УДК 617.55-089-06:616.94]-037-036.88
https://doi.org/10.20538/1682-0363-2025-3-107-115

Early clinical and laboratory predictors of in-hospital mortality in patients with postoperative abdominal sepsis

Rodionova Yu.O., Fedosenko S.V., Ivanova A.I., Arzhanik M.B., Semenova O.L., Starovoitova E.A., Nesterovich S.V., Efimova D.A., Kalyuzhin V.V.

Siberian State Medical University of the Ministry of Health of the Russian Federation (SibSMU)
2 Moskovsky trakt, 634050 Tomsk, Russian Federation

ABSTRACT

Aim. To identify early clinical and laboratory predictors of death in patients with postoperative abdominal sepsis in the first 48 hours after its verification.

Materials and methods. A retrospective study was conducted on 40 patients with abdominal sepsis hospitalized in the surgical department of Siberian State Medical University in 2019–2023. All patients were divided into groups according to the outcome of hospitalization (discharge or death). Clinical and anamnestic data, Sequential Organ Failure Assessment (SOFA) and quick SOFA (qSOFA) scores, and dynamic changes in biochemical and hematological markers were evaluated (T1– at verification, T2 – after 48 hours). The Mann – Whitney *U* test, χ^2 test, Wilcoxon test, and ROC analysis were applied.

Results. The mortality rate was 45%. Statistically significant predictors of mortality were: SOFA score > 4, serum urea > 12.1 mmol / l, calcium ≤ 1.8 mmol / l, platelet count ≤ 264 × 10^9 / l, no platelet increase > 15 × 10^9 / l, neutrophil reactivity intensity (NEUT-RI) > 57.6 fluorescence intensity (FI) at T1 and > 53.8 FI at T2. Prognostic values were also established for reticulocyte parameters and reactive lymphocyte content.

Conclusion. Early assessment of clinical and laboratory parameters, especially indicators of kidney function, calcium metabolism, blood count, and the intensity of the inflammatory response, has high prognostic value in postoperative sepsis and can be used for risk stratification and optimization of therapy.

Keywords: sepsis, surgical sepsis, abdominal sepsis, fatal outcome, predictors of fatal outcome

Conflict of interest. The authors declare the absence of obvious or potential conflicts of interest related to the publication of this article.

Source of financing. The authors state that they received no funding for the study.

Conformity with the principles of ethics. The study was approved by the Ethics Committee at Siberian State Medical University (Minutes No. 8616/1 dated March 29, 2021).

For citation: Rodionova Yu.O., Fedosenko S.V., Ivanova A.I., Arzhanik M.B., Semenova O.L., Starovoitova E.A., Nesterovich S.V., Efimova D.A., Kalyuzhin V.V. Early clinical and laboratory predictors of in-hospital mortality in patients with postoperative abdominal sepsis. *Bulletin of Siberian Medicine.* 2025;24(3):107–115. https://doi.org/10.20538/1682-0363-2025-3-107-115.

✉ *Rodionova Yulia O.,* rodionova.yo@ssmu.ru

Ранние клинико-лабораторные предикторы госпитальной летальности у пациентов с хирургическим абдоминальным сепсисом

Родионова Ю.О., Федосенко С.В., Иванова А.И., Аржаник М.Б., Семенова О.Л., Старовойтова Е.А., Нестерович С.В., Ефимова Д.А., Калюжин В.В.

Сибирский государственный медицинский университет (СибГМУ)
Россия, 634050, г. Томск, Московский тракт, 2

РЕЗЮМЕ

Цель исследования. Идентификация ранних клинико-лабораторных предикторов летального исхода у пациентов с хирургическим абдоминальным сепсисом в первые 48 ч от момента верификации состояния.

Материалы и методы. Проведено ретроспективное исследование 40 пациентов с абдоминальным сепсисом, госпитализированных в хирургическое отделение Сибирского государственного медицинского университета в 2019–2023 гг. Все пациенты были разделены на группы по исходу госпитализации (выписка или летальный исход). Оценивали клинико-анамнестические данные, показатели шкал Sequential Organ Failure Assessment (SOFA) и quick SOFA, биохимические и гематологические маркеры в динамике (Т1 – верификация, Т2 – через 48 ч). Применялись *U*-критерий Манна – Уитни, критерий Пирсона χ^2, критерий Вилкоксона, ROC-анализ.

Результаты. Уровень летальности составил 45%. Статистически значимыми предикторами летального исхода явились: оценка по шкале SOFA более 4 баллов, уровень мочевины в сыворотке крови более 12,1 ммоль/л, снижение концентрации в сыворотке крови общего кальция 1,8 ммоль/л и менее, количество тромбоцитов в общем анализе крови 264 × 10^9/л и менее, отсутствие прироста количества тромбоцитов более 15 × 10^9/л, интенсивность реактивности нейтрофилов (NEUT-RI) более 57,6 единиц интенсивности флуоресценции (ИФ) на Т1 и более 53,8 ИФ на Т2. Также установлены прогностические значения для ретикулоцитарных параметров и содержания реактивных лимфоцитов.

Заключение. Ранняя оценка клинико-лабораторных показателей, особенно показателей функции почек, кальциевого обмена, параметров гемограммы и интенсивности воспалительного ответа, имеет высокую прогностическую значимость при хирургическом сепсисе и может быть использована для стратификации риска и оптимизации терапии.

Ключевые слова: сепсис, хирургический сепсис, абдоминальный сепсис, летальный исход, предикторы летального исхода

Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с публикацией настоящей статьи.

Источник финансирования. Авторы заявляют об отсутствии финансирования при проведении исследования.

Соответствие принципам этики. Протокол исследования одобрен локальным этическим комитетом Сибирского государственного медицинского университета (решение № 8616/1 от 29.03.2021).

Для цитирования: Родионова Ю.О., Федосенко С.В., Иванова А.И., Аржаник М.Б., Семенова О.Л., Старовойтова Е.А., Нестерович С.В., Ефимова Д.А., Калюжин В.В. Ранние клинико-лабораторные предикторы госпитальной летальности у пациентов с хирургическим абдоминальным сепсисом. *Бюллетень сибирской медицины.* 2025;24(3):107–115. https://doi.org/10.20538/1682-0363-2025-3-107-115.

INTRODUCTION

Sepsis as a complication of intra-abdominal infections is widespread in surgical practice and remains a leading cause of non-traumatic mortality in emergency surgical departments both in Russia and abroad [1]. Abdominal sepsis (AS) presents a serious clinical problem due to the diversity of nosological forms, the broad spectrum of pathogens (aerobic and anaerobic bacteria, fungi), as well as limitations in microbiological diagnosis [2].

Clinical heterogeneity complicates the assessment of epidemiological indicators of AS. According to data from I. Martin-Loeches et al. (2019), mortality in complicated intra-abdominal infections without sepsis is 2–3%, whereas in cases progressing to sepsis and septic shock in intensive care units, it reaches up to 50% [3].

The effectiveness of treatment for AS largely depends on early verification of the condition, selection of the optimal surgical approach, and timely antimicrobial therapy [4]. In the context of nonspecific clinical presentations and limited diagnostic value of individual laboratory markers, the role of a comprehensive assessment of clinical and laboratory parameters increases for predicting outcomes. The aim of this study was to perform a comparative analysis of clinical and laboratory predictors of death in patients with postoperative AS within the first 48 hours after diagnosis verification, depending on the hospitalization outcome.

MATERIALS AND METHODS

A retrospective comparative study was conducted based on a protocol approved by the local Ethics Committee of Siberian State Medical University (Minutes No.8616/1 dated March 29, 2021). The study included a consecutive sample of 40 patients with postoperative AS hospitalized in the surgical department of Siberian State Medical University clinics from January 1, 2019 to April 30, 2023. The patients were divided into two groups according to the hospitalization outcome (discharge or death) for analyzing clinical, anamnestic, and laboratory parameters within the first 48 hours after AS verification.

Inclusion criteria were the presence of an abdominal bacterial infection focus and a score of ≥ 2 on the quick Sepsis-Related Organ Failure Assessment (qSOFA) scale, which considers systolic blood pressure (BP) < 100 mm Hg, respiratory rate ≥ 22 per minute, and altered mental status (Glasgow coma score < 15). The diagnosis of sepsis was confirmed using the Sequential Organ Failure Assessment (SOFA) scale, with a score of ≥ 2.

The study evaluated the duration of hospital stay and hospitalization outcome, anthropometric data, comorbidities (including immunodeficiency states), qSOFA and SOFA scores, duration of sepsis, data from intensive care unit stay, including mechanical ventilation and vasopressor support. A dynamic assessment of key clinical parameters was performed: BP, heart rate, level of consciousness, peripheral oxygen saturation. Biochemical blood parameters were also measured: C-reactive protein (CRP), lactate, procalcitonin (PCT), creatinine, urea, total and direct bilirubin, sodium, potassium, and calcium (at verification and after 48 hours).

Statistical analysis was performed using the Statistica 12.0 software (StatSoft, USA). Quantitative data were presented as the median and the interquartile range Me (Q_1; Q_3). Qualitative data were presented as n (%). Independent samples were compared using the Mann – Whitney U test for continuous variables and the χ^2 (Fisher's exact) test for categorical variables. Dependent variables were analyzed using the Wilcoxon signed-rank test. The Receiver Operating Characteristic (ROC) analysis was performed in MedCalc 18.9.1 to calculate the area under the curve (AUC), with a 95% confidence interval (CI), Youden's index for cutoff points, sensitivity, and specificity. The significance level was set at $p < 0.05$.

RESULTS

A total of 40 patients were included in the study, of whom 27 (67.5%) were men and 13 (32.5%) – women. The overall mortality rate was 45%, with 18 deceased patients and 22 survivors. The groups did not differ significantly in age (median 59.5 years [45.0; 72.0] vs. 65.0 years [61.0; 76.0]; $p = 0.068$), body mass index (BMI) (24.81 vs. 24.02 kg / m²; $p = 0.815$), or gender distribution ($p = 0.435$).

Most patients ($n = 37$) were admitted in the emergency room, while only 3 were hospitalized electively. In the group with fatal outcomes, 16 patients had emergency admissions and 2 – elective admissions; in the survivor group, these numbers were 21 and 1, respectively. Surgical intervention was required in 36 patients (90%). Among survivors, 20 patients underwent surgery (1 patient required reoperation), whereas in the deceased group, 16 patients underwent surgery (with 5 patients undergoing reoperation).

Comorbid conditions included: ischemic heart disease in 12 patients (30%), hypertension in 23 patients (57.5%), history of myocardial infarction in 8 patients (20%), stroke in 5 patients (12.5%), type 2 diabetes mellitus in 6 patients (15%), chronic heart failure in 5 patients (12.5%), bronchial asthma in 1 patient (2.5%), chronic obstructive pulmonary disease in 1 patient (2.5%), liver cirrhosis in 2 patients (5%), and chronic kidney disease in 2 patients (5%). Alcohol abuse was identified in 4 patients (10%), and drug addiction – in 2 patients (5%). No significant differences between the groups were found in the prevalence of comorbid conditions or results of objective examinations ($p > 0.05$, Table 1).

Table 1

Objective Data at the Time of Sepsis Verification, *Me* (Q_1; Q_3)

Parameter	Patients with a favorable outcome	Patients with a fatal outcome	*p*
Body temperature	38 (38; 38)	38 (37.8; 38)	0.302
HR in 1 min	100 (89; 102)	101 (80; 109)	0.643
RR in 1 min	25 (24; 26)	25 (24; 28)	0.490
SPB, mm Hg	97.5 (90; 102)	100 (92; 105)	0.657
DBP, mm Hg	60 (50; 60)	60 (60; 70)	0.253
Pulse pressure, mm Hg	40 (30; 42)	40 (30; 40)	0.966
SpO2, %	94 (93; 96)	95 (90; 97)	0.891

Note. HR – heart rate; RR – respiratory rate; SBP – systolic blood pressure; DBP – diastolic blood pressure; SpO_2 – peripheral oxygen saturation (measured during breathing ambient air).

At the time of AS diagnosis, the SOFA score for patients with fatal outcomes was 6 (5; 7), whereas for survivors, it was 4 (3; 5) (p = 0.001).

Among the biochemical parameters assessed within the first 48 hours, statistically significant intergroup differences were observed only in serum calcium and urea levels (Table 2).

Table 2

Dynamics of Biochemical Serum Test Results, *Me* (Q_1; Q_3)

Parameter	Patients with a favorable outcome	Patients with a fatal outcome	*p*
Calcium, mmol / l, T1	2.02 (1.80; 2.05)	1.80 (1.76; 2.01)	0.040
Calcium, mmol / l, T2	2.01 (1.80; 2.15)	1.90 (1.80; 2.12)	0.685
$p_{T_1\text{-}T_2}$	0.327	0.018	–
Total bilirubin, μmol / l, T1	21.0 (9.0; 27.0)	16.5 (12.0; 30.0)	0.945
Total bilirubin, μmol / l, T2	16.1 (8.1; 24.5)	11.7 (9.0; 22.0)	0.581
$p_{T_1\text{-}T_2}$	0.306	0.022	–
Conjugated bilirubin, μmol / l, T1	8.8 (7.0; 15.8)	9.5 (6.0; 14.8)	0.891
Conjugated bilirubin, μmol / l, T2	9.2 (4.0; 16.3)	6.8 (4.0; 10.3)	0.569
$p_{T_1\text{-}T_2}$	0.277	0.116	–
Urea, T1	6.9 (4.3; 12.1)	15.5 (7.6; 19.9)	0.012
Urea, T2	7.0 (3.3; 13.1)	12.2 (4.8; 22.6)	0.076
$p_{T_1\text{-}T_2}$	0.178	0.683	–
Creatinine, μmol / l, T1	81.0 (66.7; 161.0)	143.4 (92.8; 219.0)	0.070
Creatinine, μmol / l, T2	80.0 (55.0; 107.4)	70.9 (59.0; 160.0)	0.356
$p_{T_1\text{-}T_2}$	0.005	0.060	–
C-reactive protein, mg / l, T1	300.7 (201.0; 487.0)	262.5 (198.9; 480.0)	0.683
C-reactive protein, mg / l, T2	198.0 (154.4; 320.0)	198.0 (140.0; 289.0)	0.784
$p_{T_1\text{-}T_2}$	0.001	0.064	–
Procalcitonin, ng / ml, T1	3.39 (0.72; 7.44)	4.71 (0.48; 8.68)	0.479
Procalcitonin, ng / ml, T2	2.16 (0.70; 7.28)	3.81 (0.65; 10.30)	0.515
$p_{T_1\text{-}T_2}$	0.170	0.600	–
Lactate, mmol / l, T1	4.5 (3.6; 5.0)	4.5 (3.7; 4.8)	0.848
Lactate, mmol / l, T2	3.9 (2.9; 4.9)	3.9 (3.5; 4.8)	0.957
$p_{T_1\text{-}T_2}$	0.039	0.021	–

Note. Here and in Tables 3–5: T – time point of measurement (T1 – baseline value; T2 – after 48 hours).

In both groups, baseline serum calcium levels indicated hypocalcemia (normal range: 2.15–2.50 mmol / l); however, in survivors, calcium was significantly higher than in non-survivors (Table 2).

In the group with fatal outcomes, serum urea levels upon admission and after 48 hours exceeded reference values; at the time of AS diagnosis, urea was 2.3 times higher than in survivors (p = 0.012). Only in the survivor group was there a significant decrease in serum creatinine concentration after 48 hours (p = 0.005) (Table 2).

All patients exhibited elevated levels of inflammatory markers: CRP and PCT. Differences between the groups did not reach statistical significance; however, in survivors, a significant reduction (p = 0.001) in CRP was observed after 48 hours (Table 2).

Elevated serum lactate concentrations persisted in both groups throughout the observation period, with no intergroup differences (Table 2).

The analysis of the blood count did not reveal statistically significant differences between the groups for most parameters (Table 3).

Table 3

Dynamics of Peripheral Blood Erythropoiesis Parameters within the First 48 Hours from Sepsis Verification, *Me* (Q_1; Q_3)

Parameter	Patients with a favorable outcome	Patients with a fatal outcome	*p*
Erythrocytes, 10^{12} / l, T1	3.09 (2.70; 4.02)	3.59 (2.82; 4.18)	0.549
Erythrocytes, 10^{12} / l, T2	3.13 (2.64; 3.84)	3.42 (2.58; 3.83)	0.891
$p_{T_1\text{-}T_2}$	0.149	0.040	–

End of Table 2

Parameter	Patients with a favorable outcome	Patients with a fatal outcome	p
Hemoglobin, g / l, T1	89 (75;106)	91 (78;120)	0.663
Hemoglobin, g / l, T2	82.5 (76; 109)	85 (74; 108)	0.745
$p_{T_1\text{-}T_2}$	0.232	0.028	–
Hematocrit, %, T1	26.7 (24.5; 33.5)	27.7 (25.7; 34.8)	0.422
Hematocrit, %, T2	25.9 (23.7; 32.9)	26.6 (23.0; 30.5)	0.986
$p_{T_1\text{-}T_2}$	0.211	0.034	–
ESR, mm / h, T1	55 (40; 67)	50.5 (29; 57)	0.086
ESR, mm / h, T2	58 (45; 66)	45 (29; 57)	0.111
$p_{T_1\text{-}T_2}$	0.506	0.906	–
MCV, fl:T1	86.4 (83.1; 92.1)	85.9 (83.3; 89.2)	0.900
MCV, fl:T2	87.1 (84.1; 91.8)	87.2 (79.6; 88.7)	0.562
$p_{T_1\text{-}T_2}$	0.058	0.972	–
MCH, pg: T1	28.7 (27.4; 31.2)	28.5 (26.4; 29.5)	0.455
MCH, pg: T2	28.7 (27.5; 30.7)	28.7 (26.7; 29.3)	0.516
$p_{T_1\text{-}T_2}$	0.305	0.433	–
MCHC, g / l: T1	332 (321; 337)	327 (313; 339)	0.398
MCHC, g / l: T2	329 (319; 333)	329 (320; 335)	0.973
$p_{T_1\text{-}T_2}$	0.117	0.875	–
RDW-CV, %: T1	14.7 (13.4; 17.3)	16.3 (14.9; 19.0)	0.143
RDW-CV, %: T2	15.1 (14.0; 16.3)	15.2 (14.0; 18.6)	0.446
$p_{T_1\text{-}T_2}$	0.035	0.017	–
MicroR, %: T1	3.9 (2.7; 4.4)	8.5 (2.3; 13.3)	0.153
MicroR, %: T2	3.9 (1.5; 4.5)	6.8 (2.3; 11.4)	0.142
$p_{T_1\text{-}T_2}$	0.345	0.345	–
MacroR, %: T1	2.9 (2.7; 4.5)	3.7 (3.1; 5.0)	0.491
MacroR, %: T2	3.7 (2.9; 5.4)	3.9 (2.8; 4.5)	0.898
$p_{T_1\text{-}T_2}$	0.046	0.237	–

Note. MCV, fl – mean corpuscular volume, femtoliters (fl); MCH – mean corpuscular hemoglobin content; MCHC – mean corpuscular hemoglobin concentration; RDW-CV – red cell distribution width – coefficient of variation; microR – microcyte ratio; macroR – macrocyte ratio; ESR – erythrocyte sedimentation rate.

In both groups, at admission and after 48 hours from the onset of sepsis, elevated erythrocyte sedimentation rates were observed without statistically significant intergroup differences or changes over time (Table 3). At baseline and after 48 hours, all patients were diagnosed with normocytic normochromic anemia accompanied by erythropoiesis and anisocytosis – an increased red cell distribution width – coefficient of variation (RDW-CV), which, in the context of medical history, corresponds to compensatory posthemorrhagic anemia. In patients with unfavorable outcomes, a significant decrease ($p < 0.05$) in erythrocyte count, hematocrit, and hemoglobin levels was noted over 48 hours in the context of increasing RDW-CV.

Table 4

Dynamics of Peripheral Blood Leukocyte Counts in the First 48 Hours from the Moment of Sepsis Verification, *Me* (Q_1; Q_3)

Parameter	Patients with a favorable outcome	Patients with a fatal outcome	p
Leukocytes, 10^9 / l, T1	11.93 (7.85; 17.75)	17.94 (7.15; 29.71)	0.314
Leukocytes, 10^9 / l, T2	9.49 (6.80; 14.43)	13.18 (10.19; 23.97)	0.076
$p_{T_1\text{-}T_2}$	0.016	0.600	–
Neutrophils, %, T1	84.0 (77.4; 87.6)	89.7 (71.9; 92.3)	0.079
Neutrophils, %, T2	74.9 (70.9; 83.7)	84.7 (79.5; 91.7)	0.124
$p_{T_1\text{-}T_2}$	0.016	0.753	–
Neutrophils, 10^9 / l, T1	9.24 (6.32; 13.68)	15.98 (5.14; 25.1)	0.254
Neutrophils, 10^9 / l, T2	7.26 (4.66; 10.78)	10.59 (9.01; 21.35)	0.056
$p_{T_1\text{-}T_2}$	0.017	0.422	–
IG, %, T1	1.4 (0.5; 2.4)	2.0 (1.0; 3.0)	0.525
IG, %, T2	2.9 (0.7; 4.8)	2.0 (0.6; 9.8)	0.749
$p_{T_1\text{-}T_2}$	0.043	0.345	–
IG, 10^9 / l, T1	0.25 (0.09; 0.26)	0.14 (0.13; 0.65)	0.874
IG, 10^9 / l, T2	0.40 (0.16; 0.69)	0.09 (0.05; 0.95)	0.749
$p_{T_1\text{-}T_2}$	0.237	0.463	–
Platelets, 10^9 / l, T1	311 (234; 370)	252 (133; 394)	0.422
Platelets, 10^9 / l, T2	356 (254; 397)	212 (120; 264)	0.011
$p_{T_1\text{-}T_2}$	0.487	0.028	–
Platelets, %	0.76 (–10.78; 14.15)	–9.78 (–31.34; 1.33)	0.035
NEUT-GI, T1	156.1 (152.0; 159.7)	156.3 (151.7; 157.5)	0.405
NEUT-GI, T2	154.5 (151.9; 160.4)	154.5 (152.4; 156.2)	0.592
$p_{T_1\text{-}T_2}$	0.422	0.086	–
NEUT-GI, %	0.25 (–1.04; 2.37)	1.38 (0.26; 2.91)	0.367
NEUT-RI, T1	52.0 (49.1; 56.6)	58.3 (53.2; 64.8)	0.032
NEUT-RI, T2	50.1 (48.7; 53.6)	62.9 (58.0; 64.4)	0.002
$p_{T_1\text{-}T_2}$	0.363	0.594	–
NEUT-RI, %	–2.93 (–6.60; 3.32)	–3.90 (–6.98; 4.11)	0.900

Note. IG, % – relative number of immature granulocytes; IG – absolute number of immature granulocytes; NEUT-GI – neutrophil granularity intensity, scattering intensity; NEUT-RI –neutrophil reactivity intensity, fluorescence intensity.

At the time of sepsis diagnosis, neutrophilic leukocytosis was observed in both groups. In patients with fatal outcomes, the leukocyte count was nearly twice the upper limit of reference values. Despite the absence of statistically significant differences in leukocyte and neutrophil levels (including immature forms) at both measurement points, survivors showed a reduction in the severity of neutrophilic leukocytosis after 48 hours (Table 4). In the group of diseased patients, a significant decrease in platelet count was observed over time, which after 48 hours resulted in statistically significant differences between the groups ($p = 0.011$).

Both groups exhibited a pronounced inflammatory response in the blood (leukocytosis, neutrophil shift). However, in survivors, a positive dynamic was observed after 48 hours: the leukocyte level decreased from 11.93 (7.85; 17.75) to 9.49 (6.80; 14.43) × 10^9 / l ($p = 0.016$), neutrophil percentage decreased from 84.0 (77.4; 87.6)% to 74.9 (70.9; 83.7)% ($p = 0.016$), and their absolute count decreased from 9.24 (6.23; 13.68) to 7.26 (4.66; 10.78) × 10^9 / l ($p = 0.017$).

At the time of sepsis diagnosis, NEUT-RI was higher in the group of deceased patients: 58.3 (53.2; 64.8) vs. 51.95 (49.10; 56.60) FI in survivors ($p = 0.032$). After 48 hours, NEUT-RI decreased in survivors to 50.05 (48.70; 53.60) FI and increased in non-survivors to 62.9 (58.0; 64.4) FI, with differences between the groups persisting ($p = 0.002$). Regarding NEUT-GI, no significant differences between the groups were found at either time point ($p > 0.05$; Table 3).

Verification of potential early predictors of mortality in postoperative sepsis using ROC analysis. The following should be considered as significant clinical and anamnestic factors associated with the risk of death in postoperative sepsis: duration of hospitalization ≤11 bed- – days (AUC 0.720 (0.555; 0.850); $p = 0.009$, with sensitivity of 44.4% and specificity of 95.45%), as well as such indicators at the time of sepsis diagnosis as SOFA score > 4 (AUC 0.795 (0.638; 0.906); $p < 0.001$ with sensitivity of 77.78% and specificity of 72.73%), the Glasgow score ≤12 (AUC 0.616 (0.449; 0.785); $p = 0.049$ with sensitivity of 27.78% and specificity of 95.45%), as well as baseline serum urea concentration > 12.1 mmol / l (AUC 0.732 (0.569; 0.960); $p = 0.004$ with sensitivity of 61.11% and specificity of 67.27%) and serum calcium ≤ 1.8 mmol / l (AUC 0.765 (0.525; 0.923), $p = 0.013$ with sensitivity of 70% and specificity of 70%). A number of potential predictors of an unfavorable outcome were identified during the analysis of hemogram parameters (Table 5).

Table 5

Hemogram Parameters as Early Predictors of a Fatal Outcome in Postoperative Sepsis

Parameter	AUC	95% CI	*p*	Cutoff point	Sensitivity	Specificity
Neutrophils, 10^9 / l, T2	0.696	(0.518; 0.839)	0.046	> 10.15	69.23	72.73
Monocytes, %, T1	0.711	(0.536; 0.849)	0.038	≤ 4.8	66.67	85.71
Eosinophils, %, T2	0.730	(0.541; 0.872)	0.017	≤ 1.2	81.82	60.00
Platelets, 10^9 / l, T2	0.760	(0.587; 0.888)	0.003	≤ 264	76.92	72.73
Platelets, 10^9 / l (T2–T1)	0.733	(0.556; 0.867)	0.006	≤ 15	100.00	45.45
PCT, %, T2	0.782	(0.604; 0.906)	0.001	≤ 0.27	75.00	76.19
RET-He, pg (T2–T1)	0.766	(0.493; 0.936)	0.036	≤ 0.8	75.00	75.00
RET-He – RBC-He, pg, T1	0.903	(0.680; 0.990)	< 0.0001	> –1.5	81.82	87.50
RET-He – RBC-He, pg, T2	0.821	(0.543; 0.966)	0.012	> –1.9	100.00	62.50
NEUT RI, FI, T1	0.736	(0.540; 0.881)	0.019	> 57.6	77.78	85.71
NEUT RI, FI, T2	0.889	(0.688; 0.91)	< 0.0001	> 53.8	53.85	93.75
RE LYMP, %, T1	0.730	(0.534; 0.877)	0.016	≤ 0.28	83.33	58.82

Note. PCT – plateletcrit; RET-He – hemoglobin concentration in reticulocytes; RET-He – RBC-He – the difference between the measured mean concentration of hemoglobin in reticulocytes (RET-He) and mature erythrocytes (RBC-He); NEUT-RI – neutrophil reactivity intensity; RE LYMP – reactive lymphocytes.

Particular attention is drawn to potential predictors of a fatal outcome recorded in the dynamics of AS. Thus, an increase in the level of neutrophils > 10.15 × 10^9 / l after 48 hours, a relative number of monocytes ≤ 4.8% at the time of AS detection, eosinophils ≤ 1.2% after 48 hours, as well as a decrease in the number of platelets to ≤ 264 × 10^9 / l or the absence of their increase by more than 15 × 10^9 / l from the baseline level may indicate an unfavorable prognosis. Predictors also include: platelet count ≤ 0.27% after 48 hours, a decrease in reticulocyte hemoglobin concentration by ≥ 0.8 pg and / or ≥ 5.38%, a decrease in the difference in hemoglobin content between reticulocytes and mature red blood cells to –1.5 pg at baseline and > –1.9 pg after 48 hours, an increase in NEUT-RI > 57.6 FI when sepsis is detected and / or > 53.8 FI after 48 hours, and a relative number of reactive lymphocytes ≤ 0.28% at baseline (Table 5).

DISCUSSION

The results of the study confirm the significance of the early assessment of clinical and laboratory parameters in patients with AS for predicting outcomes. The mortality rate in the studied cohort was 45%, which exceeds the average values (30–38%) reported for patients with sepsis and septic shock [6]. This may be associated with a larger number of emergency surgeries in the deceased group, the severity of condition upon admission, and pronounced multiple organ failure.

The SOFA score is traditionally used to evaluate the risk of mortality in sepsis, demonstrating high sensitivity (89%) and specificity (69%) [7]. In the work by R. Garg et al., SOFA score of ≥ 9 was associated with increased mortality [8]. In our study, the SOFA score > 4 predicted mortality with sensitivity of 77.78% and specificity of 72.73%.

Hypocalcemia, previously described in critical conditions, including sepsis [9], was also observed in our patients. In the group with fatal outcomes, calcium levels were significantly lower compared to survivors. According to the literature, during sepsis, active forms of oxygen and proinflammatory mediators are released, which activate calcium-sensitive receptors, potentially contributing to the development of hypotension and endothelial dysfunction [10].

Acute kidney injury (AKI) is a frequent and severe manifestation of organ dysfunction in sepsis, detected in 60% of patients [11]. It is associated with an increase in in-hospital mortality up to 18% and an independent rise in the risk of death [12]. Indicators such as creatinine, urea, and diuresis are used to assess AKI [13]. In our patients with fatal outcomes, urea levels were statistically higher, and the value > 12.1 mmol / l was an independent predictor of death in AS.

PCT and CRP are among the most studied markers of bacterial infection [14]. Although levels of both markers were elevated in all patients, no statistically significant differences were found between the groups. This may be explained by the universal nature of the inflammatory response in sepsis. However, the dynamics of these indicators had prognostic value: in survivors, a decrease in CRP was observed after 48 hours, reflecting the effectiveness of therapy. In the group with fatal outcomes, levels of CRP and PCT either did not decrease or increased, indicating progression of inflammation and organ dysfunction. Thus, a comprehensive assessment of inflammatory markers in combination with clinical and biochemical data is essential.

Lactate is an important marker of tissue hypoperfusion and metabolic dysfunction in sepsis [15]. According to Sepsis-3 criteria, septic shock is diagnosed in the presence of persistent systemic arterial hypotension requiring vasopressor support, combined with a lactate level ≥ 2 mmol / l after fluid resuscitation [5]. In our study, lactate levels were elevated in all patients upon admission and remained elevated after 48 hours, with no significant differences between the groups. This may reflect similar early metabolic disturbances across the cohort.

The analysis of the erythrogram revealed normocytic normochromic anemia, typical of inflammation and blood loss. At baseline, all patients exhibited decreased hemoglobin, erythrocyte count, and hematocrit levels, with more pronounced reductions in the deceased group, and further declines observed after 48 hours. This supports existing literature data on septic anemia, which is caused by the effects of proinflammatory cytokines, impaired erythropoiesis, and surgical blood loss [16].

The red cell distribution width (RDW-CV) was elevated in both groups; however, a significant increase was observed after 48 hours in the patients who died. This may indicate activation of erythropoiesis and iron redistribution in response to inflammation. Elevated RDW-CV has been previously associated with a poor prognosis in sepsis [17].

Evaluation of reticulocyte parameters revealed a decrease in hemoglobin concentration within reticulocytes (RET-He) among patients with fatal outcomes, along with a decrease in the difference between RET-He and hemoglobin levels in mature erythrocytes. This indicates impaired hemoglobinization and suppression of erythropoiesis, consistent with the pathogenesis of septic anemia and disturbances in iron metabolism [18].

Coagulopathy is a key prognostic factor in sepsis, ranging from isolated thrombocytopenia to disseminated intravascular coagulation (DIC). In our study, 48 hours after diagnosis, deceased patients showed a statistically significant decrease in platelet count (212 (120; 264) × 10^9 / l, p = 0.028). These findings align with existing literature: thrombocytopenia occurs in 10–70% of sepsis patients, especially in intensive care units. Mechanisms include consumption of platelets in microcirculation, impaired production, sequestration in the liver and spleen, and apoptosis [19]. A critical level below 150 × 10^9 / l is associated with an increased risk of mortality [20]. Our data support this conclusion.

Leukocytosis in sepsis is an important criterion of systemic inflammatory response syndrome (SIRS), characterized by high sensitivity (0.85) but low specificity (0.41) [21]. Both groups exhibited neutrophilic leukocytosis; however, it was more pronounced among the deceased. In survivors, the leukocyte count decreased from 11.93 (7.85; 17.75) to 9.49 (6.80; 14.43) × 10^9 / l (p = 0.016) after 48 hours, and neutrophil percentage decreased from 84.0 (77.4; 87.6) to 74.9 (70.9; 83.7)% (p = 0.016), which may indicate a positive response to treatment.

The value of NEUT-RI at diagnosis was higher among deceased patients (58.3 [53.2; 64.8] FI) compared to survivors (51.95 [49.10; 56.60] FI) (p = 0.032). After 48 hours, NEUT-RI continued to increase in the deceased group, whereas it tended to decrease among survivors (p = 0.002). Elevated NEUT-RI has been previously associated with a poor prognosis in sepsis [22], a finding confirmed by our study results.

CONCLUSION

The results of this study confirm the clinical significance of the early comprehensive assessment of clinical and laboratory parameters for predicting hospital outcomes in patients with postoperative AS. The most prognostically valuable indicators within the first 48 hours after sepsis verification included: the severity of organ dysfunction (SOFA score > 4), hypocalcemia (≤ 1.8 mmol / l), hyperuricemia (> 12.1 mmol / l), a decrease and insufficient increase in platelet count, elevated neutrophil reactivity, as well as reduced hemoglobinization of reticulocytes and levels of reactive lymphocytes.

Additionally, the absence of positive dynamics in inflammatory markers (CRP, procalcitonin), neutrophilic leukocytosis, and hematological parameters during the first two days were associated with unfavorable outcomes. These parameters can serve as accessible and informative criteria for risk stratification and personalized therapy in patients with AS. The obtained findings require confirmation in larger cohort and prospective clinical trials.

REFERENCES

1. Vincent J.L., Marshall J.C., Namendys-Silva S.A., François B., Martin-Loeches I., Lipman J. et al.; ICON Investigators. Assessment of the Worldwide Burden of Critical Illness: The Intensive Care over Nations (ICON) Audit. *Lancet Respir. Med*. 2014;2(5):380–386. DOI: 10.1016/S2213-2600(14)70061-X.
2. Blot S., Antonelli M., Arvaniti K., Blot K., Creagh-Brown B., de Lange D. et al.; Abdominal Sepsis Study (AbSeS) Group on Behalf of the Trials Group of the European Society of Intensive Care Medicine. Epidemiology of Intra-Abdominal Infection and Sepsis in Critically Ill Patients: “Abses”, A Multinational Observational Cohort Study and ESICM Trials Group Project. *Intensive Care Med.* 2019;45(12):1703–1717. DOI: 10.1007/s00134-019-05819-3.
3. Martin-Loeches I., Timsit J.F., Leone M., de Waele J., Sartelli M., Kerrigan S. et al. Clinical Controversies in Abdominal Sepsis. Insights for Critical Care Settings. *J. Crit. Care.* 2019;53:53–58. DOI: 10.1016/j.jcrc.2019.05.023.
4. Sartelli M., Coccolini F., Kluger Y., Agastra E., Abu-Zidan F.M., Abbas A.E.S. et al. WSES/GAIS/SIS-E/WSIS/AAST Global Clinical Pathways for Patients with Intra-Abdominal Infections. *World J. Emerg. Surg.* 2021;16(1):49. DOI: 10.1186/s13017-021-00387-8.
5. Singer M., Deutschman C.S., Seymour C.W., Shankar-Hari M., Annane D., Bauer M. et al. The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). *JAMA.* 2016;315(8):801–810. DOI: 10.1001/jama.2016.0287.
6. Bauer M., Gerlach H., Vogelmann T., Preissing F., Stiefel J., Adam D. Mortality in Sepsis and Septic Shock in Europe, North America and Australia Between 2009 and 2019- Results from a Systematic Review and Meta-Analysis. *Crit. Care.* 2020;24(1):239. DOI: 10.1186/s13054-020-02950-2.
7. Qiu X., Lei Y.P., Zhou R.X. SIRS, SOFA, qSOFA, and NEWS in the Diagnosis of Sepsis and Prediction of Adverse Outcomes: A Systematic Review and Meta-Analysis. *Expert Rev. Anti. Infect. Ther.* 2023;21(8):891–900. DOI: 10.1080/14787210.2023.2237192.
8. Garg R., Tellapragada C., Shaw T., Eshwara V.K., Shanbhag V., Rao S. et al. Epidemiology of Sepsis and Risk Factors for Mortality in Intensive Care Unit: A Hospital Based Prospective Study in South India. *Infect. Dis. (Lond.).* 2022;54(5):325–334. DOI: 10.1080/23744235.2021.2017475.
9. Gallardo J., Fardella P., Pumarino H., Campino C. Niveles de Calcio Plasmático en Pacientes Críticos con y Sin Sepsis [Plasma Calcium Levels in Critical Patients with and Without Sepsis]. *Rev. Med. Chil.* 1991;119(3):262–266. (In Span.).
10. Sood A., Singh G., Singh T.G., Gupta K. Pathological Role of the Calcium-Sensing Receptor in Sepsis-Induced Hypotensive Shock: Therapeutic Possibilities and Unanswered Questions. *Drug. Dev. Res.* 2022;83(6):1241–1245. DOI: 10.1002/ddr.21959.
11. Balkrishna A., Sinha S., Kumar A., Arya V., Gautam A.K., Valis M. et al. Sepsis-Mediated Renal Dysfunction: Pathophysiology, Biomarkers and Role of Phytoconstituents in its Management. *Biomed. Pharmacother.* 2023;165:115183. DOI: 10.1016/j.biopha.2023.115183.
12. White K.C., Serpa-Neto A., Hurford R., Clement P., Laupland K.B., See E. et al; Queensland Critical Care Research Network (QCCRN). Sepsis-Associated Acute Kidney Injury in the Intensive Care Unit: Incidence, Patient Characteristics, Timing, Trajectory, Treatment, and Associated Outcomes. A Multicenter, Observational Study. *Intensive Care Med.* 2023;49(9):1079–1089. DOI: 10.1007/s00134-023-07138-0.
13. Seymour C.W., Liu V.X., Iwashyna T.J., Brunkhorst F.M., Rea T.D., Scherag A. et al. Assessment of Clinical Criteria for Sepsis: For the Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). *JAMA.* 2016;315(8):762–774. DOI: 10.1001/jama.2016.0288.

Erratum in: *JAMA.* 2016;315(20):2237. DOI: 10.1001/jama.2016.5850.
14. Pierrakos C., Velissaris D., Bisdorff M., Marshall J.C., Vincent J.L. Biomarkers of Sepsis: Time for a Reappraisal. *Crit. Care.* 2020;24(1):287. DOI: 10.1186/s13054-020-02993-5.
15. Weinberger J., Klompas M., Rhee C. What is the Utility of Measuring Lactate Levels in Patients with Sepsis and Septic Shock? *Semin. Respir. Crit. Care Med.* 2021;42(5):650–661. DOI: 10.1055/s-0041-1733915.
16. An M.M., Liu C.X., Gong P. Effects of Continuous Renal Replacement Therapy on Inflammation-Related Anemia, Iron Metabolism and Prognosis in Sepsis Patients with Acute Kidney Injury. *World J. Emerg. Med.* 2023;14 (3):186–192. DOI: 10.5847/wjem.j.1920-8642.2023.052.
17. Hong C., Xiong Y., Xia J., Huang W., Xia A., Xu S. et al. LASSO-Based Identification of Risk Factors and Development of a Prediction Model for Sepsis Patients. *Ther. Clin. Risk Manag.* 2024;20:47–58. DOI: 10.2147/TCRM.S434397.
18. Piagnerelli M., Cotton F., Herpain A., Rapotec A., Chatti R., Gulbis B. et al. Time Course of Iron Metabolism In Critically Ill Patients. *Acta Clin. Belg.* 2013;68(1):22–27. DOI: 10.2143/ACB.68.1.2062715.
19. Giustozzi M., Ehrlinder H., Bongiovanni D., Borovac J.A., Guerreiro R.A., Gąsecka A. et al. Coagulopathy and Sepsis: Pathophysiology, Clinical Manifestations and Treatment. *Blood Rev.* 2021;50:100864. DOI: 10.1016/j.blre.2021.100864.
20. Wada H., Thachil J., Di Nisio M., Matino D., Kurosawa S., Gando S. et al. The Diagnostic and Prognostic Value of Thrombocytopenia in Critically Ill Patients. *J. Thromb. Haemost*. 2019;17(6):1057–1070. DOI: 10.1111/jth.14478.
21. Qiu X., Lei Y.P., Zhou R.X. SIRS, SOFA, qSOFA, and NEWS in the Diagnosis of Sepsis and Prediction of Adverse Outcomes: A Systematic Review and Meta-Analysis. *Expert Rev. Anti. Infect. Ther.* 2023;21(8):891–900. DOI: 10.1080/14787210.2023.2237192.

Author Contribution

Rodionova Yu.O. – compilation of the database, acquisition and interpretation of clinical data, drafting of the article, review of the literature. Fedosenko S.V. – conception and design of the study, coordination of the study, drafting of the article, review of the literature, final approval of the manuscript for publication. Ivanova A.I., Semenova O.L. – statistical processing of the data, interpretation of the data. Arzhanik M.B. – statistical processing of the data, interpretation of the data, critical revision of the manuscript for important intellectual content. Starovoitova E.A., Kalyuzhin V.V. – critical revision of the manuscript for important intellectual content, final approval of the manuscript for publication. Nesterovich S.V., Efimova D.A. – collection of clinical data, coordination of the study.

Author Information

Rodionova Yulia O. – Teaching Assistant, Division of Intermediate-Level Therapy with a Course in Clinical Pharmacology,, SibSMU, Head of the Department of Clinical Pharmacology, Clinical Pharmacologist, SibSMU Clinics, Tomsk, rodionova.yo@ssmu.ru, http://orcid.org/0000-0001-6819-6968

Fedosenko Sergey V. – Dr. Sci. (Med.), Associate Professor, Professor of the Division of General Medical Practice and Polyclinic Therapy, SbSMU, Tomsk, s-fedosenko@mail.ru, http://orcid.org/0000-0001-6655-3300

Ivanova Anastasia I. – Student, Biomedical Department, SibSMU, Tomsk, nastya-170502@mail.ru, http://orcid.org/0009-0001-7948-1665

Arzhanik Marina B. – Cand. Sci. (Pedagogy), Associate Professor, Division of Medical and Biological Cybernetics, SibSMU, Tomsk, arzh_m@mail.ru, http://orcid.org/0000-0003-4844-9803

Semenova Oksana L. – Senior Lecturer, Division of Medical and Biological Cybernetics, SibSMU, Tomsk, oksleon@list.ru, http://orcid.org/0000-0002-6866-5020

Starovoitova Elena A. – Dr. Sci. (Med.), Associate Professor, Head of the Division of General Medical Practice and Polyclinic Therapy, SibSMU, Tomsk, elena-starovoytova@yandex.ru, http://orcid.org/0000-0002-4281-1157

Nesterovich Sofia V. – Cand. Sci. (Med.), Internal Medicine Doctor of the Expert Department, SibSMU, Tomsk, snesterovich@mail.ru, http://orcid.org/0000-0003-2098-2964

Efimova Daria A. – Cand. Sci. (Med.), Head of Internal Medicine Clinic, Internal Medicine Doctor, SibSMU, Tomsk, vinokurova.da@ssmu.ru, https://orcid.org/0000-000208422-8349

Kalyuzhin Vadim V. – Dr. Sci. (Med.), Professor, Head of the Advanced Therapy Division with a Course in Rehabilitation, Physiotherapy and Sports Medicine, SibSMU, Tomsk, kalyuzhinvv@mail.ru, https://orcid.org/0000-0001-9640-2028

(✉) **Rodionova Yulia O.,** rodionova.yo@ssmu.ru

.
Received on June 02, 2025;
approved after peer review on June 09, 2025;
accepted on June 18, 2025