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# Associations between serum complement component 3a and sC5b-9 levels with the prognosis of sepsis patients

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**Abstract**: **Objective** To investigate the associations of serum complement component 3a (C3a) and soluble terminal complement complex C5b-9 (sC5b-9) levels with the severity of sepsis and 28-day clinical prognosis among patients, and to provide new biomarker references for early risk stratification and prognostic assessment of sepsis. **Methods** A total of 209 sepsis patients admitted to Kunshan First People's Hospital Affiliated to Jiangsu University from March 2022 to September 2024 were retrospectively included as the study group. They were categorized into shock group ($n$= 129) and non-shock group ($n$=80) according to the severity of the disease. Based on the survival status of the patients within 28 days after admission, they were divided into survival group ($n$=137) and death group ($n$=72). Another 56 physically healthy individuals were selected as the control group during the same period. The clinical data of all subjects were collected. Serum C3a and sC5b-9 levels were compared between the groups. The associations of serum C3a and sC5b-9 levels with the severity and prognosis of sepsis patients were analyzed by Spearman correlation analysis. The value of the area under the curve (AUC) of the receiver operating characteristics (ROC) was used to assess the effects of serum C3a and sC5b-9 on predicting poor prognosis in patients with sepsis. Independent influencing factors on poor prognosis in patients with sepsis were analyzed using univariate analysis and multivariate logistic regression. **Results** C3a and sC5b-9 levels were significantly higher in the non-shock group[(169.25±21.47) ng/mL, (325.69±25.36) ng/mL]and shock group[(198.74±19.86) ng/mL, (356.98±36.21) ng/mL]compared with those in the control group[(98.25±19.25) ng/mL, (89.36±12.14) ng/mL, $P$<0.05]. C3a and sC5b-9 levels were significantly higher in the shock group compared with those in the non-shock group ($P$<0.05). C3a and sC5b-9 levels were significantly higher in the death group compared with those in the survival group ($P$<0.05). Spearman correlation analysis showed that serum C3a and sC5b-9 levels were positively correlated with the severity of sepsis ($r$=0.802, 0.744, $P$<0.05) and the poor prognosis ($r$=0.507, 0.602, $P$<0.05). The ROC analysis results showed that the AUC of the combination of C3a and sC5b-9 in predicting the poor prognosis of sepsis patients was 0.910, with a sensitivity of 80.56% and specificity of 87.59%. The results of multivariate logistic regression analysis showed that C3a, sC5b-9, white blood cell count (WBC), serum amyloid A (SAA), total bilirubin (TBIL), and Sequential Organ Failure Assessment (SOFA) score were independent risk factors for poor prognosis in patients with sepsis ($P$<0.05). **Conclusion** Serum C3a and sC5b- 9 levels are significantly correlated with the severity and poor prognosis of sepsis patients, and the combined detection of these two have a high predictive value for the poor prognosis of sepsis patients, which can be used as an effective biomarker for the clinical assessment of the severity and prognosis of sepsis.

**Keywords:** Serum complement component 3a; Soluble terminal complement complex C5b-9; Sepsis; Severity of disease; Prognosis Fund program: Jiangsu Province Advantageous Discipline Construction Project (YSHL2201-231)

Sepsis is a life-threatening organ dysfunction caused by a dysregulated host response to infection. Its high morbidity and mortality make it a major challenge in the global field of critical care medicine [1]. The clinical manifestations of this disease are complex and diverse, with rapid progression. Patients may present with symptoms such as altered consciousness, skin changes, and abnormalities in the respiratory and circulatory systems; severe cases can quickly progress to multiple organ failure and even death [2]. Despite significant advances in anti-infective therapy and organ support technologies in recent years, the prognosis of sepsis patients remains unsatisfactory, mainly due to its complex pathophysiological mechanisms, particularly the immune dysregulation characterized by the coexistence of excessive inflammatory response and immunosuppression [3]. As a key component of innate immunity, the complement system plays a dual role in the pathogenesis of sepsis: on the one hand, anaphylatoxins released after complement activation [such as complement component 3a (C3a) and C5a] can trigger inflammatory cascades, leading to endothelial damage and microthrombus formation [4]; on the other hand, deposition of the soluble terminal complement complex C5b-9 (sC5b-9) can directly cause cell lysis and tissue damage [5]. In recent years, multiple studies have shown that excessive activation of the complement system is significantly associated with the severity and poor prognosis of sepsis patients [6-7]. However, changes in the levels of specific complement

components (such as C3a and sC5b-9) and their clinical significance still need further exploration. Therefore, this study aims to investigate the association of C3a and sC5b-9 levels with the severity and prognosis of sepsis patients, in order to provide novel biomarkers for early risk stratification of sepsis, offer theoretical basis for precise therapy targeting complement regulation, and facilitate clinical translation.

## 1 Materials and Methods

### *1.1 General Information*

A total of 209 sepsis patients admitted to Kunshan First People's Hospital Affiliated to Jiangsu University from March 2022 to September 2024 were retrospectively enrolled as the study group, including 101 males and 108 females, aged 35-75 (48.21±11.85) years. Additionally, 56 healthy individuals who underwent physical examination during the same period were selected as the control group, including 29 males and 27 females, aged 35-73 (47.85±12.34) years. There were no statistically significant differences in gender composition or age distribution between the two groups (P>0.05).

Inclusion criteria: (1) Meeting the 2016 Sepsis-3 diagnostic criteria [1]; the diagnostic criteria are as follows (at least 2 of the following criteria must be satisfied): presence of confirmed infection, or abnormal body temperature (<36℃ or >38℃), or abnormal respiratory rate (>20 breaths/min or arterial partial pressure of carbon dioxide <32 mmHg), or abnormal white blood cell (WBC) count (>12×10⁹/L). (2) Aged over 18 years. (3) Complete clinical data.

Exclusion criteria: (1) Patients who died within 24 hours of admission; (2) Patients with malignant tumors or immunodeficiency diseases; (3) Patients with mental disorders; (4) Patients who received immunosuppressant therapy before admission.

This study was approved by the Medical Ethics Committee of Kunshan First People's Hospital Affiliated to Jiangsu University (approval number: KY2025-001-01) after a rigorous ethical review process.

### *1.2 Methods*

1.2.1 Data Collection

Clinical characteristics and the results of the first laboratory tests after admission were retrospectively collected for all subjects, including age, gender, smoking history, drinking history, body mass index (BMI), comorbid diabetes mellitus, comorbid hypertension, comorbid coronary artery disease (CAD), infection site (lung, thoracic cavity, other), WBC count, red blood cell (RBC) count, hemoglobin (Hb), platelet (PLT) count, procalcitonin (PCT), C-reactive protein (CRP), serum amyloid A (SAA), C3a, sC5b-9, total bilirubin (TBIL), N-terminal pro-brain natriuretic peptide (NT-proBNP), creatine kinase isoenzyme MB (CK-MB), cardiac troponin I (cTnI), and Sequential Organ Failure Assessment (SOFA) score.

Peripheral venous blood (3-5 mL) was collected from all subjects in the fasting state, centrifuged at 3000 r/min for 10 min (centrifugal radius: 15 cm), and the serum was separated and stored in a -80℃ ultra-low temperature refrigerator for later use.

1.2.2 Detection of Laboratory Indicators

WBC, RBC, Hb, and PLT levels were detected using an automatic hematology analyzer (model: Sysmex XE-2100, manufacturer: Sysmex Corporation). Serum PCT levels were detected using an automatic chemiluminescence immunoanalyzer (model: cobas 8000 e 801, manufacturer: Roche Diagnostics). Serum CRP and SAA levels were detected using an automatic specific protein analyzer (model: H780-3, manufacturer: Shenzhen Xilaiheng Medical Electronics Co., Ltd.). Serum C3a, sC5b-9, and TBIL levels were detected using an automatic biochemical analyzer (model: ADVIA 2400, manufacturer: Siemens Healthineers AG, USA). Serum NT-proBNP, CK-MB, and cTnI levels were detected using an automatic chemiluminescence immunoanalyzer (model: Centaur XP, manufacturer: Siemens Healthineers AG, USA).

### *1.3 Grouping*

1.3.1 Shock Group and Non-Shock Group

According to the severity of the disease [8], 209 sepsis patients were divided into the shock group ($n$=129) and the non-shock group ($n$=80). The diagnostic criteria for septic shock were: (1) Meeting the diagnostic criteria for sepsis accompanied by acute circulatory dysfunction, manifested as persistent hypotension (systolic blood pressure <90 mmHg), requiring vasoactive agents to maintain a mean arterial pressure (MAP) ≥ 65 mmHg, and blood lactic acid >2 mmol/L; (2) Sepsis-related SOFA score increased by ≥2 points compared with the baseline [1].

1.3.2 Survival Group and Death Group

Patients were divided into the survival group ($n$=137) and the death group ($n$=72) based on their survival status within 28 days of admission.

### *1.4 Statistical Methods*

SPSS 27.0 software was used for statistical analysis. The Shapiro-Wilk test was used to determine the normality of continuous variables. Continuous variables satisfying normality were expressed as $\bar{x}\pm s$, and intergroup comparisons were performed using one-way analysis of variance (ANOVA) with post-hoc LSD-$t$ test for pairwise comparisons. Categorical variables were expressed as cases (%), and intergroup comparisons were performed using the $\chi^2$ test. Spearman's correlation analysis was used to evaluate the correlation between serum C3a and sC5b-9 levels and the severity and prognosis of sepsis patients. The area under the receiver operating characteristic (ROC) curve (AUC) was used to assess the predictive efficacy of serum C3a and sC5b-9 for poor prognosis in sepsis patients: AUC <0.70

indicated poor predictive efficacy, 0.70-0.79 indicated moderate efficacy, 0.80-0.89 indicated good efficacy, and 0.90-1.00 indicated excellent efficacy. Comparison of AUC values was performed using the Z test. Univariate and multivariate logistic regression analyses were used to identify independent risk factors for poor prognosis in sepsis patients. A P value <0.05 was considered statistically significant.

## 2 Results

### *2.1 Comparison of Serum C3a and sC5b-9 Levels Among Patients with Different Disease Severity*

Compared with the control group, serum C3a and sC5b-9 levels were significantly higher in the non-shock group and the shock group ($P$<0.05); compared with the non-shock group, serum C3a and sC5b-9 levels were significantly higher in the shock group ($P$<0.05). See Table1.

### *2.2 Comparison of Serum C3a and sC5b-9 Levels Among Patients with Different Prognoses*

Compared with the survival group, serum C3a and sC5b-9 levels were significantly higher in the death group ($P$<0.05). See Table 2.

### *2.3 Correlation Between Serum C3a and sC5b-9 Levels and Disease Severity/Prognosis of Sepsis Patients*

Spearman's correlation analysis showed that serum C3a and sC5b-9 levels were positively correlated with disease severity ($r$=0.802, 0.744; $P$<0.05) and poor prognosis ($r$=0.507, 0.602; $P$<0.05) in sepsis patients.

### *2.4 Predictive Value of Serum C3a and sC5b-9 Levels for Poor Prognosis in Sepsis Patients*

ROC analysis showed that the AUC values of C3a and sC5b-9 for predicting poor prognosis in sepsis patients were 0.808 and 0.866, with sensitivities of 79.17% and 76.39%, and specificities of 74.45% and 83.94%, respectively. The combined AUC of C3a and sC5b-9 for predicting poor prognosis was 0.910, with a sensitivity of 80.56% and a specificity of 87.59%. The combined AUC was significantly higher than that of C3a alone ($Z$=3.755, $P$<0.01) and sC5b-9 alone ($Z$=2.790, $P$<0.01). See Table 3 and Figure 1.

### *2.5 Univariate Analysis of Risk Factors for Poor Prognosis in Sepsis Patients*

Univariate analysis showed no statistically significant differences between the two groups in age, gender, BMI, smoking history, drinking history, comorbid hypertension, comorbid diabetes mellitus, comorbid CAD, infection site, or Hb level ($P$>0.05). However, there were statistically significant differences in WBC, RBC, PLT, PCT, CRP, SAA, TBIL, SOFA score, NT-proBNP, CK-MB, and cTnI levels ($P$<0.05). See Table 4.

### *2.6 Multivariate Logistic Regression Analysis of Risk Factors for Poor Prognosis in Sepsis Patients*

Taking the prognostic status of sepsis patients as the dependent variable (death=1, survival=0) and the factors with significant differences in univariate analysis as independent variables (all continuous variables, entered into the equation as measured values), multivariate logistic regression analysis was performed. The results showed that increased levels of C3a, sC5b-9, WBC, SAA, TBIL, and SOFA score were independent risk factors for poor prognosis in sepsis patients ($P$<0.05). See Table 5.

**Tab.1** Comparison of serum levels of C3a and sC5b-9 in patients with different disease severities （ng/mL，$\bar{x}\pm s$）

| Group | *n* | C3a（ng/mL） | sC5b-9（ng/mL） |
|---|---|---|---|
| Shock group | 129 | 198.74±19.86[ab] | 356.98±36.21[ab] |
| Non-shock group | 80 | 169.25±21.47[a] | 325.69±25.36[a] |
| Control group | 56 | 98.25±19.25 | 89.36±12.14 |
| *F* value | | 481.556 | 1 695.44 |
| *P* value | | <0.001 | <0.001 |

Note：Compared with Control group, [a]$P$<0.05; Compared with non-shock group, [b]$P$<0.05.

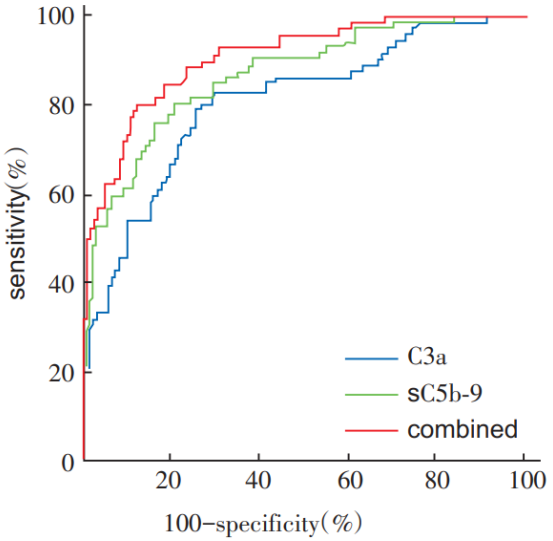
**Tab.2** Comparison of serum levels of C3a and sC5b-9 in patients with different prognoses （ng/mL，$\bar{x}\pm s$）

| Group | n | C3a（ng/mL） | sC5b-9（ng/mL） |
|---|---|---|---|
| Death group | 72 | 208.15±25.86 | 357.04±28.76 |
| Survival group | 137 | 179.14±21.47 | 314.69±23.14 |
| *t* value | | 8.639 | 11.541 |
| *P* value | | <0.001 | <0.001 |

**Tab.3** Predictive values of serum levels of C3a and sC5b-9 on poor prognosis in patients with sepsis

| Variable | AUC | Cut-off | 95%CI | Sensitivity (%) | Specificity (%) | Youden Index |
|---|---|---|---|---|---|---|
| C3a | 0.808 | 188.12 ng/mL | 0.748~0.859 | 79.17 | 74.45 | 0.536 |
| sC5b-9 | 0.866 | 340.69 ng/mL | 0.812~0.909 | 76.39 | 83.94 | 0.603 |
| Combined | 0.910 | | 0.862~0.945 | 80.56 | 87.59 | 0.682 |

**Fig.1** ROC curves of serum levels of C3a and sC5b-9 on poor prognosis in patients with sepsis



Tab.4 Univariate analysis of factors affecting poor prognosis in patients with sepsis （$\bar{x}\pm s$）

| Item | Death group (*n*=72) | Survival group (*n*=137) | t/χ² Value | P Value |
|---|---|---|---|---|
| Age (years) | 45.29±6.39 | 43.69±7.85 | 1.489 | 0.138 |
| Gender (male/female) | 33/39 | 72/65 | 0.853 | 0.356 |
| BMI (kg/m²) | 22.36±2.47 | 22.66±2.32 | 0.250 | 0.803 |
| Smoking history[case(%)] | 33(45.83) | 61(44.52) | 0.000 | 0.927 |
| Drinking history[case(%)] | 34(47.22) | 73(53.28) | 1.048 | 0.306 |
| Diabetes[case(%)] | 39(54.17) | 66(48.18) | 0.678 | 0.410 |
| Comorbid CHD[case(%)] | 40(55.56) | 65(47.45) | 1.242 | 0.265 |
| Infection site [case(%)] | | | 0.239 | 0.887 |
| Lung | 25(34.72) | 43(31.39) | | |
| Thoracic cavity | 24(33.33) | 48(35.04) | | |
| Other | 23(31.94) | 46(33.58) | | |
| WBC (×10⁹/L) | 16.14±3.69 | 13.25±5.14 | 4.230 | <0.001 |
| RBC (×10¹²/L) | 12.15±2.47 | 15.32±2.19 | 4.895 | <0.001 |
| PLT (×10⁹/L) | 83.24±24.50 | 89.22±17.84 | 1.808 | 0.072 |
| Hb (g/L) | 110.25±25.16 | 120.19±21.75 | 3.104 | 0.002 |
| PCT (ng/mL) | 2.36±3.65 | 1.75±5.36 | 7.392 | <0.001 |
| CRP (mg/L) | 40.25±5.47 | 22.69±4.68 | 24.297 | <0.001 |
| SAA (mg/L) | 39.68±5.52 | 27.57±6.53 | 13.414 | <0.001 |
| TBIL (μmol/L) | 35.58±11.51 | 26.09±4.63 | 8.450 | <0.001 |
| SOFA score | 9.25±2.31 | 7.12±2.49 | 8.069 | <0.001 |
| NT-proBNP (pg/mL) | 2 847.58±25.69 | 1 769.09±32.69 | 240.231 | <0.001 |
| CK-MB (ng/mL) | 56.93±13.44 | 36.25±8.55 | 13.547 | <0.001 |
| cTnI (ng/mL) | 0.79±0.25 | 0.42±0.09 | 15.539 | <0.001 |

Tab.5 Multivariate logistic regression analysis of factors affecting poor prognosis in patients with sepsis

| Item | *β* | *SE* | *Wald* | *OR* | 95%*CI* | *P* value |
|---|---|---|---|---|---|---|
| **C3a** | 0.035 | 0.017 | 4.146 | 1.036 | 1.001~1.072 | 0.042 |
| **sC5b-9** | 0.045 | 0.014 | 10.291 | 1.046 | 1.018~1.075 | 0.001 |
| **WBC** | 0.158 | 0.075 | 4.442 | 1.172 | 1.011~1.358 | 0.035 |
| **SAA** | 0.280 | 0.067 | 17.340 | 1.323 | 1.160~1.510 | <0.001 |
| **TBIL** | 0.141 | 0.048 | 8.796 | 1.152 | 1.049~1.265 | 0.003 |
| **SOFA** | 0.603 | 0.210 | 8.289 | 1.828 | 1.212~2.757 | 0.004 |
| **Content** | -42.917 | 7.208 | 35.455 | | | |

## 3 Discussion

Sepsis is a systemic inflammatory response syndrome triggered by infection, with persistently high morbidity and mortality, posing a major challenge to global public health [9]. A typical feature of this disease is the activation of excessive inflammatory responses, which in turn leads to systemic cellular damage and multiple organ dysfunction [10]. Clinical observations have shown that sepsis progresses rapidly; without early effective intervention, severe complications such as multiple organ failure and septic shock can occur quickly, ultimately resulting in poor prognosis [11]. Currently, in clinical practice, interleukin-6 (IL-6) and Acute Physiology and Chronic Health Evaluation (APACHE) Ⅱ score are widely used to assess the severity of sepsis patients. However, these indicators have obvious limitations in terms of sensitivity, specificity, and clinical applicability [12]. Therefore, identifying reliable early predictive indicators to accurately predict disease progression and clinical outcomes is of great significance for achieving early precise intervention and improving patients' clinical outcomes.

Previous studies have confirmed that the pathophysiological process of sepsis involves complex immune regulation mechanisms, among which immune dysfunction is an important driving factor for disease deterioration [13]. As a key component of innate immunity, the complement system plays a core role in pathogen defense, but its excessive activation may cause pathological damage [14]. In the early stage of infection, the complement system rapidly establishes the first line of host defense to effectively eliminate invading pathogenic microorganisms [15]. However, unregulated complement activation can trigger excessive inflammatory cascades, exacerbate tissue damage, and ultimately lead to multiple organ dysfunction and even death [16-17]. Studies have shown that abnormal changes in complement components and their activation products are closely associated with various diseases, including sepsis [18].

The results of this study found that serum C3a and sC5b-9 levels in sepsis patients showed significant disease-related changes and were closely associated with disease severity and clinical prognosis. Compared with the healthy control group, serum C3a and sC5b-9 levels were significantly higher in the non-shock group and the shock group; further analysis revealed that these two complement activation products were significantly higher in the shock group than in the non-shock group, and also significantly higher in the death group than in the survival group. Spearman's correlation analysis confirmed that serum C3a and sC5b-9 levels were significantly positively correlated with disease severity and poor prognosis. The changing pattern of complement components observed in this study is highly consistent with previous research results. Studies by Ren and Charchaflieh *et al.* [19-20] confirmed that sepsis patients exhibit significant consumption of C3 and C4, accompanied by increased levels of complement activation products such as C3a and C4a, and these changes are significantly associated with disease severity and mortality. In addition, a clinical study by Brandtzaeg *et al.* [21] showed that serum sC5b-9 levels are significantly increased in sepsis patients, especially in those with persistent septic shock. The observations of this study are consistent with this, further supporting the theory that excessive activation of the complement terminal pathway plays a key role in the progression of sepsis. Collectively, these studies confirm that abnormal activation of the complement system not only is deeply involved in the pathophysiological process of sepsis but also that changes in the levels of its activation products C3a and sC5b-9 have potential biomarker value for assessing disease severity and predicting clinical prognosis.

This study also evaluated the predictive value of C3a and sC5b-9 for poor prognosis in sepsis patients through ROC curve analysis. The data showed that the AUC of C3a alone for prediction was 0.808 (95%CI: 0.748-0.859), and that of sC5b-9 was 0.866 (95%CI: 0.812-0.909). Notably, when the two biomarkers were combined, the predictive efficacy was significantly improved, with the combined AUC increasing to 0.910 (95%CI: 0.862-0.945). These results indicate that the combined detection of C3a and sC5b-9 can not only serve as a novel biomarker panel for assessing the prognosis of sepsis patients but also that the complement activation pathway mediated by them may become a potential intervention target for sepsis treatment in the future. This dual-biomarker combined detection strategy shows promising clinical application prospects and provides a new research direction for early warning and precise intervention of sepsis [22-23].

Multivariate regression analysis in this study confirmed that complement activation products (C3a, sC5b-9), inflammatory indicators (WBC, SAA), organ function biomarkers (TBIL), and increased SOFA score are all independent risk factors for poor prognosis in sepsis patients. These indicators reflect disease severity through different pathophysiological mechanisms: abnormal WBC indicates systemic inflammatory response imbalance, dynamic changes in SAA reflect infection control status, elevated TBIL marks liver damage, and SOFA score systematically indicates the degree of multiple organ dysfunction. This result is consistent with previous research conclusions [24-27], further verifying the clinical value of these indicators in the prognostic assessment of sepsis. Combined monitoring of these indicators and comprehensive analysis of their evolutionary trends can provide objective basis for early identification of high-risk patients and timely adjustment of treatment plans, thereby improving patient prognosis.

Studies have found that multiple organ dysfunction in sepsis is partially caused by complement activation [28], and abnormal activation of the complement system (including C3a and sC5b-9) exacerbates the severity of infectious diseases and sepsis [29-30]. Therefore, it is important to emphasize that abnormal activation of the complement system (C3a, sC5b-9) may provide new intervention targets for the immunomodulatory treatment of sepsis.

However, this study still has several limitations that need to be improved: first, due to the limited sample size, the generalizability of the research conclusions needs to be verified by larger-scale studies; second, the study design only collected detection data at a single time point and failed to dynamically observe the changing pattern of complement levels. Future studies can add monitoring at multiple time points to more comprehensively reflect their dynamic characteristics; finally, the study subjects were from a single medical center, which may have regional selection bias. Future multi-center studies are needed to improve the representativeness and universality of the results.

In conclusion, this study confirms that serum complement C3a and sC5b-9 levels are closely associated with the severity and 28-day poor prognosis of sepsis patients. The combined detection of the two has high predictive efficacy and can serve as novel biomarkers for early clinical risk stratification and prognostic assessment, providing important reference for the precise diagnosis and treatment of sepsis.

**Conflict of interest** None

## Reference

[1] Singer M, Deutschman CS, Seymour CW, et al. The third international consensus definitions for sepsis and septic shock (sepsis-3)[J]. Jama, 2016, 315(8): 801.

[2] Edman-Wallér J, Ljungström L, Jacobsson G, et al. Systemic symptoms predict presence or development of severe sepsis and septic shock[J]. Infect Dis, 2016, 48(3): 209-214.

[3] Kyriazopoulou E, Leventogiannis K, Norrby-Teglund A, et al. Macrophage activation-like syndrome: an immunological entity associated with rapid progression to death in sepsis[J]. BMC Med, 2017, 15(1): 172.

[4] Merle NS, Church SE, Fremeaux-Bacchi V, et al. Complement system part I -molecular mechanisms of activation and regulation[J]. Front Immunol, 2015, 6: 262.

[5] Budkowska M, Ostrycharz E, Serwin NM, et al. Biomarkers of the complement system activation (C3a, C5a, sC5b-9) in serum of patients before and after liver transplantation[J]. Biomedicines, 2023, 11(7): 2070.

[6] Singla S, Machado RF. Death of the endothelium in sepsis: understanding the crime scene[J]. Am J Respir Cell Mol Biol, 2018, 59(1): 3-4.

[7] Abe T, Kubo K, Izumoto S, et al. Complement activation in human sepsis is related to sepsis-induced disseminated intravascular coagulation[J]. Shock, 2020, 54(2): 198-204.

[8] Cao Y, Chai YF, Deng Y, et al. Chinese Guidelines for Emergency Treatment of Sepsis/Sepptic Shock (2018)[J]. J Clinic Emerg Med, 2018, 19(12): 567-588.**[In Chinese]**

[9] Ahmed F, Abbasi L, Herekar F, et al. Knowledge and perception of sepsis among doctors in Karachi Pakistan[J]. Pak J Med Sci, 2022, 38(2): 380-386.

[10] Yin F, Xi YL, Wang Y, et al. The clinical outcomes and biomarker features of severe sepsis/septic shock with severe neutropenia: a retrospective cohort study[J]. Transl Pediatr, 2021, 10(3): 464-473.

[11] Webb AL, Kramer N, Rosario J, et al. Delta lactate (three-hour lactate minus initial lactate) prediction of in-hospital death in sepsis patients[J]. Cureus, 2020, 12(4): e7863.

[12] Yin J, Chen Y, Huang JL, et al. Prognosis-related classification and dynamic monitoring of immune status in patients with sepsis: a prospective observational study[J]. World J Emerg Med, 2021, 12(3): 185-191.

[13] Ke JN, Cai GL. Effect of IL-33 on pyroptosis of macrophages in mice with sepsis *via* NF-κB/p38 MAPK signaling pathway[J]. Acta Cir Bras, 2021, 36(5): e360501.

[14] Lupu F, Keshari RS, Lambris JD, et al. Crosstalk between the coagulation and complement systems in sepsis[J]. Thromb Res, 2014, 133: S28-S31.

[15] Walport MJ. Complement[J]. N Engl J Med, 2001, 344(14): 1058-1066.

[16] Wiersinga WJ, Leopold SJ, Cranendonk DR, et al. Host innate immune responses to sepsis[J]. Virulence, 2014, 5(1): 36-44.

[17] Ward PA. The harmful role of c5a on innate immunity in sepsis[J]. J Innate Immun, 2010, 2(5): 439-445.

[18] Ricklin D, Reis ES, Lambris JD. Complement in disease: a defence system turning offensive[J]. Nat Rev Nephrol, 2016, 12(7): 383-401.

[19] Ren JN, Zhao YZ, Yuan YJ, et al. Complement depletion deteriorates clinical outcomes of severe abdominal sepsis: a conspirator of infection and coagulopathy in crime [J]. PLoS One, 2012, 7(10): e47095.

[20] Charchaflieh J, Rushbrook J, Worah S, et al. Activated complement factors as disease markers for sepsis[J]. Dis Markers, 2015, 2015: 382463.

[21] Brandtzaeg P, Høgåsen K, Kierulf P, et al. The excessive complement activation in fulminant meningococcal septicemia is predominantly caused by alternative pathway activation[J]. J Infect Dis, 1996, 173(3): 647-655.

[22] Ekdahl KN, Persson B, Mohlin C, et al. Interpretation of serological complement biomarkers in disease[J]. Front Immunol, 2018, 9: 2237.

[23] Mollnes TE, Huber-Lang M. Complement in sepsis-when science meets clinics[J]. FEBS Lett, 2020, 594(16): 2621-2632.

[24] Zhao JY, Zhang YH, Wu X, et al. Relationship between serum SAA, HBP, IL-8 levels and the severity of sepsis and 28-day prognosis in patients with sepsis[J]. J N Sichuan Med Coll, 2024, 39(6): 811-814.**[In Chinese]**

[25] Peng ZH, Yan HP, Lu XL, et al. Value of complement component 3 in predicting the prognosis of children with sepsis[J]. Chin J Contemp Pediatr, 2023, 25(9): 941-946. **[In Chinese]**

[26] Ge X. Biomarkers for early diagnosis of sepsis-associated acute kidney injury[J]. Chin J Clin Res, 2024, 37(11): 1649-1654. **[In Chinese]**

[27] Song MH, Wang L, Bi Y, et al. Establishment and validation of a prediction model for death during hospitalization in elderly patients with sepsis combined with acute kidney injury[J]. Chin J Clin Res, 2024, 37(11): 1686-1690. [In Chinese]

[28] Seki K, Sueyoshi K, Miyoshi Y, et al. Complement activation and lung injury in Japanese patients with COVID-19: a prospective observational study[J]. Sci Rep, 2024, 14(1): 24895.

[29] Chen TY, Liu YW, Liu Y, et al. Clinical value of complement C3a, C5a, and sC5b-9 in evaluating the severity of patients with severe fever with thrombocytopenia syndrome[J]. J Inflamm Res, 2025, 18: 9001-9014.

[30] Abe T, Saito K, Nagano T, et al. Complement system activation through the alternative pathway associates with disseminated intravascular coagulation to increase mortality in sepsis[J]. Thromb Res, 2025, 247: 109281.

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·论　著·

# 血清补体成分3a和sC5b-9水平与脓毒症患者预后的关系

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**摘要：目的**　探讨血清补体成分3a（C3a）、可溶性终末补体复合物C5b-9（sC5b-9）水平与脓毒症患者病情严重程度及28 d临床预后的相关性，为脓毒症的早期风险分层和预后评估提供新的生物标志物参考。**方法**　回顾性纳入2022年3月至2024年9月于江苏大学附属昆山市第一人民医院收治的209例脓毒症患者作为研究组。根据病情严重程度，将其分为休克组（$n$=129）和未休克组（$n$=80）；根据患者入院后28 d的生存状态，分为生存组（$n$=137）和死亡组（$n$=72）。并纳入同期56例体检健康者作为对照组。收集所有受试者的临床资料，比较各组血清C3a、sC5b-9水平；采用Spearman相关法分析血清C3a、sC5b-9水平与脓毒症患者病情严重程度及预后的相关性；采用受试者工作特征（ROC）曲线下面积（AUC）评估血清C3a、sC5b-9对脓毒症患者预后不良的预测效能；采用单因素和多因素logistic回归分析脓毒症患者预后不良的独立影响因素。**结果**　与对照组的C3a和sC5b-9［（98.25±19.25）ng/mL，（89.36±12.14）ng/mL］相比，未休克组［（169.25±21.47）ng/mL，（325.69±25.36）ng/mL］和休克组［（198.74±19.86）ng/mL，（356.98±36.21）ng/mL］的C3a、sC5b-9水平显著升高（$P$<0.05）；与未休克组患者相比，休克组患者C3a、sC5b-9水平显著升高（$P$<0.05）。与生存组相比，死亡组患者C3a、sC5b-9水平显著升高（$P$<0.05）。Spearman相关性分析结果显示，血清C3a、sC5b-9水平与脓毒症患者病情严重程度呈正相关（$r$=0.802、0.744，$P$<0.05），与患者预后不良呈正相关（$r$=0.507、0.602，$P$<0.05）。ROC分析结果显示，C3a、sC5b-9二者联合预测脓毒症患者预后不良的AUC为0.910，灵敏度为80.56%，特异度为87.59%。多因素logistic回归分析结果显示，C3a、sC5b-9、白细胞计数（WBC）、血清淀粉样蛋白A（SAA）、总胆红素（TBIL）、序贯器官衰竭评估（SOFA）评分均为脓毒症患者预后不良的独立危险因素（$P$<0.05）。**结论**　血清补体C3a和sC5b-9水平与脓毒症患者病情严重程度及不良预后显著相关，二者联合检测对脓毒症患者预后不良具有较高的预测价值，可作为临床评估脓毒症严重程度和预后的有效生物标志物。

**关键词：**血清补体成分3a；可溶性终末补体复合物C5b-9；脓毒症；病情严重程度；预后
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# Associations between serum complement component 3a and sC5b-9 levels with the prognosis of sepsis patients

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**Abstract: Objective**　To investigate the associations of serum complement component 3a (C3a) and soluble terminal complement complex C5b-9 (sC5b-9) levels with the severity of sepsis and 28-day clinical prognosis among patients, and to provide new biomarker references for early risk stratification and prognostic assessment of sepsis. **Methods**　A total of 209 sepsis patients admitted to Kunshan First People's Hospital Affiliated to Jiangsu University from March 2022 to September 2024 were retrospectively included as the study group. They were categorized into shock group ($n$=129) and non-shock group ($n$=80) according to the severity of the disease. Based on the survival status of the patients within

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28 days after admission, they were divided into survival group ($n$=137) and death group ($n$=72). Another 56 physically healthy individuals were selected as the control group during the same period. The clinical data of all subjects were collected. Serum C3a and sC5b-9 levels were compared between the groups. The associations of serum C3a and sC5b-9 levels with the severity and prognosis of sepsis patients were analyzed by Spearman correlation analysis. The value of the area under the curve (AUC) of the receiver operating characteristics (ROC) was used to assess the effects of serum C3a and sC5b-9 on predicting poor prognosis in patients with sepsis. Independent influencing factors on poor prognosis in patients with sepsis were analyzed using univariate and multivariate logistic regression. **Results** C3a and sC5b-9 levels were significantly higher in the non-shock group [(169.25±21.47) ng/mL, (325.69±25.36) ng/mL] and shock group [(198.74±19.86) ng/mL, (356.98±36.21) ng/mL] compared with those in the control group [(98.25±19.25) ng/mL, (89.36±12.14) ng/mL, $P$<0.05]. C3a and sC5b-9 levels were significantly higher in the shock group compared with those in the non-shock group ($P$<0.05). C3a and sC5b-9 levels were significantly higher in the death group compared with those in the survival group ($P$<0.05). Spearman correlation analysis showed that serum C3a and sC5b-9 levels were positively correlated with the severity of sepsis ($r$=0.802, 0.744, $P$<0.05) and the poor prognosis ($r$=0.507, 0.602, $P$<0.05). The ROC analysis results showed that the AUC of the combination of C3a and sC5b-9 in predicting the poor prognosis of sepsis patients was 0.910, with a sensitivity of 80.56% and a specificity of 87.59%. The results of multivariate logistic regression analysis showed that C3a, sC5b-9, white blood cell count (WBC), serum amyloid A (SAA), total bilirubin (TBIL), and Sequential Organ Failure Assessment (SOFA) score were independent risk factors for poor prognosis in patients with sepsis ($P$<0.05). **Conclusion** Serum C3a and sC5b-9 levels are significantly correlated with the severity and poor prognosis of sepsis patients, and the combined detection of these two has a high predictive value for the poor prognosis of sepsis patients, which can be used as an effective biomarker for the clinical assessment of the severity and prognosis of sepsis.

**Keywords**: Serum complement component 3a; Soluble terminal complement complex C5b-9; Sepsis; Severity of disease; Prognosis

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脓毒症是由宿主对感染的反应失调所导致的危及生命的器官功能障碍，其高发病率和高病死率使其成为全球重症医学领域的重大难题[1]。该疾病临床表现复杂多样，病情进展迅猛，患者可表现出意识障碍、皮肤改变、呼吸及循环系统异常等症状，严重者可迅速进展为多器官功能衰竭甚至死亡[2]。尽管近年来抗感染治疗及器官支持技术取得了显著进展，脓毒症患者的预后改善仍不理想，这主要归因于其复杂的病理生理机制，特别是过度炎症反应与免疫抑制并存的免疫紊乱状态[3]。补体系统作为先天免疫的关键组成部分，在脓毒症的发病过程中具有双重作用：一方面，补体激活后释放的过敏毒素[如血清补体成分3a(complement component 3a, C3a)、C5a]可触发炎症级联反应，导致内皮损伤和微血栓形成[4]；另一方面，可溶性终末补体复合物C5b-9(soluble terminal complement complex C5b-9, sC5b-9)的沉积可直接引起细胞溶解和组织损伤[5]。近年来，多项研究表明，补体系统的过度激活与脓毒症患者的病情严重程度及不良预后显著相关[6-7]。然而，特定补体成分(如C3a和sC5b-9)的水平变化及其临床意义仍需进一步探索。因此，本研究旨在探讨C3a与sC5b-9水平与脓毒症患者病情严重程度及预后的关联，以期为脓毒症的早期风险分层提供新型生物标志物，为靶向补体调控的精准治疗提供理论依据，有助于转化为临床应用。

## 1 资料与方法

1.1 一般资料 回顾性纳入2022年3月至2024年9月于江苏大学附属昆山市第一人民医院收治的209例脓毒症患者作为研究组，其中男性101例，女性108例，年龄35~75(48.21±11.85)岁。另选择同期56例体检健康者为对照组，其中男性29例，女性27例，年龄35~73(47.85±12.34)岁。两组在性别构成和年龄分布方面差异均无统计学意义($P$>0.05)。纳入标准：(1)符合2016年Sepsis-3诊断标准[1]；诊断标准如下(需满足至少2项标准)，存在明确感染或体温异常(<36 ℃或>38 ℃)或呼吸异常(呼吸频率>20次/min或动脉血二氧化碳分压<32 mmHg)或白细胞计数异常(>12×$10^9$/L)。(2)年龄超过18周岁。(3)完整的临床资料。排除标准：(1)入院24 h内死亡；(2)合并恶性肿瘤和免疫缺陷病者；(3)精神异常者；(4)入院前接受过免疫抑制剂治疗者。本研究经过江苏大

学附属昆山市第一人民医院严格的医学伦理审查，已成功获得医学伦理委员会的正式批准（审批号：KY2025-001-01）。

1.2 方法

1.2.1 资料收集 回顾性收集所有受试者入院后的临床特征以及首次实验室检查结果，包括年龄、性别、吸烟史、饮酒史、身体质量指数（BMI）、合并糖尿病、合并高血压、合并冠状动脉粥样硬化性心脏病（冠心病）、感染病灶（肺部、胸腔、其它）、白细胞计数（WBC）、红细胞计数（RBC）、血红蛋白（Hb）、血小板计数（PLT）、降钙素原（PCT）、C反应蛋白（CRP）、血清淀粉样蛋白A（SAA）、C3a、sC5b-9、总胆红素（TBIL）、N末端脑钠肽前体（NT-proBNP）、肌酸激酶同工酶MB（CK-MB）、心肌肌钙蛋白I（cTnI）以及序贯器官衰竭评估（SOFA）评分等。所有研究对象均于空腹状态下采集外周静脉血3~5 mL，经3 000 r/min离心10 min后（离心半径15 cm），分离血清并保存于−80 ℃超低温冰箱中备用。

1.2.2 实验室指标的检测 使用全自动血细胞分析仪（型号：Sysmex XE-2100，厂家：希森美康株式会社）检测WBC、RBC、Hb和PLT水平；使用全自动化学发光免疫分析仪（型号：cobas 8000 e 801，厂家：罗氏诊断公司）检测血清PCT水平；使用全自动特定蛋白质分析仪（型号：H780-3，厂家：深圳希莱恒医用电子）检测血清CRP和SAA水平；使用全自动生化分析仪（型号：ADVIA 2400，厂家：美国西门子医学诊断股份有限公司）检测血清C3a、sC5b-9、TBIL水平；使用全自动发光免疫分析仪（型号：Centaur XP，厂家：美国西门子医学诊断股份有限公司）检测血清NT-proBNP、CK-MB和cTnI水平。

1.3 分组

1.3.1 休克组和非休克组 根据病情严重程度[8]，将209例脓毒症患者分为休克组（$n$=129）和未休克组（$n$=80）。脓毒症休克的诊断标准为：（1）符合脓毒症诊断标准并伴有急性循环功能障碍，表现为持续性低血压（收缩压 < 90 mmHg），需血管活性药物维持平均动脉压（MAP）≥65 mmHg且血乳酸>2 mmol/L；（2）脓毒症相关SOFA较基线水平升高≥2分[1]。

1.3.2 生存组及死亡组 根据患者入院后28 d内的生存状态，将其分为生存组（$n$=137）和死亡组（$n$=72）。

1.4 统计学方法 使用SPSS 27.0版本进行统计分析。采用Shapiro-Wilk检验来确定连续变量分布的正态性，满足正态性的连续变量表示为$\bar{x}\pm s$，两组间比较采用独立样本$t$检验，多组间比较采用单因素方差分析，两两比较采用LSD-$t$法；分类变量表示为例（%），两组间比较采用$\chi^2$检验。采用Spearman相关法分析血清补体成分C3a、sC5b-9水平与脓毒症患者病情严重程度及预后的相关性；采用受试者工作特征（receiver operating characteristic，ROC）曲线下面积（area under curve AUC）评估血清C3a、sC5b-9对脓毒症患者预后不良的预测效能，AUC值<0.70为预测效能较差，0.70 ~ < 0.80为预测效能一般；0.80 ~ < 0.90为预测效能良好；0.90 ~ 1.00为预测效能优秀；AUC值的比较采用$Z$检验；采用单因素和多因素logistic回归分析脓毒症患者预后不良的独立影响因素。$P$<0.05为差异有统计学意义。

## 2 结 果

2.1 不同病情严重程度患者血清C3a、sC5b-9水平比较 与对照组相比，未休克组和休克组患者C3a、sC5b-9水平显著升高（$P$ < 0.05）；与未休克组患者相比，休克组患者C3a、sC5b-9水平显著升高（$P$ < 0.05）。见表1。

2.2 不同预后情况患者血清C3a、sC5b-9水平比较 与生存组相比，死亡组患者C3a、sC5b-9水平显著升高（$P$ < 0.05）。见表2。

2.3 血清C3a、sC5b-9水平与脓毒症患者病情严重程度和预后的相关性 Spearman相关性分析结果显示，血清C3a、sC5b-9水平与脓毒症患者病情严重程度呈正相关（$r$=0.802、0.744，$P$ < 0.05），与患者预后不良呈正相关（$r$=0.507、0.602，$P$ < 0.05）。

2.4 血清C3a、sC5b-9水平对脓毒症患者预后不良的预测价值 ROC分析结果显示，C3a、sC5b-9水平预测脓毒症患者预后不良的AUC分别为0.808、0.866，灵敏度分别为79.17%、76.39%，特异度分别为74.45%、83.94%。二者联合预测脓毒症患者预后不良的AUC为0.910，灵敏度为80.56%，特异度为87.59%。联合预测的AUC显著高于C3a（$Z$=3.755，$P$<0.01）、sC5b-9（$Z$=2.790，$P$<0.01）单独使用时的AUC。见表3、图1。

2.5 影响脓毒症患者预后不良的单因素分析 单因素分析结果显示，两组患者在年龄、性别、BMI、吸烟史、饮酒史、合并高血压、合并糖尿病、合并冠心病、感染病灶、Hb方面差异均无统计学意义（$P$>0.05）。而在WBC、RBC、PLT、PCT、CRP、SAA、TBIL、SOFA评分、NT-proBNP、CK-MB、cTnI水平上差异均有统计学意义（$P$ < 0.05）。见表4。

2.6 影响脓毒症患者预后不良的多因素logistic回归

分析　以脓毒症患者预后状态为因变量(死亡=1，生存=0)，以单因素分析中具有显著性差异的因素为自变量(均为连续变量，以实测值代入方程)，进行多因素 logistic 回归分析。结果显示，C3a、sC5b-9、WBC、SAA、TBIL、SOFA 评分增高均为脓毒症患者预后不良的独立危险因素($P<0.05$)。见表 5。

**表 1**　不同病情严重程度患者血清 C3a、sC5b-9 水平比较(ng/mL，$\bar{x}\pm s$)

**Tab.1**　Comparison of serum levels of C3a and sC5b-9 in patients with different disease severities　(ng/mL, $\bar{x}\pm s$)

| 组别 | 例数 | C3a | sC5b-9 |
|---|---|---|---|
| 休克组 | 129 | 198.74±19.86[ab] | 356.98±36.21[ab] |
| 未休克组 | 80 | 169.25±21.47[a] | 325.69±25.36[a] |
| 对照组 | 56 | 98.25±19.25 | 89.36±12.14 |
| $F$ 值 | | 481.556 | 1 695.44 |
| $P$ 值 | | <0.001 | <0.001 |

注：与对照组比较，[a]$P$<0.05；与未休克组比较，[b]$P$<0.05。

**表 2**　不同预后情况患者血清 C3a、sC5b-9 水平比较(ng/mL，$\bar{x}\pm s$)

**Tab.2**　Comparison of serum levels of C3a and sC5b-9 in patients with different prognoses　(ng/mL, $\bar{x}\pm s$)

| 组别 | 例数 | C3a | sC5b-9 |
|---|---|---|---|
| 死亡组 | 72 | 208.15±25.86 | 357.04±28.76 |
| 生存组 | 137 | 179.14±21.47 | 314.69±23.14 |
| $t$ 值 | | 8.639 | 11.541 |
| $P$ 值 | | <0.001 | <0.001 |

**表 3**　血清 C3a、sC5b-9 水平对脓毒症患者预后不良的预测价值

**Tab.3**　Predictive values of serum levels of C3a and sC5b-9 on poor prognosis in patients with sepsis

| 变量 | AUC | 最佳截断值 | 95%*CI* | 灵敏度(%) | 特异度(%) | 约登指数 |
|---|---|---|---|---|---|---|
| C3a | 0.808 | 188.12 ng/mL | 0.748~0.859 | 79.17 | 74.45 | 0.536 |
| sC5b-9 | 0.866 | 340.69 ng/mL | 0.812~0.909 | 76.39 | 83.94 | 0.603 |
| 联合 | 0.910 | – | 0.862~0.945 | 80.56 | 87.59 | 0.682 |

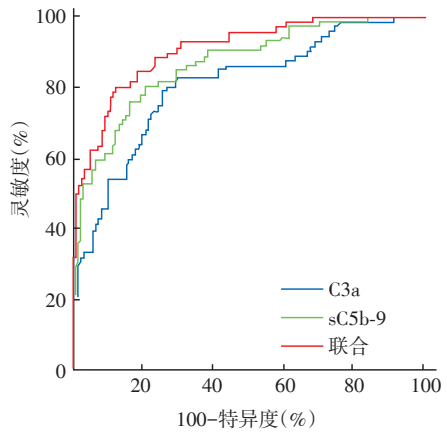


**图 1**　血清 C3a、sC5b-9 水平对脓毒症患者预后不良的 ROC 曲线

**Fig.1**　ROC curves of serum levels of C3a and sC5b-9 on poor prognosis in patients with sepsis

**表 4**　影响脓毒症患者不良预后的单因素分析　($\bar{x}\pm s$)

**Tab.4**　Univariate analysis of factors affecting poor prognosis in patients with sepsis　($\bar{x}\pm s$)

| 项目 | 死亡组($n$=72) | 生存组($n$=137) | $t/\chi^2$ 值 | $P$ 值 |
|---|---|---|---|---|
| 年龄(岁) | 45.29±6.39 | 43.69±7.85 | 1.489 | 0.138 |
| 女/男(例) | 33/39 | 72/65 | 0.853 | 0.356 |
| BMI(kg/m$^2$) | 22.36±5.47 | 22.14±6.32 | 0.250 | 0.803 |
| 吸烟史[例(%)] | 38(52.78) | 66(48.18) | 0.400 | 0.527 |
| 饮酒史[例(%)] | 33(45.83) | 73(53.28) | 1.048 | 0.306 |
| 并存高血压[例(%)] | 37(51.39) | 67(48.91) | 0.116 | 0.733 |
| 并存糖尿病[例(%)] | 39(54.17) | 66(48.18) | 0.678 | 0.410 |
| 并存冠心病[例(%)] | 40(55.56) | 65(47.45) | 1.242 | 0.265 |
| 感染病灶[例(%)] | | | | |
| 　肺部 | 25(34.72) | 43(31.39) | | |
| 　胸腔 | 24(33.33) | 48(35.04) | 0.239 | 0.887 |
| 　其他 | 23(31.94) | 46(33.58) | | |
| WBC(×10$^9$/L) | 16.14±3.69 | 13.25±5.14 | 4.230 | <0.001 |
| RBC(×10$^{12}$/L) | 12.15±2.47 | 15.32±5.19 | 4.895 | <0.001 |
| Hb(g/L) | 83.24±24.50 | 89.22±21.74 | 1.808 | 0.072 |
| PLT(×10$^9$/L) | 110.25±25.16 | 120.17±19.85 | 3.124 | 0.002 |
| PCT(ng/mL) | 22.36±3.65 | 17.15±5.36 | 7.392 | <0.001 |
| CRP(mg/L) | 40.25±5.47 | 22.69±4.68 | 24.297 | <0.001 |
| SAA(mg/L) | 39.68±5.52 | 27.57±6.53 | 13.414 | <0.001 |
| TBIL(μmol/L) | 35.58±11.51 | 26.09±4.63 | 8.450 | <0.001 |
| SOFA 评分 | 9.25±2.31 | 7.12±1.49 | 8.069 | <0.001 |
| NT-proBNP(pg/mL) | 2 847.58±25.69 | 1 769.69±32.69 | 243.021 | <0.001 |
| CK-MB(ng/mL) | 56.93±13.44 | 36.25±8.55 | 13.547 | <0.001 |
| cTnI(ng/mL) | 0.79±0.25 | 0.42±0.09 | 15.539 | <0.001 |

**表 5**　影响脓毒症患者预后不良的多因素 logistic 回归分析

**Tab.5**　Multivariate logistic regression analysis of factors affecting poor prognosis in patients with sepsis

| 项目 | $\beta$ | *SE* | Wald | *OR* 值 | 95%*CI* | $P$ 值 |
|---|---|---|---|---|---|---|
| C3a | 0.035 | 0.017 | 4.146 | 1.036 | 1.001~1.072 | 0.042 |
| sC5b-9 | 0.045 | 0.014 | 10.291 | 1.046 | 1.018~1.075 | 0.001 |
| WBC | 0.158 | 0.075 | 4.442 | 1.172 | 1.011~1.358 | 0.035 |
| SAA | 0.280 | 0.067 | 17.340 | 1.323 | 1.160~1.510 | <0.001 |
| TBIL | 0.141 | 0.048 | 8.796 | 1.152 | 1.049~1.265 | 0.003 |
| SOFA 评分 | 0.603 | 0.210 | 8.289 | 1.828 | 1.212~2.757 | 0.004 |
| 常量 | −42.917 | 7.208 | 35.455 | | | |

## 3　讨　论

脓毒症是一种由感染触发的全身性炎症反应综合征，其发病率和病死率持续处于较高水平，已成为全球公共卫生领域面临的重大挑战[9]。该疾病的典型特征为过度的炎症反应激活，进而引发全身性细胞损伤及多器官功能损害[10]。临床观察表明，脓毒症具有快速进展的特点，若未能在早期实施有效的干预，可迅速发生多器官功能衰竭、感染性休克等严

重并发症，最终导致不良预后[11]。目前临床实践中，白细胞介素-6（IL-6）、急性生理学与慢性健康状况评分系统（APACHE）Ⅱ等被广泛应用于评估脓毒症患者的病情严重程度。然而，这些指标在敏感度、特异度及临床适用性方面仍存在明显不足[12]。因此，寻找可靠的早期预测指标以准确预测疾病进展和临床转归，对于实现早期精准干预、改善患者临床结局具有重要意义。

既往研究证实，脓毒症的病理生理过程涉及复杂的免疫调控机制，其中免疫功能紊乱是疾病恶化的重要驱动因素[13]。补体系统作为先天免疫的关键组成部分，在病原体防御中发挥核心作用，但其过度激活可能引发病理性损害[14]。在感染早期阶段，补体系统迅速构建宿主防御的第一道防线，有效清除入侵病原微生物[15]。然而，不受调控的补体激活可触发过度的炎症级联反应，加剧组织损伤，最终导致多器官功能障碍甚至死亡[16-17]。研究表明，补体成分及其活化产物的异常变化与包括脓毒症在内的多种疾病密切相关[18]。本研究结果发现，脓毒症患者血清C3a和sC5b-9水平呈现显著的疾病相关变化特征，且与疾病严重程度和临床预后密切相关。与健康对照组相比，未休克组和休克组患者的C3a、sC5b-9水平均显著升高；进一步分析发现，休克组患者的这两种补体活化产物水平又显著高于未休克组，而死亡组患者的水平较生存组亦显著增高。Spearman相关性分析证实，血清C3a和sC5b-9水平与疾病严重程度及不良预后均呈现显著正相关性。本研究观察到的补体成分变化规律与既往研究结果高度一致。Ren和Charchaflieh等[19-20]的研究证实，脓毒症患者存在C3、C4显著消耗现象，同时伴随C3a、C4a等补体活化产物水平的升高，且这些变化与疾病严重程度及病死率显著相关。此外，Brandtzaeg等[21]的临床研究显示，脓毒症患者sC5b-9水平显著升高，特别是在持续性脓毒性休克患者中升高更为明显，本研究的观察结果与之相互印证，进一步支持补体终末途径过度激活在脓毒症进展中起关键作用的理论。综合这些研究可以明确，补体系统的异常活化不仅深度参与脓毒症的病理生理过程，其活化产物C3a和sC5b-9的水平变化更具有作为评估疾病严重程度和预测临床预后的潜在生物标志物价值。本研究还通过ROC曲线分析评估了C3a和sC5b-9对脓毒症患者不良预后的预测价值。研究数据显示，C3a单独预测的AUC为0.808（95%*CI*：0.748~0.859），sC5b-9的AUC为0.866（95%*CI*：0.812~0.909）。值得注意的是，将两种标志物联合应用时，预测效能显著提升，联合预测的AUC升高至0.910（95%*CI*：0.862~0.945）。这些研究结果表明，C3a和sC5b-9的联合检测不仅可作为评估脓毒症患者预后的新型生物标志物组合，其介导的补体激活通路更可能成为未来脓毒症治疗的潜在干预靶点。这种双标志物联合检测策略展现出良好的临床应用前景，为脓毒症的早期预警和精准干预提供了新的研究方向[22-23]。

本研究通过多因素回归分析证实，补体活化产物（C3a、sC5b-9）、炎症指标（WBC、SAA）、器官功能标志物（TBIL）以及SOFA评分均是脓毒症患者预后不良的独立危险因素。这些指标从不同病理生理机制反映疾病严重程度：WBC异常提示全身炎症反应失衡，SAA动态变化体现感染控制状态，TBIL升高标志肝脏损伤，而SOFA评分则系统提示多器官功能障碍程度。该结果与之前的研究结论一致[24-27]，进一步验证了上述指标在脓毒症预后评估中的临床价值。在临床实践中，对这些指标进行联合监测，通过综合分析其演变趋势，可为早期识别高危患者、及时调整治疗方案提供依据，从而改善患者预后。研究发现，脓毒症的多器官功能障碍被认为部分是由补体激活引起的[28]，补体系统的异常活化（包括C3a和sC5b-9）加重感染性疾病及脓毒症的严重程度[29-30]。因此，C3a、sC5b-9或可为脓毒症的免疫调控治疗提供新的干预靶点。

然而，本研究仍存在若干需要改进的局限性：首先，受样本量限制，研究结论的推广性有待更大规模研究验证；其次，研究设计仅采集单一时点的检测数据，未能动态观察补体水平的变化规律，后续研究可增加多个时间节点的监测以更全面反映其动态特征；最后，研究对象来自单一医疗中心，可能存在地域选择偏倚，未来需要通过多中心研究来提升结果的代表性和普适性。

综上所述，本研究证实血清补体C3a和sC5b-9水平与脓毒症患者病情严重程度及28 d不良预后密切相关，二者联合检测具有较高的预测效能，可作为临床早期风险分层和预后评估的新型生物标志物，为脓毒症的精准诊疗提供重要参考依据。

**利益冲突** 无

**参考文献**

[1] Singer M, Deutschman CS, Seymour CW, et al. The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3) [J]. JAMA, 2016, 315(8): 801-810.

[2] Edman-Wallér J, Ljungström L, Jacobsson G, et al. Systemic symptoms predict presence or development of severe sepsis and septic shock[J]. Infect Dis, 2016, 48(3): 209-214.
[3] Kyriazopoulou E, Leventogiannis K, Norrby-Teglund A, et al. Macrophage activation-like syndrome: an immunological entity associated with rapid progression to death in sepsis[J]. BMC Med, 2017, 15(1): 172.
[4] Merle NS, Church SE, Fremeaux-Bacchi V, et al. Complement system part I - molecular mechanisms of activation and regulation[J]. Front Immunol, 2015, 6: 262.
[5] Budkowska M, Ostrycharz E, Serwin NM, et al. Biomarkers of the complement system activation (C3a, C5a, sC5b-9) in serum of patients before and after liver transplantation[J]. Biomedicines, 2023, 11(7): 2070.
[6] Singla S, Machado RF. Death of the endothelium in sepsis: understanding the crime scene[J]. Am J Respir Cell Mol Biol, 2018, 59(1): 3-4.
[7] Abe T, Kubo K, Izumoto S, et al. Complement activation in human sepsis is related to sepsis-induced disseminated intravascular coagulation[J]. Shock, 2020, 54(2): 198-204.
[8] 曹钰,柴艳芬,邓颖,等. 中国脓毒症/脓毒性休克急诊治疗指南(2018)[J]. 临床急诊杂志, 2018, 19(19):567-588.
[9] Ahmed F, Abbasi L, Herekar F, et al. Knowledge and perception of sepsis among doctors in Karachi Pakistan[J]. Pak J Med Sci, 2022, 38(2): 380-386.
[10] Yin F, Xi YL, Wang Y, et al. The clinical outcomes and biomarker features of severe sepsis/septic shock with severe neutropenia: a retrospective cohort study[J]. Transl Pediatr, 2021, 10(3): 464-473.
[11] Webb AL, Kramer N, Rosario J, et al. *Delta* lactate (three-hour lactate minus initial lactate) prediction of in-hospital death in sepsis patients[J]. Cureus, 2020, 12(4): e7863.
[12] Yin J, Chen Y, Huang JL, et al. Prognosis-related classification and dynamic monitoring of immune status in patients with sepsis: a prospective observational study[J]. World J Emerg Med, 2021, 12(3): 185-191.
[13] Ke JN, Cai GL. Effect of IL-33 on pyroptosis of macrophages in mice with sepsis via NF-κB/p38 MAPK signaling pathway[J]. Acta Cir Bras, 2021, 36(5): e360501.
[14] Lupu F, Keshari RS, Lambris JD, et al. Crosstalk between the coagulation and complement systems in sepsis[J]. Thromb Res, 2014, 133 (Suppl 1): S28-S31.
[15] Walport MJ. Complement[J]. N Engl J Med, 2001, 344(14): 1058-1066.
[16] Wiersinga WJ, Leopold SJ, Cranendonk DR, et al. Host innate immune responses to sepsis[J]. Virulence, 2014, 5(1): 36-44.
[17] Ward PA. The harmful role of C5a on innate immunity in sepsis[J]. J Innate Immun, 2010, 2(5): 439-445.
[18] Ricklin D, Reis ES, Lambris JD. Complement in disease: a defence system turning offensive[J]. Nat Rev Nephrol, 2016, 12(7): 383-401.
[19] Ren JN, Zhao YZ, Yuan YJ, et al. Complement depletion deteriorates clinical outcomes of severe abdominal sepsis: a conspirator of infection and coagulopathy in crime?[J]. PLoS One, 2012, 7(10): e47095.
[20] Charchaflieh J, Rushbrook J, Worah S, et al. Activated complement factors as disease markers for sepsis[J]. Dis Markers, 2015, 2015: 382463.
[21] Brandtzaeg P, Høgåsen K, Kierulf P, et al. The excessive complement activation in fulminant meningococcal septicemia is predominantly caused by alternative pathway activation[J]. J Infect Dis, 1996, 173(3): 647-655.
[22] Ekdahl KN, Persson B, Mohlin C, et al. Interpretation of serological complement biomarkers in disease[J]. Front Immunol, 2018, 9: 2237.
[23] Mollnes TE, Huber-Lang M. Complement in sepsis-when science meets clinics[J]. FEBS Lett, 2020, 594(16): 2621-2632.
[24] 赵静媛, 张玉红, 吴雪, 等. 血清SAA、HBP、IL-8水平与脓毒症患者病情严重程度及28天预后的关系[J]. 川北医学院学报, 2024, 39(6): 811-814.
[25] 彭智慧, 颜海鹏, 卢秀兰, 等. 补体C3对儿童脓毒症患者预后的预测价值[J]. 中国当代儿科杂志, 2023, 25(9): 941-946.
[26] 葛新. 脓毒症相关急性肾损伤早期诊断标志物的研究现状[J]. 中国临床研究, 2024, 37(11):1649-1654.
[27] 宋铭慧,王磊,毕迎,等. 老年脓毒症合并急性肾损伤住院死亡预测模型建立与验证[J]. 中国临床研究, 2024, 37(11):1686-1690.
[28] Seki, K, Sueyoshi K, Miyoshi Y, et al. Complement activation and lung injury in Japanese patients with COVID-19:a prospective observational study[J]. Sci Rep,2024,14(1):24895.
[29] Chen TY, Liu YW, Liu Y,et al. Clinical value of complement C3a, C5a, and sC5b-9 in evaluating the severity of patients with severe fever with thrombocytopenia syndrome[J]. J Inflamm Res, 2025, 18: 9001-9014.
[30] Abe T, Saito K, Nagano T, et al. Complement system activation through the alternative pathway associates with disseminated intravascular coagulation to increase mortality in sepsis[J]. Thromb Res, 2025,247:109281.

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