

Mortality prediction in patients with acute brain injury using peripheral blood cell analysis: a retrospective study

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Abstract

Introduction: Acute brain injury remains a reason for high mortality as well as a cause of long-term disability among patients hospitalized in the intensive care unit (ICU). Moreover, this injury induces a cascade of changes among morphotic blood cells.

Aim of the research: Our study was to evaluate the most accurate predictor derived from peripheral blood cell counts for 30-day mortality in patients suffering from acute brain injury with intracranial bleeding, and therefore to determine whether simple indices based on blood morphology can predict mortality in acute brain injury.

Material and methods: This is a retrospective study of 71 patients presenting with an acute brain injury with intracranial bleeding, hospitalized in the ICU. Daily changes in the blood morphology and ratios between the blood cells were statistically analyzed in terms of clinical data as comorbidities.

Results and conclusions: The groups differed in terms of length of hospitalization and ICU stay, age, GCS after first assessment, along with SAPS II and APACHE II scores. Coefficients of variation were significant in platelet count throughout 72 hours of observation. Although the PLT:WBC ratio on day 2 was found to be statistically significant, with AUC estimated as satisfactory, in a multivariate analysis it did not fulfil the conditions of an independent factor able to predict the assumed short-term mortality period. No universal biomarker for predicting 30-day mortality can be defined for this heterogeneous group of patients after acute brain injury with intracranial bleeding.

Introduction

Acute brain injury (ABI) is one of the causes of hospitalization in the intensive care unit (ICU). Although it requires multidirectional personalized treatment, it still poses a risk of high mortality.

Acute subarachnoid hemorrhage (SAH) is a rare form of stroke, where bleeding occurs between the arachnoid membrane and the pia mater. The etiology of SAH can be either spontaneous, nontraumatic, of which about 85% are a result of aneurysm rupture, or are traumatic in nature [1]. SAH affects 9 per 100,000 population in developed countries, especially those aged between 50 and 60 years and the mortality rate is high. Approximately up to 20% of patients with SAH die before reaching the hospital, while about 25% die within the first 24 hours after the onset [2–4]. Moreover, the burden on public health funds is high with the mean inflation adjusted cost of hospitalization due to SAH in the United States being estimated at \$82,514 during 2002–2014 [5].

Another severe neurological condition is traumatic brain injury (TBI), which is defined as an acute brain injury that results from external physical force to the head [6].

According to the Global Burden of Disease Study published in 2016, there were 27.08 million new cas-

es of TBI [7]. In addition, the Collaborative European NeuroTrauma Effectiveness Research in Traumatic Brain Injury (CENTER-TBI) claims that increasing TBI severity is associated with higher costs of treatment [8].

Any acute brain injury has its own primary impact on brain tissue. This damage results from the direct influence of, for example, blood at the site of an aneurysm rupture or mechanical trauma.

The above-mentioned causes of primary acute brain injury are accompanied by secondary injuries [9]. These secondary injuries result in activation of numerous pro-inflammatory proteins, chemokines, microglia and immune system response, along with interference in coagulation with thrombin activation in the affected area. Pro-inflammatory cytokines (e.g. IL-1b, IL-6) concentration increase is noted in the cerebrospinal fluid, a phenomenon which is clearly observed especially in TBI-patients [10, 11].

Additionally, the excessive complement activation has been noted [12], a factor which also accelerates the cascade of inflammatory response. Recent studies prove that the inhibition of complement elements has become a target within the treatment strategy of a secondary injury [13, 14]. The insufficiency of the brain blood barrier favors the infiltration of immune cells such as mac-

rophages, leukocytes, neutrophils as a response to the activity of chemokines and cytokines [15, 16].

The accumulation of pro-inflammatory molecules may promote a systemic immune response syndrome (SIRS) leading to hyper-inflammation and, as a result, to organ dysfunction [15, 17].

By observing the peripheral immune cell activation in this pathology, the ratios of these cells are becoming a valuable tool not only to predict the severity of the patient's condition, but even their mortality after acute brain injury [18, 19].

Aim of the research

The aim of our study was to evaluate the most accurate predictor derived from peripheral blood cell counts for 30-day mortality in patients suffering from acute brain injury with intracranial bleeding. This is the first study including such a detailed evaluation of morphological indices in this important but quite heterogeneous clinical scenario.

Material and methods

This is a retrospective study based on laboratory data analysis from a medical-surgical ICU at a single medical center of the Medical University of Silesia, Katowice, Poland. All data were retrieved from the hospital electronic health records (AMMS, Asseco Medical Solutions, Rzeszow, Poland). This study was approved by the ethics committee of the Medical University of Silesia, Katowice (BNW/NWN/0052/KB/119/23). We reviewed all patients' data between January 2021 up to the end of April 2023. The inclusion criteria were as follows: acute brain injury with any presence of intracranial bleeding followed by brain edema, hospitalization in the ICU for at least 72 hours of deep sedation RASS-5 (The Richmond Agitation-Sedation Scale), and age > 18 years old. The exclusion criteria comprised the following: edema due to infection, ischemic stroke, sudden cardiac arrest, drug intoxication, along with sedation/hospitalization shorter than 72 hours. Analyzed variables were based on peripheral blood morphology test results collected routinely from the patients during 72 hours of hospitalization. Moreover, clinical data such as severity-of-disease classification systems, comorbidities such as arterial hypertension, nicotine addiction and infections were collected. Variations of numeric data ratios were calculated and analyzed statistically.

Statistical analysis

The statistical analysis was performed using MedCalc version 18 statistical software (MedCalc Software, Ostend, Belgium). The type of distribution was verified with the Shapiro-Wilk test. Continuous variables were presented as median and interquartile ranges (IQR). Categorical variables were expressed as numbers and

percentages. Sample size was determined based on the difference in illness severity represented by the SAPS II score. Using a statistical power of 80% with an α value of 0.05, a minimum number of 18 patients was required in each group. Statistical significance was established by the χ^2 or Fisher's exact test. Intergroup differences were evaluated by the Mann-Whitney test or *t*-test. Odds ratios (OR) with their 95% confidence intervals (CI) were calculated, if applicable. All tests were two-tailed. The areas under the receiver operating characteristic curves (AUC ROC) were assessed. Diagnostic accuracy was defined as unsatisfactory if an AUC was < 0.6, satisfactory if an AUC was 0.6–0.69, good if an AUC was 0.7–0.79 and very good if an AUC was at least 0.8. Moreover, a value of $p < 0.05$ was considered statistically significant.

Results

There were 880 records of all hospitalizations in the analyzed period. Admissions due to other than neurological reasons were excluded. The final groups were distinguished and are presented in Figure 1.

The study group consisted of 71 patients, namely 31 (44%) males and 40 (56%) females. Although the deceased group consisted of 15 (41%) men, mortality was not associated with sex. The median age in the whole group was 51 (IQR 44–64). The preferable outcome was present in those of a younger age. The difference was statistically significant between groups of deceased and survivors ($p = 0.02$). SAH represents 53.5% of all cases. Variables with statistically significant differences comprised body surface area (BSA), where a lower BSA is preferable ($p = 0.02$). High statistical significance was observed in duration of hospitalization and total length of stay in the ICU, at levels of $p < 0.0001$ and $p = 0.0003$, respectively. Moreover, statistically significant differences between groups were noted in the

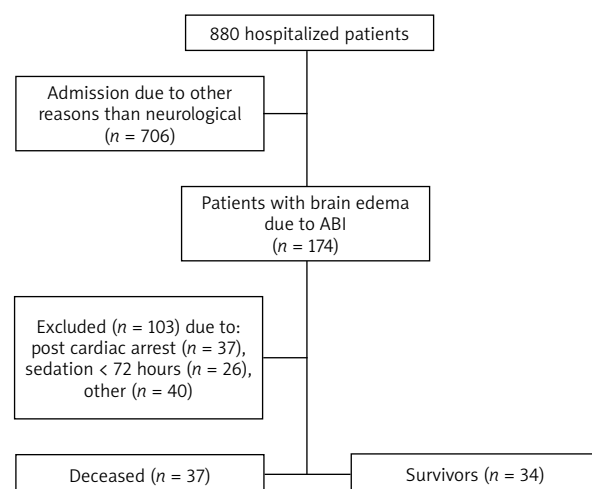


Figure 1. Flowchart of the study population
ABI – acute brain injury.

Table 1. Demographic data

Variable	Total N = 71	Deceased N = 37	Survivors N = 34	P-value
Sex	Male 31 (44%)	15 (41%)	16 (47%)	0.58
	Female 40 (56%)	22 (59%)	18 (53%)	
Etiology	SAH: 38 (53.5%)	22 (59.5%)	16 (47%)	0.30
	Other 33 (46.5%)	15 (40.5%)	18 (53%)	
Age	51 (44–64)	56 (47.75–70.5)	46 (39–58)	0.02
BSA	1.1 (0.98–1.31)	1.2 (1.04–1.37)	1 (0.9–1.22)	0.02
BMI	25.38 (22.74–28.05)	24.69 (22.12–29.32)	25.55 (23–27.68)	0.97
LOS total [days]	18 (11–30)	13 (7.75–17.25)	28.5 (20–46)	< 0.0001
LOS ICU [days]	14 (8–20.75)	10 (7–16)	19 (13–24)	0.0003
Ventilation [days]	12 (7–17)	10 (7–16)	13 (7–18)	0.30
Nicotinism	17 (24%)	5 (29%)	12 (71%)	0.05
Diabetes mellitus	4 (5.6%)	3 (7.5%)	1 (25%)	0.62
Arterial hypertension	41 (58%)	20 (48%)	21 (52%)	0.63
UTI	18 (25%)	7 (39%)	11 (61%)	0.28
Pneumonia	33 (46%)	14 (42%)	19 (58%)	0.16
GCS basic	9 (6–13)	8 (4–12)	11 (7–15)	0.03
SAPS II	43 (33–52.75)	48 (39–58)	36 (30–47)	0.0003
APACHE II	15 (12–20)	18 (14.75–23)	12.5 (11–16)	< 0.0001
SOFA	9 (8–11)	10 (9–11)	9 (8–11)	0.32
SII [10 ⁹ /l]	3179 (1470–4534)	2870 (1222–4991)	3425 (2291–4297)	0.25
Primary interventional treatment	14 (20%)	4 (29%)	10 (71%)	0.07
Secondary interventional treatment	64 (90%)	34 (53%)	30 (47%)	0.7

BSA – body surface area, BMI – body mass index, LOS – length of stay, ICU – intensive care unit, GCS – Glasgow Coma Scale, UTI – urinary tract infection, SAPS – Simplified Acute Physiology Score, APACHE – Acute Physiology And Chronic Health Evaluation, SOFA – Sequential Organ Failure Assessment Score, SII – Systemic Immune-Inflammation Index.

following classifications: GCS (Glasgow Coma Scale), APACHE II (Acute Physiology And Chronic Health Evaluation), and SAPS II (Simplified Acute Physiology Score). In cases of nicotinism, p was equal to 0.05. No statistical differences were noted, either in comorbidities or in ventilation days. SOFA (Sequential Organ Failure Assessment Score) and SII (Systemic Immune-Inflammation Index) scores presented no differences either. The groups were also analyzed in terms of the interventional treatment (endovascular or surgical) applied. Primary interventional treatment occurred when the patient had electively undergone any procedure whose side-effect resulted in bleeding with cerebral edema (e.g. aneurysm coiling or brain tumor operation). Secondary interventional treatment was applied after the onset of acute brain injury. The interventional treatment groups also presented no statistically significant

differences. Detailed characteristics of the study subgroups are depicted in Table 1.

Blood counts and their variability during the initial 72 hours of hospitalization after the onset were subjected to analysis. Median values with IQR, values with their division into subgroups are presented in Supplementary Table S1. No statistically significant differences were noted in terms of the total count of the morphotic elements of the peripheral blood throughout the whole observation period.

As brain injury and bleeding are considered to provoke an inflammatory response, the trends in counts of the morphotic elements were observed. Calculation of coefficients of variation have been analyzed. Apart from platelets' coefficient of variation ($p = 0.01$), none of the variables presented any statistically significant differences between the groups (Supplementary Table S2).

In addition, ratios among morphotic blood elements were calculated. These calculations were obtained for the total group and divided into those for the deceased and the survivors. Each day of observation was taken into consideration individually, while intergroup differences were statistically analyzed also on a daily basis. The statistical analysis revealed no specific changes when observed daily. The only ratio that presented statistically significant value in terms of intergroup differences turned out to be the platelets (PLT):white blood cells count (WBC) ratio on day 2 of the observation ($p = 0.03$). The other ratio that might prove useful was the PLT:N ratio also on day 2, where the p -value was 0.05. As this presented a limited value, it would need further investigation based on a more numerous group (Supplementary Table S3).

In Table 2, each ratio's per day area under the receiver operating characteristic curve (AUC ROC) has been calculated. Only the PLT:WBC ratio of day 2 presented a satisfactory value (AUC = 0.65) for being a predictor of 30-day mortality, the cut-off for that value being ≤ 14.81 . As presented in Table 2, the PLT:N ratio tends to be of borderline significance with $p = 0.05$ and

the AUC value is assessed as satisfactory (AUC 0.63), with a cut-off value of ≤ 25.18 .

Other AUC ROC were assessed according to findings of in-between group differences including also the clinical data. AUC labeled as satisfactory were represented by the following factors: age (AUC = 0.67, 95% CI: 0.55–0.78, $p = 0.0072$); basic GCS (AUC = 0.65, 95% CI: 0.53–0.76, $p = 0.02$); BSA (AUC = 0.67, 95% CI: 0.55–0.78, $p = 0.01$); PLT CoV 72 hours (AUC = 0.67, 95% CI: 0.55–0.78, $p = 0.009$) and PLT:WBC d.2 as previously (AUC = 0.65, 95% CI: 0.53–0.76, $p = 0.03$). Good values comprised SAPS II (AUC = 0.75, 95% CI: 0.63–0.85, $p < 0.0001$), APACHE II (AUC = 0.78, 95% CI: 0.66–0.87, $p < 0.0001$), LOS ICU (AUC = 0.75, 95% CI: 0.63–0.84, $p < 0.0001$) while very good was considered to be LOS total (AUC = 0.87, 95% CI: 0.76–0.94, $p < 0.0001$). Moreover, WBC CoV turned out to be statistically insignificant and its AUC ROC unsatisfactory (AUC = 0.52, 95% CI: 0.40–0.64, $p = 0.74$) (Supplementary Table S4).

Figure 2 presents the graphical interpretation of the usefulness of the PLT:WBC ratio on day 2 of the hospitalization as a predictor of 30-day mortality. Although the AUC (95% CI: 0.53–0.76) value is considered satisfactory and the calculations are statistically

Table 2. Selected ratios according to the day of hospitalization.

Parameter	AUC	95% CI	Cut-off	P-value
Day 1				
N:L	0.61	0.48–0.72	≤ 15.72	0.12
PLT:L	0.61	0.48–0.72	≤ 155.2	0.13
PLT:WBC	0.58	0.46–0.7	≤ 19.43	0.26
PLT:N	0.52	0.4–0.64	≤ 25.51	0.82
N:WBC	0.60	0.48–0.71	≤ 0.87	0.15
L:WBC	0.58	0.46–0.7	> 0.01	0.25
Day 2				
N:L	0.57	0.44–0.69	> 6.15	0.32
PLT:L	0.52	0.39–0.64	≤ 321.11	0.83
PLT:WBC	0.65	0.53–0.76	≤ 14.81	0.03
PLT:N	0.63	0.51–0.75	≤ 25.18	0.05
N:WBC	0.51	0.39–0.63	≤ 0.814	0.87
L:WBC	0.59	0.46–0.7	≤ 0.15	0.22
Day 3				
N:L	0.54	0.42–0.66	≤ 6.03	0.59
PLT:L	0.61	0.49–0.72	≤ 94.92	0.10
PLT:WBC	0.59	0.47–0.71	≤ 11.91	0.19
PLT:N	0.57	0.45–0.69	≤ 18.18	0.29
N:WBC	0.51	0.39–0.63	> 0.74	0.93
L:WBC	0.53	0.41–0.65	> 0.11	0.68

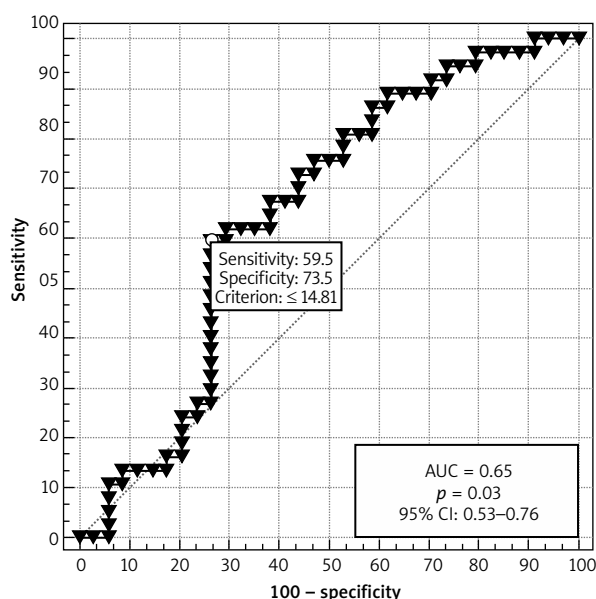


Figure 2. Predicting 30-day mortality using the PLT:WBC ratio on day 2 of hospitalization

significant, the sensitivity (59.5%) and specificity (73.5%) remain at mean levels.

Regarding the cut-off criteria that are based on AUC ROC calculations, variables were dichotomized whether they met the set criterion or not. Thus, while 31 patients met the criterion for PLT:WBC d.2, 45 patients were older than the criterion of being 46 years old. Moreover, the criterion was met in 47 patients for BSA, in 25 for PLT CoV, and in 45 for WBC CoV. In addition, 13 patients had a basic GCS score of ≤ 4 , 41 patients had spent maximum 16 days in the ICU, with the same number of individuals having spent a maximum of 20 days in hospital. Finally, 18 patients met the

Table 3. Odds ratios of 30-day mortality assuming cut-off points according to the AUC ROC criteria

Parameter	30-day mortality		
	OR	95% CI	P-value
PLT:WBC D.2	4.07	1.49–11.14	0.006
Age [years]	4.08	1.45–11.45	0.008
BSA	4.29	1.48–12.40	0.007
PLT CoV 72 h	4.93	1.65–14.68	0.004
WBC CoV 72 h	1.87	0.70–4.96	0.21
GCS basic	6.77	1.38–33.29	0.018
LOS hospital	17.78	5.29–59.74	< 0.0001
LOS ICU	6.65	2.32–19.04	0.0004
APACHE II	6.51	2.30–18.39	0.0004
SAPS II score	12.19	2.54–58.58	0.002

criterion for SAPS II and 39 for APACHE II. After taking all of these criteria into consideration, the odd ratios of 30-day mortality are presented in Table 3. The highest ORs that deserve attention, concern the total length of hospitalization (OR = 17.78, 95% CI: 5.29–59.74, $p < 0.0001$) and the SAPS II score (OR = 12.19, 95% CI: 2.54–58.58, $p = 0.002$). Again, WBC CoV values display no statistical significance.

Discussion

Any acute condition that affects the central nervous system is a devastating situation with an uncertain prediction. Many of these conditions, including those leading to any intracranial blood hemorrhage are indications for admission to an intensive care unit. Patients suffer from a wide range of symptoms that strongly correlate with higher mortality. Such factors as: hypoglycemia, $\text{PaO}_2/\text{FiO}_2$, mean arterial pressure and serum hemoglobin have been proven to play a great role in worsening patient outcomes [20]. Despite advanced medical technology that is even more widely accessible, it is essential to find a tool that will be able to help estimate the risk of death shortly after the event without involving many complicated resources. The perfect solution would be an indicator that can be easily acquired from a simple and affordable blood test. Moreover, the ideal indicator should be not only easy to gain but also universal in nature. Thus, the aim of this study comprised an attempt to determine such a biomarker.

Since the reaction of platelet to form microclots in brain vessels, this may be correlated with symptomatic vasospasm resulting in delayed cerebral ischemia (DCI). This also features in some cases and is later a cause of delayed ischemia [21]. In our statistical analysis we have shown that, in 72 hours observation, only platelets presented a statistically significant coefficient of variation in a between-group comparison.

Contrary to our findings, Hirashima *et al.* [22] have presented two conclusions, namely the minimum platelet count occurring later, namely on the fourth day after the onset, and with statistically significant differences not being noted until days 8, 9 and 10. However, as our study did not cover the same time period as that by Hirashima *et al.*, the results of both studies cannot be directly compared.

In the further part of our research, we concentrated on different configurations that may be calculated based on the results of morphotic blood elements. Day 2 of the observation turned out to be significant. Moreover, the statistical difference between the deceased and the survivors in the PLT:WBC ratio is significant ($p = 0.03$), while the PLT:N (platelets-to-neutrophil) ratio tends to be of borderline significance ($p = 0.05$). The PLT:N ratio presents a cut-off of 25 on day 2 (AUC = 0.63, 95% CI: 0.51–0.75, $p = 0.05$), a result which seems to confirm the findings of Yun *et al.* [23].

Although this indicator also has predictive ability in ischemic stroke and possible hemorrhagic transformation in patients with acute cerebral infarction, one must bear in mind possible differences due to the diverse of pathophysiological background of various neurological conditions [24–26]. The PLT:WBC ratio again remains as the only ratio that is likely to be considered as useful, with AUC ROC = 0.65, 95% CI: 0.53–0.76, $p = 0.03$ with a cut-off 14.81. Despite the level of sensitivity (59.5%) and specificity (73.5%), this ratio points out an interesting direction for further research. Recent scientific reports indicate that the relationship between platelets and white blood cells indeed should be included among these factors which play a role in predicting patient outcomes. Indeed, this relationship is one of the most commonly observed in subarachnoid hemorrhage where the PLT:WBC ratio is presented as an independent risk factor associated with poor functional outcome [26] where the result of the optimal threshold is established at 15.69, AUC = 0.628; 95% CI: 0.594–0.662; $p < 0.001$. The authors of this research study additionally indicate that patients with these ratio values present pneumonia much more often, a factor which also correlates with an unfavorable prognosis. Moreover, it should be emphasized that pneumonia is considered as the most common complication in another serious neurological disease, namely ischemic stroke.

In addition, the PLT:L (platelets-to-lymphocyte) ratio presented no statistically significant value in our analysis, thus contradicting the findings of Li and Deng [27] who stated that in moderate and severe traumatic brain injury this ratio of the first 24 hours after onset is a useful tool and a significant independent biomarker for short-term mortality prediction. Moreover, the usefulness of this ratio has been proved in cases of DCI after subarachnoid hemorrhage, as well as in accordance with other variables such as C-reactive protein at a cut-off of 27 [28]. One may presume that only one indicator is not enough to create an algorithm with a high level of validity in order to be useful in determining complications and both short-term and long-term mortality.

Another interesting finding, namely the neutrophil-to-lymphocyte ratio (NLR), is presented as a predictive factor and a poor outcome indicator in various neurological conditions [28–31]. Although we have not found the functional outcome, we have proved also the length of stay (LOS) to be also one of the variables in a multivariable analysis that is a good predictor for mortality when the LOS of total hospitalization was characterized by an AUC value of 0.87, 95% CI: 0.76–0.94, $p < 0.001$, a cut-off ≤ 20 days and an LOS in the ICU, AUC of 0.75, 95% CI: 0.63–0.84, $p < 0.001$ and a cut off of ≤ 16 days. In the analysis by Guo *et al.* [30] the tendency of increasing the in-hospital LOS was also shown to be significant.

Hathidara *et al.* [32] suggest taking a broader view of the issue of the prediction of the in-hospital outcome, especially including DCI precisely in SAH patients where a CRIG (Clinical, Radiological, Inflammatory, dysGlycemia) score is used. This takes into consideration not only radiological or clinical data but also incorporates inflammatory indications where NLR and MPV:PLT or PLT:L ratios are included.

At the same time, the prognostic value of some ratios such as NLR and PLT:L needs further research. For example, Oliveira *et al.* [33] claim that although their usefulness in conditions such as sepsis, cancer and acute coronary syndrome is undeniable, their role in the occurrence of vasospasm and, therefore its influence on final outcomes, must be investigated at a deeper level.

Further, platelet counts and their other characteristics have attracted the interest of researchers in terms of how they may be useful in predicting prognosis in neurologically affected patients. The potential of mean platelet volume (MPV) and the MPV:PLT (mean platelet volume to platelet) ratio or the MPV:L (mean platelet volume to lymphocyte) ratio seem to deserve attention [34–36]. Although there are examples of usefulness of such calculations, one must remember about the possible limitations and bias occurring due to result standardization [37].

According to the recent reports, such indices as systemic inflammation response index (SIRI) and systemic immune-inflammation index (SII) are thought to be highly promising in nature. These use easily accessible laboratory values such as neutrophil, monocyte, lymphocyte, and platelet counts. A SIRI score is obtained by neutrophil count $\times$ monocyte count/lymphocyte count while a SII is calculated by multiplying the platelet count and the neutrophil-to-lymphocyte ratio. These constitute novel independent prognostic indices especially concerning functional outcome among patients suffering from subarachnoid hemorrhage next to clinical classifications such as World Federation of Neurosurgical Societies (WFNS), Hunt and Hess, and Fisher scales [38–41]. Although in our research, SII scores presented neither statistical significance nor intergroup differences, with the accuracy for that quantity in our research being an AUC of 0.58 with a cut off of $\leq 2047 \times 10^9/l$, 95% CI: 0.46–0.69, $p = 0.25$, we hope it will prove useful probably in a more precisely defined and homogenous group of patients. Bearing in mind the broad possibilities that come with SIRI and SII, it is only a matter of time when further research will certainly appear on this issue, as well as that concerning artificial intelligence (AI) and machine learning based on electronic health record (EHR) data [42].

Firstly, despite the very large number of patients screened, our study group covered only 71 suitable candidates. Unfortunately, in the study period, our ward was temporarily transformed into a unit dedi-

cated for COVID-19 patients. Moreover, due to the character of our hospital, the surgical and medical reasons for the patients' admission took precedence over neurological reasons, with those suffering from mild and moderate forms of brain trauma or SAH being admitted to neurological or neurosurgical units. Lastly, some potential subjects did not meet the criterion of 72 hours of sedation. Secondly, our study group was quite heterogeneous. Therefore, we did not compare any other medical records such as radiologic results apart from laboratory samples. These imaging test classifications differ from each other due to clinical reasons for the patients' hospitalization. Moreover, we only focused on laboratory samples. In addition, the treatment approach, despite the established protocol in our unit for an acute brain injury, depended on the critical care specialist's decision according to the clinical situation. These included administration of neuroprotective treatment, antibiotics and maintaining an accurate fluid balance. Thirdly, some of the patients required neurosurgical or intravascular intervention more than once during their hospitalization, namely medical procedures, which also might have constituted an interfering factor regarding the study.

Conclusions

In this heterogeneous group of patients presenting with acute brain injury, with any type of intracranial bleeding, no universal indicator which is based on peripheral blood morphotic elements was found to predict 30-day mortality. Thus, further research should be provided in order to distinguish a highly accurate indicator based on peripheral blood morphotic elements which would be useful and universal in its application for acute brain injury. At the same time, we remain of the opinion that simple and easily accessible tests will prove to be useful in determining possible complications, including mortality. This will make it easier to estimate the prognosis of individual patients, which in turn will help in adapting advanced treatments and managing resources. The possibility in incorporating simple, fast, objective, minimally-invasive and, if possible, low-cost tests in the decision-making process seems to be a necessity in terms of reducing the great burdens currently affecting healthcare systems.

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Ethical approval

Approval for this study was obtained from the ethics committee of the Medical University of Silesia, Katowice (BNW/NWN/0052/KB/119/23). Date: 21st July 2023.

Conflict of interest

The authors declare no conflict of interest.

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