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Original Article

Association of nutritional risk index with severe infection in patients with acute kidney injury

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Abstract

Introduction: We aimed to investigate the association between the nutritional risk index (NRI) and severe infection in patients with acute kidney injury (AKI).

Methodology: A retrospective analysis was conducted on the clinical data of 102 AKI patients admitted to and treated in our hospital between May 2022 and May 2024. An infection group (n = 39) and a non-infection group (n = 63) were established based on the presence and absence of severe infection.

Results: NRI was smaller in the infection group than in the non-infection group ($p < 0.05$). In comparison with the non-infection group, the infection group displayed elevations in proportions of cases with age (≥ 60 years old), body mass index (BMI) (≤ 20 kg/m^2), diabetes mellitus, catheter indwelling site (femoral vein), catheter indwelling time (> 7 days), albumin (ALB) (< 35 g/L) and hemoglobin (Hb) (< 70 g/L), as well as C-reactive protein (CRP) and interleukin-6 (IL-6) levels ($p < 0.05$). NRI was a protective factor against severe infection in AKI patients [*odds ratio (OR)* < 1, $p < 0.05$], while age (≥ 60 years old), BMI (≤ 20 kg/m^2), diabetes mellitus, catheter indwelling site (femoral vein), catheter indwelling time (> 7 d), ALB (< 35 g/L), Hb (< 70 g/L), and CRP and IL-6 levels were risk factors for severe infection in such patients (*odds ratio* > 1, $p < 0.05$). The area under the Receiver operating characteristic curve (95% confidence interval) of NRI for predicting severe infection in AKI patients was 0.863 (0.781-0.946).

Conclusions: NRI has a close association with severe infection in AKI patients, and a low NRI suggests an increased risk of severe infection.

Key words: acute; association; nutritional risk index; kidney injury; severe infection.

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Introduction

Acute kidney injury (AKI), also known as acute kidney injury, is defined as a clinical syndrome characterized by an acute onset, severe condition, and rapid progression, which is ascribed to the joint effects of various factors [1]. In the case of AKI, sudden loss of renal function is induced by variations in renal tubular function or renal circulatory function, which causes a failure to discharge metabolites from the human body through the kidneys, and the resulting long-term accumulation of metabolites leads to the release of massive toxins, then seriously threatening the life safety of patients [2]. At the present stage, eliminating primary lesions is the major principle for the clinical treatment of the disease, aiming to quickly relieve symptoms, improve renal function, and prevent other complications. As a crucial treatment approach for AKI, renal dialysis can effectively compensate for the lost renal function and accumulated discharge toxins, thereby reducing the mortality rate of the disease. However, this approach consumes considerable energy, affecting the nutritional status of the human body.

As one of the most common complications in AKI patients, infection is extremely harmful, especially severe infection, which significantly enhances the difficulty of clinical treatment and poses a relatively high risk of death [3]. Moreover, acknowledged, simple, practicable, and effective assessment indicators enabling repetitive operation remain unavailable at present. In recent years, many scholars have argued that nutritional status is closely related to the prognosis of patients undergoing hemodialysis and serves as an effective indicator of protein-energy-nutrient consumption in these patients [4,5]. Nutritional risk index (NRI), a nutritional assessment tool based on nutritional indicators and body weight, has been extensively applied in cancer evaluation, hemodialysis, severe diseases and other fields. A foreign study proved that a low NRI value is an independent risk factor for infection-induced death in patients receiving hemodialysis [6]. However, no clear conclusion has been drawn on the relationship between NRI and severe infection in AKI patients. It has been speculated based on the association between NRI and infection in patients undergoing hemodialysis that NRI also possesses a certain relation to severe infection in AKI patients, but such speculation has been rarely

expounded and proved in the existing literature.

In this study, therefore, clinical data from 102 AKI patients hospitalized herein for treatment over the past two years were retrospectively analyzed to determine the association between NRI and severe infection in AKI patients and to provide guidance for risk assessment.

Methodology

Subjects

A retrospective analysis was conducted on the clinical data of 102 patients with AKI who were admitted to our hospital between May 2022 and May 2024. Patients were categorized into an infection group (n = 39) and a non-infection group (n = 63). The infection group comprised 26 males and 13 females, including 24 patients aged ≥ 60 years and 15 patients aged < 60 years. Among them, 13 had a history of smoking, and 10 reported alcohol consumption. The non-infection group included 39 males and 24 females, with 23 patients aged ≥ 60 years and 40 patients < 60 years; 22 patients had a smoking history, and 18 reported alcohol consumption. Information on smoking and alcohol consumption was obtained through structured interviews. Patients were classified as current, former, or never smokers/drinkers based on their status at admission. Duration of use and average daily consumption were also recorded when available. There were no statistically significant differences in baseline characteristics between the two groups ($p > 0.05$).

Although this was a retrospective study, the sample size (n = 102) was determined based on the principle of ensuring at least 10 outcome events per variable in logistic regression analysis, which is widely accepted for maintaining model stability and statistical power.

To address potential confounding in a study with a limited sample size, we implemented several strategies: 1) carefully selected covariates based on clinical relevance and prior literature; 2) conducted univariate analyses to screen for variables associated with infection risk ($p < 0.10$), followed by inclusion of these variables in a multivariate logistic regression model; and 3) restricted the number of variables entered into the model to ensure an appropriate events per variable ratio. This approach aimed to reduce overfitting and enhance the interpretability and validity of the model. Additionally, baseline comparability between groups was assessed, and no significant differences were observed in key demographic and clinical characteristics, which further minimized potential confounding.

Definition of Severe Infection

Severe infection was defined as a clinically diagnosed or microbiologically confirmed infection accompanied by systemic inflammatory response and/or organ dysfunction. Patients were included in the infection group if they met any of the following objective criteria during hospitalization: 1) Microbiological evidence of infection, such as a positive bacterial or fungal culture from blood, urine, sputum, or another sterile site; 2) Respiratory compromise, defined as respiratory rate > 22 breaths/min, oxygen saturation < 90% on room air, or requirement for oxygen supplementation or mechanical ventilation; 3) Hemodynamic instability, indicated by a systolic blood pressure < 90 mmHg, a mean arterial pressure < 65 mmHg, or the need for vasopressor therapy to maintain adequate perfusion; 4) Elevated body temperature, defined as > 38.5 °C; 5) Laboratory markers of systemic inflammation, including elevated CRP (CRP > 10 mg/L), IL-6 (IL-6 > 7 pg/mL), or procalcitonin (procalcitonin > 0.5 ng/mL) and 6) Chills or rigors, as documented in the nursing or physician notes, in conjunction with other systemic signs of infection. Patients who met the above criteria during their hospital stay were classified into the infection group.

Inclusion and exclusion criteria

Patients were included if they met the following criteria: 1) Diagnosed with AKI based on established diagnostic criteria [7]; 2) Diagnosis confirmed by physical examinations and laboratory tests; 3) classified as stage II-III per Kidney Disease: Improving Global Outcomes guidelines and indicated for bedside hemofiltration or hemodiafiltration; 4) Met the criteria for severe infection as defined above and 5) Complete clinical data available. Exclusion criteria included: 1) Pregnant or lactating women, 2) Patients with malignancies, autoimmune disorders, hematologic diseases, or infections not related to AKI, and 3) Those with arrhythmias, bleeding tendencies, or psychiatric disorders.

Clinical data collection

The following clinical data were recorded: gender (male or female), age (≤ 60 years or ≥ 60 years), BMI (≤ 20 or ≥ 20 kg/m^2), smoking and drinking history, diabetes mellitus, hypertension, dialysis frequency (2 or 3 times per week), catheter site (jugular or femoral vein), catheter duration (≤ 7 d or > 7 d), anticoagulants use, and laboratory parameters including CRP, IL-6, ALB, hemoglobin, platelet count, serum potassium,

serum creatinine and blood urea nitrogen.

NRI definition

NRI was calculated using the following formula: NRI = [1.489 × ALB (g/L)] + [41.7 × (actual body weight/ideal body weight)] [8]. If the actual weight exceeded the ideal weight, the ratio was set to 1; otherwise, the actual ratio was used.

Measurement of inflammatory factors

The IL-6 level was measured using ELISA-related IL-6 assay kits according to the manufacturer's instructions. CRP level was determined using an immunoturbidimetric assay on an automated biochemical analyzer. All measurements were performed in duplicate to ensure accuracy.

Statistical analysis

Statistical analysis was carried out using SPSS 23.0 software. Measurement data were presented as ($\bar{x} \pm s$) and subjected to the independent samples *t*-test. Count data were expressed as [n (%)] and compared by the χ^2 test. Multivariate logistic regression analysis was employed to identify the influencing factors of severe infection in AKI patients. Receiver operating characteristic curves were plotted to assess the value of NRI in predicting severe infection in AKI patients, with the area under the curve > 0.9 indicating an extremely high value, 0.71-0.9 indicating a high value, 0.5-0.7 indicating a fair value, and < 0.5 indicating no value. $p < 0.05$ suggested a difference of statistical significance.

Results

NRI values

NRI was lower in the infection group than in the non-infection group [(82.56 ± 5.31) *vs.* (96.35 ± 4.17), $t = 14.598$, $p < 0.001$].

Baseline data

No differences were observed in gender, smoking history, drinking history, hypertension, dialysis frequency, anticoagulant administration, serum potassium, serum creatinine, blood urea nitrogen, and platelet count between the two groups ($p > 0.05$). The proportions of cases with age (≥ 60 years old), BMI (≤ 20 kg/m^2), diabetes mellitus, catheter indwelling site (femoral vein), catheter indwelling time (> 7 d), ALB (< 35 g/L), and Hb (< 70 g/L), as well as levels of CRP and IL-6, were higher in the infection group than those in the non-infection group ($p < 0.05$) (Table 1).

Table 1. Baseline data.

Index		Infection group (n = 39)	Non-infection group (n = 63)	Statistical value	*p*
Gender [n (%)]	Male	26 (66.67)	39 (61.90)	$\chi^2 = 0.901$	0.342
	Female	13 (33.33)	29 (46.03)		
Age [n (%)]	≥ 60 years old	24 (61.54)	23 (36.51)	$\chi^2 = 6.074$	0.014
	< 60 years old	15 (38.46)	40 (63.49)		
BMI [n (%)]	≤ 20 kg/m^2	22 (56.41)	18 (28.57)	$\chi^2 = 7.832$	0.005
	> 20 kg/m^2	17 (43.59)	45 (71.43)		
Smoking history [n (%)]	Yes	13 (33.33)	22 (34.92)	$\chi^2 = 0.027$	0.870
	No	26 (66.67)	41 (65.08)		
Drinking history [n (%)]	Yes	10 (25.64)	18 (28.57)	$\chi^2 = 0.104$	0.747
	No	29 (74.36)	45 (71.43)		
Diabetes mellitus [n (%)]	Yes	21 (53.85)	15 (23.81)	$\chi^2 = 9.516$	0.002
	No	18 (46.15)	48 (76.19)		
Hypertension [n (%)]	Yes	12 (30.77)	17 (26.98)	$\chi^2 = 0.170$	0.681
	No	27 (69.23)	46 (73.02)		
Dialysis frequency [n (%)]	Twice/week	19 (48.72)	28 (44.44)	$\chi^2 = 0.177$	0.674
	3 times/week	20 (51.28)	35 (55.56)		
Catheter indwelling site [n (%)]	Femoral vein	22 (56.41)	19 (30.16)	$\chi^2 = 6.906$	0.009
	Internal jugular vein	17 (43.59)	44 (69.84)		
Catheter indwelling time [n (%)]	> 7 d	20 (51.28)	14 (22.22)	$\chi^2 = 9.154$	0.003
	≤ 7 d	19 (48.72)	49 (77.78)		
Administration of anticoagulants [n (%)]	Yes	14 (35.90)	30 (47.62)	$\chi^2 = 1.349$	0.245
	No	25 (64.10)	33 (52.38)		
CRP ($\bar{x} \pm s$, mg/L)		37.16 ± 2.05	17.26 ± 3.17	$t = 34.910$	< 0.001
IL-6 ($\bar{x} \pm s$, pg/mL)		62.35 ± 3.25	30.13 ± 4.58	$t = 38.332$	< 0.001
ALB [n (%)]	< 35 g/L	28 (71.79)	27 (42.86)	$\chi^2 = 8.119$	0.004
	≥ 35 g/L	11 (28.21)	36 (57.14)		
Hb [n (%)]	< 70 g/L	25 (64.10)	20 (31.75)	$\chi^2 = 10.229$	0.001
	≥ 70 g/L	14 (35.90)	43 (68.25)		
PLT ($\bar{x} \pm s$, ×10^9/L)		156.26 ± 15.35	160.25 ± 14.83	$t = 1.303$	0.196
Scr ($\bar{x} \pm s$, μmol/L)		752.23 ± 25.16	755.52 ± 25.46	$t = 0.637$	0.526
BUN ($\bar{x} \pm s$, mmol/L)		34.56 ± 4.22	33.76 ± 4.13	$t = 0.943$	0.348
Serum potassium ($\bar{x} \pm s$, mmol/L)		9.12 ± 1.02	9.05 ± 1.11	$t = 0.319$	0.750

Smoking and drinking histories were obtained through patient interviews and medical records. "Yes" includes both current and former smokers/drinkers; "No" indicates never users.

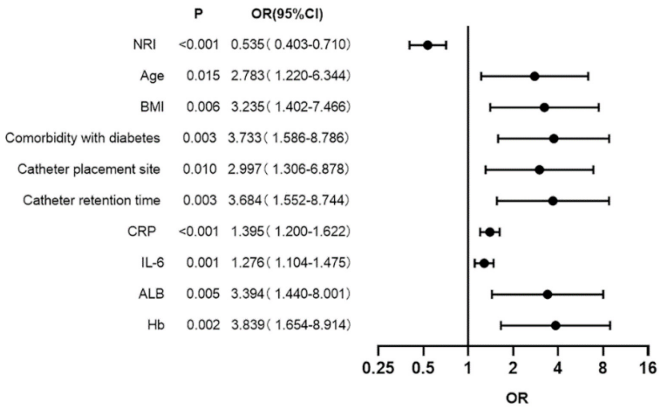
Influencing factors for severe infection in AKI patients

Multivariate logistic regression analysis was performed with the presence of severe infection in AKI patients as the dependent variable (1 = yes, 0 = no), and NRI and indicators that presented statistically significant differences in Table 1 as independent variables. It was uncovered that NRI was a protective factor against severe infection in AKI patients (odds ratio < 1, $p < 0.05$), whereas age (≥ 60 years old), BMI (≤ 20 kg/m^2), diabetes mellitus, catheter indwelling site (femoral vein), catheter indwelling time (> 7 d), ALB (< 35 g/L), Hb (< 70 g/L), and CRP and IL-6 levels acted as risk factors for severe infection in AKI patients (odds ratio > 1, $p < 0.05$) (Table 2 and Figure 1).

Value of NRI for predicting severe infection in AKI patients

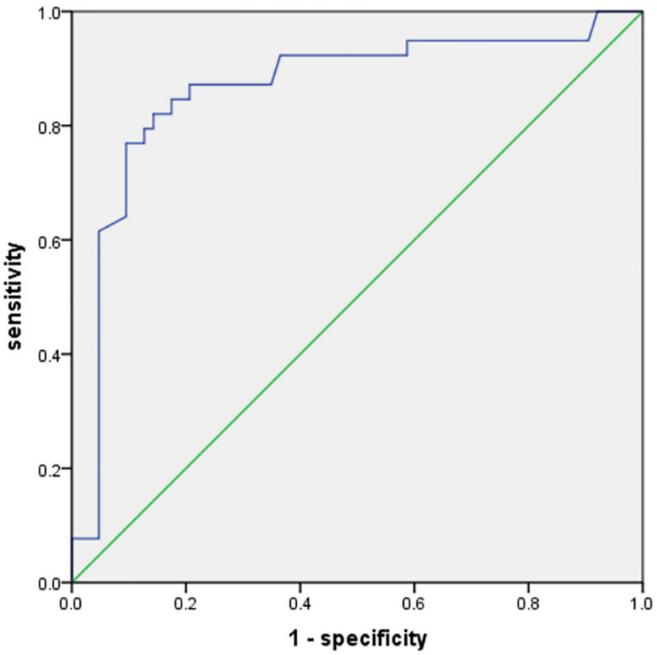
The receiver operating characteristic curve was plotted with the presence of severe infection in AKI patients as the state variable (1 = yes, 0 = no) and NRI as the test variable. The analysis showed that NRI had good discriminatory ability, with an area under the curve of 0.863 (95% CI: 0.781–0.946; standard error = 0.042, $p < 0.001$). The optimal cut-off value was 98.621, which yielded a sensitivity of 0.821, specificity of 0.825, and a Youden index of 0.646 (Figure 2).

Figure 1. Baseline comparison of nutritional risk index (NRI) between AKI patients with and without severe infection.



The boxplot illustrates the distribution of NRI values in patients with acute kidney injury (AKI), grouped by presence or absence of infection. The infection group (n = 39) showed significantly lower NRI values than the non-infection group (n = 63), indicating poorer nutritional status among those with severe infections. The central line represents the median, boxes represent the interquartile range (IQR), and whiskers represent the 5th and 95th percentiles. $p < 0.001$, two-tailed *t*-test.

Figure 2. Receiver operating characteristic (ROC) curve of NRI for predicting severe infection in AKI patients.



The ROC curve was generated to evaluate the diagnostic performance of the nutritional risk index (NRI) in predicting severe infection among AKI patients. The area under the curve (AUC) was 0.863 (95% confidence interval: 0.781–0.946), indicating good discriminatory ability. The optimal cut-off value for NRI was 98.621, yielding a sensitivity of 0.821, specificity of 0.825, and a Youden index of 0.646. The diagonal reference line indicates a non-informative test (AUC = 0.5).

Table 2. Influencing factors for severe infection in AKI patients.

Influencing factor	β	Standard error	Wald	*p*	Odds ratio	95% CI
NRI	-0.626	0.144	18.841	< 0.001	0.535	0.403-0.710
Age	1.023	0.420	5.923	0.015	2.783	1.220-6.344
BMI	1.174	0.427	7.572	0.006	3.235	1.402-7.466
Diabetes mellitus	1.317	0.437	9.101	0.003	3.733	1.586-8.786
Catheter indwelling site	1.098	0.424	6.706	0.010	2.997	1.306-6.878
Catheter indwelling time	1.304	0.441	8.745	0.003	3.684	1.552-8.744
CRP	0.333	0.077	18.827	< 0.001	1.395	1.200-1.622
IL-6	0.244	0.074	10.828	0.001	1.276	1.104-1.475
ALB	1.222	0.438	7.800	0.005	3.394	1.440-8.001
Hb	1.345	0.430	9.799	0.002	3.839	1.654-8.914

Discussion

AKI is mainly manifested as high fever, vomiting, shortness of breath, edema, *etc.*, which may affect the central nervous system, giving rise to such symptoms as coma and convulsions. If not treated in time, metabolic acidosis, azotemia, and electrolyte imbalance will be induced, severely imperiling the life safety of patients. The pathogenesis of AKI is rather complicated and has not been fully clarified yet. Accordingly, no specific therapies are available in clinical practice, and correcting fluid and electrolyte imbalance, treating primary diseases, and provisional dialysis are mainly adopted, which are effective in saving lives. However, AKI is highly likely to induce various complications due to multiple factors, with severe infection as the most common one, which is also one of the major factors affecting the outcomes of the disease. Therefore, discovering an objective and effective indicator to assess the risk of severe infection in AKI patients and decreasing the risk of severe infection through index improvement are particularly important for guiding clinical practice.

Recently, nutritional status has received increasing attention as an outcome of various diseases. NRI, developed in 2005, has been widely used to assess patients' nutritional status and identify those at risk of malnutrition. However, its association with severe infection in patients with AKI remains underexplored. Previous studies have demonstrated that malnutrition is a critical prognostic factor in patients with malignant tumors and those undergoing hemodialysis [9]. For instance, Jain *et al.* [10] reported 39% of cancer patients were malnourished, and the overall 6-month survival rate in this group was significantly lower than that in well-nourished patients. Bargetzi *et al.* [11], in a randomized controlled trial, showed that individualized nutrition support led to a significant reduction in in-hospital mortality (14% vs. 23%) compared to standard meals, indicating that mitigating nutritional risk improves outcomes. In terms of NRI cut-off values, prior studies have often classified patients into risk categories: NRI > 100 indicates no nutritional risk; 97.5 < NRI < 100 indicates mild risk; 83.5 < NRI < 97.5 indicates moderate risk; and NRI < 83.5 indicates severe nutritional risk. Subsequent studies applying these categories found that patients with NRI < 97.5 experienced significantly higher complication and infection rates [12].

In the present study, the infection group had significantly lower NRI values than the non-infection group. Multivariate logistic regression showed that NRI was a protective factor against severe infection in AKI patients. This is consistent with previous findings and underscores the importance of maintaining good nutritional status in reducing infection-related complications. NRI primarily relies on the ALB level and body weight, both of which are indicators of nutritional reserves. Higher ALB levels and body weights contribute to elevated NRI values and better immune resilience [13]. ALB plays a critical role in maintaining oncotic pressure and transporting various nutrients and metabolites. Clinically, low ALB is widely recognized as a marker of malnutrition and has been linked to increased susceptibility to infections [14,15]. Therefore, AKI patients with higher NRI values are likely to have better nutritional reserves, enhanced immune defenses, and a lower risk of developing severe infection during hospitalization. The receiver operating characteristic analysis in this study also confirmed the predictive value of NRI for severe infection, with an area under the curve (95% CI) of 0.863 (0.781–0.946), indicating strong discriminatory ability. Collectively, these findings suggest that NRI is not only a useful marker of nutritional risk but also an independent predictor of severe infection in AKI patients, which is in line with trends observed in other patient populations. Additionally, patients in the infection group had lower ALB levels and body weight compared to those in the non-infection group. These alterations likely reflect not only underlying nutritional insufficiency but also the acute pathophysiological consequences of AKI and systemic infection. Hypoalbuminemia in AKI patients may arise from multiple mechanisms, including increased capillary permeability, inflammation-induced protein catabolism, and urinary albumin loss, all of which are commonly observed in the context of sepsis and acute renal dysfunction [16,17]. Moreover, severe infections are frequently associated with hypermetabolic states, reduced dietary intake, and hepatic reprioritization of protein synthesis toward acute-phase reactants, further contributing to hypoalbuminemia and weight loss [18-20]. Therefore, the observed reductions in ALB and BMI are likely multifactorial, resulting from a complex interplay between malnutrition, systemic inflammation, and renal pathology. These findings support the notion that nutritional deterioration may serve both as a predisposing factor for and a consequence of severe infection, forming a self-reinforcing cycle that worsens clinical outcomes in AKI patients.

As a complicated process, severe infection is not only related to nutritional status, but also affected by numerous factors like autogenous diseases and treatment factors. In the present study, multivariate

logistic regression analysis was carried out, and the results revealed that age (≥ 60 years old), BMI (≤ 20 kg/m^2), diabetes mellitus, catheter indwelling site (femoral vein), catheter indwelling time (> 7 d), ALB (< 35 g/L), Hb (< 70 g/L), and CRP and IL-6 levels were risk factors for severe infection in AKI patients. This is because BMI and ALB are key factors determining NRI, and low BMI and low ALB expression will reduce NRI, thus increasing the risk of severe infection.

As to other factors, the age ≥ 60 years old suggests the elderly, whose organ functions gradually decline with the increase of age. Besides, their immune functions are directly damaged by the disease, and their repair ability is poor. As a result, the elderly are susceptible to infection by pathogens and eventually develop severe infection [21]. Secondly, diabetes mellitus is characterized by persistent hyperglycemia, and carbohydrates, as a medium for bacterial colonization, contribute to rapid bacterial reproduction, significantly increasing the risk of infection [22]. Besides, patients with diabetes mellitus often have metabolic disorders and decreased immune functions, leading to a failure to effectively kill pathogens, which also increases the probability of infection [23]. Thirdly, the catheter indwelling site and catheter indwelling time belong to disease treatment factors, and dialysis has occupied a prominent place in AKI treatment, which, however, is invasive. The femoral vein is located in a relatively discreet area, which is more humid than the neck and prone to bacterial growth. Catheter indwelling will inevitably lead to the formation of fibrous sheaths, and bacteria may invade the bloodstream along the catheter surface, elevating the risk of severe infection [24]. Fourthly, Hb levels are often employed to evaluate anemia, with low Hb levels indicating the presence of anemia. In other words, there is a negative relation between Hb levels and the degree of anemia. In addition, severe anemia not only results in malnutrition but also reduces resistance. Consequently, lower Hb levels indicate a higher probability of severe infection [25]. Lastly, as common pro-inflammatory factors, CRP and IL-6 can accurately reflect inflammatory responses, and the high expressions of CRP and IL-6 will aggravate inflammatory responses and directly induce infection [26]. Therefore, it is recommended to take the above factors into account when comprehensively assessing the risk of severe infection in AKI patients and formulating preventive measures.

Conclusions

In conclusion, NRI is closely related to severe infection in AKI patients, which is an effective indicator for predicting the risk of severe infection, and a low NRI value signifies an increase in the risk of severe infection. In clinical practice, it is necessary to be vigilant against low NRI values and actively establish schemes to prevent severe infection during the treatment of AKI, so as to improve the prognosis of patients. However, several limitations should be acknowledged in this study. First, its single-center retrospective design may introduce selection bias and limit generalizability. Second, the relatively small sample size, particularly in the infection group, may reduce statistical power and model stability. Third, although multivariate logistic regression was used to adjust for confounders, residual confounding from unmeasured variables cannot be ruled out. Future large-scale, prospective multicenter studies are needed to validate and expand upon these findings.

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Authors' contributions

Hongfei Wang designed this study and significantly revised the manuscript; Nahui Li and Ning Luo performed this study and wrote the manuscript.

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Conflict of interest

No conflict of interest is declared.

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