

ORIGINAL ARTICLE

SURGICAL TREATMENT OF ACUTE SMALL BOWEL OBSTRUCTION: CLINICAL AND LABORATORY PARAMETERS ASSOCIATED WITH STRANGULATION AND EARLY MORTALITY AFTER SURGERY

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ABSTRACT
The aim: The study aimed to evaluate some criteria for preoperative diagnosis of strangulation and significant indicators of the prognosis of short-term outcomes in patients with small bowel obstruction.
Materials and methods: The results of the treatment of 123 patients aged 18–70 years with SBO were evaluated.
Results: All of these patients underwent emergency surgery, and 22 patients (17.9%) have died. It has been shown that four lab parameters (blood leukocytes, lactate, intestinal fatty acid-binding protein, and C-reactive protein levels) and one instrumental (involving the mesentery of the small intestine, free fluid in the abdomen during CT) with 80% probability or more were associated with the strangulation type of SBO (Λ=0.276, p = 0.000). Three lab indicators (WBC count, serum lactate, and intestinal fatty acid-binding protein levels) and two clinical parameters (abdominal perfusion pressure level and the presence of abdominal sepsis) were associated with early mortality after surgery (Λ=0.626, p = 0.000) with the same probability. Immediate results of the treatment in these patients depended on the development of intra-abdominal complications after surgery (P = 0.024) and the need for early reoperation (P = 0.006) as well as the development of cardiovascular dysfunction (P = 0.000) and respiratory dysfunction (P = 0.000).
Conclusions: There were confirmed parameters that were significantly associated with strangulation before surgery and short-term in-hospital mortality with an 80% probability or more. This made it possible to develop new mathematical models for the diagnosis of strangulated bowel obstruction and early postoperative mortality with an accuracy of 84.5% and 84.2%, respectively.

KEY WORDS: diagnosis, prognosis, surgical treatment, strangulation, mortality, acute obstruction of the small intestine

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INTRODUCTION
Despite advances in medicine, acute small bowel injury in patients with small bowel obstruction (SBO) remains one of the most difficult problems in emergency abdominal surgery. Most studies have shown that this is a heterogeneous syndrome caused by an unbalanced host response to ischemia/necrosis of the small intestine and infection, which leads to organ dysfunction, and its main manifestations are characteristic both for patients with acute adhesive intestinal obstruction and for patients with acute occlusive or, in rare cases, non-occlusive ischemia In all these cases, ischemia, necrosis, and perforation of the intestinal wall due to vascular compromise in the loop of the small intestine can be observed [1,2]. At least 300,000 surgical procedures are performed annually in the United States [3], and about 40% of cases are associated with small bowel strangulation. Meanwhile, nonviable asphyxia of the small intestine is about 16% of the SBO, which four times increases the risk of death compared to the rates in patients with viable asphyxia [4], and in patients with impaired SBO, the mortality rate is 2–10 times higher than in patients with simple SBO [5]. In addition to the well-known scores of severity [6,7], a lot of laboratory indicators [8, 9] are used for earlier diagnosis and detection of complications associated with hypoxia, ischemia, and necrosis of the small intestine in these patients [10–13]. It should be noted, however, that it is often difficult to objectively predict the severity of a patient's condition based on prior information obtained from initial contact with a patient in the emergency department during the initial treatment phase before and after surgery.

In recent years, several serum markers have been identified that can be detected in SBO. One of them includes factors released by damaged enterocytes, such as intestinal fatty acid-binding protein (I-FABP) as known that enterocytes are rapidly damaged in the early stages in critical patients and its biomarker can be easily detected in both urine and plasma. It opens up promising opportunities for the use of I-FABP as a biomarker for early detection of injury of the small intestine including small bowel strangulation

[14,15]. Accordingly, such an indicator could be considered as an indicator of intoxication syndrome and used together with the definition of markers of pro-inflammatory and hypoxia status (C-reactive protein, serum lactate, etc.) to diagnose and assess the treatment of patients.

THE AIM

The study aimed to evaluate some criteria for preoperative diagnosis of strangulation and significant indicators of the prognosis of short-term outcomes in patients with small bowel obstruction.

MATERIALS AND METHODS

PATIENT CHARACTERISTICS AND RESEARCH METHODS

A two-centre retrospective study was conducted at Kharkiv National Medical University, which involved 123 patients aged 18 to 70 years, hospitalized in the intensive care unit in the immediate postoperative period. The study was conducted from September 1, 2014, to November 30, 2021, with the approval of the University Ethics Committee (protocol No. 3, September 20, 2021).

INCLUSION CRITERIA

The study included men and women who were admitted to the hospital with SBO. Based on some of the clinical data, the inclusion criteria for patients with SBO met one of the following conditions: simple abdominal radiograph or abdominal ultrasound showing certain multiple air-liquid levels in the small intestine, but no evidence of gas in the colon in it; X-ray and/or computed tomography (CT) of the abdomen, indicating SBO; confirmation of SBO during laparotomy or laparoscopy.

EXCLUSION CRITERIA

Patients with an inguinal hernia, mechanical obstruction of the colon, and early postoperative SBO less than 30 days after abdominal surgery; patients with ascites; comorbidity with acute myocardial infarction and stroke; severe acute pancreatitis with small bowel obstruction or necrosis; post-resuscitation disease due to the arrest of effective blood circulation and refractory shock; pregnancy; history of cancer.

When examining patients, the following data were collected: personal data (age, gender, previous operations on the abdominal organs and abdominal trauma); body mass index (BMI); laboratory examination: peripheral blood leukocyte count, platelets, hematocrit, D-dimer, lactate, C-reactive protein; in the dynamics of patient treatment, systolic blood pressure (SBP) was monitored and the following scores were calculated for each patient: Acute Physiology and Chronic Health Evaluation (APACHE) II, Sequential Organ Failure Assessment (SOFA); the level of I-FABP was determined using commercial kits "I-FABP, Human, ELISA kit"; data on the nature of the treatment and complications were collected and the results were assessed: short-term mortality up to 3-7 days and mortality within 30 days after surgery. To determine the level of intra-abdominal hypertension, we used the classification of the World Society of Abdominal Compartment Syndrome (WSACS, 2007) with the calculation of the abdominal perfusion pressure (APP). Patients were screened for IAH (defined as IAP≥12 mmHg) with the Foley-Manometer method (Denmark). The WSACS classification was used to assess the level of IAH with the classification of its according to the developed recommendations**:** I degree IAP registered at IAH 12-15 mm Hg; II degree – at 16-20 mm Hg; III degree – at 21-25 mm; IV degree - > 25 mm Hg.

The CT parameters included: a decrease in the density of the intestinal wall, dilatation of the small intestine; the large wall of the small intestine; involvement of the mesentery in the form of its thickening; free fluid in the abdominal cavity; air/fluid level in the small intestine; and volvulus. For the diagnosis, laboratory parameters were taken into account in two clinical categories: patients with reversible ischemia of the small intestine who underwent emergency laparoscopy or laparotomy, and patients with irreversible ischemia of the small intestine who underwent urgent laparotomy, which required resection of the small intestine, and for the prognosis, laboratory parameters were also taken into account for the prognostic indicators of short-term in-hospital mortality.

All patients were divided into two groups depending on the results of treatment: the first included patients with a positive outcome (survivors, n = 101), the second, those with an unfavourable outcome (non-survivors, n = 22).

Using it in the clinical setting, we took into account the existing WSES recommendations for this category of patients, taking into account local conditions and opportunities [16,17].

STATISTICAL ANALYSIS

Initially, statistical analyses were performed using descriptive statistics. A comparison of data from survivors and non-survivor patients was analyzed using the normality of distributions (Shapiro-Wilk's test) of the selected indicators. Continuous data were presented as mean and standard deviation (M±SD). At a significance level of $p > 0.05$, zero hypotheses (H0) in statistical tests were rejected. Odds ratio (OR) and discriminant analysis of the parameters were used to identify risk factors for the development of strangulation of the small intestine before surgery and an unfavourable outcome of the treatment in the early stages. After studying of odds ratio for all the indicators that were researched, those that had a probability of 80% or more in the preliminary distribution were taken into account for further construction of mathematical models. Statistical analysis was performed using the STATISTICA 13.3 EN software.

RESULTS

CHARACTERISTICS OF THE PATIENTS

A total of 123 patients were recruited, and all of them met the inclusion criteria. The patients' characteristics are shown in Table I.

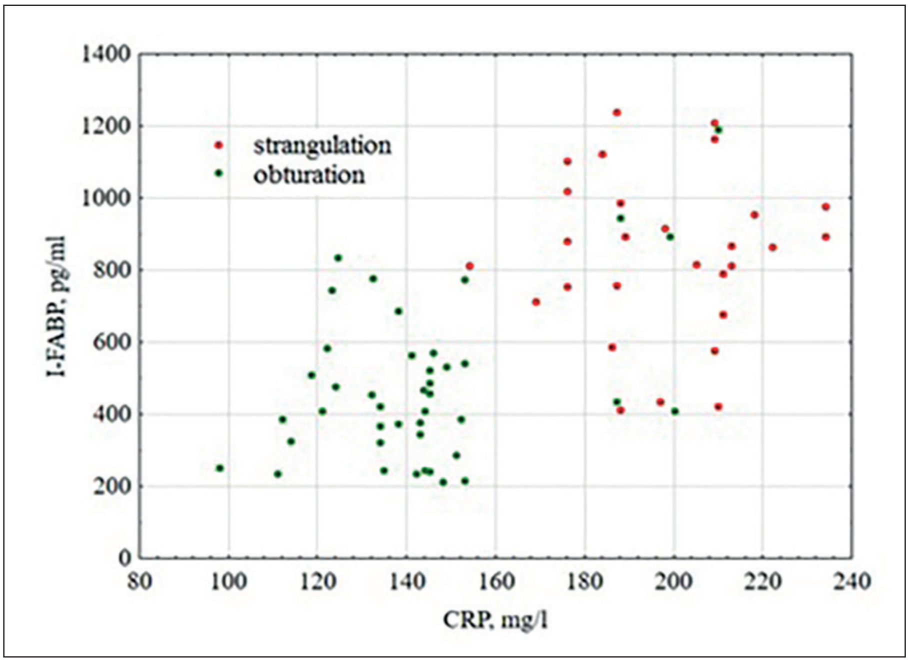

Fig. 1. A scattering graph for CRP and I-FABR indicators in patients with SBO

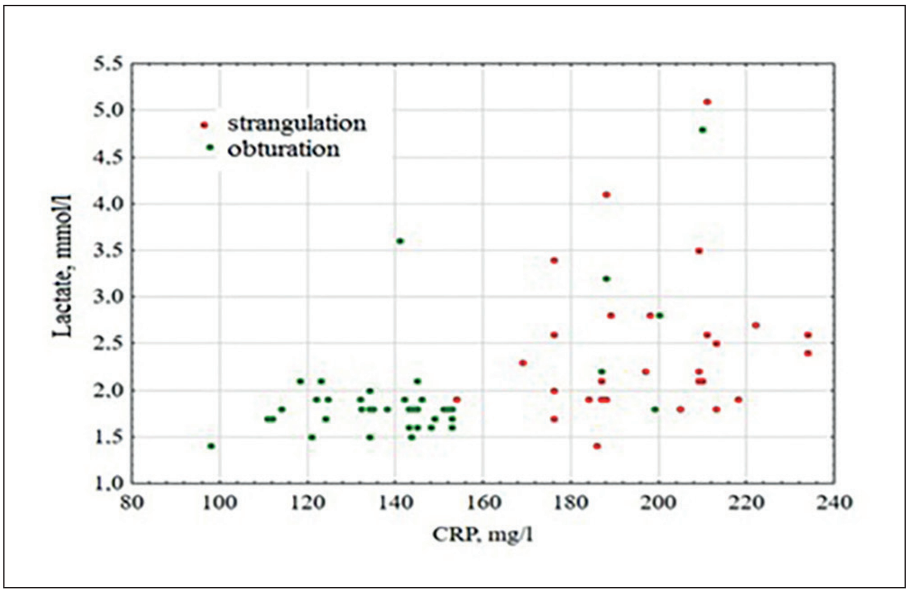

Fig. 2. A scattering graph for CRP and serum lactate indicators in patients with SBO

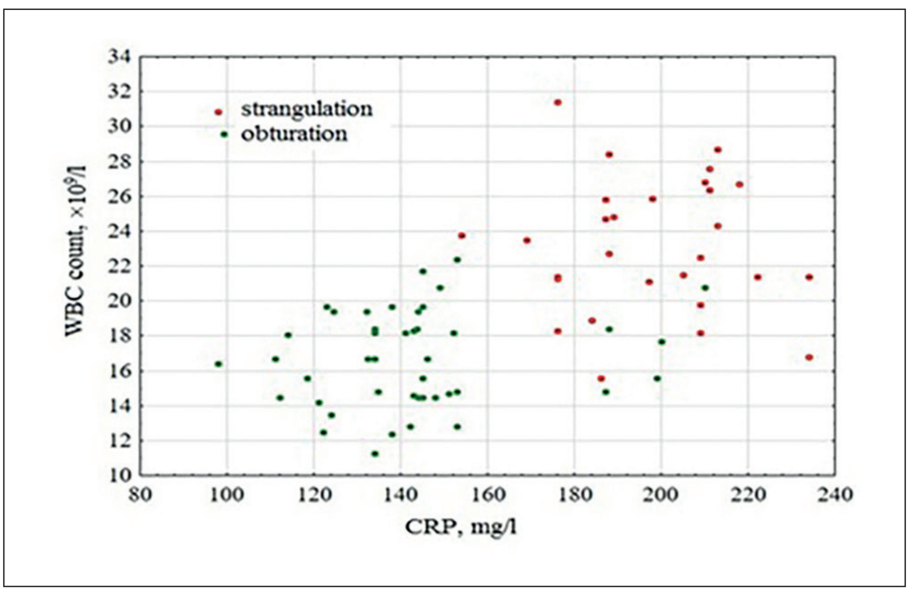

Fig. 3. A scattering graph for CRP and white blood cells indicators in patients with SBO

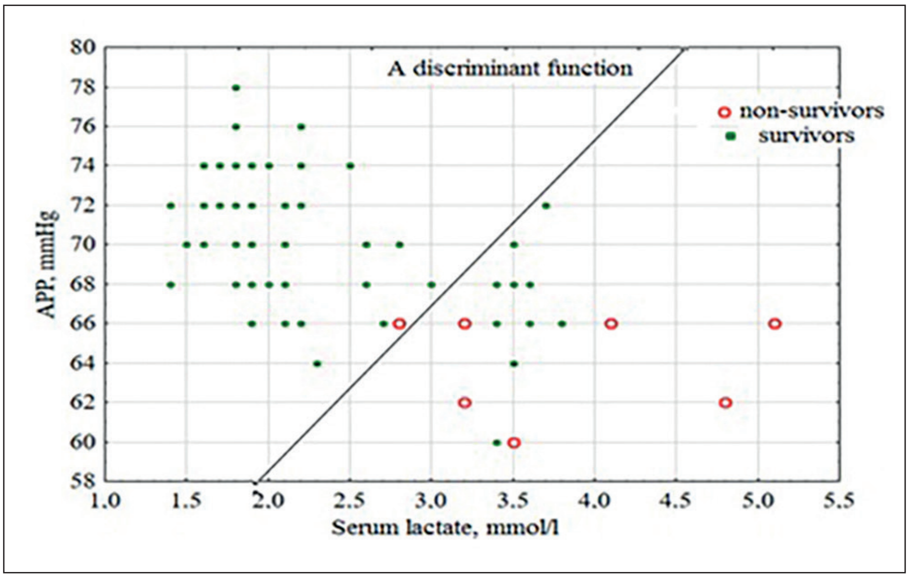

Fig. 4. A scattering graph for serum lactate and APP indicators in patients with SBO and early in-hospital mortality

Table I. Patients' characteristics and surgical data

Indicators	Outcomes		P-value
	Survivors (n = 101)	Non-survivors (n = 22)	
Years	56.43±11.19	51.59±6.23	0.052
Sex *: - men - women	 44 (43.6%) 57 (56.4%)	 13 (59.1%) 9 (40.9%)	0.417
BMI, kg/m2	26.2±5.08	28.14±3.12	0.088
Respiratory rate beats/min	18.88±2.59	25.05±2.61	0.000
Hypotension at diagnosis (SAP < 90 mm Hg), (%) * Fluid resuscitation before surgery, (%) * Vasopressors before surgery, (%) *	12 (11.9%) 101 (100%) 5 (4.95%)	15 (68.2%) 22 (100%) 14 (63.6%)	0.000 0.868 0.000
Surgical approach, (%) *: - laparoscopic - laparotomy - laparoscopy + laparotomy	 8 (13.6%) 87 (76.3%) 6 (10.1%)	 0 20 (83.3%) 2 (16.7%)	0.000
Type of surgery, (%): - adhesiolysis, NIT, drainage - small bowel resection, NIT, anastomosis - small bowel resection, stoma formation	 58 (57.4%) 15 (14.9%) 28 (27.7%)	 16 (72.7%) 1 (4.6%) 5 (22.7%)	0.309
Operation time (min)	146.5±17.65	137.7±18.43	0.038
The amount of intraoperative fluid administration, (mL)	2365.5±311.8	2980.9±286.5	0.000
Intra-abdominal complications, (%) *	26 (25.7%)	15 (68.2%)	0.024
Re-laparoscopy or re-laparotomy, (%) *	4 (4%)	6 (27.3%)	0.006
Cardiovascular dysfunction, (%) *	7 (6.9%)	14 (63.6%)	0.000
Respiratory dysfunction, (%) *	7 (6.9%)	18 (81.8%)	0.000
Length of hospital stay (days),	13.46±5.2	5.5±4.4	0.000

Abbreviations: Values are presented as mean ± SD; P-value - Student's criterion; * Statistically significant difference by criterion $\chi 2$; NA - not applicable; BMI - body mass index; NIT - nasal-intestinal tube.

During the study period, all of these patients underwent emergency surgery operations for SBO: the adhesive disease was the main cause in 101 (82.1%) patients with SBO, obstruction of the small intestine by gallstones was in 2 (1.6%), and volvulus was the cause in 20 (16.3%) patients. 14 (11.4%) patients had high SBO. There were 49 (39.8%) patients with irreversible ischemia; generalized peritonitis was present in 24 (19.5%) patients, of which 18 (75%) had abdominal sepsis according

Table II. Laboratory findings in the types of SBO and patients' severity assessment by outcomes

Indicators	Before surgery		P - value	Before surgery		P - value
	Patients with a viable small intestine (n = 74)	Irreversible ischemia of the small intestine (n = 49)		Survivors (n = 101)	Non-survivors (n = 22)	
WBC count (×109/l)	14.56±3.92	20.95±4.09	0.000	16.78±4.15	22.74±5.77	0.000
	95% CI: –7.844 to –4.936			95% CI: –8.044 to –3.876		
Haemoglobin (g/L)	154.6±8.09	156.7±4.37	0.099	146.8±9.56	151.4±8.11	0.038
	95% CI: –4.601 to 0.4014			95% CI: –8.943 to –0.2567		
Platelets (×109/l)	218.1±77.72	236.6±48.18	0.140	223.3±98.7	237.5±97.8	0.541
	95% CI: –43.14 to 6.136			95% CI: –60.1 to 31.7		
Hematocrit (%)	58.74±8.6	59.58±9.2	0.448	49.2±5.4	56.6±3.9	0.000
	95% CI: –4.464 to 1.884			95% CI: –9.809 to –4.991		
D-dimer (ng/mL)	253.6±51.51	264.3±52.75	0.266	238.9±63.47	262.3±61.32	0.118
	95% CI: –29.66 to 8.263			95% CI: –52.79 to 5.993		
Lactate (mmol/l)	1.54±0.78	2.32±0.52	0.000	1.81±0.43	2.53±0.76	0.000
	95% CI: –1.031 to –0.5289			95% CI: –0.9543 to –0.4857		
CRP (mg/l)	139.6±31.34	189.6±24.33	0.000	145.8±42.12	204.7±32.21	0.000
	95% CI: –60.49 to –39.51			95% CI: –77.8 –40		
I-FABP, pg/mL	276.2±61.86	881.8±179.3	0.000	486.2±248.7	762.2±270.5	0.000
	95% CI: –624 to –587.2			95% CI: –393.7 to –158.3		
SBP (mm Hg)	128.6±13.23	122.4±21.55	0.055	124.2±14.18	88.4±15.23	0.000
	95% CI: –0.007532 to 12.41			95% CI: 29.1 to 42.5		
APP (mm Hg)	73.31±4.85	72.29±5.61	0.286	72.84±2.92	65.51±3.08	0.000
	95% CI: –0.8633 to 2.903			95% CI: 5.957 to 8.703		
APACHE II score	11.14±3.16	12.54±4.67	0.044	10.76±4.23	14.22±5.56	0.000
	95% CI: –2.762 to –0.03809			95% CI: –7.551 to –3.369		
SOFA score	8.21±1.58	8.96±1.87	0.018	7.34±1.78	9.92±1.72	0.000
	95% CI: –1.37 to –0.1298			95% CI: –3.404 to –1.756		
AGI grade	1.81±0.5	2.07±0.7	0.018	1.73±0.55	2.67±0.19	0.000
	95% CI: –0.4742 to –0.04576			95% CI: –1.176 to –0.7042		

Abbreviations: Values are presented as mean ± SD; P - Student's criterion; CRP – C-reactive protein; SBP - systolic blood pressure; APP – abdominal perfusion pressure; AGI - acute digestive injury; 95% CI - 95% confidence interval for the difference.

to Sepsis-3 criteria. After the operation, 22 patients (17.9%) died: in the early stages (the first 72 hours), 17 patients (77.3%) and the rest (22.7%) up to 30 days of the postoperative period.

LABORATORY RESEARCH

INITIAL CHARACTERISTICS

The results of the distribution of patients by changes in laboratory data and severity depending on the outcome are presented in Table II.

As it follows from the data presented in Table II, the laboratory data of patients with strangulation SBO and non-survivors patients differed significantly from those of patients with obstructive SBO and survivors in many parameters before surgery.

An analysis of the OR and probability of signs in patients with strangulation SBO before surgery showed (Table III) that the correspondence of both of these indicators to the level of 80% and above was shown by the following data before surgery: WBC count (81.2%), lactate (80.1%), CRP (81.7%) and I-FABP (82.4%) levels, and CT data indicating the presence of such signs as mesenteric involvement of the small intestine and free fluid in the abdomen (84.1%).

DISCRIMINANT ANALYSIS OF SEVERAL BIOMARKERS FOR DIFFERENTIAL DIAGNOSIS OF OBTURATION AND STRANGULATION

For two types of SBO (obturation and strangulation) the task was to determine one canonical root (canonical discriminant function), which divides the n-dimensional

Table III. Analysis of the odds ratio and probability of signs for patients with strangulation SBO before surgery

Variables	Odds Ratio (95% CI)	Probability (%)	χ2	P-value
WBC count	4.301 (1.921 – 9.505)	81.2	11.48	0.0007
Haemoglobin	1.136 (0.517 – 3.848)	53.2	0.11	0.074
Hematocrit	2.084 (1.016 – 4.544)	67.7	2.76	0.0965
D-dimer	2.153 (1.036 – 7.424)	68.3	3.05	0.0807
Lactate	4.022 (1.814–8.918)	80.1	10.49	0.0012
CRP	4.451 (2.038–9.943)	81.7	12.01	0.0005
I-FABP	4.673 (2.007 – 10.815)	82.4	11.45	0.0007
SBP	2.182 (1.016–4.543)	68.6	3.20	0.0738
APP	2.054 (0.932 – 9.025)	67.2	2.62	0.1054
APACHE II score	1.841 (0.812–4.524)	64.8	1.29	0.2567
SOFA score	2.143 (0.923–5.115)	68.2	7.33	0.1348
AGI grade	2.543 (1.221–75.517)	71.8	4.89	0.0270
Signs of peritonitis	2.213 (1.012–4.813)	68.9	3.34	0.0674
CT: mesenteric involvement, free fluid in the abdomen	5.283 (2.449–11.811)	84.1	14.71	0.0001

Table IV. Analysis of the odds ratio and probability of early in-hospital mortality for patients with SBO before surgery

Variables	Odds Ratio (95% CI)	Probability (%)	χ2	P-value
WBC count	3.321 (1.521 – 7.505)	76,9	7.19	0.0088
Haemoglobin	1.563 (0.624 – 3.943)	60.9	0.53	0.4665
Hematocrit	1.252 (0.522 – 3.213)	55.6	0.05	0.8280
D-dimer	1.874 (0.842 – 4.535)	65.2	1.37	0.2419
Lactate	4.362 (2.014–9.618)	81.3	11.89	0.0006
CRP	3.531 (1.638–8.0341)	77.9	8.12	0.0044
I-FABP	5.614 (2.124 – 14.732)	83.6	10.66	0.0011
SBP	3.153 (1.316–7.643)	75.9	5.43	0.0198
APP	4.552 (2.031 –10.153)	82	11.20	0.0008
APACHE II score	3.451 (1.612–7.644)	77.5	8.44	0.0037
SOFA score	4.183 (1.923–9.015)	80.7	11.97	0.0005
AGI grade	2.733 (1.218–6.117)	73.2	5.02	0.0250
The presence of abdominal sepsis	4.453 (2.149–9.611)	81.9	13.31	0.0003

Table V. Matrix of the factor structure of indicators for diagnosis of strangulation of the small intestine

Indicators	Canonical correlation
CRP (mg/l)	–0.751
WBC count (×109/l)	–0.619
I-FABP, pg/mL	–0.508
Lactate (mmol/l)	–0.217

space of indicators into two areas corresponding to different types of disease. The selection of indicators for the discriminant function was carried out sequentially after determining the OR of these indicators at the level of 80% and more of its probability. The statistical significance of the obtained discriminant function was estimated based on Wilk's Λ-statistics and was $\Lambda = 0.276$ at $\chi2 = 86.24$ ($p <= 0.000$). Thus, a discriminant function was obtained that contained four indicators: CRP, WBC, lactate and serum I-FABR. The contribution of each indicator to discrimination and the division of patients by SBO types was judged by the contribution of each indicator that correlated with the discriminant function. As can be seen from the factor structure matrix (Table V), serum lactate played the least role in the discrimination.

The classification of patients according to SBO types was performed using the classification functions 'F obturation' and 'F strangulation'. The patient belonged to the type whose classification function was greater:

F obturation $= -32.89 + 0.29X_1 + 1.55X_2 - 0.72X_3 - 0.0027X_4$;

Table VI. The matrix of a posteriori classification for patients with different types of SBO

The groups of the patients with SBO	Shown the rows: the groups that were observed Shown the columns: the groups that were predicted		
	Percentage of correct observations	Obturation	Strangulation
Obturation	83.7%	36	7
Strangulation	85.7%	4	24
Total	84.5%	40	31

Table VII. Matrix of the factor structure of indicators for prognosis of early in-hospital mortality

Indicators	Canonical correlation
Lactate (mmol/l)	0.925
APP (mmHg)	–0.74

F strangulation = $-63.23 + 0.4\ X_1 + 2.13X_2 - 2.29X_3 + 0.0018X_4$,

Note: X_1 – CRP, mg/l; X_2 – WBC, $\times 10^9$/l; X_3 - lactate serum, mmol/l; X_4 - I-FABR serum, pg/mL.

To simplify the calculations for the two types of SBO, it is possible not to compare the values of F obturation with F strangulation and it is necessary to consider their difference: ΔF = F obturation – F strangulation. In this case, if DF ≥ 0, the patient is classified as a patient with obturation, and if DF < 0 the patient is classified as strangulation type SBO:

ΔF = F obturation – F strangulation = $30.35 - 0.11X_1 - 0.58X_2 + 1.56X_3 - 0.0045X_4$

A clear idea of the quality of discrimination can be obtained from scatter plots projected on the planes of CRP and I-FABR (Fig 1), CRP and serum lactate (Fig 2), CRP and white blood cells (Fig 3).

As shown in table 6, the accuracy of the a posteriori classification was 84.5% in this mathematical model, which for the statistical significance of the discriminant function indicates the adequacy of the constructed model.

DISCRIMINANT ANALYSIS OF SEVERAL BIOMARKERS FOR PREDICTING EARLY MORTALITY

The statistical significance of the obtained discriminant function was estimated based on Wilk's Λ-statistics and was $\Lambda = 0.626$ at $\chi 2 = 20.31$ ($p = 0.000$). The obtained discriminant function contained only two indicators: serum lactate and abdominal perfusion pressure. Therefore, the so-called hyperplane, which divides the n-dimensional space of indicators into two areas and is built using a discriminant function, is transformed into a line on the plane of indicators of serum lactate and APP. It is shown in the scattering graph of these indicators in patients with SBO and early in-hospital mortality (Fig 4). The contribution of each of these indicators to discrimination and patient selection based on treatment outcomes can be judged by the magnitude of the canonical correlation and how the selected indicators correlate with the discriminant function can be seen from the matrix of factor structure (Table VII). It was shown that the contribution to discrimination based on survivors' or non-survivors' status in serum lactate and APP was approximately the same.

The resulting classification functions «**F non-survivors**» and «**F survivors**» were used to predict the outcome of the operation for up to 72 hours. The patient was related to the outcome of treatment after surgery, whose classification function was greater:

F non-survivors = $-308.72 + 24.76X_1 + 8.15X_2$;

F survivors = $-322.42 + 22X_1 + 8.48X_2$,

Note X_1 - Serum lactate, mmol/l, X_2 – APP, mmHg.

When we also considered only two groups (non-survivors - survivors) for simplicity, we can not compare F survivors and F non-survivors, and consider their difference: ΔF = F survivors - F non-survivors. If ΔF ≥ 0, the patient is classified as a survivor; if ΔF < 0 the patient belongs to the group of patients who died.

ΔF = F survivors – F non-survivors = $13.7 - 2.76X_1 + 0.33X_2$.

A clear idea of the quality of discrimination can be obtained from the scatter plots of serum lactate and APP, where the discriminant function is shown in a straight line (Fig 6). The same accuracy of the discriminant model is obtained when using the classification functions 'F non-survivors' and 'F survivors' to predict the outcome of treatment. This is the so-called a posteriori classification when the result is considered unknown and is predicted using the functions «F non-survivors» and «F survivors» (Table VIII). As can be seen from Table 8, the accuracy of the a posteriori classification was 84.2%, which together with the statistical significance of the discriminant function indicates the adequacy of the constructed model.

Table VIII. The matrix of a posteriori classification for the patients with different outcomes of the treatment

The groups of the patients with SBO	Shown the rows: the groups that were observed Shown the columns: the groups that were predicted		
	Percentage of correct observations	Obturation	Strangulation
Non-survivors	85.5%	6	1
Survivors	84.1%	10	54
Total	84.2%	16	55

DISCUSSION

Since SBO is a life-threatening disease, a timely and accurate diagnosis of strangulated obstruction of the small intestine is important as it often leads to ischemia with loss of plasma and the formation of a large number of toxic substances, sequestration of blood in a closed cycle causes an increase in intraluminal pressure, necrosis, and perforation of the intestine [16-17].

Our statistical analysis confirmed the following predictors of strangulation in SBO for laboratory findings before surgery: WBC, serum lactate, CRP, and I-FABP ($P = 0.000$). All these signs were present in 41 (83.7%) of 49 patients with irreversible ischemia of the small intestine before surgery ($P < 0.001$). The statistical significance of the obtained discriminant function was $\Lambda = 0.276$ at $\chi 2 = 86.24$ ($p < 0.000$). A discriminant function was obtained that contained four indicators: CRP, WBC, lactate, and serum I-FABR. Thus, the first mathematical modal was built, and the accuracy of the a posteriori classification was 84.5% in this mathematical model. In addition, the OR also confirmed that the following indicators are important predictors of early mortality: serum lactate, serum I-FABP, level of APP before surgery, and the presence of abdominal sepsis. All these indicators had a probability contribution to mortality of 80% or more. When conducting the discriminatory analysis, only two of these indicators were selected (serum lactate (its canonical correlation was 0.925) and APP (its canonical correlation was −0.74) for the mathematical model of mortality, and the accuracy of the a posteriori classification of this model was 84.2%.

As has been shown early in our studies, some biomarkers, such as lactate, fatty acid-binding protein (I-FABP), and others, can be used as possible markers to determine the severity of patients in urgently patients as had shown early in our studies [18-21]. As is known, the intestine plays a central role in the pathogenesis of MOF in SBO and other urgent surgical diseases, when against the background of a defect of all parts of the immune system is the penetration of bacteria and their toxins through the intestinal mucosa [22,23]. Hypoxia of the intestinal wall, activation of the different processes in the membrane structures of epitheliocytes, as well as suppression of immune reactivity, leads to transient bacteria in the blood and lymphatic system, which then causes increased vascular spasm, and subsequently stable dilatation [24,25]. Intestinal insufficiency, indeed, becomes the «motor» of the pathogenesis of many critical disorders, since there are many risk factors for mortality in SBO including early MOF, the use of vasopressors, mechanical ventilation, surgical stress, etc. As you know, the digestive tract function is very complex, many researchers complex, and to develop various assessment systems to assess its severity in the ICU. The AGI score, proposed by the ESICM working group (2012), which includes abdominal signs and symptoms, IAP scores, and organ function, is considered an important indicator for assessing AT function in ICU patients. This classification is now considered «classical» and accepted by various medical societies. The results obtained in this study showed that for such an indicator as AGI grade the OR was 2.543 with the probability of 71.8% of the development of strangulation SBO before surgery and OR was 2.733 with the probability of 73.2% of the development of the early mortality after surgery. Nonetheless, using such an objective biomarker of enterocyte damage, which is I-FABP, along with the presented indicators can be used to predict strangulation SBO before surgery according to the proposed model with a probability of 84.5%. It should be noted that with almost the same probability (84.2%) it is possible to predict early mortality after surgery using the level of lactate and abdominal perfusion pressure in our proposed mathematical model.

The indicators used for prognosis in this study are not unique and new, but they give us valuable information that must be taken into account when diagnosing and predicting mortality in this category of patients. As it was being, clinicians should take into account the variables that we have analyzed since none of them is specific enough individually, but they are useful in aggregate in the preoperative judgment about the patient [26,27].

CONCLUSIONS

The study confirmed that four lab parameters (blood leukocytes, lactate, intestinal fatty acid-binding protein, and C-reactive protein levels) and one instrumental (involving the mesentery of the small intestine, free fluid in the abdomen during CT) with an 80% probability or more were significantly associated with the strangulation type of SBO ($\Lambda = 0.276$ at $\chi 2 = 86.24$, $p = 0.000$), as well as three lab indicators (WBC count, serum lactate, intestinal fatty acid-binding protein levels) and two clinical parameters (abdominal perfusion pressure level, the presence of abdominal sepsis), was associated with short-term in-hospital mortality after surgery ($\Lambda = 0.626$ at $\chi 2 = 20.31$, $p = 0.000$) with the same probability. Using the proposed two mathematical models for the differential diagnosis of obstruction and strangulation of the small intestine suggests an earlier diagnosis and adequate surgical treatment that will reduce the incidence of irreversible vascular compromise in the intestine and the development of complications after surgery. Given the complexity and ambiguity of the problem, in the future, it is necessary to continue studying the laboratory and potential factors affecting the risk of intestinal strangulation and predict mortality in SBO in different age groups.

ABBREVIATIONS

95% CI - 95% confidence interval
AGI - Acute Gastrointestinal Injury grade
APACHE II - Acute Physiology and Chronic Health Evaluation score
APP - abdominal perfusion pressure
BMI - body mass index
CRP – C-reactive protein
CT - computed tomography

EI - endogenous intoxication
I-FABP - intestinal fatty acid-binding protein
OR - odds ratio
SBO - small bowel obstruction
SBP - systolic blood pressure
SOFA - Sequential Organ Failure Assessment

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