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The Role of Hematologic Parameters in Predicting Intracranial Hemorrhage in Emergency Department Patients With Head Trauma

ABSTRACT

Background:

Traumatic brain injury (TBI) is a critical public health issue, particularly among young adults, and the presence of intracranial hemorrhage (ICH) has a direct impact on clinical outcomes. In patients presenting with mild head trauma, early prediction of ICH remains challenging. In recent years, hematologic biomarkers such as platelet indices have attracted increasing interest as potential diagnostic tools in trauma evaluation.

Objective:

This study aimed to investigate the association between platelet indices including mean platelet volume (MPV), platelet distribution width (PDW), platelet-large cell ratio (P-LCR) and the presence of ICH in patients presenting to the emergency department (ED) with isolated head trauma.

Methods:

This retrospective observational study included adult patients aged ≥18 years who presented to the ED with isolated head trauma between March 1, 2023 and March 1, 2024. Patients were divided into two groups based on the presence or absence of ICH on brain computed tomography. Hematological and biochemical parameters were recorded and comparisons between the groups were conducted using appropriate parametric and non-parametric tests (significance level set at $p < 0.05$).

Results:

A total of 215 patients were included in the study, of whom 45 (20.9%) had confirmed ICH. White blood cell (WBC) counts were significantly higher in the ICH group (11.6 ± 4.0 vs. 9.6 ± 3.5; $p = 0.003$). No significant differences were observed between groups for MPV ($p = 0.484$), PDW ($p = 0.724$) or P-LCR ($p = 0.567$). Similarly, no significant associations were found between platelet indices and emergency department disposition.

Conclusion:

While WBC count was associated with both the presence of ICH and hospital admission, MPV, PDW and P-LCR did not demonstrate predictive value for ICH in patients with isolated head trauma. Further prospective, multicenter studies with serial measurements are needed to clarify the clinical utility of these indices in neurotrauma.

Keywords: Head Injuries, Intracranial Hemorrhages, Platelet Indices, Emergency Service

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1. Introduction

Traumatic brain injury (TBI) remains a significant public health issue in both developed and developing countries, particularly affecting young adults and is associated with high rates of morbidity and mortality. According to data from the World Health Organization (WHO), as of 2020, TBI ranks as the leading cause of trauma-related deaths among individuals under the age of 45. Moreover, neurological sequelae that develop following TBI can lead to permanent impairments in quality of life [1,2].

Intracranial hemorrhage (ICH), a serious complication that may arise after head trauma, represents a critical condition requiring rapid clinical assessment and intervention. While non-contrast computed tomography (CT) of the brain remains the gold standard imaging modality for diagnosing ICH, there are clinical scenarios, such as delayed access to imaging or patients presenting with borderline symptoms, where there is a growing need for early, laboratory-based biomarkers that could indicate the presence of hemorrhage. In this context, platelet indices derived from complete blood count (CBC) parameters have emerged as promising biomarkers for early diagnosis and prognostication of ICH [3].

Platelets play a pivotal role not only in hemostasis but also in inflammation, endothelial dysfunction and the maintenance of microvascular integrity. Mean platelet volume (MPV) reflects the average size of circulating platelets platelet distribution width (PDW) indicates size heterogeneity; and platelet-large cell ratio (P-LCR) reflects the proportion of large, reactive platelets thus indirectly offering insight into platelet activation status [4,5].

Several recent studies have reported associations between elevated MPV and PDW values and various neurologic conditions such as ischemic stroke, subarachnoid hemorrhage and traumatic brain injury. These findings suggest that platelet indices may reflect both the systemic inflammatory response and vascular injury mechanisms [6,7]. However, studies specifically evaluating the relationship between ICH secondary to head trauma and platelet indices are limited and existing data are inconsistent due to methodological heterogeneity. While some reports suggest significant associations between MPV or PDW and ICH presence, others indicate limited diagnostic utility for these parameters [8,9].

In light of this knowledge, investigating the relationship between platelet indices and ICH in patients presenting to the emergency department with isolated head trauma is important for both identifying potential early biomarkers and addressing gaps in the current literature. This study aimed to evaluate the association of various platelet indices particularly MPV, PDW, and P-LCR—with the presence of intracranial hemorrhage and to assess their diagnostic value in the emergency setting.

2. Materials and Methods

Study Design and Ethical Approval

This study was designed as a single-center, retrospective, descriptive observational analysis. Ethical approval was obtained from the Clinical Research Ethics Committee of Etlik City Hospital (Approval No: AEŞH-BADEK-2024-308). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Participants and Inclusion Criteria

The study included adult patients (aged ≥18 years) who presented to the Emergency Medicine Department of Ankara Etlik City Hospital with isolated head trauma between March 1, 2023, and March 1, 2024. Eligible cases were identified retrospectively using the hospital information management system. Patients were included if they presented to the trauma area and had undergone brain CT regardless of whether intracranial hemorrhage (ICH) was detected.

Exclusion Criteria

- Pregnancy
- History of anticoagulant therapy
- Penetrating head trauma
- Liver or splenic laceration
- Concurrent hemorrhages in other organ systems
- Active external bleeding

These exclusion criteria were defined to ensure sample homogeneity and to isolate the evaluation of intracranial hemorrhage.

Data Collection Process

The patients' age, sex, mode of presentation, vital signs, laboratory parameters and cranial CT findings were evaluated. Laboratory data included CBC parameters (WBC, hemoglobin, hematocrit, MCV, MCH, platelet count, MPV, PDW, RDW-CV, P-LCR), blood gas analyses (pH, base excess, lactate) and INR.

The laboratory parameters were obtained from blood samples collected during the patients' initial presentation to the emergency department, specifically within the first hour following triage and physical examination. This timing reflects the early phase of the traumatic pathophysiological response and provides a homogeneous dataset for clinical interpretation.

CT evaluations were performed upon the request of emergency medicine physicians in accordance with clinical practice protocols and were reported by radiology specialists. However, the images were reviewed in a systematic manner by observers blinded to the laboratory data. This approach theoretically reduces the potential for observer bias.

Patients with missing data particularly those lacking CBC parameters or cranial CT reports were excluded from the analysis. All cases included in the study were selected according to the predefined inclusion and exclusion criteria. No data imputation was performed.

Only the cranial CT findings obtained at the time of ED admission were considered. Follow-up CT scans performed for monitoring purposes were not included in the analysis. Therefore, patients who initially had no evidence of ICH but developed lesions during the clinical course were excluded.

Patients were categorized based on the presence or absence of ICH. Additionally, ED outcomes (discharge, ward admission, intensive care unit admission) and mortality status were recorded. The severity of trauma was assessed using the

Glasgow Coma Scale (GCS), and patients were classified according to Advanced Trauma Life Support (ATLS) criteria.

Statistical Analysis

All statistical analyses were performed using the Jamovi software package (version 2.5.7). Descriptive statistics for categorical variables were presented as counts and percentages and comparisons between categorical variables were conducted using the chi-square test. The normality of continuous variables was assessed using the Kolmogorov–Smirnov test and histogram plots. Continuous variables that did not follow a normal distribution were presented as median and interquartile range (IQR: 25th–75th percentiles), whereas normally distributed variables were expressed as mean ± standard deviation (SD). Differences between two independent groups with normally distributed variables were evaluated using the Student's t-test or Welch's t-test, depending on the homogeneity of variances assessed by the Levene's test. For non-normally distributed variables, the Mann–Whitney U test was applied. A p-value of less than 0.05 was considered statistically significant.

Table 1. Distribution of patient demographics, laboratory parameters, and clinical characteristics

Sex	
Male	138 (64,2 %)
Female	77 (35,8 %)
Age	49 (29 – 68)
Laboratory Parameters	
WBC, 10^9/L	10.1 ± 3.7
Hemoglobin, g/dL	14.1 (12.6 – 15.8)
Hematocrit, %	42.7 (38.4 – 46.3)
MCV, fL	88 ± 6
MCH, pg	29.8 (27.5 – 30.9)
Platelet, 10^9/L	244 ± 77
MPV, fL	10.4 ± 0.9
PDW, %	11.7 (10.7 – 13.2)
RDW-CV, %	13.0 (12.4 – 13.9)
P-LCR, fL	28.3 ± 7.1
pH	7.41 ± 0.04
Base excess	(-0.3) [(-1.7) – (1.2)]
Lactate, mmol/L	1.7 (1.4 – 2.4)
INR	1.01 (0.96 – 1.07)
Intracranial presence	45 (20,9 %)
Emergency Department Outcome	
Discharge	168 (78,1 %)
Ward Admission	18 (8,4 %)
ICU Admission	29 (13,5 %)
Mortality	5 (2,3 %)

All data are presented as n (%), median (IQR) or mean ± SD.

WBC, white blood cells; MCV, mean corpuscular volüme; MCH, mean corpuscular hemoglobin;

MPV, mean platelet volüme; PDW, platelet distribution width; RDW-CV, red cell distribution width-coefficient of variation; P-LCR, platelet-large cell ratio; INR, international normalized ratio; ICU, intensive care unit

3. Results

A total of 215 patients were retrospectively evaluated. Of these, 138 (64.2%) were male and 77 (35.8%) were female. The median age was 49 years (interquartile range [IQR]: 29–68). ICH was detected in 45 patients (20.9%). Regarding ED outcomes, 168 patients (78.1%) were discharged, 18 (8.4%) were admitted to the general ward and 29 (13.5%) were transferred to the intensive care unit (ICU). Mortality occurred in 5 patients (2.3%) (Table 1).

Association Between ICH and Laboratory Parameters

When comparing patients with and without ICH, WBC count was found to be significantly higher in the ICH-positive group (11.6 ± 4.0 vs. 9.6 ± 3.5 ×10⁹/L; p = 0.003). No statistically significant differences were observed between the groups in terms of other hematologic or biochemical parameters (table 2).

Regarding platelet indices, no significant differences were found between patients with and without ICH in: MPV: 10.3 ± 0.8 vs. 10.5 ± 0.9; p = 0.484, PDW: 11.5 [10.6–13.6] vs. 11.8 [10.7–13.1]; p = 0.724, P-LCR: 27.8 ± 6.9 vs. 28.5 ± 7.2; p = 0.567 (table 2).

Lactate levels were similar between the groups (1.7 [1.4–2.2] vs. 1.7 [1.4–2.4] mmol/L; p = 0.984) and no significant difference was observed in INR values either (1.00 [0.95–1.10] vs. 1.02 [0.96–1.06]; p = 0.999) (table 2).

Comparison Between Discharged and Admitted Patients

Patients discharged from the emergency department were compared with those admitted to the general ward or intensive care unit. WBC levels were found to be significantly higher in the admitted group (11.9 ± 3.8 vs. 9.5 ± 3.5 ×10⁹/L; p <0.001). Additionally, MCH value was also significantly elevated in admitted patients compared to those discharged (30.2 [28.4–31.4] vs. 29.4 [27.1–30.7]; p = 0.024) (table 3).

Regarding platelet indices, no statistically significant differences were observed between the groups for MPV, PDW, RDW-CV or P-LCR (p> 0.05 for all). Similarly, no significant differences were found in other laboratory parameters such as pH, base

Table 2. Relationship Between Age and Laboratory Parameters and the Presence of Intracranial Hemorrhage

	Intracranial Hemorrhage		***p value***	***Mean Difference***
	Present (n=45)	**Absent (n=170)**		***(%95 CI)***
Age, years	52 (32 – 75)	48 (29 – 66)	0.248[1]	4 (-3, 12)
WBC, 10⁹/L	11.6 ± 4.0	9.6 ± 3.5	0.003[2]	1.9 (0.7, 3.2)
Hemoglobin, g/dL	14.1 (12.9 – 15.5)	14.1 (12.5 – 15.8)	0.672[1]	0.2 (-0.6, 0.9)
Hematocrit, %	42.7 (40.6 – 45.7)	42.6 (38.3 – 46.3)	0.705[1]	0.5 (-1.5, 2.5)
MCV, fL	88 ± 8	88 ± 6	0.609[3]	1.1 (-1.6, 3.8)
MCH, pg	30.2 (28.3 – 31.4)	29.6 (27.4 – 30.7)	0.136[1]	0.6 (-0.1, 1.4)
Platelet, 10⁹/L	235 ± 87	247 ± 73	0.372[2]	-11 (-37, 14)
MPV, fL	10.3 ± 0.8	10.5 ± 0.9	0.484[2]	-0.2 (-0.4, 0.2)
PDW, %	11.5 (10.6 – 13.6)	11.8 (10.7 – 13.1)	0.724[1]	-0.2 (-0.7, 0.5)
RDW-CV, %	13.1 (12.7 – 13.7)	13.0 (12.4 – 13.9)	0.471[1]	0.1 (-0.3, 0.5)
P-LCR, fL	27.8 ± 6.9	28.5 ± 7.2	0.567[2]	-0.7 (-3.3, 1.5)
pH	7.40 ± 0.03	7.41 ± 0.04	0.378[2]	-0.01 (-0.02, 0.01)
Base Excess	(-0.8) [(-2.5) – (0.9)]	(-0.2) [(-1.3) – (1.2)]	0.131[1]	-0.7 (-1.7, 0.2)
Lactate, mmol /L	1.7 (1.4 – 2.2)	1.7 (1.4 – 2.4)	0.984[1]	0.1 (-0.3, 0.3)
INR	1.00 (0.95 – 1.10)	1.02 (0.96 – 1.06)	0.999[1]	-0.1 (-0.1, 0.1)

1: Data are presented as median (IQR) and Mann Whitney U test was used.

2: Data are presented as mean ± SD and Student t test was used.

3: Data are presented as mean ± SD and Welch t test was used.

CI, confidence interval; WBC, white blood cells; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MPV, mean platelet volume; PDW, platelet distribution width; RDW-CV, red cell distribution width-coefficient of variation; P-LCR, platelet-large cell ratio; INR, international normalized ratio

excess, lactate, or INR with respect to hospital admission status (Table 3).

Notably, WBC count was significantly elevated in both patients with intracranial hemorrhage and those requiring hospital admission. In contrast, platelet indices (MPV, PDW, P-LCR) did not demonstrate any statistically significant association with the presence of ICH or the need for hospitalization. MCH was the only parameter found to be significantly higher exclusively in admitted patients (Table 3).

4. Discussion

This study aimed to evaluate the relationship between ICH and platelet indices in adult patients presenting to the ED with isolated head trauma. Our findings demonstrated that WBC counts were significantly higher in patients with ICH; however, no statistically significant differences were observed in platelet indices such as MPV, PDWor P-LCR. Similarly, patients who required hospital admission also exhibited significantly elevated WBC levels. Nevertheless, platelet indices did not show predictive value for either the presence of ICH or the need for hospital admission.

TBI is one of the leading causes of morbidity and mortality, and the presence of ICH directly influences the clinical course of the disease. In clinical practice, CT is considered the gold standard for diagnosing ICH. However, particularly in cases of mild trauma, hemorrhages that are not initially detected on imaging may still carry significant clinical implications over time [2]. Therefore, a need for laboratory-based diagnostic markers remains, especially in the pre-imaging period or in cases where hemorrhage can not be identified radiologically. In this context, platelet indices derived from CBC data have recently gained attention as potential biomarkers for both diagnostic and prognostic evaluation [5].

Platelets are not only the initiating cells of the coagulation cascade, but also play an active role in several key pathophysiological processes, including endothelial activation, increased vascular permeability and the release of proinflammatory cytokines. Specifically, MPV reflects the population of large and reactive platelets, thereby providing insight into platelet activity. PDW indicates the variation in platelet size while P-LCR represents the proportion of larger platelets in circulation [10,3].

In our study, the lack of a statistically significant association between MPV, PDWand P-LCR values and the presence of ICH contrasts with findings reported in some previous studies. In a retrospective study by Palabıyık et al., decreased platelet count and increased MPV were found to be associated with 30-day mortality in patients with TBI [11]. This finding suggests that MPV may have prognostic value, particularly in severe TBI cases requiring ICU admission. However, in our cohort, MPV levels did not differ significantly between patients with and without ICH. This discrepancy may be explained by the predominance of mild-to-moderate head trauma cases in our study population.

Similarly, in a prospective study conducted by Lippi et al., MPV levels were found to be significantly lower in patients with mild head trauma and positive CT findings for intracranial lesions compared to healthy controls [12]. This observation suggests that MPV may not only reflect platelet activation or inflammation, but also indicate platelet consumption or sequestration in the setting of trauma.

On the other hand, several studies have proposed that MPV may possess diagnostic value in conditions such as gastrointestinal bleeding, aortic dissection and mesenteric ischemia [13,14]. However, these studies exhibit considerable heterogeneity in terms of patient populations, comorbidities and laboratory methodologies. In some investigations focusing on thoracic pathologies such as traumatic hemothorax, the clinical relevance of platelet indices has also been questioned. Nevertheless, there remains a lack of high-quality studies conducted on homogeneous patient populations specifically evaluating the association between platelet indices and the presence of intracranial hemorrhage following head trauma [15].

One of the notable findings of our study was the significant association between elevated WBC count and the presence of ICH, which likely reflects the systemic inflammatory response inherent to traumatic injury. Previous studies have reported that WBC levels tend to rise in proportion to trauma severity, in conjunction with neutrophilic activation and the release of proinflammatory cytokines [16]. Therefore, the observation that WBC count was significantly associated not only with ICH but also with the need for hospital admission suggests that this parameter may serve as a practical surrogate marker of post-traumatic inflammatory burden.

Nevertheless, the absence of significant differences in platelet indices with respect to ICH suggests that these parameters may serve more as supportive markers rather than definitive diagnostic tools. In a study by Nydam et al., persistent post-traumatic thrombocytopenia was found to be associated with increased rates of organ failure and mortality; however, its direct relationship with the presence of ICH was not clearly established [17]. It has been proposed that platelet indices may gain greater clinical value in dynamic monitoring context such as through serial measurements—rather than from single time-point assessments.

5. Conclusion

In this study, we examined the relationship between ICH and platelet indices derived from CBC parameters in patients presenting to the emergency department with isolated head trauma. The findings revealed that WBC levels were significantly elevated in patients with ICH; however, no statistically significant association was observed between platelet indices and the presence of ICH.

While the increase in WBC count can be interpreted as an indicator of the inflammatory response triggered by trauma, the predictive value of platelet indices for detecting ICH appears to be limited. Nevertheless, the observation that WBC levels were also elevated in patients requiring hospital admission supports the potential role of this parameter as a surrogate marker reflecting the clinical severity of trauma in the emergency setting.

6. Limitations

This study has several methodological limitations inherent to its retrospective design. First, the use of hospital information systems for data retrieval may carry the risk of incomplete or inaccurate records, potentially limiting the standardization of laboratory and imaging parameters. Additionally, being a single-center study restricts the generalizability of the findings, as it may not account for demographic and clinical variations specific to other patient populations. Furthermore, the evaluation of platelet indices was limited to a single time point upon admission, which fails to reflect their potential dynamic fluctuations over time. Therefore, prospective, multicenter studies incorporating serial measurements are warranted to validate these findings.

Author contributions

We declare that all authors have accepted the submission and that the manuscript has not been published in whole or in part or submitted elsewher

Declarations

Ethics Committee Approval: This study was designed as a single-center, retrospective, descriptive observational analysis. Ethical approval was obtained from the Clinical Research Ethics Committee of Etlik City Hospital (Approval No: AEŞH-BADEK-2024-308).

The study was conducted in accordance with the principles of the Declaration of Helsinki.

Conflict of Interest: No conflict of interest was declared by the authors.

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