Eur J Transl Myol 35 (1) 13443, 2025 doi: 10.4081/ejtm.2025.13443

# A comparative analysis of Rotterdam score and neutrophil-to-lymphocyte ratio in predicting outcomes for patients with moderate to severe traumatic brain injury

Hamidreza Aghadoost,[1] Ghazaleh Salehabadi,[2] Esmaeil Fakharian,[3] Hanieh Jafari Mohammadabad[2]

*[1]Department of Neurosurgery, Kashan University of Medical Sciences, Kashan; [2]Department of Radiology, Iran University of Medical Sciences, Tehran; [3]Trauma Research Center, Kashan University of Medical Sciences, Kashan, Iran.*

*This article is distributed under the terms of the Creative Commons Attribution Noncommercial License (CC BY-NC 4.0) which permits any noncommercial use, distribution, and reproduction in any medium, provided the original author(s) and source are credited.*

***Abstract***

This study aimed to evaluate the role of NLR in predicting outcomes for patients with moderate to severe TBI. A retrospective analysis was conducted from April 2020 to April 2022, including patients aged 16 and older with Glasgow Coma Scale (GCS) scores of 8 or below admitted to Shahid Beheshti Hospital, Kashan. Data on NLR and other clinical markers were collected. Rotterdam scores were calculated using CT scan findings. Patients were followed up for six months post-trauma or until death, and associations between NLR and clinical outcomes were analyzed, with significance set at $P < 0.05$. Among 195 patients, 130 (66%) had unfavorable outcomes at six months. Admission NLR was significantly higher in patients with unfavorable outcomes compared to those with favorable outcomes ($P < 0.001$). Receiver operating characteristic analysis indicated that NLR had a sensitivity of 82% and specificity of 91% at a threshold of 5.2 for predicting unfavorable outcomes. Elevated admission NLR in patients with severe TBI was linked to unfavorable six-month functional outcomes and mortality. NLR may serve as a readily accessible clinical marker for prognostication in moderate to severe TBI.

**Key Words:** Glasgow Coma Scale; neutrophil-to-lymphocyte ratio; Rotterdam Score; traumatic brain injury.

*Eur J Transl Myol 35 (1) 14343, 2025 doi: 10.4081/ejtm.2025.13443*

Head injuries are among the leading causes of death and disability due to trauma.[1] The burden of head injuries is especially high in low- and middle-income countries, which represent 85% of the global population.[2] The World Health Organization estimates that nearly 90% of trauma-related deaths occur in these regions.[1]

In low- and middle-income countries, head injury risk factors are more common, yet healthcare resources to manage the resulting complications are limited. Significant disabilities from head injuries place a substantial burden on healthcare systems in these regions. Therefore, understanding the epidemiology of head injuries and developing preventive measures are critical.[3] Head injuries are a primary cause of disability in individuals under 40 years old, annually causing severe impairment in 150-200 people per million.[4,5]

Most TBIs result from road accidents (60%), followed by falls (20-25%) and violence (10%). A study in Kashan, Iran, reported an incidence rate of 429 per 100,000 people for head trauma.[6] TBIs are categorized by the Glasgow Coma Scale (GCS) as mild (GCS >13), moderate (GCS 8-13), or severe (GCS <8). As injury severity increases, so do associated disability and mortality risks. Given the high prevalence and significant impact of TBIs, predicting outcomes in these patients is crucial, making accessible, low-cost prognostic tools essential.[7]

One helpful method for assessing TBI severity involves CT-based scoring systems. Three commonly used CT scoring systems for outcome prediction are the Marshall, Rotterdam, and Helsinki scores. The Marshall system was introduced in 1991,[8] and the Rotterdam score was developed in 2005 by revising Marshall's system and adding traumatic subarachnoid hemorrhage (tSAH) and intraventricular hemorrhage.[9] The Helsinki score, introduced in 2014, combines elements from both Marshall and Rotterdam but emphasizes various intracranial injuries.[9]

Due to its extensive validation, the Rotterdam score is a practical tool for predicting TBI outcomes. Studies report that a Rotterdam score cutoff of 4 demonstrates high sensitivity and specificity for predicting outcomes.[10]

The Neutrophil-To-Lymphocyte Ratio (NLR) has gained

attention as a new prognostic marker for Traumatic Brain Injury (TBI). This study examines NLR alongside the Rotterdam CT score, a validated and widely used tool for TBI prognosis. NLR is a fast, low-cost, and easily measurable indicator linked to outcomes in various diseases, such as small-cell lung cancer,[11] and acute respiratory infections, including COVID-19.[12,13]

Concurrently, regulatory T-helper cells limit T-cell brain infiltration, promoting recovery by inducing reactive astrogliosis and gamma interferon release.[14]

Recently, NLR has emerged as a predictor of mortality and adverse outcomes in TBI. Retrospective data show that higher NLR—both at admission and peak levels—correlates with increased mortality and worse outcomes in severe TBI.[15,16]

For example, a retrospective cohort study by Zhao *et al.* (2019) in China on 1,291 TBI patients identified age, GCS at admission, subdural hematoma, intraparenchymal hemorrhage, traumatic subarachnoid hemorrhage, NLR ($p < 0.001$), and coagulopathy as independent predictors of six-month outcomes. Their model, including NLR, demonstrated higher predictive ability than a model lacking NLR.[17]

Notwithstanding, research on this topic remains limited, with no prior studies in Iran directly investigating the NLR-TBI relationship. This study thus aims to compare the Rotterdam CT score and NLR in predicting outcomes in moderate to severe TBI patients admitted to Shahid Beheshti Hospital in Kashan between 2020 and 2022.

## Materials and Methods

### *Study design*

This study was a retrospective cohort analysis with an additional focus on evaluating prognostic value of NLR and Rotterdam score.

### *Study population, sample, and setting*

The population included all patients with moderate-to-severe TBI who were admitted to an institutional tertiary hospital in Kashan, central Iran, from early 2020 to late 2022 and met the study's inclusion criteria.

### *Sample size*

This study used a convenience sampling method. All TBI patient records meeting the inclusion/exclusion criteria were reviewed. Based on the study by Chen *et al.,*[16] with a Type I error of 5%, mortality rate of 36%, sensitivity of 60%, and specificity of 71%, the target sample was 65 patients each in recovery, disability, Vegetative State Or Death (VS/D) categories, corresponding to a total of 195 patients.

### *Study procedure*

We conducted a retrospective cohort analysis of patients aged over 16 years with moderate-to-severe TBI. Eligible cases were selected from all admissions, and the inclusion criteria were: i) confirmed diagnosis of moderate-to-severe TBI on CT scans; ii) age over 16; iii) Glasgow Coma Scale (GCS) score between 3 and 13; iv) patient's willingness to participate.

Exclusion criteria included: i) lack of follow-up accessibility; ii) death within the first 24 hours of admission; iii) history of hematologic malignancies such as leukemia or lymphoma; iv) incomplete medical records

Data on patient demographics, injury mechanism, clinical findings, CT imaging results (basal cisterns, midline shift, and hemorrhage/hematoma), and severity (based on GCS score) were collected. Routine brain CT scans were performed on all patients, evaluated by a specialist who calculated the Rotterdam score based on criteria presented in Table 1.

Neutrophil-to-Lymphocyte Ratios (NLR) were derived from Complete Blood Count (CBC) tests. Outcomes were assessed using the Glasgow Outcome Scale (GOS) at 24 hours post-admission and six months post-discharge, which was determined based on criteria presented in Table 2.

### *Statistical analysis*

Data analysis was conducted with IBM SPSS 22.0. The Kolmogorov-Smirnov test assessed data normality, and parametric tests like one-way ANOVA were used for mean comparisons among groups. Receiver Operating Characteristic (ROC) curves identified optimal cutoff points for the Rotterdam score and NLR, with sensitivity, specificity, and predictive values calculated for NLR. A P-value of $<0.05$ was considered statistically significant.

### *Ethical considerations*

Ethical approval for this retrospective cohort study was obtained from the Research Ethics Committee at Kashan University of Medical Sciences (Approval ID: IR.KAUMS.MEDNT.REC.1402.222). As this research utilized existing patient records, no direct contact with participants was required, and all data were anonymized

***Table 1.*** *Criteria used for calculation of Rotterdam score.*

| CT finding | | Score |
|---|---|---|
| Basal cisterns | Normal | 0 |
| | Compressed | 1 |
| | Absent | 2 |
| Midline shift | ≤5 mm | 0 |
| | >5 mm | 1 |
| Epidural eematoma | Present | 0 |
| | Absent | 1 |
| IVH/SAH | Absent | 0 |
| | Present | 1 |

*CT, computed tomography; IVH, intraventricular hemorrhage; SAH, subarachnoid hemorrhage.*

to maintain patient confidentiality. All procedures adhered to the ethical standards of the Declaration of Helsinki, and appropriate measures were taken to protect patient privacy throughout the data collection and analysis phases.

## Results

A total of 195 patients, 37 (19%) women and 158 (81%) men, with a mean age of 44.40±13.10 were included. Baseline demographic information of patients is summarized in Table 3. The most prevalent cause of trauma in all patients was motorcycle rollover (21%), followed by fall from height (20%) and motorcycle collision with pedestrian (10.8%).

Table 4 summarizes the demographic information of patients (N=195) categorized based on 24-hour clinical outcome into three groups, namely, recovery (N=42), disability (N=121), and vegetative state or death (N=32). The highest (49.30±10.10) and lowest (30.00±7.60) mean age were recorded for patients in the VS/D and recovery group, respectively. As anticipated, the recovery group demonstrated the highest mean GCS (10.9±1.5), while the VS/D group exhibited the lowest mean GCS (5.8±2.1). Female to male ratio was consistently below 1 across all groups, with the majority of patients being male. The prevalence of severe brain injury was 7.2% in the recovery group, 71.1% in the disability group and 81.3% in the VS/D group. Fall from height was the most frequently reported cause of trauma in the recovery group (23.8%), while motorcycle rollover was the most prevalent cause of trauma in the disability group with an overall rate of 28.1%. Conversely, motorcycle collisions had the highest prevalence among patients in the VS/D group.

Table 5 presents the demographic information of patients (N=195) categorized based on 6-month clinical outcome into three groups, namely, recovery, disability, and vegetative state or death, each with a total of 65 patients.

***Table 2.*** *Glasgow Outcome Scale (GOS) classification system.*

| GOS | Interpretation | Classification in this study |
|---|---|---|
| 1 | Dead | VS/D |
| 2 | Vegetative state | |
| 3 | Severe disability | Disability |
| 4 | Moderate disability | |
| 5 | Good recovery | Recovery |

*VS/D, vegetative state or death.*

***Table 3.*** *Baseline demographic information of patients.*

| Demographic | | Patient N=195 (%) |
|---|---|---|
| Age (yr) | 44.40±13.10 | |
| Gender | Female | 37 (19) |
| | Male | 158 (81) |
| Cause of trauma | Fall from height | 39 (20) |
| | Motorcycle rollover | 41 (21) |
| | Motorcycle collision with pedestrian | 21 (10.8) |
| | Motorcycle-to-motorcycle collision | 19 (9.7) |
| | Car collision with motorcycle | 18 (9.2) |
| | Car-to-car collision | 17 (8.7) |
| | Car collision with pedestrian | 15 (7.7) |
| | Car rollover | 12 (6.2) |
| | Physical altercation | 13 (6.7) |

***Table 4.*** *Demographic information of patient groups based on 24-hour clinical outcome.*

| Demographic | | 24-hour clinical outcome | | |
|---|---|---|---|---|
| | | Recovery N=42 (%) | Disability N=121 (%) | VS/D N=32 (%) |
| Age (yr) | 30.00±7.60 | 48.10±11.80 | 49.30±10.10 | |
| GCS | 10.9±1.5 | 7.2±2.3 | 5.8±2.1 | |
| Gender | Female | 8 (19) | 28 (23.1) | 1 (3.1) |
| | Male | 34 (81) | 93 (76.9) | 31 (96.9) |
| Severity of brain injury | Moderate | 39 (92.8) | 35 (28.9) | 6 (18.7) |
| | Severe | 3 (7.2) | 86 (71.1) | 26 (81.3) |
| Cause of trauma | Fall from height | 10 (23.8) | 25 (20.7) | 4 (12.5) |
| | Motorcycle rollover | 3 (7.1) | 34 (28.1) | 4 (12.5) |
| | Motorcycle collision with pedestrian | 5 (11.9) | 9 (7.4) | 7 (21.9) |
| | Motorcycle-to-motorcycle collision | 1 (2.4) | 11 (9.1) | 7 (21.9) |
| | Car collision with motorcycle | 3 (7.1) | 15 (12.4) | 0 |
| | Car-to-car collision | 4 (9.5) | 9 (7.4) | 4 (12.5) |
| | Car collision with pedestrian | 4 (9.5) | 10 (8.3) | 0 |
| | Car rollover | 2 (4.8) | 4 (3.3) | 6 (18.7) |
| | Physical altercation | 9 (21.4) | 4 (3.3) | 0 |

*GCS, Glasgow coma scale; VS/D, vegetative state or death.*

***Table 5.*** *Demographic information of patient groups based on 6-month clinical outcome.*

| Demographic | | 6-month clinical outcome | | |
|---|---|---|---|---|
| | | Recovery N=65 (%) | Disability N=65 (%) | VS/D N=65 (%) |
| Age (yr) | 33.10±9.40 | 47.30±10.20 | 52.90±11.00 | |
| GCS | 10.2±1.7 | 7.0±2.1 | 6.0±2.3 | |
| Gender | Female | 13 (20) | 15 (23.1) | 9 (13.8) |
| | Male | 52 (80) | 50 (76.9) | 56 (86.2) |
| Severity of brain injury | Moderate | 52 (80) | 16 (24.6) | 12 (18.5) |
| | Severe | 13 (20) | 49 (75.4) | 53 (81.5) |
| Cause of trauma | Fall from height | 16 (24.6) | 8 (12.3) | 15 (23.1) |
| | Motorcycle rollover | 3 (4.6) | 22 (33.8) | 16 (24.6) |
| | Motorcycle collision with pedestrian | 12 (18.5) | 1 (1.5) | 8 (12.3) |
| | Motorcycle-to-motorcycle collision | 8 (12.3) | 2 (3.1) | 9 (13.8) |
| | Car collision with motorcycle | 3 (4.6) | 11 (16.9) | 4 (6.1) |
| | Car-to-car collision | 4 (6.1) | 8 (12.3) | 5 (7.7) |
| | Car collision with pedestrian | 5 (7.7) | 8 (12.3) | 2 (3.1) |
| | Car rollover | 4 (6.1) | 2 (3.1) | 6 (9.2) |
| | Physical altercation | 10 (15.4) | 3 (4.6) | 0 |

*GCS, Glasgow coma scale; VS/D, vegetative state or death.*

Similar to the 24-hour clinical outcome, the highest (52.90±11.00) and lowest (33.10±9.40) mean age were recorded for patients in the VS/D and recovery group, respectively. Likewise, the recovery group were found to have highest mean GCS (10.2±1.7), while the VS/D group demonstrated the lowest mean GCS (6.0±2.3). In parallel, female to male ratio was consistently below 1 across all groups, with the majority of patients being male. The frequency of severe brain injury was 20% in the recovery group, 75.4% in the disability group and 81.5% in the VS/D group. While the prevalence of severe brain injury remained mostly unchanged in the latter groups over the 6-month timeframe, the recovery group saw an increase of over 12% in the frequency of severe brain injury. Comparably, fall from height was still the most frequently reported cause of trauma in the recovery group (24.6%), while motorcycle rollover was the most prevalent cause of trauma in both disability and VS/D groups with rates of 33.8% and 24.6% respectively.

The complete blood counts and CT findings of patient groups, based on 24-hour clinical outcome, are reported in *Supplementary materials, Table 1*. As can be seen, the recovery and VS/D groups had consistently lower and higher cell counts across all categories of white blood cells, except for lymphocyte count, with the disability group demonstrating intermediate values. Regardless of comparatively lower values, the recovery group still had higher than normal counts of leukocytes, with an overall WBC count of 13.931±2.423 ($\times 10^3/\mu L$), suggesting the presence of leukocytosis. While the mean count of neutrophils in the recovery group mostly fell within the upper limit of normal neutrophil count, patients in the disability and VS/D group showed neutrophil counts of 11.847±3.111 and 13.653±1.884 ($\times 10^3/\mu L$), respectively, indicating the presence of neutrophilia. Conversely, lymphocyte count in all three groups fell within the normal range, with the recovery group showing the highest mean lymphocyte count equal to 2.862±0.610 ($\times 10^3/\mu L$). Neutrophil-to-Lymphocyte Ratio (NLR) was consistently high across all groups, ranging from 3.6±2.4 in the recovery group to 10.8±2.5 in the VS/D group. According to CT findings, the basal cisterns were mostly (64.3%) normal in the recovery group, however, the rate of absent basal cisterns was 19.8% and 50% in the disability and VS/D groups. The prevalence of significant midline shift (> 5 mm) was notably low in the recovery group (4.8%), whereas 100% of patients in the VS/D group exhibited a midline shift > 5 mm. Epidural hematoma was relatively common in both the recovery and VS/D groups, with rates exceeding 30%, but was less prevalent in the disability group (11.6%). In contrast, the VS/D group had a notably high prevalence of SAH/IVH, reaching 78.1%. Most patients in the recovery group had lower Rotterdam scores, with a cumulative mean of 2.0±0.8, while higher Rotterdam scores were observed in the other two groups, with the VS/D group averaging 4.5±1.0.

*Supplementary materials, Table 2* lists the complete blood counts and CT findings of patient groups based on 6-month clinical outcome. As reported, the recovery and VS/D groups had consistently lower and higher cell counts across all categories of WBCs, except for lymphocyte count, with the disability group exhibiting intermediate cell counts. In contrast to the 24-hour post-admission cell counts, the recovery group showed mostly normal cell counts, with an overall WBC count of 12.891±2.878 ($\times 10^3/\mu L$), which was not strongly suggestive of leukocytosis. Similarly, the mean count of neutrophils in the recovery group fell within the normal range neutrophil count, however, patients in the disability and VS/D group still showed high neutrophil counts of 12.411±1.759 and 13.848±2.220 ($\times 10^3/\mu L$), respectively. Comparably, lymphocyte count in all three groups fell within the normal range, with the recovery group maintaining a comparatively high mean lymphocyte count of 2.862±0.610 ($\times 10^3/\mu L$). NLR was consistently high in the disability and VS/D groups, ranging from 5.7±1.3 in the former to 9.3±2.6 in the latter. In the recovery group, however, NLR was slightly higher than the upper limit (3.3±2.0). Based on the CT findings, the basal cisterns were normal in the majority of patients (80%) in the recovery group. Additionally, the rate of absent basal cisterns was 21.5% and 50% in the disability and VS/D groups, which showed an improvement compared with the rates observed within 24 hours from hospitalization. The prevalence of significant midline shift (> 5 mm) was lower in the recovery group (16.9%), whereas 92.3% of patients in the VS/D group still showed a midline shift > 5 mm in their CT. Epidural hematoma rate was comparable across all groups, ranging from 18.5% to 24.6%. Similar to 24-hour outcomes, the VS/D group still had a notably high prevalence of SAH/IVH, reaching 66.2%. The majority of patients in the recovery group had lower Rotterdam scores, with an overall mean of 2.2±0.8, while higher Rotterdam scores were reported in the other two groups, with the VS/D group averaging 4.0±1.0.

As indicated in *Supplementary Materials, Table 3*, one-way Analysis Of Variance (ANOVA) across the three groups suggested a statistically significant association between NLR and 24-hour clinical outcome, unfavorable clinical outcomes associated with higher mean NLR ($P<0.001$). Similarly, Rotterdam score was also found to be significantly associated with 24-hour clinical outcome, with unfavorable outcomes, *i.e.*, disability and VS/D, being associated with higher mean Rotterdam scores ($P<0.001$). These findings suggested that NLR and Rotterdam score might be of prognostic value when predicting the outcome of moderate to severe traumatic brain injury.

Similarly, NLR and Rotterdam score were also found to confer predictive value with regard to 6-month clinical outcome, as both indicators were significantly associated with unfavorable clinical outcomes in patients within 6 months from hospitalization ($P<0.001$), i.e., higher NLR and Rotterdam scores were associated with worse clinical outcome, with patients in the VS/D group demonstrating the highest mean NLR (9.3±2.6) and Rotterdam score (4.0±1.0) by the end of the sixth month (*Supplementary Materials, Table 4*).

Figure 1 presents the Pearson correlation analysis between NLR and Rotterdam score, showing an  coefficient of 0.4 and a P-value < 0.001. This indicates a statistically significant, moderate positive correlation, suggesting that higher NLR values are moderately associated with higher Rotterdam scores.

To visualize the prognostic accuracy of NLR and Rotterdam score at predicting the 24-hour clinical outcome of TBI, we plotted ROC curves for each indicator (see Figure 2). As shown here, Rotterdam score, with an AUC of 0.870, was slightly superior to NLR (AUC=0.829) for predicting unfavorable clinical outcome in patients within the first 24 hours from TBI. Still, NLR conferred an acceptable sensitivity of 71% and specificity of 84% for distinguishing patients with poor clinical outcome from those with favorable outcome, with a cut-ff value of 5.1 (*Supplementary Materials, Table 5*).

The prognostic accuracy of NLR and Rotterdam score for predicting 6-month clinical outcome in TBI is visualized as ROC curves in Figure 3. As shown here, NLR delivered a considerably high accuracy for differentiating patients progressing into vegetative state or death from those recovering, with an AUC of 0.925, which was markedly superior to Rotterdam score in this regard. With a cut-off value of 5.2, NLR was found to be 82% sensitive and 91% specific for determining 6-month clinical outcome (*Supplementary Materials, Table 5*).

## Discussion

Traumatic brain injury is a common cause of disability and death across various populations. Therefore, finding an accessible, low-cost marker to predict TBI outcomes could assist clinicians in making decisions during the critical window and provide a reliable prognosis for the patient. In this retrospective cohort study, we evaluated 195 TBI patients classified in three categories based on 24-hour and 6-month clinical outcomes, and investigated the prognostic accuracy of NLR and Rotterdam score in predicting unfavorable clinical outcomes in these patients.

Our study found that traffic accidents were the primary cause of TBI among patients in Kashan. Globally, road in-

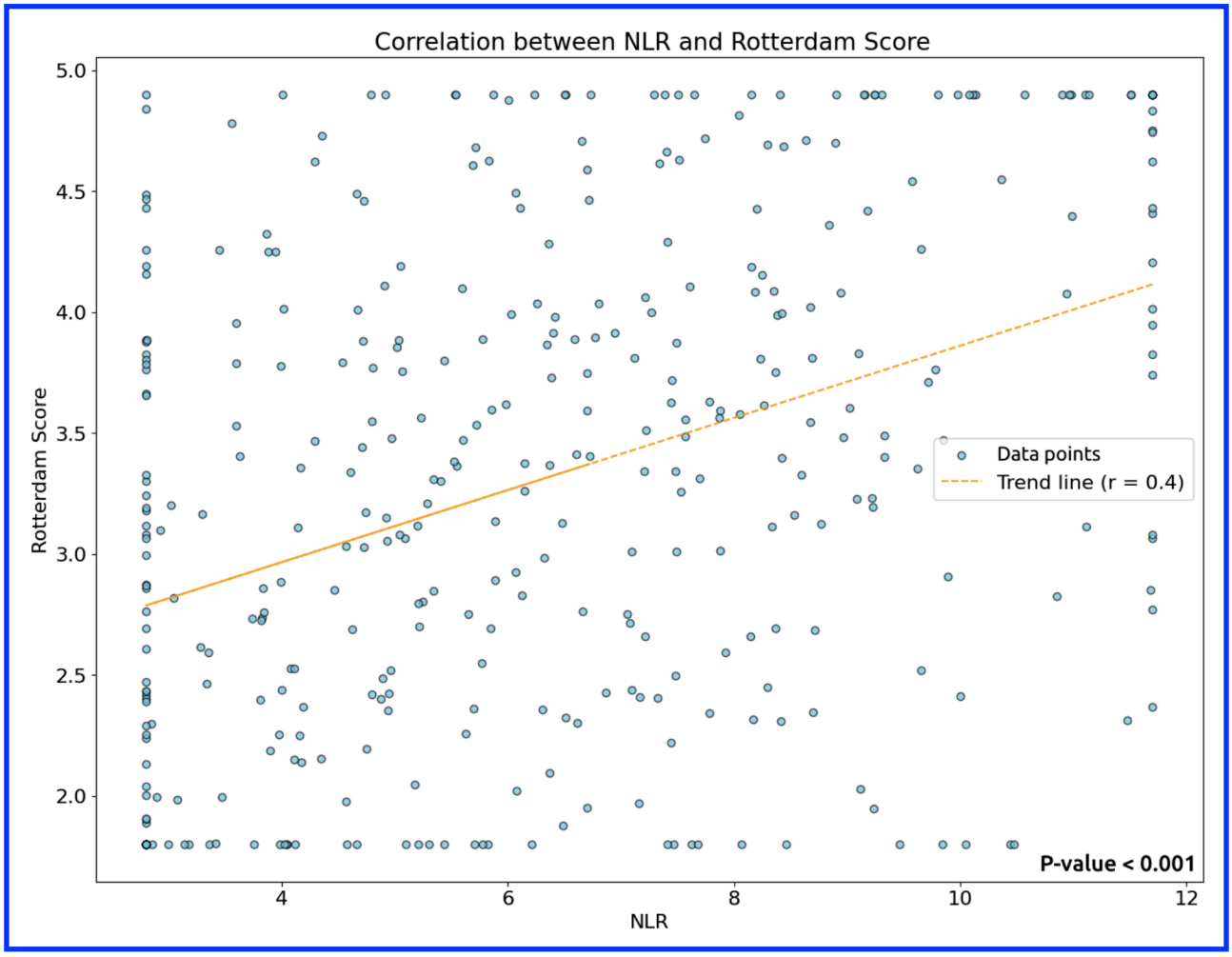


***Figure 1.*** *Scatter plot illustrating the simulated correlation between NLR and Rotterdam score in patients with moderate to severe traumatic brain injury.*

cidents are also the leading cause of brain injuries, with studies estimating that about 60% of TBI cases are due to traffic accidents.[3]

Within 24 hours of injury, most patients experienced mild to moderate disability, requiring assistance with daily activities. A 6-month follow-up showed that younger patients tended to recover more effectively, with a better prognosis. Patients with more severe TBI, lower GCS scores at admission, and higher Rotterdam scores had worse outcomes, often leading to vegetative states or death within 24 hours and at 6 months post-injury. The average Rotterdam score in patients who died or entered a vegetative state was 4.5±1.0 and 4.0±1.0, respectively, compared to 2.0±0.8 and 2.2±0.8 in patients with a favorable recovery. Statistical analysis confirmed a significant link between Rotterdam score and patient prognosis. This finding aligns with previous studies, which also found that a higher Rotterdam score correlates with worse prognosis

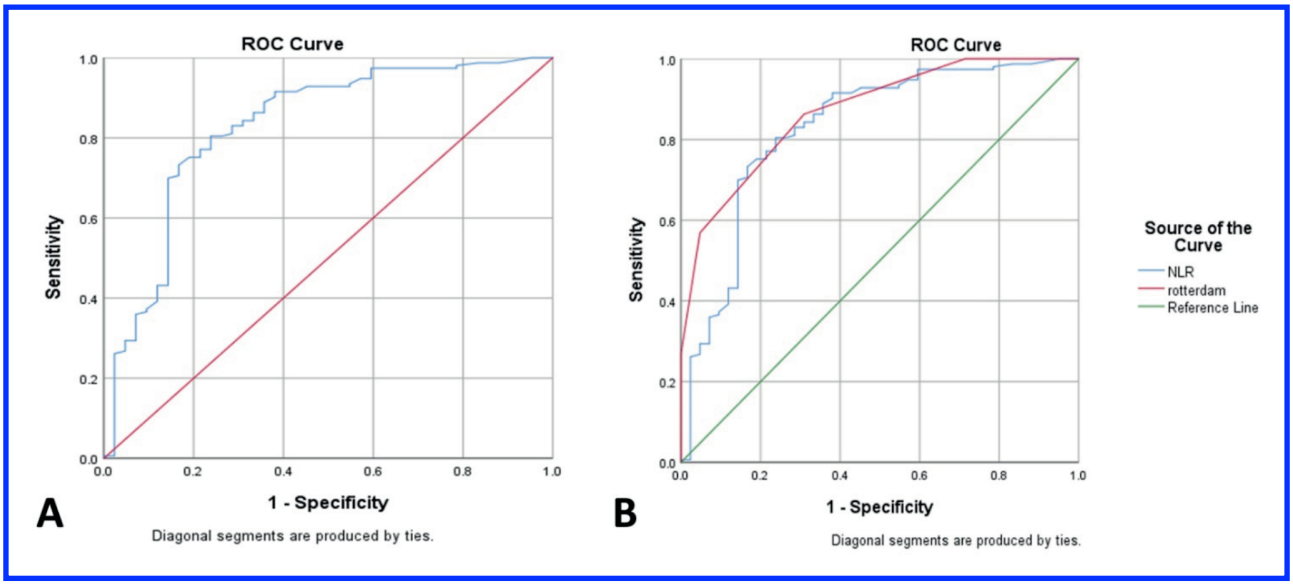


***Figure 2****. Receiver operating characteristic curves showing the 24-hour prognostic accuracy of NLR alone (A) and compared with Rotterdam score (B).*

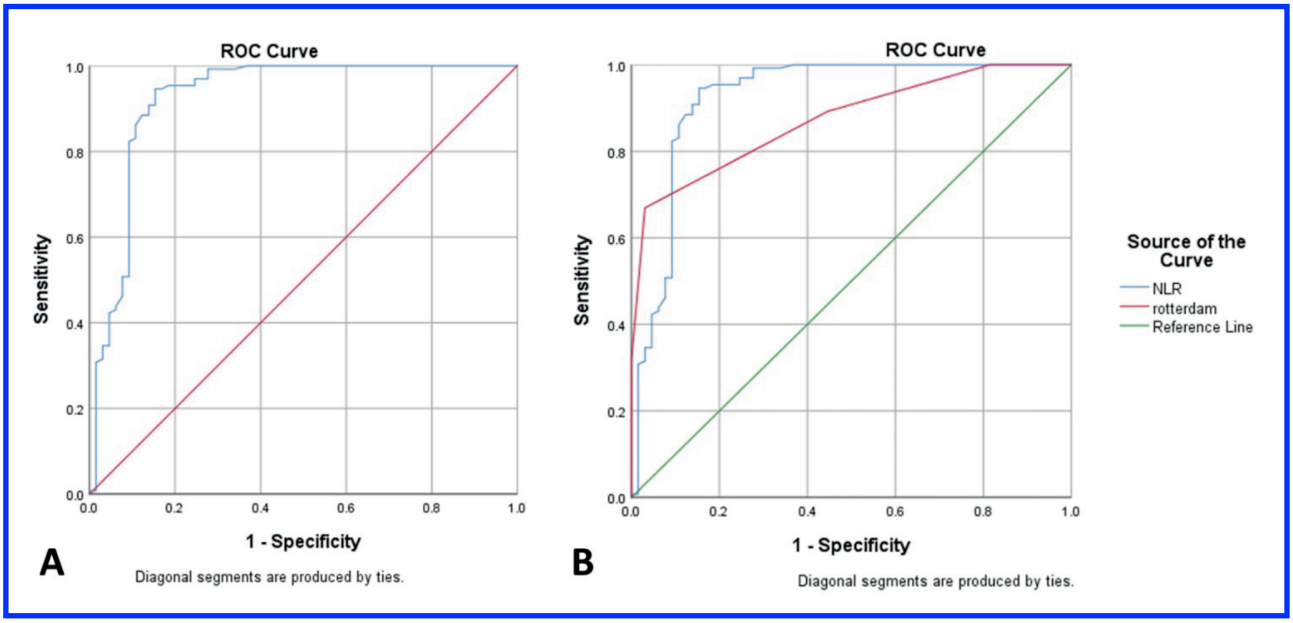


***Figure 3.*** *Receiver operating characteristic curves showing the 6-month prognostic accuracy of NLR alone (A) and compared with Rotterdam score (B).*

and higher mortality.[10,18] Earlier research has validated the cutoff of 4 in the Rotterdam scoring system as a good sensitivity-specificity threshold for predicting outcomes in TBI patients.[10] Our study also suggested the cutoff of 4 in the Rotterdam scoring system and declared that the AUC of NLR was markedly superior to the Rotterdam score in predicting 24-hour and 6-month clinical outcomes. However, in both situations, the Rotterdam score showed more specificity, while NLR showed to be more sensitive. The Neutrophil to Lymphocyte Ratio or NLR is derived from a simple blood test. White blood cells play a key role in the body's stress response, coordinating inflammation. Neutrophils are the initial responders, rapidly arriving at the injury site as part of innate immunity, while lymphocytes are slower but crucial to adaptive immunity and appear after neutrophils.[11,19,20]

NLR operates on the principle that stress hormones elevate neutrophil levels while lowering lymphocyte levels. Thus, this ratio serves as a marker for the body's stress levels during acute illness.[20] Shifts in neutrophil and lymphocyte counts correlate with disease severity in conditions like infections, cancer, and cardiovascular events. Prior studies have explored NLR's role in neurological diseases, showing that higher NLR correlates with poorer prognosis in central nervous system disorders like glioblastoma[21] and ischemic stroke treated with thrombectomy.[22] In this study, NLR was calculated using patients' lab records. Findings showed that higher NLR values, both within 24 hours after moderate to severe TBI and at 6 months follow-up, were significantly associated with poorer prognosis. In patients who died or entered vegetative states, NLR was notably higher than in the disability group, and higher in the disability group than in the recovery group. This critical finding aligns with recent retrospective studies that have demonstrated a link between higher NLR (both at admission and at peak) and adverse outcomes, including higher mortality, in severe TBI patients.[15,16]

The relationship between NLR and TBI has been addressed in several different populations, particularly Chinese subpopulations. In 2019, Chen et al. conducted a retrospective study on 216 Chinese patients with severe TBI, examining the association between NLR and one-year patient outcomes. Among these patients, 81.3% (257 individuals) experienced unfavorable outcomes. The study concluded that peak NLR levels could serve as an independent prognostic marker for poor one-year outcomes,[15] which is in agreement with our observations in the present work.

Similarly, in 2019, Zhao *et al.* conducted a retrospective cohort study to assess the relationship between NLR and six-month outcomes in patients with TBI. This study used GCS to determine six-month outcomes. A total of 1,291 patients were included, and the findings indicated that age, initial GCS, subdural hematoma, intraparenchymal hemorrhage, traumatic subarachnoid hemorrhage, NLR ($P<0.001$), and coagulopathy were all independent predictors of six-month outcomes.[17] In another study by Zhuang *et al.* in 2021, researchers examined the link between NLR and early Intracerebral Hemorrhage (ICH) after TBI. This study included 1,077 TBI patients who underwent an initial CT scan within six hours of admission, followed by a second scan 48 hours later. Results indicated that NLR could robustly predict early ICH occurrence ($P<0.001$), with a predictive accuracy of 82%.[23]

In 2018, Chen *et al.* conducted a retrospective study in China involving 855 patients with severe TBI to explore the relationship between NLR and one-year outcomes. Of the 688 patients with complete one-year follow-up data, 508 (73.8%) had unfavorable outcomes. This study found that admission NLR levels were significantly higher in the unfavorable outcome group. With a cutoff value of 13.05, the sensitivity of NLR for predicting poor one-year outcomes was estimated at 60.2%, and its specificity was 71.1%.[16] From a methodological perspective, Chen's study most closely resembles the present study, differing primarily in sample size and follow-up duration.

One of the few studies in Iran on NLR, conducted by Sabouri *et al.*, was a 2020 review concluding that NLR is an independent predictor of mortality and disability in patients with severe TBI. They also noted a significant association between NLR and GCS and recommended that combining these two factors would be useful for predicting TBI outcomes.[20]

In 2021, Aliohammadi *et al.* in Kermanshah, western Iran, investigated the association between NLR and outcomes in children with moderate-to-severe TBI. The study included 374 patients, with a mean age of 7.37±3.11 years, whose NLR levels were evaluated on the day of admission and the fourth day after admission. An unfavorable outcome was defined as a GCS score of 1–3. According to multivariable regression analysis, initial GCS, pupillary light reflex, Rotterdam CT score, and NLR were identified as independent predictors of adverse outcomes in pediatric patients with moderate-to-severe TBI.[24] Taken together, given its low cost and accessibility, the researchers recommended using NLR extensively to predict TBI outcomes in children.

### *Limitations and future perspectives*

The primary limitation of this study was the incomplete patient records, resulting in the exclusion of those patients from the study population. Another limitation is the relatively small sample size; it would be beneficial for future studies to include a larger number of patients with this condition, as a greater sample size could strengthen our findings. Additionally, the study was conducted at a single center, and it is recommended that future research examine this issue across various locations in the country and among different age groups.

One of the strengths of this study is that the NLR is a cost-effective and readily available marker that can effectively predict the prognosis of patients with moderate to severe traumatic brain injury.

Future studies should focus on a larger cohort across different centers to assess the diagnostic value of NLR as a prognostic factor in patients with moderate to severe brain injury. Longer follow-up of patients over one to two years is also suggested to evaluate the long-term diagnostic value of NLR in the prognosis of these patients.

## Conclusions

This study aimed to evaluate the diagnostic value of the NLR in determining the prognosis of patients with moderate to severe TBI. The sensitivity and specificity of the NLR criterion, when compared to the Rotterdam score, demonstrated sufficient power to predict outcomes in this patient population. Given its low cost and easy availability, the NLR can serve as an effective prognostic tool in clinical settings. This study highlights the potential of the NLR as a practical biomarker, facilitating timely and informed decision-making in managing patients with TBI. Future research should further explore its applicability across diverse populations to reinforce its utility and enhance its integration into routine clinical practice, ultimately contributing to better patient outcomes in TBI management.

## List of abbreviations

NLR, neutrophil-to-lymphocyte ratio
TBI, traumatic brain injury
GCS, Glasgow Coma Scale
CT, computed tomography
tSAH, traumatic subarachnoid hemorrhage
VS/D, Vegetative State or Death
CBC, Complete Blood Count
ROC, Receiver Operating Characteristic
ICH, Intracerebral Hemorrhage

## Ethics approval and consent to participate

Ethical approval for this retrospective cohort study was obtained from the Research Ethics Committee at Kashan University of Medical Sciences (Approval ID: IR.KAUMS.MEDNT.REC.1402.222). As this research utilized existing patient records, no direct contact with participants was required, and all data were anonymized to maintain patient confidentiality. All procedures adhered to the ethical standards of the Declaration of Helsinki, and appropriate measures were taken to protect patient privacy throughout the data collection and analysis phases.

### Availability of data and materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

## Financial support and sponsorship

The authors have not received any funding for their paper.

## Conflicts of interest

The authors declare no conflict of interest and claim for the accuracy of the data in this report.

## Corresponding author

Ghazaleh Salehabadi, Department of Radiology, Iran University of Medical Sciences, Tehran, Iran.
Tel.: +989124114835
ORCID ID: 0000-0003-1036-6295
E-mail: Ghazal.slh@gmail.com

## Co authors

*Hamidreza Aghadoost*
*ORCID ID: 0000-0002-8093-9477*
*E-mail: Hamid_Aghadoost@yahoo.com*

*Esmaeil Fakharian*
*ORCID ID: 0000-0003-0115-8398*
*E-mail: e.fakh60@gmail.com*

*Hanieh Jafari Mohammadabad*
*ORCID ID: 0009-0005-6557-2581*
*E-mail: Haniyejafari@ymail.com*

## References

1. Abbafati C, Abbas KM, Abbasi M, et al. Global burden of 369 diseases and injuries in 204 countries and territories, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet 2020;396:1204-22.
2. de Silva MJ, Roberts I, Perel P, et al. Patient outcome after traumatic brain injury in high-, middle- and low-income countries: Analysis of data on 8927 patients in 46 countries. Internat J Epidemiol 2009;38:452-8.
3. Guan B, Anderson DB, Chen L, et al. Global, regional and national burden of traumatic brain injury and spinal cord injury, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. BMJ Open 2023;13:e075049.
4. de Oliveira DV, Vieira RdCA, Pipek LZ, et al. Long-term outcomes in severe traumatic brain injury and associated factors: a prospective cohort study. J Clin Med 2022;11:6466.
5. Mostert CQB, Singh RD, Gerritsen M, et al. Long-term outcome after severe traumatic brain injury: a systematic literature review. Acta Neurochirurgica 2022;164: 599-613.
6. Farzandipour M, Ghattan H, Mazrouei L, et al. Epidemiological study of traumatic patients referred to neghavi hospital of kashan. J Kermanshah Univer Med Sci 2007;11:e81870.
7. Formisano R, Contrada M, Ferri G, et al. The Glasgow Outcome Scale Extended-Revised (GOSE-R) to include Minimally conscious state in the vegetative state/ unresponsive wakefulness syndrome category: a correlation with Coma Recovery Scale-Revised (CRS-R). Eur J Phys Rehabil Med 2019;55:139-40.
8. Marshall LF, Marshall SB, Klauber MR, et al. A new classification of head injury based on computerized tomography. J Neurosurg 1991;75:S14-S20.
9. Maas AIR, Hukkelhoven CWPM, Marshall LF, Steyerberg EW. Prediction of outcome in traumatic brain injury with computed tomographic characteristics: A comparison between the computed tomographic classi-

fication and combinations of computed tomographic predictors. Neurosurgery 2005;57:1173-81.
10. Raj R, Siironen J, Skrifvars MB, et al. Predicting outcome in traumatic brain injury: Development of a novel computerized tomography classification system (Helsinki Computerized Tomography Score). Neurosurgery 2014;75:632-46.
11. Käsmann L, Bolm L, Schild SE, et al. Neutrophil-to-lymphocyte ratio predicts outcome in limited disease small-cell lung cancer. Lung 2017;195:217-24.
12. Aghbash PS, Rasizadeh R, Shirvaliloo M, et al. Dynamic alterations in white blood cell counts and SARS-CoV-2 shedding in saliva: an infection predictor parameter. Front Med 2023;10:1208928.
13. Seyit M, Avci E, Nar R, et al. Neutrophil to lymphocyte ratio, lymphocyte to monocyte ratio and platelet to lymphocyte ratio to predict the severity of COVID-19. Am J Emerg Med 2020;40:110-4.
14. Postolache TT, Wadhawan A, Can A, et al. Inflammation in traumatic brain injury. J Alz Dis 2020;74:1-28.
15. Chen J, Qu X, Li Z, et al. Peak neutrophil-to-lymphocyte ratio correlates with clinical outcomes in patients with severe traumatic brain injury. Neurocritical Care 2019;30:334-9.
16. Chen W, Yang J, Li B, et al. Neutrophil to lymphocyte ratio as a novel predictor of outcome in patients with severe traumatic brain injury. J Head Trauma Rehabil 2018;33:E53-E9.
17. Zhao JL, Du ZY, Yuan Q, et al. Prognostic value of neutrophil-to-lymphocyte ratio in predicting the 6-month outcome of patients with traumatic brain injury: a retrospective study. world neurosurgery. 2019;124:e411-e6.
18. Bozan Ö, Altunok İ. Comparison of prognostic computed tomography scores in geriatric patients with traumatic brain injury: a retrospective study. J Contemp Med 2022;12:177-81.
19. Lowsby R, Gomes C, Jarman I, et al. Neutrophil to lymphocyte count ratio as an early indicator of blood stream infection in the emergency department. Emerg Med J 2015;32:531-4.
20. Sabouri E, Majdi A, Jangjui P, et al. Neutrophil-to-lymphocyte ratio and traumatic brain injury: a review study. World Neurosurg 2020;140:142-7.
21. Han S, Liu Y, Li Q, et al. Pre-treatment neutrophil-to-lymphocyte ratio is associated with neutrophil and T-cell infiltration and predicts clinical outcome in patients with glioblastoma. BMC Cancer 2015;15:617.
22. Inanc Y, Inanc Y. The effects of neutrophil to lymphocyte and platelet to lymphocyte ratios on prognosis in patients undergoing mechanical thrombectomy for acute ischemic stroke. Annali Italiani di Chirurgia 2018;89:367-73.
23. Zhuang D, Sheng J, Peng G, et al. Neutrophil to lymphocyte ratio predicts early growth of traumatic intracerebral haemorrhage. Annal Clin Translat Neurol 2021;8:1601-9.
24. Alimohammadi E, Foroushani AZ, Moradi F, et al. Dynamics of neutrophil-to-lymphocyte ratio can be associated with clinical outcomes of children with moderate to severe traumatic brain injury: A retrospective observational study. Injury 2022;53:999-1004.

## Disclaimer

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article or claim that may be made by its manufacturer is not guaranteed or endorsed by the publisher.

Submitted: 30 November 2024.
Accepted: 14 December 2024.
Early access: 21 February 2025.

*Online supplementary material:*

*Table 1. Complete blood counts and CT findings of patient groups based on 24-hour clinical outcome.*

*Table 2. Complete blood counts and CT findings of patient groups based on 6-month clinical outcome.*

*Table 3. Comparison of mean NLR and Rotterdam scores between patient groups based on 24-hour clinical outcome.*

*Table 4. Prognostic accuracy of NLR and Rotterdam score at predicting 24-hour clinical outcome.*

*Table 5. Prognostic accuracy of NLR and Rotterdam score at predicting 6-month clinical outcome.*