Prognostic value of red blood cell distribution width in predicting 3-month functional outcome of patients undergoing thrombolysis treatment for acute ischemic stroke

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Abstract
This study was performed to determine whether red blood cell distribution width (RDW) is associated with 3-month poor functional outcome in patients undergoing thrombolytic therapy for acute ischemic stroke.

RDW was measured in patients with thrombolytic therapy in emergency department. Functional outcome was assessed after 3 months and poor functional outcome was defined as modified Rankin scale 3 to 6.

A total of 240 patients were enrolled, and 82 (34.2%) had a poor functional outcome. The median RDW was significantly elevated in patients with a poor functional outcome compared with those with a good outcome. RDW was independently associated with a 3-month poor functional outcome (odds ratio 3.369, 95% confidence interval 2.214–5.125). The optimal RDW cutoff for predicting 3-month poor functional outcome was 12.8%, and the area under the curve for RDW was 0.818 (95% confidence interval 0.761–0.876). The area under the curve for RDW was higher in male patients than in female patients. The RDW correlated positively with the modified Rankin scale score after 3 months and the initial National Institutes of Health Stroke Scale score.

Initial higher RDW level is related to a 3-month poor functional outcome in patients undergoing thrombolytic therapy for acute ischemic stroke.

Abbreviations: AUC = area under the curve, CIs = confidence intervals, CRP = C-reactive protein, ED = emergency department, mRS = modified Rankin Scale, NIHSS = National Institutes of Health Stroke Scale, ORs = odds ratios, RDW = red blood cell distribution width, r-tPA = recombinant tissue-type plasminogen activator.

Keywords: cerebral infarction, emergency department, prognosis, red cell distribution width, stroke

1. Introduction
Acute ischemic stroke is the leading cause of disability and mortality throughout the world. The 30-day mortality rate after acute ischemic stroke is 14.2% in stroke unit patients and 20.9% in general ward patients.[1] Intravenous thrombolysis with recombinant tissue-type plasminogen activator (r-tPA) within 4.5 hours after symptom onset is an early effective treatment for patients with acute ischemic stroke.[2] Previous studies have demonstrated that higher National Institutes of Health Stroke Scale (NIHSS) scores and blood glucose levels are associated with a poor outcome for patients with acute ischemic stroke treated with intravenous thrombolysis.[3,4]

Red blood cell distribution width (RDW) is an indicator of the variation in circulating erythrocyte volume and is routinely measured during complete blood count analysis. RDW is commonly used in the differential diagnosis of various types of anemias and iron or vitamin deficiency. Previous studies have reported that elevated RDW is closely associated with inflammatory conditions, including cardiovascular events, multiple myeloma, sepsis, and chronic kidney disease.[5–8] Other recent studies have found that elevated RDW is significantly associated with mortality and a poor functional outcome in patients with acute ischemic stroke.[9–11]
However, few studies have focused on RDW as a prognostic marker of functional outcome in patients undergoing thrombolysis for acute ischemic stroke. Therefore, the purpose of our study was to investigate whether RDW is useful for estimating the 3-month functional outcome for patients undergoing thrombolysis for acute ischemic stroke and, if so, to establish a cutoff RDW value.

2. Materials and methods

2.1. Study population

This observational study was undertaken from January 2017 to April 2020 in the emergency department (ED) of Konkuk University Medical Center, an 835-bed tertiary institution in Seoul with about 58,000 ED visits annually.

The inclusion criteria were age ≥19 years and patients with acute ischemic stroke who received intravenous thrombolysis with r-tPA within 4.5 hours of their symptom onset. Acute ischemic stroke was diagnosed as sudden-onset neurological impairment and with magnetic resonance imaging at the ED. The exclusion criteria were a previous neurological disease, infection within the past month, blood transfusion in the past 4 months, current use of iron, vitamin B12, or folate, hepatic or renal disease, hematological disorder, or malignancy. The enrolled patients received intravenous administration of alteplase (0.9 mg/kg, maximum dose <90 mg) in the ED. Ten percent of the total dose was given by intravenous bolus, and the remainder was mixed with 50 mL of 0.9% saline and infused continuously for 1 hour.

The protocol for this study was approved by the ethics committee of the Konkuk University Medical Center, and individual informed consent was waived given the use of routinely measured laboratory data collected during the process of diagnosis and treatment in the ED. We confirm that all methods were performed in accordance with the relevant guidelines and regulations.

2.2. Data collection and assessment

Peripheral venous blood samples were collected within 10 minutes of ED admission. The complete blood count with differential was analyzed using a Sysmex XN-9000 analyzer (Sysmex, Kobe, Japan).

Patient demographic characteristics, clinical features, radiology images, and laboratory data were collected. The initial NIHSS score was assessed before thrombolytic therapy, and the severity of the stroke was classified into 3 groups: mild (NIHSS 1–6), moderate (NIHSS 7–15), and severe (NIHSS ≥16). The functional outcome was determined at 3 months after ED admission; a poor functional outcome was defined as modified Rankin Scale (mRS) score of 3 to 6. To assess the outcomes after 3 months, a review of the medical records or a telephone interview with the patient was conducted by a physician who was blinded to the clinical information.

2.3. Statistical analysis

IBM SPSS Statistics version 25 (IBM, Armonk, NY) and MedCalc version 19.6 (MedCalc Software, Ostend, Belgium) were used for all statistical analyses. Categorical variables are expressed as frequencies (percentages), and proportions were compared using the \( \chi^2 \) test. Nonnormally distributed continuous variables are reported as median (25%–75% interquartile range) or number (%). C-reactive protein, ED = emergency department. NIHSS = National Institutes of Health Stroke Scale. mRS = modified Rankin Scale. RDW = red blood cell distribution width. WBC = white blood cell.

A receiver-operating characteristic curve was applied to identify an optimal cutoff of RDW for predicting a poor functional outcome at 3 months. The area under the curve (AUC) and 95% confidence intervals (CIs) are reported. Logistic regression analysis was performed to identify independent predictors of a 3-month poor functional outcome after thrombolysis, and the odds ratios (ORs) and 95% CIs were calculated. Spearman correlation analysis was performed to analyze the relationships between RDW, age, mRS score at 3 months, and NIHSS score at ED admission. All statistical testing was 2-sided, and \( P < .05 \) was considered to be significant.

3. Results

3.1. RDW and clinical characteristics

Between January 2017 and April 2020, 240 patients were included in the study and observed for 3 months. The demographic and clinical characteristics, laboratory results, and outcomes of the enrolled patients are presented in Table 1. The median age was 72 (62–80) years and 131 (54.6%) patients were males. The median time from symptom onset to ED arrival...
was 49 (30–114) minutes, and the median NIHSS score at ED admission was 8 (5–14).

The initial median clinical characteristics and laboratory results of the male and female patients are presented in Table 2. The median hemoglobin and hematocrit levels were significantly higher in men, and the median platelet count and RDW levels were significantly higher in women.

Enrolled patients were classified into 3 subgroups based on their NIHSS score at ED admission. The group with severe stroke (NIHSS ≥16) accounted for 17.5% (42/240) of all enrolled patients. The median RDW at ED admission was higher in the group with severe (13.1% [12.3–14.0]) and moderate (13.0% [12.2–13.7]) stroke than the group with mild stroke (12.5% [12.0–13.3]) (P=.009 and .022, respectively). The median RDW did not differ significantly between the moderate and severe NIHSS score groups (P=.323).

### 3.2. RDW and functional outcome

Six (2.5%) patients died, and 82 (34.2%) patients had a poor functional outcome (mRS score 3–6) at 3 months after intravenous thrombolytic therapy for acute ischemic stroke. The NIHSS score at ED admission was significantly higher in the poor functional outcome group than in the good functional outcome group (11 [7–18] vs 6 [4–11]; P<.001).

The median RDW was significantly elevated in patients who had a poor functional outcome (13.7% [13.1–14.5] vs 12.3% [12.0–13.1]; P<.001) (Fig. 1). The median white blood cell count and blood glucose and C-reactive protein (CRP) levels were higher in the poor functional outcome group than in the good functional outcome group. Other laboratory results (hemoglobin level, hematocrit, and platelet count) are listed according to the functional outcome in Table 3.

The AUC of RDW for predicting 3-month poor functional outcome was 0.818 (95% CI 0.761–0.876; P<.001) (Fig. 2). The optimal cutoff value for a 3-month poor functional outcome was 12.8%. The sensitivity was 86.6%, specificity was 68.4%, positive likelihood ratio was 2.74, negative likelihood ratio was 0.20, positive predictive value was 57.7, and negative predictive value was 90.8. The 3-month poor functional outcome was

### Table 2

Comparison of clinical characteristics and laboratory results between male and female patients.

| Variable                  | Men (n = 131) | Women (n = 109) | P   |
|---------------------------|---------------|-----------------|-----|
| Age, yr                   | 70 (63–78)    | 72 (65–82)      | .682|
| Time from onset to ED arrival, min | 46 (30–102)  | 53 (30–136)     | .345|
| NIHSS score               | 8 (5–14)      | 9 (5–14)        | .429|
| WBC count, ×10^3/μL       | 7.8 (6.2–9.5) | 7.9 (6.3–9.7)   | .790|
| Hemoglobin, g/dL          | 14.6 (13.5–15.7) | 12.8 (11.9–13.8) | <.001|
| Hematocrit, %             | 41.6 (38.5–44.3) | 37.4 (34.5–39.9) | <.001|
| Platelet count, ×10^3/μL  | 210 (175–253) | 231 (192–270)   | .022|
| Blood glucose, mg/dL      | 128 (111–152) | 127 (111–159)   | .990|
| CRP, mg/dL                | 0.14 (0.06–0.35) | 0.15 (0.05–0.44) | .825|
| RDW, %                    | 12.6 (10.0–13.4) | 13.1 (12.3–13.8) | .005|
| Poor outcome (mRS score 3–6) | 38 (29.0)   | 44 (40.4)       | .076|

Values are presented as median (25%–75% interquartile range) or number (%).

CRP = C-reactive protein, ED = emergency department, mRS = modified Rankin Scale, NIHSS = National Institutes of Health Stroke Scale, RDW = red blood cell distribution width, WBC = white blood cell.

![Figure 1](image_url). Differences in RDW according to functional outcomes. RDW = red blood cell distribution width.
58.7% in the higher RDW (>12.8%) group, and 9.2% in the lower RDW (≤12.8%) group (P < .001).

The AUC for RDW in male patients was 0.835 (95% CI 0.760–0.894; P < .001). The optimal cutoff value for 3-month poor outcome was >12.9%, with a sensitivity of 84.2% and specificity of 74.2%. The AUC for RDW in female patients was 0.783 (95% CI 0.694–0.857; P < .001). The optimal cutoff value in female patients >12.8%, with a sensitivity of 88.6% and specificity of 61.5%.

The AUC of the NIHSS score at ED admission for predicting 3-month poor functional outcome was 0.722 (95% CI 0.656–0.788; P = .034). The AUC was significantly higher for the RDW than for the NIHSS score at ED admission (P = .033).

Age, sex, hypertension, diabetes mellitus, atrial fibrillation, hyperlipidemia, time from symptom onset to ED arrival, NIHSS score at ED admission, white blood cell count, hematocrit, levels of hemoglobin, blood glucose, and CRP, and RDW were included in a logistic regression analysis to identify the independent predictors of 3-month poor functional outcome. In the univariable analysis, the following variables were associated with 3-month poor functional outcome: age (OR 1.069, 95% CI 1.041–1.098; P < .001); hypertension (OR 2.282, 95% CI 1.259–4.137; P = .007); NIHSS score at ED admission (OR 1.148, 95% CI 1.090–1.209; P < .001); hemoglobin level (OR 0.812, 95% CI 0.692–0.953; P = .011); hematocrit (OR 0.920, 95% CI 0.864–0.980; P = .009); CRP level (OR 1.370, 95% CI 1.083–1.733; P = .009); and RDW (OR 2.878, 95% CI 2.062–4.017; P < .001). In the multivariable analysis, the following variables were identified as independent predictors of 3-month poor outcome: age, NIHSS score at ED admission, CRP level, and RDW (Table 4).

The Spearman correlation coefficients were 0.305 (P < .001) for the association between RDW and age, 0.130 (P = .004) for

| Variable | Good outcome (n = 158) | Poor outcome (n = 82) | P   |
|----------|------------------------|-----------------------|-----|
| Age, yr  | 68 (59–77)             | 78 (70–84)            | <.001|
| Men/women| 93/65                  | 38/44                 | .076 |
| Time from onset to ED arrival, min | 46 (30–113) | 53 (29–120) | .784 |
| NIHSS score | 6 (4–11)            | 11 (7–18)             | <.001|
| WBC count, ×10⁹/µL | 7.5 (6.2–9.1) | 8.7 (8.3–10.4) | .044 |
| Hemoglobin, g/dL | 13.7 (12.9–15.1) | 13.2 (11.8–14.5) | .008 |
| Hematocrit, % | 39.8 (37.5–42.8) | 38.6 (34.3–41.7) | .008 |
| Platelet count, ×10³/µL | 228 (190–253) | 210 (171–269) | .391 |
| Blood glucose, mg/dL | 124 (109–149) | 133 (114–166) | .046 |
| CRP, mg/dL | 0.11 (0.04–0.29) | 0.20 (0.07–0.75) | .003 |
| RDW, % | 12.3 (12.0–13.1) | 13.7 (13.1–14.5) | <.001 |

Values are presented as median (25%–75% interquartile range) or number.
CRP = C-reactive protein, ED = emergency department, NIHSS = National Institutes of Health Stroke Scale, RDW = red blood cell distribution width, WBC = white blood cell.

Figure 2. The receiver-operating characteristic curves of red blood cell width (RDW) for 3-month poor functional outcome. NIHSS = National Institutes of Health Stroke Scale, RDW = red blood cell distribution width.
the association between RDW and NIHSS score at ED admission, and 0.321 ($P < .001$) for the association between RDW and mRS score at 3 months.

4. Discussion

The present study evaluated the ability of RDW at ED admission to predict 3-month poor functional outcome (mRS score of 3–6) in patients undergoing thrombolytic therapy for acute ischemic stroke. The RDW at ED admission was significantly elevated in patients who subsequently had a poor functional outcome and seemed to be an independent predictor of 3-month poor functional outcome.

RDW is used mainly to help diagnose various types of anemia, but it has also been reported as a prognostic marker in hospitalized patients. The mechanism underlying the association between a high RDW and poor outcome in patients with acute ischemic stroke remains unclear. The inflammatory response and oxidative stress are known to play an important role in ischemic stroke. Inflammation may affect iron metabolism and bone marrow function, and induce the premature release of large reticulocytes into the peripheral circulation. Oxidative stress may lead to an increase in osmotic fragility and membrane damage of red blood cells, which may contribute to the increase in RDW.

Previous studies have found that elevated RDW correlates consistently with older age. Cheng et al reported that RDW tended to increase in parallel with age in a large healthy control group. Our study also found a significant association between increasing RDW and age ($r = .305$). Interestingly, in another study, RDW was an independent predictor of 1-year survival in older patients ($\geq 75$ years) with ischemic stroke treated with thrombolysis but not in younger patients ($< 75$ years). By contrast, Patel et al reported a significant trend toward an increased risk of all-cause mortality with higher RDW in both middle-aged ($45–64$ years) and older adults ($> 65$ years).

Kara et al reported a significant association between elevated RDW and the severity of stroke, as indicated by the NIHSS score, in patients with acute stroke. Mohindra et al also showed that stroke severity, as assessed by the initial NIHSS score, was related to higher RDW. By contrast, other studies have reported that RDW was not associated with stroke severity, as evaluated by the baseline NIHSS score. In addition, Pinho et al found no significant relationship between the initial NIHSS score and RDW in patients with ischemic stroke treated with intravenous thrombolysis. In our study, the RDW at ED admission was higher in the groups with moderate or severe stroke than that in the group with mild stroke but did not differ significantly between the moderate and severe groups ($P = .323$).

Several laboratory markers have been studied for their prognostic value in patients with acute ischemic stroke. Tu et al reported that serum 25-hydroxyvitamin D level was an independent prognostic marker for death and functional outcome within 90 days in Chinese patients with acute ischemic stroke. Zhang et al demonstrated that a higher neutrophil–lymphocyte ratio was associated with poor functional outcome at 3 months after ischemic stroke. Another study showed that serum sirtuin 1 was significantly elevated in patients with acute ischemic stroke but did not correlate with functional outcome after 1 year.

The main focus of our study was whether there is a relationship between RDW and functional outcome in patients who received thrombolytic therapy after acute ischemic stroke. In the present study, 34.2% of patients had a poor functional outcome at 3 months, and RDW was markedly elevated in the patients who later had a poor functional outcome. Age, initial NIHSS score, and CRP level were also related to a poor functional outcome at 3 months. Cong et al reported that 38% of patients had a poor outcome after 90 days and that a high RDW ($\geq 13.15\%$) and NIHSS score at 24 hours after ED admission were independent predictors of a poor outcome in patients who received thrombolytic treatment. In the study by Pinho et al, a higher percentage of patients ($55\%$) than in our study had a poor outcome, and the frequency of a poor outcome after 3 months was higher in patients with a high RDW. These findings suggest that differences in outcome between patients receiving thrombolytic therapy may be related to the severity of stroke at ED admission. By contrast, Shahsavarinia et al reported that the baseline RDW did not correlate with outcome after a 3-month follow-up in patients who received tPA treatment. Ye et al found that RDW was not associated with clinical outcome after 1 year but was significantly related to all-cause mortality.

Our study was included only patients given thrombolytic treatment and several studies have included all patients treated after acute ischemic stroke. A recent meta-analysis reported that elevated RDW is associated with a poor functional outcome at discharge and after 3 months. By contrast, Ntaios et al found that the RDW was not associated with stroke severity 1-year poor functional outcome in patients with acute ischemic stroke with 24 hours after last-well time.

Few studies have reported an optimal cutoff value of RDW for predicting outcomes in patients with acute ischemic stroke undergoing thrombolytic therapy. In our study, the AUC of the RDW for predicting 3-month poor outcome was 0.818. The optimal cutoff RDW for predicting 3-month poor outcome was determined as 12.8%, with 86.6% sensitivity and 68.4% specificity. These results suggest that the accuracy of the prediction of 3-month outcome was significantly higher in our study than the AUC of 0.663 reported by Cong et al, who included 196 patients treated with rtPA thrombolysis. They reported a suitable RDW cutoff of 13.15% for predicting 90-day poor functional outcome, with a sensitivity of 64.0% and specificity of 60.7%. The percentages of patients with a poor outcome were 34.2% in our study and 30% in the study of Cong et al, which suggests that the functional outcomes did not differ between studies.

To our knowledge, no studies have compared the prognostic value of RDW between male and female patients who received thrombolytic treatment. Some studies have found slightly higher RDW values in females than in males, whereas others have reported no sex difference in RDW values between males and females.
females. In our study, female patients had a slightly but significantly higher RDW value than male patients (13.1% vs 12.6%; P = .005). We found that the AUC value of RDW for 3-month poor outcome was higher in male patients than in female patients: 0.835 (95% CI 0.760–0.894) vs 0.783 (95% CI 0.694–0.857), respectively. For a cutoff value of >12.8% for RDW in female patients, the sensitivity and specificity for 3-month poor outcome were 88.6% and 61.5%, respectively. For a cutoff value of >12.9% for RDW in male patients, the sensitivity was 84.2%, which was lower than in female patients, but the specificity (74.2%) was higher than in female patients.

A previous study reported a significant correlation between the RDW and NIHSS score at ED admission (r = .322). We found similar relationships, in that the RDW correlated with the NIHSS score at ED admission and with the mRS score after 3 months.

Hemoglobin and hematocrit levels are generally inversely correlated with RDW. Studies have reported an association between hemoglobin or hematocrit level and the outcome of ischemic stroke. In a study, a high hemoglobin level on admission was significantly associated with disability at the time of hospital discharge, but a low hemoglobin level was not associated with disability. reported that a low hemoglobin level was associated with a poor outcome at 3 months after ischemic stroke. Hemoglobin level increases blood viscosity and can indicate iron overload, which may decrease blood flow and lead to oxygen delivery, which in turn could worsen the prognosis after ischemic stroke. A low hemoglobin level reflects systemic inflammation and is associated with a poor outcome after ischemic stroke. By contrast, reported that hematocrit was not associated with the short-term outcome of patients with cerebral infarction. In the univariable analysis in our study, hemoglobin level, hematocrit, and RDW were associated with a poor outcome. However, in the multivariable analysis, only RDW was associated with a poor outcome. We have not been able to analyze these results, and a large-scale prospective study will be needed in the future.

Our study has some limitations. First, this study was conducted at a single tertiary hospital and included a small number of patients. Therefore, the outcomes may not be generalized to all patients treated with intravenous thrombolysis. Second, RDW was measured only once at the time of ED arrival, and there were no further measurements. In addition, the CRP level was measured in this study, but other inflammatory biomarkers, such as platelet distribution width, neutrophil-to-lymphocyte ratio, and procalcitonin level, were not measured.

5. Conclusions
In conclusion, in our study, a higher RDW at ED admission, even if within the normal range, correlated independently with 3-month poor functional outcome after thrombolytic therapy. We found that the prognostic value of RDW in male patients was equal or superior to that of female patients. Although careful interpretation is needed because of the limited sensitivity and specificity, the RDW may be a useful marker for predicting 3-month functional outcome in patients undergoing thrombolytic treatment for acute ischemic stroke.

Author contributions
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References
[1] Rocha MS, Almeida AC, Abarth Neto O, Porto MP, Brucki SM. Impact of stroke unit in a public hospital on length of hospitalization and rate of early mortality of ischemic stroke patients. Arq Neuropsiquiatr 2013;71:774–9.
[2] Powers WJ, Derdeyn CP, Biller J, et al. 2015 American Heart Association/American Stroke Association focused update of the 2013 Guidelines for the Early Management of Patients with Acute Ischemic Stroke Regarding Endovascular Treatment: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke 2015;46:3020–35.
[3] Sañá D, Herzig R, Zapletalova J, et al. Predictors of good clinical outcome in acute stroke patients treated with intravenous thrombolysis. Acta Neurol Scand 2011;123:339–44.
[4] Yong M, Kaste M. Dynamic of hyperglycemia as a predictor of stroke outcome in the ECASS-II trial. Stroke 2008;39:2749–55.
[5] Batić J, Jurin I, Lucijanić M, Jerkić H, Blažeković R. High red cell distribution width at the time of ST segment elevation myocardial infarction is better at predicting diastolic than systolic left ventricular dysfunction: a single-center prospective cohort study. Medicine (Baltimore) 2018;97:e0601.
[6] Zhou D, Xu P, Peng M, et al. Pre-treatment red blood cell distribution width provides prognostic information in multiple myeloma. Clin Chim Acta 2018;481:34–41.
[7] Chen CK, Lin SC, Wu CC, Chen LM, Tseng IS, Chen KF. STAR-D-compliant article: the utility of red cell distribution width to predict mortality for septic patients visiting the emergency department. Medicine (Baltimore) 2016;95:e3692.
[8] Cao HX, Zhao XD, Yan L, Fan XG, Shao FM. Correlation between red cell distribution width and cardiovascular events in the patients receiving peritoneal dialysis: a Stroke-compliant article. Medicine (Baltimore) 2019;98:e14376.
[9] Wang L, Wang C, Wu S, Li Y, Guo W, Liu M. Red blood cell distribution width is associated with mortality after acute ischemic stroke: a cohort study and systematic review. Ann Transl Med 2020;8:81.
[10] Song SY, Hua C, Dornbors D 3rd, et al. Baseline red blood cell distribution width as a predictor of stroke occurrence and outcome: a comprehensive meta-analysis of 31 studies. Front Neurol 2019;10:1237.
[11] Kim J, Kim YD, Song TJ, et al. Red blood cell distribution width is associated with poor clinical outcome in acute cerebral infarction. Thromb Haemost 2012;108:349–56.
[12] Kho AN, Hui S, Kesterson JG, McDonald CJ. Which observations from the complete blood cell count predict mortality for hospitalized patients? J Hosp Med 2007;2:5–12.
[13] Ku NS, Kim HW, Oh HJ, et al. Red blood cell distribution width is an independent predictor of mortality in patients with gram-negative bacteremia. Shock 2012;38:123–7.
[14] Sembra RD, Patel KV, Ferrucci L, et al. Serum antioxidants and red blood cell distribution width in older women: the women’s health and aging study I. Clin Nutr 2010;29:600–4.
[15] Cheng CK, Chan J, Cembrowski GS, van Assendelft OW. Complete blood cell distribution width provides prognostic information in multiple myeloma. Clin Chim Acta 2018;97:e0601.
[18] Kara H, Degirmenci S, Bayir A, et al. Red cell distribution width and neurological scoring systems in acute stroke patients. Neuropsychiatr Dis Treat 2015;11:733–9.
[19] Mohindra R, Mishra U, Mathew R, Negi NS. Red cell distribution width (RDW) index as a predictor of severity of acute ischemic stroke: a correlation study. Adv J Emerg Med 2020;4:e24.
[20] Ntaios G, Gurer O, Fasouzi M, Aubert C, Michel P. Red cell distribution width does not predict stroke severity or functional outcome. Int J Stroke 2012;7:2–6.
[21] Tu WJ, Zhao SJ, Xu DJ, Chen H. Serum 25-hydroxyvitamin D predicts the short-term outcomes of Chinese patients with acute ischaemic stroke. Clin Sci (Lond) 2014;126:339–46.
[22] Zhang J, Ren Q, Song Y, et al. Prognostic role of neutrophil-lymphocyte ratio in patients with acute ischemic stroke. Medicine (Baltimore) 2017;96:e8624.
[23] Liu Y, Jia S, Liang X, et al. Prognostic value of Sirtuin1 in acute ischemic stroke and its correlation with functional outcomes. Medicine (Baltimore) 2018;97:e12959.
[24] Cong L, Gao H, Ma W. Prognostic relationship between peripheral red cell distribution width and acute cerebral infarction in patients with rtPA thrombolysis. Neurotox Res 2020;38:211–8.
[25] Shahsavarinia K, Ghavam Laleh Y, Moharramzadeh P, et al. The predictive value of red cell distribution width for stroke severity and outcome. BMC Res Notes 2020;13:288.
[26] Ye WY, Li J, Li X, et al. Predicting the one-year prognosis and mortality of patients with acute ischemic stroke using red blood cell distribution width before intravenous thrombolysis. Clin Interv Aging 2020;15:255–63.
[27] Lippi G, Salvagno GL, Guidi GC. Red blood cell distribution width is significantly associated with aging and gender. Clin Chem Lab Med 2014;52:e197–9.
[28] Als R, Fuster O, Rivera L, Romagnoli M, Vaya A. Influence of age and gender on red blood cell distribution width. Clin Chem Lab Med 2015;53:e25–8.
[29] Li Q, Chen X, Han B. Red blood cell distribution width is associated with frailty in older inpatients in China: sex differences in a cross-sectional study. Exp Gerontol 2021;150:111392.
[30] Turcato G, Cappellari M, Follador L, et al. Red blood cell distribution width is an independent predictor of outcome in patients undergoing thrombolysis for ischemic stroke. Semin Thromb Hemost 2017;43:30–5.
[31] Furlan JC, Fang J, Silver FL. Acute ischemic stroke and abnormal blood hemoglobin concentration. Acta Neurol Scand 2016;134:123–30.
[32] Kellert L, Martin E, Sykora M, et al. Cerebral oxygen transport failure? Decreasing hemoglobin and hematocrit levels after ischemic stroke predict poor outcome and mortality: STroke: relevant impact of hemoglobin, hematocrit and transfusion (STRAIGHT)-an observational study. Stroke 2011;42:2832–7.
[33] Ferrucci L, Guralnik JM, Woodman RC, et al. Pronflammatory state and circulating erythropoietin in persons with and without anemia. Am J Med 2005;118:1288.
[34] Ozaita G, Calandre L, Peinado E, Rodriguez-Antigüedad A, Bermejo F. Hematocrit and clinical outcome in acute cerebral infarction. Stroke 1987;18:1166–8.