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Research Article

C-reactive protein to albumin ratio as a prognostic marker in community-acquired pneumonia mortality

Toplum kökenli pnömonide mortaliteyi öngören bir belirteç olarak C-reaktif protein/albumin oranı

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Abstract

Aim: This study aimed to evaluate the prognostic value of the C-reactive protein-to-albumin ratio (CAR) in predicting 30-day mortality among patients diagnosed with community-acquired pneumonia (CAP) presenting to the emergency department (ED).

Material and Methods: A retrospective study was conducted on 312 patients diagnosed with CAP who presented to the ED of a tertiary care hospital between January 1, 2022, and January 1, 2024. Demographic, clinical, and laboratory data were collected, including C-reactive protein (CRP) and albumin levels. CAR was calculated by dividing CRP levels (mg/dL) by albumin levels (g/L). The primary outcome was 30-day mortality. The prognostic performance of CAR was evaluated using receiver operating characteristic (ROC) curve analysis.

Results: Of the 312 patients included, 87 (27.9%) died within 30 days. The deceased group had significantly higher CAR values compared to survivors (1.18 ± 0.62 vs. 0.52 ± 0.25, $p < 0.001$). CAR demonstrated excellent discriminatory power for predicting 30-day mortality, with an area under the curve (AUC) of 0.837 (95% CI: 0.791–0.876, $p < 0.001$). At a cut-off value of >0.77, CAR achieved a sensitivity of 75.9% and a specificity of 86.7%. Deceased patients also exhibited significantly lower systolic and diastolic blood pressures, oxygen saturation, and albumin levels, along with higher CRP levels and respiratory rates. Comorbidities such as stroke and congestive heart failure were more prevalent in the deceased group compared to survivors.

Conclusion: The C-reactive protein-to-albumin ratio is a reliable prognostic marker for predicting 30-day mortality in CAP patients presenting to the ED. Its ease of calculation and strong discriminatory power make CAR a valuable tool for risk stratification and clinical decision-making. Prospective studies are warranted to confirm these findings in diverse populations.

Keywords: Albumin, community-acquired pneumonia, C-reactive protein, C-reactive protein-to-albumin ratio, mortality.

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Öz

Amaç: Bu çalışma, acil servise (AS) başvuran toplum kökenli pnömoni (TKP) tanısı almış hastalarda C-reaktif protein/albumin oranının (CAR) 30 günlük mortaliteyi öngörmedeki prognostik değerini değerlendirmeyi amaçlamaktadır.

Gereç ve Yöntemler: Bu retrospektif çalışma, 1 Ocak 2022 ile 1 Ocak 2024 tarihleri arasında üçüncü basamak bir hastanenin AS'ine başvuran ve TKP tanısı konulan 312 hastayı içermektedir. Demografik, klinik ve laboratuvar verileri, C-reaktif protein (CRP) ve albumin düzeyleri dahil olmak üzere toplanmıştır. CAR, CRP düzeyinin (mg/dL) albumin düzeyine (g/L) bölünmesiyle hesaplanmıştır. Birincil sonuç, 30 günlük mortalite olarak belirlenmiştir. CAR'ın prognostik performansı, ROC eğrisi (receiver operating characteristic) analizi kullanılarak değerlendirilmiştir.

Bulgular: Çalışmaya dahil edilen 312 hastanın 87'si (%27,9) 30 gün içinde hayatını kaybetmiştir. Hayatta kalamayan hastalar, sağ kalanlara kıyasla anlamlı derecede yüksek CAR değerlerine sahipti (1,18 ± 0,62'ye karşı 0,52 ± 0,25, p < 0,001). CAR, 30 günlük mortaliteyi öngörmede mükemmel ayırt edici güce sahipti (Eğri altındaki alan (AUC): 0,837, %95 GA: 0,791–0,876, p < 0,001). >0,77 eşik değeri kullanıldığında, CAR %75,9 duyarlılık ve %86,7 özgüllük gösterdi.Hayatta kalamayan hastalar ayrıca daha düşük sistolik ve diyastolik kan basıncına, oksijen satürasyonuna ve albumin düzeylerine sahipken, daha yüksek CRP düzeyleri ve solunum hızları gösterdi. Ayrıca, inme ve konjestif kalp yetmezliği gibi komorbiditeler hayatta kalamayan hastalarda sağ kalanlara kıyasla daha yaygındı.

Sonuç: C-reaktif protein/albumin oranı (CAR), TKP hastalarında 30 günlük mortaliteyi öngörmede güvenilir bir prognostik belirteçtir. Kolay hesaplanabilirliği ve güçlü ayırt edici gücü nedeniyle, CAR risk sınıflandırması ve klinik karar verme süreçlerinde değerli bir araç olabilir. Bu bulguların farklı popülasyonlarda doğrulanması için prospektif çalışmalara ihtiyaç duyulmaktadır.

Anahtar Kelimeler: Albumin, community-acquired pneumonia, C-reactive protein, C-reactive protein-to-albumin ratio, mortality.

Introduction

Community-acquired pneumonia (CAP) is one of the leading causes of morbidity and mortality worldwide (1-3). It represents an acute infection of the pulmonary parenchyma acquired outside healthcare settings. Clinically, CAP manifests in a spectrum ranging from mild respiratory symptoms to severe cases requiring intensive care, often complicated by sepsis and respiratory failure (4). Despite advancements in diagnostic and therapeutic approaches, CAP remains a significant burden on healthcare systems, accounting for substantial hospital admissions and resource utilization (5).

C-reactive protein (CRP) and serum albumin are widely utilized biomarkers in clinical practice. CRP, an acute-phase reactant, reflects the intensity of systemic inflammation and is commonly elevated in bacterial infections, including pneumonia (6). Serum albumin, on the other hand, serves as an indicator of nutritional status and systemic inflammation. Hypoalbuminemia has been associated with poor outcomes in various critical illnesses (7).

The CRP/albumin ratio (CAR) integrates these two parameters, offering a combined assessment of inflammation and nutritional status. CAR has been explored in several clinical settings, including sepsis, malignancies, and cardiovascular diseases, as a prognostic marker (8-10). While its role in CAP has been less extensively studied, Its use in CAP has the potential to improve clinical decision-making and patient outcomes.

This study aims to evaluate the relationship between the CAR and mortality in patients diagnosed with community-acquired pneumonia presenting to the emergency department (ED).

Material And Methods

Study design

This retrospective study was conducted on patients diagnosed with CAP who presented to the ED of a tertiary care hospital. Ethical approval for the study was obtained from the Kartal Dr Lütfi Kırdar City Hospital Ethics Committee (Approval Number: 2024/010.99/10/56; Date: 29.11.2024). The study was conducted in accordance with the principles outlined in the Declaration of Helsinki.

Selection of participants

This study included patients who presented to the ED between January 1, 2022, and January 1, 2024, with a diagnosis of CAP and were admitted to the hospital. The diagnosis of CAP was based on clinical findings, including fever, cough, dyspnea, and/or pleuritic chest pain, combined with radiological evidence of a new pulmonary infiltrate on chest X-ray or computed tomography, and laboratory markers indicative of infection, such as elevated C-reactive protein or procalcitonin levels (11). Patients were included if they were aged 18 years or older, had

a confirmed diagnosis of CAP at the time of ED admission, and had complete clinical, radiological, and laboratory data available. Hospital-acquired pneumonia (HAP) and ventilator-associated pneumonia (VAP) cases were excluded from the study. Additionally, patients with incomplete data or those lost to follow-up were not included in the analysis.

Outcomes

The primary outcome of this study was the relationship between the CAR and 30-day mortality in patients diagnosed with CAP. Mortality data were obtained through hospital electronic medical records and, if necessary, follow-up phone calls to the patients' families or caregivers.

Data collection

Data for this study were retrospectively collected from the electronic medical records of patients who presented to the ED between January 1, 2022, and January 1, 2024, with a diagnosis of severe CAP. Demographic variables, including age, gender, and comorbidities, were extracted alongside clinical findings such as vital signs (systolic and diastolic blood pressure, oxygen saturation, respiratory rate, and body temperature) recorded during the initial ED evaluation. Laboratory data, including CRP, albumin levels, white blood cell (WBC) counts, and differential counts, were also collected. The CAR was calculated for each patient to evaluate its potential prognostic significance. All data were anonymized and securely stored.

Analysis

Descriptive statistics were used to summarize demographic, clinical, and laboratory parameters. Continuous variables were presented as means with standard deviations (mean ± SD) for normally distributed data or medians with interquartile ranges (IQR) for non-normally distributed data. Categorical variables were expressed as frequencies with percentages (n, %). Comparisons between survivors and deceased groups were performed using the Student's t-test for normally distributed continuous variables and the Mann-Whitney U test for non-normally distributed variables. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate.

The diagnostic performance of the CAR for predicting mortality was evaluated using receiver operating characteristic curve analysis. The area under the curve and its 95% confidence interval were calculated to assess discrimination. The Youden Index was used to determine the optimal cut-off value for CAR, maximizing the balance between sensitivity and specificity. Sensitivity and specificity values at fixed thresholds were estimated and presented with their corresponding 95% confidence intervals. All statistical analyses were performed using SPSS version 30.0 (IBM Corp, Armonk, NY, USA) and MedCalc Statistical Software (MedCalc Software Ltd., Ostend, Belgium). A p-value < 0.05 was considered statistically significant.

Results

A total of 312 patients with severe pneumonia were included, comprising 225 survivors (72.1%) and 87 deceased patients (27.9%). The mean age of the deceased group was statistically significantly higher than that of the survivor group (74.9 ± 14.0 vs. 70.5 ± 13.3 years, p < 0.001). Sex distribution was similar between groups, with male patients comprising n=118 (52.4%) of the survivor group and n=42 (48.3%) of the deceased group (p = 0.297).

Deceased patients exhibited statistically significantly lower systolic (91.6 ± 20.9 vs. 115.3 ± 29.9 mmHg, p < 0.001) and diastolic blood pressures (63.9 ± 13.8 vs. 79.4 ± 19.0 mmHg, p < 0.001), lower oxygen saturation (84% [IQR 78–92%] vs. 90% [IQR 86–93%], p < 0.001), and higher respiratory rates (17 [IQR 12–20] vs. 14 [IQR 11–18] breaths/min, p < 0.001) compared to survivors. Body temperature was also statistically significantly lower in the deceased group (36.1°C [IQR 34.8–37.3 °C] vs. 37.3°C [IQR 37.0–37.7 °C], p < 0.001).

In terms of comorbidities, stroke was more frequent in the deceased group (n=23, 26.4%) compared to the survivor group (n=27, 12.0%, p = 0.002). Congestive heart failure was also statistically significantly higher in deceased patients (n=23, 26.4%) compared to survivors (n=31, 13.8%, p = 0.008). There were no statistically significant differences in the rates of hypertension (n=30, 34.5% vs. n=72, 32.0%, p = 0.386), diabetes mellitus (n=30, 34.5% vs. n=73, 32.4%, p = 0.415), chronic kidney disease (n=5, 5.7% vs. n=13, 5.8%, p = 0.615), or COPD (n=29, 33.3% vs. n=65, 28.9%, p = 0.263; Table 1).

Laboratory findings demonstrated statistically significantly higher CRP levels (33.1 ± 17.0 vs. 17.8 ± 8.7 mg/dL, p < 0.001) and neutrophil counts (11.5 ± 7.5 vs. 8.3 ± 4.3 x10^3/µL, p < 0.001) in the deceased group, with lower albumin levels (28.3 ± 2.8 vs. 34.9 ± 3.9 g/L, p < 0.001). The CRP-to-albumin ratio (CAR) was statistically significantly higher in the deceased group (1.18 ± 0.62 vs. 0.52 ± 0.25, p < 0.001), while WBC and lymphocyte counts were similar between groups (p = 0.090 and p = 0.614, respectively; Table 1).

The CAR demonstrated excellent discriminatory power for predicting mortality, with an area under the curve (AUC) of 0.837 (95% CI: 0.791–0.876, p < 0.001). At an optimal cut-off value of >0.77, CAR had a sensitivity of 75.9% (95% CI: 65.5–84.4) and a specificity of 86.7% (95% CI: 81.5–90.8), with a Youden Index of 0.625 (Table 2, Figure 1).

Table 1. Comparison of Demographic, Clinical, and Laboratory Parameters Between Survivors and Deceased Patients				
Parameter	All (n=312)	Survivor (n=225)	Deceased (n=87)	p
Age (years)	71.7 ± 11.7	70.5 ± 13.3	74.9 ± 14.0	<0.001
Sex (male), n (%)	160 (51.3)	118 (52.4)	42 (48.3)	0.297
Altered mental status, n (%)	70 (22.4)	47 (20.9)	23 (26.4)	0.183
Systolic BP (mmHg)	108.7 ± 29.7	115.3 ± 29.9	91.6 ± 20.9	<0.001
Diastolic BP (mmHg)	75.0 ± 19.0	79.4 ± 19.0	63.9 ± 13.8	<0.001
Body temperature (°C)	37.2 (36.7 - 37.7)	37.3 (37.0 - 37.7)	36.1 (34.8 - 37.3)	<0.001
Oxygen saturation (%)	89 (85 - 93)	90 (86 - 93)	84 (78 - 92)	<0.001
Respiratory rate (breaths/min)	15 (11 - 18)	14 (11 - 18)	17 (12 - 20)	<0.001
Hypertension, n (%)	102 (32.7)	72 (32.0)	30 (34.5)	0.386
Diabetes mellitus, n (%)	103 (33.0)	73 (32.4)	30 (34.5)	0.415
Chronic kidney disease, n (%)	18 (5.8)	13 (5.8)	5 (5.7)	0.615
Stroke, n (%)	50 (16.0)	27 (12.0)	23 (26.4)	0.002
COPD, n (%)	94 (30.1)	65 (28.9)	29 (33.3)	0.263
Congestive heart failure, n (%)	54 (17.3)	31 (13.8)	23 (26.4)	0.008
WBC (x10^3/μL)	22.6 ± 3.9	22.0 ± 4.0	24.3 ± 2.8	<0.001
Neutrophils (x10^3/μL)	9.2 ± 5.6	8.3 ± 4.3	11.5 ± 7.5	<0.001
Lymphocytes (x10^3/μL)	2.2 ± 0.8	2.2 ± 0.8	2.1 ± 0.9	0.614
CRP (mg/dL)	22.1 ± 13.5	17.8 ± 8.7	33.1 ± 17.0	<0.001
Albumin (g/L)	33.1 ± 4.7	34.9 ± 3.9	28.3 ± 2.8	<0.001
CRP-to-albumin ratio	0.70 ± 0.49	0.52 ± 0.25	1.18 ± 0.62	<0.001
BP: Blood Pressure; COPD: Chronic Obstructive Pulmonary Disease; CRP: C-Reactive Protein; WBC: White Blood Cell Count;				

Table 2. Diagnostic Performance of C-Reactive protein-to-Albumin Ratio for Predicting Mortality						
Variable	AUROC (95% CI)	P	Youden Index (J)	Criterion	Sensitivity (95% CI)	Specificity (95% CI)
CAR	0.837 (0.791-0.876)	<0.001	0.625	>0.77	75.9 (65.5-84.4)	86.7 (81.5-90.8)
CAR: C-Reactive Protein-to-albumin ratio; CI: confidence interval						

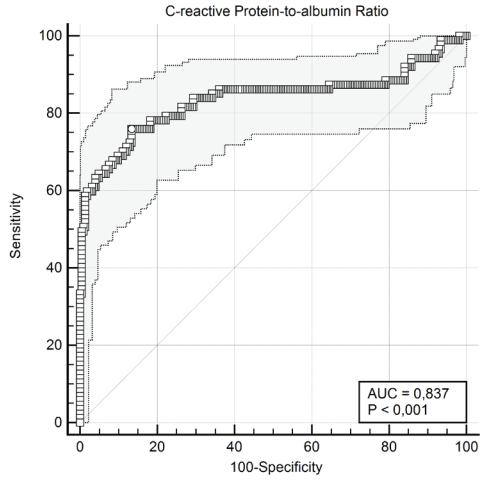

Figure 1. Receiver operating characteristic (ROC) curve of the CRP-to-albumin ratio for predicting mortality.

Discussion

In this study, we found that the CAR demonstrated significant prognostic value in predicting 30-day mortality among patients with CAP.

The CAP is a leading cause of morbidity and mortality worldwide, particularly among vulnerable populations such as the elderly and those with underlying comorbidities. Its clinical significance lies not only in its high prevalence but also in its potential to progress rapidly to severe complications, including sepsis and respiratory failure. Older age and chronic comorbidities are well-established risk factors for worse outcomes in CAP, as they can compromise the immune response and exacerbate the severity of the disease (12-14). Consistent with these observations, our study demonstrated that the mean age of deceased patients was significantly higher compared to

survivors, and chronic conditions such as stroke and congestive heart failure were more prevalent among those who deceased to the disease. In addition, lower oxygen saturation levels were observed in deceased patients, supporting the role of hypoxia as a critical determinant of mortality in CAP. Similarly, Umaç et al. reported that oxygen saturation levels were significantly reduced in patients with respiratory diseases during the COVID-19 pandemic, emphasizing the prognostic significance of hypoxia in respiratory illnesses (15).

The CRP and albumin are essential biomarkers used in the clinical assessment of systemic inflammation and nutritional status. CRP, as an acute-phase reactant, indicates the severity of inflammatory responses, while albumin reflects both nutritional reserves and the impact of chronic or acute inflammation (16,17). The CAR, by combining these two parameters, provides a comprehensive marker that captures both inflammatory and nutritional dynamics in patients.

CAR has been shown to be a reliable prognostic marker in critical illnesses (18-20). Its ability to integrate inflammation and nutritional status makes it particularly valuable in predicting outcomes and guiding clinical management. In this study, the significantly higher CAR values observed in deceased CAP patients highlight its importance as a prognostic tool, particularly in emergency settings where timely risk assessment is crucial.

In this study, the significantly higher CAR values observed in deceased CAP patients highlight its importance as a prognostic tool, particularly in emergency settings where timely risk assessment is crucial. Luo et al. identified CAR as a significant marker of CAP severity, showing a strong correlation with the CURB-65 score and demonstrating enhanced diagnostic accuracy when combined with other inflammatory indices such as FAR, NLR, and PLR. Their findings suggest that CAR effectively reflects the inflammatory burden in CAP patients and offers practical value in clinical decision-making (21). Likewise, Ozdemir et al. reported that elevated CAR values are strongly associated with short-term mortality in CAP, emphasizing its applicability in emergency departments for rapid risk stratification (22). Additionally, Lee et al. demonstrated that incorporating CAR into existing scoring systems such as the Pneumonia Severity Index (PSI) improved prognostic performance, with low albumin and high CRP levels independently linked to higher mortality rates (23). These studies demonstrate the potential of CAR as a practical and reliable prognostic marker, contributing to improved risk stratification and clinical management in patients with CAP.

Limitations

This study has several limitations. First, its retrospective design may introduce selection bias, as only patients with complete clinical and laboratory data were included. Second, the single-center nature of the study may limit the generalizability of the findings to other populations or healthcare settings. Third, while we accounted for key comorbidities, other unmeasured confounding factors could have influenced the relationship between CAR and mortality. Lastly, the reliance on electronic medical records for data collection may have introduced inaccuracies or missing information.

Conclusions

The CAR is a readily available and clinically meaningful biomarker that demonstrates significant prognostic value in predicting 30-day mortality among patients with CAP presenting to the ED. Its incorporation into routine clinical practice may aid in the early identification of high-risk patients, allowing for timely and appropriate interventions. Future prospective studies are needed to validate these findings in broader and more diverse populations.

Availability of data and materials

The authors agree to the conditions of publication including the availability of data and materials in our manuscript.

Informed consent

Retrospective study.

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Conflicts of Interest

Authors declare that they have no conflicts of interest.

Human rights

The principles outlined in the Declaration of Helsinki have been followed.

Ethical Approval

This study was approved by the local ethics committee (ethics committee ruling number: 2024/010.99/10/56, date: 29.11.2024).

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