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The relationship between hemoglobin-to-red cell distribution width (RDW) ratio (HRR) and mortality in stroke patients

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Abstract. – OBJECTIVE: In recent years, many studies have shown that hemoglobin to red cell distribution width ratio (HRR), which is the ratio of hemoglobin (Hb) to red cell distribution width (RDW), is associated with inflammation. Inflammation is linked to both the development of stroke and the severe effects that follow. Therefore, the relationship between the HRR and mortality in patients with stroke was investigated in our study.

PATIENTS AND METHODS: 127 stroke patients who visited the emergency department between March 1, 2023, and June 1, 2023, were retrospectively evaluated. The National Institutes of Health Stroke Scale (NIHSS) was used to measure stroke severity. All stroke patients were divided into four groups: patients with atrial fibrillation (AF), those without AF, and those with low and high HRR. HRR levels were compared between patients with and without AF. The relationship between HRR and mortality was also analyzed.

RESULTS: HRR levels were found to be significantly lower in patients with AF compared to those without AF ($p<0.05$ for all). NIHSS, requirement for mechanical ventilation, and mortality rate were significantly higher in the low HRR (HRR≤0.795) group compared to the high HRR group (HRR>0.795) ($p<0.05$ for all). HRR outperformed Hb and RDW alone in predicting mortality (AUC; 0.975, 0.952, 0.911, respectively). Additionally, a significant positive correlation was found between HRR levels and NIHSS ($p<0.001$).

CONCLUSIONS: Low HRR measured on admission is a useful marker for predicting mortality and determining the severity of stroke.

Key Words:
Hemoglobin-to-red cell distribution width ratio, Stroke, Atrial fibrillation, Mortality, Prognosis, NIHSS.

Introduction

Stroke, which is one of the leading causes of disability and mortality, has emerged as an important worldwide problem. The most extensive type of arrhythmia is atrial fibrillation (AF), which is the most common cause of stroke and systemic embolism. The incidence of stroke is five times higher in patients with AF, and these patients have longer hospital stays, greater recurrence rates, and higher mortality[1].

Red cell distribution width (RDW), which measures changes in the volume and size of circulating erythrocytes, is a potential indicator associated with endothelial dysfunction, oxidative stress, and inflammatory conditions[2]. Studies[3-5] have demonstrated that a high RDW in AF and stroke patients predicts negative outcomes and mortality. Hemoglobin (Hb), the part of the complete blood count (CBC), is linked to nutritional status and immune response[6]. A high Hb level may raise the risk of AF and stroke. Furthermore, decreased Hb levels may expand infarct volume and enhance the infarct growth rate[7,8].

Previous cancer studies[9,10] have proven that the hemoglobin-to-red blood cell distribution width ratio (HRR), calculated by dividing Hb by RDW, is related to inflammation. Qin et al[11] identified a negative relationship between all-cause mortality and HRR values in a study of ischemic stroke patients with AF alone. However, no other published study on how HRR, a new marker, predicts the prognosis of all stroke patients with and without AF has been found. As a result, we studied the connection of HRR with mortality and illness severity in all ischemic stroke patients in our research.

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Patients and Methods

Study Design and Patient Population

Consecutive patients diagnosed with acute stroke based on their history, clinical examination, and neuro-radiological examinations and admitted to the emergency department (ED) of a training and research hospital between 1st March 2022 and 1st June 2023 were retrospectively evaluated. We included patients over the age of 18, regardless of gender, whose complete clinical and laboratory information was accessible *via* the hospital registration system, and whose acute stroke diagnosis was confirmed according to current guidelines[12,13].

The Glasgow Coma Scale (GCS), National Institutes of Health Stroke Scale (NIHSS), and CHA2DS2-VASc scores (only for patients with AF) at presentation to the ED were calculated. Patient grouping according to risk scores was as follows:

1. According to NIHSS: mild (NIHSS ≤4), moderate (NIHSS, 5-15), moderate to severe (NIHSS, 16-20), or severe (NIHSS ≥21)[13].
2. According to the CHA2DS2-VASc score: low risk ≤2 points, moderate risk 3-4 points, and high risk ≥5 points[14].
3. According to GCS: mild (GCS ≥13), moderate (GCS 9-12), and severe (GCS ≤8)[15].

Blood samples for routine hematological and biochemical analysis and ECG were obtained on admission to the ED. To confirm the diagnosis of acute stroke, non-contrast brain computerized tomography (CT) and diffusion-weighted magnetic resonance imaging (DWI) were performed, and the results were evaluated by a radiologist. Furthermore, the department in which the patients were admitted [neurology ward/intensive care unit (ICU)], ECG Holter findings, the need for mechanical ventilation (MV), length of stay in ICU (LOS-ICU), length of stay in hospital (LOSH), and outcomes in the admitted department (discharge/death) were followed *via* the hospital registration system and epicrisis of patients. Mortality evaluation was based on in-hospital mortality. NIH Stroke Scale (NIHSS Score) Calculator was utilized to measure stroke severity *via* Medhesap (https://www.medhesap.com/nih-inme-skalasi-nihss-skoru-hesaplama/).

Exclusions comprise patients under 18, those recommended for acute thrombolytic therapy or interventional thrombectomy, pregnant women, patients with acute/chronic hematologic disease history, those with cancers, active infections, immunosuppressed patients, and individuals whose data was unavailable in the electronic registry system. HRR is calculated by dividing Hb (g/dL) by RDW-CV (%). The levels of Hb, RDW-CV, and HRR were compared between the stroke patients with and without AF. In addition, all stroke patients (including those with and without AF) were classified into high and low HRR patient groups based on their HRR cut-off value. The relationship between HRR and mortality was also analyzed. The study was approved by Necmettin Erbakan University Faculty of Medicine Local Ethics Committee (date: September 15, 2023, and number: 2023/4527[15662]).

Hematologic and Biochemical Analysis

The values of white blood cell (WBC), Hb, platelet (PLT), RDW-CV, fibrinogen, Troponin I, ferritin, D-dimer, and C-reactive protein (CRP) were measured from blood samples collected upon the patient's admission to the ED. CBC was conducted using the Mindray auto hematology analyzer BC-6800 (Shenzhen, China). Biochemical parameters were determined using the Mindray chemistry analyzer BS-2000M (Shenzhen, China).

Statistical Analysis

Numerical parameters were presented as median (min-max) or mean±SD, while categorical variables were given as frequency and percentage (%). The Kolmogorov-Smirnov test, histogram analyses, and skewness/kurtosis data were utilized to evaluate the conformity of numerical variables to a normal distribution. Levene's test was employed to examine the equality of variances across groups for numerical parameters. An independent *t*-test was employed for the comparison of two independent groups for parameters exhibiting normal distribution. For parameters not conforming to the normal distribution, the Mann-Whitney U test was employed. The profiles of effects on mortality were examined using logistic regression analysis. Variables potentially associated with mortality were further explored *via* Receiver Operating Characteristic (ROC) analysis, and diagnostic/predictive data were presented. Correlations were analyzed through Spearman's two-tailed correlation analysis. In this study, the Type-I error (alpha) was set at 0.05 (5%), and $p<0.05$ was regarded as

statistically significant. Analyses were conducted using the SPSS 21.0 program (IBM Corp., Armonk, NY, USA).

Results

Table I shows the comparison of the demographic, laboratory, and clinical findings of stroke patients with and without AF. Age, D-dimer, NIHSS, atrial extrasystole (AES), requirement for MV support, and mortality rate were significantly higher in patients with AF compared to those without AF, but HRR, Hb, and GCS were significantly lower (p<0.05 for all).

Table II shows the general features of all stroke patients (with and without AF) according to HRR groups. While age, RDW, troponin I, D-dimer, CRP, Fibrinogen, Ferritin, CHA2DS2-VASc Score, NIHSS, requirement for MV support, and mortality rate were significantly higher in the low HRR (HRR≤0.795) group, Hb, GCS, AF, normal sinus rhythm (NSR), and male gender ratio exhibited a noticeable decrease (p<0.05 for all).

The logistic regression analysis revealed that RDW-CV, Hb, HRR, CHA2DS2-VASc, NIHSS, GCS, and age were risk factors for mortality (p<0.001 for all) (Table III).

Table IV shows the ROC analysis of RDW-CV, Hb, HRR, CHA2DS2-VASc, NIHSS, and GCS in predicting mortality. When the GCS cut-off was <9, it had the best predictive ability of any risk score, with 94.7% sensitivity, 99.1% specificity, and an AUC value of 0.990 (p<0.001). Despite

Table I. Comparison of demographic, clinical and laboratory findings of AF and non-AF patients.

Variables	Non-AF patients (n=48, 37.8%)	AF patients (n=79, 62.2%)	p-value
Mean (± SD)			
Age, years	67.65 ± 15.64	74.34 ± 14.16	**0.014***
RDW-CV, (%)	13.98 ± 1.03	14.03 ± 1.45	0.807*
WBC, (10^3/mL)	8.44 ± 2.24	8.37 ± 1.89	0.845*
HRR, (g/dL/%)	1 ± 0.18	0.91 ± 0.21	**0.013***
Hb, (g/dL)	13.88 ± 2.03	12.52 ± 2.3	**0.001***
Median (IQR)			
PLT, (10^3/mL)	232.5 (152-346)	224 (152-397)	0.895**
Troponin I, (ng/ml)	3.5 (0.1-60)	5.59 (0.1-25,000)	0.138**
D-dimer, (µg/mL)	826.5 (190-19,270)	916 (200-35,200)	**0.042****
CRP, (mg/L)	5.12 (3.19-32.6)	6.4 (3.19-52.7)	0.165**
Fibrinojen, (g/L)	3.25 (1.99-6.16)	3.69 (1.92-7.02)	0.054**
Ferritin, (µg/L)	146.5 (8.4-323)	172 (73-1,650)	0.120**
CHA2DS2-VASc Score	4 (1-8)	5 (1-8)	0.298**
NIHSS	6 (0-32)	8 (0-32)	**0.008****
GCS	14.5 (3-15)	13 (3-15)	**0.002****
AES	77 (0-4,202)	456 (0-4,122)	**< 0.001****
VES	37.5 (0-4,827)	112 (0-2,287)	0.172**
LOSH, day	5 (1-36)	6 (1-27)	0.483**
LOS-ICU, day	1 (0-33)	2 (0-26)	0.093**
Gender			
Male, n (%)	28 (38.89%)	44 (61.11%)	0.771***
Female, n (%)	20 (36.36%)	35 (63.64%)	
MV support, n (%)			
Yes	2 (10.53%)	17 (89.47%)	**0.008****
No	46 (42.59%)	62 (57.41%)	
Hospitalization			
Neurology ICU	26 (32.5%)	54 (67.5%)	0.108***
Neurology service	22 (46.81%)	25 (53.19%)	
In-hospital mortality			
Yes	2 (10.53%)	17 (89.47%)	**0.008****
No	46 (42.59%)	62 (57.41%)	

*Independent *t*-test, **Mann-Whitney U test, ***Pearson's Chi-squared test, AF: Atrial fibrillation, RDW: red cell distribution width, WBC: white blood cell, HRR: hemoglobin-to-red cell distribution width ratio, Hb: hemoglobin, PLT: platelet, CRP: C-reactive protein, NIHSS: National Institutes of Health Stroke Scale, GCS: Glasgow Coma Scale, AES: atrial extrasystole, VES: ventricular extrasystole, MV: mechanical ventilation, LOSH: Length of stay in hospital, LOS-ICU: Length of stay in ICU, ICU: intensive care unit.

Table II. Characteristics of all patients according to HRR groups.

Variables	Low group† (HRR ≤ 0.795) (n = 26, 20.5%)	High group† (HRR > 0.795) (n = 101, 79.5%)	*p*-value
Mean (± SD)			
Age, years	83.77 ± 8.07	68.73 ± 14.89	**< 0.001***
RDW-CV, (%)	15.68 ± 1.17	13.58 ± 0.95	**< 0.001***
WBC, (10^3/mL)	7.85 ± 1.81	8.54 ± 2.06	0.12*
Hb, (g/dL)	9.85 ± 1.70	13.85 ± 1.61	**< 0.001***
Median (IQR)			
PLT, (10^3/mL)	219.5 (152-376)	234 (152-397)	0.678**
Troponin I, (ng/ml)	16.39 (2.5-25,000)	2.51 (0.1-25,000)	**< 0.001****
D-dimer, (µg/mL)	3,040 (340-35,200)	840 (190-35,200)	**< 0.001****
CRP, (mg/L)	8.74 (3.19-52.7)	5.03 (3.19-36.7)	**0.027****
Fibrinojen, (g/L)	4.05 (2.53-5.22)	3.19 (1.92-7.02)	**< 0.001****
Ferritin, (µg/L)	199 (8.4-1,650)	143 (20-323)	**0.001****
CHA2DS2-VASc Score	6.5 (2-8)	3 (1-8)	**< 0.001****
NIHSS	17 (0-32)	7 (0-29)	**0.03****
GCS	5 (3-15)	14 (4-15)	**< 0.001****
AES	340.5 (0-2,858)	246 (0-4,202)	0.617**
VES	131 (0-660)	75 (0-4,827)	0.186**
LOSH, day	5 (1-24)	6 (1-36)	0.071**
LOS-ICU, day	3 (0-24)	1 (0-33)	0.074**
Gender			
Male, n (%)	8 (11.11%)	64 (88.89%)	**0.003*****
Female, n (%)	18 (32.73%)	37 (67.27%)	
AF, n (%)			
Yes	21 (26.6%)	58 (73.4%)	**0.029*****
No	5 (10.4%)	43 (89.6%)	
NSR, n (%)			
Yes	5 (10.4%)	43 (89.6%)	**0.029*****
No	21 (26.6%)	58 (73.4%)	
MV support, n (%)			
Yes	18 (94.74%)	1 (5.26%)	**< 0.001******
No	8 (7.41%)	100 (92.59%)	
Hospitalization			
Neurology ICU	20 (25%)	60 (75%)	0.099***
Neurology service	6 (12.77%)	41 (87.23%)	
In-hospital mortality			
Yes	18 (94.74%)	1 (5.26%)	**< 0.001******
No	8 (7.4%)	100 (92.6%)	

†ROC analysis for performed to determine the cut-off value for HRR, *Independent *t*-test, **Mann-Whitney U test, ***Pearson's Chi-squared test,****Fisher's exact test, AF: Atrial fibrillation, RDW: red cell distribution width, WBC: white blood cell, HRR: hemoglobin-to-red cell distribution width ratio, Hb: hemoglobin, PLT: platelet, CRP: C-reactive protein, NIHSS: National Institutes of Health Stroke Scale, GCS: Glasgow Coma Scale, AES: atrial extrasystole, VES: ventricular extrasystole, MV: mechanical ventilation, LOSH: Length of stay in hospital, LOS-ICU: Length of stay in ICU, ICU: intensive care unit.

the fact that the HRR cut-off value was 0.795, it had the greatest predictive value across laboratory measurements, with 94.7% sensitivity, 92.6% specificity, and 0.975 AUC value (p<0.001). Furthermore, HRR outperformed Hb and RDW alone in predicting mortality (AUC 0.975, 0.952, 0.911, respectively).

Figure 1 depicts a comparison of risk scores based on HRR cut-off levels. As a result, as compared to the HRR>0.795 group, NIHSS and CHA2DS2-VASc were higher in the group with HRR≤0.795, but GCS was lower. Furthermore, a significant negative correlation was found between HRR and age, troponin I, D-dimer, CRP, Fibrinogen, Ferritin, CHA2DS2-VASc Score, NIHSS, AES, LOS-ICU, and a positive correlation with GCS (p<0.05 for all), according to Table V.

Discussion

It is widely acknowledged that inflammation is associated with both the onset of stroke and the ensuing severe consequences[16]. The

Table III. Logistic regression analysis of parameters according to mortality.

Factors	Mortality (Exitus)					
	B	-2LL	Nagelkerke R^2	*p*	Exp(B)	95% CI
RDW-CV (%)	1.624	61.687	0.528	**< 0.001**	5.073	2.591-9.933
Hb	-1.405	44.101	0.687	**< 0.001**	0.245	0.136-0.444
HRR†	-0.195	33.759	0.770	**< 0.001**	0.823	0.750-0.902
CHA2DS2-VASc Score	0.814	78.709	0.352	**< 0.001**	2.252	1.495-3.405
NIHSS	0.201	64.391	0.502	**< 0.001**	1.222	1.134-1.318
GCS	-1.074	14.776	0.907	**< 0.001**	0.342	0.205-0.570
Age	0.171	78.962	0.350	**< 0.001**	1.186	1.087-1.295

†Details were obtained by performing arithmetic transform, Reference category: Survival group, LL: Log Likehood, CI: Confidence Interval, RDW: red cell distribution width, Hb: hemoglobin, HRR: hemoglobin-to-red cell distribution width ratio, NIHSS: National Institutes of Health Stroke Scale, GCS: Glasgow Coma Scale.

Table IV. The ROC analysis of parameters in the prediction of mortality.

	AUC	95% CI		Cut-off	Sensitivity (%)	Specificity (%)	*p*
		Lower limit	Upper limit				
RDW-CV†	0.911	0.827	0.996	14.45	94.7	78.7	**< 0.001**
Hb†‡	0.952	0.905	0.998	11.55	84.2	91.7	**< 0.001**
HRR†‡	0.975	0.946	1.000	0.795	94.7	92.6	**< 0.001**
CHA2DS2-VASc Score	0.842	0.768	0.917	> 5	84.2	68.5	**< 0.001**
NIHSS†	0.835	0.703	0.967	23	73.7	98.1	**< 0.001**
GCS†‡	0.990	0.972	1.000	< 9	94.7	99.1	**< 0.001**

†Determination based on Youden-J index, ‡Lower values are associated with positive (mortality) cases, AUC: area under the curve, CI: Confidence Interval, RDW: red cell distribution width, Hb: hemoglobin, HRR: hemoglobin-to-red cell distribution width ratio, NIHSS: National Institutes of Health Stroke Scale, GCS: Glasgow Coma Scale.

immune response to acute cerebral ischemia is crucial in stroke pathophysiology and prognosis. Furthermore, inflammatory activity has been linked to AF and its associated complications[17]. Endothelial damage and enhanced platelet activation in AF patients may aggravate stroke's inflammatory damage. Furthermore, patients with AF-caused stroke had a substantially greater risk of mortality or disability[11]. Thus, identifying sensitive and specific inflammatory markers in stroke patients with AF is critical for prognosis[18].

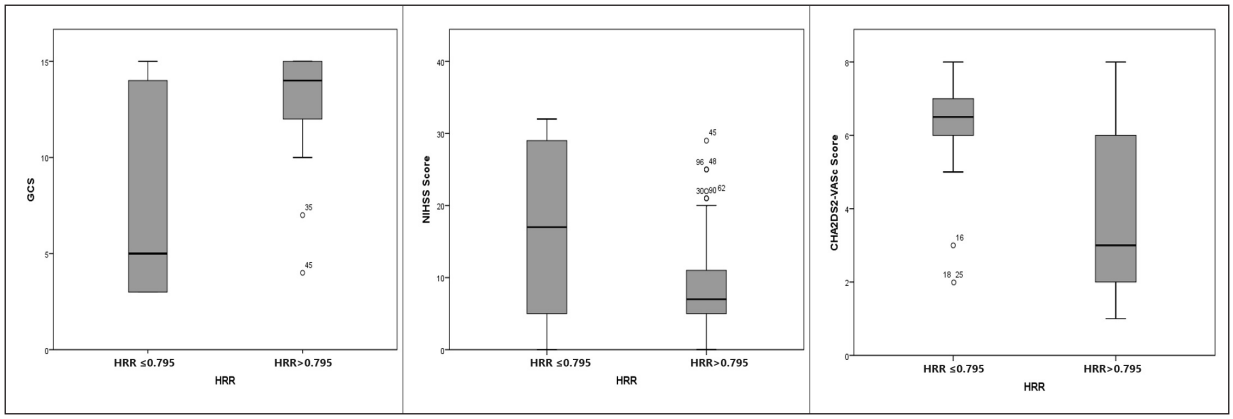

Figure 1. The cut-off level of HRR has determined *via* ROC analysis. HRR: hemoglobin-to-red cell distribution width ratio, NIHSS: National Institutes of Health Stroke Scale, GCS: Glasgow Coma Scale.

Table V. Correlation relationship between quantitative parameters.

	Correlation analysis model*							
	Age		HRR		LOSH, day		LOS-ICU, day	
	ρ/r	p	ρ/r	p	ρ/r	p	ρ/r	p
Age, years	-	-	-0.554**	**< 0.001**	0.132*	0.138	0.227*	**0.010**
RDW-CV, (%)	0.444**	**< 0.001**	-	-	-0.026*	0.769	0.285*	**0.001**
WBC, (10^3/mL)	-0.199**	**0.025**	0.148**	0.097	0.037*	0.684	0.187*	**0.036**
HRR, (g/dL/%)	-0.554**	**< 0.001**	-	-	-0.064*	0.473	-0.329*	**< 0.001**
Hb, (g/dL)	-0.482**	**< 0.001**	-	-	-0.081*	0.364	-0.270*	**0.002**
PLT, (10^3/mL)	-0.045*	0.619	0.114*	0.201	-0.034*	0.706	-0.003*	0.970
Troponin I, (ng/ml)	0.432*	**< 0.001**	-0.455*	**< 0.001**	0.085*	0.339	0.364*	**< 0.001**
D-dimer, (µg/mL)	0.339*	**< 0.001**	-0.344*	**< 0.001**	-0.091*	0.311	0.359*	**< 0.001**
CRP, (mg/L)	0.252*	**0.004**	-0.392*	**< 0.001**	0.104*	0.244	0.400*	**< 0.001**
Fibrinojen, (g/L)	0.296*	**< 0.001**	-0.318*	**< 0.001**	0.073*	0.414	0.370*	**< 0.001**
Ferritin, (µg/L)	0.307*	**< 0.001**	-0.335*	**< 0.001**	0.070*	0.436	0.256*	**0.004**
CHA2DS2-VASc Score	0.406*	**< 0.001**	-0.381*	**< 0.001**	0.060*	0.499	0.265*	**0.003**
NIHSS	0.308*	**< 0.001**	-0.412*	**< 0.001**	0.311*	**< 0.001**	0.512*	**< 0.001**
GCS	-0.395*	**< 0.001**	0.499*	**< 0.001**	-0.316*	**< 0.001**	-0.793*	**< 0.001**
AES	0.241*	**0.006**	-0.200*	**0.024**	0.170*	0.057	0.175*	**0.049**
VES	0.241*	**0.006**	-0.136*	0.127	-0.004*	0.964	0.109*	0.223
LOSH, day	0.132*	0.138	-0.064*	0.473	-	-	-	-
LOS-ICU, day	0.227*	**0.010**	-0.329*	**< 0.001**	-	-	-	-

*Spearman two-tailed correlation analysis, ρ=Spearman's rho (Correlation coefficient), **Pearson two-tailed correlation analysis, r=Pearson's r (Correlation coefficient), *p*=significance value, RDW: red cell distribution width, WBC: white blood cell, HRR: hemoglobin-to-red cell distribution width ratio, Hb: hemoglobin, PLT: platelet, CRP: C-reactive protein, NIHSS: National Institutes of Health Stroke Scale, GCS: Glasgow Coma Scale, AES: atrial extrasystole, VES: ventricular extrasystole, LOSH: Length of stay in hospital, LOS-ICU: Length of stay in ICU, ICU: intensive care unit.

Recent research[3,19] has found that high initial RDW in stroke patients is associated with a poor one-year prognosis and mortality. Inflammation and oxidative stress can impede erythropoiesis and inhibit erythrocyte maturation, resulting in anisocytosis and increased RDW. Tissue oxygenation diminishes when RDW rises, which may contribute to the development and severity of stroke. Furthermore, having a high RDW increases the chance of thromboembolism, which can lead to repeated strokes, serious brain damage, and poor outcomes[2]. RDW level was shown to be significantly higher in the group of patients with AF compared to patients without AF in a study of 4,717 patients observed in the ICU. The authors underlined that the rise in RDW might be attributed to the intensity of the inflammation[20]. Another study[21] found that RDW was directly associated with stroke risk, regardless of anemia, and improved prediction accuracy in stroke patients with AF. According to Xue et al[3], RDW is related to 3-month negative functional outcomes and stroke severity in stroke patients. Mohindra et al[4] have demonstrated that a suggested RDW index might predict stroke patients' prognosis. RDW was higher in stroke patients with AF compared to those without AF in our study, although the difference was not statistically significant. RDW levels in the low HRR group, on the other hand, were found to be significantly higher than those in the high HRR group. Furthermore, RDW levels upon admission appear to be a significant marker in predicting the outcome of all stroke patients with and without AF, according to logistic regression analysis.

Inflammation stimulates macrophages, increases erythrocyte clearance, shortens their lifetime, and decreases hemoglobin[22]. Anemia, which can lead to thrombus formation by altering endothelial adhesion molecule genes, appears to be linked to cerebro-cardiovascular events[7,23]. Hb level fluctuations may enhance the risk of AF and stroke[7,8,11]. A 1 g/dL rise in Hb level was related to an increased incidence of AF in a retrospective cohort of 434,269 participants[7]. Anemia is prevalent at the time of admission in 15-29% of acute stroke patients, and the mortality rate is higher[23]. Hb levels can potentially be used to predict stroke

recurrence and vascular events[24]. Low and high Hb levels were related to a one-year risk of mortality and poor functional outcomes in a study of patients with stroke or transient ischemic attack by Zhang et al[8]. Hb levels were found to be significantly reduced in individuals who suffered a stroke with both AF and low HRR in our study as compared to other groups. Furthermore, ROC analysis results show that Hb levels assessed at admission can highly predict mortality.

HRR, which is a component of Hb and RDW, is a new inflammatory marker that more accurately represents the body's oxidative stress and degree of systemic inflammatory response[22,25]. Many cancer studies[9,10,25] in recent years have proved the predictive value of HRR. First, Sun et al[26] reported that in patients with esophageal squamous cell carcinoma, HRR was a stronger predictive indicator than Hb or RDW alone. İlhan et al[27] also found a significant reduction in survival time for metastatic pancreatic cancer patients in the low HRR group compared with those in the high HRR group. According to the authors, low HRR was a poor prognostic factor for these patients. Furthermore, there is substantial evidence that a low HRR level is related to poor outcomes in several important situations[28,29]. A study of individuals with AF and sepsis found that an HRR of less than 5.877 was connected with an increased risk of mortality. The authors attributed the reason for the low HRR to the increase in RDW and decrease in Hb due to the underlying inflammatory condition[30]. Song et al[31] demonstrated that Hb/RDW-SD was negatively linked with 3-month readmission in elderly heart failure patients. In patients with non-traumatic subarachnoid hemorrhage, Liu et al[6] found that low HRR levels were related to poorer outcomes compared to high HRR levels. When the HRR value was 9.74, Qin et al[11] discovered a negative connection between HRR and all-cause mortality in stroke patients with AF. HRR levels were observed to be significantly lower in stroke patients with AF compared to those without AF in our study. According to previous literature, the requirement for MV, in-hospital mortality, and NIHSS were significantly higher in patients with low HRR compared to those with high HRR. Because there is a significant correlation with risk scores, it is possible that HRR can predict the severity of a stroke. Furthermore, HRR levels have been shown to have stronger predictive ability than Hb and RDW alone in predicting mortality.

Limitations

First, our study results should be evaluated with caution due to the single center and limited sample size. Further investigation is required, through multicenter studies, to provide confirmation of our findings. Second, because this is a retrospective observational study, it is difficult to prevent selection bias, and our findings may have been impacted by other unknown variables. Third, as blood data were only collected upon admission, it was not possible to analyze any changes in HRR. Fourth, we were able to investigate only the mortality rate during patients' hospitalization. Long-term results will require more investigation. Despite these limitations, our study identified a significant correlation between low HRR levels and hospital mortality, which promises well for future research.

Conclusions

Patients with decreased HRR may be classed as high-risk patients in terms of stroke severity due to greater mortality rates. Furthermore, HRR levels may act as a prognostic indication in these patients when compared to Hb and RDW alone.

Conflict of Interest

The authors declare that they have no conflict of interests.

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Ethics Approval

The study was approved by the Necmettin Erbakan University Faculty of Medicine Local Ethics Committee on September 15, 2023, and with the number 2023/4527[15662]. The study was conducted according to the principles of the Helsinki Declaration.

Informed Consent

Because the retrospective data retrieval would not affect patients' clinical management, informed consent was not sought for the present study. The identity information of the patients was kept confidential.

Availability of Data and Materials

Primary data used in this research article will be available on request.

Authors' Contribution

Concept: A.E, B.E, Design: A.E, Data Collection or Processing: A.E, B.E, Analysis or Interpretation: AE, B.E, Writing: A.E.

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