International Journal of General Medicine

Dovepress
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ORIGINAL RESEARCH

Red Blood Cell Distribution Width-to-Albumin Ratio (RAR) Is an Independent Predictor of Mortality in Non-Anemic Elderly with Hip Fractures

Taiguo Ning*, Zhenning Liu*, Liping Pan*, Hao Wang, Guanghua Liang, Ruowen Yu, Yongping Cao

Orthopedic Department, Peking University First Hospital, Beijing, People's Republic of China

*These authors contributed equally to this work

Correspondence: Yongping Cao, Orthopedic Department, Peking University First Hospital, Beijing, 100034, People's Republic of China, Email freehorse66@163.com

Background: Hip fractures in elderly patients are associated with high morbidity and mortality, and effective prognostic biomarkers to guide risk stratification remain scarce. The red blood cell distribution width-to-albumin ratio (RAR), reflecting both inflammatory and nutritional status, has shown predictive value in other diseases but has not been evaluated in hip fractures.

Methods: This retrospective single-center study analyzed 622 elderly patients with hip fractures (aged ≥70 years) treated at Peking University First Hospital between 2015 and 2021. Patients were stratified into quartiles according to RAR (Q1–Q4), and mortality outcomes were assessed at 30 days, 3 months, 6 months, and 1 year after surgery. The prognostic significance of RAR was examined using Kaplan–Meier survival analysis, Cox proportional hazards models, and receiver operating characteristic (ROC) curves.

Results: Mortality increased progressively across RAR quartiles, with patients in the highest quartile (Q4) showing a 1-year mortality rate of 21.13%, compared with 4.08% in the lowest quartile (Q1) (P<0.001). Multivariable Cox regression analysis demonstrated that RAR was an independent predictor of mortality in non-anemic patients (Q4 vs. Q1: HR=12.52, 95% CI 3.18–49.24, P<0.001), whereas no significant association was observed in anemic patients (Q4 vs. Q1: HR=1.89, 95% CI 0.83–4.30, P=0.129). ROC analysis further indicated that RAR provided superior discriminatory performance compared with red blood cell distribution width (RDW) alone.

Conclusion: RAR represents a novel and independent predictor of postoperative mortality in elderly non-anemic patients with hip fractures, offering greater predictive accuracy than RDW alone. Incorporating RAR into clinical risk stratification models may improve prognostic assessment and support individualized treatment planning. Validation through multicenter prospective studies and further investigation of underlying mechanisms are warranted.

Keywords: RDW/ALB, Hip fracture, mortality, older people

Introduction

Hip fracture is a major health concern among the elderly, characterized by high incidence, mortality, and disability rates.[1,2] With the rapid growth of the global aging population, the incidence of hip fractures continues to rise annually, making it an important public health challenge. Epidemiological data indicate that the one-year mortality rate following hip fracture ranges from 20% to 30%, while postoperative complications and poor functional recovery further increase the health burden on affected patients.[3] Despite advances in surgical techniques and perioperative management have improved clinical care, accurate prediction of prognosis in patients with hip fractures remains a pressing issue in clinical research.

Blood contains various markers used to evaluate the inflammatory level in patients with hip fractures after surgery, such as the neutrophil-lymphocyte ratio (NLR), platelet-lymphocyte ratio (PLR), and monocyte-lymphocyte ratio

https://doi.org/10.2147/IJGM.S580782
Received: 11 November 2025
Accepted: 11 March 2026
Published: 23 March 2026

(MLR).[4] Red blood cell distribution width (RDW), a parameter derived from standard laboratory assessments, reflects variation in erythrocyte volume. Elevated RDW results from impaired erythropoiesis and reduced red blood cell survival and has been associated with multiple pathological states and with increased mortality risk.[5] Serum albumin, the most abundant plasma protein, is widely recognized as an indicator of nutritional status and systemic inflammation.[6] Numerous studies have demonstrated that low albumin levels are strongly associated with dysfunction, disease progression, and increased mortality.[7,8] Since RDW reflects erythropoietic and inflammatory processes, while albumin indicates nutritional and systemic inflammatory status, their combination may yield a more comprehensive measure of patient condition than either marker alone.

The RDW-to-albumin ratio (RAR), which integrates these two parameters, can be easily calculated from standard laboratory tests. RAR has recently emerged as a prognostic marker across diverse conditions, including heart failure, diabetes, pancreatitis, acute kidney injury, acute myocardial infarction, and atrial fibrillation.[9–14] For example, in heart failure, an elevated RAR has been independently associated with higher all-cause mortality.[9] However, the role of RAR in predicting outcomes among patients with hip fractures has not been investigated.

This study represents the first to evaluate the prognostic significance of RAR in elderly patients with hip fractures who do not have anemia. Using clinical data from 622 patients, we demonstrated that elevated RAR was independently associated with an increased risk of postoperative mortality. These results identify RAR as a novel biomarker for risk stratification in hip fracture and provide a basis for its broader application in orthopedic research. The principal contribution of this work lies in extending the use of RAR to hip fracture and confirming its independent value in predicting mortality.

Methods

Study Design and Participants

This single-center retrospective study was conducted at Peking University First Hospital and included patients with hip fractures admitted between 2015 and 2021. The inclusion criteria were: (1) age ≥70 years; (2) diagnosis of femoral neck fracture or intertrochanteric fracture; and (3) surgical treatment with internal fixation, hemiarthroplasty (HHA), or total hip arthroplasty (THA). Exclusion criteria were: (1) age <70 years; (2) pathological fractures; (3) conservative management; (4) revision surgeries; and (5) concomitant multiple traumas requiring additional non-hip surgeries.

A total of 942 patients with femoral neck or intertrochanteric fractures were initially identified. After removal of duplicate records based on medical record numbers, 918 unique cases were available for review. Of these, 212 patients were excluded for being younger than 70 years, 13 for undergoing conservative treatment, and 25 for incomplete laboratory or perioperative data, leaving 668 eligible cases. Mortality data were collected through telephone follow-up, and 46 patients could not be contacted, yielding a final analytic cohort of 622 patients (Figure 1).

Ethical Considerations

This retrospective study involved no direct risk to participants, and all patients data were anonymized to protect confidentiality. The study was conducted in accordance with institutional and national research committee standards and the ethical principles of the Declaration of Helsinki (1964) and its later amendments. Approval was obtained from the Ethics Committee of Peking University First Hospital (Approval No. 2021–432). Given the retrospective design, the requirement for informed consent was waived by the Ethics Committee. Clinical trial registration and additional consent declarations were not applicable.

Data Collection

RAR was used as the classification index. Demographic and clinical variables collected before surgery included age, sex, body mass index (BMI), fracture type, American Society of Anesthesiologists (ASA) classification, Charlson Comorbidity Index (CCI), presence of preoperative anemia, and comorbidities (Table 1). Hemoglobin levels were defined according to World Health Organization criteria, with normal values specified as ≥130 g/L for men and ≥120 g/L for women.[15] Perioperative data were

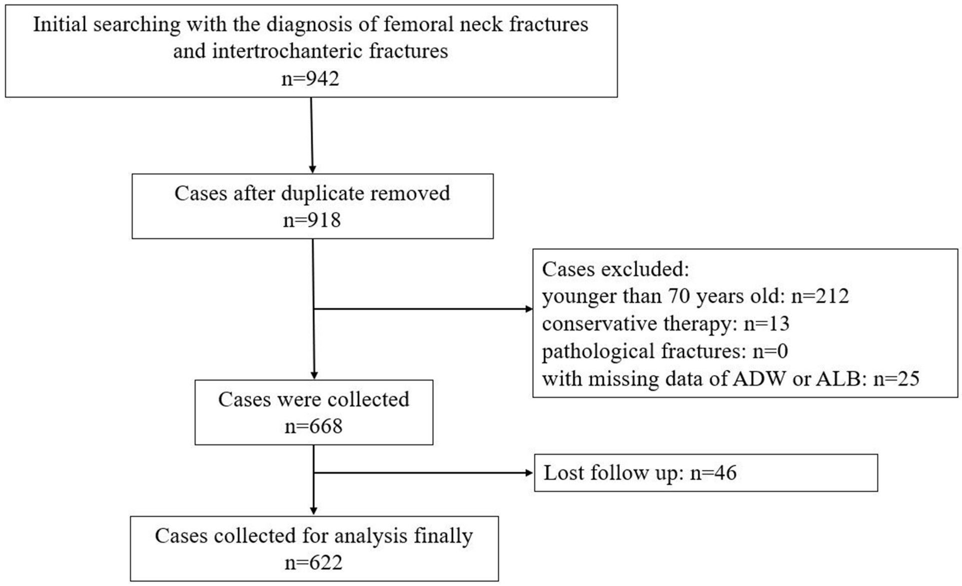

Figure 1 The flowchart of screening patients.

obtained from surgical, anesthesia, and nursing records and comprised the type of procedure, interval from admission to surgery, anesthesia method, operative duration, and transfusion details (Table 2). Postoperative outcomes included mortality at 30 days, 3 months, 6 months, and 1 year (Table 3). All baseline and perioperative variables were extracted directly from the electronic medical record system to ensure accuracy and completeness. Mortality was determined through structured telephone follow-up, with a minimum follow-up period of 7.7 months. For patients who had died prior to follow-up, the exact date of death was verified and recorded.

Table 1 Demographic and Clinical Characteristics of the Study Population Stratified Using the RAR Classification

Variables	Total	Q1	Q2	Q3	Q4	P-value
N	622	153	161	152	156	
RDW/ALB	0.37 (0.34, 0.41)	<0.34	0.34–0.37	0.37–0.41	≥0.41	
Age (years)	81.94 ± 6.19	80.19 ± 5.48	81.60 ± 6.45	82.65 ± 6.56	83.30 ± 5.81	<0.001
Male gender (%)	170 (27.33)	34 (22.22)	41 (25.47)	42 (27.63)	53 (33.97)	0.124
BMI (kg/m2)	22.27 (20.00, 24.97)	22.89 (20.57, 25.21)	23.00 (20.14, 25.39)	22.07 (20.00, 24.91)	20.55 (18.59, 23.73)	<0.001
Fracture type, n(%)						0.292
Femoral neck fracture	366 (58.84)	111 (72.55)	97 (60.25)	90 (59.21)	68 (43.59)	
Intertrochanteric fracture	256 (41.16)	42 (27.45)	64 (39.75)	62 (40.79)	88 (56.41)	
ASA, n(%)						<0.001
2	231 (37.14)	80 (52.29)	56 (34.78)	49 (32.24)	46 (30.07)	
3	349 (56.11)	69 (45.10)	94 (58.39)	95 (62.50)	91 (59.48)	
4	39 (6.27)	4 (2.61)	11 (6.83)	8 (5.26)	16 (10.46)	
Missing data	3 (0.48)					
CCI, n(%)						0.126
<4	54 (8.68)	14 (9.15)	12 (7.45)	13 (8.55)	15 (9.62)	
5	215 (34.57)	63 (41.18)	52 (32.30)	56 (36.84)	44 (28.21)	
6	247 (39.71)	61 (39.87)	65 (40.37)	62 (40.79)	59 (37.82)	
7	88 (14.15)	14 (9.15)	26 (16.15)	18 (11.84)	30 (19.23)	
More than 8	18 (2.89)	1 (0.65)	6 (3.73)	3 (1.97)	8 (5.13)	

(*Continued*)

Table 1 (Continued).

Variables	Total	Q1	Q2	Q3	Q4	P-value
Preoperative anemia, n (%)	345 (55.47)	48 (31.37)	78 (48.45)	92 (60.53)	127 (81.41)	<0.001
Comorbidities, n (%)	516 (82.96)	129 (84.31)	134 (83.23)	125 (82.24)	128 (82.05)	0.95
Heart disease	240 (38.59)	54 (35.29)	64 (39.75)	63 (41.45)	59 (37.82)	0.716
Cerebrovascular disease	165 (26.53)	37 (24.18)	47 (29.19)	39 (25.66)	42 (26.92)	0.78
Hypertension	395 (63.50)	107 (69.93)	104 (64.60)	97 (63.82)	87 (55.77)	0.077
Diabetes mellitus	183 (29.61)	43 (28.10)	48 (30.19)	46 (30.46)	46 (29.68)	0.97
Respiratory disease	83 (13.34)	17 (11.11)	20 (12.42)	19 (12.50)	27 (17.31)	0.393
Kidney disease	34 (5.47)	3 (1.96)	9 (5.59)	9 (5.92)	13 (8.33)	0.103
Liver disease	25 (4.02)	3 (1.96)	5 (3.11)	6 (3.95)	11 (7.05)	0.125

Table 2 Surgery-Related Characteristics of Patients with Hip Fracture Stratified by RAR Classification

Variables	Total (n=622)	Q1	Q2	Q3	Q4	P-value
Surgery type, n (%)						<0.001
Internal fixation	286 (45.98)	54 (35.29)	67 (41.61)	67 (44.08)	98 (62.82)	
HHA	318 (51.13)	89 (58.17)	93 (57.76)	80 (52.63)	56 (35.90)	
THA	18 (2.89)	10 (6.54)	1 (0.62)	5 (3.29)	2 (1.28)	
Surgery delay, n (%)						0.468
Less than 48 h	287 (46.14)	79 (51.63)	72 (44.72)	66 (43.42)	70 (44.87)	
More than 48 h	335 (53.86)	74 (48.37)	89 (55.28)	86 (56.58)	86 (55.13)	
Anesthesia type, n (%)						0.048
Intravertebral anesthesia	435 (70.05)	118 (77.12)	106 (65.84)	111 (73.03)	100 (64.52)	
General anesthesia	186 (29.95)	35 (22.88)	55 (34.16)	41 (26.97)	55 (35.48)	
Operation duration, N (%)						0.16
Less than 1 h	207 (33.33)	55 (35.95)	58 (36.25)	42 (27.63)	52 (33.33)	
1-2 h	358 (57.65)	87 (56.86)	94 (58.75)	92 (60.53)	85 (54.49)	
More than 2 h	56 (9.02)	11 (7.19)	8 (5.00)	18 (11.84)	19 (12.18)	
Transfusion, n (%)	273 (43.89)	35 (22.88)	59 (36.65)	81 (53.29)	98 (62.82)	<0.001

Table 3 Postoperative Mortality of Patients with Hip Fracture Stratified by RAR Classification

Variables	Total (n=622)	Q1	Q2	Q3	Q4	P-value
30-day mortality, n (%)	11 (1.77)	0 (0.00)	3 (1.86)	2 (1.32)	6 (3.85)	0.067
3-month mortality, n (%)	29 (4.66)	0 (0.00)	6 (3.73)	7 (4.61)	16 (10.26)	<0.001
6-month mortality, n (%)	34 (5.47)	1 (0.65)	6 (3.73)	7 (4.61)	20 (12.82)	<0.001
1-year mortality, n (%)	54 (9.26)	6 (4.08)	8 (5.23)	10 (7.09)	30 (21.13)	<0.001

Statistical Analysis

Continuous variables with a normal distribution are expressed as mean ± standard deviation (SD) and compared using analysis of variance (ANOVA). For skewed continuous variables, data are presented as median with interquartile range (Q1, Q3) and analyzed using the Kruskal–Wallis test. Categorical variables were summarized as frequencies and percentages (n, %) and compared using either the chi-square test or Fisher's exact test, as appropriate. A two-sided P-value <0.05 was considered statistically significant for all intergroup comparisons. Survival outcomes were evaluated using the Kaplan–Meier method, with differences between groups assessed by the Log rank test. Risk factors for postoperative mortality were first explored through univariate Cox proportional hazards regression, and variables with a P-value <0.05 were considered significant. These covariates were then entered into a backward stepwise multivariate Cox regression model to identify independent predictors of mortality. All statistical analyses were performed using R software, version 4.4.0 (2024–04-24), in conjunction with Zstats 1.0 (www.zstats.net).

Results

Baseline Characteristics

The final cohort included 622 patients who underwent hip fracture surgery, with a median follow-up of 3.6 years (interquartile range [IQR], 2.6–5.0 years), corresponding to 5349 patient-years. The median age at surgery was 81.94 years (range: 67–82 years), and 27.33% of the patients were male. Patients were divided into quartiles (Q1–Q4) according to the RAR criteria (Table 1). The cutoff values for the quartiles were <0.34 for Q1, 0.34–0.37 for Q2, 0.37–0.41 for Q3, and >0.41 for Q4.

Significant differences were observed across quartiles in age, BMI, ASA classification, and preoperative anemia (all P<0.001). Patients in Q4 were older (mean age, 83.30±5.81 years), had lower BMI (20.55 kg/m^2), and were more frequently classified as ASA class IV (10.46%). The prevalence of preoperative anemia was also highest in Q4 (81.41% compared to 55.47% overall, P<0.001). Femoral neck fracture was the predominant fracture type (58.84%), with no significant variation between groups (P=0.292). The most common comorbidities were hypertension (63.50%), cerebrovascular disease (26.53%), and diabetes (29.61%), none of which differed significantly across quartiles (all P>0.05).

When stratified by quartiles of the RAR, significant differences were observed in perioperative variables (Table 2). Internal fixation was the predominant surgical approach in Q4 (62.82%), compared with 35.3% in Q1, 41.61% in Q2, and 44.08% in Q3 (P<0.001). In contrast, hip HHA was performed more frequently in Q1–Q3 (58.17%, 57.76%, and52.63%, respectively). The use of general anesthesia increased in Q4 (35.48% vs. Q1: 22.88%, Q2: 34.16%, Q3: 26.97%, P=0.048), whereas intravertebral anesthesia decreased with rising RAR (64.5% in Q4 vs. 77.1% in Q1). Operative duration did not differ significantly between groups (P=0.16), although a higher proportion of procedures in Q4 lasted more than two hours (12.18% vs. Q1: 7.19%, Q2: 5.00%, Q3: 11.84%). Surgical delay beyond 48 hours occurred at similar rates across groups (Q4: 55.13% vs. Q1: 48.37%, Q2: 55.28%, Q3: 56.58%, P=0.468). Notably, transfusion requirements were substantially higher in Q4 (62.82% vs. Q1: 22.88%, Q2: 36.65%, Q3: 53.29%, P<0.001), indicating a strong association between elevated RAR and increased perioperative transfusion.

Association of RDW/ALB and All-Cause Mortality

The relationship between RAR and all-cause mortality was evaluated in elderly patients with hip fractures. Mortality increased progressively across RAR quartiles (Q1–Q4), as shown in Table 3. The 1-year mortality rate was 21.1% in Q4, compared with 4.08% in Q1, 5.23% in Q2, and 7.09% in Q3 (P<0.001). Similar dose–response patterns were observed at 3 months (Q4: 10.26% vs. Q1: 0.00%, P<0.001) and 6 months (Q4: 12.82% vs. Q1: 0.65%, P<0.001), indicating a strong association between elevated RAR and higher mortality risk. Kaplan–Meier survival analysis revealed a significant association between RAR and cumulative mortality in the overall cohort (Log-rank P < 0.0001, Figure 2A). Patients in the highest RAR quartile (Q4) consistently exhibited the poorest survival probability throughout the follow-up period. This association remained robust in the subgroup of non-anemic patients and anemic patients (Log-rank P < 0.0001, Figure 2B and C), where survival curves demonstrated clear stratification across RAR quartiles. Cox proportional hazards regression, stratified by anemia status and adjusted for age, ASA score, CCI, BMI, sex, and surgical delay, is summarized in Table 4. In non-anemic patients, RAR was an independent predictor of mortality, with those in Q4 having a 12.52-fold higher risk compared with Q1 (HR=12.52, 95% CI 3.18–49.24, P<0.001). In contrast, RAR was not significantly associated with mortality among anemic patients (Q4 vs. Q1: HR=1.89, 95% CI 0.83–4.3, P=0.129).

We further evaluated the predictive performance of RAR for mortality at different follow-up time points. The AUC values of RAR at 30 days, 3 months, 6 months, and 1 year post-surgery were respectively 0.704 (95% CI 0.573–0.835), 0.741 (95% CI 0.665–0.817), 0.752 (95% CI 0.672–0.831) and 0.715 (95% CI 0.639–0.791). The corresponding AUC values of RDW at these time points were 0.650 (95% CI 0.511–0.79), 0.707 (95% CI 0.623–0.792), 0.714 (95% CI 0.633–0.794) and 0.662 (95% CI 0.584–0.740). ROC curve analysis further supported the predictive utility of RAR

https://doi.org/10.2147/IJGM.S580782

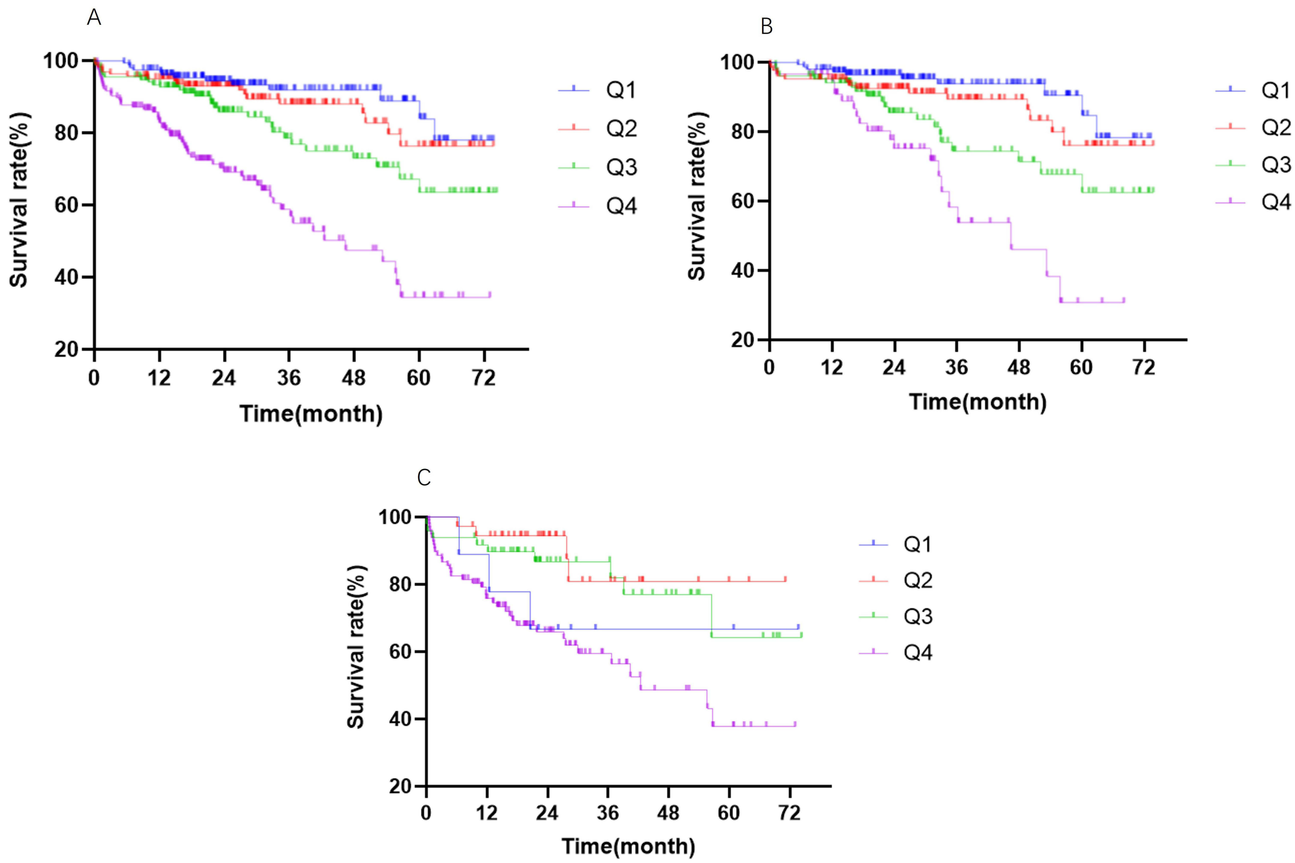

Figure 2 Kaplan–Meier survival curves according to the red blood cell distribution width-to-albumin ratio (RAR). Survival outcomes differed significantly across RAR subgroups in the overall cohort (**A**), the non-anemic group (**B**), and the anemic group (**C**) (Log rank test, P < 0.0001).

(Figure 3). Across all follow-up periods, the AUC for RAR consistently exceeded that of RDW, reflecting superior discriminative ability in identifying high-risk patients. However, the difference between RAR and RDW did not reach statistical significance (*t*-test, P=0.06).

Table 4 Hazard Ratios for Postoperative Mortality According to RAR Categories, Stratified by Anemia Status

Variables		N	HRs (95% CI)	P
	Unadjusted			
Participants with anemia	Q1	48	1.00 (Reference)	
	Q2	78	0.73 (0.28 ~ 1.90)	0.523
	Q3	92	1.16 (0.50 ~ 2.68)	0.737
	Q4	127	3.13 (1.48 ~ 6.63)	0.003
	Age, ASA, CCI, BMI, gender, and surgery delay adjusted			
	Q1	48	1.00 (Reference)	
	Q2	78	0.38 (0.13 ~ 1.07)	0.067
	Q3	92	0.63 (0.24 ~ 1.64)	0.344
	Q4	127	1.89 (0.83 ~ 4.30)	0.129

(*Continued*)

Table 4 (Continued).

Variables		N	HRs (95% CI)	P
	Unadjusted			
Participants without anemia	Q1	105	1.00 (Reference)	
	Q2	83	2.44 (0.83 ~ 7.15)	0.103
	Q3	60	5.05 (1.78 ~ 14.36)	0.002
	Q4	29	9.29 (3.17 ~ 27.24)	<0.001
	Age, ASA, CCI, BMI, gender, and surgery delay adjusted			
	Q1	105	1.00 (Reference)	
	Q2	83	2.21 (0.59 ~ 8.34)	0.241
	Q3	60	5.85 (1.78 ~ 19.18)	0.004
	Q4	29	12.52 (3.18 ~ 49.24)	<0.001

Discussion

To the best of our knowledge, this study is the first to investigate the association between the RAR and postoperative mortality in elderly patients with hip fractures. We analyzed 622 patients who underwent surgical treatment at Peking University First Hospital between 2015 and 2021, during which 59 deaths were recorded. Elevated RAR was identified as an independent predictor of postoperative mortality among patients without anemia. Receiver operating characteristic (ROC) curve analysis further demonstrated that RAR provided greater predictive accuracy than RDW alone. These findings suggest that RAR may serve as a novel biomarker for identifying elderly hip fracture patients at increased risk of mortality and could be incorporated into clinical risk assessment strategies.

Accurate risk stratification following hip fracture has been the focus of considerable investigation. Established tools such as the Nottingham Hip Fracture Score (NHFS) and the Physiological and Operative Severity Score for the Enumeration of Mortality and Morbidity (POSSUM) are widely used to estimate mortality and complication rates.[16,17] In our previous work, we developed and validated a nomogram model that identified age, CCI, and serum levels of albumin, sodium, and hemoglobin as independent predictors of postoperative mortality in elderly patients with hip fractures.[18] Consistent with these findings, a prospective study from the University Hospital of Amiens (France) reported that advanced age, surgical delay beyond 48 hours, and pre-existing medical conditions were significant predictors of one-year mortality.[19] Similarly, Chen et al showed that arrhythmias, pneumonia, heart failure, leukocytosis, and

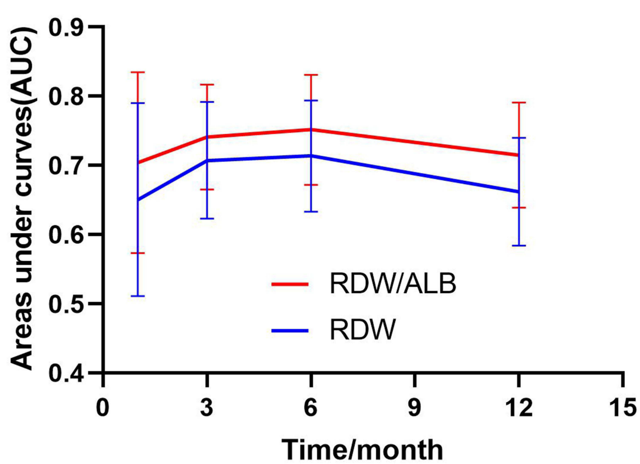

Figure 3 Time-dependent receiver operating characteristic (ROC) curves comparing the predictive performance of RDW and RAR for postoperative mortality. The area under the curve (AUC) is shown across different time points.

hypoalbuminemia were associated with increased 30-day mortality among elderly Chinese patients undergoing hip fracture surgery.[20]

The prognostic significance of integrated biomarkers is further underscored by recent large-scale epidemiological evidence. Notably, the ratio of red blood cell distribution width to albumin (RAR) has emerged as a powerful predictor of all-cause and cause-specific mortality in the general population, as demonstrated in a large cohort study by Hao et al[21] Despite these advances, no prior study has examined the prognostic role of the RAR in the setting of hip fracture. Our analysis demonstrates that RAR remained an independent predictor of postoperative mortality in non-anemic patients after adjustment for age, ASA classification, CCI, BMI, sex, and surgical delay (Q4 vs. Q1: HR=12.52, 95% CI 3.18–49.24, P<0.001). Although previous studies have shown an association between RDW alone and both short- and long-term mortality after hip fracture,[22] our results indicate that incorporating serum albumin into the index improves prognostic performance. ROC analysis confirmed that RAR offered superior discriminative ability compared with RDW alone, underscoring its potential value as a biomarker for risk stratification in elderly patients with hip fractures.

Clinical integration of RAR. The practicality of RAR lies in its derivation from routine, inexpensive blood tests, making it feasible for immediate perioperative risk assessment. To translate this finding into clinical practice, RAR could be integrated into existing risk stratification frameworks like the Nottingham Hip Fracture Score (NHFS) in several ways. First, as a continuous variable, it could be added to multivariable prediction models to enhance their discriminative performance. Second, a predefined RAR threshold (eg, >0.41, corresponding to our Q4) could serve as a simple "red flag" to identify a high-risk subgroup warranting more intensive monitoring, nutritional support, or geriatric co-management. Future studies should externally validate the additive prognostic value of RAR when combined with established clinical scores.

The biological pathways underlying the association between the RAR and mortality risk remain incompletely understood. Current evidence suggests that chronic inflammation,[23] oxidative stress,[24] and nutritional status[25] may play central roles. Inflammatory responses trigger the release of cytokines such as interleukin-6 (IL-6), which suppresses erythropoietin production and impairs the proliferation and differentiation of erythroid progenitor cells. This dysregulation leads to abnormal erythropoiesis and an increase in RDW.[26] In parallel, inflammation reduces hepatic albumin synthesis, thereby lowering serum albumin concentrations and elevating RAR.[27] Oxidative stress represents another plausible mechanism. Under pathological conditions, excessive production of reactive oxygen species (ROS) damages erythrocyte membranes, altering red blood cell morphology and promoting anisocytosis, which contributes to higher RDW.[28] Oxidative stress may also impair hepatic function, further reducing albumin synthesis and amplifying the effect of elevated RAR on adverse outcome.[29] In the present study, RAR emerged as an independent predictor of postoperative mortality in elderly non-anemic patients with hip fractures but not in those with anemia. The reasons for this discrepancy remain uncertain. It is possible that in anemic patients, other clinical factors, such as comorbid disease burden or baseline frailty, exert a stronger influence on mortality, thereby diminishing the predictive contribution of RAR. In contrast, among non-anemic patients, metabolic and inflammatory processes reflected by an elevated RAR may play a comparatively greater role in shaping postoperative outcomes.

In conclusion, this study establishes the RAR as a novel, independent, and easily obtainable predictor of postoperative mortality in non-anemic elderly patients with hip fractures. Its superiority over RDW alone underscores the clinical relevance of combining hematological and nutritional-inflammation markers. By identifying patients at the highest risk, RAR can guide more vigilant monitoring and aggressive perioperative interventions, ultimately aiming to improve outcomes for this growing patient population. However, this study has several limitations. First, it was a single-center retrospective analysis with a relatively small sample size (n=622), which may introduce selection bias and restrict the generalizability of the findings. Second, the long study period may have introduced variability in perioperative management, and unmeasured time-dependent factors could have influenced outcomes despite adjustment for known confounders. Third, as an observational study, the design allows only for the identification of associations rather than causal relationships; elevated RAR may simply reflect underlying conditions such as systemic inflammation or malnutrition. Fourth, the heterogeneity within the anemic subgroup was not fully captured, which may explain the reduced predictive value of RAR in these patients. Due to insufficient sample size, further subgroup analysis of anemic patients could not be conducted. Future investigations should include larger, multicenter prospective studies to validate these findings, incorporate inflammatory and oxidative stress markers to clarify the biological mechanisms underlying the association, and better account for patient heterogeneity to refine risk prediction.

Conclusion

This study demonstrated that RAR is an independent predictor of postoperative mortality in elderly patients with hip fractures who do not have anemia. Moreover, RAR provided stronger prognostic value than RDW alone, highlighting its potential role as a practical biomarker for risk stratification in this population.

Abbreviations

RAR, Red Cell Distribution Width to Albumin Ratio; RDW, Red blood cell distribution width; ALB, albumin; ASA, American society of anesthesiologists; AUC, area under receiver operating characteristic; CCI, Charlson comorbidity index; HR, hazard ratio; NHFS, Nottingham hip fracture score; O-POSSUM, orthopedic physiologic and operative severity score for the enumeration of mortality and morbidity; ROC, receiver operating characteristic; IL-6, interleukin-6; ROS, reactive oxygen species.

Data Sharing Statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

This retrospective chart review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. So, the study was approved by the Ethics Committee of Peking University First Hospital (NO.2021-432).

Consent for Publication

Since this study is retrospective, informed consent can be waived with the approval of the Ethics Committee at Peking University First Hospital.

Acknowledgments

The authors extend their gratitude to the doctors in the Department of Orthopedics at Peking University First Hospital for their invaluable assistance and advice during data collection. Special thanks to Tianyue Zhu, Licheng Wen, Weibing Chai, Hongzhang Lu, Jun Li, Zhenning Liu, Yilin Ye, Daojian Zhang, Xin Yang, Zhichao Meng and Hao Wu.

Funding

This study received no funding.

Disclosure

The authors report no conflicts of interest in this work.

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