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RESEARCH ARTICLE

Admission Neutrophil-to-Lymphocyte Ratio and Hospital Stay After Surgery for Chronic Subdural Hematoma Outcomes

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ABSTRACT

Objective: Chronic subdural hematoma (CSDH) is increasingly prevalent among older adults and is characterized by inflammation-driven pathophysiology. The objective of this study was to evaluate whether the admission NLR predicts postoperative length of stay (PoLOS) in surgically treated patients with CSDH and to examine its association with early quantitative radiological hematoma resolution.

Materials and Methods: This retrospective, single-center study included 111 adult patients who underwent burr-hole evacuation with subdural drainage for CSDH. Admission NLR was calculated from peripheral blood counts. The primary outcome was postoperative LOS (log_{10}-transformed for regression analysis). The secondary analysis assessed the percentage reduction in hematoma thickness on early postoperative and approximately two-week CT scans. Univariable and multivariable linear regression models were performed with adjustment for clinically relevant covariates.

Results: Higher admission NLR was associated with longer postoperative LOS in the univariable analysis (β=0.009, p=0.028). After adjustment for age and anticoagulant use, the association was attenuated and did not reach statistical significance (β=0.007, p=0.074). Age remained independently associated with postoperative LOS (β=0.003 per year, p=0.024). Admission NLR was not correlated with early postoperative hematoma reduction (ρ=0.008, p=0.933) or two-week hematoma reduction (ρ=-0.100, p=0.295).

Conclusion: Admission NLR was associated with longer postoperative LOS in the univariable analysis but not after adjustment, warranting further investigation in larger cohorts.

Keywords: Chronic subdural hematoma, postoperative hospital length of stay, neutrophil-to-lymphocyte ratio, prognostic biomarker, surgical outcomes, systemic inflammation

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INTRODUCTION

Chronic subdural hematoma (CSDH) is a common neurosurgical condition, particularly in elderly patients, and its incidence continues to rise with population aging and the increasing use of antithrombotic therapy. Although surgical evacuation via burr-hole drainage is generally effective, postoperative radiological evolution varies substantially among patients, with some demonstrating rapid resolution while others exhibit persistent residual collections or delayed clearance. This heterogeneity suggests that factors beyond mechanical evacuation alone contribute to hematoma persistence and resolution.[1–3]

Accumulating evidence indicates that CSDH is not a passive accumulation of blood but rather a chronic inflammatory disease. The outer hematoma membrane is characterized by inflammatory cell infiltration, angiogenesis, and recur-

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rent microhemorrhage, driven by a complex cytokine and growth-factor milieu. These biological processes underpin both hematoma expansion and recurrence and may also influence postoperative resorption dynamics.[2,4,5]

Systemic inflammatory markers have therefore attracted interest as potential predictors of CSDH behavior. Among these, the neutrophil-to-lymphocyte ratio (NLR) is a readily available and inexpensive biomarker reflecting the balance between innate inflammatory activation and adaptive immune regulation. Elevated NLR has been associated with adverse outcomes across a wide range of neurological and neurosurgical conditions, including intracerebral hemorrhage, traumatic brain injury, and brain tumors.[6–8]

In chronic subdural hematoma (CSDH), several studies have associated the neutrophil-to-lymphocyte ratio (NLR) with clinical outcomes, primarily focusing on hematoma recurrence or disease progression. Elevated preoperative or postoperative NLR values, as well as postoperative increases in NLR, have been linked to higher recurrence rates after surgical evacuation and to progression during conservative management.[9–11] Recently, Kartal et al.[12] examined peripheral inflammatory indices in relation to hospital length of stay in surgically treated patients with CSDH younger than 65 years, excluding patients with coagulopathy, anticoagulant or antiplatelet drug use, and bilateral hematomas, and reported an association between perioperative changes in NLR and hospitalization duration. However, CSDH predominantly affects older adults, among whom anticoagulant use is common; importantly, these patients were included in our cohort. Therefore, the relationship between NLR measured at admission and postoperative length of stay (PoLOS) in a broader, predominantly older CSDH population remains incompletely characterized. We specifically evaluated postoperative LOS because inclusion of the preoperative period could introduce additional nonclinical and treatment-related determinants of hospitalization duration, such as surgical delay related to anticoagulant use or waiting for operative scheduling in neurologically stable patients.

Postoperative hospital length of stay (PoLOS) is a clinically meaningful and resource-sensitive outcome that reflects the overall postoperative course, encompassing neurological recovery, medical complications, and readiness for discharge. Although PoLOS is multifactorial, systemic inflammatory burden may plausibly contribute to delayed recovery and prolonged hospitalization in patients undergoing surgical treatment for CSDH.

In contrast, quantitative radiological evolution—including the percentage of early postoperative hematoma resolution and short-term reduction at approximately two weeks—has received comparatively little attention in relation to systemic inflammation. Early radiological change may provide supportive biological insight into postoperative hematoma dynamics, as it reflects the balance between residual inflammatory activity and hematoma resorption. Evaluating radiological resolution alongside postoperative LOS may therefore help contextualize the clinical impact of inflammation in the early postoperative period without relying solely on dichotomous outcomes such as recurrence.

Accordingly, the objective of this study was to evaluate whether the neutrophil-to-lymphocyte ratio (NLR) predicts PoLOS in patients undergoing surgical treatment for chronic subdural hematoma. As a secondary analysis, we examined the association between NLR and early quantitative radiological hematoma resolution, expressed as the percentage of hematoma reduction in the immediate postoperative period and at approximately two-week follow-up.

MATERIALS and METHODS

Study Design and Ethical Approval

This retrospective, single-center observational study was performed at a tertiary referral neurosurgical center. Consecutive adult patients who underwent surgical treatment for chronic subdural hematoma (CSDH) between March 2018 and March 2025 were identified from institutional surgical and radiological databases. The study protocol was reviewed and approved by the Göztepe Prof. Dr. Süleyman Yalçın City Hospital Ethics Review Board (Approval No: 2025/0369; Date: 18/12/2025) and was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Population and Eligibility Criteria

Patients were eligible for inclusion if they were adults with radiologically confirmed CSDH who underwent burr-hole evacuation with placement of a subdural drain during the study period. Exclusion criteria included incomplete clinical or imaging data, absence of drain placement, lack of postoperative CT imaging, primary craniotomy or other nonstandard surgical approaches, and the presence of concurrent acute medical conditions that could substantially influence neurological status or perioperative recovery, including but not limited to significant electrolyte disturbances, acute exacerbation of chronic obstructive pulmonary disease, or acute cardiovascular events such as myocardial infarction.

In cases of bilateral CSDH treated during the same surgical session, both hematomas were managed simultaneously and analyzed as a single clinical case.

Surgical Technique

All procedures were performed using a standard burr-hole craniostomy technique under either general or local anesthesia, according to surgeon and anesthetic preference. Following dural opening and irrigation of the subdural space, a subdural drain was inserted through the burr hole, with the catheter tip positioned within the subdural compartment. All operations were performed by using uniform institutional surgical protocols.

Data Collection

Clinical, laboratory, and radiological data were retrospectively extracted from electronic medical records and the institutional picture archiving and communication system (PACS). Baseline demographic and clinical variables included patient age and sex, history of hypertension, diabetes mellitus, and prior stroke, use of anticoagulant medication at presentation, composite score, and documented head trauma, with the interval between trauma and hospital admission recorded when applicable. Neurological status at admission was assessed using the Glasgow Coma Scale (GCS), and the presence of focal neurological deficits was recorded as a dichotomous variable. A focal deficit was defined as muscle strength graded ≤4/5 on the Medical Research Council (MRC) scale.

Radiological Assessment

Radiological evaluation was based on noncontrast cranial CT scans obtained preoperatively, in the early postoperative period, and at approximately 14 days postoperatively. Hematoma thickness was measured on coronal images as the maximum subdural width (mm) on the operated side. In patients with bilateral hematomas, measurements from both sides were obtained separately and summed to yield the total hematoma thickness. Midline shift was measured in millimeters at the level of the foramen of Monro on preoperative CT as an indicator of mass effect. Hematoma laterality (right, left, or bilateral) and the presence of internal membranes or septations within the hematoma cavity were also recorded.

Outcome Measures

The primary clinical outcome was postoperative hospital length of stay (PoLOS), defined as the number of days from surgery to hospital discharge. As a supportive radiological assessment, changes in subdural hematoma thickness were quantified as the percentage reduction in thickness across the predefined imaging time points (preoperative, early postoperative, and 14-day postoperative). Secondary outcomes included intensive care unit (ICU) admission (yes/no) and hematoma recurrence, defined as symptomatic reaccumulation requiring repeat surgical evacuation during follow-up. Postoperative neurological status was assessed using the GCS obtained either in the early postoperative period or at discharge.

Baseline disease severity was characterized using preoperative midline shift and Markwalder grading, which were used descriptively to characterize clinical and radiological severity profiles in subsequent analyses.

Ethical Statement

This study was conducted in accordance with the ethical standards of the institutional research committee and the 1964 Declaration of Helsinki and its later amendments. The study protocol was reviewed and approved by the Göztepe Prof. Dr. Süleyman Yalçın City Hospital Ethics Review Board (Approval No: 2025/0369; Date: 18/12/2025).

Statistical Analysis

Continuous variables are presented as mean±standard deviation (SD) or median with interquartile range (IQR), depending on their distribution, and categorical variables are summarized as counts and percentages. Normality of continuous variables was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Baseline demographic, clinical, and radiological characteristics—including preoperative midline shift and Markwalder grade as indicators of disease severity—were compared between groups using independent-samples t-tests or Mann–Whitney U tests for continuous variables and χ^2 or Fisher's exact tests for categorical variables, as appropriate.

The primary outcome was postoperative hospital length of stay (PoLOS), defined as the number of days from surgery to discharge. Because LOS showed a right-skewed distribution, a $\log_{10}$ transformation was applied prior to regression analysis. The association between the neutrophil-to-lymphocyte ratio (NLR) and PoLOS was evaluated using multiple linear regression, with $\log_{10}$-transformed LOS as the dependent variable. Potential covariates were initially examined individually. Given the exploratory nature of the study and the relatively limited sample size, a multivariable model including age, anticoagulant use, and admission NLR was used to assess whether the observed NLR–PoLOS association persisted after adjustment for selected clinically relevant factors.

Binary outcomes, including ICU admission and hematoma recurrence requiring reoperation, were summarized descriptively and compared using χ^2 or Fisher's exact tests, depending on expected cell counts. Given the limited number of events, multivariable logistic regression was not performed for these outcomes. All statistical analyses were conducted using IBM SPSS Statistics version 26 (IBM Corp., Armonk, NY, USA), and a two-sided p value <0.05 was considered statistically significant.

RESULTS

A total of 111 patients who underwent surgical treatment for chronic subdural hematoma were included in the analysis (Table 1). The median age was 74 years (interquartile range [IQR], 19 years), and 71 patients (64.0%) were male. Hematoma laterality was right-sided in 42 patients (37.8%), left-sided in 48 patients (43.2%), and bilateral in 21 patients (18.9%). A history of head trauma recalled by the patient or relatives was reported in 62 patients (55.9%).

Hypertension, diabetes mellitus, and prior cerebrovascular disease were present in 66 (59.5%), 24 (21.6%), and 15 (13.5%) patients, respectively. Based on these conditions, the composite comorbidity score was 0 in 41 patients (36.9%), 1 in 39 (35.1%), 2 in 27 (24.3%), and 3 in 4 (3.6%). Thirty patients (27.0%) were receiving anticoagulant therapy at admission.

Radiologically, the mean total hematoma thickness—calculated as the sum of bilateral thicknesses in patients with bilateral hematomas—was 25.9±9.5 mm (range, 10.4–55.5 mm), and the median midline shift was 5.8 mm (IQR, 9.6 mm; range, 0–19.0 mm). At presentation, the median Glasgow Coma Scale score was 15 (IQR, 2; range, 7–15), and the median Markwalder grade was 1 (IQR, 1; range, 0–4).

Regarding inflammatory markers at admission, the median neutrophil count was 5.21×10^9/L (IQR, 3.40×10^9/L), the median lymphocyte count was 1.60×10^9/L (IQR, 1.10×10^9/L), and the median neutrophil-to-lymphocyte ratio (NLR) was 3.46 (IQR, 4.29), demonstrating a right-skewed distribution.

In univariable linear regression analyses with $\log_{10}$-transformed PoLOS as the dependent variable, a higher preoperative neutrophil-to-lymphocyte ratio was significantly associated with longer hospitalization (β=0.009, p=0.028), corresponding to an approximately 2% increase in PoLOS per unit increase in NLR. Increasing age was also significantly associated with prolonged PoLOS (β=0.004 per year, p=0.002), equating to an approximately 10% increase per decade. Patients receiving anticoagulant therapy at presentation experienced significantly longer PoLOS than non-anticoagulated patients (β=0.153, p=0.006). A higher Markwalder grade was likewise associated with increased PoLOS (β=0.066, p=0.021), reflecting greater baseline clinical severity. In contrast, sex, overall comorbidity burden, total hematoma thickness, and preoperative midline shift were not significantly associated with PoLOS in univariable analyses. Postoperative neutrophil-to-lymphocyte ratio was also not associated with PoLOS.

Table 1. Baseline demographic, clinical, and radiological characteristics of patients undergoing surgical treatment for chronic subdural hematoma (n=111)

Variable	Value (n=111)
Age (years)	69.2±18.5 [74±20]
Male sex, n (%)	71 (64.0)
Anticoagulant use, n (%)	30 (27.0)
Bilateral hematoma, n (%)	24 (21.6)
Neurological deficit at presentation, n (%)	37 (33.3)
Radiological membranes present, n (%)	65 (58.6)
Hypertension, n (%)	66 (59.5)
Diabetes mellitus, n (%)	24 (21.6)
History of CVA, n (%)	15 (13.5)
History of trauma, n (%)	62 (55.9)
Total hematoma load (mm)	25.6±9.2 [25.2±12.5]
Midline shift (mm)	6.1±4.8 [5.9±10.1]
Markwalder grade, n (%)	
Grade 0	24 (21.8)
Grade 1	44 (40.0)
Grade 2	36 (32.7)
Grade 3	5 (4.5)
Grade 4	1 (0.9)
Preoperative NLR	5.79±6.09 [3.45±4.32]
Early postoperative thickness (mm)	7.2±3.5 [6.45±4.25]
Second-week postoperative thickness (mm)	6.5±4.4 [5.50±5.75]
Postoperative NLR	7.82±7.87 [5.35±6.77]
Postoperative GCS	14.5±1.4 [15±0]
PoLOS (days)	8.45±8.91 [6±5]
Log10 PoLOS	0.82±0.26 [0.78±0.35]
Recurrence requiring surgery, n (%)	4 (3.6)

Continuous variables are presented as mean ± standard deviation [median± interquartile range]. Categorical variables are expressed as number (n) and percentage (%). Percentages were calculated using valid cases. Markwalder grade was available for 110 patients. NLR: Neutrophil-to-lymphocyte ratio; GCS: Glasgow coma scale; CVA: Cerebrovascular accident; PoLOS: Postoperative hospital length of stay

A multivariable model including admission NLR, age, and anticoagulant use was subsequently evaluated.

In multivariable linear regression analysis adjusting for age and anticoagulant use, preoperative neutrophil-to-lymphocyte ratio demonstrated a trend toward an association with PoLOS (β=0.007, p=0.074), with higher values corresponding to longer hospitalization. Increasing age remained independently associated with prolonged PoLOS (β=0.003 per year, p=0.024), while anticoagulant use showed a borderline association with longer hospital stay (β=0.107, p=0.056).

Regarding radiological resolution, quantitative analysis demonstrated a substantial reduction in total subdural hematoma thickness following surgical evacuation. The mean early postoperative reduction in hematoma thickness was 72.2%±8.6% (median, 72.4%; IQR, 9.6%). At approximately two-week follow-up, the mean reduction increased to 75.5%±14.9% (median, 76.9%; IQR, 16.4%), indicating continued hematoma resolution over time.

Spearman correlation analysis demonstrated no significant association between preoperative neutrophil-to-lymphocyte ratio and either early postoperative radiological hematoma reduction (ρ=0.008, p=0.933) or the magnitude of hematoma reduction at approximately two-week follow-up (ρ=-0.100, p=0.295).

These findings indicate that while baseline systemic inflammation is associated with prolonged hospitalization, it does not appear to influence the early radiological resolution of chronic subdural hematoma.

DISCUSSION

In this study, higher admission NLR was significantly associated with longer PoLOS in univariable analysis. After adjustment for age and anticoagulant use, the magnitude and direction of the association remained broadly consistent, although it no longer reached conventional statistical significance. In contrast, admission NLR was not associated with early postoperative or short-term radiological hematoma resolution. These findings do not establish NLR as an independent predictor of postoperative LOS but suggest that admission NLR may capture aspects of inflammatory and physiological vulnerability that overlap with other clinical determinants of postoperative recovery.

The NLR was originally proposed by Zahorec (2001) as a rapid, simple marker of systemic inflammatory stress in critically ill patients.[6] It has since evolved into a widely used surrogate of disease severity across acute and chronic conditions. Early "severity" studies subsequently showed that higher NLR is associated with worse clinical phenotypes and outcomes in high-burden fields such as cardiovascular disease, including associations with impaired coronary perfusion and higher in-hospital and long-term mortality after STEMI treated with PCI, and oncology, where NLR is frequently incorporated into prognostic frameworks and linked to poorer survival.[13] Importantly, the literature has also established a relationship between NLR and resource utilization, particularly prolonged hospitalization, in several settings where inflammatory dysregulation parallels clinical complexity. In acute ischemic stroke, for example, Zhao et al.[14] demonstrated that admission NLR independently predicted longer length of stay and higher acute hospital costs, complementing broader evidence connecting inflammation-related markers with stroke severity and early deterioration. Similar LOS associations have been reported in other acute neurological syndromes, such as status epilepticus, where admission NLR predicted length of hospitalization and ICU need. The concept has also recently extended into psychiatry, where large multicenter analyses have shown that elevated NLR and related inflammatory ratios are associated with longer inpatient stays independent of diagnosis and site.[15,16]

Taken together, these data reinforce the concept that NLR reflects not only biological disease activity but also clinical trajectory and healthcare resource utilization. In this context, our findings are consistent with the broader literature: higher preoperative NLR was associated with prolonged postoperative length of stay (PoLOS), suggesting that even in chronic subdural hematoma—a condition not traditionally conceptualized as primarily inflammatory—systemic inflammatory status may influence recovery dynamics and the inpatient course. Our findings are therefore consistent with a potential relationship between systemic inflammatory status and postoperative clinical trajectory. However, because the association between admission NLR and postoperative LOS did not remain statistically significant after adjustment, the present results should be considered exploratory and do not establish NLR as an independent prognostic biomarker for hospitalization duration.

An elevated NLR likely reflects increased systemic inflammation and physiological stress, which may slow recovery and delay discharge even after successful hematoma evacuation. In contrast, early radiological reduction in hematoma thickness is primarily determined by surgical evacuation and brain expansion and may therefore be less influenced by systemic inflammatory status in the short term.

The earliest study to evaluate NLR in the setting of chronic subdural hematoma appears to be the report by Zhang et al.,[17] who examined peripheral blood inflammatory markers in a large CSDH cohort and found higher NLR and PLR values in patients with CSDH than in healthy controls. Importantly, their work primarily supported the concept of CSDH as an inflammatory condition and highlighted the need for subsequent studies to clarify the prognostic role of these indices. Building on this foundation, later studies shifted from case–control comparisons toward outcome prediction, most commonly focusing on recurrence risk and postoperative inflammatory dynamics.

Dobran et al.[9] specifically evaluated preoperative NLR and reported that higher values were associated with an increased risk of postoperative recurrence, proposing NLR as a simple preoperative risk marker. In contrast, de Oliveira et al.[10] emphasized postoperative inflammatory dynamics, showing that patients who experienced recurrence had higher postoperative neutrophil counts and NLR values and that the postoperative-to-preoperative NLR ratio was associated with recurrence, whereas preoperative laboratory parameters were not predictive in their cohort.

In 2025, Yang et al.[11] broadened the question to hematoma progression rather than recurrence after surgery and found that NLR, alongside coagulation and comorbidity factors such as INR, hypertension, diabetes, and WBC, was independently associated with progression in their retrospective analysis. Taken together, these studies consistently support a relationship between systemic inflammatory markers and "harder" CSDH behaviors such as recurrence or progression, whereas our results add nuance by suggesting that admission NLR may relate more to early clinical recovery and resource utilization, such as PoLOS, than to short-term, mechanically driven radiological thickness reduction.

More recently, Kartal et al.[12] examined peripheral inflammatory indices in relation to clinical outcomes, including hospital length of stay, in 53 surgically treated patients with CSDH younger than 65 years. Notably, the preoperative N/L ratio itself was not significantly correlated with hospital length of stay ($r=-0.128$, $p=0.360$), whereas the perioperative change in the N/L ratio showed a significant positive correlation with hospitalization duration ($r=0.562$, $p=0.001$). Their findings therefore suggest that perioperative inflammatory dynamics may be related to hospitalization duration. The present study addresses a related but distinct question by evaluating NLR measured at admission in a larger, predominantly older CSDH cohort and examining its association with PoLOS using regression analysis with adjustment for relevant clinical covariates. In addition, we evaluated admission NLR in relation to quantitative early postoperative hematoma resolution. These differences extend the available evidence by examining whether inflammatory status already present at admission is associated with the subsequent postoperative course.

Limitations

This study has several limitations. First, its retrospective and single-center design limits the ability to establish definitive associations and may reduce generalizability to other institutions. Second, PoLOS is influenced by multiple factors beyond medical recovery, including institutional practices and discharge planning, particularly for older adults, which could not be fully accounted for.

Third, the neutrophil-to-lymphocyte ratio is a nonspecific marker of systemic inflammation and may be affected by comorbid conditions or physiological stress unrelated to chronic subdural hematoma. Other inflammatory markers were not evaluated, and postoperative changes in NLR over time were not analyzed. Radiological resolution was assessed only in the early postoperative and short-term follow-up periods; longer-term imaging and functional outcomes were not examined.

Fourth, although the Markwalder grade was associated with postoperative LOS in univariable analysis, it was not included in the final multivariable model. Residual confounding by baseline neurological severity therefore cannot be excluded, and the adjusted association between NLR and LOS should be interpreted cautiously.

Finally, radiological evolution was assessed using maximal hematoma thickness rather than volumetric measurements; therefore, particularly in bilateral or irregularly shaped hematomas, this approach may not fully capture changes in total hematoma volume.

CONCLUSION

In patients undergoing surgical treatment for CSDH, higher admission NLR was associated with longer postoperative LOS in univariable analysis, but this association did not remain statistically significant after adjustment for age and anticoagulant use. Admission NLR was not associated with early radiological hematoma resolution. These findings suggest a possible relationship between admission inflammatory status and postoperative recovery, but the independent prognostic value of NLR remains uncertain and requires confirmation in larger studies.

Disclosures

Ethics Committee Approval: The study was approved by the Göztepe Prof. Dr. Süleyman Yalçın City Hospital Ethics Committee (No: 2025/0369, Date: 18/12/2025).

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