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Vacuum-Assisted Laparotomy in Patients With Penetrating Gunshot Wounds to the Abdomen

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ABSTRACT

BACKGROUND: In modern armed conflicts, peritonitis incidence in penetrating abdominal injuries involving hollow organ damage reaches 31%.

AIM: This study aimed to evaluate the effectiveness of vacuum-assisted laparotomy as a temporary abdominal closure technique in the open abdomen approach for patients with penetrating abdominal gunshot wounds complicated by peritonitis.

METHODS: The outcomes of vacuum-assisted laparostomy were analyzed in 100 patients with penetrating abdominal gunshot wounds complicated by peritonitis between March 1, 2022, and March 1, 2024. The patients were divided into three groups based on hospital department and clinical outcome: group 1, 9 patients from the surgical department; group 2, 59 wounded patients from the anesthesiology and intensive care unit who underwent definitive abdominal closure; and group 3, 32 patients with documented in-hospital mortality. The patients in groups 1 and 2 were further subdivided according to definitive abdominal closure technique: layered closure of the abdominal wall (primary fascial closure) or skin-only closure of the laparotomy wound (planned ventral hernia) performed during the final relaparotomy. Each relaparotomy was performed with vacuum-assisted laparotomy according to a standardized protocol. Predictive models to achieve primary fascial closure and for in-hospital mortality were developed.

RESULTS: Primary fascial closure was achieved in 78% of group 1 cases and in 29% of group 2 cases ($p < 0.007$). In group 2, the planned ventral hernia subgroup had significantly more relaparotomies ($p < 0.001$), longer open abdomen duration ($p < 0.001$), and longer intensive care unit stays ($p = 0.008$) than the primary fascial closure subgroup. An increase in the duration of open abdomen management (group 2) by 1 day decreased the possibility of primary fascial closure by 18% (odds ratio [OR] = 0.817; 95% confidence interval [CI]: 0.706–0.945; $p = 0.007$). In group 2, a decrease in the interval between surgical interventions was a predictor of in-hospital mortality (OR = 0.934; 95% CI: 0.876–0.997; $p = 0.040$). An increase in patient age by 1 year increased the possibility of death by 15% (OR = 1.153; 95% CI: 1.035–1.284; $p = 0.010$), whereas a 1 point increase in organ failure severity score at the initiation of open abdomen approach increased it by 82% (OR = 1.817; 95% CI: 1.255–2.632; $p = 0.002$).

CONCLUSION: Achieving primary fascial closure is associated with a smaller number of preceding surgical interventions and duration of intensive care unit treatment. The shorter the open abdomen duration, the higher the possibility of primary fascial closure. Patient age and the initial organ failure severity score are potential predictors of in-hospital mortality in patients with penetrating abdominal gunshot wounds complicated by peritonitis.

Keywords: abdominal compartment syndrome; vacuum-assisted laparostomy; open abdomen; primary fascial closure; peritonitis; relaparotomy; negative pressure therapy; organ failure.

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Вакуум-ассистированная лапаротомия у пациентов с огнестрельными проникающими ранениями живота

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АННОТАЦИЯ

Обоснование. В современных вооруженных конфликтах частота развития перитонита при проникающих ранениях живота, сопровождающихся повреждением полых органов, достигает 31%.

Цель — оценить эффективность вакуум-ассистированной лапаротомии как методики временного закрытия брюшной полости в ходе тактики «открытый живот» у пациентов с огнестрельными проникающими ранениями живота, осложненными развитием перитонита.

Методы. Проанализированы результаты применения вакуум-ассистированной лапаростомии для лечения 100 пациентов с огнестрельными проникающими ранениями живота, осложненными развитием перитонита с 01.03.2022 по 01.03.2024. В зависимости от отделения пребывания и клинического исхода все пациенты были разделены на 3 группы: 1-ю группу составили 9 пациентов хирургического отделения; во 2-ю группу включены 59 раненых отделения анестезиологии и реанимации, у которых выполнено «окончательное закрытие брюшной полости»; 32 пациента с зафиксированным внутрибольничным летальным исходом составили 3-ю группу. Кроме того, в 1-й и 2-й группах было предусмотрено разделение пациентов на подгруппы в зависимости от методики «окончательного закрытия брюшной полости»: послойное ушивание брюшной полости (первичное фасциальное закрытие) или ушивание только кожи лапаротомной раны (запрограммированная вентральная грыжа), реализованной в ходе заключительной релапаротомии. Каждую релапаротомию завершали вакуум-ассистированной лапаротомией по единому протоколу. Произведено построение прогностических моделей выполнения первичного фасциального закрытия и развития внутрибольничного летального исхода.

Результаты. В 1-й группе первичное фасциальное закрытие достигнуто в 78% случаев, во 2-й группе — в 29% случаев (p <0,007). Во 2-й группе в подгруппе запрограммированной вентральной грыжи большее, чем в подгруппе первичного фасциального закрытия, количество релапаротомий (p <0,001), длительность ведения открытого живота (p <0,001), длительность нахождения в отделении (p=0,008). Увеличение длительности открытого живота (2-я группа) на 1 сутки уменьшает вероятность первичного фасциального закрытия на 18% (отношение шансов равно 0,817; 95% доверительный интервал: 0,706–0,945; p=0,007). Уменьшение временного интервала между оперативными вмешательствами для пациентов 2-й группы — предиктор развития летального исхода (отношение шансов равно 0,934; 95% доверительный интервал: 0,876–0,997; p=0,040). Увеличение возраста пациента на один год увеличивает вероятность летальных исходов на 15% (отношение шансов равно 1,153; 95% доверительный интервал: 1,035–1,284; p=0,010); повышение суммы баллов по шкале оценки тяжести органной недостаточности, при инициации тактики открытого живота, на 1 балл — на 82% (отношение шансов равно 1,817; 95% доверительный интервал: 1,255–2,632; p=0,002).

Заключение. Достижение первичного фасциального закрытия сопряжено с уменьшением количества предшествующих оперативных вмешательств, длительностью лечения пациентов в отделении анестезиологии и реанимации. Чем меньше длительность ведения открытого живота, тем выше вероятность первичного фасциального закрытия. Возраст пациента и сумма баллов по шкале оценки тяжести органной недостаточности можно рассматривать в качестве предикторов внутрибольничного летального исхода у раненных с огнестрельными проникающими ранениями живота, осложненными развитием перитонита.

Ключевые слова: абдоминальный компартмент-синдром; вакуум-ассистированная лапаростомия; открытый живот; первичное фасциальное закрытие; перитонит; релапаротомия; терапия отрицательным давлением; органная недостаточность.

Как цитировать

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BACKGROUND

In local armed conflicts, the incidence of peritonitis in penetrating abdominal injuries involving hollow organ damage reaches 31% [1]. To date, the open abdomen (OA) approach has been widely applied for the treatment of peritonitis and as the first stage of damage control, taking into account the need to prevent abdominal compartment syndrome. This approach involves staged relaparotomies, during which the abdominal cavity is not closed by layered suturing, but by temporary abdominal closure (TAC) techniques, such as Bogota bag, zipper, mesh implants, Wittmann patch, dynamic closure sutures, Barker's vacuum pack technique, and vacuum-assisted laparostomy (VALS) [2–4].

VALS is one of the most common and effective TAC methods used in the OA approach [2, 3]. This technique is based on negative pressure therapy [4, 5]. Notably, in OA management, lateralization of the fascial edges of the unclosed laparotomy wound is inevitable [6, 7]. This creates difficulties in achieving primary fascial closure (PFC), which is the layered suturing of the laparotomy wound upon completion of OA management [8]. If PFC is not feasible and there are no further indications for continuation of the OA approach, only the skin of the laparotomy wound is closed; this results in a planned ventral hernia (PVH) that should be subsequently repaired electively [2, 9].

Thus, PFC and PVH represent the options for definitive abdominal closure (DAC) when continuation of the OA approach is not warranted. Early achievement of PFC is an objective of the OA approach, and the frequency of PFC reflects the effectiveness of a given TAC technique [2, 10]. As a TAC method, VALS allows for a high PFC rate and demonstrates a low risk of complications and in-hospital mortality (IHM) [11, 12].

This study aimed to evaluate the effectiveness of VALS as a TAC method in the OA approach for patients with penetrating abdominal gunshot wounds complicated by peritonitis.

METHODS

This single-center, uncontrolled, non-blinded study included 102 patients with penetrating abdominal gunshot wounds complicated by peritonitis, in whom VALS was used as the TAC method during the OA approach. The patients' surgical history was obtained retrospectively from medical records. In 98% of cases, the patients had combined and multiple injuries. At previous stages of treatment, they underwent laparotomies and other surgical interventions in various anatomical regions. Two patients were excluded from the study owing to transfer to other healthcare facilities before DAC could be conducted. VALS was performed by different surgical teams according to a standardized technique.

The initial cohort of patients was divided into groups based on hospital department and clinical outcome: group 1, 9 patients (9%) treated in the surgical department (SD); group 2, 59 patients (65%) in the anesthesiology and intensive care unit (ICU) in whom DAC was achieved; and group 3, 32 patients (35%) treated in the ICU who developed IHM. In groups 1 and 2, patients were subdivided based on the DAC technique applied during the current hospitalization (PFC or PVH). Moreover, analysis within groups 1 and 2 (between subgroups) was performed. Table 1 presents the age and selected clinical parameters of patients in all groups.

The study was conducted in several stages: selection and creation of the database; statistical analysis of differences in parameters between groups and subgroups; and development of predictive models for patient groups to identify predictors of achieving PFC and IHM. The study design is shown in Fig. 1.

The inclusion criteria were age >18 years, male sex, presence of a penetrating abdominal gunshot wound complicated by peritonitis, and the use of the OA approach with VALS. Conversely, the exclusion criteria included transfer to other healthcare facilities before DAC (making it impossible to track the subsequent implementation of the OA approach).

Table 1. Age and clinical parameters of patients in all groups, *Me* [Q_1; Q_3]

Parameter	Group			*p*, 1 vs 2	*p*, 2 vs 3
	1	2	3		
Age, years	26 [24; 38.5]	32 [26; 36]	34 [29.7; 45.3]	=0.605	=0.026
Length of stay, bed days	30 [19; 57]	11 [7; 21]	9.5 [6; 17.5]	=0.019	=0.247
Interval from injury to first relaparotomy with VALS, days	9 [4; 9.5]	5 [4; 9]	6.5 [5; 10.75]	=0.312	=0.220
SOFA score at the first relaparotomy with VALS	–	2 [1; 4]	7.5 [5.25; 13]	–	<0.001

Note (applies to all tables): VALS, vacuum-assisted laparostomy; SOFA score, Sequential Organ Failure Assessment score; vs, versus.

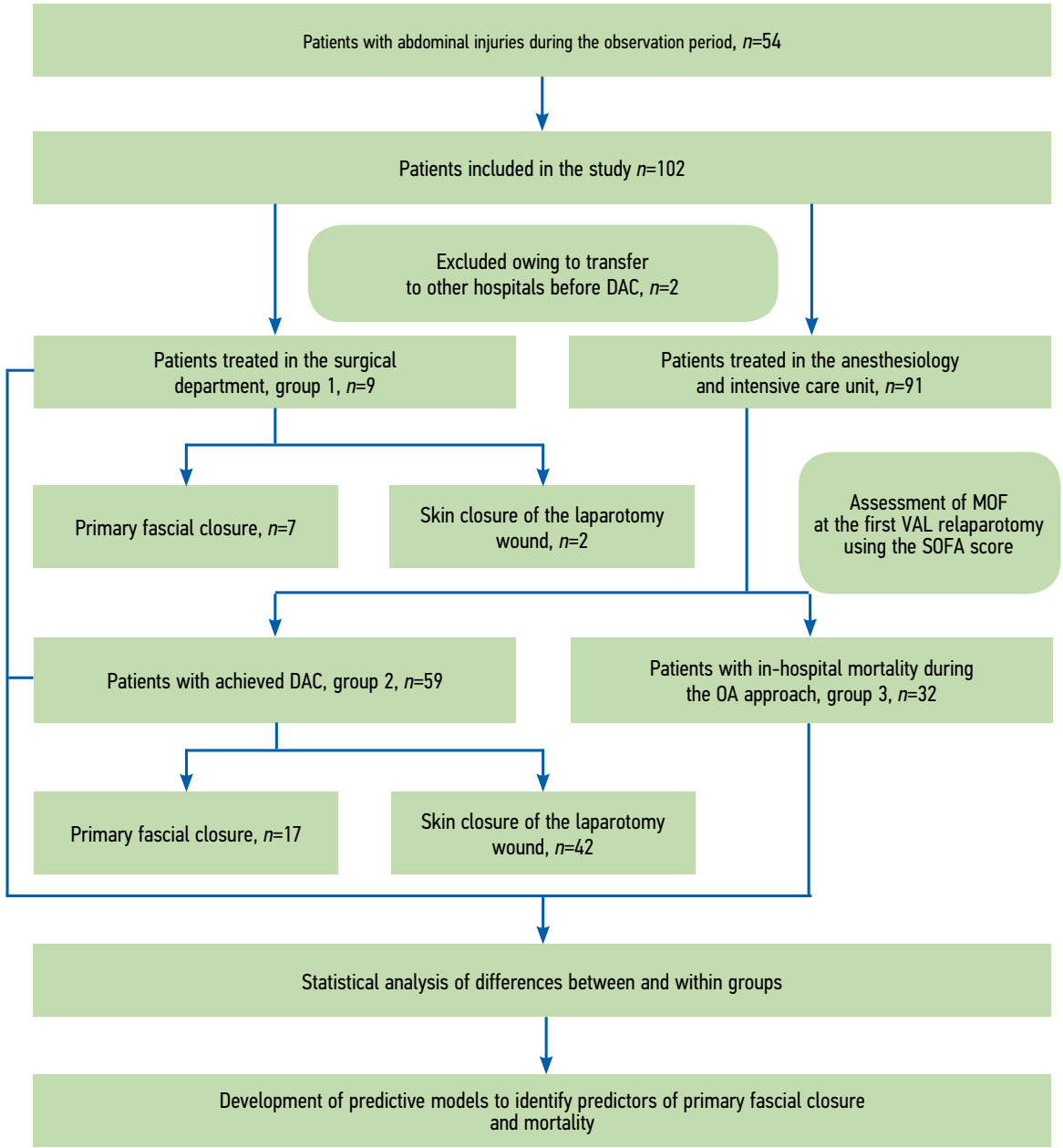
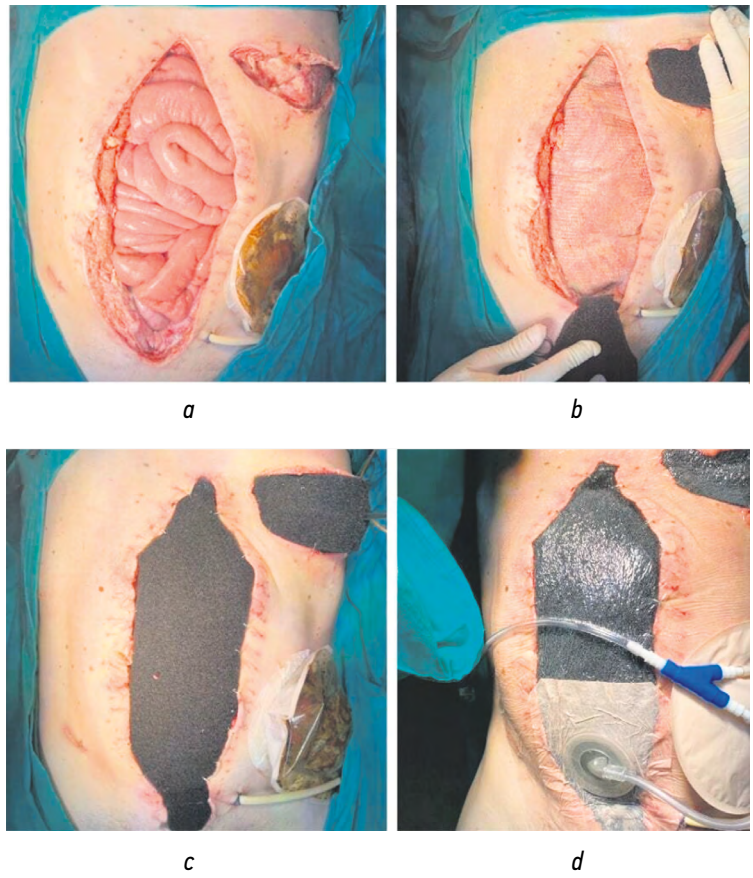


Fig. 1. Study design: MOF, multiple-organ failure; OA, open abdomen; DAC, definitive abdominal closure.

The study analyzed treatment outcomes of patients admitted to the anesthesiology and ICU departments and the SD of the diagnostic and treatment center (clinical, multidisciplinary, and high-technology) of the S.M. Kirov Military Medical Academy between March 1, 2022, and March 1, 2024.

At the final stage of surgery (Fig. 2, *a*) (laparotomy/relaparotomy), a perforated double-layer Suprasorb CNP drainage film was placed into the abdominal cavity, evenly distributed over the greater omentum and intestinal loops, with its edges laid into the lateral canals and pelvic cavity. The film served as a protective visceral layer between the abdominal organs and aspirating layer (polyurethane foam/sponge), ensuring effective evacuation of pathological fluid from dependent recesses of the abdominal cavity (Fig. 2, *b*). The film was trimmed to the required size without loss of its functional properties.

Then, a protective visceral layer was covered with Suprasorb CNP wound foam, modeled to the size of the abdomen and placed between the edges of the laparotomy wound (Fig. 2, *c*). If targeted drainage of phlegmons, purulent tracks, or intra-abdominal abscesses was required, additional polyurethane foams were placed in these areas. The aponeurosis was left unsutured. Separate intracutaneous interrupted stitches were applied to the skin edges of the laparotomy wound to approximate them,



a *b*

c *d*

Fig. 2. Vacuum-assisted laparostomy using a self-assembled system (details provided in the text).

leaving a 7–12 cm gap. Alternatively, to shorten operative time, the polyurethane foam was fixed to the skin edges of the laparotomy wound with a surgical stapler (Fig. 2, *c*). Finally, an occlusive Suprasorb F film was applied to the skin of the anterior abdominal wall. A drainage port was secured over an opening created in this occlusive layer (Fig. 2, *d*).

Negative pressure was achieved using stationary vacuum sources installed in the ward panels of the ICU and SD. The drains were connected to the source of continuous negative pressure with tubing connectors, with a pressure level of 80–120 mmHg, depending on the intraoperative assessment of the abdominal cavity and the operating surgeon's preference.

Scheduled relaparotomies with replacement of the negative pressure system were performed every 24–72 h, determined by objective indicators of the patient's condition severity, extent of peritonitis, and medical–tactical situation. During staged relaparotomy, when continuation of the OA approach was no longer required and the fascial edges could be approximated without excessive tension, PFC was conducted, with separate interrupted sutures placed in the fascia and skin. If approximation of the musculoaponeurotic layer was not feasible, only the skin of the laparotomy wound was closed. All staged relaparotomies were carried out under general anesthesia with endotracheal intubation.

The primary endpoint of the study was treatment outcome during the OA approach: definitive abdominal closure (PFC or PVH) or IHM. Additionally, we analyzed the length of stay, interval from the date of injury to the first relaparotomy with VALS, interval between relaparotomies with VALS, duration of OA management, number of relaparotomies with VALS, Sequential Organ Failure Assessment (SOFA) score at the first relaparotomy with VALS, and predictive value of these indicators for achieving PFC and for IHM.

The secondary outcomes included the incidence of complications (hollow organ fistulas and intra-abdominal abscesses).

The study cohort was divided into groups according to hospital department and clinical outcome: group 1 included patients treated in the SD, group 2 comprised ICU patients who underwent DAC, and group 3 consisted of ICU patients with IHM. In groups 1 and 2, patients were subdivided depending on the DAC technique applied during the current hospitalization (PFC or PVH). Furthermore, an intragroup comparison was performed within groups 1 and 2 (between subgroups).

Outcome registration was performed based on clinical observations documented in medical records, from the day of the first relaparotomy with VALS until transfer to another department, hospital discharge, or IHM. In patients treated in the ICU, at the initiation of the OA approach, organ dysfunction and sepsis risk were assessed using the SOFA score.

The study was approved by the Local Ethics Committee of the S.M. Kirov Military Medical Academy (protocol no. 296; dated November 19, 2024).

Statistical analysis was performed using IBM SPSS Statistics v.27 (USA). When analyzing quantitative variables, the Kolmogorov–Smirnov and Shapiro–Wilk tests were employed to determine whether the distribution of data in the sample corresponded to the normal law. As the distribution of quantitative variables did not correspond to the normal law, descriptive statistics included the median, upper and lower quartiles (*Me* [Q_1; Q_3]), arithmetic mean, and minimum and maximum values (*min* [*x*–], *max* [*x*–]). Binomial variables were evaluated using contingency tables. For comparison, Fisher's exact test was applied, and odds ratios (OR) with 95% confidence intervals (CI) were calculated. In the comparative analysis of results, when the distribution differed from normal in at least one of the compared groups, the nonparametric Mann–Whitney *U* test for independent samples was utilized. The significance level was set at $\alpha = 0.05$. Predictive models of outcomes (achievement of PFC and risk of IHM) were established using logistic regression. Prior to modeling, predictor variables were examined for multicollinearity by correlation matrix analysis and variance inflation factor calculation. Predictors with high multicollinearity were excluded to improve model stability. Additionally, predictors with $p > 0.1$ were excluded from the model. The Hosmer–Lemeshow goodness-of-fit test was used to assess the model's predictive ability. The proportion of variation in the dependent variable elucidated by the model with predictors was measured using the Nagelkerke coefficient. The regression coefficients, *p* values, ORs, and 95% CIs for ORs of each predictor in the final model were reported. Relative values are presented as percentages.

RESULTS AND DISCUSSION

Differences in the frequency of PFC and interval between VALS procedures between the patient groups were identified. It was noted that the possibility of achieving PFC was 8.2 times higher in group 1 than in group 2, whereas in group 3, the interval between relaparotomies with VALS was shorter (Table 2).

No significant differences were found between the subgroups within group 1, potentially because of the small sample size, which limits the use of logistic regression for constructing a predictive model in this patient group (Table 3).

In group 2, the interrelated indicators length of stay, number of VAL procedures, and duration of OA management were higher in the PVH subgroup than in the PFC subgroup (Table 4).

When constructing a predictive model for PFC outcomes in group 2, the predictor number of VAL procedures was excluded because of high collinearity with the predictor duration of OA management (correlation coefficient $r = 0.913$; $p < 0.001$). The predictors patient age ($p = 0.577$), length of stay ($p = 0.232$), time from injury to first VALS procedure ($p = 0.924$), and interval between relaparotomies with VALS ($p = 0.145$) were excluded from the model owing to lack of statistical significance (Table 5).

According to the constructed predictive model, the predictor SOFA score at the first relaparotomy with VALS was significantly associated with an increased probability of achieving PFC (OR = 1.364; 95% CI: 1.011–1.841; $p = 0.042$). An increase in this predictor value increased the probability of achieving PFC. The predictor duration of OA management was significantly associated with a decreased probability of PFC (OR = 0.817; 95% CI: 0.706–0.945; $p = 0.007$). An increase in this predictor value decreased the probability of achieving PFC. ROC analysis yielded an area under the curve (AUC) of

Table 2. Clinical indicators assessed during treatment, *Me* [Q_1; Q_3]

Parameter	Group			*p*, 1 vs 2	*p*, 2 vs 3
	1	2	3		
Number of relaparotomies with VALS	2 [2; 6]	4 [3; 9]	3 [2; 6.75]	=0.095	=0.125
Interval between relaparotomies with VALS, h	64.5 [48; 90.5]	56.8 [48; 64.15]	48 [36; 54]	=0.436	<0.001
Primary fascial closure, *n* (%)	7 (78)	17 (29)	–	=0.007*	–
Duration of open abdomen management, days	7 [5; 17.5]	12 [7; 25]	7 [3; 13.75]	=0.195	–

Note: OR = 8.198 (95% CI: 1.629–45.908).

0.849 units (95% CI: 0.748–0.951), indicating the model's good predictive performance. The Hosmer–Lemeshow test showed good agreement between the model and data (χ^2 = 7.545; p = 0.479). The Nagelkerke R^2 coefficient revealed that the model explained 42.3% of the variance in the dependent variable (PFC or PVH).

When constructing a predictive model of IHM for the group 2 patients, the predictor number of VALS procedures was excluded from the model because of high collinearity with the predictor time from first VALS procedure to IHM (r = 0.913; p < 0.001). The predictors time from injury to first VALS procedure (p = 0.165) and time from first VAL procedure to IHM (p = 0.917) were excluded from the model owing to lack of statistical significance (Table 6).

According to the constructed predictive model, the predictor patient age was significantly associated with an increased probability of IHM (OR = 1.153; 95% CI: 1.035–1.284; p = 0.010). An increase in this predictor value increased the likelihood of IHM. The predictor length of stay was significantly associated with a decreased probability of IHM (OR = 0.924; 95% CI: 0.871–0.980; p = 0.010). An increase in this predictor value decreased

Table 3. Age and clinical parameters of group 1 patients subdivided by outcome, *Me* [Q_1; Q_3], *min* ($\bar{x}$), *max* ($\bar{x}$)

Parameter	Subgroup		p=, PVH vs PFC
	PVH*, n=2 (22%)	PFC, n=7 (78%)	
Age, years	37.5; 35, 40	25 [23; 38]; 22, 39	0.222
Length of stay, bed days	64.5; 56, 73	25 [14; 34]; 6, 58	0.111
Interval from injury to first relaparotomy with VALS, days	10; 5, 15	9 [3; 9]; 3, 10	0.667
Number of relaparotomies with VALS	7; 3, 11	2 [2; 3]; 1, 9	0.111
Interval between relaparotomies with VALS, h	85; 74, 96	52.5 [48; 78]; 48, 96	0.143
Duration of open abdomen management, days	29; 13, 45	7 [4; 7]; 3, 22	0.111

Note (applies to all tables): PFC, primary fascial closure; PVH, planned ventral hernia. * For the PVH subgroup, in addition to *Me* [Q_1; Q_3], mean, minimum, and maximum values are provided owing to the small sample size.

Table 4. Age and clinical parameters of group 2 patients subdivided by outcome, *Me* [Q_1; Q_3]

Parameter	Subgroup		p, PVH vs PFC
	PVH*, n=42 (71%)	PFC, n=17 (29%)	
Age, years	31.5 [26; 35.25]; 20, 48	32 [24.5; 40]; 21, 50	= 0.801
Length of stay, bed days	15.5 [7.75; 32.75]; 2, 112	7 [5; 12.5]; 2, 33	= 0.008
Interval from injury to first relaparotomy with VALS, days	6 [4; 8.25]; 2, 25	5 [3; 9.5]; 2, 12	= 0.200
SOFA score at the first relaparotomy with VALS	2 [0.75; 3.25]; 0. 12	2 [0.5; 4]; 0, 10	= 0.696
Number of relaparotomies with VALS	6 [3; 12.5]; 1, 25	3 [1.5; 3]; 1, 9	< 0.001
Интервал времени между релапаротомиями с ВАЛС, ч	56.4 [48; 64.575]; 24, 128	60 [48; 66]; 43.2, 96	= 0.826
Длительность ведения «открытого живота», сут	16.5 [8.75; 32.25]; 2, 79	7 [3.5; 10]; 1, 23	< 0.001

* For the PVH subgroup, in addition to *Me* [Q_1; Q_3], mean, minimum, and maximum values are provided owing to the small sample size.

Table 5. Predictive model for primary fascial closure in group 2 patients

Predictor	Regression coefficient, p	p =	OR	95% CI for OR
SOFA score at the first relaparotomy with VALS	0.310	0.042	1.364	1.011–1.841
Duration of open abdomen management	–0.202	0.007	0.817	0.706–0.945
Constant	0.662	0.305	1.939	–

Note (applies to all tables): OR, odds ratio; CI, confidence interval.

Table 6. Predictive model for IHM in group 2 patients

Predictor	Regression coefficient	*p*	OR	95% CI for OR
Age	0.142	0.010	1.153	1.035–1.284
Length of stay	–0.079	0.008	0.924	0.871–0.980
SOFA score at the first relaparotomy with VALS	0.597	0.002	1.817	1.255–2.632
Interval between relaparotomies with VALS	–0.068	0.040	0.934	0.876–0.997
Constant	–3.429	0.182	0.032	–

the possibility of IHM. The predictor SOFA score at the first relaparotomy with VALS was significantly associated with an increased probability of IHM (OR = 1.817; 95% CI: 1.255–2.632; $p = 0.002$). An increase in this predictor value increased the likelihood of IHM. The predictor interval between relaparotomies with VALS was significantly associated with a decreased probability of IHM (OR = 0.934; 95% CI: 0.876–0.997; $p = 0.040$). An increase in this predictor value decreased the likelihood of IHM. The AUC value was 0.943 units (95% CI: 0.895–0.991), showing good predictive ability of the model for IHM (Fig. 3).

The Hosmer–Lemeshow test determined that the model demonstrated good fit with the data ($\chi^2 = 3.937$; $p = 0.863$). The Nagelkerke R^2 coefficient indicated that the model accounted for 70.4% of the variance in the dependent variable (IHM).

During treatment, two patients developed small bowel fistulas and one patient had an intra-abdominal abscess.

It was found that the length of stay of the group 1 patients in the SD was longer than that of the group 2 patients, as patients from the ICU were transferred to other departments after stabilization, whereas most patients in the SD, after DAC, required further surgical procedures in other anatomical regions. The higher frequency of PFC in group 1 was predictable and possibly due to the greater severity of patients treated in the ICU.

The predictive model for group 2 demonstrated the effectiveness of the predictor duration of OA management in determining the outcome: the longer the laparotomy wound remained unclosed, the lower the probability of achieving PFC. An increase in OA approach duration by 1 day decreased the probability of PFC by 18%. This can be explained by the progressive lateralization of fascial structures of the unclosed laparotomy wound [6, 7]. Moreover, a consistent difference was observed in interrelated parameters such as the number of VALS and duration of OA management between

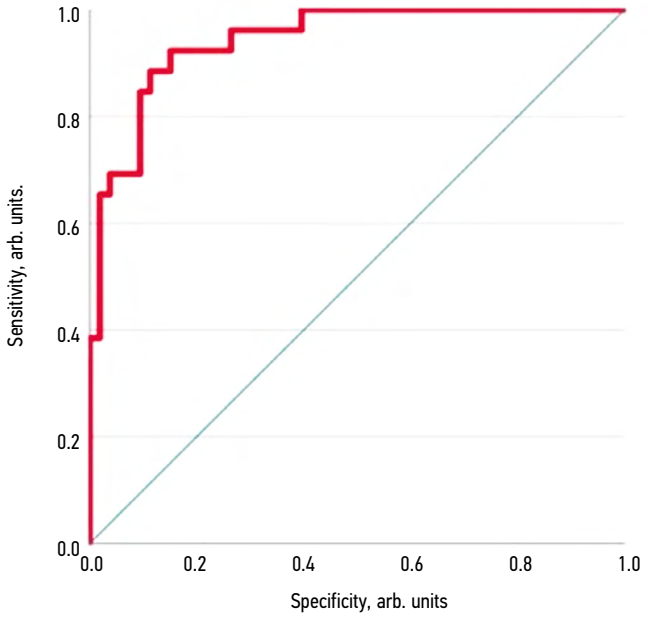


Fig. 3. ROC curve for the predictive model of in-hospital mortality in group 2 patients.

the subgroups in group 2 (Table 4). Notably, the length of ICU stay in the PFC subgroup was significantly shorter.

The conclusion that an increase in the predictor SOFA score at the first relaparotomy with VALS significantly increased the probability of achieving PFC is difficult to interpret. This result may be because of the small sample size of the PFC subgroup in group 2 ($n = 17$). Additional studies are required to confirm or refute this finding. The inefficacy of such a crucial parameter as the interval between relaparotomies with VALS as a predictor of PFC in group 2 is explained by the fact that most patients underwent staged relaparotomies with VALS at a similar frequency: the interquartile time intervals were [48; 66] h (PFC) and [48; 64.5] h (PVH).

The results for group 3 are noteworthy. In these patients, the interval between surgical interventions was significantly shorter. A decrease in this parameter was considered a predictor of IHM. It was noted that the group 3 patients required shorter intervals between relaparotomies to ensure more effective control of the peritonitis source, evacuation of pathological abdominal effusion, and improvement of abdominal sepsis manifestations. Nevertheless, in this group, the severity of multiple-organ failure (*Me* SOFA score at the initiation of the OA approach: 7.5 points) was the decisive factor underlying the high IHM rate (32%).

The length of stay parameter, despite reaching statistical significance, is not a significant predictor of IHM. Rather, it indicates that death occurred earlier than the median ICU stay duration. The predictive value of parameters such as patient age and SOFA score at the first vacuum-assisted relaparotomy was also consistent. An increase in age by 1 year increased the probability of IHM by 15%, whereas a 1-point increase in SOFA score (at the initiation of the OA approach) increased it by 82%. A similar result was reported in a study by Cristaudo et al. [13], wherein the effectiveness of patient age and the Acute Physiology and Chronic Health Evaluation II score was demonstrated as predictors of IHM.

The results of the present study are consistent with international research on the use of the OA approach. Review of the scientific data showed that the probability of achieving PFC decreases with increasing OA approach duration and the number of relaparotomies performed [14–16]. According to other studies [17–19], the incidence of complications (intra-abdominal abscesses and hollow-organ fistulas) is directly proportional to the duration of the OA approach. The optimal frequency of staged relaparotomies is equally important to achieve PFC. International studies emphasized the importance of standardizing the OA approach with VALS, recommending a time interval of 24–72 h between relaparotomies [2, 20], which aligns with the findings of the present study.

A limitation of the present study may be its design, as it is cohort-based and clinical, which carries a risk of bias due to objective or subjective factors. Additionally, it should be noted that surgical interventions were performed by different surgical teams, which may account for certain variations in the technical aspects of VALS application during the OA approach. The small sample size in certain subgroups influenced the accuracy of the statistical methods used in the study. Furthermore, this study analyzed the outcomes of patients with peritonitis caused by abdominal gunshot wounds. This does not allow extrapolation of the findings to patients with peritonitis caused by inflammatory diseases of the abdominal organs.

CONCLUSION

Layered abdominal closure is the final stage of effective OA approach. Its achievement depends, among other factors, on the appropriate choice of TAC technique. The study results indicate that the optimal method of TAC is VALS. Comprehensive analysis of VALS outcomes in patients with penetrating abdominal gunshot wounds complicated by peritonitis who were treated in the ICU revealed that patient age and SOFA score (at the first relaparotomy with VALS) are predictors of IHM.

It was established that decreasing the duration of the OA approach increases the likelihood of PGC, and this may be considered a predictor of achieving layered abdominal closure. It is also critical to note that ICU stay, the number of relaparotomies, and consequently the duration of the AO approach were significantly decreased in patients who achieved PFC than in those in whom fascial closure could not be achieved.

ADDITIONAL INFORMATION

Authors' contribution: A.A. Pichugin: development of a general concept, data analysis, writing an article; T.A. Isaev: research design, collection of material, analysis and statistical processing of data, literature review, writing an article; V.Y. Markevich: development of a general concept, data analysis; V.V. Suvorov: literature review, writing an article; V.I. Badalov: data analysis; A.V. Goncharov: data analysis, writing an article; I.M. Samokhvalov: research design, literature review, data analysis. The authors have approved the version for publication and have also agreed to be responsible for all aspects of the work, ensuring that issues relating to the accuracy and integrity of any part of it are properly considered and addressed.

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ДОПОЛНИТЕЛЬНАЯ ИНФОРМАЦИЯ

Вклад авторов. А.А. Пичугин — разработка общей концепции, анализ данных, написание статьи; Т.А. Исаев — дизайн исследования, сбор материала, анализ и статистическая обработка данных, обзор литературы, написание статьи; В.Ю. Маркевич — разработка общей концепции, анализ данных; В.В. Суворов — обзор литературы, написание статьи; В.И. Бадалов — анализ данных; А.В. Гончаров — анализ данных, написание статьи; И.М. Самохвалов — дизайн исследования, обзор литературы, анализ данных. Авторы одобрили версию для публикации, а также согласились нести ответственность за все аспекты работы, гарантируя надлежащее рассмотрение и решение вопросов, связанных с точностью и добросовестностью любой ее части.

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Оригинальность. При создании настоящей работы авторы не использовали ранее опубликованные сведения (текст, иллюстрации, данные). Доступ к данным. Все данные, полученные в настоящем исследовании, доступны в статье.

Генеративный искусственный интеллект. При создании настоящей статьи технологии генеративного искусственного интеллекта не использовали.

Рассмотрение и рецензирование. Настоящая работа подана в журнал в инициативном порядке и рассмотрена по обычной процедуре. В рецензировании участвовали два рецензента: внутренний и внешний.

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