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The red blood cell distribution width to albumin ratio was a potential prognostic biomarker for acute respiratory failure: a retrospective study

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Abstract

Background The association between red blood cell distribution width (RDW) to albumin ratio (RAR) and prognosis in patients with acute respiratory failure (ARF) admitted to the Intensive Care Unit (ICU) remains unclear. This retrospective cohort study aims to investigate this association.

Methods Clinical information of ARF patients was collected from the Medical Information Mart for Intensive Care IV (MIMIC-IV) version 2.0 database. The primary outcome was, in-hospital mortality and secondary outcomes included 28-day mortality, 60-day mortality, length of hospital stay, and length of ICU stay. Cox regression models and subgroup analyses were conducted to explore the relationship between RAR and mortality.

Results A total of 4547 patients with acute respiratory failure were enrolled, with 2277 in the low ratio group (RAR < 4.83) and 2270 in the high ratio group (RAR > = 4.83). Kaplan-Meier survival analysis demonstrated a significant difference in survival probability between the two groups. After adjusting for confounding factors, the Cox regression analysis showed that the high RAR ratio had a higher hazard ratio (HR) for in-hospital mortality (HR 1.22, 95% CI 1.07–1.40; $P = 0.003$), as well as for 28-day mortality and 60-day mortality. Propensity score-matched (PSM) analysis further supported the finding that high RAR was an independent risk factor for ARF.

Conclusion This study reveals that RAR is an independent risk factor for poor clinical prognosis in patients with ARF admitted to the ICU. Higher RAR levels were associated with increased in-hospital, 28-day and 60-day mortality rates.

Keywords Acute respiratory failure, Red blood cell distribution width, Albumin, RAR, Prognosis, MIMIC-IV

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Background

Respiratory failure refers to the failure of pulmonary ventilation and gas exchange function. Acute respiratory failure is characterized by hypoxia with or without hypercapnia. The respiratory system can not meet the oxygenation, ventilation, or metabolic needs of patients, resulting in acid-base disorders and life-threatening [1]. ARF is one of the most common acute organ failures in hospitals, with 784 cases occurring per 100,000 hospitalizations [2]. It is a prevalent and serious complication among hospitalized patients, with the number of cases increasing from about 100,000 instances in 2001 to nearly 1.9 million instances in 2009 [3]. ARF is the leading cause of ICU admission for patients. Once the condition progresses severely to necessitate invasive mechanical ventilation (IMV), the mortality rate for ARF reaches 34–37% [4].Although the acute physiology and chronic health evaluation (APACHE) score and sequential organ failure assessment (SOFA) have been related to the prognosis of ARF patients at present,, these scoring systems can not be used as a satisfactory prediction tool in clinical practice due to the inconvenient use of many indicators involved [5]. Therefore, there is a need for biomarkers with good predictive power and convenience to help physicians quickly identify high-risk patients.

Red cell distribution width (RDW) is a common clinical hematological marker, which is a parameter of red cell volume heterogeneity obtained by standard complete blood count. Some clinical studies have shown that RDW is associated with the prognosis of acute diseases such as cerebral infarction, sepsis, infective endocarditis, and diabetic ketoacidosis [6–8]. ARF can lead to severe hypoxemia, as well as being closely related to the inflammatory response. Hypoxia can lead to the production of hypoxia-inducible factors, which can cause increased renal and hepatic erythropoietin production. The erythropoietin not only increases the rate of formation of erythrocytes, but also increases the volume of erythrocytes leading to an increase in RDW. on the other hand, Inflammatory factors can also affect the cell membrane glycoproteins and ion channels of erythrocytes, leading to altered erythrocyte morphology. All these pathological alterations increase the heterogeneity of red blood cell volume, leading to elevated RDW. A recent study showed that RDW was significantly associated with mortality in ARF [9]. Serum albumin can reflect the systemic nutritional status and has anti-inflammatory effects by reducing oxidative stress and inhibiting endothelial cell apoptosis. Decreased serum albumin levels are usually associated with increased blood viscosity and impaired endothelial function. Albumin has been proposed as a reliable predictor of prognosis in critically ill patients [10]. Recent studies have shown that hypoalbuminemia is associated with poor prognosis in patients with ARF [11]. The RDW to albumin ratio (RAR) serves as an innovative and straightforward biomarker for assessing inflammation. Previous studies have demonstrated that RAR was originally used to assess the outcomes in patients with diabetic ketoacidosis and solid stroke [12–14]. In a study of sepsis, high RAR was found to be significantly associated with in-hospital mortality [15]. Further studies have found RAR to be a promising biomarker for assessing the prognosis of critically ill patients with sepsis [16]. A recent study has demonstrated that the RAR is associated with 60-day mortality in patients with acute respiratory distress syndrome [17]. However, it is unclear whether RAR is associated with the prognosis of ARF. Therefore, the aim of this study is to investigate the correlation between RAR in ARF patients and clinical outcomes.

Methods

Data source

We included patients diagnosed with acute respiratory failure (ARF) from the MIMIC-IV (Medical Information Mart for Intensive Care IV, version 2.0) database, which comprises extensive data from 315,460 inpatients spanning the years 2008 to 2019. we fulfilled the requirements of the Protecting Human Research Participants online course, certified by the National Institutes of Health (author certification number: 49872601). Approval for database use was obtained from the MIT Institutional Review Committee and Beth Israel Deaconess Medical Center. To safeguard patient confidentiality, all identifiable information within the database repository was removed. The study adhered to the principles outlined in the Declaration of Helsinki.

Study population

All personal information was removed to protect the privacy of patients.

Patients were included in the study if they diagnosed with acute respiratory failure at hospital admission(age > 18 year old). The data extraction codes are "acute Respiratory failure" ("51851", "51881") in the 9th edition of the International Classification of Diseases and "acute respiratory failure" or "acute respiratory failure with hypoxia" or "acute respiratory failure with hypercapnia" ("J95821", "J960", "J9601", "J9602") in the 10th edition. The exclusion criteria were as follows: (1) patients with repeated ICU admissions; (2) patients with incomplete clinical data. (3) length of hospital stay < 24 h. We included a total of 4547 patients diagnosed with acute respiratory failure from 2008 to 2019 in MIMIC-IV database.

Data extraction and outcomes

From the MIMIC-IV version 2.0 database, we extracted various data points including demographic

characteristics such as age, gender, ethnicity and weight. Vital signs recorded within 24 h of ICU admission consisted of heart rate, mean arterial pressure (MAP), SPO2 and respiratory rate. Laboratory parameters measured during the same timeframe encompassed hemoglobin, hematocrit, platelet count, anion gap, bicarbonate, chloride, glucose, white blood cell (WBC) count, creatinine, albumin, red cell distribution width (RDW), serum sodium, and serum potassium levels.Comorbidities were documented and included congestive heart failure (CHF), chronic pulmonary disease (CPD), renal failure, diabetes, malignancy, and liver disease. Additionally, data on Sequential Organ Failure Assessment (SOFA) scores, Oxford Acute Severity of Illness Scores (OASIS), acute physiology score III(APSIII); ventilator utilization, and renal replacement therapy (RRT) were recorded. The primary outcome variable of interest was in-hospital mortality, with secondary outcomes including 28-day mortality(28 days after hospital admission), 60-day mortality(60 days after hospital admission), length of hospital stay, and length of ICU stay.

Statistical analysis

The study participants were stratified into two groups based on the median value of RAR. Due to the non-normal distribution of continuous variables, they were presented as median and interquartile range (IQR), and group differences were assessed using the Mann-Whitney U test. Categorical variables were summarized as frequencies or percentages and analyzed using Chi-square or Fisher's exact test.

Survival probabilities across different RAR groups were evaluated using Kaplan-Meier (KM) curves and log-rank tests. Multivariate Cox regression models were employed to investigate the association between RAR and all-cause mortality in ARF patients. The Cox proportional hazards regressions examined the relationship between RAR and ARF. Model 1 was unadjusted, while Model II adjusted for age and gender, and Model III additionally adjusted for weight, ethnicity, hematocrit, hemoglobin, platelets, white blood cell count (WBC), anion gap, bicarbonate, chloride, creatinine, sodium, potassium, glucose, respiratory rate, heart rate, mean arterial pressure (MAP), SPO2, renal replacement therapy (RRT), ventilator use, Oxford Acute Severity of Illness Score (OASIS), Sequential Organ Failure Assessment (SOFA) score, acute physiology score III(APSIII); congestive heart failure, chronic pulmonary disease, diabetes, renal disease, malignant cancer, and liver disease.

To enhance the robustness of the results, propensity-score matching (PSM) was employed to minimize baseline differences between groups. PSM was conducted at a 1:1 ratio with a caliper width set at 0.01 of the standard deviation of the logit of the propensity score.We performed the Receiver operating characteristic (ROC) curves to assess the predictive value of RAR for in-hospital mortality of patients. Statistical analyses were performed using R software (version 4.2.2) and SPSS version 23.0 (IBM Corp, Armonk, NY, USA), with a significance threshold set at $p<0.05$.

Results

Baseline characteristics

A total of 4547 patients with acute respiratory failure were included in this study (Fig. 1). According to the RAR value, patients were divided into the high group(RAR>=4.83) and the low group(RAR<4.83). Demographic characteristics, vital signs, laboratory indicators, and details of comorbidities at baseline are shown in Table 1. ARF patients with high RAR had low levels of MAP, hemoglobin, hematocrit, and albumin, but higher heart rates, respiratory rates, RDW, SOFA scores, APSIII and OASIS scores. For patient outcomes, patients with elevated RAR had significantly higher in-hospital, 28 and 60-day mortality rates and longer lengths of hospital stay and ICU stays (all $P<0.001$). In Table S1, we compare the characteristics of surviving and non-surviving patients. Non-surviving ARF patients have lower body weight, MAP, albumin, hemoglobin, oxygen saturation, platelet levels and higher RAR, RDW, SOFA scores, OASISscores and APSIII.

Survival analysis and cox proportional-hazards regression model

The Kaplan-Meier survival curves indicated that patients in the low RAR group had significantly higher in-hospital survival rates than those in the high RAR group ($P<0.001$). In addition, similar results were observed in the 28-day and 60-day survival curves (Fig. 2). The raw model(model 1), which did not adjust for any variables, showed that the RAR ratio was associated with in-hospital mortality in ARF patients (HR:1.44; 95CI%1.29,1.62; $P<0.001$). In Model 2, sex and gender were adjusted, and the HR for the high RAR ratio was 1.48 (95CI%:1.32,1.66; $P<0.001$), compared with the low RAR ratio. In Model 3, after adjusting for age, gender, weight, ethnicity, hematocrit, hemoglobin, platelets, wbc, aniongap, bicarbote, chloride, creatinine, sodium, potassium, glucose, respiratory rate, heart rate, map, SPO2, RRT, Ventilator use, oasis, sofa, APSIII, congestive heart failure, chronic pulmory disease, diabetes, renal disease, malignant cancer, liver disease, a high RAR ratio is still an independent risk factor for ARF (HR:1.22; 95CI%1.07,1.40; $P=0.003$). A similar relationship was also observed for 28-day and 60-day mortality. (Table 2).

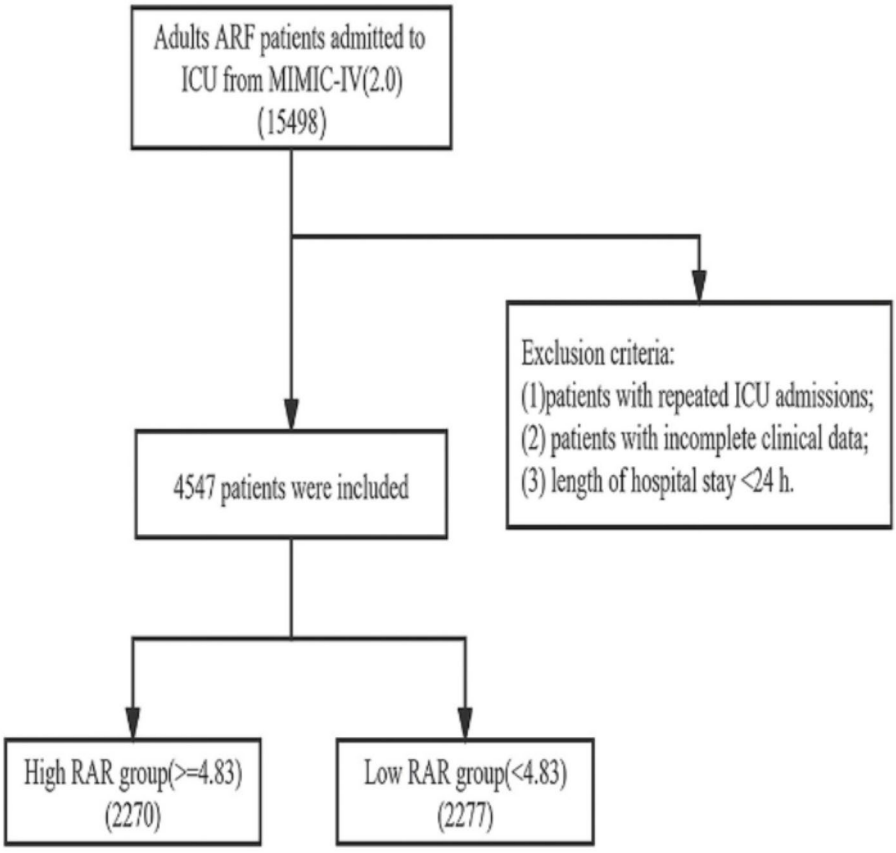

Fig. 1 The flow chart of the included population

Subgroup analyses and propensity score matching

Subgroup analyses were performed according to age, gender, congestive heart failure, chronic pulmonary disease, renal failure, liver disease, malignant cancer, diabetes, SOFA score, APSIII and OASIS score for the primary outcomes (Table 3). There was an interaction between APSIII and RAR on in-hospital mortality (p for interaction < 0.05). No significant interactions were observed in other subgroups.

The relationship between the RAR ratio and ARF was further verified by propensity score matching(PSM) analysis. After PSM, a total of 2242 patients were included in the matched cohort. the two groups were balanced on Baseline characteristics. (Table 4). Results of COX regression analysis showed that a high RAR ratio was independently correlated to in-hospital mortality (HR:1.26; 95CI%1.07,1.48; $P=0.005$), 28-day mortality (HR:1.22; 95CI%1.05,1.42; $P=0.009$) and 60-day mortality (HR:1.27; 95CI%1.10,1.45; $P=0.001$).

ROC curve analysis

The ROC curve of in-hospital mortality rate generated using indicator variables (RAR, APS III, OASIS, SOFA) is plotted in Fig. 3. The AUC for RAR was 0.734, which was significantly higher than the APSIII, OASIS and SOFA scores (0.668; 0.631;0.673;$P<0.001$, Fig. 3).

Discussion

Acute respiratory failure is one of the most common complications of hospitalization and ICU, and usually leads to high mortality [18]. Timely identification and treatment of ARF can shorter the length of ICU, and hospital stay, and improve survival. To this day, the APACHE II score and SOFA score are commonly used in the ICU to predict the prognosis of the disease [19]. However, it also has limitations in predicting the progression and disease severity, because it involves subjective measurements and complicated calculations that lead to ambiguities. Hence, it is necessary to find a new predictor with simple calculations and objectively for ARF.

RDW originally is an indicator of anemia detection, mainly reflecting the heterogeneity of peripheral red

Table 1 Baseline characteristics of the original population

Characteristics	RAR < 4.83	RAR > = 4.83	*P*
N	2277	2270	
Age (year)	65.96(52.88,77.70)	65.33(54.83 76.51)	0.85
Gender, n			
Female	935	1025	0.005
Male	1342	1245	
Ethnicity			
White	1429	1471	0.48
Black	222	199	
Asian	69	69	
Others	557	531	
Weight (kg)	80.20(67.11,96.93)	79.13(65.40,97.30)	0.09
Vital signs			
HR(beats/min)	86.46(75.18,98.76)	92.48(98.76,105.54)	< 0.001
MAP(mmHg)	78.58(71.92,86.47)	73.99(68.56,80.55)	< 0.001
Respiratory rate (breaths/min)	20.05(17.53,23.00)	20.91(18.06,24.26)	< 0.001
SPO2(%)	96.96(95.31,98.60)	96.93(95.18,98.43)	0.05
Laboratory parameters			
RAR	4.00(3.58,4.40)	6.00(5.35,7.13)	< 0.001
RDW(%)	14.00(13.28,14.81)	15.90(14.66,17.55)	< 0.001
Albumin(g/dL)	3.60(3.30,3.90)	2.60(2.30,2.95)	< 0.001
WBC count(10^9 /L)	11.90(8.78,15.85)	12.35(8.40,17.86)	0.04
Hemoglobin(g/dL)	11.75(10.25,13.20)	9.65(8.45,11.10)	< 0.001
Hematocrit(%)	35.65(31.25,39.88)	29.65(26.25,34.05)	< 0.001
Platelet(10^9 /L)	202.50(150.00,260.25)	164.50(99.50,259.13)	< 0.001
Anion gap(mg/dl)	15.50(13.50,18.00)	15.50(12.50,18.50)	0.19
Bicarbonate(mg/dl)	22.50(19.5,25.5)	21.00(17.5,24.0)	< 0.001
Chloride(mmol/L)	103.50(99.50,107.00)	104.00(99.50,108.50)	< 0.001
Glucose(mmol/L)	141.00(116.00,185.50)	133.00(108.50,175.50)	< 0.001
Creatinine (mg/dl)	1.10(0.80,1.70)	1.30(0.85,2.30)	< 0.001
Sodium(mg/dl)	139.00(136.50,141.50)	138.50(135.00,141.50)	< 0.001
Potassium(mg/dl)	4.20(3.85,4.65)	4.20(3.80,4.75)	0.26
Severity of illness			
SOFA score	7.00(4.00,10.00)	9.00(6.00,13.00)	< 0.001
OASIS score	37.00(31.00,44.00)	41.00(35.00,48.00)	< 0.001
APSIII	55(39.76)	71(53.96)	< 0.001
Comorbidities			
CHF(n)	794	754	0.24
CPD(n)	695	671	0.48
Renal failure(n)	487	579	0.001
Liver disease(n)	349	712	< 0.001
Diabetes(n)	700	667	0.32
Malignant cancer(n)	250	466	< 0.001
Treatment			
Ventilator use(n)	1445	1510	0.03
RRT use(n)	130	255	< 0.001
Mortality			
In-hospital mortality(n)	457	799	< 0.001
28-day mortality(n)	534	831	< 0.001
60-day mortality(n)	626	998	< 0.001
Los ICU(day)	4.06(1.99,8.62)	4.97(2.45,9.77)	< 0.001
Los hospital (day)	9.82(5.58,17.41)	13.10(7.29,22.24)	< 0.001

HR: heart rate; MAP: mean arterial pressure; RDW: red cell distribution width; WBC: white blood cell; CHF: congestive heart failure; CPD: chronic pulmonary disease; RRT: renal replacement therapy; OASIS: Oxford Acute Severity of Illness, SOFA: Sequential Organ Failure Assessment, APSIII: Acute Physiology Score III.

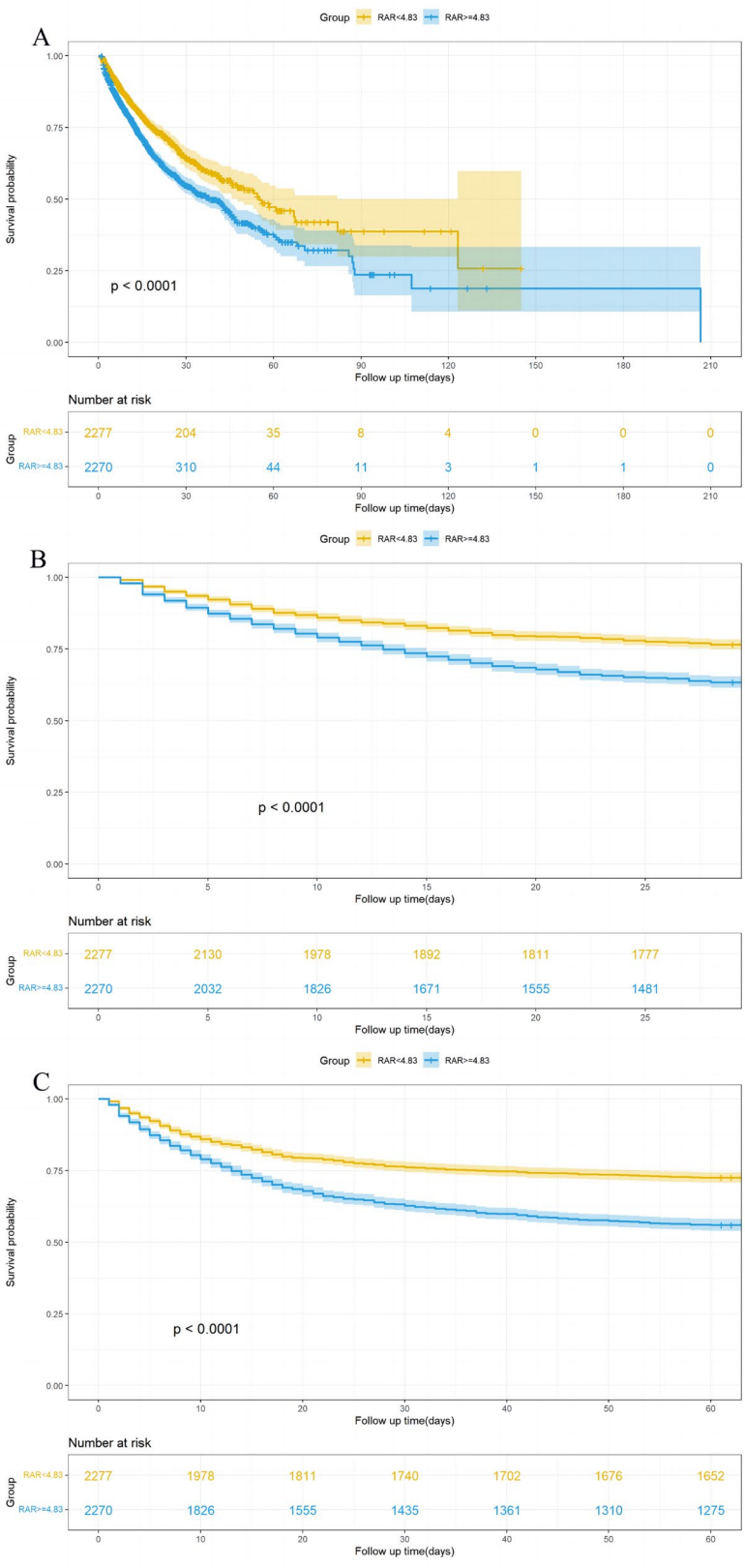

Fig. 2 (**A**) Kaplan Meier curve of In-hospital mortality in two groups of ARF patients. (**B**) Kaplan Meier curve of 28 day mortality in two groups of ARF patients. (**C**) Kaplan Meier curve of 60 day mortality in two groups of ARF patients

Table 2 Results of Cox proportional hazard models

Outcomes	Model 1		Model 2		Model 3	
In-hospital mortality	HR(95% CIs)	*P* value	HR(95% CIs)	*P* value	HR(95% CIs)	*P* value
RAR < 4.83	Reference		Reference		Reference	
RAR > = 4.83	1.44(1.29,1.62)	< 0.001	1.48(1.32,1.66)	< 0.001	1.22(1.07,1.40)	0.003
p for trend		< 0.001		< 0.001		0.003
28-day mortality						
RAR < 4.83	Reference		Reference		Reference	
RAR > = 4.83	1.68(1.52,1.88)	< 0.001	1.71(1.53,1.90)	< 0.001	1.16(1.02,1.32)	0.02
p for trend		< 0.001		< 0.001		0.02
60-day mortality						
RAR < 4.83	Reference		Reference		Reference	
RAR > = 4.83	1.77(1.60,1.96)	< 0.001	1.80(1.62,1.98)	< 0.001	1.23(1.09,1.38)	0.001
p for trend		< 0.001		< 0.001		0.001

Model1 covariates were adjusted for nothing

Model2 covariates were adjusted for age and gender.

Model3covariates were adjusted for age, gender, weight, ethnicity, hematocrit, hemoglobin, platelets, wbc, aniongap, bicarbote, chloride, creatinine, sodium, potassium, glucose, respiratory rate, heart rate, map, SPO2,RRT, Ventilator use, oasis, sofa, APSIII, congestive heart failure, chronic pulmory disease, diabetes, renal disease, malignant cancer, liver disease.

blood cell size. In recent years, many studies have shown the significant clinical value of RDW in multiple diseases. For example, several articles have reported that RDW is closely related to the disease severity or prognosis of patients with heart failure, pulmonary embolism and inflammatory bowel disease [20–22]. In addition, research showed that high RDW is associated with poor neurological outcome among cardiac arrest survivors [23]. In clinical, ARF is often accompanied by inflammation. Many studies found that systemic inflammatory reactions and cytokines released can affect the hematopoietic function of bone marrow, iron metabolism in red blood cells, and maturation of red blood cells, leading to an increase in RDW [24]. In a Korean study [25], the RDW at the onset of bacteremia was identified as an independent predictor of mortality in patients with gram-negative bacteremia. Additionally, RDW measured at 72 h post-admission was also found to predict all-cause mortality in these patients. In another study focused on community-acquired pneumonia (CAP) [26], higher RDW levels were associated with increased 30-day mortality and longer hospital stays among hospitalized CAP patients. Hu et al. conducted a prospective study examining the association between RDW and one-year mortality in 442 patients with acute exacerbation of chronic obstructive pulmonary disease (COPD) [27]. They found that RDW remained independently associated with mortality even after adjusting for factors such as age, body mass index, %FEV1 (forced expiratory volume in 1 s), coronary heart disease, heart failure, renal dysfunction, blood pH, PO2 (partial pressure of oxygen), and PCO2 (partial pressure of carbon dioxide). As we known, severe COVID-19 must be accompanied by ARF. Research has shown that RDW may predict mortality in severe COVID-19 pneumonia and reflects the hyperinflammatory background [28]. Morever, Zhang et al showed that there is an association between the RDW and survival time of 3-year follow-up, particularly a high RDW on admission was associated with an increased risk of long-term mortality in patients with ARF[9].

Serum ALB as a negative acute phase reactant, can be used to evaluate the inflammatory process. Previous studies have confirmed that inflammatory reactions can affect the synthesis of ALB, leading to a decrease in serum ALB levels [29]. In a study involving 3463 hospitalized patients with Community-Acquired Pneumonia (CAP) [30], the median serum albumin level upon admission was 3.1 g/dL. Lower levels of albumin were found to be significantly associated with both longer hospital stays and higher 30-day mortality rates. Low serum levels of albumin, along with inappropriate antibiotic therapy, have been found to be associated with increased 30-day mortality in patients with vancomycin-resistant Enterococcus bacteremia [31]. In patients with intra-abdominal infections, host-related factors predominantly determine the type, extent, and source of infection, with low serum albumin being one of the few identified risk factors for mortality [32]. Besides, ALB reflects the level of visceral protein and is one of the important indicators of malnutrition. Malnutrition can weaken the strength of respiratory muscles, reduce the endurance of respiratory muscles, damage the function of T lymphocytes, damage the immune function of the body, further aggravate respiratory failure, and increase mortality [11, 33]. Most studies have found that severe patients often have decreased serum ALB levels, and hypoproteinemia seriously damages the organ structure and function of patients [34]. For example, Chen et al. showed that lowest albumin level was a risk factor of Intensive Care Unit-Acquired Weakness in ECMO population [35]. Moreover, the

Table 3 Results from subgroup analysis showing the relationship between in-hospital all-cause mortality and RAR

	N	RAR		*P* value	*P*-interaction
		< 4.83	>=4.83		
Gender					0.53
Male	2587	1	1.06(0.78,1.45)	0.72	
Female	1960	1	1.23(0.94,1.62)	0.13	
Age					0.89
>=60	2852	1	1.18(0.93,1.49)	0.16	
<60	1695	1	0.98(0.65,1.47)	0.92	
SOFA score					0.06
< 8	2163	1	1.11(0.77,1.60)	0.59	
>=8	2384	1	1.09(1.92,1.27)	0.32	
OASIS score					0.09
< 39	2177	1	1.29(1.01,1.64)	0.04	
>=39	2370	1	1.12(0.95,1.32)	0.17	
APSIII					< 0.001
>=67	2074	1	1.18(1.00,1.39)	0.05	
< 67	2473	1	1.16(0.91,1.47)	0.23	
CHF					0.36
no	2999	1	1.10(0.93,1.29)	0.27	
yes	1548	1	1.41(1.12,1.78)	0.004	
CPD					0.69
no	3181	1	1.20(1.02,1.40)	0.03	
yes	1366	1	1.24(0.97,1.59)	0.09	
Renal failure					0.83
no	3481	1	1.09(0.93,1.28)	0.27	
yes	1066	1	1.56(1.19,2.04)	0.001	
Liver disease					0.06
no	3486	1	1.27(1.08,1.49)	0.004	
yes	1061	1	1.15(0.57,1.23)	0.33	
Malignant cancer					0.09
no	3831	1	1.08(1.01,1.25)	0.15	
yes	716	1	1.21(1.29,1.76)	0.01	
Diabetes					0.53
no	3180	1	1.25(0.79,1.23)	0.17	
yes	1367	1	1.24(1.14,1.59)	0.01	

CHF: congestive heart failure; CPD: chronic pulmonary disease; RRT: renal replacement therapy; OASIS: Oxford Acute Severity of Illness, SOFA: Sequential Organ Failure Assessment, APSIII: Acute Physiology Score III.

HRs (95% CIs) were derived from Cox proportional hazards regression models. Each stratification adjusted for all the factors of model 3 in the Multivariable cox regression, except for the stratification factor itself.

degree of decrease is associated with the prognosis of the condition [36]. Research showed that albumin levels were associated with the development and progression of acute respiratory distress syndrome [37]. As we know, patients with respiratory failure often received mechanical ventilation and the demand for nutrition is increased. Moreover, some underlying diseases including fever, stress response, infection, etc. will further aggravate the energy loss. Both reasons can further aggravate respiratory failure and increase mortality. Although the above studies all suggest that RDW and ALB had a predictive value for respiratory failure, is it more predictive to combine both indexes for ARF? Previous studies have shown that RAR can predict the prognosis of heart failure, acute myocardial infarction, and diabetic retinopathy [13, 38, 39]. Acute respiratory distress syndrome is non-cardiogenic pulmonary edema induced by lung injury caused by inflammation, which results in fatal respiratory failure. Yoo et al. found that RAR was independently associated with 60-day mortality in patients with acute respiratory distress syndrome [17]. In our study, we found that in patients with ARF, elevated RAR was significantly associated with 28 days, 60 days, in-hospital mortality, and length of hospital stay. After PSM, the cox proportional-hazards regression model showed that RAR had good predictive power for 28 days, 60 days and in-hospital mortality in patients with ARF. As far as we know, this is the first report describing the relationship between the RAR and ARF and show RAR can be used as a prognostic factor for patients with ARF. Compared with the APACHE II score and SOFA score, RAR is simpler, faster, cheaper, and more convenient.

However, our study has some limitations. First, as a retrospective cohort study, there are still some unmeasured variables that may affect our results. we used the ICD codes to screen patients with ARF in MIMIC database, but the ICD code validity of the database is not clear. so our study is subject to misclassification bias.Second, we measured only the RDW and ALB levels of patients upon admission, without investigating their trends over time, which could have provided more detailed insights. Third, some variables in the MIMIC-IV database had too many missing values, which may have an impact on the study results.

Conclusions

We report that RAR is an independent prognostic indicator for patients with ARF and is associated with a poor clinical prognosis. The higher the RAR, the higher the in-hospital, 28 and 60-day mortality. The RAR is a promising biomarker that is easy to obtain and predicts mortality in ARF.

Table 4 Characteristics of the study population after propensity score matching

	RAR < 4.83	RAR > = 4.83	*P*	Standardized mean difference(%)
N	1121	1121		
Age(year)	66.78(53.96,78.81)	65.82(55.74,77.16)	0.41	0.06
Gender				
Female	514	510	0.90	0.03
male	607	611		
Ethnicity				
White	719	724	0.98	0.001
Black	106	99		
Asian	37	37		
Others	259	261		
Weight (kg)	80.00(66.68,96.90)	78.80(65.00,97.78)	0.23	0.005
Vital signs				
HR(beats/min)	89.70(77.61,101.93)	89.63(77.23,102.53)	0.65	0.03
MAP(mmHg)	75.84(69.96,84.75)	75.77(70.10,82.67)	0.89	0.04
Respiratory rate (breaths/min)	20.66(17.92,23.72)	20.57(17.74,23.51)	0.33	0.03
SPO2%	96.80(95.14,98.52)	96.96(95.27,98.52)	0.49	0.02
Laboratory parameters				
WBC count(10^9 /L)	11.90(8.40,15.85)	12.35(8.65,17.23)	0.06	0.04
Hemoglobin(g/dL)	10.60(9.35,11.90)	10.45(9.25,11.90)	0.33	0.016
Hematocrit(%)	32.60(28.50,36.40)	32.00(28.25,36.30)	0.17	0.015
Platelet(10^9 /L)	194.50(135.75,259.00)	181.00(118.25,266.00)	0.05	0.08
Anion gap(mg/dl)	15.50(13.00,18.00)	15.50(13.00,19.00)	0.73	0.09
Bicarbonate(mg/dl)	21.50(19.00,25.00)	21.50(18.50,25.00)	0.28	0.05
Chloride(mmol/L)	104.00(99.50,107.50)	103.50(99.00,108.50)	0.82	0.005
Glucose(mmol/L)	140.00(114.00,185.75)	135.00(110.50,181.25)	0.06	0.004
Creatinine (mg/dl)	1.25(0.85,2.00)	1.20(0.80,2.20)	0.87	0.04
Sodium(mg/dl)	138.50(135.50,141.00)	138.50(135.00,141.50)	0.80	0.02
Potassium(mg/dl)	4.25(3.85,4.76)	4.25(3.80,4.80)	0.84	0.03
Severity of illness				
SOFA score	8(5,11)	8(5,11)	0.71	0.07
OASIS	39.00(33,46)	39.00(33,45)	0.64	0.02
APSIII	64(46,87)	64(47,85)	0.74	0.06
Comorbidities				
CHF(n)	424	408	0.51	0.05
CPD(n)	361	363	0.96	0.009
Renal failure(n)	298	294	0.89	0.002
Liver disease(n)	256	260	0.88	0.04
Diabetes(n)	365	353	0.62	0.02
Malignant cancer(n)	171	194	0.21	0.01
Treatment				
Ventilator use(n)	704	713	0.73	0.02
RRT use(n)	84	90	0.69	0.03
Mortality				
28-day mortality(n)	311	367	0.01	
60-day mortality(n)	363	438	0.001	
In-hospital mortality(n)	277	336	0.006	
Los ICU stay(day)	4.58(2.25,9.50)	4.32(2.24,8.80)	0.17	
Los hospital (day)	10.97(6.39,18.21)	12.10(7.14,20.72)	0.003	

HR: heart rate; MAP: mean arterial pressure; RDW: red cell distribution width; WBC: white blood cell; CHF: congestive heart failure; CPD: chronic pulmonary disease; RRT: renal replacement therapy; OASIS: Oxford Acute Severity of Illness, SOFA: Sequential Organ Failure Assessment, APSIII: Acute Physiology Score III.

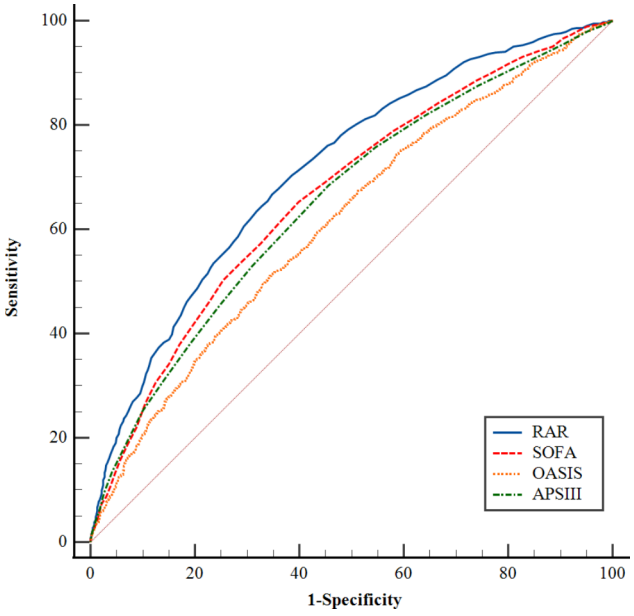

Fig. 3 ROC analyses of predictors of RAR for in-hospital mortality in ARF patients, which were compared with APS III, OASIS and SOFA

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12911-024-02639-4.

Supplementary Material 1

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Author contributions
QH and CL designed the study. SH, JX, and HL collected and analyzed the data. QH and SH wrote the paper. QH and SH analyzed and interpreted the result. All authors read and approved the final manuscript.

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Data availability
Publicly available datasets were analyzed in this study. This data can be found here: https://physionet.org/content/mimiciv/2.0/.

Declarations

Ethics approval and consent to participate
The research involving human participants underwent review and approval by the Institutional Review Board of the Massachusetts Institute of Technology and Beth Israel Deaconess Medical Center. Written informed consent for participation was not deemed necessary for this study, aligning with national legislation and institutional requirements.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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