Leukocyte Count and Neutrophil-To-Lymphocyte Ratio as Simple Hematologic Predictors of Stroke Severity and Functional Outcome in Acute Ischemic Stroke Patients

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Abstract:
Background: It has long been recognized that inflammation plays a critical role in the pathogenesis of ischemic stroke. However, whether leukocyte count and neutrophil-to-lymphocyte ratio are related to stroke severity and functional outcome is uncertain.

Objective: This clinical study aimed to evaluate the association of leukocyte count and neutrophil-to-lymphocyte ratio with stroke severity and functional outcome in acute ischemic stroke patients.

Methods: This hospital-based, retrospective observational study included 112 subjects with acute ischemic stroke. All subjects had their demographic, clinical, and laboratory data obtained. The leukocyte count and neutrophil-to-lymphocyte ratio were evaluated by stroke severity on admission and 3-month functional outcome. The severity of stroke at admission was measured using the National Institutes of Health Stroke Scale (NIHSS), whereas the Barthel Index was used to measure 3-month functional outcome (BI). We conducted a regression analysis, adjusting for any confounding variables.

Results: Higher leukocyte count was significantly associated with increased risk of stroke severity (odds ratio [OR] 1.391, 95% confidence intervals [CI], 1.121-1.725, p: 0.003) and unfavorable functional outcome (OR 1.434, 95% CI, 1.068-1.925, p: 0.017). Higher neutrophil-to-lymphocyte ratio was not significantly associated with increased risk of stroke severity (OR 1.181, 95% CI, 0.947-1.474, p: 0.140) and unfavorable functional outcome (OR 1.246, 95% CI, 0.905-1.716, p: 0.177).

Conclusion: Our study indicates that leukocyte count is an independent predictor of stroke severity on admission and unfavorable functional outcome.

Keywords: Ischemic stroke, Inflammation, Leukocyte count, Neutrophil-to-lymphocyte ratio, Prognosis, Stroke.

1. INTRODUCTION

A stroke is a neurological deficit classically defined as an acute focal injury to the central nervous system caused by a vascular cause, such as cerebral infarction, intracerebral hemorrhage, or subarachnoid hemorrhage. It is a leading cause of disability and death worldwide. Ischemic stroke refers to an episode of neurological impairment induced by a focal cerebral, spinal, or retinal infarction [1]. After ischemic heart disease, stroke is the second leading cause of mortality worldwide. Additionally, stroke was the second largest cause of disability-adjusted life years globally. Ischemic strokes accounted for 84.4% (82.1–86.4) of all strokes [2].

Inflammation is a crucial factor in the pathophysiology of
ischemic stroke, with a complex process. Both pro-inflammatory and anti-inflammatory mediators have a role in the pathophysiology of ischemic stroke, and an imbalance between the two results in inflammation. Early leukocytosis is associated with the volume of infarcted tissue in patients with acute ischemic stroke [3]. Neutrophils are the first leukocyte subtype recruited to ischemic brain injury; lymphocytes were recruited following neutrophils [4 - 7].

Leukocyte counts and ratios (for example, the neutrophil-to-lymphocyte ratio) in peripheral blood have been shown to be good predictors of outcome [8, 9]. Prognosis assessment of acute ischemic stroke patients sooner and accurately may minimize the consequences of ischemic stroke. As a result, it is critical to identify novel predictors capable of predicting stroke severity and functional outcome in patients with acute ischemic stroke. This clinical study aimed to evaluate the association of leukocyte count and neutrophil-to-lymphocyte ratio with stroke severity and functional outcome in acute ischemic stroke patients.

2. MATERIALS AND METHODS

2.1. Study Design and Subjects

This was a hospital-based, retrospective observational study conducted from March to June 2021 at the Bethesda Hospital's Stroke Center, Yogyakarta, Indonesia. The study's inclusion criteria were as follows: (i) male or female above the age of 18 years old, (ii) stroke onset within 24 hours, (iii) complete radiological and laboratory data. Patients were excluded if they were: (i) discharged according to medical advice, (ii) referred to another hospital, (iii) patients with infection from any origin, (iv) received anti-inflammatory or immunosuppressant medications. During this study, all participants got the same treatment and underwent the same rehabilitation, adjusted to each patient's needs.

2.2. Clinical Data

The clinical data obtained included demographic information (age, gender), medical history (hypertension, diabetes mellitus, dyslipidemia, and atrial fibrillation), muscle strength, and laboratory findings. Venous blood samples of all subjects were taken upon admission and analyzed within 24 hours of admission. The NIHSS score was used to determine stroke severity on admission; meanwhile, the Barthel Index (BI) was used to determine functional outcomes 30 days following stroke onset. The NIHSS score measures stroke severity on a scale of 0 to 42, with higher scores indicating more severe stroke severity [10]. Stroke severities were classified into two categories based on the National Institutes of Health Stroke Scale (NIHSS) on admission: those with mild stroke (NIHSS <6) and those with moderate-to-severe stroke (NIHSS ≥6) [11]. The Barthel Index (BI) is a 10-item assessment that measures basic activities of daily living (ADL) on a scale ranging from 0 to 100 [12]. A previous study used a cutoff score of 50 for the Barthel Index to define a favorable outcome; a score of ≥50 indicates a favorable outcome, whereas a score of <50 indicates an unfavorable outcome [13].

2.4. Statistical Analysis

Percentages are used to describe categorical variables, while medians represent numerical variables (interquartile range). After adjusting for confounding variables, multivariate logistic regression was performed to determine whether higher leukocyte count and NLR predicted worse stroke severity and functional outcome in patients with acute ischemic stroke. Potential confounding variables included age, gender, hypertension, diabetes mellitus, dyslipidemia, atrial fibrillation, muscle strength, random blood glucose, total cholesterol, triglycerides, low-density lipoproteins, and high-density lipoproteins. Odds ratios were obtained with 95% confidence intervals. Statistical significance was defined as a 2-sided p-value of <0.05. The area under the curve (AUC) and 95% confidence intervals for the neutrophil-to-lymphocyte ratio and leukocyte count were determined using receiver operating characteristic (ROC) curve analysis. The analysis was conducted using SPSS Statistics version 21.0 software. Missing data will be imputed.

2.5. Ethical Considerations

This study adhered to the ethical standards outlined in the 1964 Declaration of Helsinki and its subsequent amendments and was approved by the Ethics Committee of Bethesda Hospital, Yogyakarta, Indonesia, with an approval number of 19/KEP-RSB/I/21.

3. RESULTS

3.1. Baseline Characteristics

The current study included 122 subjects; 65 (58%) were male and 47 (42%) were female, with the majority of subjects aged 51 to 70. The baseline characteristics of the subjects are shown in Table 1. Hypertension (53.6%) was the most frequent comorbidity among all subjects, followed by dyslipidemia (26.8%), diabetes mellitus (24.1%), and atrial fibrillation (1.8%). The majority of subjects (64.3%) demonstrated muscle power on a scale of 4, which equates to active movement against gravity and resistance, according to the Medical Research Council’s (MRC) muscle strength scale. The median leukocyte count and NLR obtained at admission were 9.10 x 10^9/L (4.89 - 18.40) and 2.86 (0.64 - 21.00) consecutively.

3.2. Stroke Severity and Functional Outcome

Thirty-six (32.1%) subjects had mild stroke severity and 76 (67.9%) subjects had moderate to severe stroke severity on admission, whereas 7 (6.3%) subjects had an unfavorable functional outcome and 105 (93.8%) subjects had a favorable functional outcome 3 months following stroke onset (Table 1).
Table 1. Baseline characteristics of subjects.

| Age (years) | n= 112 |
|-------------|--------|
| ≤ 50        | 10 (8.9%) |
| 51-60       | 38 (33.9%) |
| 61-70       | 38 (33.9%) |
| > 70        | 26 (23.2%) |

| Gender   | n= 112 |
|----------|--------|
| Male     | 65 (58.0%) |
| Female   | 47 (42.0%) |

| Comorbidities | n= 112 |
|---------------|--------|
| Hypertension  | 60 (53.6%) |
| Diabetes mellitus | 30 (26.8%) |
| Dyslipidemia  | 27 (24.1%) |
| Atrial fibrillation | 2 (1.8%) |

| Muscle strength (MRC scale) | n= 112 |
|-----------------------------|--------|
| 0-no contraction            | 0 (0%) |
| 1-Flicker or trace of contraction | 2 (1.8%) |
| 2-Active movement, with gravity eliminated | 8 (7.1%) |
| 3-Active movement against gravity | 25 (22.3%) |
| 4-Active movement against gravity and resistance | 72 (64.3%) |
| 5-Normal power              | 5 (4.5%) |

| Stroke Severity | n= 112 |
|-----------------|--------|
| Mild stroke severity (NIHSS <6) | 36 (32.1%) |
| Moderate to severe stroke severity (NIHSS ≥6) | 76 (67.9%) |

| Functional Outcome | n= 112 |
|--------------------|--------|
| Unfavorable functional outcome (BI <50) | 7 (6.3%) |
| Favorable functional outcome (BI ≥50) | 105 (93.8%) |

| Laboratory Findings–Median (IQR) | n= 112 |
|-----------------------------------|--------|
| Leukocyte count (x10^9/L)         | 9.10 (4.89 - 18.40) |
| NLR                               | 2.86 (0.64 - 21.00) |
| Random blood glucose (mmol/L)     | 8.02 (5.33 - 41.90) |
| Total cholesterol (mmol/L)        | 10.96 (5.63 - 17.98) |
| Triglycerides (mmol/L)            | 9.75 (3.00 - 35.46) |
| Low-density lipoproteins (mmol/L) | 7.42 (3.44 - 12.54) |
| High-density lipoproteins (mmol/L)| 2.25 (1.00 - 3.70) |

Abbreviations: BI, Barthel Index; IQR, Interquartile Range; MRC, Medical Research Council; NIHSS, National Institutes of Health Stroke Scale; NLR: Neutrophil-to-Lymphocyte Ratio.

Higher leukocyte count (OR 1.357, 95% CI, 1.063-1.734, p: 0.014) and NLR (OR 1.609, 95% CI, 1.201-2.155, p: 0.001) were significantly related to a worse functional outcome 3 months after stroke onset. Higher leukocyte count (OR 1.247, 95% CI 1.056-1.473, p 0.009) was also associated with an increased risk of worse stroke severity on admission. Meanwhile, a higher NLR (OR 1.039, 95% CI, 0.895-1.206, p = 0.167) was not significantly related to an increased risk of worse stroke severity on admission. Following adjustment for age, gender, hypertension, diabetes mellitus, dyslipidemia, atrial fibrillation, muscle strength, random blood glucose, total cholesterol, triglycerides, low-density lipoproteins, and high-density lipoproteins, higher leukocyte count was found to be an independent risk factor for moderate to severe stroke (OR 1.391, 95% CI, 1.121-1.725, p: 0.003) and unfavorable functional outcome (OR 1.434, 95% CI, 1.068-1.925, p: 0.017) (Table 2).

Table 2. Risk of stroke severity and functional outcome according to NLR and leukocyte count on admission.

|                       | Leukocyte Count on Admission | NLR on Admission |
|-----------------------|------------------------------|------------------|
| **Moderate to severe stroke severity (NIHSS ≥6)** | | |
| Crude OR (95% CI)     | 1.247 (1.056-1.473; p: 0.009) | 1.039 (0.895-1.206; p: 0.167) |
| Adjusted OR (95% CI)  | 1.391 (1.121-1.725; p: 0.003) | 1.181 (0.947-1.474; p: 0.140) |

| **Unfavorable functional outcome (BI <50)** | | |
| Crude OR (95% CI)     | 1.357 (1.063-1.734; p: 0.014) | 1.609 (1.201-2.155; p: 0.001) |
| Adjusted OR (95% CI)  | 1.434 (1.068-1.925; p: 0.017) | 1.246 (0.905-1.716; p: 0.177) |

Abbreviations: BI, Barthel Index; CI, Confidence Interval; NIHSS, National Institutes of Health Stroke Scale; NLR, Neutrophil-to-Lymphocyte Ratio, OR: Odds Ratio.
In the receiver operating characteristic curve analysis, the optimal cutoff value of leukocyte count for prediction of stroke severity was $8.94 \times 10^9/L$ with a sensitivity of 57.9% and a specificity of 58.3% (area under the curve: 0.651, 95% CI 0.545-0.757; $p$: 0.010), and for prediction of unfavorable functional outcome was $9.44 \times 10^9/L$ with a sensitivity of 57.1% and a specificity of 62.9% (area under the curve: 0.752, 95% CI 0.595-0.910; $p$: 0.026) (Fig. 1). The optimal cutoff value of NLR for predicting stroke severity was 2.81 with a sensitivity of 53.9% and a specificity of 52.8% (area under the curve: 0.517, 95% CI 0.401-0.633; $p$: 0.772), and for prediction of unfavorable functional outcome was 3.85 with a sensitivity of 71.4% and a specificity of 71.4% (area under the curve: 0.883, 95% CI 0.773-0.993; $p$: 0.001) (Fig. 2).

The results (OR) are reported per 1 increase in NLR and per $1 \times 10^9$ increase in leukocyte count.

Multivariable model: adjusted for age, gender, hypertension, diabetes mellitus, dyslipidemia, atrial fibrillation, muscle strength, random blood glucose, total cholesterol, triglycerides, low-density lipoproteins, and high-density lipoproteins.

4. DISCUSSION

This clinical study aimed to evaluate whether the neutrophil-to-lymphocyte ratio and leukocyte count are associated with stroke severity and functional outcome in acute ischemic stroke patients. Our findings indicate that a higher NLR is associated with worse stroke severity and a less favorable 3-month functional outcome, whereas a higher leukocyte count is significantly associated with worse stroke severity and a worse 3-month functional outcome. Numerous studies have established that leukocyte count is a significant independent predictor of stroke severity, disability, and overall mortality following ischemic stroke [14, 15]. Furthermore, an elevated leukocyte count has been linked to recurrent ischemic stroke and the presence of large vessel occlusion [16, 17].

Immune cell activation is one of the earliest biological reactions discovered following ischemic stroke, indicating that the ischemic brain and the peripheral immune system are closely related. Ischemic brain injury causes a local inflammatory response and a systemic and sterile inflammatory response [18]. A prior study indicated that shortly following the onset of ischemic stroke, the neutrophil count increased exponentially, whereas the lymphocyte count decreased exponentially [19].

At stroke onset, the hypothalamo-pituitary-adrenal axis, the sympathetic–adrenal–medullary axis, and the parasympathetic nervous system (vagus nerve) are all implicated in immune response modulation [20]. During the first 24 hours following stroke onset, growth factors and chemokines promote neutrophils in the bone marrow, facilitating neutrophil transport and contributing to neutrophilia [21, 22]. Elevated catecholamine levels are related to increased lymphocyte apoptosis, leading to a reduction in peripheral blood lymphocytes [23 - 25]. Lymphocytes aggregate in the ischemic brain three to six days following stroke, whereas neutrophils accumulate sooner [26].

![Fig. (1). The receiver operating characteristic (ROC) curve of leukocyte count to determine the optimal cutoff values of (A) stroke severity on admission, (B) functional outcome.](image)

Abbreviations: AUC, Area under the curve; CI, Confidence interval.
The inflammatory process is critical in ischemic stroke, and a higher leukocyte count in individuals with acute ischemic stroke is correlated with a worse outcome. The effect of leukocyte recruitment is controversial; while these cells may contribute to tissue regeneration, their deleterious consequences are more pronounced [27]. Increased numbers and activity of circulating leukocytes have been previously hypothesized to actively contribute to organ ischemia by increased adhesion to and disruption of the endothelium [28]. Proteases, inflammatory mediators, and free radicals released by leukocytes may cause proteolytic and oxidative damage to endothelial cells [16]. Moreover, since leukocytes are larger than all other blood cells, they may directly clog the microvasculature [29]. Some studies hypothesized that the negative effect of the increased neutrophil count could be related to neutrophils releasing matrix metalloproteinase-9, free oxygen radicals, and other inflammatory mediators, resulting in disruption of the blood-brain barrier (BBB), brain edema, and subsequent brain injury [4 - 7]. The lymphocytes' role in acute ischemic stroke is debatable. Several studies established that lymphocytes can repair inflammation-induced damage [4, 30]. However, other studies have reported that lymphocytes can emit proinflammatory cytokines and cytotoxic chemicals, resulting in brain injury in ischemia patients [30, 31]. Leukocyte count has also been demonstrated to be an independent predictor of recurrent coronary events in previous studies [32, 33]. Moreover, recent publications have also highlighted the association between NLR and carotid artery stenosis [34, 35].

Several limitations should be considered. Laboratory results for this study were only available at the time of admission. Since stroke-induced inflammation is a dynamic process that could vary dramatically even within the first 24 hours following a stroke, further research is needed to examine blood samples at various time intervals following a stroke. This study made no distinction between subtypes of ischemic stroke. In future investigations, the NLR and leukocyte count should be evaluated in various subtypes of ischemic stroke. Patients who underwent reperfusion therapy and those who did not get reperfusion therapy were not divided in this study. In addition, this study did not further differentiate the types of anti-diabetic medicines the patients received. Future studies are necessary to categorize patients on reperfusion therapy since reperfusion might cause an improvement in the inflammatory process, as well as identify patients' anti-diabetic medicines since some medications may have anti-inflammatory activity.

**CONCLUSION**

Our study indicates that leukocyte count is an independent predictor of stroke severity upon admission and unfavorable functional outcome. Additionally, the findings of this study provide possibilities for future studies into the potential utility of anti-inflammatory therapy for patients with acute ischemic stroke.

**AUTHORS’ CONTRIBUTIONS**

RTP is responsible for the investigation, initial manuscript, data processing, and supervision. VV is responsible for the initial manuscript, data processing, and editing.
**LIST OF ABBREVIATIONS**

- NIHSS = The National Institutes of Health Stroke Scale
- BI = Barthel Index
- AUC = Area Under the Curve
- ROC = Receiver Operating Characteristic

**ETHICS APPROVAL AND CONSENT TO PARTICIPATE**

This study was approved by the Ethics Committee of Bethesda Hospital, Yogyakarta, Indonesia, with an approval number of 19/KEP-RSB/II/21.

**HUMAN AND ANIMAL RIGHTS**

No animals were used for studies that are the basis of this research. All the humans were used in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national), and with the Helsinki Declaration of 1964 and its subsequent amendments.

**CONSENT FOR PUBLICATION**

The authors acquired the patients’ written consent for the involvement in and publishing of this study.

**STANDARDS OF REPORTING**

STROBE guidelines were followed.

**AVAILABILITY OF DATA AND MATERIALS**

The data that support the findings of this study are available from the corresponding author, [R.T.P], on special request.

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**CONFLICT OF INTEREST**

The authors declare no conflict of interest, financial or otherwise.

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**REFERENCES**

[1] Sacco RL, Kasner SE, Broderick JP, et al. An updated definition of stroke for the 21st century: A statement for healthcare professionals from the American Heart Association/American Stroke Association. Stroke 2013; 44(7): 2064-89. [http://dx.doi.org/10.1161/STR.0b013e3182964eeac] [PMID: 23652265]

[2] Johnson CO, Nguyen M, Roth GA, et al. Global, regional, and national burden of stroke, 1990-2016: A systematic analysis for the Global Burden of Disease Study 2016. Lancet Neurol 2019; 18(5): 439-58. [http://dx.doi.org/10.1016/S1474-4422(19)30034-1] [PMID: 30871944]

[3] Back BH, Liebeskind DS, Saver JL, et al. Early neutrophilia is associated with volume of ischemic tissue in acute stroke. Stroke 2008; 39(2): 355-60. [http://dx.doi.org/10.1161/STROKEAHA.107.490128] [PMID: 18162626]

[4] Maestrelli I, Srbian D, Gautier S, et al. Higher neutrophil counts before thrombolysis for cerebral ischemia predict worse outcomes. Neurology 2015; 85(16): 1408-16. [http://dx.doi.org/10.1212/WNL.0000000000002029] [PMID: 26362283]

[5] Frangogiannis N, Smith CW, Entman ML. The inflammatory response in myocardial infarction. Cardiovasc Res 2002; 53(1): 31-47. [http://dx.doi.org/10.1016/S0006-6373(01)00434-5] [PMID: 11744011]

[6] Ceulemans AG, Zagac T, Kooijman R, Hachimi-Idrissi S, Sarre S, Michotte Y. The dual role of the neuroinflammatory response after ischemic stroke: Modulatory effects of hypothermia. J Neuroinflammation 2010; 7(1): 17. [http://dx.doi.org/10.1186/1742-2094-7-174] [PMID: 21040547]

[7] Petrovic-Djorgovic D, Groenewarden SN, Pinsky DJ. Inflammatory disequilibrium in stroke. Circ Res 2016; 119(1): 142-58. [http://dx.doi.org/10.1161/CIRCRESAHA.116.308022] [PMID: 27340273]

[8] Song SY, Zhao XX, Rajah G, et al. Clinical significance of baseline neutrophil-to-lymphocyte ratio in patients with ischemic stroke or hemorrhagic stroke: An updated meta-analysis. Front Neurol 2019; 10: 1032. [http://dx.doi.org/10.3389/fneur.2019.01032] [PMID: 31636598]

[9] Liu H, Wang R, Shi J, et al. Baseline neutrophil counts and neutrophil ratio may predict a poor clinical outcome in minor stroke patients with intravenous thrombolysis. J Stroke Cerebrovasc Dis 2019; 28(11): 104340. [http://dx.doi.org/10.1016/j.jstrokecerebrovasdis.2019.104340] [PMID: 31462383]

[10] Brott T, Adams HP Jr, Olinger CP, et al. Measurements of acute cerebral infarction: A clinical examination scale. Stroke 1989; 20(7): 864-70. [http://dx.doi.org/10.1161/01.STR.20.7.864] [PMID: 2749846]

[11] Ducrocqet A, Leys D, Saabi AA, et al. Influence of chronic ethanol consumption on the neurological severity in patients with acute cerebral ischemia. Stroke 2013; 44(8): 2324-6. [http://dx.doi.org/10.1161/STROKEAHA.113.001355] [PMID: 23686975]

[12] Mahoney FI, Barthel DW. Functional evaluation: The BARTHEL Index. Md State Med J 1965; 14: 61-5. [PMID: 14526950]

[13] Franke CL, Palm R, Dalby M, et al. Flumaronzine in stroke treatment (FIST): A double-blind, placebo-controlled trial in Scandinavia and the Netherlands. Acta Neurol Scand 1996; 93(1): 56-60. [http://dx.doi.org/10.1111/j.1600-4049.1996.tb00171.x] [PMID: 8825274]

[14] Furlan JG, Vergouwen M, Fanger J, Silver FL. White blood cell count is an independent predictor of outcomes after acute ischaemic stroke. Eur J Neurol 2014; 21(2): 215-22. [http://dx.doi.org/10.1111/ene.12233] [PMID: 23848934]

[15] Quan K, Wang A, Zhang X, Wang Y. Leukocyte count and adverse clinical outcomes in acute ischemic stroke patients. Front Neurol 2019; 10: 1240. [http://dx.doi.org/10.3389/fneur.2019.01240] [PMID: 32038447]

[16] Grau AJ, Boddy AW, Dukovic DA, et al. Leukocyte count as an independent predictor of recurrent ischemic events. Stroke 2004; 35(5): 1147-52. [http://dx.doi.org/10.1161/01.STR.0000124212.71702.64] [PMID: 15077613]

[17] Tarkanyi G, Karadi ZN, Szabo Z, Szegedi I, Csiba L, Szapary L. Relationship between leukocyte counts and large vessel occlusion in acute ischemic stroke. BMC Neurol 2020; 20(1): 440. [http://dx.doi.org/10.1186/s12883-020-00917-3] [PMID: 32772235]

[18] Iadecola C, Anrather J. The immunology of stroke: From mechanisms to translation. Nat Med 2011; 17(7): 796-808. [http://dx.doi.org/10.1038/nm.2399] [PMID: 21738161]

[19] Gill D, Sivakumar P, Aravind A, Tank A, Dush R, Velkamp R. Temporal trends in the levels of peripherally circulating leukocyte subtypes in the hours after ischemic stroke. J Stroke Cerebrovasc Dis 2018; 27(1): 198-202. [http://dx.doi.org/10.1016/j.jstrokecerebrovasdis.2017.08.023] [PMID: 30871944]
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Meisel C, Schwab JM, Prass K, Meisel A, Dirnagl U. Central nervous system injury-induced immune deficiency syndrome. Nat Rev Neurosci 2005; 6(10): 775-86. [http://dx.doi.org/10.1038/nrn1765] [PMID: 16163382]

Cai W, Liu S, Hu M, et al. Functional dynamics of neutrophils after ischemic stroke. Transl Stroke Res 2020; 11(1): 108-21. [http://dx.doi.org/10.1007/s12975-019-00694-y] [PMID: 30847778]

de Jager CPC, Wever PC, Gemen EFA, et al. The neutrophil-lymphocyte count ratio in patients with community-acquired pneumonia. PLoS One 2012; 7(10): e46561. [http://dx.doi.org/10.1371/journal.pone.0046561] [PMID: 23049706]

Vogelgesang A, Becker KJ, Dressel A. Immunological consequences of ischemic stroke. Acta Neurol Scand 2014; 129(1): 1-12. [http://dx.doi.org/10.1111/ane.12165] [PMID: 23848237]

Otxoa-de Amezaga A, Miro-Mur F, Pedragosa I, et al. Microglial cell loss after ischemic stroke favors brain neutrophil accumulation. Acta Neuropathol 2019; 137(2): 321-41. [http://dx.doi.org/10.1007/s00401-018-1954-4] [PMID: 30580383]

Li GZ, Zhong D, Yang LM, et al. Expression of interleukin-17 in ischemic brain tissues. Scand J Immunol 2005; 62(5): 481-6. [http://dx.doi.org/10.1111/j.1365-3083.2005.01683.x] [PMID: 16305645]

Rasouli M, Nesarhosseini V, Kiasati AM, et al. The multiplicative interactions of leukocyte counts with some other risk factors enhance the prognostic value for coronary artery disease. Cardiol J 2011; 18(3): 246-53. [PMID: 21660912]

Schwartz M, Moalem G. Beneficial immune activity after CNS injury: Prospects for vaccination. J Neuroimmunol 2001; 113(2): 185-92. [http://dx.doi.org/10.1016/S0165-5728(00)00447-1] [PMID: 11164901]

Schlant RC, Forman S, Stanler J, Canner PL. The natural history of coronary heart disease: Prognostic factors after recovery from myocardial infarction in 2789 men. The 5-year findings of the coronary drug project. Circulation 1982; 66(2): 401-14. [http://dx.doi.org/10.1161/01.CIR.66.2.401] [PMID: 7094247]

Lowe GDO, Machado SG, Krol WF, Barton BA, Forbes CD. White blood cell count and haematocrit as predictors of coronary recurrence after myocardial infarction. Thromb Haemost 1985; 54(3): 700-3. [http://dx.doi.org/10.1055/s-0038-1660101] [PMID: 4089799]

Köklü E, Yüksel İÖ, Arslan Ş, et al. Is elevated neutrophil-to-lymphocyte ratio a predictor of stroke in patients with intermediate carotid artery stenosis? J Stroke Cerebrovasc Dis 2016; 25(3): 578-84. [http://dx.doi.org/10.1016/j.jstrokecerebrovasdis.2015.10.031] [PMID: 26706445]

Hyun S, Kwon S, Cho S, et al. Can the neutrophil-to-lymphocyte ratio appropriately predict carotid artery stenosis in patients with ischemic stroke?—A retrospective study. J Stroke Cerebrovasc Dis 2015; 24(11): 2646-51. [http://dx.doi.org/10.1016/j.jstrokecerebrovasdis.2015.07.024] [PMID: 26316355]

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