровим діабетом 2 типу: ретроспективне когортне дослідження

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Мета — порівняти ефективність рукавної гастректомії (РГ) із транзитною біпартицією (ТБ) та нової метаболічної процедури — рукавної гастректомії з єдиним анастомозом та ілеальним шунтуванням (single anastomosis sleeve ileal bypass (SASI)) для лікування пацієнтів із морбідним ожирінням і цукровим діабетом 2 типу.

Матеріали та методи. Проведено ретроспективне когортне дослідження за участю 33 пацієнтів із морбідним ожирінням і цукровим діабетом 2 типу (ЦД2), яким було виконано баріатричні хірургічні втручання РГ + ТБ або SASI у нашій лікарні в період із вересня 2013 р. до грудня 2024 р. Критерії залучення: наявність в анамнезі баріатричної операції, верхньої лапаротомії, тяжких супутніх захворювань (ASA III—IV) та психічної нестабільності. Пацієнтів розподілили на дві групи залежно від методу лікування: у першій виконано РГ + ТВ, у другій — SASI. Середній вік пацієнтів становив 42,6 року (26—64 роки), середня доопераційна маса тіла — 107,5 кг (92—189,5 кг), середній доопераційний індекс маси тіла — 43,2 кг/м^2 (36,7—65 кг/м^2), середня надлишкова маса — 50,8 кг (28—106 кг). Метаболічне захворювання тривало в середньому 7,5 року до операції (3—21 рік).

Середній рівень доопераційної глікемії становив 11,8 ммоль/л (6,5—23 ммоль/л), глікозильованого гемоглобіну (HbA1c) — 7,6% (6,5—13,2%). Основними кінцевими точками були: відсоток втрати надлишкової маси тіла (%EWL), ремісія цукрового діабету та поліпшення супутніх патологій, вторинною кінцевою точкою — післяопераційний нутритивний статус.

Результати. Тривалість спостереження становила від 12 до 48 міс. Після операції Санторо втрата надлишкової маси тіла (EWL) становила 72% через 6 міс, 88% через рік, 92% через два роки та 86% через чотири роки, після операції SASI — 76, 89, 93 і 82% відповідно. Усі пацієнти мали повну ремісію цукрового діабету протягом перших 6 міс після операції. Середні післяопераційні рівні глікемії та HbA1c нормалізувалися з першого року післяопераційного спостереження. Захворювання вважали контрольованим при досягненні нормального рівня HbA1c (< 6%). Пацієнти, які отримували інсулін, досягли цього контролю в 76% випадків упродовж 12—48 міс спостереження. У пацієнтів, які приймали пероральні цукрознижувальні препарати, вміст HbA1c був нормальним в усіх випадках протягом першого року після операції та у 89% випадків протягом наступних п'яти років. Через два роки після операції середня концентрація загального білка становила (7,7 ± 1,7) г/дл у пацієнтів першої групи та (7,2 ± 1,5) г/дл у пацієнтів другої групи ($p > 0,1$), альбуміну — (4,1 ± 0,6) і (4,0 ± 0,8) г/дл відповідно, середня кількість щоденних актів дефекації — 1,6 ± 1,8 у пацієнтів обох груп.

Висновки. Нова методика — рукавна гастректомія з єдиним анастомозом та ілеальним шунтуванням (SASI) є ефективним і щадним хірургічним методом лікування морбідного ожиріння та ЦД2. Слід провести дослідження ефективності цього методу, а також уточнити показання й протипоказання до виконання SASI.

Ключові слова: рукавна гастректомія з транзитною біпартицією, операція Санторо, одноанастомозне ілеальне шунтування з рукавною гастректомією, пацієнти з морбідним ожирінням, цукровий діабет 2 типу.

FOR CITATION

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Organization of evacuation of the wounded in wartime: the impact of patient routing on treatment outcomes and infection risks

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Combat-related limb injuries in modern warfare are characterised by high-energy tissue destruction, extensive soft-tissue defects, and a high risk of infectious complications. Evidence from previous military conflicts in Iraq and Afghanistan, as well as civilian trauma centres, indicates that optimal management of such patients requires not only appropriate surgical tactics but also timely routing to specialised orthoplastic centres. Early radical debridement and definitive wound coverage within the orthoplastic «fix and flap» concept and BOAST standards are associated with reduced infection rates, fewer reoperations, and avoidance of delayed amputations. Despite the central role of evacuation pathways, quantitative data on how different evacuation models influence clinical outcomes in contemporary war conditions remain limited.

Objective – to assess the effectiveness of two medical evacuation models – mass (stepwise) and targeted (selective) – in patients with combat-related injuries based on the length of hospital stay and surgical burden.

Materials and methods. A retrospective cohort study was conducted among patients admitted to a specialised orthoplastic centre. Patients were stratified into two groups: targeted evacuation (direct transport to the reconstructive centre ≤72 hours post-injury) and mass evacuation (stepwise transfer through ≥2 intermediate hospitals). The primary endpoints included the length of hospital stay and the number of surgical procedures per patient. Time from injury to admission was analysed as a key factor. Statistical methods included descriptive analysis and intergroup comparison using the t-test/Mann-Whitney U test ($p < 0.05$).

Results. The mean time from injury to hospital admission in the targeted evacuation group was 1.77 ± 0.32 days (range: 0–6), compared with 11.84 ± 1.45 days (range: 3–53) in the mass evacuation group – a sevenfold increase. Mean length of hospital stay was significantly longer in the mass group: 37.03 ± 3.68 vs. 27.27 ± 2.47 days in the targeted group ($p = 0.03$). The average number of surgical procedures per patient was 2.78 ± 0.33 vs. 2.36 ± 0.38, respectively ($p = 0.41$), excluding prior operations performed before referral. No delayed amputations related to infectious complications or reconstruction failure were observed in either group.

Conclusions. Targeted evacuation enables a significantly shorter time to specialised surgical care, leading to reduced hospital stay and a more predictable clinical course. Although differences in surgical burden were not statistically significant, a consistent trend toward fewer interventions was observed with targeted routing. Optimising medical evacuation systems is a critical determinant in the management of limb combat injuries and may be scaled to healthcare systems operating in wartime or resource-limited environments.

Keywords
combat-related injury, medical evacuation, targeted evacuation, orthoplastic surgery, reconstructive surgery, fix and flap, hospital length of stay, infection prevention, early radical debridement, trauma system organisation, plastic surgery, facial trauma, limb trauma.

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The full-scale invasion of Ukraine by the Russian Federation on 24 February 2022 presented unprecedented challenges to the national healthcare system. Intense hostilities, particularly in the eastern and southern regions, led to a significant increase in military personnel suffering from mine-blast and gunshot injuries, polytrauma, massive blood loss, and a high risk of infectious complications [5, 7].

Frontline healthcare facilities have been operating under conditions of critical overload due to limited human resources, equipment, and infrastructure [5, 12]. Shortages of medical equipment, medications, and transport, along with the presence of multidrug-resistant pathogens (*Acinetobacter baumannii*, *Klebsiella pneumoniae*, *MRSA*), have further complicated the provision of adequate care [2, 7].

During the initial phase of the war, the absence of a clearly established patient routing system posed a substantial challenge. Casualties were often evacuated to the nearest healthcare facilities, regardless of their specialization. This practice led to overcrowding and elevated infectious risks [7], underscoring the need for a formalized medical evacuation system.

Two primary approaches to medical evacuation can be distinguished:

- **Mass (non-specific) evacuation** – transportation to the nearest healthcare facility regardless of its profile; typical for critical situations but associated with facility overload and repeated hospitalizations.
- **Targeted (selective) evacuation** – routing to specialized centers based on injury severity and resource availability.

Targeted evacuation has been implemented in Ukraine since the second half of 2022. An example is evacuation by rail in cooperation with international organizations: between March and November 2022, more than 2,400 patients were successfully transported using specially equipped medical trains [12]. Appropriate patient routing enables delivery times of 2–8 hours from the moment of injury to a specialized facility, which significantly reduces complication rates [2]. The experience of the Lviv Military Hospital confirmed that early transfer and a multidisciplinary approach reduce infection rates and improve reconstructive outcomes [9].

International data also confirm the critical role of timing and a multidisciplinary approach in infection prevention. An analysis of combat injuries (Timing of Wound Coverage in Extremity War Injuries, JAAOS, 2006) demonstrated that delayed wound closure substantially increases the risk of infectious complications and amputations [8]. Current standards of the British Orthopaedic Association (BOA) and the British Association of Plastic, Reconstructive and Aesthetic Surgeons (BAPRAS) for trauma care, document number 4 (BOAST 4) – joint guidelines of the British Orthopaedic Association and the British Association of Plastic, Reconstructive and Aesthetic Surgeons for the management of open fractures–emphasize the need for radical debridement and orthoplastic defect coverage within the first 72 hours [6]. These principles underpin our protocol for targeted evacuation and reconstructive treatment in wartime conditions.

Objective – to evaluate the effectiveness of two medical evacuation models – mass (non-specific) and targeted (selective) – in patients with combat-related extremity injuries, using treatment duration and the number of surgical interventions as outcome measures.

To assess the effectiveness of two medical evacuation models – mass (stepwise) and targeted (selective) – in patients with combat-related injuries based on the length of hospital stay and surgical burden.

Materials and methods

A total of 59 patients requiring surgical treatment were included in the study. They were evacuated to the medical center of the Charitable Organization «Superhumans» between October 2024 and June 2025. The majority of patients sustained severe mine-blast injuries to the extremities that necessitated multistage reconstructive management.

Depending on the medical evacuation pathway, patients were stratified into two groups:

- Targeted (selective) evacuation – 22 patients – direct transportation to a reconstructive center within ≤ 72 hours after injury, with early radical debridement (≤ 24 hours after admission) and definitive wound closure within 5–7 days.
- Mass (general) evacuation – 37 patients – staged transportation through two or more intermediate medical facilities prior to admission to the reconstructive center.

Although allocation to evacuation pathways was not randomized, transportation routes were determined primarily by geographic and logistical factors rather than injury severity or wound characteristics that could influence treatment outcomes. Both groups included patients with comparable injury mechanisms and anatomical patterns, minimizing the risk of significant systematic bias when assessing the impact of evacuation models on clinical outcomes.

The results were analyzed using descriptive statistical methods. The Student's t-test was applied to compare mean values between the two samples. Data are presented as M ± m, where M denotes the

Table. **Comparative characteristics of treatment outcomes depending on the medical evacuation model**

Parameter	Targeted evacuation	Mass evacuation	p
Time from injury to admission to a specialized center, days (M ± m (min–max))	1.77 ± 0.32 (0–6)	11.84 ± 1.45 (3–53)	< 0.001
Length of inpatient treatment, days (M ± m)	27.27 ± 2.47	37.03 ± 3.68	0.03
Number of surgical interventions in the specialized center per patient (M ± m)	2.36 ± 0.38	2.78 ± 0.33	0.41
Cases of delayed amputations	0	0	–

arithmetic mean and m the standard error of the mean, reflecting the precision of the mean estimate. Differences were considered statistically significant at $p < 0.05$.

Artificial intelligence tools were used exclusively for linguistic editing and stylistic improvement of the text. The authors bear full responsibility for the content, data analysis, and conclusions presented in the article.

Results

At the first stage of the study, the organization of medical evacuation and the duration of transportation to the specialized reconstructive center were evaluated. Analysis of evacuation routes revealed significant differences between targeted and mass (staged) evacuation models in the time required for patient transport to the center of definitive surgical care (Table).

In the targeted evacuation group, patients were transported directly to a specialized orthoplastic center after injury. Transportation time in this group ranged from 0 to 6 days, with a mean interval from injury to hospitalization of 1.77 ± 0.32 days. The conceptual features of targeted routing and the opportunity for early primary surgical debridement upon admission to a specialized center are illustrated in Fig. 1.

In the mass (staged) evacuation group, patients were transported through several intermediate medical facilities. The interval between injury and admission to the reconstructive center ranged from 3 to 53 days, with a mean of 11.84 ± 1.45 days, which was nearly seven times longer than in the targeted evacuation group.

The characteristics of combat-related injuries requiring early orthoplastic planning upon admission to the specialized center are demonstrated on primary radiographs (Fig. 2).

Further analysis of clinical parameters revealed differences in the length of hospital stay between the groups. Patients evacuated via the mass (staged) pathway had a mean inpatient treatment duration of 37.03 ± 3.68 days, compared with 27.27 ± 2.47 days in the targeted evacuation group. This difference was statistically significant ($p = 0.03$).

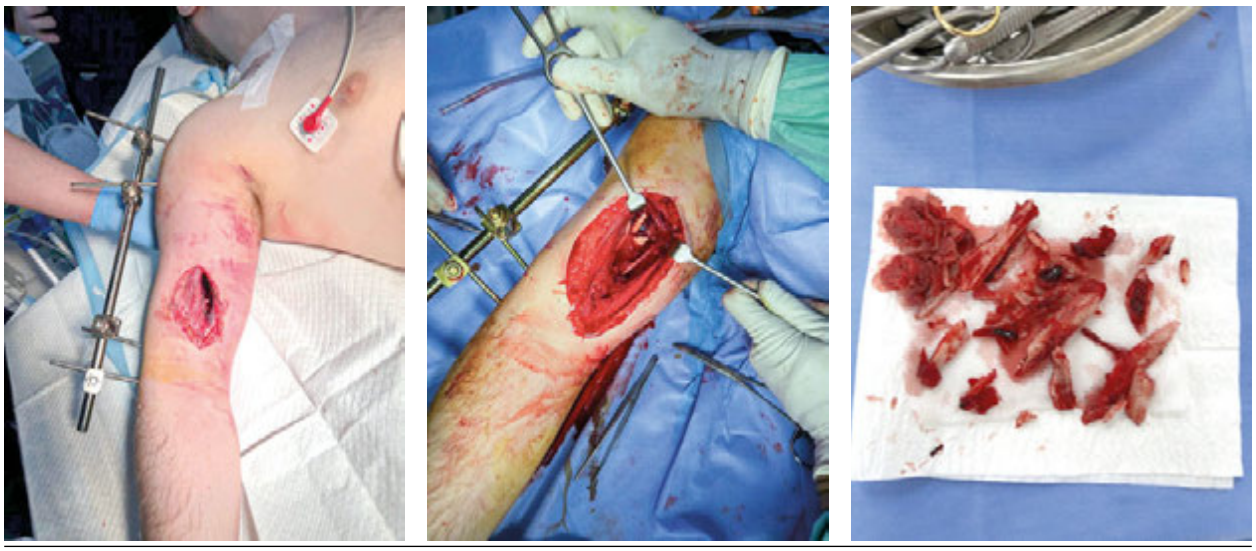

Figure 1. **Primary surgical debridement performed 48 hours after a mine-blast injury following targeted evacuation of the patient to the specialized orthoplastic center «Superhumans»**

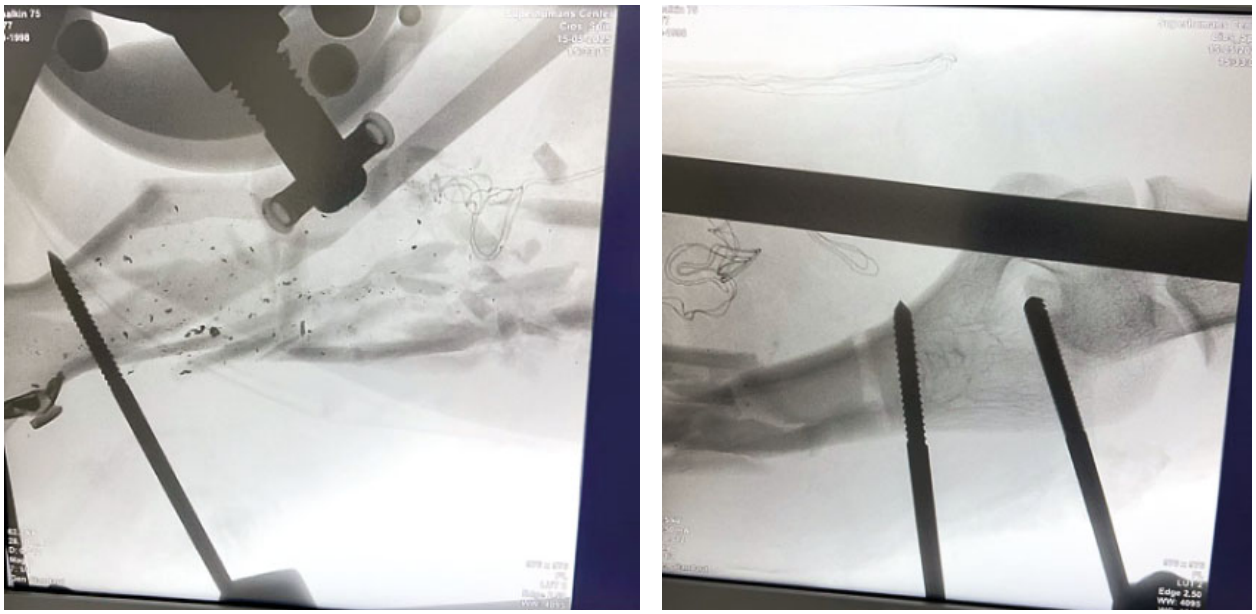

Figure 2. **Primary intraoperative radiograph demonstrating a comminuted fracture resulting from a mine-blast injury and the pattern of damage requiring early orthoplastic planning after targeted evacuation to a specialized center**

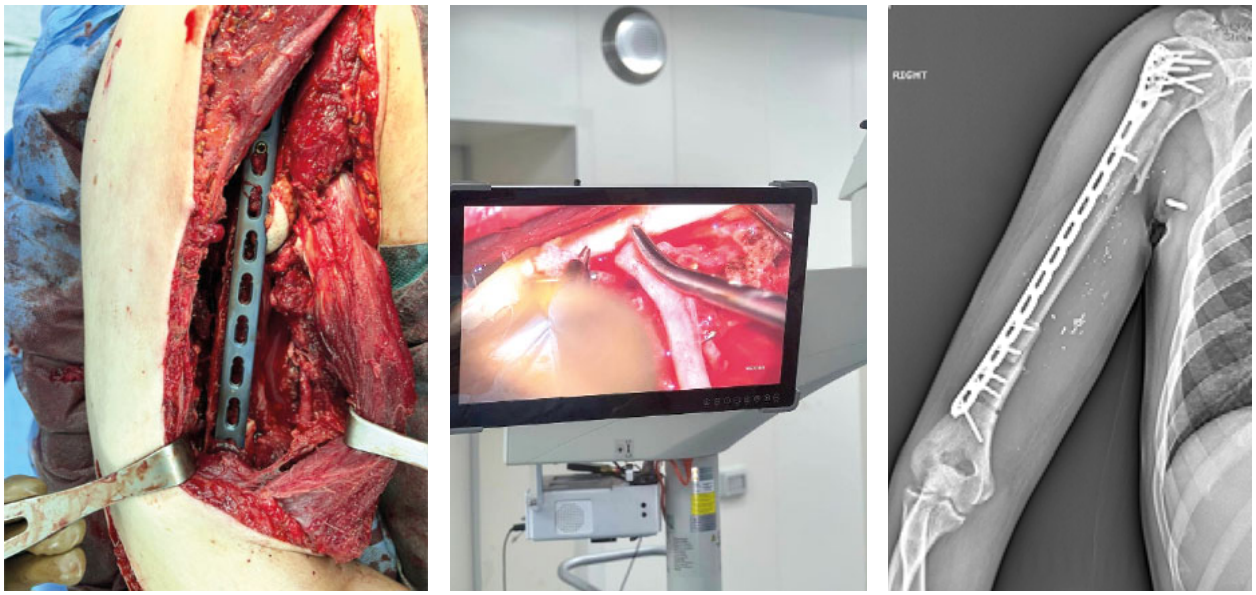

Figure 3. **Reconstruction with a free fibular flap performed on day 5 after injury following targeted evacuation of the patient and within the framework of early orthoplastic planning**

The mean number of surgical procedures per patient in the mass (staged) evacuation group was 2.78 ± 0.33, excluding at least one surgical intervention performed in general-profile facilities prior to admission to the specialized center. In the targeted evacuation group, the mean number of surgical procedures was 2.36 ± 0.38. No statistically significant difference was identified between the groups for this parameter ($p = 0.41$).

The feasibility of early definitive reconstructive intervention following targeted evacuation and early orthoplastic planning is illustrated by a clinical example of free fibular flap reconstruction (Fig. 3).

In both groups, a proportion of patients underwent amputations that were a consequence of the severity of the primary injury at the time of trauma. No cases of delayed amputations related to infectious complications, progression of tissue necrosis, or failure of reconstructive treatment were recorded in either group.

The mass (staged) evacuation group showed greater heterogeneity in clinical outcomes, as

evidenced by variability in wound healing rates and postoperative course. In contrast, the clinical course in the targeted evacuation group was more uniform and stable.

Discussion

Our findings demonstrate fundamental organizational differences between targeted and mass (staged) models of medical evacuation, primarily in the time required to transport wounded patients to a specialized orthoplastic center. The significantly shorter interval between injury and hospitalization in the targeted evacuation group facilitates early radical surgical debridement and timely planning of definitive reconstructive treatment, as demonstrated by the clinical examples presented (see Fig. 1–3).

The reduced length of inpatient treatment observed in patients after targeted evacuation may reflect a more controlled and predictable course of wound-healing. Early routing to a specialized center minimizes delays between treatment stages and helps avoid repeated or interim procedures that are often performed in non-specialized facilities during staged evacuation.

Although no statistically significant difference in the number of surgical interventions between groups was identified, this analysis included only procedures performed at the specialized reconstructive center «Superhumans». At the same time, patients evacuated via the mass (staged) model typically underwent additional surgical interventions at earlier stages of evacuation, including staged debridements and other urgent procedures, which were not included in the present count. This limitation should be considered when interpreting results on the number of operations. Comprehensive assessment of the total surgical burden, including interventions performed at all stages of medical evacuation, represents a promising direction for future research.

Infection control was assessed indirectly using clinically relevant surrogate markers, including length of hospital stay, stability of the clinical course, and absence of delayed amputations. This approach is consistent with established practices for analyzing infectious risks in complex combat trauma settings, where standardized microbiological endpoints are limited or not feasible.

The observed findings are consistent with international data. In particular, the study Timing of Wound Coverage in Extremity War Injuries (JAAOS, 2006) demonstrated that delayed wound closure is associated with an increased risk of infectious complications and amputations, while the multicenter TIDOS study confirmed the substantial impact of infection on clinical outcomes in military patients [10]. Current BOA–BAPRAS standards (BOAST 4) emphasize the necessity of early debridement and orthoplastic defect coverage within 72 hours [6], which underpins the «fix and flap» concept proposed by S. Gopal et al. [1].

Our data indicate that these principles remain applicable even in the context of full-scale hostilities. However, given the high-energy nature of mine-blast injuries, the interval to definitive defect closure may be safely extended to 5–7 days, provided that BOAST 4 recommendations are followed and a multidisciplinary orthoplastic team is involved.

The prevalence of multidrug-resistant pathogens among Ukrainian military patients is among the highest in Europe. Under these conditions, the key factor in preventing infectious complications is not prolonged antibiotic therapy, but rapid routing of wounded patients to specialized centers capable of providing early orthoplastic treatment.

Formalized injury severity scoring systems (ISS, NISS) were not applied in this study due to its retrospective design and the lack of complete standardized data across all stages of evacuation, which should be considered a limitation. Nevertheless, the comparability of groups in terms of injury mechanisms and anatomical patterns allows the observed differences to be interpreted primarily in the context of the organizational model of medical evacuation rather than the severity of the primary injury.

Conclusions

Targeted evacuation ensures rapid patient transport to a specialized reconstructive center (mean time: 1.77 ± 0.32 days versus 11.84 ± 1.45 days under mass (staged) evacuation), facilitating early radical wound debridement and reducing clinical variability during treatment.

Mass (staged) evacuation is associated with a longer inpatient treatment duration (37.03 ± 3.68 days versus 27.27 ± 2.47 days in the targeted evacuation group, $p = 0.03$) and greater heterogeneity in clinical outcomes.

The mean number of surgical interventions did not differ statistically significantly between groups (2.78 ± 0.33 in the mass evacuation group and 2.36 ± 0.38 in the targeted evacuation group, $p = 0.41$), excluding procedures performed in general-profile facilities before admission to the specialized center. Although this difference did not reach statistical significance, the clinical trend suggests fewer interventions with targeted evacuation, consistent with the concept of early routing to specialized centers.

No delayed amputations related to infectious complications or failure of reconstructive treatment were recorded in either group, demonstrating the effectiveness of the treatment protocols and infection control measures.

Future studies will focus on evaluating the impact of evacuation routes on the structure, staging, and final outcomes of surgical treatment.

Declaration of interests

The authors declare no conflict of interest.

Authors contributions

Conception and design – D. Turkevych, A. Vilenskyi; acquisition of data – S. Kuchabskyi, M. Farmaha; analysis and interpretation of data – D. Turkevych, A. Vilenskyi, M. Farmaha; drafting the article – D. Turkevych; critical revision of the article — Y. Medvid, A. Vilenskyi, S. Tucker

References

1. Gopal S, Majumder S, Batchelor AG, Knight SL, De Boer P, Smith RM. Fix and flap: the radical orthopaedic and plastic treatment of severe open fractures of the tibia. J Bone Joint Surg Br. 2000 Sep;82(7):959-66. doi: 10.1302/0301-620x.82b7.10482. PMID: 11041582.
2. Khersonska TB. Organization of medical evacuation of servicemen with combat injuries of the maxillofacial region in the area of the Anti-Terrorist Operation / Joint Forces Operation in Donetsk and Luhansk regions. Problemy viiskovoi okhorony zdorovia. 2020;27:60-68. Ukrainian. doi: 10.32751/2310-4910-2020-27-06.
3. Kovalchuk V, Kondratiuk V, McGann P, Jones BT, Fomina N, Nazarchuk O, Fomin O, Kovalenko I. Temporal evolution of bacterial species and their antimicrobial resistance characteristics in wound infections of war-related injuries in Ukraine from 2014 to 2023. J Hosp Infect. 2024 Oct;152:99-104. doi: 10.1016/j.jhin.2024.06.011. Epub 2024 Jul 10. PMID: 38997008.
4. Ljungquist O, Nazarchuk O, Kahlmeter G, Andrews V, Koithan T, Wasserstrom L, Dmytriiev D, Fomina N, Bebyk V, Matuschek E, Riesbeck K. Highly multidrug-resistant Gram-negative bacterial infections in war victims in Ukraine, 2022. Lancet Infect Dis. 2023 Jul;23(7):784-786. doi: 10.1016/S1473-3099(23)00291-8. Epub 2023 May 23. PMID: 37236220.
5. Mueller A, Salek M, Oszer A, Evseev D, Yakimkova T, Wlodarski M, Vinitsky A, Kizyma R, Pogorelyy M, Zuber M, Escalante J, Lipska E, Fendler W, Nowicka Z, Szyszka A, Kacharian A, Rodriguez-Galindo C, Wise PH, Agulnik A, Mlynarski W; SAFER Ukraine collaborative. Retrospective comparative analysis of two medical evacuation systems for Ukrainian patients affected by war. Eur J Cancer. 2024 Oct;210:114271. doi: 10.1016/j.ejca.2024.114271. Epub 2024 Aug 8. PMID: 39232428.
6. Nanchahal J, Nayagam S, Khan U, Moran C, Barrett S, Sanderson F, Pallister I. Standards for the Management of Open Fractures of the Lower Limb. London: BOA/BAPRAS; 2020.
7. Quinn J, Panasenko SI, Leshchenko Y, Gumeniuk K, Onderková A, Stewart D, Gimpelson AJ, Buriachyk M, Martinez M, Parnell TA, Brain L, Sciulli L, Holcomb JB. Prehospital Lessons From the War in Ukraine: Damage Control Resuscitation and Surgery Experiences From Point of Injury to Role 2. Mil Med. 2024 Jan 23;189(1-2):17-29. doi: 10.1093/milmed/usad253. PMID: 37647607.
8. Sherman R, Rahban S, Pollak AN. Timing of wound coverage in extremity war injuries. J Am Acad Orthop Surg. 2006;14(10 Spec No.):S57-61. doi: 10.5435/00124635-200600001-00013. PMID: 17003209.
9. Sinyuk M, Polishchuk V, Yuschak P, Burachok I. Management of war-related facial wounds in Ukraine: the Lviv military hospital experience. BMJ Mil Health. 2025 Jan 28;171(1):12-15. doi: 10.1136/military-2023-002527. PMID: 38124117.
10. Tribble DR, Conger NG, Fraser S, Gleeson TD, Wilkins K, Antonille T, Weintrob A, Ganesan A, Gaskins LJ, Li P, Grandits G, Landrum ML, Hospenthal DR, Millar EV, Blackbourne LH, Dunne JR, Craft D, Mende K, Wortmann GW, Herlihy R, McDonald J, Murray CK. Infection-associated clinical outcomes in hospitalized medical evacuees after traumatic injury: trauma infectious disease outcome study. J Trauma. 2011 Jul;71(suppl. 1):S33-42. doi: 10.1097/TA.0b013e318221162e. PMID: 21795875; PMCID: PMC4265636.
11. Uren H, Aliieva N, Matolinets N, Hemsley C, Holcomb JB, Samchuk O, Herych H. Cumulative antibiogram results of over 6800 diagnostic isolates from the First Lviv Territorial Medical Union, Ukraine. Lancet Infect Dis. 2025 Apr;25(4):e200-e201. doi: 10.1016/S1473-3099(25)00116-1. Epub 2025 Mar 8. PMID: 40064191.
12. Walravens S, Zharkova A, De Weggheleire A, Burton M, Cabrol JC, Lee JS. Characteristics of Medical Evacuation by Train in Ukraine, 2022. JAMA Netw Open. 2023 Jun 1;6(6):e2319726. doi: 10.1001/jamanetworkopen.2023.19726. PMID: 37351882; PMCID: PMC10290241.

Організація евакуації поранених в умовах війни: як маршрутизація впливає на лікування та інфекційні ризики

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Бойові пошкодження кінцівок в умовах сучасної війни характеризуються високою енергетикою ураження, значним дефектом тканин і високим ризиком інфекційних ускладнень. За даними, отриманими під час військових конфліктів в Іраку та Афганістані, а також згідно із досвідом цивільних травматологічних центрів, ефективне ведення таких пацієнтів потребує не лише адекватної хірургічної тактики, а й своєчасної маршрутизації до спеціалізованого ортопластичного центру. Раннє проведення радикальної некректомії та остаточного закриття дефектів відповідно до концепції ортопластичного підходу «fix and flap» і стандартів BOAST асоціюється зі зниженням частоти інфекційних ускладнень, повторних операцій

і потреби у відстрочених ампутаціях. Попри ключову роль медичної евакуації, кількісні дані щодо впливу її різних моделей на клінічні результати в умовах сучасної війни обмежені.

Мета — оцінити ефективність двох моделей організації медичної евакуації — масової (етапної) і прицільної (селективної) у пацієнтів із бойовою травмою за показниками тривалості госпіталізації та кількості хірургічних втручань.

Матеріали та методи. Проведено ретроспективне когортне дослідження пацієнтів, госпіталізованих у спеціалізований ортопластичний центр. Пацієнтів розподілили на дві групи залежно від маршруту евакуації: прицільна (безпосереднє транспортування до реконструктивного центру) та масова (етапна через ≥ 2 проміжні медичні заклади). Первинні кінцеві точки — тривалість стаціонарного лікування та кількість оперативних втручань на одного пацієнта, додаткова — час від поранення до госпіталізації. Статистичний аналіз передбачав описову статистику та порівняння груп із використанням t-критерію або U-тесту Манна — Уїтні ($p < 0,05$).

Результати. Середній час від моменту травми до госпіталізації в групі прицільної евакуації становив (1,77 ± 0,32) доби (0—6 діб), у групі масової евакуації — (11,84 ± 1,45) доби (3—53 доби), що в 7 разів довше. Середня тривалість стаціонарного лікування була суттєво більшою в групі масової евакуації ((37,03 ± 3,68) і (27,27 ± 2,47) доби, $p = 0,03$). Середня кількість операцій становила 2,78 ± 0,33 у групі масової евакуації та 2,36 ± 0,38 у групі прицільної евакуації ($p = 0,41$) без урахування втручань, виконаних у попередніх стаціонарах. Випадків відстрочених ампутацій, пов'язаних з інфекційними ускладненнями або неефективністю реконструктивного лікування, не зареєстровано.

Висновки. Прицільна евакуація забезпечує значно коротший час до спеціалізованого хірургічного втручання, що асоціюється зі скороченням тривалості госпіталізації та прогнозованішим клінічним перебігом. Незважаючи на відсутність статистично значущих відмінностей за кількістю оперативних втручань, клінічна тенденція свідчить про менше хірургічне навантаження за прицільної евакуації. Оптимізація маршруту медичної евакуації є критичним чинником лікування бойових травм кінцівок і може бути впроваджена в систему охорони здоров'я в умовах воєнних дій або ресурсних обмежень.

Ключові слова: бойова травма, медична евакуація, цільова (селективна) евакуація, ортопластична хірургія, реконструктивна хірургія, фіксація та клаптеве покриття, тривалість перебування в лікарні, профілактика інфекцій, раннє радикальне видалення некротичних тканин, організація системи травматологічної допомоги, пластична хірургія, травма обличчя, травма кінцівок.

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First clinical application of Permacol biological mesh in Ukraine. Case report

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The article presents the first clinical experience in Ukraine of using the Permacol biological implant in the surgical treatment of a giant postoperative ventral hernia in a patient with morbid obesity and an external fistula of the anterior abdominal wall. The study is relevant due to the high incidence of postoperative ventral hernias, particularly after open surgical interventions, and the considerable risk of infectious complications in contaminated surgical fields. Additionally, the absence of standardized guidelines for the combined approach to hernioplasty and bariatric surgery in obese patients remains a significant clinical challenge. A detailed clinical case is presented involving a 63-year-old patient with class III obesity, a giant defect of the anterior abdominal wall aponeurosis, and a chronic external fistula, along with a complicated surgical history that included peritonitis and postoperative wound suppuration. Preoperative management involved intramuscular administration of botulinum toxin type A to relax the anterior abdominal wall muscles, reduce the risk of tissue tension, and prevent abdominal compartment syndrome. The patient underwent herniolaparotomy, viscerolysis, hernioplasty with intra-abdominal placement of the Permacol biological implant using the open intraperitoneal onlay mesh (IPOM) technique, mini-gastric bypass, excision of the anterior abdominal wall fistula, and drainage of both the abdominal cavity and postoperative wound according to Redon. The postoperative period was uneventful, with no evidence of intra-abdominal hypertension or infection. These findings support the feasibility and safety of the Permacol biological implant in patients with complex anterior abdominal wall defects and a high risk of infectious complications.

Keywords
postoperative ventral hernia, hernioplasty, biological mesh.

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Median hernias represent the most prevalent type of hernia affecting the anterior abdominal wall. Notably, up to 5 % of these cases are classified as postoperative ventral hernias (PVH) [4]. The overall incidence of PVH after surgery ranges from 2 to 23 %.

When abdominal organ surgery is performed using the open technique, PVH occurs in 1 to 16 % of patients within the first 2 years postoperatively. In the long term, ten years after surgery, this incidence increases to 20 % [2, 6, 10, 17, 24]. Open surgical interventions are associated with a significantly higher incidence of PVH (10.1 %) than laparoscopic procedures (4.3 %) after 12 months of follow-up, as demonstrated by a meta-analysis of 24 randomized controlled trials involving 3,490 patients [18].

Key factors contributing to PVH include the technique of surgical wound suturing, the application of antibacterial solutions, the presence of concomitant diseases, and episodes of surgical wound infection. In high-risk patients with a combination of several contributing factors, the incidence of PVH can reach up to 69 % [21].

The primary treatment for PVH is hernioplasty using a mesh implant. Implants are categorized as synthetic, biological, and composite based on their material composition and the biological tissue response to the mesh. Each mesh type presents distinct advantages and disadvantages. Synthetic meshes offer strong mechanical properties and are relatively inexpensive, but are associated with

increased risk of inflammation, stiffness, soreness, infection, and fistula formation. Composite meshes are preferable for intra-abdominal placement; however, the risk of infection in a contaminated wound is comparable to, or may even exceed, that of synthetic meshes [27].

Biological meshes offer notable advantages over the two previously described types, including a moderate risk of inflammation in surrounding tissues, a low risk of fistula formation, and reduced fibrosis at the site of mesh implantation. However, biological meshes are associated with higher costs and lower mechanical strength than synthetic meshes. Mesh selection should be individualized, considering factors such as mesh position, the presence of infection or wound contamination, including previously installed meshes, and the risk of infection of both the wound and the mesh. Furthermore, managing purulent complications of hernioplasty, particularly when infected synthetic or composite mesh must be removed, may incur significantly higher costs than the initial use of biological mesh [3, 14].

Clinical case

A 63-year-old patient presented with a hernial protrusion at the site of a postoperative scar, the formation of an external purulent fistula in the umbilical region, and discomfort in the right hypochondrium. The body mass index (BMI) was 43 kg/m^2, consistent with Class III obesity.

Medical history revealed that in 2010, the patient underwent a laparoscopic cholecystectomy for gallstone disease and chronic calculous cholecystitis. The postoperative course was without complications.

On 04/08/2024, the patient underwent laparoscopic Nissen fundoplication combined with gastroplication for the surgical treatment of obesity and hiatal hernia. On postoperative day 4, clinical signs of peritonitis developed, necessitating a second surgical intervention on 04/12/2024. Relaparoscopy revealed perforation of a gastric ulcer; laparoscopic suturing of the gastric wall defect and regastroplication were performed. On 04/26/2024, recurrent signs of peritonitis prompted an urgent median laparotomy. Intraoperatively, perforation of the small intestine wall was detected, most likely secondary to a stress ulcer. The small intestine wall defect was sutured. The postoperative period was complicated by total suppuration of the anterior abdominal wall wound, requiring prolonged inpatient and outpatient treatment.

Within 6 months after the open operation, the patient lost 10 kg; however, her weight returned to baseline after 3 months. One month postoperatively, a hernial protrusion developed at the site of the postoperative scar and progressively increased in size. Additionally, a fistula opening appeared in the umbilical region along the postoperative scar. The volume and nature of the discharge changed over time, ranging from minimal smears on a napkin to 100 ml per day. The discharge was serous and periodically contained small intestine contents. The patient underwent conservative treatment for the external fistula at the institution where the previous surgeries had been performed.

In July 2025, the patient was evaluated at the Department of General Surgery No2, Bogomolets National Medical University, during an outpatient visit. The patient's general condition was relatively satisfactory. Objective examination revealed recurrent obesity, with a BMI of 43 kg/m^2. A postoperative scar, measuring up to 25 cm in length, was visualized along the midline of the anterior abdominal wall, extending above and below the umbilicus. Along the entire length of the scar, a hernial protrusion measuring up to 30 cm in width and 25 cm in length was identified. Accurate assessment of the hernial defect size by palpation was complicated by obesity and by a large, densely filled hernial sac containing loops of the small intestine, with visible subcutaneous peristalsis. The hernial hilum measured up to 20 cm in width and 25 cm in length. Laboratory tests showed no pronounced inflammatory changes (leukocytes – $4.7 \cdot 10^9$/L, erythrocyte sedimentation rate – 24 mm/h). Biochemical analysis revealed total bilirubin of 10.9 μmol/L, direct bilirubin of 3.3 μmol/L, ALT of 32 U/L, and AST of 24 U/L. Ultrasound examination (UE) of the abdominal cavity and anterior abdominal wall demonstrated moderate dilation of the intrahepatic bile ducts up to 8 mm and the choledochus up to 20 mm. Video gastroscopy revealed no pathological findings in the stomach or duodenum.

Measurement of the hernial defect size during ultrasound examination with linear and convex sensors was not feasible because the defect width exceeded the sensor's field of view. Ultrasound imaging identified the contents of the hernial sac as loops of the small intestine and bands of the large intestine. Computed tomography (CT) of the abdominal cavity with intravenous contrast revealed the postoperative condition of the stomach after fundoplication and gastroplication, as well as suture material along the greater curvature of the posterior gastric wall. Additionally, CT revealed a midline aponeurotic hernial defect measuring up to 172 mm in width and a hernial sac measuring 264 mm in width. The vertical dimension of the hernial defect reached up to 225 mm. The hernial sac contained

bands of the large intestine, loops of the small intestine, right-sided segments of the large intestine, and the appendix (Fig. 1*A*).

During CT, fistulography was performed by injecting 20 ml of radiopaque substance (Tomohexol-350) into the external opening of the fistula passage in the umbilical region. Imaging revealed a fistula canal measuring up to 90 mm in length and up to 10 mm in thickness, extending along the lower contour of the hernial sac and within the aponeurosis of the anterior abdominal wall, with a right-sided branch measuring up to 30× 12 mm (Fig. 1*B,* 1*C*). CT also confirmed expansion of the intrahepatic bile ducts to 5–8 mm, the choledochus to 20 mm, and the intrapancreatic section of the choledochus to 11 mm. Subsequent magnetic resonance cholangiopancreatography with intravenous contrast further confirmed biliary hypertension, with dilation of the common bile duct to 23, 14, and 8 mm. No additional formations or areas of pathological contrast enhancement were detected. These findings were interpreted as resulting from fibrous narrowing of the ampullary part of the common bile duct.

The patient insisted on the treatment of obesity and PVH recurrence, including removal of the anterior abdominal wall fistula. Given the size of the hernial defect and the high risk of compartment syndrome in the early postoperative period, a decision was made, in agreement with the patient, to perform preoperative preparation with intramuscular injection of botulinum toxin type A (BTA) into the muscles of the anterior abdominal wall. This intervention blocks neuromuscular transmission and induces muscle relaxation. It is a technically simple, low-traumatic method for increasing the elasticity and length of the anterior abdominal wall muscles to facilitate closure of the hernial defect during surgical repair of large ventral hernias, without extensive tension and with reduced risk of increased intra-abdominal pressure [15, 29].

The patient received an outpatient injection of BTA (Botox, USA) at a dose of 100 U, administered in layers into the transverse, external, and internal oblique muscles of the anterior abdominal wall under ultrasound and neurostimulator guidance. No complications were detected during or after the BTA injection. A bandage was recommended until hernia surgery. Although surgery was initially scheduled for 4 to 5 weeks post-injection, it was postponed to 2 months due to family circumstances (Fig. 2).

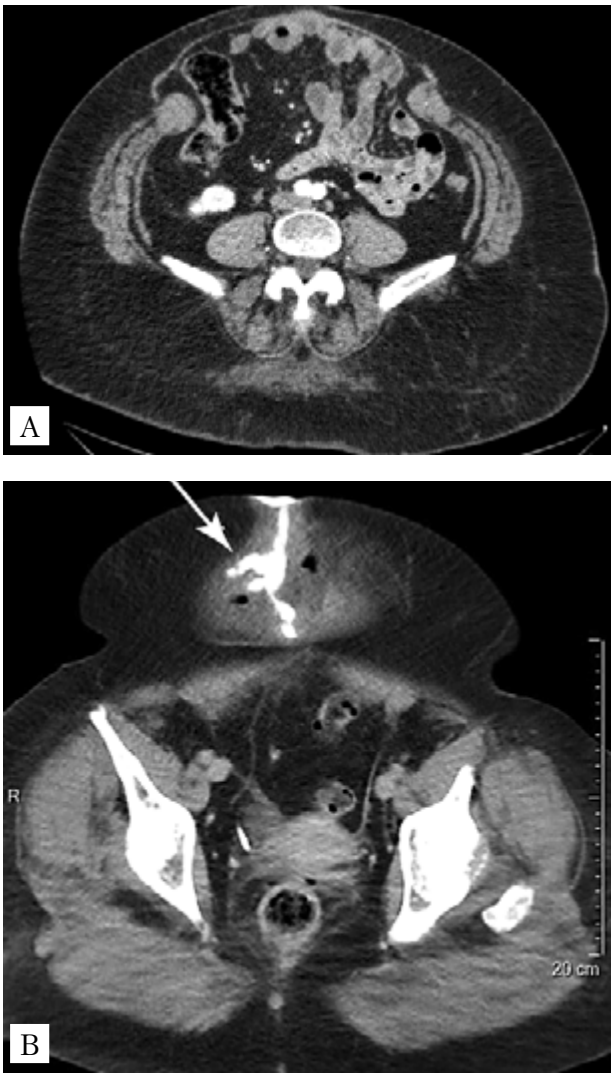

Figure 1. **Section of the computed tomography of the patient before surgery (hernioplasty) in the horizontal (A, B) and sagittal (C) planes at the level of the hernial protrusion. The arrow indicates the location of the fistula passage contrast in the horizontal (B) and sagittal (C) planes**

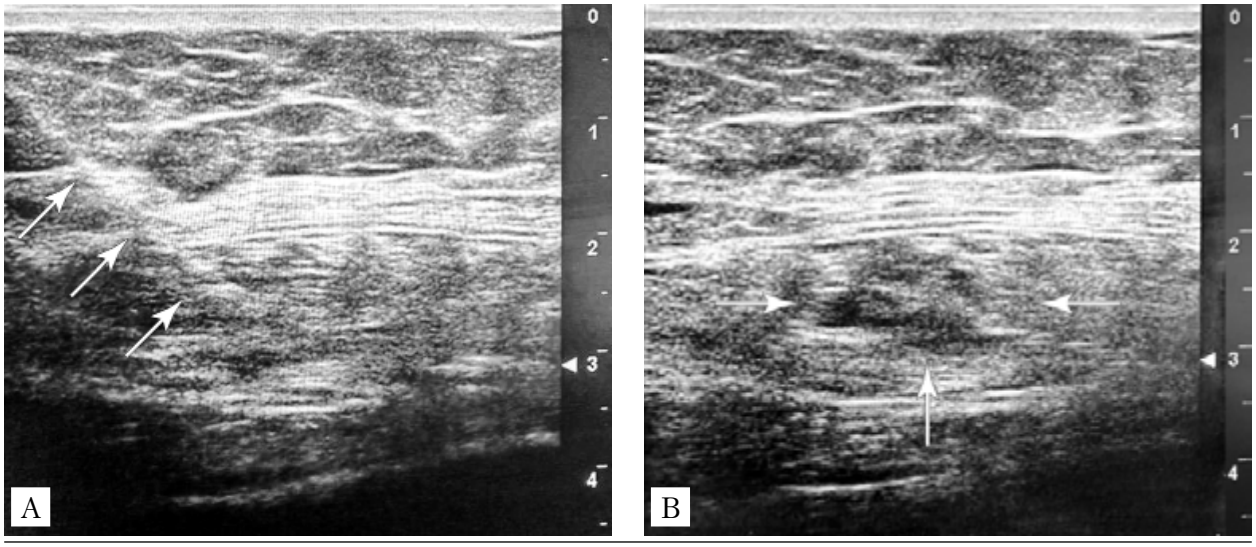

Figure 2. **Echogram during puncture of the external oblique muscle of the abdomen under ultrasound control (A) and its infiltration with a solution containing BTA (B). Arrows indicate the needle during muscle puncture (A) and the area of muscle infiltration with a solution containing BTA (B)**

Due to the presence of stenosing papillitis and intrahepatic bile duct hypertension, endoscopic retrograde cholangiopancreatography with papillosphincterotomy was performed on 08/27/2025, one month before the planned hernioplasty. A temporary stent was installed in the common bile duct and subsequently removed after 2 weeks. No evidence of recurrent biliary hypertension was observed during the next 2 weeks of monitoring, as assessed by laboratory and ultrasound examinations.

On 09/22/2025, the patient was hospitalized in the surgical department of Kyiv City Clinical Hospital No 3 for management of a giant postoperative ventral hernia, Class III obesity (condition after gastroplication in 04/2024), and an external fistula of the anterior abdominal wall. Examination revealed a decrease in the width of the hernial defect to 10 cm. Mini-gastric bypass was selected as the planned bariatric surgery. Longitudinal gastrectomy was not considered due to prior gastroplication and the ineffectiveness of previous restrictive surgery. Given the potentially contaminated anterior abdominal wall, the extremely high risk of postoperative wound suppuration, and the need to open the stomach and small intestine during anastomotic formation, the use of a biological mesh for anterior abdominal wall reconstruction was indicated.

On 09/23/2025, the patient underwent herniolaparotomy, viscerolysis, hernioplasty with intra-abdominal placement of a Permacol (Medtronic) biological implant using the open intraperitoneal onlay mesh (IPOM) method, mini-gastric bypass, excision of the anterior abdominal wall fistula, abdominal cavity drainage, and postoperative wound drainage according to the Redon technique. Intraoperatively, the external course of the fistula at the umbilical region was stained with a 1% solution of brilliant green in 3% hydrogen peroxide (1:1), in a volume of 20 ml. After viscerolysis, an infiltrate was visualized within the anterior abdominal wall, extending as a band from the umbilicus along the midline for 5 cm inferiorly. The umbilicus and fistula tract, along with infiltrated tissues, were excised within the margins of healthy anterior abdominal wall tissue.

A pronounced hernial process was observed in the abdominal cavity, involving the stomach and accompanied by multiple adhesions between the loops of the small intestine and the bands of the large intestine. The anterior gastric wall was tightly fixed to the inner surface of the left lobe of the liver. Palpation of the stomach was possible due to prior gastroplication. After viscerolysis and mobilization of the hernial contents (bands of the large intestine, loops of the small intestine, transverse colon, and right parts of the colon), the stomach was released from adhesions. Subsequently, a «small stomach» was created by transversely cutting the stomach at the level of its angle with the Endo GIA stapling device with Tri-Staple technology (Medtronic), 60 mm, black cassette. A pre-colonic gastroenteroanastomosis was constructed 200 cm distal to the Treitz ligament: the posterior lip was formed using the Endo GIA stapling device with Tri-Staple technology (Medtronic), 45 mm, purple cassette, and the anterior lip was completed with a manual double-row suture. After a negative pneumotest, a nasogastric tube was inserted posterior to the gastroenteroanastomosis. The hernia sac was then excised from the anterior abdominal

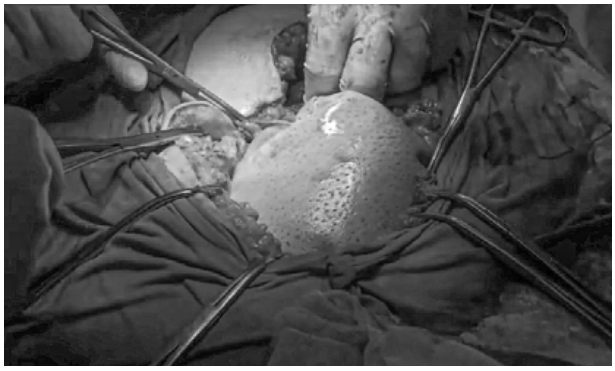

Figure 3. **Intraoperative photo of intra-abdominal hernioplasty using the Permacol biological implant (Medtronic)**

wall, and a site for mesh placement was prepared. Using the IPOM technique, a Permacol (Medtronic) biological implant measuring 20 cm by 30 cm, and 1.5 mm thick, was installed intra-abdominally and secured to the anterior abdominal wall with separate nodal sutures (Fig. 3). The aponeurosis was closed over the mesh with a continuous suture.

After restoration of aponeurosis integrity, intra-abdominal pressure was measured intraoperatively using the indirect method and found to be 13 mm Hg, consistent with Grade I intra-abdominal hypertension. The operation was then completed with layer-by-layer wound closure and drainage placement according to the Redon technique.

Examination and opening of the macropreparation, namely the resected fistula canal with surrounding infiltrated tissues measuring up to 6 × 3 cm, revealed a green polyfilament thread in the form of a rolled-up ball. This finding most likely represented the remains of the ligature used for aponeurosis suturing during the previous surgical intervention (2024).

In the postoperative period, the patient was in the intensive care unit for the first day before transfer to the surgical department. Intra-abdominal pressure was monitored by the indirect method at 6, 12, and 24 hours postoperatively, with no evidence of intra-abdominal hypertension. The patient received antibacterial therapy (ciprofloxacin 200 mg 2 times/day), anti-ulcer therapy (pantoprazole 40 mg 2 times/day), anti-inflammatory therapy (paracetamol 1000 mg 2 times/day), antithrombotic therapy (enoxaparin sodium 4000 anti-Xa IU 1 time/day), and infusion therapy for 5 days. The postoperative period was uneventful. On September 28, 2025, the drainage from the abdominal cavity and anterior abdominal wall was removed. On September 29, 2025, control ultrasound of the abdominal cavity and anterior abdominal wall revealed no pathological changes. Gastrography with liquid contrast demonstrated no contrast leakage outside the gastrointestinal tract, confirmed viability of the gastroenteroanastomosis, and unimpaired evacuation of contrast from the «small stomach». The patient was discharged in satisfactory condition on September 29, 2025.

Discussion

Biological meshes (implants) with different characteristics and matrix bases have been proposed as alternatives to synthetic meshes in contaminated surgical fields. A biological mesh consists of a collagen matrix derived from animal tissues (porcine, bovine, etc.). The primary function is to provide a biological framework that facilitates integration with the surrounding tissues of the anterior abdominal wall and supports collagen regeneration [3]. Over time, this biological framework (mesh) degrades, with the degradation profile influenced by the mesh matrix type and the specific manufacturing technology employed [25].

Permacol (Medtronic) is a biological surgical implant made of treated porcine dermis used for tissue reconstruction in complex hernia cases. Current guidelines for ventral hernia repair do not recommend the routine use of biological meshes but emphasize their use in clean-contaminated (Class II) and contaminated (Class III) surgical wounds [3, 9, 25]. The use of biological meshes in the urgent treatment of primary PVH in a contaminated (Class III) field is also under consideration [1]. Permacol is one of the most widely used biological meshes. It demonstrates recurrence rates comparable to those of other biological meshes, including both cross-linked and non-cross-linked porcine meshes [25]. In contrast, synthetic meshes are associated with high rates of complications and mesh removal due to suppuration when used in a contaminated surgical field. D. M. Parker et al. reported that the Permacol implant is a safe and acceptable alternative to synthetic meshes for repairing complex anterior abdominal wall defects, as it integrates into tissues through ingrowth and neovascularization [23].

Some studies reported outcomes associated with the use of biological meshes in the surgical treatment of primary ventral hernias, namely umbilical hernias. These studies also highlighted high patient comfort after implantation of this mesh type [11].

A primary argument against the widespread adoption of biological meshes was their higher cost compared to synthetic alternatives. G. DeNoto et al. analyzed complications and treatment costs in 740 patients with ventral hernias over 18 months from the moment of surgery. The cohort included

patients who underwent Grade 3 (potentially contaminated, including those with previous wound infection, stoma, or gastrointestinal tract violation) and Grade 4 (infected, including those with infected mesh and septic dehiscence) hernioplasty. The study found no significant difference in total treatment costs over 18 months between patients receiving biological versus synthetic mesh. However, the complication rate was substantially lower in patients with biological meshes (17.9 %) compared to those with synthetic meshes (36.9 %) [7].

Concerns have been raised regarding the potential for increased hernia recurrence rates with biological meshes, given their biodegradable nature compared to non-absorbable synthetic meshes [12, 22, 26]. H. Shi et al. conducted a systematic review of 10 studies involving 1,305 patients and found that biological meshes had reoperation and mesh removal rates similar to those of synthetic meshes. Furthermore, no significant difference in hernia recurrence rates was observed between biological and synthetic meshes in clean-contaminated and contamination-infected surgical fields [28]. M. Dirani et al. corroborated these findings, demonstrating that biological mesh use did not affect hernia recurrence rates in contaminated surgical fields or in patients with hernias exceeding 10 cm during a 2-year follow-up. Multivariate analysis indicated that the only factor influencing hernia recurrence was the completeness of fascial closure [8].

Currently, there are no established guidelines regarding the optimal approach for combined surgical interventions in patients with both obesity and ventral hernia. Existing publications on bariatric procedures performed concurrently with hernioplasty report a range of surgical techniques and mesh types [5, 16, 19, 20, 30]. The limited sample sizes, variability in mesh selection, and the lack of implant-specific data hinder systematic analysis. For example, A. Lazzati et al. reported hernia recurrence rates of 25.7 % with hernia suturing, 14.3 % with biological mesh, and 1.1 % with synthetic mesh during combined bariatric and hernioplasty procedures. However, no significant differences were observed in mesh infection rates or the need for reoperation. Notably, these studies do not provide comparative data on the mechanical strength of biological meshes based on implant matrix type.

Randomized controlled trials with adequate sample sizes are necessary to objectively assess the benefits and limitations of biological versus synthetic meshes in simultaneous abdominal wall reconstruction for hernia repair and bariatric procedures such as sleeve gastrectomy and gastric bypass. In current surgical practice, biological meshes are generally preferred when the risk of surgical site infection is high.

Conclusions

In the presented clinical case, preoperative intramuscular injection of BTA combined with the use of the Permacol (Medtronic) biological implant enabled effective anterior abdominal wall reconstruction without excessive tissue tension and facilitated restoration of aponeurotic integrity. The intraperitoneal hernioplasty (IPOM) technique using the Permacol (Medtronic) biological implant represents an effective alternative to synthetic and composite implants in patients with complex postoperative defects and a high risk of infectious complications.

Declaration of interests

The authors declare no conflict of interest.

Authors contributions

O. Y. Ioffe: work concept and design, critical review; T. V. Tarasiuk: work concept and design, data collection and analysis, statistical analysis, writing the manuscript; O. P. Stetsenko: critical review; M. S. Kryvopustov: statistical analysis, writing the manuscript; P. A. Kobzar: data collection and analysis, critical review.

References

1. Birindelli A, Sartelli M, Di Saverio S, Coccolini F, Ansaloni L, van Ramshorst GH, et al. 2017 update of the WSES guidelines for emergency repair of complicated abdominal wall hernias. World J Emerg Surg. 2017;12:37. doi: 10.1186/s13017-017-0149-y.
2. Bittner R, Bingener-Casey J, Dietz U, Fabian M, Ferzli GS, Fortelny RH, et al. Guidelines for laparoscopic treatment of ventral and incisional abdominal wall hernias (International Endohernia Society (IEHS)—Part 1). Surg Endosc. 2014;28(1):2-29. doi: 10.1007/s00464-013-3170-6.
3. Bougard H, Coolen D, de Beer R, Folscher D, Kloppers J, Koto M, et al. HIG (SA) guidelines for the management of ventral hernias. S Afr J Surg. 2016;54(suppl. 4):S1–S32.
4. Dabbas N, Adams K, Pearson K, Royle G. Frequency of abdominal wall hernias: Is classical teaching out of date? JRSM Short Rep. 2011;2(1):1-6. doi: 10.1258/shorts.2010.010071.
5. Dantas ACB, Pajecki D, Murakami AHF, Baraviera TM, Kawamoto FM, de Oliveira DRCF, et al. Feasibility of laparoscopic sleeve gastrectomy in patients with severe obesity and complex abdominal wall hernias with loss of domain. Hernia. 2025;29(1):170. doi: 10.1007/s10029-025-03380-1.
6. Deerenberg EB, Henriksen NA, Antoniou GA, Antoniou SA, Bramer WM, Fischer JP, et al. Updated guideline for closure of abdominal wall incisions from the European and American Hernia Societies. Br J Surg. 2022;109(12):1239-1250. doi: 10.1093/bjs/znac302.
7. DeNoto G 3rd, Reaven N, Funk S, Willis S. Ventral hernia: Retrospective cost analysis of primary repair, repair with synthetic mesh, and repair with acellular xenograft implant. Open Access Surg. 2013;6:23-32. doi: 10.2147/OAS.S44647.
8. Dirani M, Chahine E, D'Alessandro A, Chouillard MA, Gumbs AA, Chouillard E. The use of Permacol® biological mesh for complex abdominal wall repair. Minerva Surg. 2022;77(1):41-49. doi: 10.23736/S2724-5691.21.08779-4.
9. Earle D, Roth JS, Saber A, Haggerty S, Bradley JF 3rd, Fanelli R, et al. SAGES guidelines for laparoscopic ventral hernia repair. Surg Endosc. 2016;30(8):3163-3183. doi: 10.1007/s00464-016-5072-x.
10. Edmiston CE, Leaper DJ. Intra-operative surgical irrigation of the surgical incision: What does the future hold—saline, antibiotic agents, or antiseptic agents? Surg Infect (Larchmt). 2016;17(6):656-664. doi: 10.1089/sur.2016.158.
11. Greco DP, Fei L, Guerriero L, Pradella P, Mazzola M, Magistro C, et al. Feasibility and effectiveness of primary umbilical hernia repair with biologic graft: Preliminary study. Acta Chir Belg. 2014;114(2):125-130.

12. Harris HW, Primus F, Young C, Carter JT, Lin M, Mukhtar RA, et al. Preventing recurrence in clean and contaminated hernias using biologic versus synthetic mesh in ventral hernia repair. Ann Surg. 2021;273(4):648-655. doi: 10.1097/SLA.0000000000004336.
13. Henriksen NA, Montgomery A, Kaufmann R, Berrevoet F, East B, Fischer J, et al. Guidelines for treatment of umbilical and epigastric hernias. Br J Surg. 2020;107(3):171-190. doi: 10.1002/bjs.11489.
14. Idrees S, Jindal S, Gupta M, Sarangi R. Surgical meshes–The search continues. Curr Med Res Pract. 2018;8:177-182. doi: 10.1016/j.cmrp.2018.08.005.
15. Ioffe OY, Tarasiuk TV, Kryvopustov MS, Stetsenko OP. Management of ventral hernias: Treatment results based on the developed algorithm. Gen Surg (Ukraine). 2024;(4):25-35. doi: 10.30978/GS-2024-4-25.
16. Khitaryan A, Miziev I, Mezhunts A, Veliev C, Zavgorodnyaya R, Orekhov A, et al. Roux-en-Y gastric bypass and parastomal hernia repair: Case report of concurrent operation in comorbid patient. Int J Surg Case Rep. 2020;71:360-363. doi: 10.1016/j.ijscr.2020.05.024.
17. Köckerling F, Hoffmann H, Mayer F, Zarras K, Reinpold W, Fortelny R, et al. What are the trends in incisional hernia repair? Real-world data over 10 years from the Herniamed registry. Hernia. 2021;25(2):255-265. doi: 10.1007/s10029-020-02319-y.
18. Kössler-Ebs JB, Grummich K, Jensen K, Hüttner FJ, Müller-Stich B, Seiler CM, et al. Incisional hernia rates after laparoscopic or open abdominal surgery–A systematic review and meta-analysis. World J Surg. 2016;40(10):2319-2330. doi: 10.1007/s00268-016-3520-3.
19. Lazzati A, Nassif GB, Paolino L. Concomitant ventral hernia repair and bariatric surgery: A systematic review. Obes Surg. 2018;28(9):2949-2955. doi: 10.1007/s11695-018-3366-x.
20. Moolla M, Dang J, Modasi A, Byrns S, Switzer N, Birch DW, et al. Concurrent laparoscopic ventral hernia repair with bariatric surgery: A propensity-matched analysis. J Gastrointest Surg. 2020;24(1):58-66. doi: 10.1007/s11605-019-04291-0.
21. Muysoms FE, Antoniou SA, Bury K, Campanelli G, Conze J, Cuccurullo D, et al. European Hernia Society guidelines on the closure of abdominal wall incisions. Hernia. 2015;19(1):1-24. doi: 10.1007/s10029-014-1342-5.
22. Olavarria OA, Bernardi K, Dhanani NH, Lyons NB, Harvin JA, Millas SG, et al. Synthetic versus biologic mesh for complex open ventral hernia repair: A pilot randomized controlled trial. Surg Infect (Larchmt). 2021;22(5):496-503. doi: 10.1089/sur.2020.166.
23. Parker DM, Armstrong PJ, Frizzi JD, North JH Jr. Porcine dermal collagen (Permacol) for abdominal wall reconstruction. Curr Surg. 2006;63(4):255-258. doi: 10.1016/j.cursur.2006.05.003.
24. Pérez-Köhler B, Bayon Y, Bellón JM. Mesh infection and hernia repair: A review. Surg Infect (Larchmt). 2016;17(2):124-137. doi: 10.1089/sur.2015.078.
25. Romain B, Story F, Meyer N, Delhorme JB, Brigand C, Rohr S. Comparative study between biologic porcine dermal meshes: Risk factors of postoperative morbidity and recurrence. J Wound Care. 2016;25(6):320-325. doi: 10.12968/jowc.2016.25.6.320.
26. Rosen MJ, Krpata DM, Petro CC, Carbonell A, Warren J, Poulose BK, et al. Biologic vs synthetic mesh for single-stage repair of contaminated ventral hernias. JAMA Surg. 2022;157(4):293-301. doi: 10.1001/jamasurg.2021.6902.
27. See CW, Kim T, Zhu D. Hernia mesh and hernia repair: A review. Eng Regen. 2020;1:19-33. doi: 10.1016/j.engreg.2020.05.002.
28. Shi H, Wang R, Dong W, Yang D, Song H, Gu Y. Synthetic versus biological mesh in ventral hernia repair and abdominal wall reconstruction. World J Surg. 2023;47(10):2416-2424. doi: 10.1007/s00268-023-07067-5.
29. Tarasiuk TV. The first experience of use botulinum toxin type a in the surgical treatment of ventral hernias. Hospital Surgery. Journal named by L.Ya. Kovalchuk. 2020;90(2):102-105. doi: 10.11603/2414-4533.2020.2.10775. Ukrainian.
30. Vilallonga R, Beisani M, Sanchez-Cordero S, Garcia Ruiz de Gordejuela A, Rodríguez-Luna MR, Fort JM, et al. Abdominal wall hernia and metabolic bariatric surgery. J Laparoendosc Adv Surg Tech A. 2020;30(8):891-895. doi: 10.1089/lap.2020.0257.

Перший в Україні досвід використання біологічної сітки Permacol. Клінічний випадок

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Представлено перший в Україні клінічний досвід застосування біологічного імплантату Permacol при хірургічному лікуванні гігантської післяопераційної вентральної грижі в пацієнтки з морбідним ожирінням та зовнішньою норицею передньої черевної стінки. Актуальність дослідження зумовлена високою частотою післяопераційних вентральних гриж, особливо після відкритих оперативних втручань, а також значним ризиком інфекційних ускладнень у контамінованому операційному полі. Уніфіковані рекомендації щодо поєднаного виконання герніопластики та баріатричних операцій у пацієнтів з ожирінням відсутні. Наведено детальний опис клінічного випадку пацієнтки віком 63 років із ожирінням III ступеня, гігантським дефектом апоневрозу передньої черевної стінки, хронічною зовнішньою норицею з обтяженим хірургічним анамнезом абдомінальних втручань, що супроводжувалися перитонітом і нагноєнням післяопераційної рани. Доопераційна підготовка передбачала внутрішньом'язове введення ботулотоксину типу А для розслаблення м'язів передньої черевної стінки, зниження ризику натягу тканин і профілактики розвитку абдомінального компартмент-синдрому. Пацієнтці виконано герніолапаротомію, вісцероліз, герніопластику з інтраабдомінальним розміщенням біологічного імплантату Permacol (за методикою відкритого інтраперитонеального розміщення сітки — IPOM), мінішунтування шлунка, висічення нориці передньої черевної стінки, дренування черевної порожнини, дренування післяопераційної рани за Редоном. Післяопераційний період перебіг без ускладнень. Ознак внутрішньочеревної гіпертензії та інфекції не відзначено. Отримані результати свідчать про доцільність і безпечність застосування біологічного імплантату Permacol у пацієнтів зі складними дефектами передньої черевної стінки та високим ризиком інфекційних ускладнень.

Ключові слова: післяопераційна вентральна грижа, герніопластика, біологічна сітка.

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Clinical characteristics of stem cell application in the surgical management of post-traumatic and trophic skin defects. Literature review

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Chronic post-traumatic and trophic skin defects present a significant clinical challenge, particularly in the context of ischemia, infection, diabetic angiopathy and neuropathy, or severe traumatic injuries. Conventional treatments such as debridement, skin grafts, and local or free flaps often fail to achieve durable healing, thereby increasing interest in regenerative technologies. Mesenchymal stem cells (MSCs), particularly those derived from bone marrow and adipose tissue (ADSCs), exert significant paracrine, angiogenic, and immunomodulatory effects. These properties enhance the wound microenvironment and augment the efficacy of standard surgical interventions. Clinical studies and meta-analyses indicate that autologous MSC therapy accelerates healing of diabetic, venous, arterial, and mixed ulcers, decreases the risk of amputation, and improves tissue perfusion. In reconstructive surgery for post-traumatic defects, ADSC/SVF-assisted lipofilling and nanofat technologies are widely utilized. These approaches promote scar tissue remodeling, improve tissue elasticity, reduce contractures, and optimize conditions for subsequent flap reconstruction. Furthermore, cellular or cell-matrix constructs (MSCs combined with scaffolds) have the potential to manage complex soft-tissue defects with bone exposure, thereby reducing the need for extensive reconstructive procedures. Despite these promising outcomes, current evidence is limited by small sample sizes, methodological heterogeneity, the absence of standardized dosing protocols, and a lack of large multicenter randomized controlled trials. Furthermore, although no significant risks have been reported in existing studies, the issue of long-term oncological safety warrants continued monitoring. Emerging strategies include cell-free approaches such as exosomes and MSC secretions. Additionally, the integration of cellular technologies with 3D-printed and bioengineered matrices, as well as the development of standardized surgical algorithms that leverage MSCs to enhance the efficacy of conventional reconstructive techniques, are being explored.

Keywords
chronic wounds, trophic ulcers, post-traumatic defects, reconstructive surgery, mesenchymal stem cells (MSCs), adipose-derived stem cells (ADSCs), stromal vascular fraction (SVF), skin regeneration.

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Chronic post-traumatic and trophic skin defects, including venous, arterial, and mixed ulcers, diabetic foot, pressure ulcers, radiation injuries, and postoperative wounds, represent a significant medical and social challenge. In the United States alone, chronic wounds affect approximately 6.5 million patients and require more than $25 billion annually for treatment; this burden continues to rise due to an aging population and the increasing prevalence of diabetes and obesity [65]. The prevalence of chronic wounds in developed countries is estimated at 1–2 % of the population, and the high frequency of complications such as infection, osteomyelitis, amputation, and disability makes them a major cause of disability [21, 24, 50]. Standard interventions, including surgical debridement, necrectomy, split-thickness skin grafts, local and regional flaps, negative pressure therapy, compression therapy, and revascularization, often fail to achieve stable epithelialization, particularly in cases of severe ischemia, diabetic angiopathy and neuropathy, systemic connective tissue diseases, radiation injury, or military trauma [65, 66]. The frequent recurrence of ulcers, prolonged disease course, and substantial costs have driven the search for regenerative strategies, with stem and progenitor cells emerging as key therapeutic options [15, 53, 55].

This review aims to synthesize current evidence on the clinical application of stem cells in the

surgical management of post-traumatic and trophic skin defects, with particular emphasis on integrating cellular technologies into surgical protocols, including debridement, skin grafting, flap reconstruction, lipofilling, and combined techniques.

Pathophysiological prerequisites and limitations of traditional surgery

Chronic wounds are characterized by a delayed inflammatory phase, manifested by prolonged neutrophil and macrophage activity and persistent secretion of proinflammatory cytokines (TNF-α, IL-1β) [36, 53]. They also have impaired angiogenesis [26], a deficiency of local precursor cells (fibroblasts, endothelial progenitor cells) [25], an imbalance of metalloproteinases (MMP) and their inhibitors (TIMP) in favour of proteolysis [26, 53], as well as damage and destruction of the extracellular matrix (ECM) [46, 53].

In diabetic foot and ischemic ulcers, additional factors such as micro- and macroangiopathy, neuropathy, and increased susceptibility to infection are present. In contrast, post-traumatic defects are characterized by cicatricial changes, the presence of foreign bodies, and trophic disorders after multistage reconstructions [5, 82].

Even when debridement and split-thickness skin graft (STSG) are performed optimally, the presence of poor perfusion or a significantly altered wound bed is associated with a high incidence of partial or complete graft necrosis [39]. Flap reconstruction in patients with severe comorbid conditions is also associated with an increased risk of complications [54]. This creates a niche where adjuvant regenerative approaches can accelerate wound healing, improve the quality of the wound bed tissues, and increase the chances of skin graft engraftment.

Biological foundations of stem cell applications in skin regeneration

Mesenchymal stem cells (MSCs) derived from bone marrow, adipose tissue, umbilical cord, dental pulp, placenta, and other adult stem cells have a number of properties essential for wound healing. These include the capacity to differentiate into fibroblasts, endothelial cells, pericytes, and keratinocytes; robust secretion of growth factors such as VEGF, bFGF, TGF-β, and HGF; production of cytokines and chemokines; and immunomodulatory effects, including reduced proinflammatory cytokine production and polarization of macrophages toward the M2 phenotype [35, 36, 53, 55].

Recent reviews indicate that the clinical efficacy of MSCs in chronic wound treatment is primarily mediated by paracrine signaling and modification of the wound microenvironment, rather than by extensive direct differentiation into skin cells [15, 19, 34, 53]. This distinction carries significant clinical implications:

- Therapeutic effects may be achieved with relatively small numbers of cells.
- Cell-free technologies, such as conditioned media and exosomes, represent promising, safer, and more standardized alternatives.
- The interaction of cells with the surgically prepared wound bed is more critical than their physical integration into the tissue.

Sources and types of stem cells used in the clinical practice

Bone marrow-derived mesenchymal stem cells

Bone marrow mesenchymal stem cells (BM-MSCs) are among the earliest sources used for the treatment of chronic wounds. In the early 2000s, E. V. Badiavas and V. Falanga demonstrated that local application of autologous bone marrow cells, which may not be highly purified MSCs, promotes healing of refractory chronic skin ulcers in humans [8].

A prospective study by N. R. Dash et al. involved 24 patients with chronic lower extremity ulcers who received local injections of BM-MSCs (approximately 10^6 cells per 1 cm^2 of wound area) at the periphery and base of the defect following surgical debridement. The study reported a significant reduction in ulcer area and a higher rate of complete healing compared to historical controls, with an acceptable safety profile [17].

Contemporary approaches emphasize the topical application of allogeneic BM-MSCs as components of ready-to-use products for the treatment of chronic ulcers. Phase I/II studies have confirmed good tolerability, a tendency to accelerate epithelialization, and improvements in pain and quality of life [7].

Adipose-derived stem cells and stromal vascular fraction

Adipose tissue represents the most accessible source of MSCs. Adipose-derived stem cells (ADSCs) and the stromal vascular fraction (SVF) can be isolated via liposuction with minimal donor morbidity, a factor of particular significance in surgical patients [31, 32, 62, 63].

A systematic review by J. S. Holm et al. demonstrated that, in most studies, ADSCs and adipose tissue derivatives used for treating chronic ulcers (venous, diabetic, ischemic) result in accelerated healing, reduced pain, and an acceptable safety

profile. However, the included trials often exhibit heterogeneous designs and small sample sizes [32].

ADSCs may be administered through several approaches:

- local injection into the wound bed and edges as a cell suspension [20, 30];
- as a component of SVF, a minimally manipulated concentrate containing MSCs, pericytes, endothelial cells, fibroblasts, and immune cells [18, 27, 45];
- as part of nanofat, which is mechanically emulsified fat with a high concentration of progenitor cells [18, 71];
- in combination with platelet-rich plasma (PRP), hydrogels, or collagen matrices [45, 64].

Other sources: umbilical cord, placenta, Wharton's jelly, and epidermal stem cells

Perinatal sources of MSCs, such as the umbilical cord, placenta, and Wharton's jelly, are of increasing interest due to their high secretory potential, low immunogenicity, and the feasibility of standardized allogeneic production in accordance with good manufacturing practice (GMP). Wharton's jelly-derived MSCs are found in the mucopolysaccharide connective tissue of the umbilical cord, situated between the amniotic epithelium and the umbilical cord vessels. These cells exhibit a potent paracrine profile (VEGF, HGF, TGF-β, IL-10), high proliferative capacity, and the ability to differentiate into both mesenchymal and angiogenic lineages [6, 49, 75].

Experimental data and initial preclinical or small clinical studies indicate that placenta-derived MSCs (PMSCs) or their exosomes may enhance skin wound healing, stimulate angiogenesis, and modulate inflammation. However, large-scale randomized studies are still lacking [43, 72, 78].

Epidermal and dermal stem cells, delivered as cell coverings, keratinocyte sheet grafts, or composite skin substitutes (including cultured epidermal autografts), have been used in burn centers for many years to treat extensive post-burn and post-traumatic defects. Clinical evidence demonstrates that these grafts can achieve sufficient re-epithelialization, restore barrier function, and enable defect closure when donor sites are limited [10, 67]. However, outcomes are highly dependent on the wound bed conditions, and complications such as contractures or partial loss of coverage are common. Complete regeneration of all skin structures, including dermis, appendages, nerves, and vessels, remains unachievable [10]. Consequently, these technologies are less frequently incorporated into treatment protocols for chronic trophic ulcers, where ischemia, infection, and trophic disturbances hinder the successful integration of cell sheet grafts.

Dental pulp stem cells (DPSCs), which originate from the neurectoderm, exhibit high proliferative capacity, the ability to differentiate into mesenchymal (osteogenic, chondrogenic, adipogenic) and neuronal lineages, and a robust secretory profile (VEGF, NGF, BDNF, HGF) that supports angiogenesis, inflammation modulation, and tissue regeneration. Unlike many adult MSC sources, DPSCs are readily accessible, free from ethical concerns, and consistently express early stem cell markers (STRO-1, CD146) [4, 80]. Experimental studies indicate that DPSCs can accelerate skin wound healing by promoting fibroblast proliferation, enhancing vascularization, and reducing local inflammatory responses, although clinical application for skin defects remains limited to preclinical models [16, 29].

Clinical application of stem cells in the management of trophic defects

Diabetic foot

Diabetic foot ulcer represents one of the most extensively studied indications for autologous cell therapy of the lower extremities, often in conjunction with surgical debridement and reconstructive procedures.

A meta-analysis by X. Jiang et al., which included 10 clinical studies involving BM-MSCs, ADSCs, and bone marrow mononuclear cells, demonstrated that in patients with lower extremity ulcers–primarily diabetic foot and ischemic ulcers associated with occlusive disease–autologous stem cell therapy increases the frequency of ulcer healing and reduces the risk of lower extremity amputations compared to conservative or standard surgical approaches [37]. Specifically, autologous stem cell therapy was linked to improved healing of lower extremity ulcers (12 comparisons, 290 patients, partial healing relative risk (RR) = 3.07, 95 % confidence interval [CI] 1.14–8.24; p = 0.03; complete healing RR = 2.26; 95 % CI 1.48–3.16; p < 0.001) with minimal heterogeneity (I = 0 %). Additionally, autologous stem cell therapy resulted in a greater reduction in mean ulcer size (SMD = –0.63; 95 % CI from –1.03 to –0.22; p = 0.002).

A more recent meta-analysis by Y. Sun et al., which included 14 studies with 683 participants and focused specifically on diabetic foot, demonstrated that stem cell therapy (primarily BM-MSCs and ADSCs) was more effective than conventional therapy. Improvements were observed in ulcer or wound healing rate [odd ratio (OR) = 8.20 (5.33; 12.62)], lower limb ischemia (neovascularization) [OR = 16.48 (2.88; 94.18)], ankle-brachial index (ABI) [mean differences (MD) = 0.13 (0.04; 0.08)], transcutaneous oxygen

pressure ($TcPO_2$) [MD = 4.23 (1.82; 6.65)], pain-free walking distance [MD = 220.79 (82.10; 359.48)], and resting pain score [MD = –1.94 (–2.50; –1.39)]. The amputation rate was also significantly reduced [OR = 0.19 (0.10; 0.36)] [69].

Current clinical experience with autologous adipose-derived mesenchymal cells in chronic diabetic lower limb ulcers is primarily based on small phase I–II studies and non-randomized clinical trials. In a phase I study by M. H. Carstens et al., local injections of ADSCs following surgical debridement of diabetic ulcers were found to be safe and to accelerate epithelialization [12]. Comparable outcomes have been reported in other clinical studies utilizing SVF containing ADSCs. Several prospective and open-label studies have shown that administration of autologous SVF in combination with standard therapy leads to a reduction in diabetic ulcer area, improved tissue perfusion, enhanced granulation, more rapid wound area reduction, decreased need for amputation, and a higher rate of complete healing compared to standard treatment [11, 22, 74, 81]. While these findings support the therapeutic potential of adipose tissue-derived cells in diabetic foot ulcers, large-scale randomized trials of ADSCs in this context remain limited.

Notably, most clinical studies do not consider stem cells as a stand-alone therapy, but rather as an adjunct to standard surgical interventions, including radical wound debridement, infection control, correction of ischemia through endovascular or open reconstructive procedures, and optimization of glycemic and metabolic status. This integrative approach aligns with current understanding of stem cells as modifiers of the wound microenvironment, capable of reducing inflammation, stimulating angiogenesis, improving wound bed quality prior to skin grafting, and enhancing the likelihood of secondary epithelialization. The most significant clinical outcomes are observed when cell therapy is combined with active surgical and vascular interventions.

Venous, arterial, and mixed lower leg ulcers

A systematic review by B. Amato et al. evaluated clinical trials investigating adult tissue stem cells for the treatment of chronic lower leg ulcers of various etiologies, including venous, arterial, and post-traumatic. Most studies reported improved healing rates and reduced pain; however, the overall quality of evidence is moderate, primarily due to small sample sizes and heterogeneity in study design [3]. X. Jiang et al. further demonstrated that autologous stem cell therapy is associated with a higher rate of complete ulcer closure and a greater reduction in defect area compared to controls [37].

Meta-analyses and systematic reviews indicate that autologous stem cell therapy (BM-MSC/ADSC/SVF), may improve perfusion, promote ulcer healing, and reduce the risk of amputation in cases of critical lower limb ischemia. This approach is considered a potential solution when standard vascular or plastic surgical methods have been exhausted or proven ineffective [76, 77, 79]. However, current evidence is primarily derived from small case studies rather than large randomized controlled trials, so MSC therapy should be regarded as experimental or adjuvant rather than standard care.

Pressure ulcers, radiation, and postoperative defects

Although data on pressure ulcers and radiation injuries are limited, available clinical studies suggest the potential of MSC therapy. In case studies involving patients with pressure ulcers resulting from spinal cord injury, the application of autologous bone marrow cells (BM-MNC or BM-MSC), including delivery within plasma or fibrin matrices, has resulted in healing of deep defects that previously necessitated extensive flap reconstruction [2, 61].

For patients with chronic radiation ulcers, the use of bone marrow-derived or perinatal (placental, amniotic) MSCs in combination with biomatrices, such as decellularized amniotic membrane, lyophilized placental membrane, or other placental coatings, has demonstrated healing of defects that are resistant to standard treatment methods [13, 38, 58].

The role of stem cells in plastic and reconstructive surgery for post-traumatic defects

In plastic and reconstructive surgery, post-traumatic defects resulting from high-energy trauma, burns, blast injuries, or onco-orthopedic resections are characterized by loss of soft tissue volume, fibrosis, contractures, impaired microcirculation, and chronic inflammation. Even technically successful flap reconstructions or skin grafts frequently result in hard, painful, adhesive scars that limit function. In this context, cell-based technologies, particularly those utilizing ADSC or SVF, are regarded as adjuncts to conventional reconstructive methods rather than as replacements [27, 68, 70].

Clinically, the predominant strategy involves the use of autologous fat enriched with the SVF or progenitor cell-rich nanofat to address post-traumatic and post-burn scars, soft-tissue deformities, and contour defects [23, 40]. Systematic reviews of clinical studies indicate that ADSC/SVF-assisted lipofilling in scarred areas results in scar softening,

increased elasticity, reduced pain and itching, improved pigmentation and skin thickness, and high patient satisfaction, with an acceptable safety profile [68, 70]. However, the supporting evidence is primarily level III–IV, consisting of case studies, prospective uncontrolled trials, and small cohort observations [51, 52, 60, 68].

Seminal studies by G. Rigotti et al. demonstrated that transplantation of purified lipoaspirate, rich in adult adipose tissue stem cells, significantly improves soft tissue condition in areas affected by radiation damage, including reductions in pain, fibrosis, and scar retraction, as well as enhanced skin trophism and the feasibility of further reconstructive procedures [59]. Subsequent research by M. Klinger et al. found that repeated lipofilling sessions in patients with severe post-burn complications result in clinically meaningful scar remodeling, including improved elasticity, reduced contractures, and superior aesthetic outcomes, which correlate with morphological evidence of neovascularization and partial normalization of the dermis [40]. These findings are particularly relevant for surgeons managing complex post-traumatic defects with concurrent burn or radiation fibrosis.

Review summaries indicate that ADSC/SVF-assisted lipofilling is applied in reconstructive practice primarily in two scenarios: first, as a form of biological preprocessing to optimize the recipient bed prior to complex skin-flap reconstruction or future endoprosthesis placement (such as after oncological resection or severe soft tissue trauma); and second, as repeated staged interventions to address residual scar deformities, contractures, and volume deficits following primary reconstruction [19, 28, 39, 52]. The primary objectives in the first scenario are to enhance vascularization, decrease fibrosis, and create a more receptive environment for grafts or flaps. In the second, the focus is on long-term scar tissue remodeling and improved functional outcomes, including increased joint range of motion, prosthesis compatibility, and reduced pain on exertion.

Some clinical studies have described the use of BM-MSCs, perinatal MSCs (from amniotic or placental membranes), and combined constructs, such as «MSCs + biomatrix», in managing complex post-traumatic soft tissue defects. In these approaches, cell-rich matrices are employed to cover exposed bone or fill defects, either prior to or in conjunction with flap reconstruction. Observational reports highlight the formation of high-quality granulation tissue, a reduced need for extensive reconstructive procedures, and a lower incidence of wound-edge dehiscence compared with standard techniques [1, 44, 47]. Nevertheless, the patient cohorts are typically heterogeneous, encompassing mixed trophic, oncological, and post-traumatic wounds, and the study designs preclude definitive conclusions regarding the superiority of any specific MSC type.

Overall, clinical evidence indicates that, in plastic and reconstructive surgery for post-traumatic defects, stem cells–primarily ADSC/SVF–should be regarded as adjuncts to enhance the tissue microenvironment, including scar quality, vascularization, and elasticity. These approaches complement but do not replace established methods such as skin grafts, local and free flaps, and microsurgical techniques. Current data support their use in complex cases resistant to standard treatments, provided that rigorous patient selection and adherence to oncological safety protocols are maintained. However, there remains a clear need for large-scale randomized studies to assess efficacy and long-term outcomes.

Clinical features of the use of stem cells in the surgical treatment of skin defects

Current evidence allows for the identification of several key clinical aspects relevant to surgical practice.

Patient selection

Patients most likely to benefit from stem cell therapy include the following groups:

- with chronic (> 3–6 months) trophic ulcers that do not heal despite optimal standard treatment [3, 37, 69];
- those with combined pathologies, such as diabetic foot with critical ischemia or post-traumatic defects in the context of obesity or systemic diseases;
- individuals at high risk of amputation for whom standard reconstructive options have been exhausted or present excessive risk [14, 37, 55, 69].

However, stem cell therapy does not replace the fundamental principles of wound management, such as the «TIME» framework (tissue, infection/inflammation, moisture, edge), or modern vascular interventions. Instead, it enhances their effectiveness [9, 41].

Wound preparation and the surgical «window of opportunity»

Almost all studies emphasize the need for radical surgical debridement, infection control, and optimization of systemic factors before stem cell administration [3, 32, 53, 55].

This sequence establishes a critical period for intervention, commonly referred to as a «window of opportunity»:

- stage 1 – radical debridement, correction of ischemia, and stabilization of the general condition;

• stage 2 – cell therapy (injectable, topical, or within a matrix or adipose tissue) for the prepared wound bed;

• stage 3 – if necessary, skin grafting or flap reconstruction of the prepared wound bed (often after 1–3 weeks).

For example, combined techniques such as nanofat with STSG or high-density nanofat with NPWT have been used to manage chronic lower leg defects [18, 39].

Routes of administration and doses

Clinical studies have employed various routes of stem cell administration:

• **local injections** into the wound bed and edges, using BM-MSC, ADSC, or SVF, represent the most common approach;

• **intramuscular administration** in the vicinity of the ischemic zone, particularly in cases of critical limb ischemia;

• **topical application** incorporated into gels, fibrin sprays, or three-dimensional matrices [7, 8, 53, 57].

Typical doses for local administration range from 10^6 to 10^7 cells/cm^2 of defect area, or 10^7 to 10^8 cells for the entire wound. When using SVF or nanofat, the administered volume of lipoaspirate (in milliliters) is more commonly reported than the absolute cell count [32, 57, 62]. The absence of standardized dosing regimens remains a significant barrier to widespread clinical adoption.

Combination with other regenerative technologies

Stem cell therapies are increasingly integrated with the following adjunctive modalities:

• **platelet-rich plasma** (PRP), which contains high concentrations of growth factors such as PDGF, TGF-β, VEGF, and EGF, and may potentiate the paracrine effects of MSCs [57];

• **negative pressure therapy** (NPWT) – high-density nanofat + NPWT in chronic wounds [18];

• **biomatrices,** including collagen, acellular dermal matrices, and placental matrices [31, 55].

In practical terms, this approach represents a shift from single-stage procedures to stepwise combination therapies, in which cellular components are integrated alongside flaps, grafts, and physiotherapeutic interventions.

Safety and potential risks

Serious adverse events directly attributable to stem cell therapy are infrequent in most clinical trials [14, 32, 37, 55, 69]. The most frequently reported events include:

• local pain at the injection site, hematoma, or transiently increased exudation;

• infectious complications, which are typically associated with the underlying wound condition rather than the cellular product.

Concerns about the potential stimulation of tumour growth have not been substantiated in clinical trials with limited follow-up. Nevertheless, reviews emphasize the necessity for ongoing oncological vigilance, especially when allogeneic cells are used or in patients with a history of cancer [15, 55].

Regulatory requirements, including GMP standards, classification as Advanced Therapy Medicinal Products (ATMP), and logistical complexity, continue to present significant barriers to the widespread adoption of stem cell therapy outside research centers.

Unresolved issues and prospects

Although recent findings are promising, current reviews consistently identify several critical gaps in the literature:

Study heterogeneity: Variability in cell sources, collection and cultivation protocols, dosing regimens, administration routes, and efficacy criteria complicates the development of unified recommendations [3, 14, 15, 55].

Insufficient large-scale multicenter RCTs with long-term follow-up (i 2–3 years), particularly for specific surgical indications such as post-traumatic defects and complex reconstructions.

Lack of standardized study endpoints: There is a need for unified outcome measures, including time to complete epithelialization, sustained healing over 6–12 months, recurrence rates, and both functional and cosmetic results.

Comparative evaluation of different cell sources (BM-MSC vs. ADSC vs. placental MSCs) within standardized surgical treatment protocols.

Promising avenues

Promising avenues for future research include the following:

• cell-free strategies, such as the use of exosomes and MSC conditioned media, which may offer more standardized and potentially safer alternatives [33, 56];

• integration of stem cells with 3D-printed and bioengineered matrices to enable individualized reconstruction of tissue defects [48, 75];

• systematic incorporation of cell-based technologies into military and trauma surgery protocols, including early application of MSCs for extensive soft tissue injuries [42, 73, 75].

Conclusions

Chronic post-traumatic and trophic skin defects represent a persistent clinical and economic challenge. Traditional surgical interventions, such as debridement, skin grafting, and flap procedures, often fail to achieve stable healing in certain patient populations.

Stem cells, particularly BM-MSCs and ADSCs, have demonstrated efficacy in enhancing chronic wound healing through paracrine, angiogenic, and immunomodulatory mechanisms. These therapies are regarded as adjuncts to standard surgical approaches rather than replacements.

Clinical trials and meta-analyses indicate that autologous stem cell therapy for lower limb ulcers, including diabetic foot, venous, and ischemic ulcers, increases the rate of complete healing, accelerates epithelialization, and reduces amputation risk, while maintaining an acceptable safety profile.

In surgical practice, combined approaches involving stem cell therapies are of particular interest. These include:

- local injections of MSC/ADSC/SVF into the prepared wound bed;
- application of nanofat and SVF beneath split-thickness skin grafts for challenging post-traumatic defects;
- stem cell-enriched lipofilling for the correction of post-traumatic scars and contractures.

The safety profile of stem cell therapy for skin defects is generally favourable; however, extended long-term follow-up is necessary, particularly concerning potential oncogenic risks and the application of allogeneic cells.

Major barriers to widespread adoption include the absence of standardized protocols, heterogeneity among clinical trials, regulatory constraints, and high associated costs.

A promising direction involves developing explicit surgical algorithms that integrate stem cells, their secretions, or exosomes into sequential treatment regimens for post-traumatic and trophic defects. This approach may include debridement, followed by cell or exosome therapy and subsequent skin graft or flap reconstruction, with further validation required through well-designed multicenter randomized trials.

Declaration of interests

The author declares no conflicts of interest.

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References

1. Aghayan HR, Hosseini MS, Gholami M, Mohamadi-Jahani F, Tayanloo-Beik A, Alavi-Moghadam S, Payab M, Goodarzi P, Abdollahi M, Larijani B, Arjmand B. Mesenchymal stem cells' seeded amniotic membrane as a tissue-engineered dressing for wound healing. Drug Deliv Transl Res. 2022 Mar;12(3):538-549. doi: 10.1007/s13346-021-00952-3.
2. Alvarez-Viejo M, Romero-Rosal L, Perez-Basterrechea M, García-Gala JM, Hernando-Rodriguez P, Marana-Gonzalez J, Rubiera-Valdes M, Vivanco-Allende B, Fernandez-Rodriguez A, Martinez-Revuelta E, Perez-Lopez S. Plasma-Based Scaffold Containing Bone-Marrow Mononuclear Cells Promotes Wound Healing in a Mouse Model of Pressure Injury. Cell Transplant. 2024 Jan-Dec;33:9636897241251619. doi: 10.1177/09636897241251619.
3. Amato B, Compagna R, Amato M, Butrico L, Fugetto F, Chibireva MD, Barbetta A, Cannistrà M, de Franciscis S, Serra R. The role of adult tissue-derived stem cells in chronic leg ulcers: a systematic review focused on tissue regeneration medicine. Int Wound J. 2016 Dec;13(6):1289-1298. doi: 10.1111/iwj.12499.
4. Anderson S, Prateeksha P, Das H. Dental Pulp-Derived Stem Cells Reduce Inflammation, Accelerate Wound Healing and Mediate M2 Polarization of Myeloid Cells. Biomedicines. 2022 Aug 17;10(8):1999. doi: 10.3390/biomedicines10081999.
5. Armstrong DG, Boulton AJM, Bus SA. Diabetic Foot Ulcers and Their Recurrence. N Engl J Med. 2017 Jun 15;376(24):2367-2375. doi: 10.1056/NEJMra1615439.
6. Arno AI, Amini-Nik S, Blit PH, Al-Shehab M, Belo C, Herer E, Tien CH, Jeschke MG. Human Wharton's jelly mesenchymal stem cells promote skin wound healing through paracrine signaling. Stem Cell Res Ther. 2014 Feb 24;5(1):28. doi: 10.1186/scrt417.
7. Askø Andersen J, Rasmussen A, Frimodt-Møller M, Engberg S, Steeneveld E, Kirketerp-Møller K, O'Brien T, Rossing P. Novel topical allogeneic bone-marrow-derived mesenchymal stem cell treatment of hard-to-heal diabetic foot ulcers: a proof of concept study. Stem Cell Res Ther. 2022 Jun 28;13(1):280. doi: 10.1186/s13287-022-02951-8.
8. Badiavas EV, Falanga V. Treatment of chronic wounds with bone marrow-derived cells. Arch Dermatol. 2003;139(4):510-516. doi: 10.1001/archderm.139.4.510.
9. Bowers S, Franco E. Chronic Wounds: Evaluation and Management. Am Fam Physician. 2020 Feb 1;101(3):159-166.
10. Boyce ST, Lalley AL. Tissue engineering of skin and regenerative medicine for wound care. Burns Trauma. 2018 Jan 24;6:4. doi: 10.1186/s41038-017-0103-y.
11. Brembilla NC, Vuagnat H, Boehncke WH, Krause KH, Preynat-Seauve O. Adipose-Derived Stromal Cells for Chronic Wounds: Scientific Evidence and Roadmap Toward Clinical Practice. Stem Cells Transl Med. 2023 Jan 30;12(1):17-25. doi: 10.1093/stcltm/szac081.
12. Carstens MH, Quintana FJ, Calderwood ST, Sevilla JP, Ríos AB, Rivera CM, Calero DW, Zelaya ML, Garcia N, Bertram KA, Rigdon J, Dos-Anjos S, Correa D. Treatment of chronic diabetic foot ulcers with adipose-derived stromal vascular fraction cell injections: Safety and evidence of efficacy at 1 year. Stem Cells Transl Med. 2021 Aug;10(8):1138-1147. doi: 10.1002/sctm.20-0497.
13. Castellanos G, Bernabé-García Á, Moraleda JM, Nicolás FJ. Amniotic membrane application for the healing of chronic wounds and ulcers. Placenta. 2017 Nov;59:146-153. doi: 10.1016/j.placenta.2017.04.005. Epub 2017 Apr 10. PMID: 28413063.
14. Chiang KJ, Chiu LC, Kang YN, Chen C. Autologous Stem Cell Therapy for Chronic Lower Extremity Wounds: A Meta-Analysis of Randomized Controlled Trials. Cells. 2021 Nov 25;10(12):3307. doi: 10.3390/cells10123307.
15. Coalson E, Bishop E, Liu W, Feng Y, Spezia M, Liu B, Shen Y, Wu D, Du S, Li AJ, Ye Z, Zhao L, Cao D, Li A, Hagag O, Deng A, Liu W, Li M, Haydon RC, Shi L, Athiviraham A, Lee MJ, Wolf JM, Ameer GA, He TC, Reid RR. Stem cell therapy for chronic skin wounds in the era of personalized medicine: From bench to bedside. Genes Dis. 2019 Sep 17;6(4):342-358. doi: 10.1016/j.gendis.2019.09.008.
16. d'Aquino R, De Rosa A, Laino G, Caruso F, Guida L, Rullo R, Checchi V, Laino L, Tirino V, Papaccio G. Human dental pulp stem cells: from biology to clinical applications. J Exp Zool B Mol Dev E Vol. 2009 Jul 15;312B(5):408-15. doi: 10.1002/jez.b.21263.

17. Dash NR, Dash SN, Routray P, Mohapatra S, Mohapatra PC. Targeting nonhealing ulcers of lower extremity in human through autologous bone marrow-derived mesenchymal stem cells. Rejuvenation Res. 2009;12(5):359-366. doi: 10.1089/rej.2009.0872.
18. Deng C, Yao Y, Liu Z, Li H, Yang Z, Wang D, Wei Z. Chronic wound treatment with high-density nanofat grafting combined with negative pressure wound therapy. Int J Clin Exp Med. 2019;12(2):1402-1411.
19. Deng Z, Iwasaki K, Peng Y, Honda Y. Mesenchymal Stem Cell Extract Promotes Skin Wound Healing. Int J Mol Sci. 2024 Dec 23;25(24):13745. doi: 10.3390/ijms252413745. PMID: 39769505; PMCID: PMC11679360.
20. Deptuła M, Brzezicka A, Skoniecka A, Zieliński J, Pikuła M. Adipose-derived stromal cells for nonhealing wounds: Emerging opportunities and challenges. Med Res Rev. 2021 Jul;41(4):2130-2171. doi: 10.1002/med.21789.
21. Díaz-Herrera MÁ, Martínez-Riera JR, Verdú-Soriano J, Capillas-Pérez RM, Pont-García C, Tenllado-Pérez S, Cunillera-Puértolas O, Berenguer-Pérez M, Gea-Caballero V. Multicentre Study of Chronic Wounds Point Prevalence in Primary Health Care in the Southern Metropolitan Area of Barcelona. J Clin Med. 2021 Feb 16;10(4):797. doi: 10.3390/jcm10040797.
22. Didangelos T, Koliakos G, Kouzi K, Arsos G, Kotzampassi K, Tziomalos K, Karamanos D, Hatzitolios AI. Accelerated healing of a diabetic foot ulcer using autologous stromal vascular fraction suspended in platelet-rich plasma. Regen Med. 2018 Apr;13(3):277-281. doi: 10.2217/rme-2017-0069.
23. Ding P, Lu E, Li G, Sun Y, Yang W, Zhao Z. Research Progress on Preparation, Mechanism, and Clinical Application of Nanofat. J Burn Care Res. 2022 Sep 1;43(5):1140-1144. doi: 10.1093/jbcr/irab250.
24. Falanga V, Isseroff RR, Soulika AM, Romanelli M, Margolis D, Kapp S, Granick M, Harding K. Chronic wounds. Nat Rev Dis Primers. 2022 Jul 21;8(1):50. doi: 10.1038/s41572-022-00377-3.
25. Falanga V. Wound healing and its impairment in the diabetic foot. Lancet. 2005 Nov 12;366(9498):1736-43. doi: 10.1016/S0140-6736(05)67700-8.
26. Frykberg RG, Banks J. Challenges in the Treatment of Chronic Wounds. Adv Wound Care (New Rochelle). 2015 Sep 1;4(9):560-582. doi: 10.1089/wound.2015.0635.
27. Gentile P, De Angelis B, Pasin M, Cervelli G, Curcio CB, Floris M, Di Pasquali C, Bocchini I, Balzani A, Nicoli F, Insalaco C, Tati E, Lucarini L, Palla L, Pascali M, De Logu P, Di Segni C, Bottini DJ, Cervelli V. Adipose-derived stromal vascular fraction cells and platelet-rich plasma: basic and clinical evaluation for cell-based therapies in patients with scars on the face. J Craniofac Surg. 2014 Jan;25(1):267-72. doi: 10.1097/01.scs.0000436746.21031.ba. PMID: 24406591.
28. Ghosh K, Patel RA, Hanson SE. Cell-supplemented autologous fat grafting: a review from bench to bedside. Plast Aesthet Res. 2024;11:70. doi: 10.20517/2347-9264.2024.70.
29. Gronthos S, Mankani M, Brahim J, Robey PG, Shi S. Postnatal human dental pulp stem cells (DPSCs) in vitro and in vivo. Proc Natl Acad Sci U S A. 2000 Dec 5;97(25):13625-30. doi: 10.1073/pnas.240309797.
30. Han Y, Li X, Zhang Y, Han Y, Chang F, Ding J. Mesenchymal Stem Cells for Regenerative Medicine. Cells. 2019 Aug 13;8(8):886. doi: 10.3390/cells8080886.
31. Heras KL, Igartua M, Santos-Vizcaino E, Hernandez RM. Cell-based dressings: A journey through chronic wound management. Biomater Adv. 2022 Apr;135:212738. doi: 10.1016/j.bioadv.2022.212738.
32. Holm JS, Toyserkani NM, Sørensen JA. Adipose-derived stem cells for treatment of chronic ulcers: current status. Stem Cell Res Ther. 2018;9(1):142. doi: 10.1186/s13287-018-0887-0.
33. Hu Y, Rao SS, Wang ZX, Cao J, Tan YJ, Luo J, Li HM, Zhang WS, Chen CY, Xie H. Exosomes from human umbilical cord blood accelerate cutaneous wound healing through miR-21-3p-mediated promotion of angiogenesis and fibroblast function. Theranostics. 2018 Jan 1;8(1):169-184. doi: 10.7150/thno.21234.
34. Huang YZ, Zhou C, Zhao Z, et al. Mesenchymal Stem Cells for Chronic Wound Healing. Tissue Eng Part B Rev. 2020;26(5):447-460. doi: 10.1089/ten.TEB.2019.0351.
35. Huynh PD, Tran QX, Nguyen ST, Nguyen VQ, Vu NB. Mesenchymal stem cell therapy for wound healing: An update to 2022. Biomed Res Ther. 2022;9(12):5437-5449. doi: 10.15419/bmrat.v9i12.782.
36. Isakson M, de Blacam C, Whelan D, McArdle A, Clover AJ. Mesenchymal Stem Cells and Cutaneous Wound Healing: Current Evidence and Future Potential. Stem Cells Int. 2015;2015:831095. doi: 10.1155/2015/831095.
37. Jiang X, Zhang H, Teng M. Effectiveness of Autologous Stem Cell Therapy for the Treatment of Lower Extremity Ulcers: A Systematic Review and Meta-Analysis. Medicine (Baltimore). 2016 Mar;95(11):e2716. doi: 10.1097/MD.0000000000002716.
38. Kakabadze Z, Chakhunashvili D, Gogilashvili K, Ediberidze K, Chakhunashvili K, Kalandarishvili K, Karalashvili L. Bone Marrow Stem Cell and Decellularized Human Amniotic Membrane for the Treatment of Nonhealing Wound After Radiation Therapy. Exp Clin Transplant. 2019 Jan;17(Suppl 1):92-98. doi: 10.6002/ect.MESOT2018.O29.
39. Kemaloğlu CA. Nanofat grafting under a split-thickness skin graft for problematic wound management. Springerplus. 2016;5:138. doi: 10.1186/s40064-016-1808-2.
40. Klinger M, Klinger F, Caviggioli F, Maione L, Catania B, Veronesi A, Giannasi S, Bandi V, Giaccone M, Siliprandi M, Barbera F, Battistini A, Lisa A, Vinci V. Fat Grafting for Treatment of Facial Scars. Clin Plast Surg. 2020 Jan;47(1):131-138. doi: 10.1016/j.cps.2019.09.002.
41. Leaper DJ, Schultz G, Carville K, Fletcher J, Swanson T, Drake R. Extending the TIME concept: what have we learned in the past 10 years? Int Wound J. 2012 Dec;9 Suppl 2(Suppl 2):1-19. doi: 10.1111/j.1742-481X.2012.01097.x.
42. Li A, Mano JF, David L, Tay A. Military regenerative medicine. Biomater Sci. 2025 Nov 18;13(23):6562-6571. doi: 10.1039/d5bm01098e.
43. Li F, Gao C, Song G, Zhang K, Huang G, Liu H. Human Placenta-Derived Mesenchymal Stem Cells Combined With Artificial Dermal Scaffold Enhance Wound Healing in a Tendon-Exposed Wound of a Rabbit Model. Cell Transplant. 2024 Jan-Dec;33:9636897241228922. doi: 10.1177/09636897241228922.
44. Li J, Zhou Z, Wen J, Jiang F, Xia Y. Human amniotic mesenchymal stem cells promote bone and soft tissue regeneration: potential clinical applications. Front Endocrinol (Lausanne). 2020;11:543623. doi: 10.3389/fendo.2020.543623.
45. Liu J, Li Y, Zhang Y, Zhao Z, Liu B. Engineered stromal vascular fraction for tissue regeneration. Front Pharmacol. 2025;16:1510508. doi: 10.3389/fphar.2025.1510508.
46. Loots MA, Lamme EN, Zeegelaar J, Mekkes JR, Bos JD, Middelkoop E. Differences in cellular infiltrate and extracellular matrix of chronic diabetic and venous ulcers versus acute wounds. J Invest Dermatol. 1998 Nov;111(5):850-7. doi: 10.1046/j.1523-1747.1998.00381.x.
47. Lopes B, Sousa P, Alvites R, Branquinho M, Sousa A, Mendonça C, Atayde LM, Maurício AC. The Application of Mesenchymal Stem Cells on Wound Repair and Regeneration. Applied Sciences. 2021;11(7):3000. https://doi.org/10.3390/app11073000.
48. Luo Y, Xu X, Ye Z, Xu Q, Li J, Liu N, Du Y. 3D bioprinted mesenchymal stromal cells in skin wound repair. Front Surg. 2022 Oct 14;9:988843. doi: 10.3389/fsurg.2022.988843.
49. Marino L, Castaldi MA, Rosamilio R, Ragni E, Vitolo R, Fulgione C, Castaldi SG, Serio B, Bianco R, Guida M, Selleri C. Mesenchymal Stem Cells from the Wharton's Jelly of the Human Umbilical Cord: Biological Properties and Therapeutic Potential. Int J Stem Cells. 2019 Jul 31;12(2):218-226. doi: 10.15283/ijsc18034.
50. Martinengo L, Olsson M, Bajpai R, Soljak M, Upton Z, Schmidtchen A, Car J, Järbrink K. Prevalence of chronic wounds in the general population: systematic review and meta-analysis of observational studies. Ann Epidemiol. 2019 Jan;29:8-15. doi: 10.1016/j.annepidem.2018.10.005.
51. Mbiine R, Wayengera M, Ocan M, Kiwanuka N, Munabi I, Muwonge H, Lekuya HM, Kawooya I, Nakanwagi C, Kinengyere AA, Joloba M, Galukande M. Adipose-derived stromal vascular fraction (SVF) in scar treatment: a systematic review protocol. Am J Stem Cells. 2022 Aug 20;11(4):56-63. https://pmc.ncbi.nlm.nih.gov/articles/PMC9520234.
52. Negenborn VL, Groen JW, Smit JM, Niessen FB, Mullender MG. The use of autologous fat grafting for treatment of scar tissue and scar-related conditions: a systematic review. Plast Reconstr Surg. 2016;137:31e–43e. doi: 10.1097/PRS.0000000000001850.
53. Otero-Viñas M, Falanga V. Mesenchymal Stem Cells in Chronic Wounds: The Spectrum from Basic to Advanced Therapy. Adv Wound Care (New Rochelle). 2016 Apr 1;5(4):149-163. doi: 10.1089/wound.2015.0627.
54. Peterson AM, Rapoport NA, Sprow HN, Kallogjeri D, Rich JT. Risk Factors for Wound Complications of Local Flap Reconstruction of the Scalp. Otolaryngol Head Neck Surg. 2025 Oct;173(4):867-874. doi: 10.1002/ohn.1327.
55. Raghuram AC, Yu RP, Lo AY, Sung CJ, Bircan M, Thompson HJ, Wong AK. Role of stem cell therapies in treating chronic wounds: A systematic review. World J Stem Cells. 2020 Jul 26;12(7):659-675. doi: 10.4252/wjsc.v12.i7.659.

56. Rani S, Ritter T. The Exosome – A Naturally Secreted Nanoparticle and its Application to Wound Healing. Adv Mater. 2016 Jul;28(27):5542-52. doi: 10.1002/adma.201504009.
57. Raposio E, Bertozzi N, Bonomini S, Bernuzzi G, Formentini A, Grignaffini E, Pio Grieco M. Adipose-derived Stem Cells Added to Platelet-rich Plasma for Chronic Skin Ulcer Therapy. Wounds. 2016 Apr;28(4):126-31. PMID: 27071140.
58. Regulski MJ, Danilkovitch A, Saunders MC. Management of a chronic radiation necrosis wound with lyopreserved placental membrane containing viable cells: a case report. Clin Case Rep. 2019;7(3):456-460. doi: 10.1002/ccr3.2011.
59. Rigotti G, Marchi A, Galiè M, Baroni G, Benati D, Krampera M, Pasini A, Sbarbati A. Clinical treatment of radiotherapy tissue damage by lipoaspirate transplant: a healing process mediated by adipose-derived adult stem cells. Plast Reconstr Surg. 2007 Apr 15;119(5):1409-1422. doi: 10.1097/01.prs.0000256047.47909.71. PMID: 17415234.
60. Riyat H, Touil LL, Briggs M, Shokrollahi K. Autologous fat grafting for scars, healing and pain: a review. Scars Burn Heal. 2017 Sep 18;3:2059513117728200. doi: 10.1177/2059513117728200. PMID: 29799544; PMCID: PMC5965331.
61. Sarasúa JG, López SP, Viejo MA, Basterrechea MP, Rodríguez AF, Gutiérrez AF, Gala JG, Menéndez YM, Augusto DE, Arias AP, Hernández JO. Treatment of pressure ulcers with autologous bone marrow nuclear cells in patients with spinal cord injury. J Spinal Cord Med. 2011;34(3):301-7. doi: 10.1179/2045772311Y.0000000010.
62. Sbitan L, Qandah A, Alzraikat N, Camargo CP. Adipose tissue and fat-derived products in wound, ulcer, and scar management: a systematic review. Front Surg. 2025 Oct 9;12:1666776. doi: 10.3389/fsurg.2025.1666776.
63. Schneider I, Calcagni M, Buschmann J. Adipose-derived stem cells applied in skin diseases, wound healing and skin defects: a review. Cytotherapy. 2023 Feb;25(2):105-119. doi: 10.1016/j.jcyt.2022.08.005.
64. Segreto F, Marangi GF, Nobile C, Alessandri-Bonetti M, Gregorj C, Cerbone V, Gratteri M, Caldaria E, Tirindelli MC, Persichetti P. Use of platelet-rich plasma and modified nanofat grafting in infected ulcers: Technical refinements to improve regenerative and antimicrobial potential. Arch Plast Surg. 2020 May;47(3):217-222. doi: 10.5999/aps.2019.01571.
65. Sen CK, Gordillo GM, Roy S, et al. Human skin wounds: a major and snowballing threat to public health and the economy. Wound Repair Regen. 2009;17(6):763-771. doi: 10.1111/j.1524-475X.2009.00543.x. PubMed.
66. Sharma R, Hruska J, Peter L, Randlova K, Kuca K. Trends in the Treatment of Chronic Wounds. Curr Med Chem. 2025;32(26):5370-5396. doi: 10.2174/0109298673312649240829103906. PMID: 39279699.
67. Sood R, Roggy D, Zieger M, Balledux J, Chaudhari S, Koumanis DJ, Mir HS, Cohen A, Knipe C, Gabehart K, Coleman JJ. Cultured epithelial autografts for coverage of large burn wounds in eighty-eight patients: the Indiana University experience. J Burn Care Res. 2010 Jul-Aug;31(4):559-68. doi: 10.1097/BCR.0b013e3181e4ca29.
68. Stachura A, Paskal W, Pawlik W, Mazurek MJ, Jaworowski J. The Use of Adipose-Derived Stem Cells (ADSCs) and Stromal Vascular Fraction (SVF) in Skin Scar Treatment-A Systematic Review of Clinical Studies. J Clin Med. 2021 Aug 17;10(16):3637. doi: 10.3390/jcm10163637.
69. Sun Y, Zhao J, Zhang L, Li Z, Lei S. Effectiveness and safety of stem cell therapy for diabetic foot: a meta-analysis update. Stem Cell Res Ther. 2022 Aug 13;13(1):416. doi: 10.1186/s13287-022-03110-9. PMID: 35964145; PMCID: PMC9375292.
70. Tan SS, Ng ZY, Zhan W, Rozen W. Role of Adipose-derived Stem Cells in Fat Grafting and Reconstructive Surgery. J Cutan Aesthet Surg. 2016 Jul-Sep;9(3):152-156. doi: 10.4103/0974-2077.191672.
71. Tonnard P, Verpaele A, Peeters G, Hamdi M, Cornelissen M, Declercq H. Nanofat grafting: basic research and clinical applications. Plast Reconstr Surg. 2013 Oct;132(4):1017-1026. doi: 10.1097/PRS.0b013e31829fe1b0.
72. Troyer DL, Weiss ML. Wharton's jelly-derived cells are a primitive stromal cell population. Stem Cells. 2008 Mar;26(3):591-9. doi: 10.1634/stemcells.2007-0439.
73. Ude CC, Miskon A, Idrus RBH, Abu Bakar MB. Application of stem cells in tissue engineering for defense medicine. Mil Med Res. 2018 Feb 26;5(1):7. doi: 10.1186/s40779-018-0154-9. PMID: 29502528; PMCID: PMC6389246.
74. Uzun E, Güney A, Gönen ZB, Özkul Y, Kafadar İH, Günay M, Mutlu M. Intralesional allogeneic adipose-derived stem cells application in chronic diabetic foot ulcer: Phase I/2 safety study. Foot Ankle Surg. 2021 Aug;27(6):636-642. doi: 10.1016/j.fas.2020.08.002.
75. Vaidya A, Hariharan S, Saini S, Rameshbabu AP. Enhancing wound healing through secretome-loaded 3D-printed biomaterials. J Mater Chem B. 2021;9(48):10014-10036. doi: 10.1039/D1TB01917G.
76. Wang B, Zhao G, Zhang J, Chen W, Yang S, Sun Y. Advances in Stem Cell Therapy for Diabetic Foot Ulcers. Diabetes Metab Syndr Obes. 2025 Oct 29;18:4021-4034. doi: 10.2147/DMSO.S564011. PMID: 41185855; PMCID: PMC12579874.
77. Xia Y, Wu P, Chen H, Chen Z. Advances in stem cell therapy for diabetic foot. Front Genet. 2024 Sep 3;15:1427205. doi: 10.3389/fgene.2024.1427205. Erratum in: Front Genet. 2024 Dec 12;15:1520519. doi: 10.3389/fgene.2024.1520519.
78. Xiao J, Zhang Q, Wu B, Wang M, Zhu Y, Zhao D, Zhao F, Xie Y. Effect of placental mesenchymal stem cells on promoting the healing of chronic burn wounds. Heliyon. 2024 Aug 22;10(17):e36584. doi: 10.1016/j.heliyon.2024.e36584. PMID: 39281490; PMCID: PMC11401119.
79. Xie B, Luo H, Zhang Y, Wang Q, Zhou C, Xu D. Autologous Stem Cell Therapy in Critical Limb Ischemia: A Meta-Analysis of Randomized Controlled Trials. Stem Cells Int. 2018 May 24;2018:7528464. doi: 10.1155/2018/7528464.
80. Yang Z, Ma L, Du C, Wang J, Zhang C, Hu L, Wang S. Dental pulp stem cells accelerate wound healing through CCL2-induced M2 macrophages polarization. iScience. 2023 Sep 24;26(10):108043. doi: 10.1016/j.isci.2023.108043.
81. Yin S, Yang X, Bi H, Zhao Z. Combined Use of Autologous Stromal Vascular Fraction Cells and Platelet-Rich Plasma for Chronic Ulceration of the Diabetic Lower Limb Improves Wound Healing. Int J Low Extrem Wounds. 2021 Jun;20(2):135-142. doi: 10.1177/1534734620907978.
82. Zeiderman MR, Pu LLQ. Contemporary approach to soft-tissue reconstruction of the lower extremity after trauma. Burns Trauma. 2021 Jul 30;9:tkab024. doi: 10.1093/burnst/tkab024. PMID: 34345630; PMCID: PMC8324213.

Клінічні особливості застосування стовбурових клітин при хірургічному лікуванні посттравматичних і трофічних дефектів шкірних покривів. Огляд літератури

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Хронічні посттравматичні й трофічні дефекти шкіри залишаються складною клінічною проблемою, особливо в умовах ішемії, інфекції, діабетичної ангіопатії та нейропатії чи наслідків високотравматичних ушкоджень. Традиційні методи (дебридмент, шкірні трансплантати, місцеві й вільні клапті) не завжди забезпечують стійке загоєння, що стимулює інтерес до регенеративних технологій. Мезенхімальні стовбурові клітини (MSC), насамперед кістково-мозкові й адипозо-деривовані (ADSC), чинять виразний паракринний, ангіогенний та імуномодулювальний вплив, поліпшуючи мікрооточення рани та підвищуючи ефективність стандартних хірургічних втручань. Клінічні дослідження й метааналізи демонструють, що автологічна терапія MSC сприяє швидшому загоєнню діабетичних, венозних, артеріальних і змішаних виразок, знижує ризик ампутацій та поліпшує перфузію тканин. У реконструктивній хірургії посттравматичних дефектів найбільш затребуваними є ADSC/SVF-асистований ліпофілінг і nanofat-технології, які забезпечують ремоделювання рубцевої тканини, підвищення її еластичності, зменшення контрактур і поліпшення умов для подальших клаптевих реконструкцій. Клітинні або клітинно-матриксні конструкції (MSC + scaffold) продемонстрували потенціал у лікуванні складних дефектів м'яких тканин з оголенням кістки, зменшуючи потребу в об'ємних реконструкціях. Незважаючи на обнадійливі результати, докази мають обмеження: невеликі вибірки, гетерогенність методик, відсутність стандартизованих доз і недостатня кількість великих багатоцентрових рандомізованих контрольованих досліджень. Питання щодо тривалої онкологічної безпечності потребує подальшого спостереження, хоча значущих ризиків у наявних серіях не виявлено. Перспективними є безклітинні підходи (екзосоми, секретом MSC), інтеграція клітинних технологій із 3D-друкованими та біоінженерними матрицями, розробка чітких хірургічних алгоритмів, де MSC є інструментом для підсилення ефективності стандартних реконструктивних методів.

Ключові слова: хронічні рани, трофічні виразки, посттравматичні дефекти, реконструктивна хірургія, мезенхімальні стовбурові клітини, адипозо-деривовані стовбурові клітини, стромально-васкулярна фракція, регенерація шкіри.

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Minimally invasive percutaneous interventions in the final stage of treatment of infected necrotizing pancreatitis. Review of recent studies

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Infected necrotizing pancreatitis represents one of the most challenging conditions in abdominal surgery and requires multi-stage minimally invasive interventions as part of the widely accepted step-up approach. This strategy involves collaboration between interventional radiologists and interventional gastroenterologists. Navigation-assisted minimally invasive interventions are crucial during the initial 3–4 weeks of the disease, serving as the primary method for managing infected necrotic collections in the retroperitoneal tissue.

Objective – to analyze studies published between 2020 and 2025 and evaluate the effectiveness of percutaneous interventions as the definitive treatment for acute infected pancreatitis.

The analysis indicates that navigation-assisted minimally invasive interventions are effective in 35–55 % of cases involving infected pancreatic necrosis. The increasing effectiveness of these interventions facilitates rapid reduction of systemic intoxication and stabilization of the patient's condition. Effectiveness is evaluated by clinical and laboratory parameters, including reductions in body temperature, leukocytosis, and C-reactive protein or procalcitonin levels within 48–72 hours, as well as radiological assessment of the necrotic collection volume in retroperitoneal tissue. A reduction in the size of the necrotic focus by approximately 70–75 % within 10–14 days reliably predicts successful isolated drainage without the need for necrosectomy (M. Wroński et al., 2014). Clinical success rates were 67.6 % in the early drainage group (up to 2 weeks) and 77.0 % in the late drainage group (fourth week from disease onset). These findings support the integration of percutaneous and endoscopic methods as complementary components within a step-up strategy and underscore the necessity for further development of navigation-assisted minimally invasive percutaneous techniques for the treatment of complex infected retroperitoneal masses.

Keywords
infected necrotizing pancreatitis, percutaneous drainage, step-up-approach, navigation-assisted minimally invasive interventions, interventional radiology, interventional endoscopy.

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Current surgical strategies for acute necrotizing pancreatitis are guided by the step-up approach, which entails a progressive transition from navigation-assisted minimally invasive percutaneous interventions (MIPI) to more extensive surgical procedures, depending on patient clinical dynamics [2, 3, 10, 11, 30, 47, 55]. Initially, navigation-assisted MIPIs with drainage of fluid collections are performed. In some cases, this serves as the definitive method for managing infected formations, eliminating the need for further necrosectomy. The randomized PANTER trial [59] demonstrated that the step-up approach significantly reduced mortality and serious complications from 69 % to 40 % ($p = 0.006$), and decreased the incidence of multiple organ dysfunction from 40 % to 12 % ($p = 0.002$), with comparable overall mortality rates (19 % vs. 16 %) [59]. Long-term follow-up indicated that patients treated with the step-up approach had lower rates of postoperative hernias and exocrine insufficiency, along with a tendency toward reduced endocrine deficiency [28, 38, 60].

Subsequent meta-analyses have validated the effectiveness of navigation-assisted MIPIs as the

definitive treatment. For example, M. C. van Baal et al. [58] reported that navigation-assisted MIPIs and endoscopic methods prevented open necrosectomy in 55.7 % of patients.

K. Horvath et al. found that navigation-assisted MIPIs were effective in 23 % of patients. In 81 % of cases, a single surgical intervention after navigation-assisted MIPI was sufficient, with no need for additional debridement. The 30-day in-hospital mortality rate was 2.5 %. Bleeding occurred in 7.5 % of patients, while intestinal fistulas developed in 17.5 % [29].

Navigation-assisted MIPIs are typically indicated when infection of necrotic foci is suspected. Indications include the presence of gas bubbles within fluid collections on ultrasound or computed tomography (CT), as well as clinical and laboratory evidence of sepsis–such as fever, leukocytosis, elevated C-reactive protein, and increased procalcitonin levels–despite optimal conservative therapy [6, 18, 56]. On CT, a medium density (≥ 20–30 HU) suggests a higher proportion of solid necrotic infected tissue and is associated with an increased risk of failure for percutaneous isolated drainage [16, 27].

The optimal timing for intervention is during the «walled-off necrosis» phase, typically the fourth week after disease onset, when necrotic tissue is well-formed and demarcated, allowing safer access. However, in cases of escalating septic intoxication or persistent multiorgan failure, early drainage (within 2–3 weeks of disease onset) is permitted as part of the step-up approach [4, 5, 18, 39, 44, 64].

Drainage is conducted under ultrasound or CT guidance using pigtail catheters, typically beginning with sizes of 8–12 Fr. The tract may be gradually expanded to 14–20 Fr, and multiple drains may be placed for multi-chamber collections [16, 17, 41, 54]. When indicated, active irrigation through the drains with isotonic NaCl 0.9 % solution, with or without antiseptic additives, is performed according to local protocols to enhance infection control and support organ function [12, 17].

Effectiveness is evaluated by clinical and laboratory parameters, including reductions in temperature, leukocytosis, C-reactive protein, and procalcitonin levels within 48–72 hours. Radiological assessment involves measuring the decrease in collection volume on follow-up CT scans performed 7–14 days after the initial CT. Several studies indicate that a reduction in lesion size by approximately 70–75 % within 10–14 days reliably predicts successful isolated drainage without the need for necrosectomy [5, 21, 63].

Notably, in some instances, navigation-assisted MIPI serves as both the initial and final stage of treatment [4, 8, 20, 30, 41, 49]. This approach gradually reduces bacterial load, eliminates the source of endotoxemia, and stabilizes systemic hemodynamics without additional surgical trauma [12]. Continuous drainage of liquid necrotic material and the reabsorption process facilitate granulation capsule formation and progressive cavity reduction. The adjunctive use of vacuum-assisted systems further stimulates microcirculation, promotes angiogenesis, and accelerates healing by applying negative pressure to the necrotic area [13, 17, 19, 48]. Table 1 presents the results of key studies demonstrating the effectiveness of navigation-assisted MIPIs in patients with infected pancreatitis.

A representative meta-analysis by P. Keshavarz et al., which included 32 clinical trials and a total of 1,398 patients, reported a clinical success rate of navigation-assisted MIPIs of 63 % (95 % CI 55–71 %), defined as infection and symptom control without further necrosectomy. Approximately 33 % of patients required a step-up approach. The overall mortality rate was 13 %, underscoring navigation-assisted MIPI's effectiveness in mixed patient cohorts with varying disease severity [36].

In contrast, A. K. Singh et al. analyzed a more homogeneous and severely ill cohort of patients with persistent organ failure due to acute necrotizing pancreatitis (n = 83). Despite the severity, navigation-assisted MIPI achieved clinical success in 56.6 % of patients, with 100 % of patients recovering without surgical necrosectomy. Only 13.3 % required surgical intervention, indicating that navigation-assisted MIPI can stabilize critically ill patients. The high mortality rate (37.3 %) in this group reflects the initial severity and systemic involvement, rather than a lack of technique efficacy [51].

In a prospective study by H. Bhatia et al. involving 148 patients with acute necrotic collections, the effectiveness of early (≤ 2 weeks) versus late (after 3–4 weeks) navigation-assisted MIPI was compared. Clinical success was 67.6 % in the early drainage group and 77.0 % in the late drainage group. The need for repeated necrosectomy was significantly lower with delayed intervention (6.8 % vs. 17.6 %), and complication rates were also reduced with late navigation-assisted MIPI (5.4 % vs. 16 %). These findings highlight the importance of allowing a walled-off cavity to form, which improves navigation-assisted MIPI outcomes and reduces the need for surgical intervention [15].

Collectively, these studies indicate that navigation-assisted MIPI achieves clinical success in 55–77 % of cases, enabling the avoidance of open necrosectomy for most patients. The effectiveness of navigation-assisted MIPIs is notably higher when

Table 1. **Effectiveness of navigation-assisted minimally invasive percutaneous interventions**

Research	Design	Clinical success parameters	Clinical success after navigation-assisted MIPI without surgery	Surgery required after navigation-assisted MIPI	Mortality
P. Keshavarz et al. [36] Systematic review and meta-analysis	32 studies, 1398 patients with pancreatic necrosis/ pseudocysts	Infection/ symptom control without the need for further intervention	63 % (95 % CI 55–71 %)	33 % (95 % CI 25–40 %) still required surgery after navigation-assisted MIPI	13 % (95 % CI 9–17 %) overall mortality
A. K. Singh et al. [51] Outcome of percutaneous drainage in patients with pancreatic necrosis having organ failure	83 patients with persistent organ failure, percutaneous catheter drainage on day 25	Complete recovery after PCD + survival without necrosectomy	56.6 % (47/83) successful with PCD only	13.3 % (11/83) proceeded to surgery	37.3 % (31/83) overall mortality (very severe OF cohort)
H. Bhatia et al. [15] Early vs. late PCD of acute necrotic collections (ANC) in necrotizing pancreatitis	148 patients, PCD ≤ 2 weeks (n = 74) vs. 3–4 weeks (n = 74)	Infection/ symptom control without further necrosectomy	67.6 % with early PCD vs. 77.0 % with late PCD	Surgery required by 17.6 % (13/74) vs. 6.8 % (5/74)	Mortality is mentioned in the article, but not detailed in the abstract. The authors did not find a significant difference between the groups.

drainage is performed during the walled-off necrosis (WON) phase. Therefore, navigation-assisted MIPI often serves as both the initial and final stage of treatment within modern step-up-approach protocols [15, 36, 51]. Data presented in Table 1 suggest that navigation-assisted MIPI for acute infected pancreatic necrosis, particularly when integrated with a multidisciplinary approach and advanced control technologies, may become a standard of definitive treatment for selected patients with infected necrotizing pancreatitis.

Comparison of these results reveals a consistent trend toward reduced surgical aggressiveness in the management of acute infected necrotizing pancreatitis. In the 1990s, mortality after open necrosectomy reached 40 %, as documented in early surgical series [42, 70]. However, studies from 2014 to 2024 utilizing navigation-assisted MIPIs report a reduced mortality rate of 15–20 % [3, 34, 46, 61, 68, 69].

Furthermore, navigation-assisted MIPI serves as the final stage of treatment for acute post-necrotic collections and WON in 40–60 % of patients. It demonstrates the method's capacity to effectively control infection sources and stabilize systemic conditions without further surgical intervention [3, 8, 24, 61].

A systematic review by M. C. van Baal et al. involving 384 patients found that navigation-assisted MIPI was a definitive treatment in 55.7 % of cases, thereby eliminating the need for further necrosectomy and resulting in an overall mortality rate of 17.4 % [58]. Subsequent cohort studies support these findings. For example, X. Cao et al. reported that 41.8 % of 74 patients with infected necrosis were cured with navigation-assisted MIPI monotherapy, with a mortality rate of 3.1 % [16]. Similarly, C. Garret et al. observed successful outcomes with isolated percutaneous drainage in 44.4 % of patients [25].

Table 2 presents a comparison of the primary advantages and disadvantages of minimally invasive approaches for treating infected necrotizing pancreatitis.

A meta-analysis by M. Gjeorgjievski et al. (16 studies, 282 patients) reported that percutaneous endoscopic necrosectomy (PEN) achieved clinical success in 82 % of patients, with a procedural mortality of 0 % and an overall mortality of approximately 16 % during follow-up [26]. Similarly, a review by M. Jagielski et al. demonstrated that PEN via a percutaneously placed esophageal stent achieved technical success in 100 % of cases and clinical success in 81 % [31]. Smaller series by L. Ke et al. and M. Saumoy et al. reported clinical success rates for minimally invasive interventions ranging from 70 % to 89 % [35, 43, 50].

Current studies indicate that the endoscopic transluminal approach to necrosequestrectomy in infected pancreatitis, primarily via transgastric

Table 2. **Comparative characteristics of the advantages and disadvantages of minimally invasive techniques in the treatment of infected necrotizing pancreatitis**

Method	Basic technique	Average clinical success	Clinical benefits	Limitations/ Disadvantages
Navigation-assisted percutaneous drainage	Ultrasound/ CT-guided catheter placement	Up to 77 %	Minimally invasive, can be performed in critically ill patients, effective with fluid collections	Risk of repeated punctures, obturation, need for irrigation, high risk of external fistulas
Percutaneous drainage + endoscopic necrosectomy (PEN)	Tract dilation, nephroscopy, mechanical debridement	80 %	Visual control, effective evacuation of detritus, lower trauma compared to traditional surgery, possibility of irrigation	Requires equipment, skills, lengthy procedure, risk of fistula development, requires canal dilation
Transgastric necrosectomy	Transmural access, negative pressure	Up to 90 %	Minimally invasive access without the development of external fistulas, better infection control in centrally located WON, possibility of multiple revisions	High cost, requires highly qualified interventional gastroenterologist, multiple endoscopy sessions required

access, achieves a clinical success rate of 80–90 %, a procedural complication rate of 20–35 %, and a mortality rate of 5–10 %, which is significantly lower than that observed with open necrosectomy [9, 33, 37, 47, 67, 71].

The selection of minimally invasive strategies in necrotizing pancreatitis follows a step-up approach: initial management involves drug therapy, followed by drainage (percutaneous or endoscopic) if infected necrosis or clinical deterioration occurs, and minimally invasive necrosequestrectomy if these measures are ineffective. Open surgical intervention is reserved for refractory cases [3, 39, 53, 59, 63, 65, 71]. Ideally, invasive procedures should be postponed until WON has developed, typically after approximately four weeks, as early necrosequestrectomy is associated with increased morbidity. Debridement within the first two weeks should be avoided [13, 22, 32, 40, 43, 59, 65]. Routine drainage is not recommended during the sterile phase; intervention is indicated for symptoms or complications such as obstruction, persistent pain, nutritional insufficiency, fistulas, persistent systemic inflammatory response syndrome (SIRS), or prolonged organ failure lasting several weeks [1, 3, 21, 22, 32, 62]. The choice of intervention is determined by the anatomical location and extent of the necrotic collection in the retroperitoneal tissue: endoscopic approaches are preferred for encapsulated WON adjacent to the stomach or duodenum, while percutaneous drainage is recommended as an adjunct or salvage method for collections extending into the paracolic gutters or pelvis [3, 7, 21, 43, 45, 53, 60, 62].

The described minimally invasive techniques should not be viewed as alternative or mutually exclusive, as each addresses specific clinical challenges and has distinct anatomical and technical indications. In the management of acute necrotizing pancreatitis, these methods should be applied within an integrated step-up approach, either sequentially or in combination, depending on the localization of the pathological process. For example, a single patient may present with centrally located collections in the lesser omentum, best managed by transgastric necrosectomy, alongside retroperitoneal paracolic accumulations, which are more suitable for percutaneous access. Therefore, effective removal of necrotic and purulent material often requires the complementary use of both endoscopic and percutaneous interventions to optimize therapeutic outcomes.

Conclusions

Minimally invasive percutaneous interventions play a crucial role in the current step-up approach to managing infected necrotizing pancreatitis, with clinical success rates of 55 % to 77 % without the need for necrosectomy. The effectiveness of these interventions depends on the location and structural characteristics of the necrosis, frequently requiring a combination of percutaneous and endoscopic techniques to achieve complete debridement of both central and retroperitoneal collections in the right and left paracolic gutters. Ongoing development of navigation-assisted percutaneous methods is essential, as these approaches remain the primary option for managing infected parietal and paracolic fluid collections.

Declaration of interests

The author declares no conflict of interest.

References

1. Андрющенко ВП, Андрющенко Д, Куновський ВВ, Прикупенко ОВ, Яворська ТП. Імплементація принципу мультимодальної аналгезії у хірургії гострого панкреатиту. Актуальні проблеми сучасної медицини. 2025;25(3):87-91. doi: https://doi.org/10.31718/2077-1096.25.3.87.
2. Діденко ВІ, Кленіна ІА, Шупик ОМ. Результати лікування хворих на панкреонекроз та розробка нових підходів. Матеріали XII наукової сесії Інституту гастроентерології НАМН України. Буковель, 2024.
3. Дронов ОІ, Ковальська ІО, Горлач АІ, Лубенець ТВ. Етапна хірургічна тактика при гострому інфікованому некротичному панкреатиті. Сучасні медичні технології. 2019;(2):29-34. doi: 10.34287/MMT.2(41).2019.21.
4. Колосович І, Сидоренко РА, Ганол І. Застосування мініінвазивних ехо-контрольованих черезшкірних втручань у хворих з ускладненим перебігом гострого панкреатиту. Медична наука України. 2023;19(4):46-54. doi: 10.32345/2664-4738.4.2023.06.
5. Меркулов АО, Шевченко ОМ, Кулик ІА, Білодід ЄО. Інструментальна діагностика інфікованих форм панкреонекрозу. Харківська хірургічна школа. 2023;(1-2). doi: 10.37699/2308-7005.1-2.2023.07.
6. Меркулов АО, Ткач СВ, Зеленова ГВ та ін. Маркери диференційної діагностики системної запальної реакції за різних форм панкреонекрозу. Харківська хірургічна школа. 2025;(3). doi: 10.37699/2308-7005.3.2025.05.
7. Міщенко ВВ, Руденко ІВ. Особливості лікування тяжкого гострого панкреатиту в умовах воєнного часу. Одеський медичний журнал. 2024;(2):31-36.
8. Набойченко ЮВ, Шевченко РС. Мініінвазивне черезшкірне УЗД-контрольоване дренування псевдокіст підшлункової залози, доповнене лазерною вапоризацією. Харківська хірургічна школа. 2020;(4):32-36. doi: 10.37699/2308-7005.4.2020.06.
9. Arvanitakis M, Dumonceau JM, Albert J, Badaoui A, Bali MA, Barthet M, Besselink M, Deviere J, Oliveira Ferreira A, Gyökeres T, Hritz I, Hucl T, Milashka M, Papanikolaou IS, Poley JW, Seewald S, Vanbiervliet G, van Lienden K, van Santvoort H, Voermans R, Delhaye M, van Hooft J. Endoscopic management of acute necrotizing pancreatitis: European Society of Gastrointestinal Endoscopy (ESGE) evidence-based multidisciplinary guidelines. Endoscopy. 2018 May;50(5):524-546. doi: 10.1055/a-0588-5365. Epub 2018 Apr 9. PMID: 29631305.
10 Arvanitakis M, Ockenga J, Bezmarevic M, Gianotti L, Krznarić Ž, Lobo DN, Löser C, Madl C, Meier R, Phillips M, Rasmussen HH, Van Hooft JE, Bischoff SC. ESPEN practical guideline on clinical nutrition in acute and chronic pancreatitis. Clin Nutr. 2024 Feb;43(2):395-412. doi: 10.1016/j.clnu.2023.12.019. Epub 2023 Dec 27. PMID: 38169174.
11. Banks PA, Bollen TL, Dervenis C, Gooszen HG, Johnson CD, Sarr MG, Tsiotos GG, Vege SS; Acute Pancreatitis Classification Working Group. Classification of acute pancreatitis--2012: revision of the Atlanta classification and definitions by international consensus. Gut. 2013 Jan;62(1):102-11. doi: 10.1136/gutjnl-2012-302779. Epub 2012 Oct 25. PMID: 23100216.
12. Bansal A, Gupta P, Singh AK, Shah J, Samanta J, Mandavdhare HS, Sharma V, Sinha SK, Dutta U, Sandhu MS, Kochhar R. Drainage of pancreatic fluid collections in acute pancreatitis: A comprehensive overview. World J Clin Cases. 2022 Jul 16;10(20):6769-6783. doi: 10.12998/wjcc.v10.i20.6769. PMID: 36051118; PMCID: PMC9297419.
13. Baron TH, DiMaio CJ, Wang AY, Morgan KA. American Gastroenterological Association Clinical Practice Update: Management of Pancreatic Necrosis. Gastroenterology. 2020;158(1):67-75.e1. doi: 10.1053/j.gastro.2019.07.064.
14. Baron TH. Drainage for Infected Pancreatic Necrosis — Is the Waiting the Hardest Part? N Engl J Med. 2021 Oct 7;385(15):1433-1435. doi: 10.1056/NEJMe2110313. PMID: 34614334.
15. Bhatia H, Farook S, Bendale CU, Gupta P, Singh AK, Shah J, Samanta J, Mandavdhare H, Sharma V, Sinha SK, Gupta V, Yadav TD, Dutta U, Sandhu MS, Kochhar R. Early vs. late percutaneous catheter drainage of acute necrotic collections in patients with necrotizing pancreatitis. Abdom Radiol (NY). 2023 Jul;48(7):2415-2424. doi: 10.1007/s00261-023-03883-4. Epub 2023 Apr 17. PMID: 37067560.
16. Cao X, Cao F, Li A, Gao X, Wang XH, Liu DG, Fang Y, Guo DH, Li F. Predictive factors of pancreatic necrosectomy following percutaneous catheter drainage as a primary treatment of patients with infected necrotizing pancreatitis. Exp Ther Med. 2017 Nov;14(5):4397-4404. doi: 10.3892/etm.2017.5107. Epub 2017 Sep 5. PMID: 29104650; PMCID: PMC5658722.
17. Dell'Anna G, Lavalle S, Biamonte P, Fanizza J, Masiello E, Bruni A, Mandarino FV, Preatoni P, Azzolini F, Dhar J, Samanta J, Facciorusso A, Stasi E, Brigida M, Dell'Anna A, Spampinato M, Maida M, Massironi S, Annese V, Fuccio L, Donatelli G, Danese S. Clinical, Radiological, and Endoscopic Features of Pancreatic Pseudocyst and Walled-Off Necrosis: How to Diagnose and How to Drain Them. J Clin Med. 2025 Nov 3;14(21):7818. doi: 10.3390/jcm14217818. PMID: 41227213; PMCID: PMC12608859.
18. Denis F, Mahalli R, Delpierre A, Romagna C, Selimovic D, Renaud M. Psychobiological Factors in Global Health and Public Health. Int J Environ Res Public Health. 2022; 19(11): 6728. doi: 10.3390/ijerph19116728.
19. Dong Y, Zhang Y, Lin Z, Li X, Guo Z, Li T, Ma F, Li J. Negative pressure mechanical signal increases the phosphorylation of eNOS Ser1177 by upregulating HSP90 expression to promote wound angiogenesis. J Adv Res. 2025 Jul 26:S2090-1232(25)00570-3. doi: 10.1016/j.jare.2025.07.041. Epub ahead of print. PMID: 40721022.
20. Dumitrascu I, Zarnescu NO, Zarnescu EC, Pahomeanu MR, Constantinescu A, Minca DG, Costea RV. Acute Necrotizing Pancreatitis-Advances and Challenges in Management for Optimal Clinical Outcomes. Medicina (Kaunas). 2025 Jun 30;61(7):1186. doi: 10.3390/medicina61071186. PMID: 40731816; PMCID: PMC12300309.
21. Expert Panel on Gastrointestinal Imaging, Porter KK, Zaheer A, et al. ACR Appropriateness Criteria® Acute Pancreatitis. J Am Coll Radiol. 2019;16(11S):S316-S330. doi: 10.1016/j.jacr.2019.05.017.
22. Ferrari A, Martinetti C, Guastavino A, Urru A, Morcaldi D, Curone P, et al. Percutaneous catheter drainage of pancreatic and peripancreatic necrotic collections: a review. J Radiol Rev 2023;10:188-96. doi: 10.23736/S2723-9284.23.00242-9.
23. Foster BR, Jensen KK, Bakis G, Shaaban AM, Coakley FV. Revised Atlanta Classification for Acute Pancreatitis: A Pictorial Essay. Radiographics. 2016;36(3):675-687. doi: 10.1148/rg.2016150097.
24. Ganaie KH, Choh NA, Parry AH, Shaheen FA, Robbani I, Gojwari TA, Singh M, Shah OJ. The effectiveness of image-guided percutaneous catheter drainage in the management of acute pancreatitis-associated pancreatic collections. Pol J Radiol. 2021 Jun 15;86:e359-e365. doi: 10.5114/pjr.2021.107448. PMID: 34322185; PMCID: PMC8297482.
25. Garret C, Douillard M, David A, Péré M, Quenehervé L, Legros L, Archambeaud I, Douane F, Lerhun M, Regenet N, Gournay J, Coron E, Frampas E, Reignier J. Infected pancreatic necrosis complicating severe acute pancreatitis in critically ill patients: predicting catheter drainage failure and need for necrosectomy. Ann Intensive Care. 2022 Aug 2;12(1):71. doi: 10.1186/s13613-022-01039-z. PMID: 35916981; PMCID: PMC9346045.
26. Gjeorgjievski M, Bhurwal A, Chouthai AA, Abdelqader A, Gaidhane M, Shahid H, Tyberg A, Sarkar A, Kahaleh M. Percutaneous endoscopic necrosectomy (PEN) for treatment of necrotizing pancreatitis: a systematic review and meta-analysis. Endosc Int Open. 2023 Mar 23;11(3):E258-E267. doi: 10.1055/a-1935-4738. PMID: 36968976; PMCID: PMC10036203.
27. Gupta P, Koshi S, Samanta J, Mandavdhare H, Sharma V, K Sinha S, Dutta U, Kochhar R. Kissing catheter technique for percutaneous catheter drainage of necrotic pancreatic collections in acute pancreatitis. Exp Ther Med. 2020 Sep;20(3):2311-2316. doi: 10.3892/etm.2020.8897. Epub 2020 Jun 17. PMID: 32765710; PMCID: PMC7401886.
28. Hollemans RA, Bakker OJ, Boermeester MA, et al. Superiority of Step-up Approach vs Open Necrosectomy in Long-term Follow-up of Patients With Necrotizing Pancreatitis. Gastroenterology. 2019;156(4):1016-1026. doi: 10.1053/j.gastro.2018.10.045.
29. Horvath K, Freeny P, Escallon J, Heagerty P, Comstock B, Glickerman DJ, Bulger E, Sinanan M, Langdale L, Kolokythas O, Andrews RT. Safety and efficacy of video-assisted retroperitoneal debridement for infected pancreatic collections: a multicenter, prospective, single-arm phase 2 study. Arch Surg. 2010 Sep;145(9):817-25. doi: 10.1001/archsurg.2010.178. PMID: 20855750.
30. Iskra HI, Guryev SO, Kushnir VA, Dyrda OO. Selected aspects of etiology, pathogenesis and treatment of acute pancreatitis and its complicated forms. Ukrainian Journal of Clinical Surgery. 2025;92(4):67-72. doi: 10.26779/2786-832X.2025.4.67.
31. Jagielski M, Chwarścianek A, Piątkowski J, Jackowski M. Percutaneous Endoscopic Necrosectomy-A Review of the Literature. J Clin Med. 2022 Jul 6;11(14):3932. doi: 10.3390/jcm11143932. PMID: 35887696; PMCID: PMC9324430.
32. Jagielski M, Smoczyński M, Studniarek M, Adrych K: Description of minimally invasive methods of treatment of walled-off pancreatic necrosis (WOPN)- the use of «step up approach» in patient with pancreatic n. Pol Przegl Chir 2015; 87(8): 409-412.

33. Karstensen JG, Novovic S, Hansen EF, Jensen AB, Jorgensen HL, Lauritsen ML, Werge MP, Schmidt PN. EUS-guided drainage of large walled-off pancreatic necroses using plastic versus lumen-apposing metal stents: a single-centre randomised controlled trial. Gut. 2023 Jun;72(6):1167-1173. doi: 10.1136/gutjnl-2022-328225. Epub 2022 Nov 29. PMID: 36446550.
34. Ke L, Li J, Hu P, Wang L, Chen H, Zhu Y. Percutaneous Catheter Drainage in Infected Pancreatitis Necrosis: a Systematic Review. Indian J Surg. 2016 Jun;78(3):221-228. doi: 10.1007/s12262-016-1495-9. Epub 2016 May 4. PMID: 27358518; PMCID: PMC4907923.
35. Ke L, Mao W, Zhou J, Ye B, Li G, Zhang J, Wang P, Tong Z, Windsor J, Li W. Stent-Assisted Percutaneous Endoscopic Necrosectomy for Infected Pancreatic Necrosis: Technical Report and a Pilot Study. World J Surg. 2019 Apr;43(4):1121-1128. doi: 10.1007/s00268-018-04878-9. PMID: 30569220.
36. Keshavarz P, Azrumelashvili T, Yazdanpanah F, Nejati SF, Ebrahimian Sadabad F, Tarjan A, Bazyar A, Mizandari M. Percutaneous catheter drainage of pancreatic associated pathologies: A systematic review and meta-analysis. Eur J Radiol. 2021 Nov;144:109978. doi: 10.1016/j.ejrad.2021.109978. Epub 2021 Sep 28.
37. Kim YS, Cho JH, Cho DH, Park SW, Moon SH, Park JS, Lee YN, Lee SS. Long-term Outcomes of Direct Endoscopic Necrosectomy for Complicated or Symptomatic Walled-Off Necrosis: A Korean Multicenter Study. Gut Liver. 2021 Nov 15;15(6):930-939. doi: 10.5009/gnl20304. PMID: 33767033; PMCID: PMC8593507.
38. Lawson E. Step-up vs open necrosectomy for necrotizing pancreatitis. Surgical Focus. 2022 Apr 22. Available from: https://emorysurgicalfocus.com/2022/04/22/step-up-vs-open-necrosectomy-necrotizing-pancreatitis/.
39. Leppäniemi A, Tolonen M, Tarasconi A, et al. 2019 WSES guidelines for the management of severe acute pancreatitis. World J Emerg Surg. 2019;14:27. Published 2019 Jun 13. doi: 10.1186/s13017-019-0247-0.
40. Lindgaard L, Lauritsen ML, Novovic S, Hansen EF, Karstensen JG, Schmidt PN. Simultaneous endoscopic and video-assisted retroperitoneal debridement in walled-off pancreatic necrosis using a laparoscopic access platform: Two case reports. World J Gastroenterol. 2022;28(5):588-593. doi: 10.3748/wjg.v28.i5.588.
41. Liu Y, Wang X, Wang H, Tian Y, Fu X. Application and Value of Percutaneous Catheter Drainage in Contemporary Surgical Treatment of Pancreatic Necrosis. Dig Dis Sci. 2025 Sep;70(9):2977-2989. doi: 10.1007/s10620-025-09110-y. Epub 2025 Jun 11. PMID: 40498410; PMCID: PMC12411323.
42. Miller BJ, Henderson A, Strong RW, Fielding GA, DiMarco AM, O'Loughlin BS. Necrotizing pancreatitis: operating for life. World J Surg. 1994 Nov-Dec;18(6):906-10; discussion 910-1. doi: 10.1007/BF00299103. PMID: 7846917.
43. Onnekink AM, Boxhoorn L, Timmerhuis HC, Bac ST, Besselink MG, Boermeester MA, Bollen TL, Bosscha K, Bouwense SAW, Bruno MJ, van Brunschot S, Cappendijk VC, Consten ECJ, Dejong CH, Dijkgraaf MGW, van Eijck CHJ, Erkelens WG, van Goor H, van Grinsven J, Haveman JW, van Hooft JE, Jansen JM, van Lienden KP, Meijssen MAC, Nieuwenhuijs VB, Poley JW, Quispel R, de Ridder RJ, Römkens TEH, van Santvoort HC, Scheepers JJ, Schwartz MP, Seerden T, Spanier MBW, Straathof JWA, Timmer R, Venneman NG, Verdonk RC, Vleggaar FP, van Wanrooij RL, Witteman BJM, Fockens P, Voermans RP; Dutch Pancreatitis Study Group. Endoscopic Versus Surgical Step-Up Approach for Infected Necrotizing Pancreatitis (ExTENSION): Long-term Follow-up of a Randomized Trial. Gastroenterology. 2022 Sep;163(3):712-722.e14. doi: 10.1053/j.gastro.2022.05.015. Epub 2022 May 14. PMID: 35580661.
44. Paramythiotis D, Karlafti E, Tsavdaris D, Giakoustidis A, Panidis S, Ioannidis A, Prassopoulos P, Michalopoulos A. When to Intervene in Acute Necrotizing Pancreatitis: A Narrative Review of the Optimal Timing for Intervention Strategies. Medicina. 2024; 60(10):1592. https://doi.org/10.3390/medicina60101592.
45. Patil G, Maydeo A, Dalal A, Iyer A, More R, Thakare S. Endoscopic Retroperitoneal Necrosectomy for Infected Pancreatic Necrosis Using a Self-Expandable Metal Stent. GE Port J Gastroenterol. 2021;28(6):425-430. Published 2021 Jan 22. doi: 10.1159/000510025.
46. Pavlek G, Romic I, Kekez D, Zedelj J, Bubalo T, Petrovic I, Deban O, Baotic T, Separovic I, Strajher IM, Bicanic K, Pavlek AE, Silic V, Tolic G, Silovski H. Step-Up versus Open Approach in the Treatment of Acute Necrotizing Pancreatitis: A Case-Matched Analysis of Clinical Outcomes and Long-Term Pancreatic Sufficiency. J Clin Med. 2024 Jun 27;13(13):3766. doi: 10.3390/jcm13133766. PMID: 38999333; PMCID: PMC11242895.
47. Pearson EG, Scaife CL, Mulvihill SJ, Glasgow RE. Roux-en-Y drainage of a pancreatic fistula for disconnected pancreatic duct syndrome after acute necrotizing pancreatitis. HPB (Oxford). 2012 Jan;14(1):26-31. doi: 10.1111/j.1477-2574.2011.00397.x. Epub 2011 Oct 31. PMID: 22151448; PMCID: PMC3252988.
48. Rayzah M, Alzerwi NAN, Idrees B, Alhumaid AA, Baksh Y, Alsultan A, Rayzah F. Negative Pressure Wound Therapy for Surgical Site Infection Prevention Following Pancreaticoduodenectomy: A Systematic Review and Meta-Analysis. Surgeries. 2025;6:88. https://doi.org/10.3390/surgeries6040088.
49. Sahu SK, Giri S, Das S, Patro CD, Praharaj DL, Mallick B, Nath P, Panigrahi SC, Anand AC. Approach to the Diagnosis and Management of Infected Pancreatic Necrosis: A Narrative Review. Cureus. 2025 Apr 25;17(4):e83020. doi: 10.7759/cureus.83020. PMID: 40421342; PMCID: PMC12104691.
50. Saumoy M, Kumta NA, Tyberg A, Brown E, Lieberman MD, Eachempati SR, Winokur RS, Gaidhane M, Sharaiha RZ, Kahaleh M. Transcutaneous Endoscopic Necrosectomy for Walled-off Pancreatic Necrosis in the Paracolic Gutter. J Clin Gastroenterol. 2018 May/Jun;52(5):458-463. doi: 10.1097/MCG.0000000000000895. PMID: 28697152.
51. Singh AK, Samanta J, Gulati A, Gautam V, Bhatia A, Gupta P, Gupta V, Yadav TD, Sinha SK, Kochhar R. Outcome of percutaneous drainage in patients with pancreatic necrosis having organ failure. HPB (Oxford). 2021 Jul;23(7):1030-1038. doi: 10.1016/j.hpb.2020.10.021. Epub 2020 Nov 21. PMID: 33234445.
52. Susak YM, Dyrda OO. Ultrasound-guided percutaneous surgical techniques as a definitive treatment for acute infected necrotizing pancreatitis. General Surgery. 2025;(1):34-41. doi: 10.30978/GS-2025-1-34.
53. Takada T, Isaji S, Mayumi T, et al. JPN clinical practice guidelines 2021 with easy-to-understand explanations for the management of acute pancreatitis. J Hepatobiliary Pancreat Sci. 2022;29(10):1057-1083. doi: 10.1002/jhbp.1146.
54. Thoeni RF. The revised Atlanta classification of acute pancreatitis: its importance for the radiologist and its effect on treatment. Radiology. 2012;262(3):751-764. doi: 10.1148/radiol.11110947.
55. Tringali A, Vadalà di Prampero SF, Bove V, Perri V, La Greca A, Pepe G, Cozza V, Costamagna G. Endoscopic necrosectomy of walled-off pancreatic necrosis by large-bore percutaneus metal stent: a new opportunity? Endosc Int Open. 2018 Mar;6(3):E274-E278. doi: 10.1055/s-0043-125313. Epub 2018 Feb 28. PMID: 29497687; PMCID: PMC5829994.
56. Troncone E, Amendola R, Gadaleta F, De Cristofaro E, Neri B, De Vico P, Paoluzi OA, Monteleone G, Anderloni A, Del Vecchio Blanco G. Indications, Techniques and Future Perspectives of Walled-off Necrosis Management. Diagnostics (Basel). 2024 Feb 9;14(4):381. doi: 10.3390/diagnostics14040381.
57. Valentin C, Le Cosquer G, Tuyeras G, et al. Step-up approach for the treatment of infected necrotising pancreatitis: real life data from a single-centre experience with long-term follow-up. BMC Gastroenterol. 2024;24(1):213. Published 2024 Jun 28. doi: 10.1186/s12876-024-03289-6.
58. Van Baal MC, van Santvoort HC, Bollen TL, Bakker OJ, Besselink MG, Gooszen HG; Dutch Pancreatitis Study Group. Systematic review of percutaneous catheter drainage as primary treatment for necrotizing pancreatitis. Br J Surg. 2011 Jan;98(1):18-27. doi: 10.1002/bjs.7304. PMID: 21136562.
59. Van Santvoort HC, Besselink MG, Bakker OJ, Hofker HS, Boermeester MA, Dejong CH, van Goor H, Schaapherder AF, van Eijck CH, Bollen TL, van Ramshorst B, Nieuwenhuijs VB, Timmer R, Laméris JS, Kruyt PM, Manusama ER, van der Harst E, van der Schelling GP, Karsten T, Hesselink EJ, van Laarhoven CJ, Rosman C, Bosscha K, de Wit RJ, Houdijk AP, van Leeuwen MS, Buskens E, Gooszen HG; Dutch Pancreatitis Study Group. A step-up approach or open necrosectomy for necrotizing pancreatitis. N Engl J Med. 2010 Apr 22;362(16):1491-502. doi: 10.1056/NEJMoa0908821. PMID: 20410514.
60. Van Veldhuisen CL, Sissingh NJ, Boxhoorn L, van Dijk SM, van Grinsven J, Verdonk RC, Boermeester MA, Bouwense SAW, Bruno MJ, Cappendijk VC, van Duijvendijk P, van Eijck CHJ, Fockens P, van Goor H, Hadithi M, Haveman JW, Jacobs MAJM, Jansen JM, Kop MPM, Manusama ER, Mieog JSD, Molenaar IQ, Nieuwenhuijs VB, Poen AC, Poley JW, Quispel R, Römkens TEH, Schwartz MP, Seerden TC, Dijkgraaf MGW, Stommel MWJ, Straathof JWA, Venneman NG, Voermans RP, van Hooft JE, van Santvoort HC, Besselink MG; Dutch Pancreatitis Study Group. Long-Term Outcome of Immediate Versus Postponed Intervention in Patients With Infected Necrotizing Pancreatitis (POINTER): Multicenter Randomized Trial. Ann Surg. 2024 Apr 1;279(4):671-678. doi: 10.1097/SLA.0000000000006001. Epub 2023 Jul 17. PMID: 37450701; PMCID: PMC10922655.
61. Varadarajulu S, Phadnis MA, Christein JD, Wilcox CM. Multiple transluminal gateway technique for EUS-guided drainage of symptomatic walled-off pancreatic necrosis. Gastrointest Endosc. 2011 Jul;74(1):74-80. doi: 10.1016/j.gie.2011.03.1122. Epub 2011 May 25. PMID: 21612778.

62. Working Group IAP/APA Acute Pancreatitis Guidelines. IAP/APA evidence-based guidelines for the management of acute pancreatitis. Pancreatology. 2013 Jul-Aug;13(4 Suppl 2):e1-15. doi: 10.1016/j.pan.2013.07.063. PMID: 24054878.
63. Wroński M, Cebulski W, Słodkowski M, Krasnodębski IW. Minimally invasive treatment of infected pancreatic necrosis. Prz Gastroenterol. 2014;9(6):317-24. doi: 10.5114/pg.2014.47893. Epub 2014 Dec 30. PMID: 25653725; PMCID: PMC4300346.
64. Xiao NJ, Cui TT, Liu F, Li W. Invasive intervention timing for infected necrotizing pancreatitis: Late invasive intervention is not late for collection. World J Clin Cases. 2022 Aug 16;10(23):8057-8062. doi: 10.12998/wjcc.v10.i23.8057. PMID: 36159514; PMCID: PMC9403682.
65. Yareshko VG, Marusii AI. Minimally invasive surgical operations in the treatment of patients with necrotizing pancreatitis. Медичні перспективи. 2018;23(4):131-134.
66. Yokoe M, Takada T, Mayumi T, et al. Japanese guidelines for the management of acute pancreatitis: Japanese Guidelines 2015. J Hepatobiliary Pancreat Sci. 2015;22(6):405-432. doi: 10.1002/jhbp.259.
67. Zeng Y, Yang J, Zhang JW. Endoscopic transluminal drainage and necrosectomy for infected necrotizing pancreatitis: Progress and challenges. World J Clin Cases. 2023 Mar 26;11(9):1888-1902. doi: 10.12998/wjcc.v11.i9.1888. PMID: 36998953; PMCID: PMC10044952.
68. Zhang W, He S, Cheng Y, Xia J, Lai M, Cheng N, Liu Z. Prophylactic abdominal drainage for pancreatic surgery. Cochrane Database Syst Rev. 2018 Jun 21;6(6):CD010583. doi: 10.1002/14651858.CD010583.pub4. Update in: Cochrane Database Syst Rev. 2021 Dec 18;12:CD010583. doi: 10.1002/14651858.CD010583.pub5. PMID: 29928755; PMCID: PMC6513487.
69. Zhang ZH, Ding YX, Wu YD, Gao CC, Li F. A meta-analysis and systematic review of percutaneous catheter drainage in treating infected pancreatitis necrosis. Medicine (Baltimore). 2018 Nov;97(47):e12999. doi: 10.1097/MD.0000000000012999. Erratum in: Medicine (Baltimore). 2019 Feb;98(6):e14457. doi: 10.1097/MD.0000000000014457. PMID: 30461605; PMCID: PMC6392933.
70. Zorger N, Hamer OW, Feuerbach S, Borisch I. Percutaneous treatment of a patient with infected necrotizing pancreatitis. Nat Clin Pract Gastroenterol Hepatol. 2005 Jan;2(1):54-7; quiz 58. doi: 10.1038/ncpgasthep0082. PMID: 16265101.
71. Zuber-Jerger I, Zorger N, Kullmann F. Minimal invasive necrosectomy in severe pancreatitis. Clin Gastroenterol Hepatol. 2007;5(11):e45. doi: 10.1016/j.cgh.2007.09.006

Роль перкутанних малоінвазивних втручань на завершальному етапі лікування інфікованого некротичного панкреатиту. Огляд сучасних досліджень

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Інфікований некротичний панкреатит залишається однією із найскладніших патологій в абдомінальній хірургії та потребує застосування багатоетапних малоінвазивних втручань у межах загальновизнаної тактики поетапного підходу із залученням у лікувальний процес інтервенційного радіолога та інтервенційного ендоскопіста. Малоінвазивні навігаційні втручання відіграють провідну роль як стартовий етап лікування в перші 3—4 тиж захворювання. Їх застосовують як остаточний метод санації інфікованих некротичних скупчень у заочеревинній клітковині.

Мета — проаналізувати дослідження, проведені в 2020—2025 рр., та оцінити ефективність перкутанних втручань як остаточного методу лікування гострого інфікованого панкреатиту.

Аналіз продемонстрував, що навігаційні малоінвазивні втручання є ефективними в 35—55% випадків лікування інфікованого панкреонекрозу. Ефективність втручання зростає, що дає змогу швидко знизити системну інтоксикацію та стабілізувати стан. Ефективність оцінюють за клініко-лабораторною динамікою (зменшення температури тіла, лейкоцитозу, рівня С-реактивного білка/прокальцитоніну впродовж перших 48—72 год) та радіологічно — за ступенем зменшення об'єму скупчення. Зменшення розмірів вогнища приблизно на 70—75% протягом 10—14 днів вірогідно прогнозує успіх ізольованого дренування без потреби в некректомії (M. Wroński et al., 2014). Частота клінічного успіху становила 67,6% у групі ранньої інтервенції (до 2 тиж) та 77,0% у групі пізнього дренування (4-й тиждень від початку захворювання). Отримані дані свідчать про необхідність розгляду перкутанних та ендоскопічних методів як інструментів step-up стратегії, що доповнюють один одного, та наголошують на важливості подальшого розвитку навігаційних перкутанних технологій для лікування складних інфікованих ретроперитонеальних утворень.

Ключові слова: інфікований некротичний панкреатит, перкутанне дренування, поетапний підхід, малоінвазивні навігаційні втручання, інтервенційна радіологія, інтервенційна ендоскопія.

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Prevention and treatment of acute secondary sarcopenia in patients with infected necrotizing pancreatitis. Literature review

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This review of the current scientific literature focuses on the etiological factors, pathophysiological mechanisms, diagnostic approaches, and methods of prevention and treatment of acute secondary sarcopenia in patients with acute necrotizing pancreatitis. Acute secondary sarcopenia represents a severe complication of acute pancreatitis, resulting from a combination of systemic inflammation, physical inactivity, and nutritional deficiency. Scientific evidence indicates that sarcopenia and sarcopenic obesity are associated with higher mortality, an increased incidence of complications in acute pancreatitis, and longer hospital stays. According to the literature, the prevalence of secondary sarcopenia among patients with acute pancreatitis ranges from 18% to 70–80%, with variability in these indicators attributed to differences in diagnostic approaches, assessment criteria, and clinical characteristics of the patient cohorts studied. Contemporary studies have explored various approaches to diagnosing this condition, emphasizing the importance of early detection of secondary sarcopenia through functional tests, imaging, and instrumental diagnostic methods. It has been demonstrated that the prevention and treatment model for secondary sarcopenia requires a multidisciplinary team approach and includes effective anti-inflammatory therapy, optimization of nutritional support (early enteral nutrition with adequate protein and energy provision and correction of micronutrient deficiencies), the use of nutrients with anti-catabolic and anti-inflammatory properties (omega-3 polyunsaturated fatty acids, β-hydroxy-β-methylbutyrate, creatine), as well as early mobilization according to an individualized physiotherapy program. Clinical observations have confirmed that such interventions are associated with improved preservation and restoration of muscle mass and functional status, which directly influence survival rates, hospital stay duration, risk of complications, and disability. In summary, the review of international publications enabled the synthesis of current evidence on the diagnosis, prevention, and treatment of secondary sarcopenia in patients with acute necrotizing pancreatitis. The limited number of studies addressing this issue in the context of complicated acute pancreatitis underscores the relevance and necessity of further research aimed at refining and identifying optimal preventive and therapeutic strategies in this patient population.

Keywords
acute pancreatitis, necrotizing pancreatitis, secondary sarcopenia, sarcopenic obesity, diagnosis, nutritional support, multidisciplinary management.

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Sarcopenia as a complication of acute pancreatitis: current state of research. Etiopathogenic mechanisms of acute secondary sarcopenia development

Secondary sarcopenia (SSP) is associated with increased mortality in the adult population and typically has a multifactorial etiology, including systemic inflammatory conditions, organ failure (OF), physical inactivity, and nutritional deficiencies [40]. According to the EWGSOP2 (2019) consensus, two forms are distinguished: an acute form (lasting < 6 months), which develops in the context of acute diseases or trauma, and a chronic form (> 6 months), which is mainly associated with chronic pathologies [8]. In clinical practice, cases of superacute, «fulminant» muscle loss developing within days or weeks have been reported in patients with sepsis, acute necrotizing pancreatitis (ANP), and following major surgical interventions [39]. According to systematic reviews, sarcopenia (SP) is an independent predictor of postoperative complications and mortality among emergency and surgical patients [20]. Thus,

in patients with acute pancreatitis (AP), sarcopenia (SP) is almost always secondary, acute in nature, and develops as a result of acute inflammation, OF, and nutritional deficiency (ND).

The scientific community's interest in studying the metabolic complications of AP is increasing every year; however, acute secondary sarcopenia (AS, an acute form of SSP) remains poorly understood. Currently, only a limited number of studies systematically and comprehensively analyze the relationship between AP and the reduction in skeletal muscle mass and function. Most of these studies have a retrospective design, use non-standardized criteria, include heterogeneous samples, and apply different methods and terminologies for assessing muscle mass. Few studies on SP classify pancreatitis according to morphology and etiology, and to date, no published research has analyzed AS specifically in infected necrotizing pancreatitis (INP).

According to individual studies, the prevalence of SP among patients with AP ranges from 18 % (assessed in a mixed cohort) [16] to 70–80 % (assessed in cohorts with severe AP treated in intensive care units (ICUs)) [32].

Secondary sarcopenia often has a multifactorial origin; however, the following types are conventionally distinguished based on pathophysiological mechanisms: inflammation-associated (mainly occurring in the context of systemic inflammatory response syndrome), immobilization-associated (resulting from loss of mobility due to trauma, prolonged stay in intensive care, etc.), endocrine (associated with hypothyroidism, diabetes mellitus, and other hormonal disorders), nutritional (due to malabsorption and/or reduced protein intake), and neurological (resulting from denervation caused by stroke or neurodegenerative diseases) [35].

Scientific studies rarely distinguish between primary and SSP in AP, which limits the ability to analyze specific mechanisms. According to most researchers, malnutrition and physical inactivity are considered the main factors contributing to SP, although the results of some studies show a weak or no association between muscle loss and baseline nutritional status, emphasizing instead the roles of physical inactivity and inflammation [18, 21].

The inflammatory mechanism of AS involves a cascade of reactive changes–systemic inflammation, immune-endocrine dysregulation, and anabolic resistance–that begins with the activation of serum cytokines (IL-6, IL-1β, TNF-α). These cytokines stimulate gene expression within the ubiquitin–proteasome system (UPS), leading to a rapid depletion of the muscle protein pool. In the context of a cytokine storm and energy depletion, autophagy becomes excessive, further exacerbating muscle loss. Among patients in severe and/or septic conditions, the key pathophysiological mechanisms underlying SP development include activation of the UPS, impaired insulin metabolism, and inhibition of mTOR-dependent anabolic processes [10, 41]. The above changes are accompanied by endocrine disturbances resulting from activation of the hypothalamic–pituitary–adrenal axis. Elevated cortisol levels, together with decreased concentrations of IGF-1, insulin, and testosterone, as well as increased myostatin levels, contribute to a pronounced predominance of catabolism over anabolism, leading to muscle dysfunction and structural remodeling (inflammation, fibrosis, fatty infiltration). In such a pathological environment, the anabolic capacity of muscle fibers declines, contributing to anabolic resistance, which substantially reduces the effectiveness of therapeutic interventions, including nutritional support (NS), dietary modifications, and physical activity, even when these are optimally implemented. Unlike systemic immune–endocrine dysregulation, which involves multiple physiological systems, anabolic resistance is a pathophysiological phenomenon specific to skeletal muscle tissue [9]. It has also been demonstrated that both SP and AP are associated with persistently elevated cytokine levels (TNF-α and IL-6) and, therefore, share a common catabolic profile [44].

Nutritional deficiency is considered a key pathogenetic mechanism of AS, as inflammation increases total energy expenditure and leads to the redistribution of amino acids for the synthesis of acute-phase proteins, activation of the immune response, and restoration of tissue integrity. Even with adequate nutritional intake, the protein–energy balance remains negative, resulting in hepatic gluconeogenesis and an increased demand for amino acids derived from skeletal muscle. Consequently, even with sufficient NS, this process–similar to cachexia–is only partially reversible, particularly in patients with severe disease [3]. Nutritional deficiency in AP is also driven by malabsorption and maldigestion. Exocrine pancreatic insufficiency, which is especially pronounced in severe AP, leads to impaired digestion of proteins and fats, steatorrhea, and micronutrient deficiencies, ultimately resulting in weight loss, especially of muscle mass [1], and predisposing to the development of SP.

Micronutrient deficiencies are independent risk factors for SP. For example, serum vitamin D levels are directly correlated with indicators of muscle strength [9]. It should be noted that this factor has also been investigated in the context of AP, where vitamin D deficiency has been associated with

a more severe disease course and adverse clinical outcomes [19]. This finding suggests a synergistic effect of vitamin D deficiency in the setting of the pathophysiological interplay between SP and AP during the disease course.

Other risk factors for the development of SP in patients with AP–associated with the inhibition of muscle regeneration and the intensification of catabolic processes–have also been reported, including a prolonged stay in the intensive care unit, characteristic of severe AP [18], and the occurrence of OF [32].

Against the backdrop of acute inflammation, prolonged periods of physical inactivity–such as bed rest or immobilization–serve as potent triggers of muscle atrophy through the activation of several pathophysiological pathways. Suppression of the IGF-1/Akt/mTOR signaling pathway, which normally stimulates protein synthesis, results in a markedly reduced capacity for renewal of the structural muscle protein pool. This process is further enhanced by the activation of FOXO (Forkhead box O) transcription factors, which induce the expression of E3 ubiquitin ligases–MuRF1 and MAFbx–thereby stimulating the UPS and promoting proteolysis. The accumulation of reactive oxygen species (ROS) and disturbances in calcium homeostasis further damage protein structures and activate proteolytic enzymes such as calpains and caspases, ultimately triggering apoptosis [15].

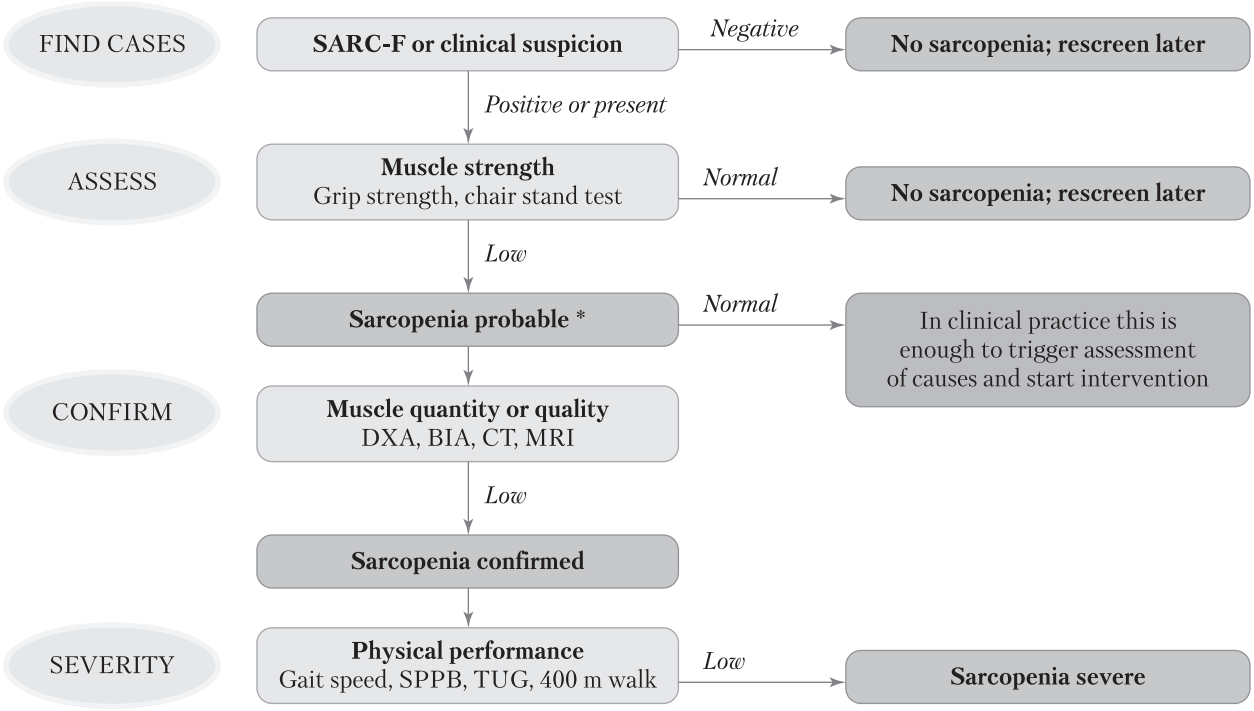
Diagnosis of sarcopenia in acute pancreatitis

Diagnosing and assessing the severity of SP in AP is a challenging task, as each available approach has both advantages and limitations. The presence of acute pain and systemic inflammation, combined with restricted access to diagnostic techniques, reduces the validity and objectivity of assessment methods, particularly in the ICU setting. For the diagnosis of SP in the European population, the EWGSOP2 algorithm is considered the most appropriate tool (Figure).

It is recommended to begin the assessment with the SARC-F rapid screening questionnaire [26], which is based on the patient's subjective evaluation of five functional characteristics (Table).

Only one published study has reported the assessment of muscle strength in patients with AP using handgrip dynamometry [16]. Functional tests for evaluating physical performance are not feasible in patients during the early stages of AP due to weakness, impaired consciousness, OF, and severe pain. These limitations significantly reduce the comprehensiveness and objectivity of SP severity assessment in this population [18].

Bioelectrical impedance analysis (BIA) was used to assess SP in patients with AP in two studies. The authors of one of them emphasized that the method is not optimal due to significant errors associated with water–electrolyte imbalance, edema, and body



* Consider other possible causes of reduced muscle strength (e.g., depression, stroke, balance disorders, peripheral vascular disease)

Figure. **EWGSOP2 algorithm for diagnosing sarcopenia [8]**

Table. **SARC-F questionnaire for SP screening [26]**

Question	Scoring
Strength	
How much difficulty do you have in lifting and carrying 10 pounds (4.5 kg)?	
None	0
Some	1
A lot or unable	2
Assistance in walking	
How much difficulty do you have walking across a room?	
None	0
Some	1
A lot, use aids, or unable	2
Rise from a chair	
How much difficulty do you have transferring from a chair or bed?	
None	0
Some	1
A lot or unable without help	2
Climb stairs	
How much difficulty do you have climbing a flight of 10 stairs?	
None	0
Some	1
A lot or unable	2
Falls	
How many times have you fallen in the past year?	
None	0
1–3 falls	1
4 or more falls	2

Note. SARC-F score ≥ 4 best predicts the need for further, more comprehensive evaluation to confirm evidence of sarcopenia.

position [35]. There is also very limited availability of equipment for measurements in the ICU, as examinations are mainly performed in a standing position.

Computed tomography (CT) is considered the most optimal method for confirming SP, as most patients with AP undergo abdominal CT, which enables quantitative assessment of skeletal muscle mass and density at the L3 vertebral level. However, this approach may delay the identification of SP, since imaging is typically performed not at the time of hospital admission but after a certain period of disease progression [18]. A number of potential predictors of SP in AP have been identified, including low muscle density on CT and a reduced skeletal muscle index (SMI) measured at the level of the third lumbar vertebra (L3), both recognized as independent risk factors for mortality and the development of AP-related complications. However, this method also has certain limitations, such as the need for manual or semi-automatic muscle segmentation, insufficient standardization of measurement parameters, and limited feasibility for dynamic monitoring [17, 24].

Ultrasound examination (US) is one of the primary diagnostic methods for patients with AP and is also recognized as an effective tool for evaluating muscle parameters in the context of SP diagnosis. The technique for measuring muscle thickness, cross-sectional area, pennation angle, and echogenicity of the lower-limb muscles is being actively investigated and is considered a promising approach for dynamic monitoring of SP; however, it has not yet been applied in patients with AP.

Histological studies of muscle tissue in patients with AP in the context of SP diagnosis and treatment have not been conducted to date. In experimental mouse models of severe AP, pronounced muscle fiber atrophy has been observed, accompanied by a reduction in cross-sectional area and increased expression of catabolic protein markers (MuRF-1 and MAFbx) [11]. In a rat model of ANP, morphological alterations and functional impairment of the diaphragm and peripheral muscles were also reported [27]. Given the absence of clinical histological data, this area remains poorly explored and offers new perspectives for further investigation.

Specific features of sarcopenia in acute pancreatitis complicated by infected necrosis

INP is defined as an infection of pancreatic and/or peripancreatic necrotic tissue, confirmed by the presence of gas collections on CT or by microbiological evidence of infection in aspirated fluid or necrotic material [2]. Infected necrosis (INP) develops in 20–40 % of severe AP cases, significantly complicating the disease course, increasing mortality, and raising the need for surgical interventions within the step-up approach [22].

Despite the relevance of the problem, no studies specifically addressing SP or sarcopenic obesity (SO) in INP had been published at the time of preparing this literature review. Therefore, the only data currently available include patient cohorts with severe AP, particularly those with ANP.,However, the number of studies focusing on sarcopenic complications in these clinical entities also remains very limited.

The data demonstrate a correlation between reduced skeletal muscle mass and the severity of acute pancreatitis, including mortality. A lower SMI at the L3 level correlates with higher MCTSI/Balthazar scores and increased in-hospital mortality in patients with severe AP [24]. Moreover, decreased

morphometric and qualitative parameters of the psoas major muscle–psoas muscle index (PMI) and psoas muscle density (PMD)–have been associated with a higher incidence of systemic complications, infectious events, and prolonged hospital stays [17]. In studies focusing on severe AP–where the inclusion criterion was the presence of OF–a relationship was identified between SP or SO and increased 30-day mortality, as well as higher mortality during subsequent follow-up periods [14]. The overall prognostic value of confirmed SP in the context of AP requires further investigation, given the heterogeneity and limited quantity of available data. A systematic review of four studies found insufficient evidence of an association between SP, assessed by CT, and the development of necrotic and systemic complications, disease recurrence, or increased mortality related to AP and its complications [21].

A pronounced long-term decline in muscle mass was observed among ICU patients with severe AP, particularly those with ANP, where the reduction in the iliopsoas muscle area reached approximately 48 %. A higher rate of muscle mass loss was associated with worse outcomes–about 1.34 % per day in non-survivors and 0.74 % per day in survivors [18]. In a cohort of patients with ANP, a decrease in both the cross-sectional area and density of the iliopsoas muscle (Hounsfield Unit Average Calculation, HUAC) was significantly associated with infected necrosis, OF, and mortality [41].

SO may pose a particular risk to patients with severe AP and serve as an additional predictor of mortality, alongside factors such as age and the number of OFs. The mortality rate among patients with severe AP and SO was 45 %, whereas in the cohort of patients with AP without obesity, the mortality rate was 20 %, and among those without any manifestations of OF, it was 10 % [14]. In another study, in addition to the association with a more severe course of AP, a correlation was also observed between visceral obesity and reduced muscle mass and quality on CT [6]. These particularly important findings suggest a bidirectional relationship–a «vicious cycle» mechanism–within cohorts of patients with AP and obesity. At the same time, some authors have denied the existence of a consistent link between body composition (particularly the amount of visceral fat) and mortality in AP, instead emphasizing muscle quality deterioration as the key determinant of an unfavorable outcome. Although baseline muscle characteristics on CT are not considered independent predictors of mortality, a i 10 % decrease in skeletal muscle HUAC within one month was significantly associated with increased in-hospital mortality [37].

Prevention and treatment of secondary sarcopenia in infected necrotizing pancreatitis

To date, no published studies have specifically addressed the prevention or treatment of SP in patients with either INP or AP in general. Therefore, this section summarizes the principles of NS recommended by leading clinical nutrition societies–ESPEN (European Society for Clinical Nutrition and Metabolism) and ASPEN (American Society for Parenteral and Enteral Nutrition)–for patients with AP and for critically ill individuals, as well as the current consensus statements regarding SP.

The primary clinical objective is to prevent or minimize the development of SP in patients during the acute phase of AP. In patients with mild disease, early reintroduction of oral feeding is recommended, with gradual progression from liquid to soft and solid foods as soon as pain and nausea subside–even within the first day of the AP episode. In cases of moderate to severe AP, particularly INP, oral feeding is often not feasible due to the severity of symptoms. Therefore, enteral nutrition (EN) is recommended within 24–72 hours of hospitalization. This approach significantly reduces the risk of infectious complications and mortality compared with delayed or parenteral nutrition (PN) [1, 31]. It should be noted that complications related to EN may occur only under specific clinical conditions that represent absolute contraindications to its early initiation–such as suspected intestinal ischemia or perforation, complete obstruction, or prolonged paralytic ileus–until the underlying cause is resolved [1, 26]. Relative contraindications include hemodynamic instability [38], recurrent vomiting with a risk of aspiration [29], uncontrolled intra-abdominal hypertension, and abdominal compartment syndrome [1].

Enteral nutrition via a nasogastric tube is considered to be as effective and safe for patients with acute pancreatitis as feeding via a nasojejunal tube [12]. The latter is preferred in cases of severe gastroesophageal reflux, gastric paresis, mechanical pyloric obstruction, aspiration, or other persistent intolerance to EN that remains despite standard safety measures (such as the use of prokinetic agents and elevating the head of the bed by 30–45°) [1, 29].

To prevent refeeding syndrome (RFS), it is advisable to initiate EN slowly (10–20 mL/hour) at 70–80 % of the target requirements (approximately 20–25 kcal/kg/day), with gradual titration to the full target dose over 4–7 days, depending on tolerance [1, 4, 26, 31]. Monitoring of serum phosphorus and magnesium levels is mandatory before initiation and during the first 72 hours of EN. Thiamine, a critical cofactor of glucose oxidation enzymes,

should be administered at a dose of 100–200 mg 30–60 minutes before initiation and during the first days of EN to prevent typical complications of RFS–lactic acidosis, heart failure, and Wernicke's encephalopathy [8, 31]. If signs of intolerance to EN occur, feeding should be temporarily stopped, with the duration of the pause depending on the severity of symptoms, and the position of the feeding tube should be verified [4, 12]. In cases of aspiration or abdominal compartment syndrome, EN should be postponed until the patient's condition stabilizes, or temporary PN should be initiated, with continued prophylactic administration of thiamine [1, 13].

Adequate protein and energy support play a key role in the treatment and postoperative recovery of patients with acute pancreatitis. First-line therapy consists of polymeric isocaloric and isonitrogenous formulas for enteral nutrition [1, 4]. Second-line therapy includes oligomeric or peptide-based formulas, which are indicated in cases of intolerance to first-line products or in the presence of malabsorption (e.g., steatorrhea or diarrhea) [1, 12]. Specialized immunomodulatory formulas–enriched with arginine, omega-3 fatty acids, nucleotides, and other bioactive compounds–do not demonstrate significant advantages for routine use and are recommended only in selected cases [1, 31].

The acute phase of AP is characterized by a high risk of both hypervolemia and hypovolemia. Therefore, adequate fluid resuscitation aims to minimize the risks of edema, ascites, pleural effusion, and progression of abdominal hypertension, intestinal edema, and pulmonary congestion. In this context, it is also important to consider the total fluid volume when selecting an EN formula and to prescribe high-caloric formulas (1.5–2 kcal/mL) for patients with severe edema [1, 13].

The recommended target energy intake is 25–30 kcal/kg/day, including 1.2–2.0 g/kg/day of protein [1, 31]. For a long time, it was believed that fat intake worsened the course of AP, but this hypothesis has not been confirmed. According to current guidelines, fat restriction is not recommended in patients with AP unless severe malabsorption is present. In cases of diarrhea and/or steatorrhea, the use of enteral formulas containing medium-chain triglycerides (MCTs) is recommended [1, 9]. Strict glycemic control should also be maintained, keeping blood glucose levels between 7.8 and 10 mmol/L [4, 31].

Correction of nutritional deficiencies is an integral component of dietary management in AP. Patients rapidly deplete their stores of water-soluble vitamins (B_6, B_{12}, folate, and vitamin C) due to their catabolic state, significant fluid losses, and limited food intake [1, 31]. Malabsorption and steatorrhea can also rapidly lead to deficiencies of fat-soluble vitamins (A, D, E, and K) as a result of impaired lipid absorption [1, 25].

Daily monitoring of phosphorus, potassium, and magnesium levels is an essential component of RFS prevention [1, 9]. In cases of ANP and hypoalbuminemia, ionized or corrected calcium should also be monitored, as necrosis leads to the release of large amounts of calcium-binding fatty acids (saponification). Control of systemic inflammation in patients with INP is another key strategy for slowing catabolic processes, since a persistent inflammatory and infectious focus, even under conditions of adequate NS, promotes insulin resistance, hyperglycemia, proteolysis, and lipolysis, ultimately leading to muscle mass loss and a poorer prognosis [1, 31].

During a prolonged stay in the ICU–which is common in complicated necrotizing pancreatitis–a specific pathological condition often develops, characterized by hypodynamia and contributing to the progression of SP: ICU-acquired weakness (ICU-AW) [30, 33]. To preserve muscle function, early mobilization strategies are recommended, including frequent repositioning, passive range-of-motion exercises, gradual verticalization, and the early introduction of active movements under the supervision of a rehabilitation specialist [30, 31]. In patients in the early postoperative period after laparotomy, excessive physical activity may increase the risk of complications; therefore, management is limited to elevating the head of the bed, passive limb mobilization, breathing exercises, and preventive measures against deep vein thrombosis [30, 33].

The above SP prevention model for patients with AP emphasizes the importance and relevance of involving a multidisciplinary medical team to ensure effective inflammation control, comprehensive glycemic management, and minimization of the risk of infection or sepsis, along with meeting AP patients' energy requirements.

Modern approaches to the inpatient management of established SSP, particularly in patients with AP, emphasize the need for early intervention aimed at restoring muscle mass and function during the patient's stay in the ICU or hospital. The main clinical challenge is to initiate muscle recovery during the acute phase of the disease and to minimize catabolic processes.

In cases of severe catabolism and negative nitrogen balance, which are characteristic of postoperative states, sepsis, INP, and continuous renal replacement therapy, intensified NS is indicated. For patients in these categories, the daily protein requirement may reach 2.2–2.5 g/kg/day, with a standard energy intake of 25–30 kcal/kg/day [1, 31]. If target

values cannot be achieved using standard polymeric formulas, it is recommended to supplement with high-protein formulas or to combine them with PN [1, 25]. Determining the nitrogen balance (NB = total protein intake in grams/6.25 – 4) is an important component in assessing changes in nutritional status; however, this method has significant limitations due to the inability to accurately account for extraurinary nitrogen losses (e.g., via drainage, recurrent vomiting, or diarrhea) [31].

Replacement enzyme therapy is an essential component of NS for patients with severe maldigestion and steatorrhea, aimed at improving the absorption of macro- and micronutrients and thereby significantly enhancing the effectiveness of nutritional therapy. The recommended dosage ranges from 10,000 to 40,000 units of lipase per meal, depending on the amount of food consumed, with subsequent titration according to clinical response [1].

The use of specific nutraceuticals for SP correction has not been studied in cohorts of patients with AP, particularly those with INP. However, data from several systematic reviews and meta-analyses indicate beneficial effects of β-hydroxy-β-methylbutyrate (HMB), omega-3 polyunsaturated fatty acids, and creatine (as an adjunct supplement) in preserving and restoring muscle mass and strength [5, 7, 23, 34, 36]. Therefore, the use of these nutraceuticals may be considered an experimental component of NS in patients with AP, especially those with INP, to justify further targeted research in this population.

Early initiation of physical therapy is one of the main components of treatment for AS in patients with AP. The primary goal is to restore muscle strength and physical performance during hospitalization. According to current guidelines, patients are advised to begin early and gradual verticalization (sitting, standing, and walking) under the supervision of a multidisciplinary medical team, along with simple strength exercises such as isometric contractions and movements using resistance bands or body weight. These interventions have been shown to slow muscle loss and shorten the length of stay in the ICU. For patients who have undergone laparotomy in the early postoperative period, the range and intensity of movement should be determined individually in consultation with both the surgeon and the rehabilitation specialist [28, 31, 43].

Thus, modern inpatient approaches to the treatment of acute secondary sarcopenia in infected necrotizing pancreatitis are multifaceted and require the involvement of a multidisciplinary team of specialists. The preservation and restoration of muscle mass and function directly influence patient survival, length of hospitalization, risk of complications, and long-term disability. The limited number of studies addressing this issue in the context of complicated acute pancreatitis underscores the relevance and necessity of further research to refine and optimize treatment strategies for this patient population.

Declaration of interests

The author declares that she has no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Arvanitakis M, Ockenga J, Bezmarevic M, Gianotti L, Krznarić Ž, Lobo DN, Löser C, Madl C, Meier R, Phillips M, Rasmussen HH, Van Hooft JE, Bischoff SC. ESPEN guideline on clinical nutrition in acute and chronic pancreatitis. Clin Nutr. 2020 Mar;39(3):612-31. doi: 10.1016/j.clnu.2020.01.004. Epub 2020 Jan 22. PMID: 32008871.
2. Banks PA, Bollen TL, Dervenis C, Gooszen HG, Johnson CD, Sarr MG, Tsiotos GG, Vege SS; Acute Pancreatitis Classification Working Group. Classification of acute pancreatitis-2012: revision of the Atlanta classification and definitions by international consensus. Gut. 2013 Jan;62(1):102-11. doi: 10.1136/gutjnl-2012-302779. Epub 2012 Oct 25. PMID: 23100216.
3. Barone M, Baccaro P, Molfino A. An Overview of sarcopenia: focusing on nutritional treatment approaches. Nutrients. 2025 Apr 1;17(7):1237. doi: 10.3390/nu17071237. PMID: 40218995; PMCID: PMC11990658.
4. Boullata JI, Carrera AL, Harvey L, Escuro AA, Hudson L, Mays A, McGinnis C, Wessel JJ, Bajpai S, Beebe ML, Kinn TJ, Klang MG, Lord L, Martin K, Pompeii-Wolfe C, Sullivan J, Wood A, Malone A, Guenter P; ASPEN Safe Practices for Enteral Nutrition Therapy Task Force, American Society for Parenteral and Enteral Nutrition. ASPEN Safe Practices for Enteral Nutrition Therapy [Formula: see text]. JPEN J Parenter Enteral Nutr. 2017 Jan;41(1):15-103. doi: 10.1177/0148607116673053. Epub 2016 Nov 5. PMID: 27815525.
5. Chen W, Song J, Gong S. Advances in nutritional metabolic therapy to impede the progression of critical illness. Front Nutr. 2024 Jul 5;11:1416910. doi: 10.3389/fnut.2024.1416910. PMID: 39036495; PMCID: PMC11259093.
6. Chhoda A, Bohara M, Liyen Cartelle A, Manoj MA, Noriega MA, Olivares M, Kelly J, Brook O, Freedman SD, Bezuidenhout AF, Sheth SG. Association of Visceral Adiposity and Sarcopenia with Geospatial Analysis and Outcomes in Acute Pancreatitis. J Clin Med. 2025 Apr 26;14(9):3005. doi: 10.3390/jcm14093005. PMID: 40364037; PMCID: PMC12072196.
7. Cornish SM, Cordingley DM, Shaw KA, Forbes SC, Leonhardt T, Bristol A, Candow DG, Chilibeck PD. Effects of Omega-3 Supplementation Alone and Combined with Resistance Exercise on Skeletal Muscle in Older Adults: A Systematic Review and Meta-Analysis. Nutrients. 2022 May 26;14(11):2221. doi: 10.3390/nu14112221. PMID: 35684018; PMCID: PMC9182791.
8. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al; Writing Group for the European Working Group on Sarcopenia in Older People 2 (EWGSOP2), and the Extended Group for EWGSOP2. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing. 2019 Jan 1;48(1):16-31. doi: 10.1093/ageing/afy169. Erratum in: Age Ageing. 2019 Jul 1;48(4):601. doi: 10.1093/ageing/afz046. PMID: 30312372; PMCID: PMC6322506.
9. Da Silva JSV, Seres DS, Sabino K, Adams SC, Berdahl GJ, Citty SW, Cober MP, Evans DC, Greaves JR, Gura KM, Michalski A, Plogsted S, Sacks GS, Tucker AM, Worthington P, Walker RN, Ayers P; Parenteral Nutrition Safety and Clinical Practice Committees, American Society for Parenteral and Enteral Nutrition. ASPEN Consensus Recommendations for Refeeding Syndrome. Nutr Clin Pract. 2020 Apr;35(2):178-95. doi: 10.1002/ncp.10474. Epub 2020 Mar 2. Erratum in: Nutr Clin Pract. 2020 Jun;35(3):584-85. doi: 10.1002/ncp.10491. PMID: 32115791.

10. Damanti S, Senini E, De Lorenzo R, et al. Acute sarcopenia: mechanisms and management. Nutrients. 2024 Oct 10;16(20):3428. doi: 10.3390/nu16203428. PMID: 39458423; PMCID: PMC11510680.
11. Dong X, Luo W, Wang Y, et al. Role and mechanism of myonectin in severe acute pancreatitis: a crosstalk between skeletal muscle and pancreas. Skelet Muscle. 2024 Dec 3;14(1):29. doi: 10.1186/s13395-024-00363-1. PMID: 39627746; PMCID: PMC11613728.
12. Dutta AK, Goel A, Kirubakaran R, Chacko A, Tharyan P. Nasogastric versus nasojejunal tube feeding for severe acute pancreatitis. Cochrane Database Syst Rev. 2020 Mar 26;3(3):CD010582. doi: 10.1002/14651858.CD010582.pub2. PMID: 32216139; PMCID: PMC7098540.
13. Evans L, Rhodes A, Alhazzani W, Antonelli M, Coopersmith CM, French C, Machado FR, Mcintyre L, Ostermann M, Prescott HC, Schorr C, Simpson S, Wiersinga WJ, Alshamsi F, Angus DC, Arabi Y, Azevedo L, Beale R, Beilman G, Belley-Cote E, Burry L, Cecconi M, Centofanti J, Coz Yataco A, De Waele J, Dellinger RP, Doi K, Du B, Estenssoro E, Ferrer R, Gomersall C, Hodgson C, Møller MH, Iwashyna T, Jacob S, Kleinpell R, Klompas M, Koh Y, Kumar A, Kwizera A, Lobo S, Masur H, McGloughlin S, Mehta S, Mehta Y, Mer M, Nunnally M, Oczkowski S, Osborn T, Papathanassoglou E, Perner A, Puskarich M, Roberts J, Schweickert W, Seckel M, Sevransky J, Sprung CL, Welte T, Zimmerman J, Levy M. Surviving Sepsis Campaign: International Guidelines for Management of Sepsis and Septic Shock 2021. Intensive Care Med. 2021 Nov;47(11):1181-247. doi: 10.1007/s00134-021-06506-y. Epub 2021 Oct 2. PMID: 34599691; PMCID: PMC8486643.
14. Farquhar R, Matthews S, Baxter N, et al. Sarcopenia and sarcopenic obesity on body composition analysis is a significant predictor of mortality in severe acute pancreatitis: a longitudinal observational study. World J Surg. 2023 Nov;47(11):2825-33. doi: 10.1007/s00268-023-07122-1. Epub 2023 Aug 4. PMID: 37541981; PMCID: PMC10545625.
15. Gao Y, Arfat Y, Wang H, Goswami N. Muscle atrophy induced by mechanical unloading: mechanisms and potential countermeasures. Front Physiol. 2018 Mar 20;9:235. doi: 10.3389/fphys.2018.00235. PMID: 29615929; PMCID: PMC5869217.
16. Kilic GS, Tahtaci M, Yagmur F, Akin FE, Tayfur Yurekli O, Ersoy O. Influence of sarcopenia as determined by bioelectrical impedance analysis in acute pancreatitis. Medicine (Baltimore). 2024 Dec 6;103(49):e40868. doi: 10.1097/MD.0000000000040868. PMID: 39654169; PMCID: PMC11630989.
17. Kirzhner A, Rossels A, Sapojnik D, Zaharoni H, Cohen R, Lin G, Schiller T. Psoas muscle index and density as prognostic predictors in patients hospitalized with acute pancreatitis. J Clin Med. 2024 Oct 22;13(21):6314. doi: 10.3390/jcm13216314. PMID: 39518454; PMCID: PMC11547049.
18. Kolck J, Hosse C, Leimbach A, et al. Opportunistic screening for long-term muscle wasting in critically ill patients: insights from an acute pancreatitis cohort. Eur J Med Res. 2024 May 22;29(1):294. doi: 10.1186/s40001-024-01884-7. PMID: 38778361; PMCID: PMC11110383.
19. Kolosovych I, Hanol I, Bystrytska M, Uzun H. Changes in vitamin D and calcium-phosphorus metabolism in patients with severe acute pancreatitis. Turk J Surg. 2022 Dec 20;38(4):327-33. doi: 10.47717/turkjsurg.2022.5669. PMID: 36875274; PMCID: PMC9979554.
20. Knoedler S, Schliermann R, Knoedler L, et al. Impact of sarcopenia on outcomes in surgical patients: a systematic review and meta-analysis. Int J Surg. 2023 Dec 1;109(12):4238-4262. doi: 10.1097/JS9.0000000000000688. PMID: 37696253; PMCID: PMC10720826.
21. Le KDR, Patel H, Downie E. A systematic review on the prognostic role of radiologically-proven sarcopenia on the clinical outcomes of patients with acute pancreatitis. PLoS One. 2025 Apr 29;20(4):e0322409. doi: 10.1371/journal.pone.0322409. PMID: 40299837; PMCID: PMC12040213.
22. Leppäniemi A, Tolonen M, Tarasconi A, Segovia-Lohse H, Gamberini E, Kirkpatrick AW, Ball CG, Parry N, Sartelli M, Wolbrink D, van Goor H, Baiocchi G, Ansaloni L, Biffl W, Coccolini F, Di Saverio S, Kluger Y, Moore E, Catena F. 2019 WSES Guidelines for the Management of Severe Acute Pancreatitis. World J Emerg Surg. 2019 Jun 13;14:27. doi: 10.1186/s13017-019-0247-0. PMID: 31210778; PMCID: PMC6567462.
23. Li N, Chen S, He Y, et al. Effects of oral supplementation of β -hydroxy-β -methylbutyrate on muscle mass and strength in individuals over the age of 50: a meta-analysis. Front Nutr. 2025 Apr 3;12:1522287. doi: 10.3389/fnut.2025.1522287. PMID: 40248035; PMCID: PMC12003145.
24. Lin C, Zhang J, Wang C, Lian W, Liu Y. The impact of skeletal muscle index at the third lumbar spine on nosocomial deterioration and short-term prognosis in acute pancreatitis: a retrospective observational study. PeerJ. 2024 Apr 30;12:e17283. doi: 10.7717/peerj.17283. PMID: 38708354; PMCID: PMC11067894.
25. McClave SA, Taylor BE, Martindale RG, Warren MM, Johnson DR, Braunschweig C, McCarthy MS, Davanos E, Rice TW, Cresci GA, Gervasio JM, Sacks GS, Roberts PR, Compher C; Society of Critical Care Medicine; American Society for Parenteral and Enteral Nutrition. Guidelines for the Provision and Assessment of Nutrition Support Therapy in the Adult Critically Ill Patient: Society of Critical Care Medicine (SCCM) and American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.). JPEN J Parenter Enteral Nutr. 2016 Feb;40(2):159-211. doi: 10.1177/0148607115621863. Erratum in: JPEN J Parenter Enteral Nutr. 2016 Nov;40(8):1200. doi: 10.1177/0148607116670155. PMID: 26773077.
26. Malmstrom TK, Morley JE. SARC-F: a simple questionnaire to rapidly diagnose sarcopenia. J Am Med Dir Assoc. 2013 Aug;14(8):531-2. doi: 10.1016/j.jamda.2013.05.018. Epub 2013 Jun 25. PMID: 23810110.
27. Matuszczak Y, Viires N, Allamedin H, Aubier M, Desmonts JM, Dureuil B. Alteration in diaphragmatic function induced by acute necrotizing pancreatitis in a rodent model. Am J Respir Crit Care Med. 1999 Nov;160(5 Pt 1):1623-8. doi: 10.1164/ajrccm.160.5.9806004. PMID: 10556131.
28. Wang YT, Lang JK, Haines KJ, Skinner EH, Haines TP. Physical rehabilitation in the ICU: A systematic review and meta-analysis. Crit Care Med. 2022 Mar 1;50(3):375-88. doi: 10.1097/CCM.0000000000005285. PMID: 34406169.
29. Pathak A, Blackwell S, Sealock RJ. Should an NPO order be placed for my patient with acute pancreatitis? Cleve Clin J Med. 2024 Jun 3;91(6):341-3. doi: 10.3949/ccjm.91a.24009. PMID: 38830703.
30. Schweickert WD, Pohlman MC, Pohlman AS, et al. Early physical and occupational therapy in mechanically ventilated, critically ill patients: a randomised controlled trial. Lancet. 2009 May 30;373(9678):1874-82. doi: 10.1016/S0140-6736(09)60658-9. Epub 2009 May 14. PMID: 19446324; PMCID: PMC9906655.
31. Singer P, Blaser AR, Berger MM, Calder PC, Casaer M, Hiesmayr M, Mayer K, Montejo-Gonzalez JC, Pichard C, Preiser JC, Szczeklik W, van Zanten ARH, Bischoff SC. ESPEN Practical and Partially Revised Guideline: Clinical Nutrition in the Intensive Care Unit. Clin Nutr. 2023 Sep;42(9):1671-89. doi: 10.1016/j.clnu.2023.07.011. Epub 2023 Jul 15. PMID: 37517372.
32. Singh T, Azim A, Gutte S, Gurjar M, Poddar B, Niyaz Z, Ghosh NK. Impact of sarcopenia on the outcome of patients of severe acute pancreatitis in a critical care setting: a retrospective observational study. Indian J Crit Care Med. 2024 Mar;28(Suppl 1):S263-5. doi: 10.5005/jaypee-journals-10071-24667.97. Epub 2024 Mar 7. PMCID: PMC11886205.
33. Stevens RD, Dowdy DW, Michaels RK, Mendez-Tellez PA, Pronovost PJ, Needham DM. Neuromuscular dysfunction acquired in critical illness: a systematic review. Intensive Care Med. 2007 Nov;33(11):1876-91. doi: 10.1007/s00134-007-0772-2. Epub 2007 Jul 17. PMID: 17639340.
34. Su H, Zhou H, Gong Y, et al. The effects of β-hydroxy-β-methylbutyrate or HMB-rich nutritional supplements on sarcopenia patients: a systematic review and meta-analysis. Front Med (Lausanne). 2024 Jul 12;11:1348212. doi: 10.3389/fmed.2024.1348212. PMID: 39071082; PMCID: PMC11272589.
35. Tournadre A, Vial G, Capel F, Soubrier M, Boirie Y. Sarcopenia. Joint Bone Spine. 2019 May;86(3):309-14. doi: 10.1016/j.jbspin.2018.08.001. Epub 2018 Aug 8. PMID: 30098424.
36. Tseng PT, Zeng BY, Zeng BS, et al. Omega-3 polyunsaturated fatty acids in sarcopenia management: A network meta-analysis of randomized controlled trials. Ageing Res Rev. 2023 Sep;90:102014. doi: 10.1016/j.arr.2023.102014. Epub 2023 Jul 11. PMID: 37442370.
37. Van Grinsven J, van Vugt JLA, Gharbharan A, Bollen TL, Besselink MG, van Santvoort HC, van Eijck CHJ, Boerma D; Dutch Pancreatitis Study Group. The association of computed tomography-assessed body composition with mortality in patients with necrotizing pancreatitis. J Gastrointest Surg. 2017 Jun;21(6):1000-8. doi: 10.1007/s11605-016-3352-3. Epub 2017 Mar 15. PMID: 28299618; PMCID: PMC5443861.
38. Wang L, Zhong X, Yang H, et al. When can we start early enteral nutrition safely in patients with shock on vasopressors? Clin Nutr ESPEN. 2024 Jun;61:28-36. doi: 10.1016/j.clnesp.2024.03.007. Epub 2024 Mar 12. PMID: 38777444.

39. Welch C, K Hassan-Smith Z, A Greig C, M Lord J, A Jackson T. Acute sarcopenia secondary to hospitalisation – an emerging condition affecting older adults. Aging Dis. 2018 Feb 1;9(1):151-64. doi: 10.14336/AD.2017.0315. PMID: 29392090; PMCID: PMC5772853.
40. Xu J, Wan CS, Ktoris K, Reijnierse EM, Maier AB. Sarcopenia is associated with mortality in adults: a systematic review and meta-analysis. Gerontology. 2022;68(4):361-76. doi: 10.1159/000517099. Epub 2021 Jul 27. PMID: 34315158.
41. Yee EJ, Maatman TK, Sood AJ, Gunderman L, Zyromski NJ. Dynamic frailty: Objective physiological assessment to guide management in necrotizing pancreatitis. Surgery. 2021 May;169(5):1078-85. doi: 10.1016/j.surg.2020.10.017. Epub 2020 Dec 15. PMID: 33339652.
42. Yoshihara I, Kondo Y, Okamoto K, Tanaka H. Sepsis-associated muscle wasting: a comprehensive review from bench to bedside. Int J Mol Sci. 2023 Mar 6;24(5):5040. doi: 10.3390/ijms24055040. PMID: 36902469; PMCID: PMC10003568.
43. Zhang L, Hu W, Cai Z, et al. Early mobilization of critically ill patients in the intensive care unit: A systematic review and meta-analysis. PLoS One. 2019 Oct 3;14(10):e0223185. doi: 10.1371/journal.pone.0223185. PMID: 31581205; PMCID: PMC6776357.
44. Zhang S, Hu C, Wang X, Huang Z, Xia Q, Deng L. Identification of biomarkers and immune-metabolic regulators in acute pancreatitis and sarcopenia: a multi-modal transcriptomics study. J Cell Mol Med. 2025 Aug;29(15):e70769. doi: 10.1111/jcmm.70769. PMID: 40785039; PMCID: PMC12336052.

Профілактика та лікування гострої вторинної саркопенії у пацієнтів з інфікованим некротичним панкреатитом. Огляд літератури

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Проведено огляд сучасної наукової літератури, присвяченої вивченню етіологічних чинників, патогенетичних механізмів, діагностичних підходів і методів профілактики та лікування гострої вторинної саркопенії у хворих на гострий некротичний панкреатит. Гостра вторинна саркопенія — тяжке ускладнення гострого панкреатиту, зумовлене поєднанням системного запалення, гіподинамії та нутритивної недостатності. У наукових дослідженнях доведено, що саркопенія та саркопенічне ожиріння асоціюються з вищою смертністю та частотою виникнення ускладнень гострого панкреатиту, а також із тривалішим перебуванням у стаціонарі. За даними літератури, поширеність вторинної саркопенії серед хворих із гострим панкреатитом становить від 18 до 70—80 %. Варіабельність показників зумовлена відмінностями в діагностичних підходах, критеріях оцінки та клінічних характеристиках досліджуваних когорт пацієнтів. У сучасних наукових роботах розглянуто різні підходи до діагностики зазначеного захворювання. Наголошено на важливості раннього виявлення вторинної саркопенії за допомогою функціональних тестів, візуалізаційних та інструментальних методів діагностики. Обґрунтовано, що модель профілактики й лікування вторинної саркопенії потребує залучення мультидисциплінарної команди лікарів і полягає в ефективній протизапальній терапії, оптимізації нутритивної підтримки (раннє ентеральне харчування з адекватним білково-енергетичним забезпеченням, корекція дефіцитів мікроелементів), застосуванні нутрієнтів з антикатаболічними та протизапальними властивостями (ω-3 поліненасичені жирні кислоти, β-гідрокси-β-метилбутират, креатин), а також ранній активізації хворого за індивідуальною програмою фізіотерапії. У клінічних спостереженнях підтверджено, що такі втручання асоціюються з кращими результатами збереження та відновлення м'язової маси й функціонального статусу пацієнтів, що безпосередньо впливає на виживаність хворих, тривалість госпіталізації, ризик ускладнень та інвалідизації. Огляд зарубіжних публікацій дав змогу узагальнити сучасні дані щодо діагностики, профілактики та лікування вторинної саркопенії у хворих із гострим некротичним панкреатитом. Невелика кількість праць, присвячених цій проблемі в контексті ускладненого гострого панкреатиту, свідчить про актуальність і необхідність проведення досліджень для уточнення та пошуку оптимальних профілактичних і лікувальних стратегій для цієї категорії пацієнтів.

Ключові слова: гострий панкреатит, некротичний панкреатит, вторинна саркопенія, саркопенічне ожиріння, діагностика, нутритивна підтримка, мультидисциплінарний підхід.

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