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Neutrophil-to-Lymphocyte Ratio as a Marker of Systemic Inflammation in Hypertensive Individuals: A Cross-Sectional Study

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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KEYWORDS

Neutrophil-to-lymphocyte ratio, Hypertension, Inflammation, Biomarker

ABSTRACT:

Background: Hypertension is increasingly recognized as a chronic inflammatory condition. The neutrophil-to-lymphocyte ratio (NLR) has emerged as a simple and cost-effective marker of systemic inflammation.

Aim: To evaluate the association of NLR with blood pressure and its role as a marker of systemic inflammation in hypertensive individuals.

Methods: This cross-sectional study included 80 participants (40 hypertensive and 40 normotensive). Blood pressure and hematological parameters were recorded, and NLR was calculated. Statistical analysis included chi-square test, t-test, correlation, and logistic regression.

Results: Hypertensive individuals showed significantly higher NLR (3.14 ± 1.02 vs. 1.89 ± 0.61, $p < 0.0001$). Elevated NLR (≥3.0) was observed in 47.5% of hypertensives compared to 7.5% of normotensives. NLR ≥3.0 was strongly associated with hypertension (OR = 25.33, $p < 0.0001$).

Conclusion: NLR is significantly elevated in hypertension and may serve as a simple, cost-effective marker of systemic inflammation.

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Introduction

Hypertension is a major global public health concern and a leading modifiable risk factor for cardiovascular morbidity and mortality. It is increasingly recognized as a state of chronic low-grade inflammation, contributing to vascular dysfunction, endothelial injury, and target organ damage. Immune system activation, particularly involving leukocytes, plays a crucial role in the pathogenesis of hypertension through the release of pro-inflammatory cytokines, oxidative stress mediators, and vascular remodeling factors [1,2]. Among circulating immune cells, neutrophils and lymphocytes are key mediators of innate and adaptive immune responses, respectively, and their imbalance reflects systemic inflammatory status [1,3].

The neutrophil-to-lymphocyte ratio (NLR), derived from routine complete blood count parameters, has emerged as a simple, cost-effective, and reproducible biomarker of systemic inflammation. Elevated NLR has been associated with various cardiovascular and metabolic disorders, reflecting heightened inflammatory activity and immune dysregulation [3,4]. In hypertensive individuals, several studies have demonstrated significantly higher NLR values compared to normotensive controls, suggesting its potential role as an indicator of inflammatory burden [4,5]. Furthermore, NLR has been shown to correlate positively with blood pressure levels and severity of hypertension, supporting its clinical relevance in cardiovascular risk stratification [6,7].

Recent evidence, including meta-analytical data, further supports the association between elevated NLR and hypertension, highlighting its potential utility as a readily accessible inflammatory marker in clinical practice [8]. Therefore, the present study aims to evaluate the association of NLR with blood pressure and to explore its role as a marker of systemic inflammation in hypertensive individuals.

Materials and Methods

This cross-sectional prospective observational study was conducted in the Department of Physiology in collaboration with the Department of Medicine and Central Laboratory at MGM Medical College and Hospital, Aurangabad, Maharashtra, India, over a period of six months from April 2024 to September 2024. The study protocol was approved by the Institutional Ethics Committee (Approval No.: MGM-ECRHS/PHYSIOLOGY/MD/2024/02), and written informed consent was obtained from all participants prior to enrollment. A total of 80 participants were included in the study and divided into two groups: 40 normotensive individuals and 40 hypertensive individuals. Hypertension was defined as systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg, or current use of antihypertensive medication. Participants were recruited from outpatient departments and general health check-up clinics based on predefined inclusion and exclusion criteria. Individuals with systemic inflammatory or autoimmune diseases, recent infections, malignancy, glucocorticoid therapy, or chronic systemic illnesses such as renal, hepatic, cardiovascular, or cerebrovascular diseases were excluded to minimize confounding factors affecting inflammatory markers.

A detailed clinical history including demographic variables such as age and sex was recorded, followed by general and systemic examination. Blood pressure was measured using a validated automated digital sphygmomanometer (OMRON HEM-7124) with participants in a seated position after a rest period of at least five minutes. Two readings were recorded at an interval of 1–2 minutes, and the average value was considered for analysis. Venous blood samples (3 mL) were collected under aseptic conditions from the median cubital vein and transferred into EDTA anticoagulant tubes. Hematological parameters,

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including absolute neutrophil count and absolute lymphocyte count, were analyzed using an automated hematology analyzer (ADVIA 2120i, Siemens Healthcare Diagnostics). The neutrophil-to-lymphocyte ratio (NLR) was calculated by dividing the absolute neutrophil count by the absolute lymphocyte count.

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 20.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. The Chi-square test was used to assess associations between categorical variables. Independent Student's t-test was applied to compare continuous variables between the two groups. Pearson's correlation coefficient was used to evaluate the relationship between NLR and blood pressure parameters. Odds ratios (OR) with 95% confidence intervals (CI) were calculated to determine the association between elevated NLR and hypertension. A p-value of less than 0.05 was considered statistically significant.

Results

A total of 80 participants were included in the study, comprising 40 normotensive and 40 hypertensive individuals. The baseline demographic characteristics of the study population are presented in Table 1. The distribution of participants across different age groups was comparable between the two groups, with the majority belonging to the 40–59 years age range. There was no statistically significant difference in age distribution ($p = 0.2137$) or sex distribution ($p = 0.6508$) between normotensive and hypertensive groups, indicating homogeneity of the study population. Smoking status was also comparable between the groups ($p = 0.2596$). However, a significantly higher proportion of hypertensive individuals had a positive family history of hypertension compared to normotensive individuals (62.5% vs. 27.5%, $p = 0.0021$).

Table 1. Baseline Demographic Characteristics of Study Participants

Variable	Category	Normotensive (n=40)	Hypertensive (n=40)	p-value
Age group (years)	30–39	10 (25.0)	6 (15.0)	0.2137
	40–49	14 (35.0)	11 (27.5)	
	50–59	11 (27.5)	15 (37.5)	
	60–65	5 (12.5)	8 (20.0)	
Sex	Male	22 (55.0)	24 (60.0)	0.6508
	Female	18 (45.0)	16 (40.0)	
Smoking status	Non-smoker	34 (85.0)	30 (75.0)	0.2596
	Current/Former smoker	6 (15.0)	10 (25.0)	
Family history of hypertension	Absent	29 (72.5)	15 (37.5)	0.0021
	Present	11 (27.5)	25 (62.5)	

Footnote: Values are expressed as n (%). Chi-square test applied.

The distribution of blood pressure parameters is shown in Table 2. As expected, systolic and diastolic blood pressure values were significantly higher in the hypertensive group compared to the normotensive group ($p < 0.0001$). The majority of normotensive individuals had systolic blood

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pressure below 130 mmHg and diastolic blood pressure below 80 mmHg, whereas hypertensive individuals predominantly fell within higher blood pressure categories. Among hypertensive participants, 60% were classified as Stage 1 hypertension and 40% as Stage 2 hypertension, with no overlap between groups, confirming appropriate categorization.

Table 2. Distribution of Blood Pressure Parameters Among Study Groups

Variable	Category	Normotensive (n=40)	Hypertensive (n=40)	p-value
Systolic BP (mmHg)	<120	21 (52.5)	0 (0.0)	<0.0001
	120–129	14 (35.0)	0 (0.0)	
	130–139	5 (12.5)	4 (10.0)	
	140–159	0 (0.0)	22 (55.0)	
	≥160	0 (0.0)	14 (35.0)	
Diastolic BP (mmHg)	<80	28 (70.0)	0 (0.0)	<0.0001
	80–84	8 (20.0)	0 (0.0)	
	85–89	4 (10.0)	3 (7.5)	
	90–99	0 (0.0)	21 (52.5)	
	≥100	0 (0.0)	16 (40.0)	
Hypertension classification	Normotensive	40 (100.0)	0 (0.0)	<0.0001
	Stage 1 HTN	0 (0.0)	24 (60.0)	
	Stage 2 HTN	0 (0.0)	16 (40.0)	

Footnote: Classification based on standard hypertension guidelines. Chi-square test applied.

The hematological and inflammatory profiles of the participants are presented in Table 3. A significantly higher proportion of hypertensive individuals had elevated neutrophil counts (≥6000/μL) compared to normotensive individuals (35.0% vs. 12.5%, p = 0.0187). Conversely, lower lymphocyte counts (<1500/μL) were more frequently observed in the hypertensive group (22.5% vs. 5.0%, p = 0.0408). Notably, the neutrophil-to-lymphocyte ratio (NLR) was significantly elevated in hypertensive individuals. Nearly half of the hypertensive group (47.5%) had NLR ≥3.0 compared to only 7.5% in the normotensive group (p < 0.0001). Similarly, when categorized dichotomously, elevated NLR (≥3.0) was observed in 47.5% of hypertensive individuals compared to 7.5% of normotensive individuals, demonstrating a strong association with hypertensive status.

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Table 3. Hematological and Inflammatory Profile of Participants

Variable	Category	Normotensive (n=40)	Hypertensive (n=40)	p-value
Neutrophil count (/μL)	<4000	18 (45.0)	7 (17.5)	0.0187
	4000–5999	17 (42.5)	19 (47.5)	
	≥6000	5 (12.5)	14 (35.0)	
Lymphocyte count (/μL)	<1500	2 (5.0)	9 (22.5)	0.0408
	1500–2999	31 (77.5)	27 (67.5)	
	≥3000	7 (17.5)	4 (10.0)	
NLR categories	<2.0	24 (60.0)	6 (15.0)	<0.0001
	2.0–2.99	13 (32.5)	15 (37.5)	
	≥3.0	3 (7.5)	19 (47.5)	
NLR status	<3.0	37 (92.5)	21 (52.5)	<0.0001
	≥3.0	3 (7.5)	19 (47.5)	

Footnote: NLR: Neutrophil-to-Lymphocyte Ratio. Chi-square test applied.

The association between NLR and hypertension is further elaborated in Table 4. Individuals with NLR ≥3.0 had significantly higher odds of being hypertensive compared to those with NLR <2.0 (OR = 25.33, 95% CI: 5.82–110.23, p < 0.0001). Even moderate elevations in NLR (2.0–2.99) were associated with increased odds of hypertension (OR = 4.62, 95% CI: 1.45–14.73, p = 0.0102). When analyzed as a binary variable, individuals with elevated NLR (≥3.0) had more than 11-fold higher odds of hypertension compared to those with normal NLR values (OR = 11.16, 95% CI: 2.91–42.82, p < 0.0001), indicating a strong and statistically significant association.

Table 4. Association of Neutrophil-to-Lymphocyte Ratio with Hypertensive Status

Variable	Category	Normotensive (n=40)	Hypertensive (n=40)	Odds Ratio (95% CI)	p-value
NLR categories	<2.0	24 (60.0)	6 (15.0)	Reference	<0.0001
	2.0–2.99	13 (32.5)	15 (37.5)	4.615 (1.445–14.734)	0.0102
	≥3.0	3 (7.5)	19 (47.5)	25.333 (5.823–110.228)	<0.0001
NLR status	<3.0	37 (92.5)	21 (52.5)	Reference	<0.0001

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Variable	Category	Normotensive (n=40)	Hypertensive (n=40)	Odds Ratio (95% CI)	p-value
	≥3.0	3 (7.5)	19 (47.5)	11.160 (2.907–42.819)	<0.0001

Footnote: Odds ratios calculated using binary logistic regression. Reference category: lowest NLR group.

The comparison of continuous variables between the two groups is summarized in Table 5. The mean systolic and diastolic blood pressure values were significantly higher in hypertensive individuals compared to normotensive individuals ($p < 0.0001$). Additionally, hypertensive individuals exhibited significantly higher mean neutrophil counts and lower mean lymphocyte counts. Consequently, the mean NLR was markedly elevated in the hypertensive group (3.14 ± 1.02) compared to the normotensive group (1.89 ± 0.61), and this difference was statistically highly significant ($p < 0.0001$).

Table 5. Continuous Variables Comparison

Variable	Normotensive (n=40) Mean ± SD	Hypertensive (n=40) Mean ± SD	p-value
Systolic BP (mmHg)	118.6 ± 8.4	151.8 ± 12.6	<0.0001
Diastolic BP (mmHg)	76.4 ± 6.2	96.3 ± 8.7	<0.0001
Neutrophil count (/µL)	4560 ± 980	5820 ± 1180	<0.0001
Lymphocyte count (/µL)	2480 ± 620	2110 ± 590	0.0076
NLR	1.89 ± 0.61	3.14 ± 1.02	<0.0001

Footnote: Continuous variables compared using independent Student's t-test.

Discussion

The present study demonstrates a significant association between neutrophil-to-lymphocyte ratio (NLR) and hypertension, with hypertensive individuals exhibiting markedly elevated NLR values compared to normotensive controls. These findings reinforce the concept that hypertension is associated with a chronic low-grade inflammatory state driven by immune activation [1,2].

Our findings are consistent with those of Belen et al., who reported significantly elevated NLR levels in resistant hypertension [4]. Similarly, Demir et al. demonstrated higher NLR in non-dipper hypertension (3.1 ± 0.95 vs. 1.8 ± 0.52, $p < 0.001$) [5]. Çimen et al. further showed a significant association between NLR and ambulatory blood pressure parameters [6]. A recent meta-analysis also confirmed significantly higher NLR in hypertensive individuals [8].

Therapeutic studies support this association; Hussain et al. demonstrated that antihypertensive treatment significantly reduces NLR [9], while Şaylık et al. reported a relationship between NLR and morning blood pressure surge [10]. From a mechanistic perspective, neutrophil-mediated inflammation and lymphocyte dysregulation contribute to vascular injury and hypertension progression [1,2,12].

Our study also demonstrated significantly higher odds of hypertension in individuals with elevated NLR, consistent with previous findings showing

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NLR as an independent predictor of hypertension [4,7].

NLR is a reliable, cost-effective marker of systemic inflammation in hypertension and may have clinical utility in risk stratification and disease monitoring.

Conclusion

The present study demonstrates that the neutrophil-to-lymphocyte ratio (NLR) is significantly elevated in hypertensive individuals compared to normotensive controls and shows a strong association with blood pressure status. The findings support the role of NLR as a simple, cost-effective, and readily available marker of systemic inflammation in hypertension. Elevated NLR may reflect the underlying inflammatory mechanisms contributing to the pathogenesis of hypertension and could serve as a useful adjunct in early risk assessment and clinical evaluation of hypertensive patients.

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Conflict of Interest

The authors declare that there is no conflict of interest related to this study.

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