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Role of platelet-to-lymphocyte ratio at the time of arrival to the emergency room as a predictor of short-term mortality in trauma patients with severe trauma team activation

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Background: Platelet-to-Lymphocyte ratio (PLR) has been studied as a prognostic factor for various diseases and traumas. This study examined the utility of PLR as a tool for predicting 30-day mortality in patients experiencing severe trauma.

Methods: This study included 139 patients who experienced trauma and fulfilled ≥1 criteria for activation of the hospital's severe trauma team. Patients were divided into non-survivor and survivor groups. Mean PLR values were compared between the groups, the optimal PLR cut-off value was determined, and mortality and survival analyses were performed. Statistical analyses were performed using SPSS ver. 26.0. The threshold of statistical significance was P<0.05.

Results: There was a significant difference in mean (±standard deviation) PLR between the non-survivor (n=36) and survivor (n=103) groups (53.4±30.1 vs. 89.9±53.3, respectively; P<0.001). Receiver operating characteristic (ROC) curve analysis revealed an optimal PLR cut-off of 65.35 (sensitivity, 0.621; specificity, 0.694, respectively; area under the ROC curve, 0.742), and Kaplan-Meier survival analysis revealed a significant difference in mortality rate between the two groups.

Conclusions: PLR can be calculated quickly and easily from a routine complete blood count, which is often performed in the emergency department for individuals who experience trauma. The PLR is useful for predicting 30-day mortality in trauma patients with severe trauma team activation.

Key Words: blood platelets; lymphocytes; mortality; multiple trauma

Original Article

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INTRODUCTION

Trauma is a major cause of death worldwide [1]. Prolonged response and transport times for individuals who experience trauma is associated with a decreased survival rate; therefore, rapid diagnosis and treatment are critical [2]. Accordingly, various studies are underway to improve the prognosis of trauma patients through rapid diagnosis and treatment. Studies investigating trauma team activation guidelines for quick and appropriate treatments have been reported [3,4]. In addition, some studies have aimed to predict the prognosis of trauma

patients to improve survival rates [5-7]. It is believed that a biomarker that can quickly predict prognosis would be helpful in monitoring and treating this patient population.

The platelet-to-lymphocyte ratio (PLR) is the ratio of platelet count to lymphocyte count and is used as a biomarker for systemic inflammatory response. It can be calculated quickly and inexpensively using data from a routine complete blood count investigation. It has been identified as a prognostic predictor in patients with cancer, cardiovascular diseases, pulmonary diseases, and sepsis [8-11]. Trauma-related research has reported the utility of PLR as a prognostic predictor for organ damage, such as abdominal trauma and brain injury [12,13]. A significant correlation between PLR and patient prognosis for the aforementioned diseases and trauma has been reported. Until now, no studies have focused on patients with severe trauma team activation. As such, this study aimed to determine the utility of PLR as a tool for predicting short-term mortality in trauma patients with severe trauma team activation to help improve survival rates.

KEY MESSAGES

- Platelet to lymphocyte ratio (PLR) has been studied as a prognostic predictor in various medical diseases, and single organ damage and single trauma mechanism.
- This study showed that PLR obtained at the time of admission to the emergency room in trauma patients with severe trauma team activation can predict short-term mortality.
- A low PLR is associated with high short-term mortality in severe trauma patients.

MATERIALS AND METHODS

This retrospective study included patients who experienced severe trauma and were transported to the emergency department of a tertiary hospital in South Korea between January 2020 and June 2023. This study was approved by the Institutional Review Board of Chosun University Hospital (No. CHOSUN 2023-09-016). Because of the retrospective nature of this study, the requirement for patient consent was waived.

All data were obtained from electronic medical records. This study involved trauma patients ≥18 years of age who fulfilled ≥1 of the criteria for activation of the hospital's severe trauma team (Table 1) [14]. Individuals <18 years of age, those transferred from another hospital, those with chronic kidney disease, insufficient medical records, and death on arrival were excluded from the study. Among patients who were transported to the hospital's emergency department for trauma during the study period, 249 fulfilled the criteria for activation of the severe trauma team. Ultimately, 139 patients were enrolled and 110 were excluded from this study (Figure 1). The non-survivor group included patients who died within 30 days of arrival to the emergency department, while the survivor group included patients who survived >30 days. Data including age, sex, Glasgow coma scale (GCS) score, blood pressure, heart rate, Acute Physiology and Chronic Health Evaluation (APACHE) II score, Injury Severity Score (ISS), Abbreviated Injury Scale (AIS) score, Transfusions, trauma mechanism, emergency surgery, and laboratory values (complete blood count, electrolyte, blood urea nitrogen, and creatinine levels, arterial blood gas analysis findings, lactate, and PLR) were analyzed to determine whether there were significant differences between groups (Tables 2 and 3). Emergency surgery was performed based on surgical indications and physician judgement. All statistical analyses were performed using IBM SPSS ver. 26.0 (IBM Corp.). The Shapiro-Wilk test was performed to confirm normal distribution of the data. Continuous variables

Table 1. Criteria for severe trauma team activation

Physiological parameter	Injury patterns	Me chanism of injury
Systolic blood pressure <90 mm Hg after trauma	Penetrating injuries of neck and truck	Fall from height >3 m
Glasgow coma scale score <9 after trauma	Gunshot injuries of neck and trunk	Road traffic accident
Breathing disturbance/need for intubation after trauma	Fractures of more than two proximal bones	Frontal collision with intrusion of more than 50 to 75 cm
	Unstable thorax, unstable pelvic fracture	Changes in velocity of delta >30 km/hr
	Amputation proximal to heads/feet	Pedestrian/motorcycle collision
	Injuries with neurological signs of paraplegia	Death of a passenger
	Open cranial injury	Ejection of a passenger
	Burns >20%	

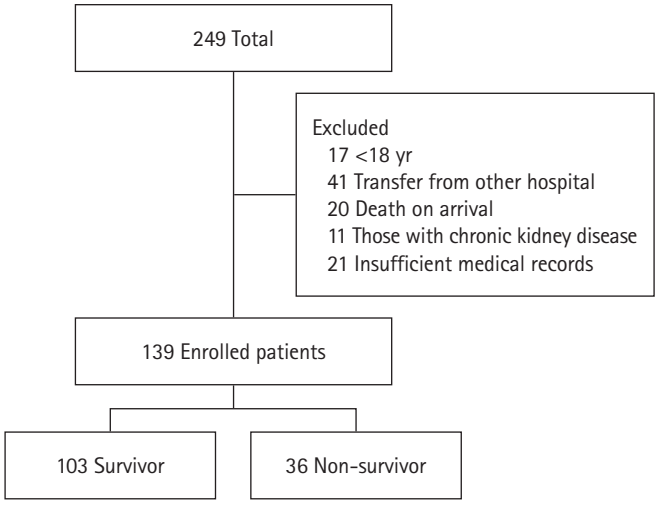

Figure 1. Flow diagram of patient enrollment.

are expressed as mean±standard deviation, and categorical variables are expressed as frequency and percentage. Student t-test was used to compare the continuous variables, and the chi-square test with Fisher's exact test for categorical variables. Multivariate analysis was performed using logistic regression for variables that were significant in the univariate analysis. Receiver operating characteristic (ROC) curve analysis was used to determine the appropriate PLR cut-off value for predicting mortality. Kaplan-Meier survival analysis was performed to analyze the cumulative survival rate according to PLR cut-off value. Differences with P<0.05 were considered to be statistically significant.

RESULTS

We studied a total of 139 patients meeting the study criteria (Table 1). Thirty-six patients (25.9%) died within 30 days of admission to the emergency department, and 103 (74.1%) survived (Figure 1).

In the comparative analysis between the non-survivor and the survivor groups, significant differences were observed in GCS (P<0.001), systolic blood pressure (P=0.025), diastolic blood pressure (P=0.002), mean arterial pressure (P=0.014), APACHE II (P<0.001), ISS (P<0.001), head and neck AIS (P<0.001), abdominal AIS (P=0.034), transfusion (red blood cell [RBC] <4 hr, P=0.011; RBC <24 hr, P=0.004; fresh frozen plasma [FFP] <4 hr, P=0.006; FFP <24 hr, P<0.001; platelet [PLT] <4 hr, P=0.040; PLT <24 hr, P=0.010), and emergency operation (P=0.027) (Table 2).

There were no significant differences between the two groups in terms of age, sex, heart rate, facial AIS, chest AIS, extremity AIS, external AIS, cryoprecipitate transfusion, or trauma mechanism (Table 2). PLR, from blood tests performed immediately after transport to the emergency department, significantly differed (P<0.001) between the non-survivor and survivor groups, at 53.35 (±30.14) versus 89.92 (±53.31), respectively. Other variables that were significantly different between the two groups include hemoglobin (P=0.029), platelets (P=0.022), potassium (P=0.016), pH (P=0.002), base deficit (P=0.001), and lactate (P<0.001) (Table 3). Multivariate logistic regression analysis was performed on variables that significantly differed between the two groups in the univariate analysis. Results revealed significant between-group differences in PLR (odds ratio [OR], 1.036; 95% confidence interval [CI], 1.013–1.059; P=0.002), ISS (OR, 0.9; 95% CI, 0.830–0.976; P=0.011), diastolic blood pressure (OR, 1.171; 95% CI, 1.043–1.315; P=0.008), MAP (OR, 1.084; 95% CI, 1.009–1.164; P=0.027), head and neck AIS (OR, 0.534; 95% CI, 0.328–0.869; P=0.012), lactate (OR, 0.396; 95% CI, 0.104–0.838; P=0.022) (Table 4).

ROC analysis was performed to determine the optimal cut-off value for PLR in predicting mortality, yielding a threshold of 65.35 (sensitivity, 0.621; specificity, 0.694), with an area under the ROC curve was 0.742 (Figure 2). Using the chi-square test, analysis of the non-survivor and survivor groups based on a PLR value of 65.35 (P=0.002) revealed that PLR was a significant biomarker for predicting mortality (Table 5). Kaplan-Meier survival analysis based on the same cut-off value also demonstrated a significantly higher mortality rate in the group with a PLR lower than the cut-off value (Figure 3). In comparing transfusion volumes between the high PLR (≥65.35) and low PLR (<65.35) groups, all transfusion components showed higher volume in the low PLR groups, though no significant difference was observed between two groups (Table 6).

DISCUSSION

The present study aimed to determine the relationship between 30-day mortality and PLR among individuals who experienced severe trauma. Several blood tests, including PLR, used in this study were based on values obtained at the time of arrival to the emergency department. Blood test results demonstrated that PLR and lactate levels differed significantly between the non-survivor and survivor groups.

Platelets normally circulate in an inactive and non-adhesive

Table 2. Analysis of patient characteristics between non-survivors and survivors

Variable	Total (n=139)	Non-survivor (n=36)	Survivor (n=103)	P-value
Age (yr)	55±18	56±18	55±18	0.629
Sex				0.068
Male	99 (71.2)	21 (58.3)	78 (75.7)	
Female	40 (28.2)	15 (41.7)	25 (24.3)	
GCS	11.3±3.8	8.4±4.1	12.3±3.1	<0.001
SBP (mm Hg)	93.0±54.6	75.6±73.2	99.1±45.3	0.025
DBP (mm Hg)	55.0±30.7	38.6±36.3	60.8±26.3	0.002
MAP (mm Hg)	67.1±37.9	50.9±47.9	72.8±32.1	0.014
HR (beat/min)	89.7±26.5	87.0±34.2	90.6±23.3	0.562
APACHE II score	13.9±8.4	21.3±9.5	11.4±6.1	<0.001
ISS	32.7±10.3	41.1±9.1	29.8±9.0	<0.001
Head & neck AIS	2.1±1.4	3.1±1.7	1.7±1.2	<0.001
Face AIS	1.4±0.7	1.4±0.7	1.4±0.7	0.573
Chest AIS	3.1±1.2	3.3±1.3	3.0±1.2	0.267
Abdomen AIS	2.6±1.3	3.0±1.3	2.5±1.3	0.034
Extremity AIS	2.5±1.2	2.5±1.2	2.5±1.2	0.854
External AIS	1.2±0.4	1.2±0.4	1.2±0.4	0.983
Transfusion (units)[a]				
RBC <4 hr	2.2±3.4	4.0±5.4	1.6±2.0	0.011
RBC <24 hr	3.8±5.3	7.0±8.2	2.7±3.1	0.004
FFP <4 hr	1.6±2.5	2.9±3.6	1.1±1.7	0.006
FFP <24 hr	3.3±4.9	6.9±7.3	2.0±2.8	<0.001
PLT <4 hr	0.4±1.9	0.9±2.9	0.2±1.4	0.040
PLT <24 hr	2.0±4.7	3.7±6.8	1.4±3.5	0.010
CP <4 hr	0.1±0.7	0.3±1.4	0.0±0.0	0.160
CP <24 hr	2.1±4.2	3.3±5.3	1.7±3.6	0.098
Trauma mechanism				0.561
Pedestrian TA	32 (23.0)	9 (25.0)	23 (22.3)	
Passenger TA	37 (26.6)	9 (25.0)	28 (27.2)	
Motorcycle or bicycle TA	16 (11.5)	6 (16.7)	10 (9.7)	
Fall	34 (24.5)	8 (22.2)	26 (25.2)	
Stab wound	4 (2.9)	1 (2.8)	3 (2.9)	
Crush injury	16 (11.5)	3 (8.3)	13 (12.6)	
Emergency operation	96 (73.8)	21 (58.3)	81 (78.6)	0.027

Values are presented as mean±standard deviation or number (%).
GCS: Glasgow coma scale; SBP: systolic blood pressure; DBP: diastolic blood pressure; MAP: mean arterial pressure; HR: heart rate; APACHE: Acute Physiology and Chronic Health Evaluation; ISS: Injury Severity Score; AIS: Abbreviated Injury Scale; RBC: red blood cell; FFP: fresh frozen plasma; PLT: platelet; CP: cryoprecipitate; TA: traffic accident.
a) RBC: 320 ml/unit; FFP: 400 ml/unit; PLT: 400 ml/unit; CP: 320 ml/unit.

state within the bloodstream [15]. Their primary function is to rapidly adhere to injured blood vessels and form blood clots to prevent excessive bleeding [15]. Platelets contribute significantly to strengthening blood clots at all stages after injury and play a role in inflammatory and immune responses [15,16]. Previous research has investigated platelet-related aspects in patients who experience trauma. Within the first 48 hours post-injury, thrombocytopenia was observed in 35% of patients and was linked to a significant increase in ISS and the need for RBC transfusions [17]. At two specific time points—admission and 24 hours after injury—thrombocytopenia was associated with the occurrence of multi-organ failure and higher mortality rates [18]. In our study, the survivor group exhibited a significantly higher platelet count than non-survivor group in

Table 3. Comparative analysis of blood tests results between non-survivors and survivors

Variable	Total (n=139)	Non-survivor (n=36)	Survivor (n=103)	P-value
WBC (×1,000/ul)	16.9±11.2	19.6±18.2	16.0±7.2	0.096
Lymphocyte (×1,000/ul)	3.4±1.8	4.1±2.0	3.1±1.6	0.063
Hemoglobin (g/dl)	12.0±2.7	11.2±3.0	12.3±2.6	0.029
Platelet (×1,000/ul)	210.1±70.9	187.0±60.5	218.2±72.7	0.022
Sodium (mEq/L)	139.7±3.4	139.7±4.7	139.8±2.9	0.924
Potassium (mEq/L)	3.9±0.8	4.3±1.2	3.8±0.5	0.016
Chloride (mEq/L)	104.1±4.6	102.9±5.3	104.6±4.3	0.061
BUN (mg/dl)	17.4±8.8	17.1±7.1	17.5±9.3	0.809
Creatinine (mg/dl)	1.1±1.1	1.2±0.4	1.1±1.3	0.843
pH	7.3±0.1	7.3±0.2	7.4±0.1	0.002
PaO_2 (mm Hg)	90.7±36.9	92.1±34.6	90.2±37.9	0.792
$PaCO_2$ (mm Hg)	38.6±13.0	40.4±16.8	38.0±11.3	0.426
HCO_3^- (mmol/L)	21.3±5.2	19.9±8.3	21.8±3.4	0.188
Base deficit (mmol/L)	5.2±5.9	9.1±8.0	3.9±4.2	0.001
Lactate (mg/dl)	48.0±41.5	82.2±16.8	36.6±11.3	<0.001
PLR	80.5±50.9	53.4±30.1	89.9±53.3	<0.001

Values are presented as mean±standard deviation.
WBC: white blood cell; BUN: blood urea nitrogen; PaO_2: arterial oxygen pressure; $PaCO_2$: partial pressure of carbon dioxide; HCO_3^-: bicarbonate; PLR: platelet-to-lymphocyte ratio.

Table 4. Variables affecting survival in trauma patients by multivariable logistic regression analysis

Variable	OR	95% CI	P-value
PLR	1.036	1.013–1.059	0.002
ISS	0.900	0.830–0.976	0.011
DBP	1.171	1.043–1.315	0.008
MAP	1.084	1.009–1.164	0.027
Head & neck AIS	0.534	0.328–0.869	0.012
Lactate	0.396	0.104–0.838	0.022

OR: odds ratio; CI: confidence interval; PLR: platelet-to-lymphocyte ratio; ISS: Injury Severity Score; DBP: diastolic blood pressure; MAP: mean arterial pressure; AIS: Abbreviated Injury Scale.

Table 5. Correlation between PLR and mortality

	Survivor	Non-survivor	Total	P-value
High PLR (≥65.35)	63 (45.3)	11 (7.9)	74 (53.2)	0.002
Low PLR (<65.35)	40 (28.8)	25 (18.0)	65 (46.8)	
Total	103 (74.1)	36 (25.9)	139 (100)	

Values are presented as number (%).
PLR: platelet-to-lymphocyte ratio.

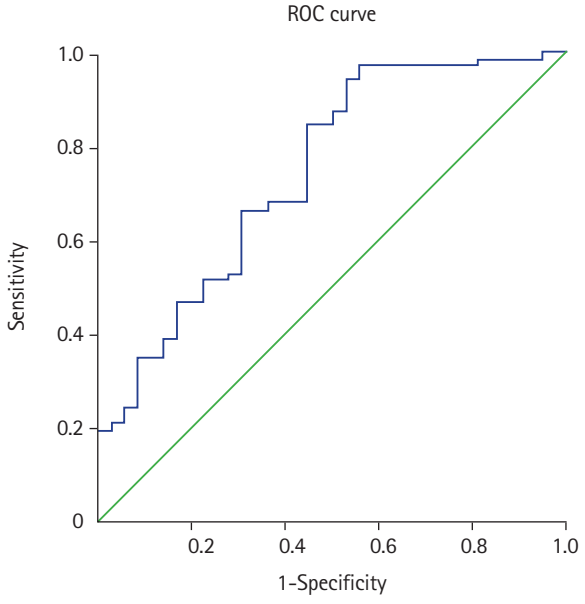

Figure 2. Receiver operating characteristic (ROC) curve for the platelet-to-lymphocyte ratio in predicting mortality in patient with severe trauma (area under the curve=0.742).

univariate analysis. However, multivariate analysis revealed no significant difference between the two groups (Tables 2 and 3). Jo et al. [19] indicate significant differences in both PLR and platelet levels between the survivor and non-survivor groups in multivariate analysis among adult traffic accident patients. However, Lee et al. [20] yielded results consistent with ours in an investigation of severe trauma patients. The variations observed among these studies are attributed to differences in the variables employed in multivariate analysis and variations

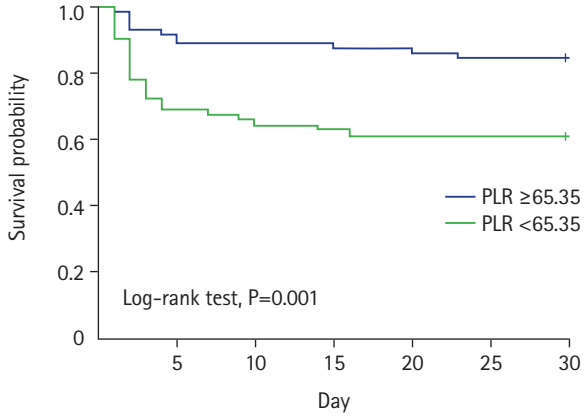

Figure 3. Kaplan-Meier survival curve according to platelet-to-lymphocyte ratio (PLR) cut-off value (65.35).

Table 6. Correlation between PLR and transfusions

Transfusion (units)[a]	High PLR (≥65.35)	Low PLR (<65.35)	P-value
RBC <4 hr	1.8±2.3	2.7±4.3	0.124
RBC <24 hr	3.1±4.4	4.6±6.1	0.126
FFP <4 hr	1.3±1.9	2.0±3.0	0.139
FFP <24 hr	2.6±4.3	4.1±5.4	0.090
PLT <4 hr	0.3±1.6	0.5±2.2	0.414
PLT <24 hr	1.7±4.4	2.4±5.0	0.352
CP <4 hr	0.0±0.0	0.2±1.1	0.159
CP <24 hr	1.8±3.9	2.5±4.4	0.328

Values are presented as mean±standard deviation.
PLR: platelet-to-lymphocyte ratio; RBC: red blood cell; FFP: Fresh frozen plasma; PLT: platelet; CP: cryoprecipitate.
a) RBC: 320 ml/unit; FFP: 400 ml/unit; PLT: 400 ml/unit; CP: 320 ml/unit.

in the correlation between those variables and platelet levels. To accurately investigate the impact of platelets on trauma mortality, a prospective study is needed after identifying and controlling of variables that may confound the results.

In cases of bleeding due to trauma, symptoms such as hypovolemia and low blood pressure due to insufficient blood volume are observed. In patients experiencing low blood pressure and blood loss, leukocytosis and an increase in white blood cell count may also be observed [21]. Additionally, an increase in catecholamine levels due to stress can lead to elevated lymphocyte and neutrophil counts [22]. For these reasons, because platelets tend to decrease and lymphocytes increase in patients who experience severe trauma, PLR appears to decrease as the severity of trauma increases, which is believed to be associated with mortality. In this study, patients with chronic kidney were excluded due to the potential impact of platelet dysfunction and lymphocyte depletion on the study results [23,24]. El-Menyar et al. [13] confirmed that PLR was a predictive biomarker in abdominal trauma patients. This study was conducted on 1,199 trauma patients, and the mortality rate was 6.5%. PLR was lower in the non-survivor group (76.3 vs. 149.3, P=0001), and at a PLR cut-off value of 98.5, sensitivity was 81.3%, and specificity was 61.1%. Jo et al. [19] studied PLR as a predictor of mortality in traffic accident patients. They examined a total of 488 individuals and identified a mortality 8.8%. Consequently, the PLR value was significantly lower in the non-survivor group (51.3 vs. 124.2, P<0.001), and at a PLR cut-off value of 85.6, sensitivity was 90.7%, and specificity was 35.5%. In our study, a total of 139 patients who met the criteria for major trauma team activation were investigated, and the mortality rate was 25.9%, The PLR value was significantly lower in the non-survivor group (53.35 vs. 89.92, P<0.001), and the PLR cut-off value was 65.35, demonstrating 62.1% of sensitivity and 69.4% of specificity. Although the optimal cut-off value for PLR reported in previous studies was different from that in the present study, the overall trend was similar.

Previous studies have focused on damage to single organs, such as the brain and abdomen, and single-injury mechanisms, such as traffic accidents. This study, however, addressed severe trauma with damage to all organs and various damage mechanisms. Due to these variations between studies, it is assumed that the mechanisms of trauma and causes of shock differ in each study, resulting in variation in the results. The preceding two studies, as well as our own, relied on blood tests conducted upon arrival at the emergency room. In a study by Lee et al. [20] trauma patients with an ISS >15 exhibited a lower survival rate in the group with a low PLR 6 hours after admission to the emergency room (52.23 vs. 123.74, P<0.001). Our study focused on patients meeting the criteria for severe trauma team activation, while the other study targeted critically ill patients with an ISS >15. Furthermore, there were difference in the timing of the blood test to calculate PLR. Despite these variations, the results of both studies were similar.

According to Rau et al. [25], although the lymphocyte count was significantly higher in the non-survivor group, there was no significant difference in PLR between the non-survivor and survivor group in patient with polytrauma. The subjects of this study were patients with two or more organs with an AIS >3. Researchers attributed the variation in this result from previous studies to a difference in patient severity. Considering these research findings, further investigation is warranted to

explore the potential of PLR in predicting death based on trauma severity classification.

Studies investigating PLR as a prognostic predictor have mainly focused on cancer and respiratory diseases. The results of those studies differ from those involving patients experiencing trauma. High PLR was associated with larger tumor size, advanced tumor invasion, lymph node metastasis, and advanced TNM stage in patients with gastric cancer and was associated with a lower survival rate than in those with breast cancer [26,27]. PLR is significantly higher in patients with chronic obstructive pulmonary disease (COPD) and in patients with acute exacerbation of COPD (AECOPD), PLR is associated with an increased risk for 28-day mortality [28,29]. Platelet activation is crucial for cancer progression [30,31]. Platelets promote tumor cells by enhanced metalloproteinase-9 [32]. Lymphocytes inhibit tumor cell proliferation and metastasis [33]. Platelet activation is also observed in patients with AECOPD [34]. For these reasons, a high PLR value in patients with a disease appears to indicate worse prognosis, unlike in trauma patients. Considering the above research results, caution is needed when interpreting the PLR as a prognostic predictor in trauma patients and those with medical diseases.

There was a significant difference in RBC, FFP, and PLT transfusion between the survivor and non-survivor groups, but no significant difference in CP. This result is attributed to the limited performance of disseminated intravascular coagulopathy tests on all trauma patients and the practical challenge of administering CP within a short timeframe, even if prescribed. Due to the absence of a significant difference in blood transfusion volume between low PLR and high PLR groups, the predictive role of PLR in transfusion needs seems inconclusive. This results warrant additional research on other variables, including PLR, given the multitude of factors in situation requiring blood transfusion.

The present study had some limitations, including its single-center design, which made it difficult to assess long-term mortality because many survivors were transferred to secondary hospitals before day 30 of admission. Additionally, because the study period was not long and the sample size for each trauma mechanism was small, additional long-term research is necessary to obtain more accurate results.

In conclusion, PLR, which can be calculated quickly and easily through a complete blood count which is routinely performed on trauma patients admitted to the emergency department and may be a useful tool for predicting mortality in patients with severe trauma team activation.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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AUTHOR CONTRIBUTIONS

Conceptualization: KHS. Methodology: KHS. Data curation: JKK. Formal analysis: KHS. Visualization: all authors. Project administration: KHS. Writing-original draft: JKK. Writing-review and editing: all authors.

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