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Association Between C-reactive Protein to Albumin Ratio and Mortality in Geriatric Hip Fracture Patients

Geriatrik Kalça Kırığı Hastalarında C-reaktif Protein/Albümin Oranı ile Mortalite Arasındaki İlişki

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Abstract

Objective: The objective of this study was to evaluate the relationship between admission C-reactive protein (CRP) to albumin ratio (CAR) and 30-day mortality in older adults undergoing surgical treatment for hip fractures.

Methods: This retrospective study included patients aged ≥65 years who presented to the emergency department of a tertiary care hospital with a diagnosis of hip fracture and subsequently underwent surgical treatment between January 2023 and January 2025. Demographic, clinical, and laboratory data were extracted from electronic records. The CAR was determined by dividing the serum CRP level (mg/L) by the serum albumin level (g/L), based on laboratory values obtained upon hospital admission. The primary outcome was 30-day all-cause mortality. Multivariable logistic regression was used to identify independent predictors. Model discrimination was assessed using the area under the receiver operating characteristic curve (AUROC), and calibration was evaluated using the Hosmer-Lemeshow test. The optimal CAR cut-off was determined via Youden's index.

Results: Among the 411 patients, 43 (10.5%) died within 30 days. Non-survivors were older, predominantly male, and had higher American Society of Anesthesiologists scores, lower serum albumin and hemoglobin levels, and higher CRP levels. Median CAR was significantly higher in deceased patients (14.8 vs. 3.5, p<0.001). In multivariate analysis, CAR remained an independent predictor of 30-day mortality [adjusted odds ratio: 2.77; 95% confidence interval (CI): 2.14-3.76]. The AUROC for CAR was 0.930 (95% CI: 0.860-0.988), and the optimal cut-off value of 6.5 yielded 88.4% sensitivity and 96.2% specificity.

Conclusion: CAR at admission was independently associated with short-term mortality in geriatric patients undergoing hip fracture surgery. As a readily obtainable marker reflecting systemic inflammation and nutritional status, CAR may serve as a valuable tool for early risk stratification in emergency orthopedic care.

Keywords: C-reactive protein, albumin, hip fracture, mortality, elderly

Öz

Amaç: Bu çalışmanın amacı, kalça kırığı nedeniyle cerrahi uygulanan yaşlı hastalarda, başvuru anındaki C-reaktif protein (CRP)/albümin oranının (CAR) 30 günlük mortalite ile ilişkisini araştırmaktır.

Yöntem: Bu retrospektif çalışmaya, Ocak 2023 ile Ocak 2025 tarihleri arasında bir üçüncü basamak hastanesinin acil servisine kalça kırığı tanısıyla başvuran ve cerrahi tedavi uygulanan ≥65 yaş hastalar dahil edildi. Demografik, klinik ve laboratuvar verileri elektronik kayıtlardan elde edildi. CAR, başvuru sırasında

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Öz

ölçülen serum CRP (mg/L) değerinin serum albümin (g/L) değerine bölünmesiyle hesaplandı. Birincil sonlanım 30 günlük tüm nedenlere bağlı mortaliteydi. Bağımsız prediktörleri belirlemek için çok değişkenli lojistik regresyon analizi kullanıldı. Modelin ayırt ediciliği alıcı çalışma karakteristik eğrisinin altındaki alan (AUROC) ile, kalibrasyonu ise Hosmer-Lemeshow testi ile değerlendirildi. En uygun CAR kesim noktası Youden indeksi ile belirlendi.

Bulgular: Toplam 411 hastanın 43'ü (%10,5) 30 gün içinde hayatını kaybetti. Hayatını kaybeden hastalar daha yaşlı, çoğunlukla erkekti; Amerikan Anesteziyoloji Derneği skorları daha yüksek, serum albümin ve hemoglobin düzeyleri daha düşük, CRP düzeyleri ise daha yüksekti. Ortanca CAR değeri ölen hastalarda anlamlı olarak daha yüksekti (14,8 vs. 3,5; p<0,001). Çok değişkenli analizde CAR, 30 günlük mortalitenin bağımsız bir prediktörü olarak kaldı [düzeltilmiş olasılık oranı: 2,77; %95 güven aralığı (GA): 2,14-3,76]. CAR için AUROC 0,930 (%95 GA: 0,860-0,988) olarak bulundu ve 6,5'lik eşik değeri %88,4 duyarlılık ve %96,2 özgüllük sağladı.

Sonuç: Kalça kırığı nedeniyle cerrahi uygulanan yaşlı hastalarda başvuru anındaki CAR değeri, kısa vadeli mortalite ile bağımsız olarak ilişkilidir. Sistemik enflamasyonu ve beslenme durumunu yansıtan kolay elde edilebilen bir belirteç olarak CAR, acil ortopedi bakımında erken risk sınıflandırması için değerli bir araç olabilir.

Anahtar Kelimeler: C-reaktif protein, albümin, kalça kırığı, mortalite, yaşlı

Introduction

Hip fractures in older adults represent a major public health concern due to their high incidence, associated comorbidities, and significant postoperative morbidity and mortality. Globally, the number of hip fractures is projected to exceed 6 million by 2050, with mortality rates 19% at 30 days and up to 30% at one year following surgery[1-3]. Given the vulnerability of this population, early identification of patients at high risk of adverse outcomes remains a clinical priority.

Among various prognostic markers, inflammation and nutritional status have emerged as critical determinants of postoperative survival in geriatric patients. C-reactive protein (CRP), an acute-phase reactant produced by hepatocytes in response to interleukin-6 and other pro-inflammatory cytokines, is widely used to reflect systemic inflammation[4,5]. On the other hand, serum albumin serves as an indicator of both nutritional status and chronic disease burden and has been shown to inversely correlate with frailty and postoperative complications[6,7].

The CRP-to-albumin ratio (CAR) combines these two markers into a single index, capturing both inflammatory and nutritional dimensions of physiological stress. CAR has been proposed as a prognostic marker in various clinical settings, including sepsis, cardiovascular disease, malignancy, and postoperative complications[8-10]. Recent studies have suggested that elevated CAR may be independently associated with higher mortality in patients undergoing orthopedic surgeries, including hip fracture repair[11,12]. However, despite these findings, data specific to the geriatric hip fracture population remain limited. Few studies have systematically evaluated the association between CAR measured at admission and short-term mortality outcomes in this high-risk group.

Moreover, the integration of CAR into routine preoperative assessment remains controversial due to variability in study designs, thresholds, and confounding factors.

Accordingly, this study investigates the prognostic value of the admission CAR in predicting 30-day mortality among elderly patients undergoing surgical treatment for hip fractures.

Materials and Methods

This retrospective observational study included patients presenting to the emergency departments of two tertiary care hospitals-Memorial Bahçelievler Hospital and Beykent University Faculty of Medicine Hospital-with a diagnosis of hip fracture. The study includes patients aged 65 years and older who were admitted with a diagnosis of hip fracture and underwent surgical treatment between January 1, 2023, and January 1, 2025. All patients were managed according to standardized institutional protocols for perioperative care and rehabilitation. Ethical approval was obtained from the Local Research Ethics Committee of Memorial Bahçelievler Hospital (approval no: 147, date: 27.03.2025). Inclusion criteria were: patients aged ≥65 years with low-energy, fragility hip fractures (including femoral neck, intertrochanteric, and subtrochanteric fractures), who underwent surgical treatment within 72 hours of hospital admission, and had complete preoperative laboratory data, including serum CRP and albumin levels. Patients were excluded if they had pathological or periprosthetic fractures, high-energy trauma, recent surgery (within the last 6 months), chronic liver disease, immunosuppressive therapy, active malignancy, or if they were discharged against medical advice. Patients with missing key laboratory data (CRP or albumin) were also excluded.

Demographic characteristics (age, sex), comorbidities (e.g., diabetes, cardiovascular, pulmonary diseases), American Society of Anesthesiologists scores (ASA) classification, time to surgery, type of anesthesia, and laboratory results (including CRP, albumin, hemoglobin, creatinine, and sodium) were recorded at admission. CAR, calculated as the ratio of serum CRP (mg/L) to albumin (g/L), serves as a composite marker of systemic inflammation and nutritional condition[13]. Postoperative complications were classified as minor or major. Minor complications included urinary tract infections, superficial wound infections, and delayed wound healing. Major complications included pulmonary embolism, myocardial infarction, cardiac arrest, sepsis, and unplanned intubations. Complications were identified within 30 days postoperatively, based on clinical and laboratory documentation in patient records.

The primary outcome was 30-day all-cause mortality, defined as death occurring within 30 days of surgery. Mortality status was verified through hospital records and national electronic death notification systems.

Statistical Analysis

All statistical analyses were conducted using R version 4.4.2 (R Foundation for Statistical Computing, Vienna, Austria). Descriptive statistics were used to summarize baseline characteristics, and comparisons between survivors and non-survivors were performed using independent samples t-tests or Mann-Whitney U tests for continuous variables, depending on normality, assessed via the Kolmogorov-Smirnov test and visual inspection of histograms. Categorical variables were analyzed using the chi-square test or Fisher's exact test, as appropriate. A multivariable logistic regression model was constructed to identify independent predictors of 30-day mortality. Variables with $p<0.20$ in univariate analysis were considered for inclusion, and it was ensured that CAR remained in the model regardless of statistical significance. Multicollinearity was assessed using the variance inflation factor (VIF), with variables exhibiting VIF >5 removed to improve model stability. Model performance was evaluated using the Hosmer-Lemeshow goodness-of-fit test, Nagelkerke's R^2, and area under the receiver operating characteristic curve (AUROC). The AUROC was internally validated using 5-fold cross-validation. The diagnostic accuracy of CAR was further assessed using receiver operating characteristic (ROC) analysis. The optimal cut-off value for predicting 30-day mortality was determined using Youden's index, and corresponding sensitivity, specificity, positive predictive value (PPV), and negative predictive value with 95% confidence intervals (CIs), were computed using the Wilson score interval method. The ROC curve was plotted with a 95% confidence band, and model discrimination was evaluated via DeLong's test for area under the curve comparison. All statistical tests were two-tailed, with $p<0.05$ considered statistically significant.

Results

A total of 411 patients were included in the analysis, of whom 43 (10.5%) died within 30 days. The mean age was significantly higher in the deceased group (87.3±6.9 years) compared to the survivor group (82.2±6.2 years, $p<0.001$) (Table 1). The proportion of male patients was higher among deceased patients (51.2% vs. 30.2%, $p=0.009$). The Parker Mobility score was significantly lower in the deceased group (4.3±2.0 vs. 5.8±1.9, $p<0.001$), and cognitive impairment was more prevalent (48.8% vs. 28.3%, $p=0.009$).

Among comorbidities, diabetes mellitus (37.2% vs. 19.3%, $p=0.012$), chronic heart disease (60.5% vs. 32.9%, $p=0.001$), and chronic lung disease (41.9% vs. 19.6%, $p=0.002$) were significantly more common in deceased patients. No significant differences were observed for hypertension, chronic kidney disease, or malignancy.

Table 1. Baseline characteristics of hip fracture patients stratified by 30-day mortality

Variable	Survivors (n=368)	Deceased (n=43)	p
Demographics & baseline			
Age (years)	82.2±6.2	87.3±6.9	<0.001
Male sex	111 (30.2)	22 (51.2)	0.009
Parker mobility score	5.8±1.9	4.3±2.0	<0.001
Cognitive impairment	104 (28.3)	21 (48.8)	0.009
Comorbidities			
Hypertension	225 (61.1)	25 (58.1)	0.829
Diabetes mellitus	71 (19.3)	16 (37.2)	0.012

Table 1. Continued

Variable	Survivors (n=368)	Deceased (n=43)	p
Chronic heart disease	121 (32.9)	26 (60.5)	0.001
Chronic lung disease	72 (19.6)	18 (41.9)	0.002
Chronic kidney disease	58 (15.8)	9 (20.9)	0.516
Malignancy	46 (12.5)	9 (20.9)	0.194
Surgical & perioperative factors			
Time to surgery (hours)	24.5±5.3	30.6±5.2	<0.001
ASA score	3.0±0.7	3.9±0.4	<0.001
Laboratory markers			
Hemoglobin (g/dL)	12.5±1.8	10.8±2.4	<0.001
Serum albumin (g/dL)	3.9±0.5	3.2±0.6	<0.001
CRP (mg/L)	11.9 (6.5-18.9)	28.6 (15.4-38.4)	<0.001
CAR	3.5 (1.8-6.2)	14.8 (7.5-24.3)	<0.001
Creatinine (mg/dL)	0.9±0.3	1.5±0.5	<0.001
eGFR (mL/min/1.73 m^2)	68.5±15.4	48.9±18.1	<0.001
BMI (kg/m^2)	24.7±4.2	22.2±3.9	<0.001
Postoperative & metabolic indicators			
Minor complications	112 (30.4)	13 (30.2)	1.000
Major complications	40 (10.9)	17 (39.5)	<0.001
Lactate (mmol/L)	1.9±0.5	3.7±1.3	<0.001

CRP: C-reactive protein, CAR: C-reactive protein to albumin ratio, ASA: American Society of Anesthesiologists, eGFR: Estimated glomerular filtration rate, BMI: Body mass index

Deceased patients had significantly longer time until surgery (30.6±5.2 hours vs. 24.5±5.3 hours, p<0.001) and a higher ASA score (3.9±0.4 vs. 3.0±0.7, p<0.001). Regarding laboratory markers, deceased patients had lower hemoglobin (10.8±2.4 g/dL vs. 12.5±1.8 g/dL, p<0.001) and had lower serum albumin (3.2±0.6 g/dL vs. 3.9±0.5 g/dL, p<0.001). Conversely, they exhibited significantly higher CRP levels [28.6 (15.4-38.4) mg/L vs. 11.9 (6.5-18.9) mg/L, p<0.001] and CAR [14.8 (7.5-24.3) vs. 3.5 (1.8-6.2), p<0.001]. Postoperative complications were more frequent in the deceased group, with major complications occurring in 39.5% of deceased patients compared to 10.9% of survivors (p<0.001). Lactate levels were also significantly higher among deceased patients (3.7±1.3 mmol/L vs. 1.9±0.5 mmol/L, p<0.001).

In the multivariable model, CAR remained a significant predictor of 30-day mortality (adjusted odds ratio: 2.77, 95% CI: 2.14-3.76) (Table 2). Other independent predictors included ASA score (1.89, 95% CI: 1.57-2.24), hemoglobin (0.78, 95% CI: 0.62-0.99), CRP (2.12, 95% CI: 1.64-2.70), creatinine (2.23, 95% CI: 1.77-2.78), and major complications (1.39, 95% CI: 1.10-1.73). The AUROC of the multivariable model was 0.889 (95% CI: 0.833-0.941), the Hosmer-Lemeshow goodness-of-fit test was p=0.41, and Nagelkerke's R^2 was 0.78.

The AUROC for CAR in predicting 30-day mortality was 0.930 (95% CI: 0.860-0.988) (Table 3, Figure 1). The optimal cut-off, determined by Youden's index, was 6.5, yielding a sensitivity of 88.4% (95% CI: 75.5-94.9) and specificity of 96.2% (95% CI: 93.7-97.7). At lower thresholds (3.5 and 5.0), sensitivity remained high (93.0%), but specificity improved significantly at 5.0 (81.0%). A cut-off of 7.5 provided a balanced trade-off with a specificity of 98.6% and a PPV of 87.5%. At higher cut-offs (10.0 and 14.0), specificity reached 100%, but sensitivity declined to 72.1% and 46.5%, respectively.

Discussion

In this retrospective cohort of elderly patients undergoing hip fracture surgery, the CAR measured at admission was significantly associated with 30-day mortality. The ratio remained an independent predictor even after adjusting for clinical and laboratory confounders, demonstrating strong discriminative power for early mortality risk. These findings suggest that CAR may serve as a practical and biologically plausible marker for early risk stratification in this high-risk population.

Table 2. Multivariable logistic regression analysis for 30-day mortality in hip fracture patients

Variable	Adjusted OR (95% CI)
ASA score	1.89 (1.57-2.24)
Hemoglobin	0.78 (0.62-0.99)
CRP	2.12 (1.64-2.70)
Creatinine	2.23 (1.77-2.78)
Major complications	1.39 (1.10-1.73)
CAR	2.77 (2.14-3.76)

OR: Odds ratio, CI: Confidence interval, CRP: C-reactive protein, CAR: C-reactive protein to albumin ratio, ASA: American Society of Anesthesiologists

Table 3. Diagnostic performance of CAR for 30-day mortality

CAR	Sensitivity (%) (95% CI)	Specificity (%) (95% CI)	PPV (%) (95% CI)	NPV (%) (95% CI)	PLR (95% CI)	NLR (95% CI)
3.5	93.0 (81.4-97.6)	50.0 (44.9-55.1)	17.9 (13.4-23.4)	98.4 (95.4-99.5)	1.86 (1.50-2.31)	0.14 (0.05-0.34)
5.0	93.0 (81.4-97.6)	81.0 (76.7-84.7)	36.4 (28.0-45.7)	99.0 (97.1-99.7)	4.89 (3.72-6.33)	0.09 (0.03-0.24)
7.5	81.4 (67.4-90.3)	98.6 (96.9-99.4)	87.5 (73.9-94.5)	97.8 (95.8-98.9)	59.91 (28.85-124.41)	0.19 (0.09-0.37)
10.0	72.1 (57.3-83.3)	100.0 (99.0-100)	100.0 (89.0-100)	96.8 (94.6-98.2)	Inf (NA)	0.28 (0.16-0.49)
14.0	46.5 (32.5-61.1)	100.0 (99.0-100)	100.0 (83.9-100)	94.1 (91.3-96.0)	Inf (NA)	0.53 (0.37-0.77)

CAR: C-reactive protein to albumin ratio, CI: Confidence interval, PPV: Positive predictive value, NPV: Negative predictive value, PLR: Positive likelihood ratio, NLR: Negative likelihood ratio, NA: Not available

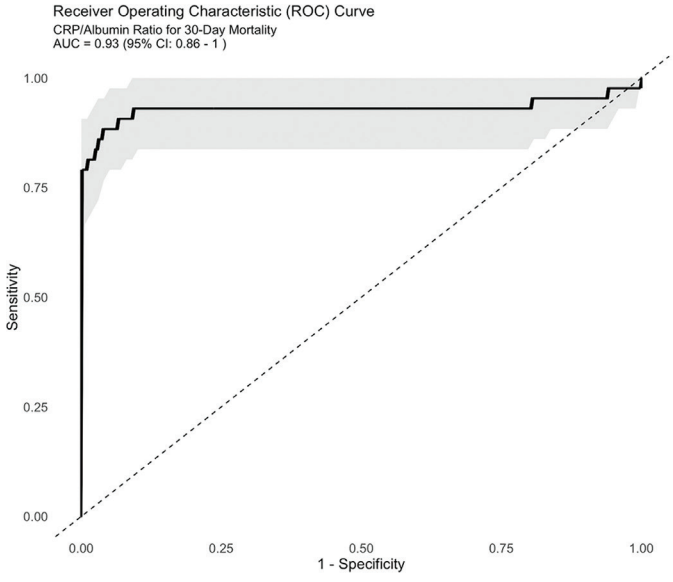

Figure 1. ROC curve of C-reactive protein (CRP)/albumin ratio for predicting 30-day mortality in hip fracture patients

CI: Confidence interval, AUC: Area under the curve

The CAR represents the dynamic interaction between systemic inflammation and nutritional status-two interdependent pathways influencing outcomes in elderly patients with hip fractures. Elevated CRP levels are a hallmark of the acute-phase response, triggered by cytokines such as interleukin-6 during tissue injury and trauma[14]. In hip fracture patients, a pronounced inflammatory response has been associated with increased risks of postoperative complications including delirium, pneumonia, and cardiovascular events[15]. Conversely, serum albumin, a negative acute-phase reactant and marker of visceral protein stores, reflects both baseline nutritional reserve and the body's ability to counteract catabolic stress[16]. Hypoalbuminemia is frequently observed in frail older adults and has been linked to impaired wound healing, immune dysfunction, and higher infection rates[17,18]. As such, CAR integrates two biologically relevant dimensions-proinflammatory activation and protein depletion-into a single composite index. In geriatric trauma patients, who often exhibit diminished physiological reserve and multimorbidity, this ratio may serve as a more sensitive indicator of vulnerability and mortality risk than either marker alone[19].

In the present study, the CAR was identified as an independent predictor of 30-day mortality in elderly patients undergoing surgery for hip fracture. This finding aligns with prior evidence that supports the role of CAR as a robust biomarker

combining inflammatory and nutritional status in predicting short-term postoperative outcomes. In the study by Aydın and Kaçmaz[19] CAR was evaluated in a cohort of elderly patients undergoing hemiarthroplasty and was found to be independently associated with both intensive care unit admission and 1-year mortality. The authors reported a CAR cut-off value of 1.03, with a high specificity (92.7%) and significant discriminative ability in ROC analysis[19]. Balta et al.[20] investigated preoperative inflammatory biomarkers, including CAR, in patients with intertrochanteric femur fractures and demonstrated that CAR had the highest predictive value among the studied ratios. A cut-off value of 12.42 yielded a sensitivity of 81.8% and specificity of 69.4%. CAR remained statistically significant in both univariate and multivariate models for 30-day mortality. In a more recent study, Kaya and Efendioglu[21] reported that a CAR threshold of 0.15 was significantly associated with early mortality, though with more modest sensitivity and specificity (74% and 53%, respectively). They concluded that CAR was superior to CRP or albumin alone and recommended its use as part of routine risk stratification for elderly hip fracture patients[21]. Collectively, these findings reinforce the clinical utility of CAR as a non-invasive, cost-effective, and biologically meaningful tool to identify elderly patients at increased risk of early postoperative mortality following hip fracture surgery. Despite variability in methodological design and cut-off values across studies, the consistent independent association between CAR and mortality across different clinical settings highlights its translational relevance.

Study Limitations

This study has several limitations that merit consideration. As a single-center, retrospective analysis, the findings may be subject to selection bias and may not be generalizable to other healthcare settings with different perioperative protocols or patient demographics. Although multivariate modeling was used to adjust for potential confounders, the presence of residual confounding cannot be entirely excluded, particularly with respect to unmeasured variables such as frailty scales or detailed nutritional assessments. Furthermore, CRP and albumin levels were assessed only at the time of admission, without accounting for perioperative changes that may influence outcomes. Finally, although mortality data were obtained through national registries and hospital records, other important outcomes such as functional recovery, or long-term complications were not evaluated.

Conclusion

This study demonstrates that the CAR at hospital admission is significantly associated with short-term mortality in elderly patients undergoing surgery for hip fracture. As a combined marker of systemic inflammation and nutritional status, the ratio showed strong independent predictive value and diagnostic accuracy. These findings support its potential utility as an accessible and cost-effective tool for early risk stratification in the emergency care of geriatric trauma patients. Future prospective studies are warranted to validate these results and explore whether targeted interventions based on CRP/albumin levels could improve clinical outcomes.

Ethics

Ethics Committee Approval: The study was approved by the Ethics Committee of University of Memorial Bahçelievler Hospital (approval no: 147, date: 27.03.2025).

Informed Consent: Given the retrospective nature of the study, the institutional review board approved a waiver of informed consent.

Footnotes

Authorship Contributions

Surgical and Medical Practices Concept: S.A., S.Y., Design: S.A., S.Y., Data Collection or Processing: S.A., Analysis or Interpretation: S.A., S.Y., Literature Search: S.A., S.Y., Writing: S.A., S.Y.

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