European Review for Medical and Pharmacological Sciences 2023; 27: 8438-8446

# CRP/albumin ratio in predicting 1-year mortality in elderly patients undergoing hip fracture surgery

A. AYDIN[1], O. KAÇMAZ[2]

[1]Department of Anesthesiology and Reanimation, Faculty of Medicine, Malatya Turgut Özal University, Malatya Training and Research Hospital, Malatya, Turkey
[2]Department of Anesthesiology and Reanimation, Malatya Training and Research Hospital, Malatya, Turkey

**Abstract. – OBJECTIVE: In the literature, rates of up to 37.1% have been reported for 1-year mortality after hip fractures. In this study, we aimed to determine whether the C-reactive protein/albumin ratio (CAR) is an independent risk factor for 1-year mortality after hip fracture and whether CAR, neutrophil/lymphocyte ratio (NLR), CRP, albumin level, and other parameters have an effect on mortality and morbidity.**

**PATIENTS AND METHODS: Over a 3-year period, 480 patients aged 65 years and older who underwent hemiarthroplasty for hip fracture were analyzed. A univariate logistic regression analysis was performed to identify prognostic factors for 1-year mortality. Significant variables were re-evaluated using binary logistic regression analysis.**

**RESULTS: The number of patients who died within 1 year postoperatively was 95 (27.7%), and the median age was 85 years. In the receiver operating characteristic analysis (ROC) for 1-year mortality after hip fracture, the optimal cut-off value of CAR was found to be 1.03. The area under the curve (AUC) for mortality was 0.843, the sensitivity was 65.3%, and the specificity was 92.7% [95% confidence interval (CI), 0.791-0.895; $p < 0.001$]. The optimal cut-off value for CRP was 2.85, the AUC was 0.838, the sensitivity was 70%, and the specificity was 89% (95% CI, 0.785-0.890; $p < 0.001$). The optimal cut-off value of NLR for postoperative intensive care unit (ICU) admission was determined to be 6.64.**

**CONCLUSIONS: CAR was a predictive factor for 1-year postoperative mortality and postoperative ICU admission, whereas NLR was a predictive factor for postoperative ICU admission.**

*Key Words:*
CRP/albumin ratio, Neutrophil to lymphocyte ratio, Elderly patients, Hip fracture, Mortality.

## Introduction

Due to physiological changes and increased comorbidities that occur with aging, elderly people have become frailer. These age groups have difficulty adapting to stressful situations such as trauma[1,2]. Low-energy traumas are the most common cause of hip fractures in elderly patients. In addition, osteoporosis and malnutrition are known to cause age-related disabilities[3,4].

Geriatric hip fractures are a leading cause of functional impairment and death[5]. With the increase in the elderly population worldwide, the number of people with hip fractures has been gradually increasing; it is estimated that this number will exceed six million by 2050[6,7]. The incidence of mortality and morbidity from hip fractures is considerably higher in elderly people with a high frailty index and more comorbidities[8]. Sex, advanced age, and multiple comorbidities have an irreversible effect on mortality, whereas nutritional status and disturbances in fluid-electrolyte balance can be improved[8].

In the literature, rates of up to 37.1% have been reported for 1-year mortality after hip fracture[9]. Public health issues may arise as the number of individuals with hip fractures rises in tandem with the elderly population[7]. Therefore, it is critical to identify the prognostic factors affecting mortality and morbidity in elderly patients with hip fractures. In this study, we aimed to determine whether the C-reactive protein (CRP)/albumin ratio (CAR) is an independent risk factor for 1-year mortality after hip fracture in elderly patients aged 65 years and older and to determine whether CAR, neutrophil/lymphocyte ratio (NLR), CRP, albumin level, and other parameters have an effect on mortality and morbidity.

## Patients and Methods

The medical records of 480 patients aged 65 years and older who underwent hemiarthroplasty



*Corresponding Author:* Ahmet Aydin, MD; e-mail: ketamin2323@gmail.com

for hip fracture in the pre-pandemic period (from January 2016 to January 2019) were reviewed retrospectively. The data were obtained from the hospital's automation system.

Patients with deficient medical records, a previous contralateral hip fracture, pathologic hip fracture, multiple traumas, or a suspected or diagnosed bacterial infection at presentation or preoperatively were excluded from the study. A total of 343 patients were included in the research. American Society of Anesthesiologists (ASA) classification, age, sex, type of anesthesia (general/spinal/nerve block), time from admission to surgery, length of hospital stay (LOS), comorbidities, postoperative intensive care unit (ICU) admission status, preoperative CRP/albumin ratio, NLR, other laboratory parameters, and 1-year mortality status were recorded. The patients were classified according to their ages as 65-74 years, 75-84 years, and ≥ 85 years. To calculate preoperative CAR, the serum CRP level was divided by the serum albumin level. The NLR was calculated similarly. To obtain survival data, hospital medical records were reviewed, and telephone interviews were conducted. Patients whose survival status was uncertain or those who could not be interviewed were not included in the study.

### Statistical Analysis

SPSS software version 21.0 (IBM Corp., Armonk, NY) was used for statistical analyses. The descriptive statistics were presented as mean ± standard deviations, ranges, medians, and percentages. The data were tested for normality using the Kolmogorov-Smirnov test. Pearson's Chi-square test or the Fisher's exact test was used to compare the categorical variables. The independent samples *t*-test was used to analyze the parametric data, and the Mann-Whitney U test was used for non-parametric data. The cut-off value of CAR for 1-year mortality was calculated using receiver operating characteristic (ROC) analysis and the Youden index. The positive and negative predictive values of CAR were presented. The cut-off values for NLR and CRP were calculated similarly. A univariate logistic regression analysis was performed to identify independent prognostic factors for 1-year mortality. Significant variables were re-evaluated by binary logistic regression analysis. The results were evaluated at a 95% confidence interval (CI), and significance was evaluated at the $p < 0.05$ level.

## Results

The flow diagram of the study is described in Figure 1. The mean age of 343 patients was 80.81 ± 7.57 years (range, 65-98). Of the patients, 131 were males (38.2%). There was no significant relationship between sex and 1-year mortality ($p = 0.241$). The number of patients who died within 1 year postoperatively was 95 (27.7%), and the median age was 85 years. The mortality rate of women among all patients was 15.7% (n = 54). The majority of those who did not survive were women (56.8%). The patients were divided into two groups according to their risk status: ASA1-2 and ASA3-4. In preoperative evaluation, 4 patients (1.16%) were ASA-1, 109 (31.77%) were ASA-2, 217 were ASA-3 (63.26%), and 13 (3.79%) were ASA-4. Only two patients died in the ASA score 1-2 patient groups. All patients who received peripheral nerve block anesthesia were in the ASA 3-4 risk group. The anesthesia type had no significant effect on 1-year mortality ($p = 0.678$). The mean time between hospital admission and surgery was 2.88 ± 1.8 days (range, 1-14), and the mean LOS was 11.8 ± 8.1 days. The length of hospital stay was longer in the non-surviving group ($p = 0.04$). The time from hospital admission to surgery was similar between the survivors and the deceased ($p = 0.237$) (Table I). The most common comorbidities were related to the cardiovascular system, with hypertension being the most prevalent (n = 217, 63.2%). The clinical features of the patients are presented in Table I.

The patients' age, postoperative ICU admission status, length of hospital stay, presence of multiple comorbidities, and high ASA score

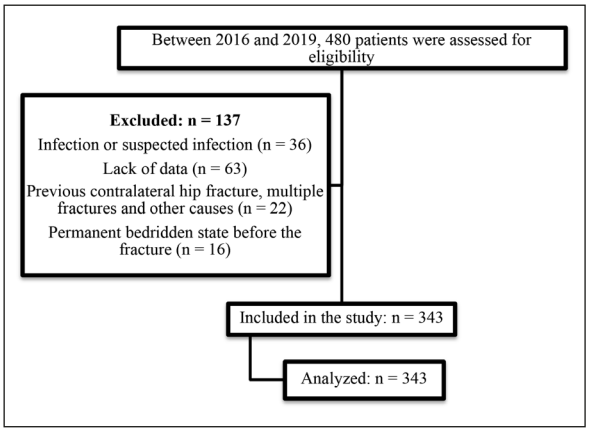


**Figure 1.** Flow diagram.

**Table I.** Baseline characteristics of the patients.

| | All patients (n = 343) | Survivors (n = 248) | Nonsurvivors (n = 95) | *p*-value |
|---|---|---|---|---|
| Median age, years (min-max) | 80 (65-98) | 79 (65-98) | 85 (69-98) | **< 0.001** |
| Age groups, n, (%) | | | | **< 0.001*** |
| 65-74 | 74 (21.6) | 69 (20.1) | 5 (1.5) | |
| 75-84 | 157 (45.8) | 118 (34.4) | 39 (11.4) | |
| ≥ 85 | 112 (32.7) | 61 (17.8) | 51 (14.9) | |
| Sex, n (%) | | | | |
| Male | 131 (38.2) | 90 (26.2) | 41 (12) | 0.241* |
| Female | 212 (61.8) | 158 (46.1) | 54 (15.7) | |
| Comorbid disease, n (%) | | | | |
| Cardiac diseases, (HT+CAD+CHF+Others) | 245 (71.4) | 176 (51.3) | 69 (20.1) | 0.760* |
| Respiratory diseases (Asthma+COPD) | 95 (27.7) | 56 (16.3) | 39 (11.4) | 0.001* |
| Diabetes Mellitus | 46 (13.4) | 34 (9.9) | 12 (3.5) | 0.793* |
| CRF | 6 (1.7) | 4 (1.2) | 2 (0.6) | 0.671* |
| Cerebrovascular diseases | 73 (21.3) | 43 (12.5) | 30 (8.7) | **0.004*** |
| Comorbidities | | | | **< 0.001*** |
| ≤ 1 | 91 | 88 (25.7) | 3 (0.9) | |
| ≥ 2 | 252 | 160 (46.6) | 92 (26.8) | |
| ASA Score, n (%) | | | | **< 0.001*** |
| ASA I-II | 113 (32.9) | 111 (32.4) | 2 (0.6) | |
| ASA III-IV | 230 (67.1) | 137 (39.9) | 93 (27.1) | |
| Intensive care unit admission, n (%) | 172 (50.1) | 96 (28) | 76 (22.2) | **< 0.001** |
| Type of anesthesia, Groups, n (%) | | | | 0.678* |
| Spinal/Epidural anesthesia | 322 (93.9) | 234 (68.2) | 88 (25.7) | |
| General Anesthesia | 11 (3.2) | 8 (2.3) | 3 (0.9) | |
| Nerve Block | 10 (2.9) | 6 (1.7) | 4 (1.2) | |
| Length of stay in the hospital (Day), (Me ± SD) | 11.85 ± 8.14 | 11.22 ± 6.51 | 13.51 ± 11.23 | **0.044** |
| Time to surgery from hospital admission (day), (Me ± SD) | 2.89 ± 1.84 | 2.81 ± 1.74 | 3.10 ± 2.06 | 0.237 |

Me: mean; SD: standard derivation, Mann-Whitney U test; *Chi-square test; CRF: chronic renal failure; CAD: coronary artery disease; COPD: chronic obstructive pulmonary disease; CHF: chronic heart failure; CVD: cerebrovascular disease; ASA: American Society of Anesthesiologists.

were significantly associated with 1-year mortality (Table I). Among comorbidities, only respiratory diseases and cerebrovascular diseases were found to be associated with mortality (Table I).

The analysis of the laboratory findings of the patients is shown in Table II. In the 1-year survival analysis, non-surviving patients had lower preoperative albumin levels and higher CRP and CAR levels. In terms of ICU admission status, non-surviving patients had lower lymphocyte and albumin levels and higher CRP, CAR, and NLR. These results were statistically significant (Table II).

Univariate regression analysis revealed that age, ASA score, ICU admission status, LOS, multiple comorbidities, and albumin, CRP, and CAR levels were significant prognostic risk factors for 1-year postoperative mortality. However, binary logistic regression analysis showed that only age, ICU admission status, ASA score, and CAR levels were significant predictors of 1-year mortality (Table III).

In the univariate regression analysis for ICU admission status, age, ASA score, multiple comorbidities, NLR, CRP, CAR, and albumin levels were statistically significant, while only age, ASA score, and CAR were found to be significant predictive factors in the binary logistic regression analysis (Table III).

In our ROC analysis for 1-year mortality after hip fracture, the optimal cut-off value of CAR was found to be 1.03. The area under the curve (AUC) for mortality was 0.843, the sensitivity was 65.3%, and the specificity was 92.7% (95% confidence interval, 0.791-0.895; $p < 0.001$) (Table III, Figure 2). The optimal cut-off value for CRP was 2.85, the AUC was 0.838, the sensitivity was 70%, and the specificity was 89% (95% CI, 0.785-0.890; $p < 0.001$). For albumin, the AUC was 0.276 (95% CI, 0.215-0.338; $p < 0.001$) (Figure 2).

**Table II.** Baseline laboratory findings of the patients.

| | All patients (n = 343) | Survivors (n = 248) | Nonsurvivors (n = 95) | p-value |
|---|---|---|---|---|
| Neu ($10^3$/μL) | 8.18 ± 3.29 | 8.22 ± 3.44 | 8.10 ± 2.88 | 0.938 |
| Lymph ($10^3$/μL) | 1.61 ± 1.23 | 1.64 ± 0.97 | 1.55 ± 1.74 | 0.099 |
| CRP (mg/dL) | 2.56 ± 3.84 | 1.13 ± 1.64 | 6.26 ± 5.23 | < 0.001 |
| Albumin | 3.62 ± 0.52 | 3.74 ± 0.44 | 3.30 ± 0.58 | **< 0.001** |
| CAR | 0.79 ± 1.29 | 0.32 ± 0.49 | 2.03 ± 1.81 | **< 0.001** |
| NLR | 7.10 ± 5.37 | 7.02 ± 5.46 | 7.32 ± 5.17 | 0.264 |
| | **All patients (n = 343)** | **ICU Admission, (YES, n = 172)** | **ICU Admission, (NO, n = 171)** | **p-value** |
| Neu ($10^3$/μL) | 8.18 ± 3.29 | 8.56 ± 3.52 | 7.81 ± 2.99 | 0.052 |
| Lymph ($10^3$/μL) | 1.61 ± 1.23 | 1.56 ± 1.44 | 1.67 ± 0.98 | **0.040** |
| CRP (mg/dL) | 2.56 ± 3.84 | 3.61 ± 4.57 | 1.50 ± 2.54 | **< 0.001** |
| Albumin | 3.62 ± 0.52 | 3.49 ± 0.54 | 3.75 ± 0.46 | **< 0.001** |
| CAR | 0.79 ± 1.29 | 1.15 ± 1.55 | 0.44 ± 0.81 | **< 0.001** |
| NLR | 7.10 ± 5.37 | 7.73 ± 5.49 | 6.48 ± 5.20 | **0.009** |

Mann Whitney U Test, $p < 0.05$. Neu: neutrophils; lymph: lymphocytes; CRP: C-reactive protein; CAR: CRP/Albumin ratio; NLR: neutrophil/lymphocyte ratio; ASA: American Society of Anesthesiologists.

The optimal cut-off value of NLR for postoperative ICU admission was determined to be 6.64. The AUC was 0.582, the sensitivity was 52%, and the specificity was 65% (95% CI, 0.522-0.642; $p = 0.009$) (Figure 3). For CAR, the optimal cut-off value was 0.32, the AUC was 0.653, the sensitivity was 55%, and the specificity was 72% (95% CI, 0.595-0.711; $p < 0.001$) (Figure 3).

**Table III.** Binary logistic regression analysis of 1-year mortality predictors and ICU admission predictors. Cut-off value, positive prediction, sensitivity, and specificity of CAR.

| | | | 95.0% CI | |
|---|---|---|---|---|
| **Variables for ICU admission** | **Odds Ratio** | **p-value** | **Lower bound** | **Upper bound** |
| Age | .962 | .043 | .926 | .999 |
| ASA score (ASA I-II, ASA III-IV) | .390 | .009 | .192 | .790 |
| NLR | .968 | .158 | .925 | 1.013 |
| CAR | .732 | .008 | .581 | .922 |
| Comorbidities (≤ 1, ≥ 2) | .483 | .054 | .230 | 1.014 |
| **Variables for 1-year mortality** | **Odds Ratio** | **p-value** | **Lower bound** | **Upper bound** |
| Age | .939 | .017 | .892 | .989 |
| ASA score (ASA I-II, ASA III-IV) | .107 | .011 | .019 | .602 |
| CAR | .255 | .000 | .170 | .382 |
| Comorbidities (≤ 1, ≥ 2) | 1.127 | .874 | .259 | 4.906 |
| ICU Admission | .358 | .007 | .170 | .755 |
| Length of stay in the hospital | .988 | .486 | .957 | 1.021 |

| **Cut-off value, positive prediction, sensitivity, and specificity of CAR** | | | | | | |
|---|---|---|---|---|---|---|
| | **Survivors** | **Positive prediction** | **Nonsurvivors** | **Positive prediction** | **Sensitivity** | **Specificity** |
| **CAR** | | | | | | |
| ≤ 1.03 | 230 | 87.5% | 33 | 77.5% | 65.3% | 92.7% |
| > 1.03 | 18 | | 62 | | | |

$p < 0.001$; CI; Confidence Interval; CAR: CRP/Albumin ratio; ASA: American Society of Anesthesiologists.

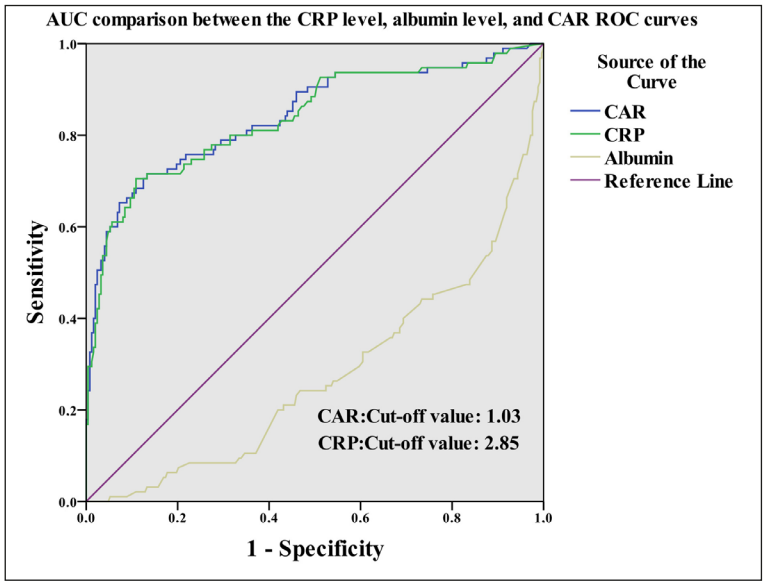


**Figure 2.** AUC comparison between the CRP level, Albumin level, and CAR ROC curves (1-year mortality).

## Discussion

Inflammatory changes that occur as a result of trauma and surgery in patients undergoing hip fracture surgery may affect patient mortality[10]. In our study, the 1-year postoperative mortality rate was 27.7% in patients who underwent hemiarthroplasty for hip fracture. Important prognostic markers for 1-year mortality were CAR, CRP, and albumin levels, whereas the important prognostic marker for ICU admission was NLR. In the ROC analysis, the cut-off value of CAR for mortality was 1.03. In this study, CAR was significant as an independent predictive factor for both mortality and ICU admission status. Moreover, the positive predictive value of CAR for the surviving patients was 87.5%.

In the literature, there are higher rates of 1-year mortality after hip fracture than in our study. In a systematic review[11] of patients under 65 years of age, a 1-year mortality rate of up to 34.8% was found. In the same study, the mean overall 1-year mortality rate was 22%, and the mean 1-year mortality rate in patients over 60 years of age was 21.8%. In a study conducted with patients over 70 years of age, the mean

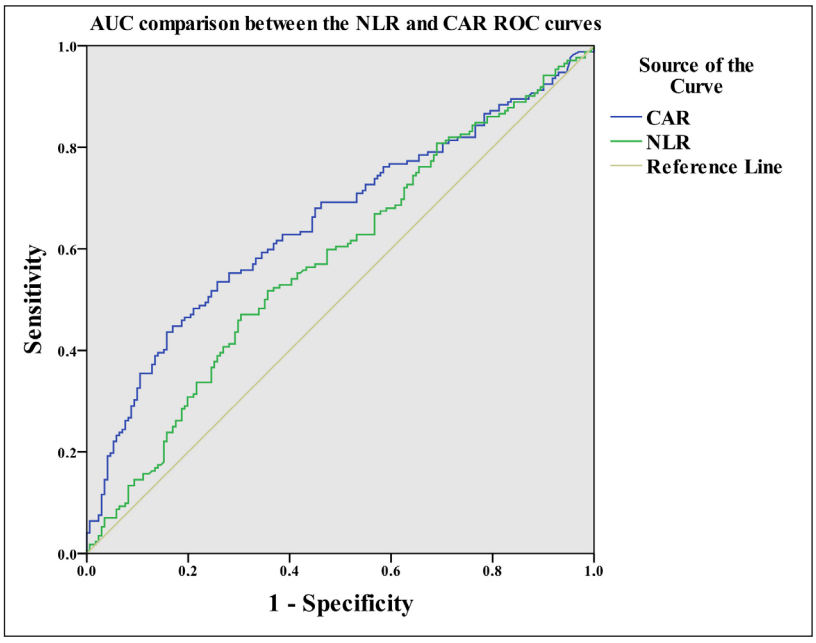


**Figure 3.** AUC comparison between the NLR and CAR ROC curves (ICU Admission).

overall 1-year mortality rate was 31.4%[12]. In studies[11,13-15] involving patients aged 65 years and older, 1-year mortality rates ranged between 11.9% and 30%. In a study[15] involving patients aged 65-79 years, 1-year mortality decreased from 14.3% to 10.4% between 2010-2012 and 2018-2020. This decrease has been reported to be effective due to changes in patient management and a multidisciplinary approach. In this study, the 1-year postoperative mortality rates were 27.7% in patients aged 65 years and older, 6.7% in patients aged 65-75 years, 33.4% in patients aged 75 years and older, and 45.5% in patients aged 85 years and older, which is similar to the literature.

Elderly patients often tend to suffer injuries that can cause hip fractures. In parallel with the increase in the elderly population, the increase in the incidence of hip fractures may lead to serious public health issues[16]. Therefore, determining laboratory parameters that predict mortality in advance would be beneficial. CRP, one of the parameters we examined for this purpose, is an acute inflammatory marker that is secreted in response to inflammation and reaches a peak in plasma within 48 hours. It has a wide range of biological functions and properties. Many studies[17,18] have been conducted to examine the effect of CRP level on disease prognosis, and it has been shown that CRP level is associated with disease severity and prognosis. In a study of patients with hip fractures, CRP level (CRP > 10 mg/dL) was reported as an independent risk factor for 1-year mortality after hip fracture[18].

Albumin is a plasma protein that indicates nutritional status. In a study[19], decreased albumin levels were found to be associated with an increased risk of 30-day postoperative mortality in patients with hip fractures, whereas another study[20] reported that it is an indicator of increased 1-year mortality in patients with femoral neck fractures.

Many studies[21-24] have been conducted to determine whether the CAR level obtained by the ratio of these two parameters (CRP and albumin) has a predictive effect on the prognosis of the disease and mortality. CAR was reported as a risk factor for contralateral hip fracture after total hip arthroplasty[21]. One study[22] found that a CAR level of 1.06 (95% CI, 1.03-1.10) was predictive of patient mortality in patients with sepsis, while another study[23] showed that patients with a CAR level of > 2 had a lower 90-day survival. In elderly patients with intertrochanteric femur fractures studied for 30-day mortality, preoperative CRP and CAR levels were higher in those who died, and the cut-off value of CAR in the ROC analysis was 12.42[24]. Finally, in a recent study[13], CAR was a predictive factor for mortality in patients undergoing hemiarthroplasty after hip fracture, and the cut-off value was 2.49.

NLR, another parameter we examined in our study, has been used as a cut-off value of > 5 in various studies[25,26]. A high NLR (≥ 5.1) in orthogeriatric patients was reported to be moderately predictive of poor postoperative outcomes (myocardial injury, infection, and in-hospital death)[25,26]. In a study[27] of people over the age of 60 years, the mean preoperative NLR was 6.59 and the cut-off value was 7.53 in the ROC analysis. In another study[28], it was stated that NLR could be used to predict the need for ICU, and the mean NLR was found to be 6.57 in all patients and 7.65 in those admitted to the ICU. The cut-off value of NLR was found to be 6.14. In addition, it has been shown that NLR is not discriminative in predicting in-hospital mortality after hip fractures[29].

In our study, we examined whether CRP, albumin, CAR, and NLR levels are predictive of 1-year mortality after hip fracture in elderly patients and postoperative ICU admission status. In our separate analyses for both conditions, we found that a high CRP level, a low albumin level, the CAR, and the NLR were important risk factors. The cut-off value for CRP in 1-year postoperative mortality was 2.85. For CAR, the cut-off was 1.03, the sensitivity was 65.3%, and the specificity was 92.7%. CAR was an independent predictor of 1-year mortality in binary regression analysis. In addition, the NLR level, with a cut-off value of 6.64, was an independent indicator for admission to the ICU postoperatively. However, in terms of postoperative 1-year mortality, the NLR, which was significant in single regression analysis, was not significant in binary regression analysis. Although the cut-off value of CAR is different in the literature, our study supports the literature in terms of prognostication.

There are some preoperative risk factors (age, ASA score, and comorbidity index) that increase the risk of mortality in elderly patients undergoing surgery for hip fractures[18,24,30,31]. Age, one of these factors, was also associated with mortality in our study, and our patients consisted of individuals with advanced age (mean = 80.81 years).

According to one study[18], an ASA classification of 3-4 is an independent risk factor for 1-year mortality after hip fracture, and the majority

of deaths (66.2%) occurred in ASA 3 patients, with a mortality rate of 31.2% in ASA 3-4 patients, while another reported a mortality rate of 49.5%[13,15,31]. The ASA classification 3-4 was also the most common in our study, with a 1-year mortality rate of 40.4%.

The relationship between sex and mortality varies in the literature. Female patients have a higher incidence[15,28], and the male sex has been shown to be a risk factor[30,32]. However, there have been studies[13,29,33] that show that sex has no statistical significance in mortality. Women (61.8%) were also the majority in this study population, but 1-year mortality rates were similar.

Long periods of waiting after hip fractures may increase mortality and the occurrence of postoperative complications[34-36]. In patients who are eligible for surgery, it has been shown that surgery performed within the first 24 hours improves 1-year survival[37], whereas a delay of more than 48 hours increases complications[38]. However, there are studies[33,39] that show no relationship between waiting time and mortality. In this study, the time from hospital admission to surgery was not found to be a risk factor for mortality.

In the literature, comorbidities were frequently associated with mortality, and the presence of three or more comorbidities was shown to be an important preoperative risk factor[13,30,40]. In our study, the comorbidities that were present in patients were considered as $\leq 1$ and $\geq 2$ in number. The comorbidity-mortality relationship, which was significant in univariate analysis, lost its significance in multivariate analyses. We believe this result is due to the way our study dealt with comorbidities.

Finally, admission status to a postoperative ICU, which has been shown to be an independent risk factor for 1-year mortality[18], was a strong risk factor in our study.

### Limitations

The study data were obtained retrospectively from a single center. The incomplete data and the exclusion of patients with suspected infections led to a reduction in the number of patients.

## Conclusions

The study data showed that CAR was a determining factor in postoperative ICU admissions and 1-year postoperative patient mortality after hip fracture, while NLR was a determining factor in postoperative ICU admissions. In our ROC analysis for 1-year mortality after hip fracture, the optimal cut-off value of CAR was found to be 1.03. The optimal cut-off value of NLR for postoperative ICU admission was determined to be 6.64. Some risk factors that are important in predicting mortality after hip fracture were also supportive of the literature in this study.

### Conflict of Interest

The Authors declare that they have no conflict of interests.

### Ethics Approval

Our research was carried out in accordance with the Declaration of Helsinki and the STROBE Checklist. It was conducted with the approval of Malatya Turgut Özal University Faculty of Medicine Ethics Committee numbered 2022/133.

### Funding

No funding was received for conducting this study.

### Informed Consent

Informed consent was obtained from all individual participants included in the study.

### Authors' Contribution

Ahmet Aydın; Paper concept creation, manuscript writing, manuscript editing, statistical analysis, literature search, material preparation and data collection. Osman Kaçmaz; Paper concept creation, manuscript editing, material preparation and data collection. All authors read and approved the final manuscript.

### Data Availability

Data information can be obtained from the author on request.

### ORCID ID

Ahmet Aydin: 0000-0003-1836-2061
Osman Kaçmaz: 0000-0002-1219-7758

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