JCEN Journal of Cerebrovascular and Endovascular Neurosurgery

Journal of Cerebrovascular and Endovascular Neurosurgery
pISSN 2234-8565, eISSN 2287-3139, https://doi.org/10.7461/jcen.2022.E2021.10.003

Clinical Article

Prognostic significance of platelet-to-lymphocyte and platelet-to-neutrophil ratios in patients with mechanical thrombectomy for acute ischemic stroke

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J Cerebrovasc Endovasc Neurosurg. 2022 September;24(3):221-231

Received: 26 October 2021
Revised: 23 December 2021
Accepted: 23 December 2021

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Objective: The present study aimed to analyze the correlation between platelet-to-lymphocyte ratio (PLR) and platelet-to-neutrophil ratio (PNR) with prognosis of patients who underwent mechanical thrombectomy (MT).

Methods: A total of 432 patients was included, PLR and PNR were calculated from laboratory data on admission. Prognosis was evaluated with a modified Rankin Scale at 3 months after MT. Using receiver operating characteristic (ROC) analysis, optimal cutoff values of PLR and PNR were identified to predict the prognosis after MT. Multivariate analyses were performed to identify the relationship of PLR and PLR with prognosis of MT.

Results: Patients with favorable outcomes had a lower mean PLR (135.0, standard deviation [SD] 120.3) with a higher mean PNR (47.1 [SD] 24.6) compared with patients with unfavorable outcomes (167.6 [SD] 139.3 and 35.4 [SD] 22.4) (p<0.001 and <0.001, respectively). In ROC analyses, the optimal cutoff value of PLR and PNR to predict the 3 months prognosis were 145 and 41, respectively (p=<0.001 and p=0.006). In multivariate analysis, PLR less than 145 (odds ratio [OR] 1.29, 95% confidence interval [CI] 1.06–2.06; p=0.016) and PNR greater than 41 (OR 1.22, 95% CI 1.10–1.62; p=0.022) were predictors of favorable outcome at 3 months.

Conclusions: In patients with MT, PLR and PNR on admission could be predictive factors of prognosis and mortality at 3 months. Decreased PLR and increased PNR were associated with favorable clinical outcome 3 months after MT.

Keywords Leukocytes, Lymphocytes, Neutrophils, Platelets, Thrombectomy

INTRODUCTION

Stroke is a major cause of mortality and morbidity, and ischemic stroke accounts for about 80% of all stroke.[12)32)] Among the types of stroke, acute ischemic stroke (AIS) caused by large vessel occlusion (LVO) can cause severe disabilities and life threatening

conditions.[9] The current potent treatment paradigm for LVO is mechanical thrombectomy (MT), and its recanalization rate is greater than 90%.[10] However, the independent functional outcomes of patients after MT is in the 50% range, and is influenced by various factors.[26][35][38] Recently, many studies have analyzed the factors affecting clinical prognosis of MT, and the inflammatory response plays a pivotal role in progression of brain damage caused by AIS.[7][22][30]

Thromboembolism, as main cause of LVO, has been considered as a complicated interaction of the inflammatory response.[34] Platelets are involved in the process of thrombosis, which plays a crucial role in initiation and development of the atherosclerotic process with plaque rupture.[16][21][37] In addition, white blood cells (WBC) contributed to the pathophysiology of ischemic changes in the brain, and activated leukocytes are released in damaged brain tissues with pro-inflammatory chemokines.[14][18] Among the leukocytes, neutrophils enhance the release of inflammatory mediators; in contrast, lymphocytes contribute to healing and repair mechanisms of inflammation.[5][15][30]

Various studies have been conducted to determine the ratios of platelets with WBC subtypes, as diagnostic or prognostic predictive factors. The platelet-to-lymphocyte ratio (PLR) has been used as a systemic inflammatory biomarker to predict the prognosis of neoplasms, coronary disease, autoimmune disease and stroke.[23][24][33][36] Furthermore, the platelet-to-neutrophil ratio (PNR) and platelet-to-WBC ratio (PWR) have been introduced as prognostic markers in patients with AIS.[4][20] However, only a limited number of papers has evaluated these ratios to predict the prognosis for patients who underwent MT for LVO. Thus, we evaluated the PLR, PNR, and PWR of peripheral blood in patients who underwent MT. We also aimed to investigate the potential predictive value of these ratios on clinical outcome after MT. The associations of PLR, PNR, and PWR with functional outcomes and prognosis of patients with MT were analyzed.

MATERIALS AND METHODS

Study population

In our retrospective study, prospectively collected data from each institution's stroke data base were reviewed, after obtaining approval of the local Institutional Review Board. From January 2014 to February 2020, a total of 432 patients who underwent MT by LVO was identified. The inclusion criteria was AIS patients who underwent MT for LVO at each institution. Exclusion criteria were as follows: (1) patients with missing laboratory data, or loss to follow up within 3 months; (2) history of infection or surgery within 4 weeks prior to AIS onset; (3) history of autoimmune disease (e.g. rheumatic autoimmune disease, lupus), or malignancy; and (4) known underlying hematologic disorders and severe kidney or liver dysfunction. Pretreatment infection was defined as pneumonia, urinary tract infections, or fever or other typical clinical manifestations, during the pre-interventional period. Before the MT, intravenous thrombolysis (IVT) with a tissue plasminogen activator (alteplase) was applied within 4.5 hours after stroke onset at a maximum dose of 0.9 mg/kg in accordance with the European Cooperative Acute Stroke Study (ECASS) III trial.[13] All of MT procedures were performed with a stent retriever or a combined technique.[6] LVO included occlusion of the intracranial carotid artery, middle cerebral artery, anterior cerebral artery, or posterior circulation (vertebral artery, or basilar artery), as established with computed tomography angiography.

Clinical data and laboratory measurements

Clinical characteristics of the patients included demographic findings; age, gender, risk factors, stroke etiology by TOAST criteria,[2] target occlusion site, laboratory findings on admission, IVT, alberta stroke program early CT score (ASPECTS), national institutes of health stroke scale (NIHSS) (range, 0-42, with higher score indicating more severe neurologic deficit), and time from symptom onset to groin puncture. Risk factors constituted history of hypertension, diabetic mellitus, atrial fibrillation, coronary artery disease, prior stroke or transient isch-

emic attack (TIA), smoking, dyslipidemia, and body mass index (BMI). Laboratory findings contained red blood cells, WBC differentials, hemoglobin, hematocrit, platelets, prothrombin time, activated partial thromboplastin time, high-sensitivity C-reactive protein (hsCRP), erythrocyte sedimentation rate (ESR), total protein, blood urea nitrogen (BUN), creatinine (Cr), BUN/Cr ratio, glycated hemoglobin (HbA1c), serum glucose, total cholesterol, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and triglycerides (TG). All laboratory findings were evaluated using the peripheral venous blood samples collected on admission to the emergency department. PLR, PNR, and PWR were calculated by dividing the platelet count by the lymphocyte count, the platelet count by the neutrophil count, and the platelet count by WBC count, respectively.[4)20)]

Procedure details and clinical outcomes

Procedure time was determined as time from groin puncture to reperfusion. Based on the final angiogram, a successful recanalization was defined, according to the modified treatment in the cerebral infarction (m-TICI) scale of 2b or 3,[39)] and the first-pass reperfusion indicated an m-TICI of 2b or 3 reperfusion with the first pass of the stent retriever.[28)] Clinical outcomes comprised the modified Rankin Scale (mRS) score at 3 months (a favorable functional outcome means 3 months mRS score of 0 to 2), symptomatic intracerebral hemorrhage (sICH), hemorrhagic transformation (HT) of infarct, and mortality at 3 months. sICH was defined as any hemorrhage on a computed tomography taken after the procedure with an increase of ≥4 points on the initial NIHSS score. HT of infarct was confirmed by susceptibility weighted imaging at 7 days after MT.

Statistical analysis

All data were processed using Stata Statistical Software, release 15 (Stata, College Station, TX, USA). All of the patients were dichotomized according to the mRS at 3 months (favorable 0-2 vs unfavorable 3-6). Categorical variables were analyzed with χ^2 test or Fisher's exact test, and Student's t-test or Mann-Whitney U test was used to compare continuous variables. Receiver operating characteristic (ROC) curves were used to determine the optimal cutoff values of PLR, PNR, and PWR to predict the prognosis of patients with MT. Univariate and multivariate logistic regression analyses were used to verify factors that correlated with clinical outcomes, and to compute odds ratio (OR) with 95% confidence interval (CI) estimates for each endpoint. The variables with $p<0.20$ in univariate analysis were entered into a backward multivariate logistic regression analysis, and a two-tailed p-value ≤0.05 was considered to indicate a significant difference.

RESULTS

Baseline characteristics and outcomes

A total of 432 patients, 240 showed favorable outcomes at 3 months (mRS score 0-2, 56.7% were male), and unfavorable outcomes at 3 months (mRS score 3-6, 50.5% were male) were found in the other 192 patients. Patients with unfavorable outcomes (mean 73.4 yrs [SD] 11.8) were older than those with favorable outcomes (mean 66.0 yrs [SD] 13.5) (p=<0.001). There were no significant differences in risk factors, stroke etiology, and distribution of occlusion site between the groups. Compared with the unfavorable outcome group, the favorable outcome group showed lower mean levels of neutrophils and hsCRP, but higher mean lymphocyte level (p=0.032, 0.010, and 0.030, respectively). A lower mean value of PLR (135.0 [SD] 120.3) with higher mean value of PNR (47.1 [SD] 24.6) and PWR (27.7 [SD] 12.1) were found in favorable outcome patients, compared with those of unfavorable outcome patients (167.6 [SD] 139.3, 35.4 [SD] 22.4, and 22.4 [SD] 10.8, respectively) (p=<0.001, <0.001, and 0.009) (Fig. 1). In addition, the favorable outcome patients had a higher median ASPECT (9 [inter interquartile range, IQR] 8-10), lower mean initial NIHSS (8.1 [SD] 5.1), and shorter mean symptom to puncture time (212 [SD] 98) than patients with unfavorable outcomes (8 [IQR] 6-10, 13.9 [SD] 6.6, and 298 [SD] 133, respectively) (p=0.014, <0.001, and <0.001).

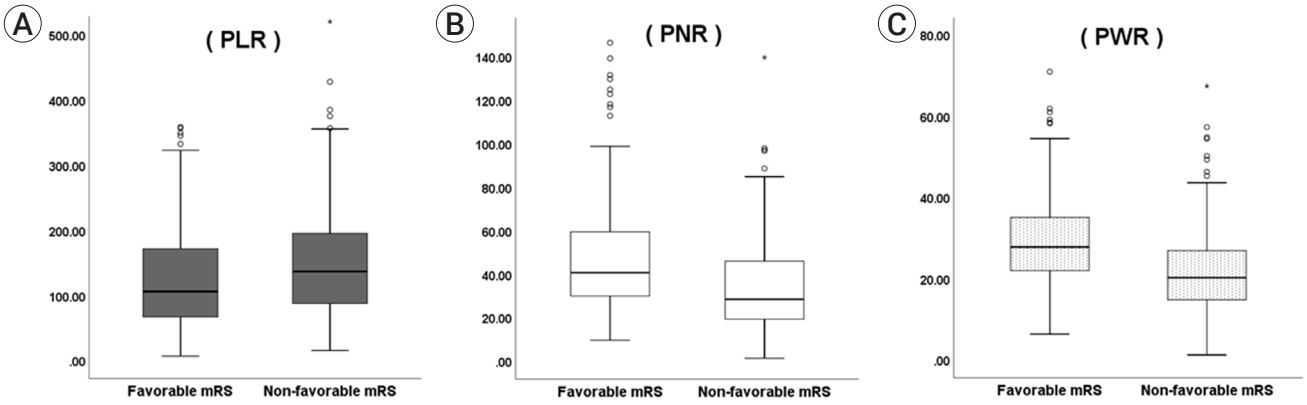

Fig. 1. Box plots of platelet-to-lymphocyte ratio (PLR), platelet-to-neutrophil ratio (PNR), and platelet-to-white blood cell ratio (PWR) between the groups. (A) The patients with favorable modified Rankin Scale (mRS) score (0-2) had lower mean PLR value than patients with unfavorable mRS (p<0.001). (B) Comparison of PNR between groups showed significantly higher PNR in patients with favorable mRS (p<0.001). (C) The mean value of PWR was higher in favorable mRS patients, compared with unfavorable mRS patients (p=0.009).

The differences in other baseline characteristics and laboratory findings between the groups not statistically significant. Patients with favorable outcomes had shorter procedure times with greater achievement of successful recanalization and first pass reperfusion, than patients with unfavorable outcomes (p=0.002, <0.001, and 0.015, respectively). In terms of clinical outcomes, lower occurrence of sICH and HT of infarct was found in the favorable outcome group, compared with the unfavorable outcome group (p=<0.001 and <0.001, respectively) (Table 1).

Association of PLR, PNR, and PWR with 3 months clinical outcomes

According to ROC analysis, the optimal cutoff value of PLR level was 145 to predict the 3 months prognosis (area under the curve [AUC] 0.663, 95% CI 0.611–0.715; p<0.001). In addition, the optimal cutoff values of PNR and PWR to differentiate between favorable (mRS 0-2) and unfavorable (mRS 3-6) outcomes at 3 months were identified as 41 and 25, respectively (AUC 0.616, 95% CI 0.572–0.660; p=0.001, and AUC 0.583, 95% CI 0.521–0.645; p=0.006) (Fig. 2).

Predictors of favorable clinical outcome after MT

Binary univariate and multivariate logistic regression

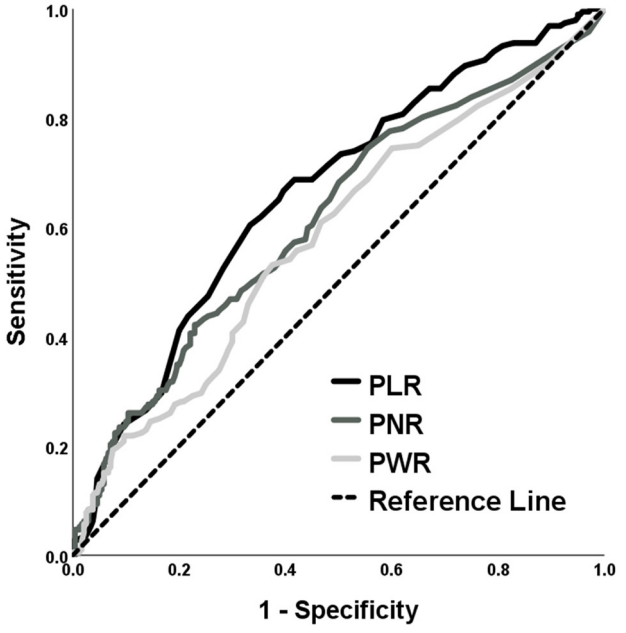

Fig. 2. Receiver operating characteristic (ROC) curve of platelet-to-lymphocyte ratio (PLR), platelet-to-neutrophil ratio (PNR), and platelet-to-white blood cell ratio (PWR) on prognosis of patients who underwent MT for LAO. The optimal cutoff value of PLR level to discriminate between favorable (0-2) and unfavorable (3-6) modified Rankin Scale (mRS) scores at 3 months was 145 (area under the curve (AUC) 0.663, 95% CI 0.611−0.715; p<0.001). In addition, a PNR value of 41 (AUC 0.616, 95% CI 0.572-0.660; p=0.001) and PWR value of 25 (AUC 0.583, 95% CI 0.521-0.645; p=0.006) were identified as the optimal cutoff values to predict favorable 3 months mRS after MT, respectively. MT, mechanical thrombectomy; CI, confidence interval

Table 1. Baseline characteristics and outcomes of patients, according to functional outcomes at 3 month

Variables	Favorable	Unfavorable	*p*-value
Demographics			
Number of patients (%)	240 (55.6)	192 (44.4)	
Age, mean±SD	66.0±13.5	73.4±11.8	**<0.001***
Men, n (%)	136 (56.7)	97 (50.5)	0.203
Risk factors, n (%)			
Hypertension	136 (56.7)	117 (60.9)	0.279
Diabetic mellitus	61 (25.4)	52 (27.1)	0.695
Atrial fibrillation	86 (35.8)	76 (39.6)	0.287
Coronary artery disease	41 (17.1)	26 (13.5)	0.138
Prior stroke or TIA	26 (10.8)	30 (15.6)	0.141
Smoking	47 (19.6)	39 (20.3)	0.850
Dyslipidemia	104 (43.3)	74 (38.5)	0.315
Body mass index ≥25 kg/m^2	65 (27.1)	55 (28.6)	0.719
Stroke etiology, n (%)			
Cardio-embolic	104 (43.3)	76 (39.6)	0.401
Atherosclerosis	75 (31.3)	70 (36.5)	0.374
Dissection	4 (1.7)	2 (1.0)	0.288
Other or undetermined	57 (23.8)	44 (22.9)	0.408
Occlusion site, n (%)			
Middle cerebral artery	138 (57.5)	99 (51.6)	0.327
Distal internal carotid artery	42 (17.5)	41 (21.4)	0.309
Proximal internal carotid artery	34 (14.2)	31 (16.1)	0.411
Anterior cerebral artery	4 (1.7)	3 (1.6)	0.889
Posterior circulation	22 (9.2)	18 (9.4)	0.851
Laboratory findings, mean±SD			
Red blood cells, $\times10^{12}$/L	4.45±0.75	4.55±1.61	0.363
White blood cells, $\times10^{9}$/L	8.35±3.29	9.68±3.73	0.104
Neutrophils, $\times10^{9}$/L	6.77±3.38	7.43±3.81	**0.032***
Lymphocytes, $\times10^{9}$/L	1.99±1.03	1.72±1.37	**0.030***
Monocytes, $\times10^{9}$/L	0.56±0.24	0.61±0.29	0.251
Hemoglobin, g/dL	13.79±1.97	13.55±2.79	0.299
Hematocrit, %	42.09±16.79	39.41±13.28	0.129
Platelets, $\times10^{9}$/L	229.1±86.6	220.1±64.5	0.232
PLR	135.0±120.3	167.6±139.3	**<0.001***
PNR	47.1±24.6	35.4±22.4	**<0.001***
PWR	27.7±12.1	22.4±10.8	**0.009***
Prothrombin time, sec	13.4±5.78	13.6±6.28	0.421
Activated partial thromboplastin time, sec	36.4±12.4	37.1±14.5	0.537
High-sensitivity C-reactive protein, mg/L	0.65±1.65	1.18±2.51	**0.010***
Erythrocyte sedimentation rate, mm/h	19.4±16.9	22.7±19.8	0.107
Total protein, g/dL	6.79±0.69	6.81±0.68	0.713
Blood urea nitrogen (BUN), mg/dL	16.77±9.61	17.85±8.37	0.224
Creatinine (Cr), mg/dL	0.86±0.45	0.90±0.67	0.500
BUN/Cr ratio	20.62±12.71	21.04±10.39	0.686
HbA1c, %	6.20±1.23	6.19±1.24	0.947

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Variables	Favorable	Unfavorable	*p*-value
Serum glucose, mg/dL	148.8±61.4	154.8±58.3	0.299
Total cholesterol, mg/dL	178.1±49.9	177.1±41.6	0.831
HDL-C, mg/dL	51.1±21.2	48.9±19.5	0.244
LDL-C, mg/dL	104.5±34.8	105.2±31.5	0.837
Triglyceride, mg/dL	141.1±103.4	124.0±80.1	0.244
Pre-interventional details			
Left hemisphere stroke, n (%)	139 (57.9)	102 (53.1)	0.319
Intravenous thrombolysis, n (%)	84 (35.0)	73 (38.0)	0.517
ASPECTS, median (IQR)	9 [8-10]	8 [6-10]	**0.014***
Initial NIHSS, mean±SD	8.1±5.1	13.9±6.6	**<0.001***
Sx to puncture time (min), mean±SD	212±98	298±133	**<0.001***
Procedure detail			
Procedure time (min), mean±SD	34±18	59±36	**0.002***
Successful recanalization, n (%)	235 (97.9)	172 (89.6)	**<0.001***
First pass reperfusion, n (%)	105 (43.8)	62 (32.3)	**0.015***
Clinical outcomes, n (%)			
Symptomatic intracerebral hemorrhage	4 (1.7)	27 (14.1)	**<0.001***
Hemorrhagic transformation	37 (15.4)	62 (32.3)	**<0.001***
Mortality at 3 months	0 (0.0)	39 (20.3)	**<0.001***

Data are presented as n (%), mean±SD and median [IQR].
* Statistically significant
SD, standard deviation; TIA, transient ischemic attack; PLR, platelet-to-lymphocyte ratio; PNR, platelet-to-neutrophil ratio; PWR, platelet-to-white blood cell ratio; HbA1c, glycated hemoglobin; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; ASPECTS, alberta stroke program early CT score; IQR, interquartile range; NIHSS, national institutes of health stroke scale; Sx, symptom

analyses were performed to verify the predicting factors that were independently associated with favorable outcomes and mortality at 3 months. Younger age (<70 yrs) (OR 1.39, 95% CI 1.04–1.63; p=0.022), higher ASPECT (>8) (OR 2.24, 95% CI 1.64–4.08; p=0.012), lower NIHSS at admission (<8) (OR 3.64, 95% CI 2.21–6.01; p=0.002), achievement of successful recanalization (OR 2.27, 95% CI 1.17–4.43; p=0.036), lower occurrence of sICH (OR 0.14, 95% CI 0.04–0.52; p=0.003), decreased PLR value (<145) (OR 1.29, 95% CI 1.06–2.06; p=0.016), and increased PNR value (>41) (OR 1.22, 95% CI 1.10–1.62; p=0.022) were independently associated with favorable outcome at 3 months after MT (Table 2). In addition, greater occurrence of sICH was associated with increased of 3 month mortality (OR 2.23, 95% CI 1.02–4.96; p=0.040); in contrast, younger age (<70 yrs) (OR 0.31, 95% CI 0.12–0.76; p=0.010), lower NIHSS at admission (<70 yrs) (OR 0.37, 95% CI 0.16–0.86; p=0.021), decreased PNR value (<145) (OR 0.83, 95% CI 0.76–0.92; p=0.018), and increased PNR value (>41) (OR 0.94, 95% CI 0.82–0.96; p=0.042) could be predictive factors for a decrease in 3 month mortality (Table 3).

DISCUSSION

In this observational study, lower PLR value with higher PNR and PWR values was identified in patients with favorable prognoses, compared to patients with unfavorable prognoses. The optimal cutoff values of PLR, PNR, and PWR to predict the prognosis of MT were 145, 41, and 25, respectively. Our results revealed that PLR and PNR on admission could be independent predictive factors of prognosis in patients who underwent MT for LVO. Furthermore, there were significant correlations of prognosis after MT with the degree of PLR and PNR.

Atherosclerosis and thrombosis are primarily involved

Table 2. Predictors of favorable clinical outcome in univariate and multivariate logistic regression analyses

	Univariate		Multivariate	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Age (<70 yr)	1.58 (1.02-2.07)	**0.012***	1.39 (1.04-1.63)	**0.022***
Gender (male)	1.19 (0.68-2.06)	0.536		
Hypertension	0.77 (0.44-1.35)	0.363		
Diabetic mellitus	0.92 (0.49-1.71)	0.802		
Atrial fibrillation	1.11 (0.63-1.94)	0.715		
Coronary artery disease	1.68 (0.70-2.22)	0.241		
Prior stroke or TIA	0.54 (0.24-1.18)	0.224		
Dyslipidemia	1.15 (0.68-1.96)	0.594		
Body mass index ≥25 kg/m^2	0.86 (0.48-1.53)	0.613		
PLR (<145)	1.44 (1.04-2.20)	**0.010***	1.29 (1.06-2.06)	**0.016***
PNR (>41)	1.32 (1.08-1.88)	**0.012***	1.22 (1.10-1.62)	**0.022***
PWR (>25)	1.21 (1.06-1.92)	**0.039***	1.14 (0.82-2.02)	0.075
hsCRP (<1 mg/L)	1.22 (1.04-1.64)	**0.042***	1.18 (0.96-1.82)	0.068
Intravenous thrombolysis	0.74 (0.43-1.22)	0.261	1.64 (0.82-3.42)	0.202
ASPECTS (>8)	2.42 (1.44-5.08)	**0.008***	2.24 (1.64-4.08)	**0.012***
Initial NIHSS (<8)	3.76 (2.22-6.34)	**<0.001**	3.64 (2.21-6.01)	**0.002**
Successful recanalization	2.42 (1.03-5.22)	**0.027**	2.27 (1.17-4.43)	**0.036**
First pass reperfusion	1.25 (0.54-1.72)	0.157	1.22 (0.68-1.66)	0.180
sICH	0.14 (0.03-0.54)	**0.002**	0.14 (0.04-0.52)	**0.003**
Hemorrhagic transformation	0.87 (0.68-1.74)	0.227		

* Statistically significant
OR, odds ratio; CI, confidence interval; TIA, transient ischemic attack; PLR, platelet-to-lymphocyte ratio; PNR, platelet-to-neutrophil ratio; PWR, platelet-to-white blood cell ratio; hsCRP, high-sensitivity C-reactive protein; ASPECTS, alberta stroke program early CT score; NIHSS, national institutes of health stroke scale; sICH, symptomatic intracerebral hemorrhage

in the pathogenesis of LVO with AIS, and platelets and WBC subtypes are crucial in these processes.[8] Platelets participate in inflammation and thrombosis by releasing of pro-inflammatory chemokines, and its activation plays an important role in thrombus formation in response to atherosclerotic plaque rupture or endothelial cell erosion.[19][25] Excessive activation and aggregation of platelets may lead to thrombosis with vascular occlusion, and result in cardiovascular and cerebrovascular events.[24] Leukocytes also play a significant role in the vascular inflammatory response and brain damage after AIS.[18] In ischemic brain tissue, neutrophils exaggerate edema and promote the death of neurons by releasing inflammatory mediators and toxic-effective substances.[31] In previous studies, leukocytosis and neutrophilia have been reported to be associated with increased infarct volume and recurrence of stroke.[3][11] On the other hand, lymphocytes are inversely associated with inflammation, and a lower lymphocyte count represents an increased risk of stroke and mortality.[1][24]

The PLR is a novel biomarker of systemic inflammation, and a number of studies has investigated the association of PLR with prognosis of patients with cerebrovascular diseases. Altintas et al. performed a comparative study to assess the relationship of PLR with clinical outcome and final infarct core volume in patients with endovascular therapy for AIS.[1] The patients were divided into two groups based on a PLR level cut-off value of 145, and m-TICI 3 recanalization was more frequent in the low PLR group. Patients with low PLR had more favorable functional outcomes (mRS 0-2) compared to patients with high PLR. Jin et al. showed the prognostic significance of PLR for 3 months prognosis after AIS.[20] Idil Soylu et al. reported that the rate of carotid

Table 3. Predictors of 3 month mortality in univariate and multivariate logistic regression analyses

	Univariate		Multivariate	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Age (< 70 yr)	0.25 (0.09-0.68)	**0.007***	0.31 (0.12-0.76)	**0.010***
Gender (male)	1.56 (0.66-3.72)	0.310		
Hypertension	1.60 (0.67-3.82)	0.289		
Diabetic mellitus	0.54 (0.19-1.49)	0.238		
Atrial fibrillation	0.83 (0.35-1.98)	0.682		
Coronary artery disease	1.29 (0.47-3.51)	0.615		
Prior stroke or TIA	1.17 (0.40-3.43)	0.767		
Dyslipidemia	0.97 (0.39-2.09)	0.818		
Body mass index ≥25 kg/m^2	0.81 (0.24-2.74)	0.742		
PLR (<145)	0.81 (0.74-0.88)	**0.010***	0.83 (0.76-0.92)	**0.018***
PNR (>41)	0.89 (0.80-0.98)	**0.034***	0.94 (0.82-0.96)	**0.042***
PWR (>25)	0.88 (0.80-1.38)	0.082	1.04 (0.89-1.36)	0.135
hsCRP (<1 mg/L)	0.72 (0.62-0.98)	**0.014***	0.82 (0.68-1.10)	0.082
Intravenous thrombolysis	0.98 (0.42-2.27)	0.973		
ASPECTS (>8)	0.60 (0.42-1.44)	0.130	0.61 (0.44-1.28)	0.144
Initial NIHSS (<8)	0.36 (0.15-0.88)	**0.025***	0.37 (0.16-0.86)	**0.021***
Successful recanalization	3.18 (0.51-6.99)	0.220		
First pass reperfusion	0.54 (0.26-1.14)	0.217		
sICH	2.52 (1.05-6.05)	**0.038***	2.23 (1.02-4.96)	**0.040***
Hemorrhagic transformation	1.03 (0.44-2.44)	0.394		

* Statistically significant
OR, odds ratio; CI, confidence interval; TIA, transient ischemic attack; PLR, platelet-to-lymphocyte ratio; PNR, platelet-to-neutrophil ratio; PWR, platelet-to-white blood cell ratio; hsCRP, high-sensitivity C-reactive protein; ASPECTS, alberta stroke program early CT score; NIHSS, national institutes of health stroke scale; sICH, symptomatic intracerebral hemorrhage

artery stenosis was higher in patients with a high PLR value (>163), and PLR was an independent predictor of stroke.[17] Deser et al. revealed that PLR is a predictor of stroke following carotid endarterectomy, with a threshold level of 145.30.[5] These findings were similar to our study in patients who underwent MT, where the optimal cutoff value of PLR to predict a favorable outcome was 145. In addition, PLR less than 145 is an independent predictor of favorable mRS (0-2) and mortality at 3 months, and the proportion of patients with favorable outcome decreased as PLR increased.

There is currently limited amount of research for PNR in patients with stroke. Jin et al. investigated PNR in patients with AIS.[20] The PNR level on admission in the good prognosis group (53.7) was significantly higher than that of the poor prognosis group (44.3), and PLR level was associated with 3 months prognosis after AIS.[20] In our study, patients with favorable outcome (47.1) had higher PNR than those with unfavorable outcome (35.4). Furthermore, PNR (greater than 41) is an independent predictor of favorable outcome and decrease of mortality at 3 months. In terms of PWR, Chen et al. investigated its association with prognosis in AIS patients with IVT and determined that PWR (>23.52) was a predictor of good 3 month outcome.[4] Jin et al. also showed that PWR was correlated with 3 months outcome in patients with AIS, but the accuracy of PWR was lower than that of PNR for predicting prognosis.[20] The results of these studies are different from ours. In our study, the PWR value of patients with favorable outcome (27.7) was higher than for patients with unfavorable outcome (22.4), and 25 was the optimal cut-off value for predicting favorable outcome. However, based on our multivariate analysis, PWR is not an independent predictor of clin-

ical outcome or mortality.

Leukocyte platelet aggregates have been considered as a novel marker of activated platelets, and prior studied have shown that leukocytes can be recruited via platelet secretory components with multiple chemokines and membrane ligands.[4)8)18)27)] Similarly, our study revealed that platelet to WBC subtypes ratios reflect the inflammatory response and are associated with prognosis of MT. In addition to the PLR, PNR, and PWR, we previously conducted an analysis of other inflammation-based scores, including neutrophil to lymphocyte ratios and monocyte to high-density lipoprotein cholesterol ratio which are known to reflect the inflammation status after MT.[29)] The exact mechanism of various hematological factors that reflect the inflammation status have not been clarified, but they are helpful in predicting the prognosis of patients with MT, and further research is needed.

There were some limitations to our study. First, this was a retrospective study with a relatively small sample size, which may induce selection bias and allow for errors in data interpretation. Second, unmeasured laboratory findings, such as platelet distribution width and mean platelet volume, could have contributed to the results of our study, although we adjusted our analyses for possible confounding variables. Third, we only measured laboratory data once on admission and did not evaluate dynamic changes with repeated measurements of laboratory findings at different time points. Fourth, other various disease or past history of drug use that we did not include in this study could affect the inflammatory reaction and results of our analyses. However, every effort was made to adjust for the possibility of confounding factors when we analyzed the data and interpreted the results.

CONCLUSIONS

Our study shows the clinical importance of PLR and PNR in MT for LVO. PLR and PNR on admission could be predictive factors of prognosis and mortality at 3 months in patients with MT. Furthermore, decreasing PLR and increasing PNR are independent factors for predicting favorable prognoses of patients who underwent MT. Further investigation is required to verify the results of our study and identify the mechanisms behind these findings.

ACKNOWLEDGEMENTS

This work was supported by the Soonchunhyang University Research Fund.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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