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ORIGINAL RESEARCH

Predictive value of combined CRP/ALB ratio and D-D/FIB ratio for MODS in patients with severe polytrauma

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Abstract

Background: This study evaluated the predictive value of combining the C-reactive protein/albumin ratio (CRP/CAR) with the D-dimer/fibrinogen ratio (DFR) for multiple organ dysfunction syndrome (MODS) in patients with severe polytrauma. **Methods**: This single-center retrospective study analyzed clinical data from 197 polytrauma patients admitted to our institution between April 2022 and March 2025. Based on the occurrence of MODS within 48 hours of admission, the patients were assigned to a MODS group (n = 64) and a non-MODS group (n = 133). **Results**: The MODS group had a higher proportion of patients with $\geq$3 injured body regions, a longer time from injury to admission, and a higher Injury Severity Score (ISS) at admission compared with the non-MODS group ($p < 0.05$). In addition, the MODS group exhibited significantly higher levels of CRP, CAR, D-dimer, and DFR, while the levels of Albumin (ALB) and Fibrinogen (FIB) were significantly lower ($p < 0.05$). Receiver operating characteristic (ROC) analysis showed that the areas under the curve (AUCs) for CAR and DFR in predicting MODS were 0.871 (95% confidence interval (CI): 0.816–0.914) and 0.851 (95% CI: 0.794–0.898), respectively. The combined prediction model achieved an AUC of 0.939 (95% CI: 0.896–0.968), which was significantly higher than that of either marker alone ($Z = 3.133$, $p = 0.002$; $Z = 3.574$, $p < 0.001$). Multivariable logistic regression analysis identified the time from injury to admission, ISS score at admission, CAR, and DFR as independent risk factors for MODS in patients with severe polytrauma ($p < 0.05$). **Conclusions**: Elevated levels of CAR and DFR were associated with the development of MODS in patients with severe polytrauma. Monitoring these ratios may serve as an important reference for the early clinical prediction of MODS.

Keywords

C-reactive protein; Albumin; D-dimer; Fibrinogen; Polytrauma; Multiple organ dysfunction syndrome

1. Introduction

Severe polytrauma, also known as severe multiple trauma, is defined as a condition in which an individual sustains injuries to multiple body regions or organ systems, with at least one injury considered life-threatening. This condition may result from blunt or penetrating trauma, burns, or other forms of physical damage [1]. Multiple organ dysfunction syndrome (MODS) is a common complication of severe polytrauma. It is characterized by the simultaneous or sequential dysfunction of multiple organ systems, which can compromise the body's ability to maintain normal physiological functions [2]. Patients with severe multiple trauma are prone to developing MODS due to mechanisms such as tissue hypoxia and reperfusion injury, immune and inflammatory responses, and metabolic disturbances [3]. Therefore, early recognition and timely management of MODS are crucial for improving clinical outcomes and the overall prognosis in this patient population.

In recent years, increasing attention has been directed toward the roles of inflammation and coagulation dysfunction in the progression of MODS. C-reactive protein (CRP), synthesized in response to acute inflammatory stimuli, shows levels that closely correlate with the severity of inflammation [4]. In patients with severe multiple trauma, persistently elevated CRP levels may indicate a higher likelihood of developing MODS [5]. Albumin (ALB), a plasma protein synthesized by the liver, is regarded as a negative acute-phase reactant. Hypoalbuminemia during inflammation may be partly attributed to reduced hepatic albumin synthesis mediated by inflammatory cytokines released from monocytes and macrophages [6]. The CRP/ALB ratio (CAR), a composite inflammatory marker that incorporates the characteristics of both CRP and ALB, has been applied in prognostic evaluation across various critical illnesses [7]. D-dimer (D-D), a degradation product of fibrin, plays an important role in inflammation, coagulation, and fibrinolysis. Elevated D-D levels often reflect a hyper-

coagulable state accompanied by secondary hyperfibrinolysis. In severe polytrauma patients, increased D-D levels may, therefore, suggest a greater risk of coagulation dysfunction and subsequent MODS [8]. Fibrinogen (FIB) is a key protein activated during the coagulation process. Tissue injury and bleeding may lead to excessive consumption of FIB, resulting in coagulation abnormalities and enhanced fibrinolysis. The D-D/FIB ratio (DFR), a relatively new coagulation marker, reflects the balance between coagulation and fibrinolysis [9, 10]. However, research exploring the predictive value of CAR and DFR for MODS in patients with severe polytrauma remains limited.

This study aims to investigate the combined predictive value of CAR and DFR for MODS in such patients, with the intent of providing meaningful clinical references for potential early intervention.

2. Materials and methods

2.1 Study participants

This study was a single-center, retrospective analysis involving patients with multiple injuries who were admitted to our hospital between April 2022 and March 2025. The inclusion criteria were: (1) meeting the diagnostic criteria for multiple injuries [11] with an Injury Severity Score (ISS) [12] $\geq$16 upon admission; (2) age $\geq$18 years; (3) time from injury to hospital admission $\leq$6 h; and (4) complete clinical data. The exclusion criteria were: (1) a history of severe dysfunction of vital organs, such as the heart, liver, or kidney; (2) concomitant malignant tumors; (3) the presence of hematological diseases or ongoing anticoagulant/thrombolytic therapy; and (4) pregnancy or lactation. The study was approved by our hospital's ethics committee.

2.2 Sample size calculation

The sample size was calculated using the formula (Eqn. 1):

$$n = \left(Z^2_{\alpha/2} \times P(1 - P)\right)/\delta^2 \quad (1)$$

Where P represents the incidence of MODS, δ denotes the margin of error, with α = 0.05 and $Z_{\alpha/2}$ = 1.96. Based on previous literature, the anticipated incidence P was 35%, and δ was set at 8%. By substituting these values into the formula, the minimum required sample size was calculated to be 137. To account for a potential 10% inefficiency rate during the study, the planned sample size was increased to 152, and ultimately, 197 patients were enrolled, thereby meeting and exceeding the minimum sample size requirement.

2.3 Data collection

Patient data were collected through the hospital's electronic medical record system. The baseline characteristics recorded included age, sex, underlying diseases (hypertension, diabetes, and coronary heart disease), cause of trauma (traffic accident injury, fall injury, sharp instrument injury, or other causes), number of injured body regions, time from injury to hospital admission, ISS on admission, intensive care unit (ICU) admission within 24 h after admission, and emergency surgical intervention after admission. Laboratory parameters assessed upon admission included complete blood count indicators (white blood cell count, hemoglobin level, and platelet count), as well as levels of CRP, ALB, D-D, and FIB. The CAR and DFR were calculated based on these values, with CAR defined as the CRP/ALB ratio and DFR defined as the D-D/FIB ratio.

2.4 Diagnostic criteria for MODS

MODS was diagnosed according to the criteria established in the *Expert Consensus on Definitions and Diagnosis of Post-Traumatic Complications*. Cardiac dysfunction was defined as systolic blood pressure $<$90 mmHg or mean arterial pressure $<$70 mmHg, accompanied by shock, ventricular tachycardia, ventricular fibrillation, myocardial infarction, or other severe arrhythmias. Respiratory dysfunction was characterized by bilateral acute inflammatory exudative shadows on chest X-ray or Computed Tomography (CT) persisting for at least 24 h, with an oxygenation index Partial pressure of arterial oxygen/Fraction of inspired oxygen (PaO_2/FiO_2) $\leq$300 mmHg and positive end-expiratory pressure (PEEP) $\geq$5 cmH_2O, in the absence of left atrial hypertension (pulmonary capillary wedge pressure (PCWP) $\leq$18 mmHg or no congestive heart failure (PCWP $\leq$18 mmHg for at least 12 h within 24 h)). Central nervous system dysfunction manifested as lethargy, agitation, drowsiness, light coma, or deep coma, with a Glasgow Coma Scale (GCS) score $\leq$14. Coagulation dysfunction was defined as a platelet count $<100 \times 10^9$/L, or activated partial thromboplastin time (APTT), coagulation time, or prothrombin time (PT) prolonged or shortened by more than 3 seconds outside the normal range. Liver dysfunction was characterized by alanine aminotransferase (ALT) $>$2 times the upper limit of normal or total serum bilirubin $>$17.1 μmol/L. Renal dysfunction was defined as an absolute increase in serum creatinine $\geq$26.5 μmol/L within 48 h, or a $\geq$50% increase from baseline, or urine output $<$0.5 mL/(kg·h) for more than 6 h. Gastrointestinal dysfunction included gastrointestinal bleeding (hematemesis, melena, or bloody stool), gastric retention, paralytic ileus, intolerance to enteral nutrition, or enterogenic infection. Central nervous system dysfunction was considered for those presenting with drowsiness or coma and a GCS score $\leq$14. MODS was diagnosed when two or more of the above dysfunctions were present [13]. Based on the occurrence of MODS within 48 h after admission, patients with severe polytrauma were divided into the MODS group (n = 64) and the non-MODS group (n = 133).

2.5 Statistical analysis

Statistical analysis was performed using SPSS software (version 22.0, SPSS, Inc., Chicago, IL, USA). Continuous data conforming to a normal distribution were expressed as mean $\pm$ standard deviation and compared between the two groups using the independent samples t-test. Categorical data were presented as percentages and compared using the chi-square test. Receiver operating characteristic (ROC) curve analysis was used to evaluate the predictive value of CAR, DFR, and their combination for the occurrence of MODS in patients with

severe polytrauma, and the area under the curve (AUC), sensitivity, and specificity were calculated. Multivariable logistic regression analysis was conducted to identify independent risk factors for MODS in patients with severe polytrauma. A p-value < 0.05 was considered statistically significant.

3. Results

3.1 Comparison of clinical data between the MODS and non-MODS groups

The MODS group had a significantly higher proportion of patients with ≥3 injured body regions, a longer time interval from injury to hospital admission, and higher ISS scores at admission when compared with the non-MODS group ($p < 0.05$; Table 1).

3.2 Comparison of laboratory parameters between the MODS and non-MODS groups

Levels of CRP, CAR, D-D, and DFR were markedly higher in the MODS group than in the non-MODS group ($p < 0.05$, Fig. 1). In contrast, ALB and FIB levels were significantly lower in the MODS group ($p < 0.05$, Fig. 1).

3.3 Predictive value of combined CAR and DFR for MODS in patients with severe polytrauma

ROC curve analysis revealed that the AUC values for predicting MODS were 0.852 for CRP and 0.709 for ALB. The AUC for CAR was 0.871, which was higher than those of CRP and ALB (Table 2, Fig. 2A). Similarly, the AUC values were 0.833 for D-D and 0.733 for FIB, while the AUC for DFR reached 0.851, exceeding that of both D-D and FIB (Table 2, Fig. 2B).

We then incorporated CAR and DFR into a logistic regression model. Using the resulting regression coefficients, we constructed a combined index formula as follows: CAR + DFR $= -11.768 + 5.032 \times$ CAR $+ 0.924 \times$ DFR. ROC curve analysis indicated that this combined predictor had an AUC of 0.939, which was significantly higher than the predictive ability of CAR alone ($Z = 3.133$, $p = 0.002$) and DFR alone ($Z = 3.574$, $p < 0.001$) (Table 2, Fig. 2C).

3.4 Analysis of influencing factors for MODS in patients with severe polytrauma

Using the occurrence of MODS within 48 h of admission as the dependent variable, and the number of injured body regions, time from injury to admission, ISS score at admission,

TABLE 1. Comparison of clinical data between the MODS group and the non-MODS group.

Parameters	MODS group (n = 64)	Non-MODS group (n = 133)	t	p
Gender (n (%))				
Male	34 (53.13)	68 (51.13)	0.069	0.793
Female	30 (46.88)	65 (48.87)		
Age (yr)	52.73 ± 5.24	51.87 ± 5.27	1.078	0.282
Basic diseases (n (%))				
Hypertension	18 (28.13)	32 (24.06)	0.377	0.539
Diabetes	15 (23.44)	28 (21.05)	0.144	0.704
Coronary heart disease	12 (18.75)	20 (15.04)	0.438	0.508
Cause of trauma (n (%))				
Car accident injury	29 (45.31)	55 (41.35)	0.447	0.978
Falling injury	16 (25.00)	38 (28.57)		
Sharp instrument injury	14 (21.88)	28 (21.05)		
Other	5 (7.81)	12 (9.02)		
Number of damaged parts (n (%))				
≥3	33 (51.56)	37 (27.82)	10.633	0.001
2	31 (48.44)	96 (72.18)		
Time from injury to admission (h)	3.63 ± 0.66	3.08 ± 0.59	5.617	<0.001
ISS score at admission (points)	25.16 ± 3.68	20.89 ± 3.10	8.490	<0.001
Admission to ICU within 24 h after admission (n (%))	23 (35.94)	36 (27.07)	1.620	0.203
Emergency surgery after admission (n (%))	22 (34.38)	30 (22.56)	3.106	0.078
White blood cells ($\times 10^9$/L)	14.42 ± 2.79	13.74 ± 2.06	1.728	0.087
Hemoglobin (g/L)	115.28 ± 19.27	117.31 ± 20.13	0.671	0.503
Platelets ($\times 10^9$/L)	201.28 ± 33.12	206.82 ± 34.15	1.077	0.283

MODS, multiple organ dysfunction syndrome; ISS, Injury Severity Score; ICU, intensive care unit.

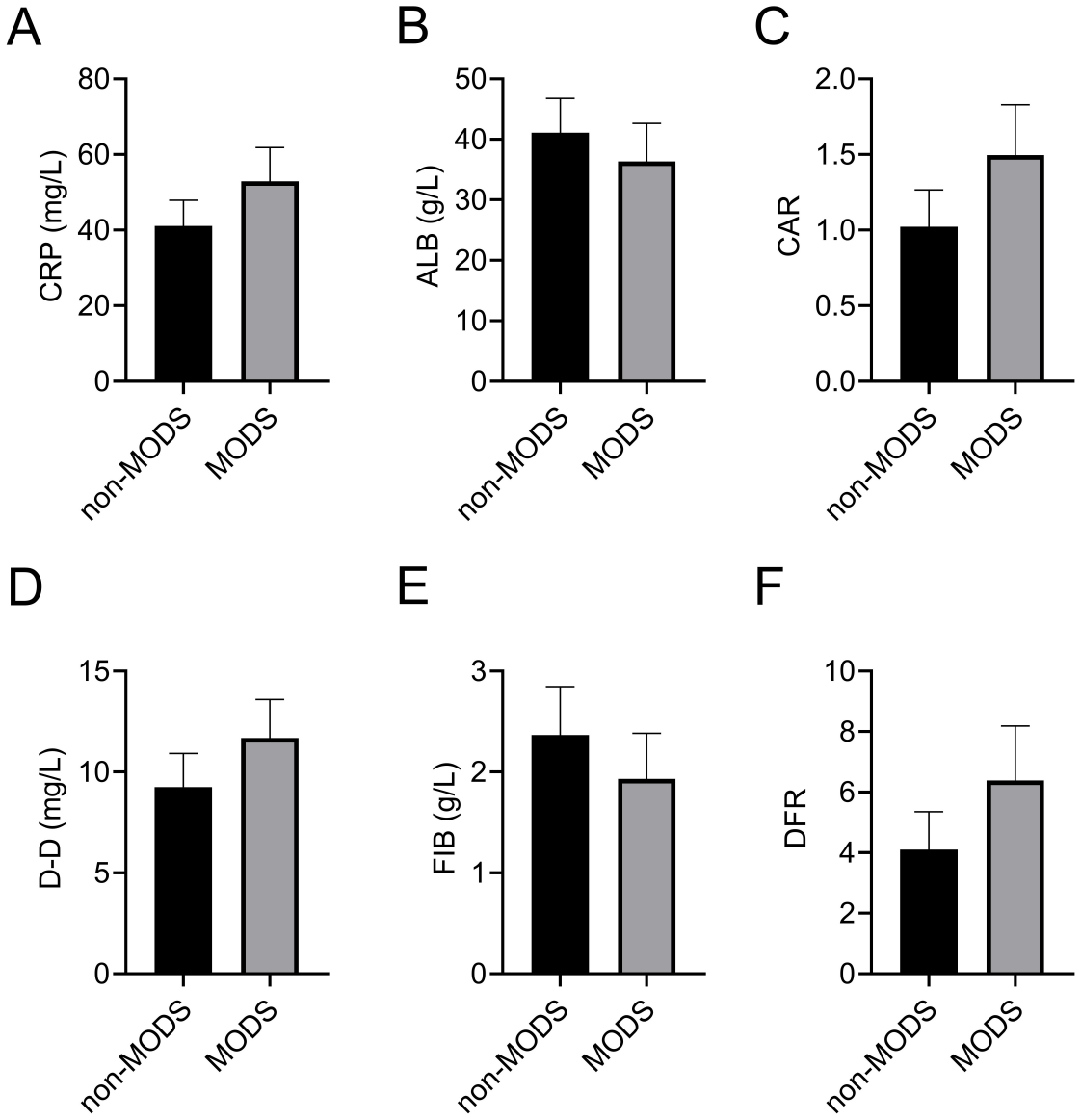

FIGURE 1. Comparison of serological indicators between the MODS and non-MODS groups. (A) CRP; (B) ALB; (C) CAR; (D) D-D; (E) FIB; (F) DFR. CRP, C-reactive protein; ALB, albumin; CAR, C-reactive protein/albumin ratio; D-D, D-dimer; FIB, fibrinogen; DFR, D-dimer/fibrinogen ratio; MODS, multiple organ dysfunction syndrome.

TABLE 2. Predictive value of combined detection of CAR and DFR for the occurrence of MODS in patients with severe polytrauma.

Indicators	AUC	95% CI	Youden index	Cut-off value	*p*	Sensitivity (%)	Specificity (%)
CRP	0.852	0.794–0.898	0.555	46.71	<0.001	75.00 (48/64)	80.45 (107/133)
ALB	0.709	0.640–0.771	0.395	38.40	<0.001	71.87 (46/64)	67.67 (90/133)
CAR	0.871	0.816–0.914	0.615	1.29	<0.001	76.56 (49/64)	84.96 (113/133)
D-D	0.833	0.744–0.882	0.587	10.00	<0.001	81.25 (52/64)	77.44 (103/133)
FIB	0.733	0.666–0.794	0.350	2.25	<0.001	71.87 (46/64)	63.16 (85/133)
DFR	0.851	0.794–0.898	0.552	4.53	<0.001	87.50 (56/64)	67.67 (90/133)
CAR + DFR	0.939	0.896–0.968	0.761	-	<0.001	82.81 (53/64)	93.23 (124/133)

AUC, area under the curve; CRP, C-reactive protein; ALB, albumin; CAR, C-reactive protein/albumin ratio; D-D, D-dimer; FIB, fibrinogen; DFR, D-dimer/fibrinogen ratio; CI, confidence interval.

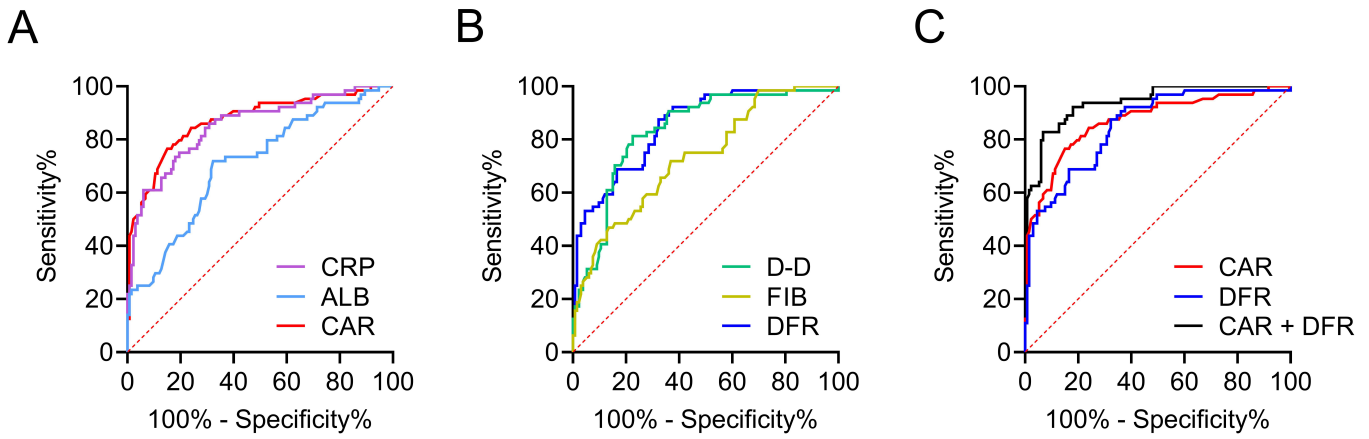

FIGURE 2. ROC curve analysis for predicting the occurrence of MODS in patients with severe polytrauma. (A) ROC curves for CRP, ALB, and CAR. (B) ROC curves for D-D, FIB, and DFR. (C) ROC curves for CAR, DFR, and the combined predictor (CAR + DFR). ROC, receiver operating characteristic; CRP, C-reactive protein; ALB, albumin; CAR, C-reactive protein/albumin ratio; D-D, D-dimer; FIB, fibrinogen; DFR, D-dimer/fibrinogen ratio; MODS, multiple organ dysfunction syndrome.

CAR, and DFR as independent variables, multicollinearity testing was performed. The results showed significant multicollinearity (Variance inflation factor (VIF) >10) between the number of injured body regions and the ISS score at admission. Therefore, the number of injured body regions was excluded, and the remaining four variables were incorporated into the logistic regression analysis model. Logistic regression analysis identified the time from injury to hospital admission, ISS score at admission, CAR, and DFR as independent risk factors for MODS in patients with severe multiple trauma ($p < 0.05$, Table 3). The Hosmer-Lemeshow goodness-of-fit test yielded a p-value of 0.352, indicating that the regression model was well-calibrated, with predicted risks aligning with observed risks.

4. Discussion

MODS frequently develops secondary to severe trauma, shock, infection, or other critical illnesses. This condition triggers uncontrolled systemic inflammatory responses, immune dysregulation, and tissue hypoxia, ultimately resulting in multiple organ dysfunction. In patients with severe polytrauma, the first 48 h after admission represent a particularly high-risk period for MODS onset. Once established, MODS carries a mortality rate of 50%–90%, posing a serious threat to patient survival [3]. Therefore, the early identification of patients at risk of MODS is crucial for improving prognosis and guiding timely clinical intervention. Biomarkers such as CRP, ALB, D-D, and FIB have demonstrated potential value in predicting MODS; however, the predictive significance of composite markers derived from these parameters, specifically the CAR and the DFR, remains inadequately clarified in this context. Consequently, this study comprehensively evaluates the predictive value of these indicators measured within the first 48 h after admission for forecasting MODS in patients with severe multiple trauma.

Inflammation is a defensive response following severe multiple trauma. Major trauma can activate inflammatory cells, leading to the release of large amounts of inflammatory mediators, which trigger systemic inflammatory response syndrome (SIRS). This cascade may result in vascular endothelial cell injury, microcirculatory dysfunction, and hypoperfusion of tissues and organs, ultimately contributing to the development of MODS [14]. CRP is a sensitive yet non-specific inflammatory marker that has been shown to be elevated in various clinical diseases. Upon activation of the acute-phase response and the immune system, serum CRP levels rise rapidly. This increase may trigger a cascade of immune reactions that promote organ dysfunction and eventually MODS [15]. Therefore, elevated serum CRP is considered an early indicator of MODS in clinical settings associated with severe trauma and infection. ALB reflects the body's nutritional reserves and synthetic function, and it plays important roles in maintaining plasma

TABLE 3. Analysis of influencing factors of MODS in patients with severe polytrauma.

Indicators	β	S.E.	Wald	OR	95% CI	p
CAR	5.331	1.118	22.731	206.673	23.093–1849.620	<0.001
DFR	1.051	0.233	18.998	2.758	1.748–4.353	<0.001
Time from injury to hospital admission	1.107	0.511	4.695	3.025	1.111–8.231	0.030
ISS score at admission	0.491	0.109	20.258	1.633	1.319–2.022	<0.001

CAR, C-reactive protein/albumin ratio; DFR, D-dimer/fibrinogen ratio; ISS, Injury Severity Score; S.E., Standard Error; OR, Odds Ratio; CI, Confidence Interval.

colloid osmotic pressure, transporting substances, and providing metabolic substrates [16]. CAR, a composite marker incorporating both CRP and ALB, provides a more comprehensive reflection of inflammatory, infectious, and nutritional status than either parameter alone. It has been reported in prognostic evaluations of traumatic brain injury [7], end-stage renal disease [17], acute myocardial infarction [18]. Elevated CAR has been shown to be closely associated with organ failure in septic patients, where it is regarded as an important predictor of prognosis in sepsis [19]. Consistent with these findings, the present study also found that CAR levels were significantly higher in the MODS group than in the non-MODS group. It is hypothesized that an elevated CAR indicates the coexistence of a pronounced inflammatory response and impaired nutritional status. This combination may disrupt internal homeostasis, impair organ function, and consequently increase the risk of developing MODS.

Trauma can activate the coagulation system [20], a process that often manifests as an elevation in D-D levels and consumption of FIB. D-D is a fibrin degradation product formed in the bloodstream through the degradation of fibrin by plasminogen activators and plasmin [21]. In the context of systemic inflammatory response and coagulation activation, D-D levels typically rise. During systemic inflammatory responses or shock, this increase may occur rapidly, leading to microcirculatory disturbances and thrombus formation, which in turn contribute to organ dysfunction and the eventual development of MODS. He *et al*. [8] reported that elevated D-D levels within the first 24 h after admission could predict the occurrence of MODS in patients with multiple trauma, demonstrating considerable diagnostic value—a finding consistent with the present study. In comparison, FIB is a key substrate in the coagulation pathway. Under the action of thrombin, FIB is converted into fibrin, which subsequently promotes thrombus formation [22]. Following traumatic tissue injury, the body activates protective coagulation mechanisms to promote clotting at the injury site, leading to a reduction in FIB levels. This decrease may result in hyperfibrinolysis and coagulation dysfunction [23]. Therefore, D-D serves as a marker of fibrinolysis, while FIB reflects coagulation activity. Consequently, the DFR provides an indication of the balance between fibrinolysis and coagulation. An elevated DFR suggests a disruption of this balance, indicating abnormal coagulation function that may lead to microcirculatory impairment, thrombosis, and tissue hypoperfusion [24], ultimately resulting in MODS. In this study, the observation window for MODS was set within 48 h after hospital admission, based on the "golden hour" concept in post-traumatic pathophysiology. During this period, inflammatory and coagulative cascades reach their early peak, representing a critical window for the initiation and progression of organ dysfunction. This timeframe facilitates the detection of MODS directly attributable to early and modifiable pathological processes, thereby highlighting the clinical value of the CAR and DFR as early warning indicators, while also helping to exclude later-onset organ insufficiency caused by secondary infections or other confounding factors.

Currently, most research has focused on the prognostic value of individual biomarkers for MODS risk assessment. However, reliance on a single biomarker has inherent limitations, as different biomarkers reflect distinct pathophysiological mechanisms. The combined use of multiple biomarkers enables a more comprehensive evaluation by integrating inflammatory, nutritional, coagulative, and fibrinolytic factors, thereby enhancing predictive accuracy and reliability. Therefore, this study investigated the combined predictive value of CAR and DFR for MODS onset. The results demonstrated that the combination of CAR and DFR yielded a significantly higher AUC for predicting MODS in patients with severe polytrauma than either biomarker alone. Mechanistically, CAR reflects an imbalance between inflammation and nutritional status, whereas DFR indicates disturbances in coagulation and fibrinolysis. Thus, their combination provides a more holistic assessment of pathological changes from complementary perspectives, effectively overcoming the limitations of single-marker analysis. The combined detection of CAR and DFR in patients with severe multiple trauma can assist clinicians in the early identification of high-risk individuals for MODS during initial hospitalization. Such early risk stratification may facilitate timely interventions, including intensified anti-infection therapy, correction of coagulopathy, and optimized nutritional support, which could ultimately reduce the incidence and mortality of MODS. Based on ROC curve analysis, the optimal cut-off values of CAR and DFR for predicting MODS were determined to be 1.29 and 4.53, respectively. Patients with CAR $>$1.29 and DFR $>$4.53 upon admission should be classified as a very high-risk group for MODS. For these patients, we recommend enhanced monitoring and proactive therapeutic measures, including consideration of early transfer to the ICU, to prevent clinical deterioration and potential organ failure.

Furthermore, this study identified the time from injury to hospital admission and the ISS at admission as independent risk factors for MODS in patients with severe polytrauma. Following trauma, the body enters a state of physiological stress, and tissue damage accompanied by hemorrhage can trigger a series of complex pathophysiological responses. A prolonged interval from injury to hospital admission extends the duration of stress and hypoperfusion, leading to persistent ischemia and hypoxia in tissues and organs. This state can compromise the integrity of the intestinal mucosal barrier, facilitating the translocation of bacteria and endotoxins into the systemic circulation. Consequently, systemic infection and endotoxemia may ensue, both of which are key contributors to MODS [25]. The ISS, as an important indicator of trauma severity, reflects the extent of anatomical damage. A higher ISS signifies more severe trauma [26], greater physiological insult, a more pronounced systemic inflammatory response, and more extensive organ dysfunction, collectively increasing susceptibility to MODS. The study by He *et al*. [8] demonstrated that the ISS is a significant risk factor for MODS in patients with multiple trauma and exhibits moderate diagnostic value in predicting its occurrence. Consistent with these findings, our study also confirmed a strong correlation between the ISS and the incidence of MODS. These results suggest that both the time from injury to hospital admission and the ISS should be regarded as key clinical indicators. Reducing pre-hospital delay by strengthening emergency response systems and optimizing patient transport can shorten the period of

tissue ischemia and hypoxia, thereby mitigating the risk of early organ dysfunction. For admitted patients, accurate ISS assessment is critical for formulating individualized treatment plans, optimizing therapeutic strategies, and determining the need for intensive monitoring or early ICU transfer. In addition, close monitoring of organ function throughout the early hospitalization phase is essential to reduce the risk of MODS in patients with severe multiple trauma and potentially improve overall clinical outcomes.

This study has several limitations. Although the sample size was determined based on statistical principles and practical considerations during the research design stage, it may still be insufficient to fully represent the broader population of patients with severe polytrauma, which could affect the generalizability and external validity of the findings. Due to the limited number of enrolled patients, subgroup analysis for internal validation would have markedly reduced statistical power; therefore, internal validation procedures, such as Bootstrap resampling or cross-validation, were not performed. This limitation suggests that a certain degree of model overfitting cannot be completely ruled out. In addition, the follow-up period was relatively short, capturing outcomes only within a defined early window after injury, which restricts the ability to evaluate long-term prognosis and evaluate the full clinical impact of combined CAR and DFR testing. Future research should aim to enlarge the sample size and adopt multicenter designs involving patients treated in hospitals across different regions, so as to improve representativeness and external applicability. Internal validation processes should also be strengthened to enhance the reliability and stability of the predictive model. Moreover, studies incorporating long-term follow-up are required to track extended clinical outcomes, explore associations between combined biomarker testing and long-term survival and rehabilitation, and ultimately provide more comprehensive prognostic information for clinical practice.

5. Conclusions

Both CAR and DFR, as easily accessible clinical indicators, were found promising in predicting the risk of MODS in patients with severe polytrauma. Development of targeted intervention strategies based on these markers could provide guidance for improving outcomes in this subset of patients.

AVAILABILITY OF DATA AND MATERIALS

The authors declare that all data supporting the findings of this study are available within the paper and any raw data can be obtained from the corresponding author upon request.

AUTHOR CONTRIBUTIONS

LGW, SWZ—designed the study and carried them out; prepared the manuscript for publication and reviewed the draft of the manuscript. LGW, SWZ, FBG, WCL—supervised the data collection; interpreted the data. LGW, SWZ, FBG—analyzed the data. All authors have read and approved the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Ethics Committee of The First Affiliated Hospital of Soochow University (Approval no. 2025828). Written informed consent was obtained from a legally authorized representative(s) for anonymized patient information to be published in this article.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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