ORIGINAL ARTICLE

C-reactive Protein/Albumin Ratio as a Predictive Inflammatory Marker for Postoperative Systemic Inflammatory Response Syndrome and/or Sepsis in Polytraumatized Patients in ICU

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Visual Abstract

Abstract

Background and aims: Trauma continues to represent a major global contributor to morbidity and mortality, with individuals sustaining polytrauma particularly vulnerable to developing systemic inflammatory response syndrome (SIRS) and sepsis. This study aims to evaluate the C-reactive protein (CRP) to albumin ratio (CAR) in predicting the postoperative SIRS and sepsis occurrence among polytrauma cases admitted to intensive care units (ICUs).

Patients and methods: This prospective observational study involved 100 polytrauma cases admitted to Ain Shams University Hospital ICUs. C-reactive protein and albumin levels were measured upon ICU admission and on postoperative days 1, 3, and 5. The CAR was calculated, and its association with SIRS and sepsis was assessed.

Results: Systemic inflammatory response syndrome developed in 35% and sepsis in 28% of patients. C-reactive protein/albumin ratio (CAR) was significantly higher in SIRS-positive patients at Day-1 (median 9.7 vs 8.0, $p < 0.001$), Day-3 (17.5 vs 11.9, $p < 0.001$), and Day-5 (28.9 vs 13.8, $p < 0.001$). C-reactive protein/albumin ratio (CAR) also differentiated sepsis-positive patients at Day-3 (17.7 vs 12.1, $p < 0.001$) and Day-5 (29.0 vs 14.0, $p < 0.001$). Receiver-operating characteristic (ROC) analysis showed that CAR at Day-5 had an area under the curve (AUC) of 0.989 for SIRS (sensitivity: 91.4%, specificity: 98.5%) and 0.934 for sepsis (sensitivity: 89.3%, specificity: 88.9%).

Conclusion: Progressive elevation of CAR is a reliable early predictor of postoperative SIRS and sepsis in polytrauma patients, peaking on Day-5.

Clinical significance: Early detection of postoperative sepsis in polytrauma patients by a simple, inexpensive screening tool allows risk stratification and timely intervention of this high-risk group, improving clinical outcomes.

Keywords: Albumin ratio, C-reactive protein, Polytrauma, Sepsis, Systemic inflammatory response syndrome.

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Highlights

Polytrauma is a risk factor for SIRS and sepsis, conditions that result in increased morbidity and mortality. C-reactive protein (CRP)/albumin ratio (CAR) is a promising marker for predicting postoperative SIRS and sepsis in polytrauma. It is a simple, cost-effective tool for postoperative risk assessment.

Introduction

Trauma remains a major global public health burden, accounting for ~6 million deaths annually (≈10% of all deaths) worldwide, with ~10,000 deaths each year reported in England and Wales, and an estimated 8% of all-cause mortality in Egypt in 2010.[1,2]

The pathophysiology following polytrauma involves complex interactions. While it was once believed that injury-related complications primarily stemmed from hypoperfusion and changes in endothelial permeability, emerging evidence highlights the critical contribution of innate immune responses in regulating organ dysfunction following trauma. A study has shown that the innate immune response significantly alters organ response following trauma.[3] Research by Khurana et al.[4] indicated that traumatic injuries disturb the balance of the immune system, significantly impacting both innate and adaptive immunity, which increases patients' susceptibility to opportunistic infections and the risk of post-trauma complications.

Because trauma triggers an early, dynamic imbalance of innate and adaptive immune responses that drives endothelial dysfunction and organ injury, a composite biomarker that captures both inflammatory escalation and catabolic/nutritional decline may better reflect this trajectory. Systemic inflammatory

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response syndrome (SIRS) is an early body response to various stimuli, including trauma, burns, and infections, representing the initial stage of widespread inflammation. An observational study involving 200 polytrauma patients found that 78% developed SIRS following polytrauma.[5] This reaction is characterized by endothelial leakage, typically starting in a localized region, such as the lungs, but potentially progressing to multiple organs.[6]

Biomarkers have emerged as valuable tools in sepsis management, offering potential for use in diagnosis, prognosis, and guiding treatment decisions.[7]

C-reactive protein/albumin ratio (CAR) has emerged as a significant inflammatory marker with predictive and prognostic implications for critically ill patients, particularly those suffering from SIRS and sepsis. This ratio integrates two widely recognized biomarkers: CRP serves as an acute-phase marker that escalates with inflammation, whereas albumin exhibits a characteristic decline under similar conditions. The interplay between these markers provides insights into the inflammatory status of patients, especially in the context of polytrauma, where the risk of developing SIRS and sepsis is notably heightened. Accordingly, CAR holds potential as a valuable predictor for the development of postoperative SIRS and sepsis.[8]

The CAR integrates complementary biology: CRP rises with acute inflammation, whereas albumin typically falls due to capillary leak, hemodilution, and reduced hepatic synthesis in critical illness. By combining these opposing trajectories, CAR can amplify signal-to-noise, mitigate isolated marker limitations (e.g., CRP's delayed peak; albumin's susceptibility to fluid shifts when interpreted alone), and enhance discrimination of clinically relevant systemic inflammation.[9] Prior work in critical care populations has linked higher CAR with adverse outcomes, supporting its potential utility as a pragmatic, low-cost index in the ICU setting.

This study aims to assess the CAR predictive value in polytraumatized ICU cases, focusing on its ability to identify those at heightened risk for development of postoperative SIRS and sepsis. By exploring this ratio, we hope to enhance early detection, guide therapeutic strategies, and ultimately improve clinical outcomes in critically injured patients.

Patients and Methods

Design and Population

This prospective observational cohort study was carried out between December 2023 and December 2024, involving 100 polytrauma patients admitted to the ICUs of Ain Shams University Hospital.

We used convenience enrollment of eligible polytrauma patients admitted during the study period. To mitigate selection bias, we applied predefined inclusion/exclusion criteria prospectively and recorded reasons for non-inclusion.

Eligibility Criteria

Both sexes ≥ 18 years were included in our study. All cases were identified based on the New Berlin definition of polytrauma, which requires an abbreviated injury scale (AIS) score of 3 or higher in two or more body regions, along with one or more physiological variables: disturbed level of consciousness, acidosis, coagulopathy, hypotension, or age over 70 years.[10] Using the American Society of Anesthesiologists (ASA) criteria, patients were classified into physical status groups I to III.[11]

Patients undergoing immunosuppressive therapy or chemotherapy, as well as those with known hematologic disorders or malignancies, were excluded from the study. Cases with liver cirrhosis classified as Child-Pugh class C, evidence of liver failure, or those administered albumin supplementation throughout the study period were also excluded.

Procedures

Polytrauma cases were identified according to the New Berlin definition, and CRP and albumin levels were measured upon ICU admission and on postoperative days 1, 3, and 5. C-reactive protein/albumin ratio (CAR) was calculated, and the modified Glasgow prognostic score (mGPS) was derived from these measurements.[12] All cases received a prophylactic 2 g dose of cefazolin intravenously one hour before surgery.

The choice of cefazolin 2 g IV within 60 min before incision followed our institutional surgical antimicrobial prophylaxis policy, which is aligned with international guidelines recommending a first-generation cephalosporin for most clean-contaminated procedures and trauma-related orthopedic and general surgical interventions.[13]

Postoperative Monitoring

Recording body temperature, heart rate (HR), blood pressure (BP), and respiratory rate (RR), with follow-up for SIRS, sepsis, and infections, including surgical site and pulmonary infections. Systemic inflammatory response syndrome was diagnosed based on specific criteria, requiring at least two of the following: respiratory rate more than 20 breaths every minute or $PaCO_2$ value below 32 mm Hg, temperature more than 38°C or less than 36°C, HR > 90 bpm, and WBC abnormalities.[14] Sepsis was identified using the sequential organ failure assessment (SOFA) score, with a score of ≥2 suggestive of sepsis, and the quick SOFA (qSOFA) tool for rapid bedside screening. Severity of illness and mortality risk were assessed using the acute physiology and chronic health evaluation (APACHE) II scoring system.[15]

Clinical outcome assessors (SIRS/sepsis adjudication) were blinded to CAR values; laboratory personnel operated independently and reported CRP/albumin results to a data manager who was not involved in bedside assessments.

Follow-up

Cases were monitored for 5 days postoperatively during their hospital stay, with daily assessments and a comprehensive reassessment on day 5 to evaluate outcomes related to SIRS, sepsis, and infections. Five-day follow-up was conducted to minimize confounding factors, such as hospital-acquired infections, that could be unrelated to surgery and polytrauma.

ClinicalTrials.gov registration number: NCT06050759, date: 16/9/2023.

Sample Size Calculation

Based on the results of Kim et al.,[16] with area under the curve for CRP/albumin ratio (for detection of mortality) was 0.62 (95% CI 0.56–0.68), alpha error 5% and power of study 80%, the required sample is 100 patients, the program for sample calculation is STATA 10.

Statistical Methods

Statistical analysis was conducted after coding and tabulating data, utilizing IBM SPSS Statistics, version 28.0 (IBM Corp., Armonk, NY, USA, 2021). Qualitative data were expressed as frequencies and

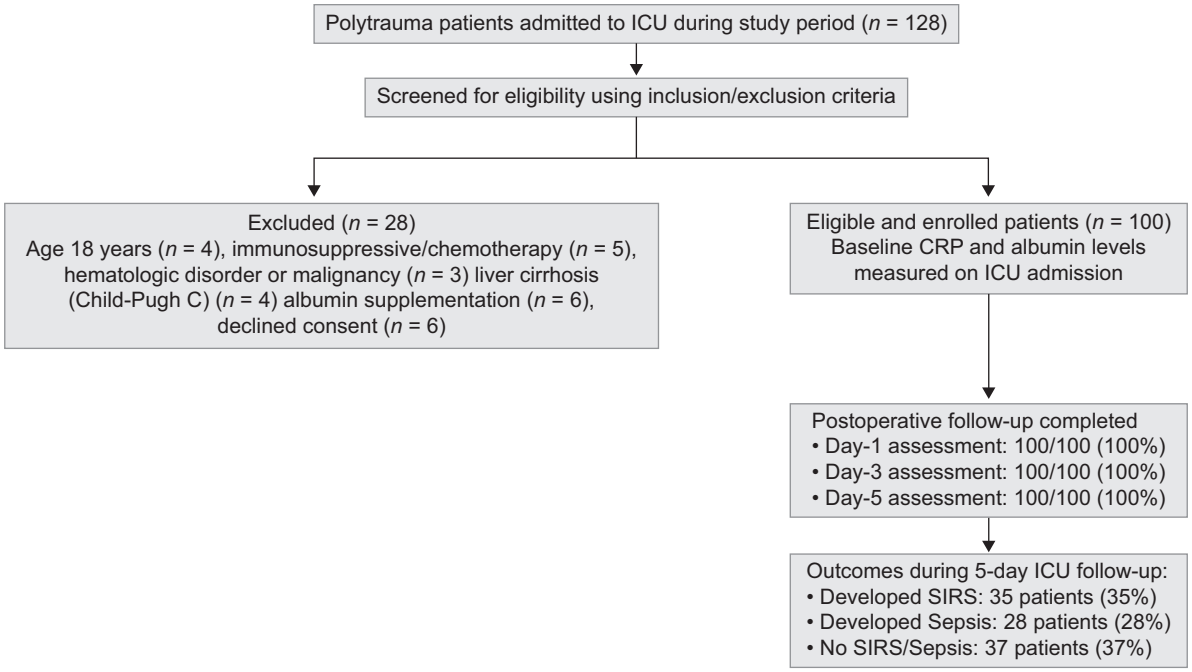

Fig. 1: CONSORT flowchart of eligible patients

percentages and analyzed using the Chi-squared test or Fisher's Exact test, as appropriate. Quantitative data were found to be non-normally distributed based on the Shapiro–Wilk test and were therefore presented as median (first–third interquartile range), along with minimum and maximum values. Comparisons were conducted using the Mann–Whitney *U* test, Wilcoxon signed-rank test, and Friedman test with *post hoc* Dunnett's test for comparing levels at each day with baseline. Diagnostic performance of clinical outcomes was assessed using ROC curve analysis, and the cut points were selected based on the maximum Youden's index. A $p \leq 0.05$ was considered statistically significant.

Results

A study flow diagram depicts the number of patients screened, eligible, excluded (with reasons), enrolled ($n = 100$), and analyzed with 5-day follow-up (Fig. 1).

The median age of all cases was 48.5 years (IQR: 31.5–57.0), with a range from 19 to 84 years. Out of 100 participants, 64% were male, and 36% were female. According to ASA classification, 57% of participants were ASA I, 35% were ASA II, and 8% were ASA III. Predominant comorbidities identified were HTN in 27% of cases, followed by DM in 18%, and CAD in 7%. Thirty-five cases (35%) developed SIRS, and 28 patients (28%) developed sepsis out of the 100 patients. Patients who developed postoperative SIRS were notably older ($p = 0.049$) and had a higher prevalence of DM ($p = 0.010$) and elevated ASA physical status grades ($p < 0.001$). We observed that there were no significant differences between the groups concerning hypertension or other comorbid conditions. The incidence of postoperative sepsis was markedly associated with DM presence ($p = 0.004$) and elevated ASA classification ($p = 0.007$), whereas age and other comorbidities did not vary notably between groups (Table 1).

Statistical analysis demonstrated notable variations between SIRS-positive and SIRS-negative patients across all variables (CRP, serum albumin, and CRP/albumin ratio) at various time points. For CRP (mg/dL), baseline values were 21.7 (18.5–24.6) in SIRS-positive patients versus 19.8 (17.1–22.4) in SIRS-negative patients ($p = 0.067$). However, at Day-1, Day-3, and Day-5, CRP levels were significantly higher in SIRS-positive patients (Table 2).

A marked enhancement in CAR's ability to predict SIRS was observed over time. At baseline, the AUC was 0.622 ($p = 0.045$), with a sensitivity of 94.3%, specificity of 24.6%, and diagnostic accuracy of 49.0%. By Day-1, the AUC increased to 0.719 ($p < 0.001$), with sensitivity at 57.1%, specificity at 76.9%, and diagnostic accuracy at 70.0%. Area under the curve (AUC) further improved to 0.938 on Day-3 ($p < 0.001$), and on Day-5, AUC reached its highest value of 0.989 ($p < 0.001$). Youden's index increased from 18.9% at baseline to 89.9% on Day-5, indicating the growing effectiveness of the CRP/albumin ratio over time as a diagnostic tool for SIRS (Table 3).

The comparison of CRP, albumin, and CAR between sepsis-positive and sepsis-negative groups revealed significant differences over time. Baseline CRP values were not significantly different across groups ($p = 0.057$), whereas substantial differences were evident on Day 3 and Day 5 ($p < 0.001$ each). Albumin levels at baseline showed no significant difference ($p = 0.089$), but notable changes were found from Day-3 ($p = 0.002$) onward, with Day-5 having the most notable change ($p < 0.001$). Significant intergroup differences in CRP/albumin ratio were identified at baseline ($p = 0.049$), and these differences became more pronounced on Day 1 ($p = 0.015$), Day 3 ($p < 0.001$), and Day 5 ($p < 0.001$) (Table 4).

Over the course of observation, the diagnostic efficacy of CAR in sepsis prediction increased markedly. The sensitivity remained high across all days, peaking at 96.4% at baseline and decreasing slightly over time, with Day-5 at 89.3%. Specificity significantly increased over time, from 23.6% at baseline to 76.4% on Day-1, 91.7% on Day-3, and 88.9% on Day-5. The diagnostic accuracy was lowest at baseline (44.0%) but increased sharply to 70.0% on Day-1, and remained relatively stable on Day-3 (90.0%) and Day-5 (89.0%).

Table 1: Demographic characteristics of the studied patients

		SIRS			*Sepsis*		
Characteristics	*ALL (n = 100)*	*Positive (n = 35)*	*Negative (n = 65)*	*p-value*	*Positive (n = 28)*	*Negative (n = 72)*	*p-value*
Age (years)	48.5 (31.5–57.0)	51.0 (40.0–58.0)	45.0 (30.0–55.0)	0.049*	50.5 (39.5–56.5)	46.0 (30.0–57.0)	0.257
Sex							
Male	64	19 (54.3%)	45 (69.2%)	0.138	15 (53.6%)	49 (68.1%)	0.175
Female	36	16 (45.7%)	20 (30.8%)		13 (46.4%)	23 (31.9%)	
ASA							
I	57	10 (28.6%)	47 (72.3%)	<0.001*	9 (32.1%)	48 (66.7%)	0.007*
II	35	20 (57.1%)	15 (23.1%)		15 (53.6%)	20 (27.8%)	
III	8	5 (14.3%)	3 (4.6%)		4 (14.3%)	4 (5.6%)	
Hypertension	27	9 (25.7%)	18 (27.7%)	0.832	8 (28.6%)	19 (26.4%)	0.825
Diabetes mellitus	18	11 (31.4%)	7 (10.8%)	0.010*	10 (35.7%)	8 (11.1%)	0.004*
Coronary artery disease	7	3 (8.6%)	4 (6.2%)	0.651	2 (7.1%)	5 (6.9%)	0.999
Chronic kidney disease	5	3 (8.6%)	2 (3.1%)	0.340	3 (10.7%)	2 (2.8%)	0.132
Chronic liver disease	3	2 (5.7%)	1 (1.5%)	0.280	2 (7.1%)	1 (1.4%)	0.189
Cerebrovascular stroke	1	1 (2.9%)	0 (0.0%)	0.350	1 (3.6%)	0 (0.0%)	0.280

ASA, American Society of Anesthesiologists; SIRS, systemic inflammatory response syndrome. *Significant *p*-value ≤ 0.05

Table 2: Comparison according to SIRS regarding CRP, albumin, and CRP/albumin ratio

		SIRS		*p-value*[a]
Variables	*Time*	*Positive (total = 35)*	*Negative (total = 65)*	
CRP (mg/dL)	Baseline	21.7 (18.5–24.6)	19.8 (17.1–22.4)	0.067
	Day-1	35.5 (29.0–45.0)[b]	29.3 (27.6–33.0)[b]	0.003*
	Day-3	53.6 (49.0–73.0)[b]	42.4 (37.5–45.7)[b]	<0.001*
	Day-5	82.0 (66.3–101.0)[b]	47.0 (43.4–51.0)[b]	<0.001*
	p-value[c]	<0.001*	<0.001*	
Serum albumin (gm/dL)	Baseline	3.9 (3.5–4.0)	4.0 (3.7–4.2)	0.052
	Day-1	3.6 (3.3–3.9)[b]	3.9 (3.6–4.2)[b]	0.007*
	Day-3	3.1 (3.0–3.4)[b]	3.6 (3.2–3.9)[b]	<0.001*
	Day-5	2.9 (2.7–3.1)[b]	3.4 (3.2–3.8)[b]	<0.001*
	p-value[c]	<0.001*	<0.001*	
CRP/albumin ratio	Baseline	5.5 (4.7–6.9)	4.9 (4.3–6.0)	0.045*
	Day-1	9.7 (8.1–12.2)[b]	8.0 (7.0–9.0)[b]	<0.001*
	Day-3	17.5 (15.6–24.7)[b]	11.9 (10.7–13.2)[b]	<0.001*
	Day-5	28.9 (23.3–37.5)[b]	13.8 (12.3–15.2)[b]	<0.001*
	p-value[c]	<0.001*	<0.001*	

CRP/albumin ratio, ratio of C-reactive protein to serum albumin; CRP, C-reactive protein; gm/dL, grams per deciliter; mg/dL, grams per liter; SIRS, systemic inflammatory response syndrome. *Significant *p*-value ≤0.05.[a]Mann–Whitney test; [b]Based on *post hoc* Dunnett's test; [c]*p*-value: *p*-value for overall changes; Friedman test, homogeneous groups had the same symbol

The negative predictive value remained high throughout, with Day-1 showing the highest value (97.1%) (Table 5).

Modified Glasgow prognostic score (mGPS) score showed notable variations in both SIRS and sepsis groups over time. For SIRS, baseline scores did not exhibit a significant difference between the positive and negative groups ($p = 0.271$), nor did Day-1 scores ($p = 0.118$). However, by Day-3, there was a substantial increase in mGPS score for the SIRS positive group (median 2.0, $p = 0.001$*), and this was maintained on Day-5 (median 2.0, $p < 0.001$*). For sepsis, no notable variations were observed at baseline ($p = 0.122$) or Day-1 ($p = 0.438$). Notable changes were found at Day-3 ($p = 0.013$) and Day-5 ($p < 0.001$*) in mGPS scores between sepsis-positive and negative groups (Table 6).

Discussion

Several studies have assessed the value of the CAR in multiple clinical settings across different patient groups, indicating its promising potential. However, there is very limited research

Table 3: Diagnostic performance on CRP/albumin ratio in predicting SIRS

	CRP/albumin			
Characteristics	*Baseline*	*Day-1*	*Day-3*	*Day-5*
AUC	0.622 (0.509–0.735)	0.719 (0.614–0.824)	0.938 (0.895–0.982)	0.989 (0.975–1.000)
p-value	0.045*	<0.001*	<0.001*	<0.001*
Cut point	≥4.3	≥9.1	≥15.5	≥20.5
Sensitivity	94.3% (80.8%–99.3%)	57.1% (39.4%–73.7%)	77.1% (59.9%–89.6%)	91.4% (76.9%–98.2%)
Specificity	24.6% (14.8%–36.9%)	76.9% (64.8%–86.5%)	95.4% (87.1%–99.0%)	98.5% (91.7%–100.0%)
Diagnostic accuracy	49.0% (38.9%–59.2%)	70.0% (60.0%–78.8%)	89.0% (81.2%–94.4%)	96.0% (90.1%–98.9%)
Youden's index	18.9% (5.9%–31.9%)	34.1% (14.7%–53.4%)	72.5% (57.7%–87.3%)	89.9% (80.1%–99.6%)
Positive predictive value	40.2% (29.6%–51.7%)	57.1% (39.4%–73.7%)	90.0% (73.5%–97.9%)	97.0% (84.2%–99.9%)
Negative predictive value	88.9% (65.3%–98.6%)	76.9% (64.8%–86.5%)	88.6% (78.7%–94.9%)	95.5% (87.5%–99.1%)

Data are presented, as well as the value (95% confidence interval). AUC, area under the curve, *p*-value, probability value. *Significant *p*-value ≤0.05.

Table 4: Comparison according to sepsis regarding CRP, albumin, and CRP/albumin ratio

		Sepsis		
Variables	*Time*	*Positive (Total = 28)*	*Negative (Total = 72)*	*p*-value[a]
CRP (mg/dL)	Baseline	21.9 (18.8–24.5)	19.9 (17.1–22.8)	0.057
	Day-1	35.4 (29.0–44.3)[b]	29.9 (27.7–34.7)[b]	0.053
	Day-3	56.0 (50.5–71.5)[b]	43.0 (38.8–47.5)[b]	<0.001*
	Day-5	82.0 (65.0–100.5)[b]	49.0 (43.5–53.4)[b]	<0.001*
	p-value[c]	<0.001*	<0.001*	
Serum albumin (gm/dL)	Baseline	3.9 (3.5–4.1)	4.0 (3.7–4.2)	0.089
	Day-1	3.7 (3.5–4.0)[b]	3.9 (3.6–4.1)[b]	0.073
	Day-3	3.1 (3.0–3.5)[b]	3.6 (3.2–3.8)[b]	0.002*
	Day-5	3.0 (2.7–3.1)[b]	3.4 (3.1–3.8)[b]	<0.001*
	p-value[c]	<0.001*	<0.001*	
CRP/albumin ratio	Baseline	5.5 (4.7–6.9)	5.0 (4.3–6.0)	0.049*
	Day-1	9.6 (7.9–11.0)[b]	8.3 (7.0–9.2)[b]	0.015*
	Day-3	17.7 (16.0–24.2)[b]	12.1 (10.8–13.6)[b]	<0.001*
	Day-5	29.0 (22.6–35.9)[b]	14.0 (12.3–16.3)[b]	<0.001*
	p-value[c]	<0.001*	<0.001*	

AUC, area under the curve; CRP, C-reactive protein; CRP/albumin ratio: the ratio of CRP to albumin levels. *Significant *p*-value ≤0.05. [a]Mann–Whitney test; [b]Based on *post hoc* Dunnett's test; [c]Friedman test, homogeneous groups had the same symbol

Table 5: Diagnostic performance of CRP/albumin in predicting sepsis

	CRP/albumin			
Characteristics	*Baseline*	*Day-1*	*Day-3*	*Day-5*
AUC	0.627 (0.510–0.745)	0.656 (0.538–0.775)	0.924 (0.870–0.977)	0.934 (0.886–0.982)
p-value	0.049*	0.015*	<0.001*	<0.001*
Cut point	≥4.3	≥9.4	≥15.5	≥20.5
Sensitivity	96.4% (81.7–99.9%)	53.6% (33.9–72.5%)	85.7% (67.3–96.0%)	89.3% (71.8–97.7%)
Specificity	23.6% (14.4–35.1%)	76.4% (64.9–85.6%)	91.7% (82.7–96.9%)	88.9% (79.3–95.1%)
Diagnostic accuracy	44.0% (34.1–54.3%)	70.0% (60.0–78.8%)	90.0% (82.4–95.1%)	89.0% (81.2–94.4%)
Youden's index	20.0% (8.1–32.0%)	30.0% (9.0–50.9%)	77.4% (62.9–91.8%)	78.2% (64.6–91.7%)
Positive predictive value	32.9% (22.9–44.2%)	46.9% (29.1–65.3%)	80.0% (61.4–92.3%)	75.8% (57.7–88.9%)
Negative predictive value	97.1% (72.7–99.9%)	80.9% (69.5–89.4%)	94.3% (86.0–98.4%)	95.5% (87.5–99.1%)

Data are presented as well as value (95% confidence interval). AUC, area under curve; CI, confidence interval; CRP, C-reactive protein. *Significant *p*-value ≤ 0.05

Table 6: mGPS in SIRS and sepsis

mGPS score	*SIRS*			*Sepsis*		
Time	*Positive (total = 35)*	*Negative (total = 65)*	*p-value*	*Positive (Total = 28)*	*Negative (Total = 72)*	*p-value*[a]
Baseline	1.0 (1.0–1.0)	1.0 (1.0–1.0)	0.271	1.0 (1.0–1.0)	1.0 (1.0–1.0)	0.122
Day-1	1.0 (1.0–2.0)	1.0 (1.0–1.0)	0.118	1.0 (1.0–1.5)	1.0 (1.0–1.0)	0.438
Day-3	2.0 (2.0–2.0)[b]	1.0 (1.0–2.0)	0.001*	2.0 (1.5–2.0)[b]	1.0 (1.0–2.0)	0.013*
Day-5	2.0 (2.0–2.0)[b]	2.0 (1.0–2.0)[b]	<0.001*	2.0 (2.0–2.0)[b]	2.0 (1.0–2.0)[b]	<0.001*
p-value[c]	<0.001*	<0.001*		<0.001*	<0.001*	

mGPS, modified Glasgow Prognostic Score; SIRS, systemic inflammatory response syndrome. *Significant *p*-value ≤0.05. [a]Mann–Whitney test; [b]Based on *post hoc* Dunnett's test; [c]Friedman test, homogenous groups had the same symbol

and a lack of evidence on the usefulness of CAR in polytrauma patients. Chen et al.[17] reported that an elevated preoperative CAR was significantly linked to an increased risk of developing postoperative SIRS in elderly patients. Kutluhan et al.[18] indicated that a high-sensitivity CRP/albumin ratio could predict post-URS SIRS. In another study by Donlon et al.[19] stated that postoperative CAR serves as a valuable adjunct at 24 and 48 hours postsurgery in predicting the development of surgical site infection (SSI) after undergoing emergency major abdominal surgery.

As per existing knowledge, our study is the first one to assess the predictive value of CAR for SIRS and sepsis in polytrauma patients in the ICU. A study by Lu et al.[20] investigated the correlation between CAR and posttraumatic shock in multiple trauma patients, revealing that high CAR values were strongly associated with elevated shock indices. Wang et al.[21] demonstrated that CAR serves as a risk factor that acts independently for the occurrence of mortality in patients with traumatic brain injury. Our study revealed that polytrauma patients who developed SIRS or sepsis postoperatively exhibited significantly higher CAR compared to those who did not develop SIRS or sepsis, starting from baseline and increasing markedly over time.

The observed elevation in CRP levels over time in the SIRS-positive group and sepsis-positive group represents a dynamic inflammatory process triggered by trauma and sustained or intensified by surgical intervention. Conversely, a decrease in albumin levels likely indicates increased capillary permeability, fluid resuscitation, and decreased hepatic synthesis, all of which are common in critically ill patients. C-reactive protein/albumin ratio (CAR) effectively captures these opposing trends, yielding a combined measure of the body's inflammatory activity and nutritional state.

In the case of sepsis in our study, the diagnostic performance of CAR for predicting sepsis improved significantly over time, with the highest AUC values observed on Day-5, followed by Day-3. At Day-1, the AUC was 0.656, with high sensitivity and specificity. Therefore, at Day-1, we suggest using a cutoff value of ≥9.4 as a simple-to-measure screening tool for early sepsis prediction and exclusion, with a notably high negative predictive value. In this study, all sepsis cases were detected starting from Day-3 postoperatively. We suggest that CAR can be used at baseline upon admission to the ICU, on Day-1, and on Day-3 postoperatively for early prediction of sepsis. At Day-5, a cutoff value of ≥20.5 can be used for prediction and as an easy, simple tool for diagnosing sepsis along with other diagnostic scores. Furthermore, in the case of sepsis at baseline and Day-1, the individual values of CRP and albumin did not reveal a substantial difference between the two groups. However, the CAR revealed a significant variation between patients with and without sepsis, favoring it as a promising, easy screening tool for sepsis upon ICU admission.

In the case of SIRS in our study, the diagnostic performance of CAR for predicting SIRS also improved significantly over time, with the highest AUC values observed on Day-5, followed by Day-3, along with high sensitivity and specificity, as well as diagnostic accuracy. At baseline upon ICU admission, CAR had high sensitivity and NPV. In the study, SIRS cases were detected starting from Day-1 postoperatively, within 24 hours. Thus, it is suggested that CAR can be used at baseline upon ICU admission with a cutoff value ≥4.3 as an early screening tool for postoperative SIRS.

These findings have significant implications for the management of polytrauma patients. Early identification of patients at high risk of developing SIRS or sepsis is crucial for timely intervention and improved outcomes. C-reactive protein/albumin ratio (CAR) offers a readily available and cost-effective tool for risk stratification in polytrauma patients, allowing clinicians to implement targeted interventions, such as early antibiotic therapy, aggressive fluid management, and nutritional support.

Compared with other biomarkers such as procalcitonin, IL-6, or serum lactate, CAR offers several advantages. Procalcitonin and IL-6 are sensitive early indicators of sepsis but are costly and not universally available, while lactate reflects tissue hypoperfusion rather than inflammation. In contrast, CAR uses routinely measured laboratory parameters (CRP and albumin), making it a simple, inexpensive, and reproducible index suitable for early risk stratification in resource-limited ICUs. This practical accessibility underscores its potential as an adjunct or alternative to more specialized biomarkers.[7,8,22]

Furthermore, the association of DM and higher ASA grades with both SIRS and sepsis highlights the importance of considering pre-existing comorbidities and overall patient health status in risk assessment. These factors may contribute to a heightened inflammatory response and impaired immune function, increasing susceptibility to postoperative complications.

Modified Glasgow prognostic score (mGPS) has demonstrated utility in predicting survival across various cancers. In this study, we extended the application of mGPS to polytrauma patients, evaluating its association with SIRS and sepsis. Notable variations in mGPS scores were observed between patients with and without SIRS on Day-3 and Day-5, and also between septic and nonseptic patients on Day-3 and Day-5. However, there was no change at Day-1 or at baseline, so its role is limited before Day-3 postoperatively. This may require further research to establish its role in polytrauma patients.

The delayed rise in mGPS predictivity beyond Day-3 likely reflects the kinetics of CRP and albumin components—both

require sustained systemic inflammation and nutritional decline to shift categories within the mGPS scale. Thus, mGPS may capture subacute inflammatory trajectories rather than early postoperative changes, explaining its limited discrimination before Day-3 in our cohort.[12,22,23]

Although this study offers important insights into CAR prognostic utility, several limitations should be acknowledged. Firstly, the investigation was performed at a single center with a relatively limited sample size, potentially restricting the external validity and generalizability of the results. Secondly, the use of a convenience sampling approach may have introduced selection bias. Lastly, the postoperative follow-up period was restricted to five days, which may have precluded the identification of longer-term or delayed complications. However, this timeframe was chosen to minimize and eliminate confounding factors related to infections other than those caused by surgery and polytrauma, such as hospital-acquired infections. Finally, we did not investigate the impact of specific interventions on CAR, such as blood products (especially fresh frozen plasma). However, we excluded patients who received albumin supplementation.

Future studies should validate these findings through multicenter collaborations, with larger and more diverse populations and *longer postoperative follow-up* to evaluate the persistence and prognostic value of CAR beyond the early ICU phase. Incorporating additional inflammatory markers such as *procalcitonin*, *IL-6*, or *presepsin* may further clarify the additive or complementary value of CAR in multimarker prediction models.

Conclusion

C-reactive protein/albumin ratio (CAR) progressively increases in polytrauma patients who develop SIRS and sepsis, with significant differences observed as early as postoperative Day-1 and peaking by Day-5 compared to individual CRP and albumin assessments.

Clinical Significance

Early prediction and detection of postoperative SIRS and sepsis in polytrauma patients by a simple, inexpensive screening tool allows risk stratification, timely intervention, and early treatment of this high-risk group of patients to improve their clinical outcomes.

Ethics Approval and Consent to Participate

Ethical approval for the present study was secured from the Research Ethics Committee of the Faculty of Medicine, Ain Shams University (approval number: FMASU MD134/2023). Written informed consent was secured from either the patients themselves or their first-degree relatives prior to enrollment. All methodologies were conducted in compliance with institutional and/or national ethical regulations and followed the ethical principles set forth in the Declaration of Helsinki (1964) and its later amendments or comparable standards.

Authors' Contributions

All authors made substantial contributions to the study's conception, design, data acquisition, analysis, and interpretation. They were actively involved in drafting the manuscript, critically revising it for important intellectual content, and approving the final version for submission. Each author accepts responsibility for the integrity and accuracy of the work.

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