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Neutrophil Percentage-to-Albumin Ratio as a Predictor of Collateral Circulation in Chronic Total Occlusion

ABSTRACT

Background: This study aimed to investigate the relationship between neutrophil percentage-to-albumin ratio (NPAR) and collateral circulation in patients with chronic total occlusion (CTO). Chronic total occlusion is an advanced stage of coronary artery disease (CAD) and is characterized by complete occlusion of the coronary arteries. Collateral circulation provides alternative routes that supply blood flow instead of occluded arteries and may affect the prognosis of CTO patients. Neutrophil percentage-to-albumin ratio is recognized as an indicator of inflammation and can be used to predict the prognosis of various diseases.

Methods: In this retrospective study, 320 patients with CAD who were diagnosed with CTO by coronary angiography were included. Demographic characteristics, clinical findings, and laboratory test results were recorded. The degree of coronary collateral circulation was classified according to the Cohen-Rentrop method. Neutrophil percentage-to-albumin ratio and other inflammatory parameters were measured. The relationship between NPAR and collateral circulation was evaluated using multivariate analysis.

Results: Neutrophil percentage-to-albumin ratio levels were significantly associated with poor collateral circulation. Neutrophil percentage-to-albumin ratio, together with other inflammatory parameters (white blood cell count, neutrophil-to-lymphocyte ratio, C-reactive protein), was identified as an independent marker of poor collateral circulation in CTO patients. Fasting blood glucose levels and diabetes mellitus were also associated with poor collateral circulation.

Conclusion: Neutrophil percentage-to-albumin ratio is emerging as a simple and effective inflammatory marker that can be used to predict the quality of collateral circulation in CTO patients. This is important for predicting the prognosis of CTO patients and the success of percutaneous revascularization. However, more extensive studies are needed.

Keywords: Chronic total occlusion, coronary collateral circulation, neutrophil percentage-to-albumin ratio

ORIGINAL INVESTIGATION

INTRODUCTION

Chronic coronary total occlusion (CTO) is an end-stage coronary artery atherosclerosis frequently seen in patients with coronary artery disease (CAD).[1] A coronary artery that is completely occluded due to a narrowing that has persisted for more than 3 months is characterized by angiographic examination as complete cessation of anterograde blood flow or minimal contrast passage across the lesion and no visualization of the distal vessels. In the presence of lesions in major epicardial coronary arteries that severely obstruct blood flow, smaller diameter coronary collateral vessels activate the collateral circulation to maintain myocardial perfusion.

Coronary collaterals (CCs) are a natural response to blocked coronary arteries, creating new connections to ensure adequate blood flow to the heart. Typically, CCs are not visible on angiography until coronary artery stenosis exceeds 90%. In cases of complete coronary artery occlusion, collateral arteries can supply up to 50% of antegrade flow, perfusing the myocardium to meet increased oxygen demands.[2] Recurrent ischemia is one of the most important reasons for collateral

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development. The protective effect of a well-developed coronary collateral circulation (CCC) against myocardial ischemia and cell death in people with CAD has been proven by clinical and experimental studies. In coronary artery occlusions, CCs prolong myocardial viability by limiting myocardial ischemia and infarct size, thus improving prognosis.[3,4] Coronary collateralization is a complex process showing heterogeneity among patients. In this process, inflammatory cytokines as well as clinical, angiographic, and biochemical factors are known to play an important role.[5]

The relationship between new vessel formation and inflammation is a multifaceted and poorly understood issue. There is strong evidence in the literature that markers such as monocytes and C-reactive protein, which are important biomarkers of inflammation, have a critical role in the development of CCC.[6,7] Recently, new biomarkers, such as the neutrophil percentage-to-albumin ratio (NPAR), have been recognized to play an important role in the prognostic assessment of a wide range of diseases. Neutrophil percentage-to-albumin ratio is recognized as a reflection of systemic inflammation. In particular, NPAR has emerged as a potential biomarker for conditions in which chronic inflammation is an important component, such as liver diseases, cerebrovascular diseases, and cardiovascular diseases.[8-10]

Inflammation is thought to play a central role in the pathophysiology of CCC.[11] However, the variety of inflammatory markers used to evaluate this relationship and the inconsistency of the results obtained indicate that more research is needed on the subject. In this study, the aim was to contribute to the literature by examining the potential role of NPAR, which is considered as a new generation inflammatory marker, in coronary collateral development.

METHODS

This study included 320 consecutive patients (180 men and 140 women, median age: 66 [48-76] years) diagnosed with stable CAD and documented total occlusion in at least 1 major coronary artery during coronary angiography at Malatya Training and Research Hospital between April 2021 and May 2024. Patients were excluded if they had a history of acute or chronic infections, chronic kidney disease (serum creatinine >2.0 mg/dL), previous coronary artery bypass grafting, acute coronary syndrome within the past 3 months, severe valvular heart disease, malignancies, hematological proliferative diseases, chronic inflammatory conditions, active hepatobiliary disorders, autoimmune disease under steroid therapy or symptomatic heart failure with a left ventricular ejection fraction (LVEF) <45%. Demographic and clinical data, including age, sex, hypertension, smoking status, and diabetes mellitus (DM), were recorded for all participants. The study was approved by the local ethics committee, and written informed consent was obtained from each participant. No artificial intelligence-based tools, such as large language models, chatbots, or image generation technologies, were used in the development of this manuscript.

Coronary angiography was performed using the Judkins technique, and the images were independently assessed by 2 experienced interventional cardiologists who were blinded to the patients' clinical and laboratory data. The extent of CCC was classified based on the Cohen-Rentrop grading system as follows: grade 0, no collateral vessel filling; grade 1, collateral filling of side branches without visualization of the epicardial artery; grade 2, partial filling of the epicardial artery; and grade 3, complete filling of the epicardial artery via collateral vessels. For analysis, patients were categorized into 2 groups: those with poor CCC (grades 0-1) and those with good CCC (grades 2-3). If multiple vessels exhibited collateralization, the classification was based on the vessel with the most well-developed antegrade or retrograde collateral flow.

Venous blood samples were obtained upon hospital admission and processed within 30 minutes. Hematological parameters were measured using an automated blood counter. Serum biochemical markers, including creatinine, alanine aminotransferase (ALT), aspartate aminotransferase (AST), and lipid profile, were analyzed with an automated clinical chemistry analyzer. Serum albumin levels were determined using the bromocresol green (BCG) dye-binding method, a widely accepted standard in laboratory practice. The NPAR was calculated using the following formula: Neutrophil percentage (in total white blood cell [WBC] count) (%) 100/Albumin(g/dL). Neutrophil percentage-to-albumin ratio was analyzed as a potential biomarker for its association with CCC.

Interobserver variability was assessed using data from 20 randomly selected subjects in each group. These data were independently reviewed by 2 experienced cardiologists, both blinded to each other's findings. Additionally, intraobserver variability was evaluated by reanalyzing a subset of the data by the same observers. Interobserver variability was 2.9%, while intraobserver variability was 2.6%.

Statistical Analysis

All statistical analyses were conducted using SPSS version 20.0 for Windows (SPSS Inc., Chicago, IL, USA). Continuous variables were expressed as mean ± SD for normally distributed data and as median (minimum–maximum) for non-normally distributed data. The normality of data distribution was assessed using the Kolmogorov–Smirnov test. For comparison between 2 independent groups, the independent samples t-test was used for normally distributed continuous variables, while the Mann–Whitney *U*-test was applied for

HIGHLIGHTS

- Neutrophil percentage-to-albumin ratio (NPAR) predicts poor collateral circulation in chronic total occlusion (CTO) patients.
- Elevated inflammatory markers like NPAR, C-reactive protein, and white blood cells are linked to poor collateral development.
- Neutrophil percentage-o-albumin ratio can aid in treatment planning and predicting outcomes in CTO patients.

non-normally distributed continuous variables. Categorical variables were presented as frequencies and percentages and were compared using the Pearson chi-square test, Fisher's exact test, or continuity correction chi-square test as appropriate.

To identify independent predictors of poor CCC, univariate binary logistic regression analysis was first performed. Variables with a significance level of $P < .05$ or a borderline significance ($P < .10$) in the univariate analysis were included in the multiple binary logistic regression analysis using the enter method. The odds ratio (OR), 95% confidence interval (CI), and *P*-value were reported for each prognostic factor. Additionally, receiver operating characteristic (ROC) curve analysis was performed to determine the optimal cutoff value of the NPAR in predicting poor CCC. Area under the curve (AUC), 95% CI, and *P*-value were reported. İntra and interobserver variabilities were evaluated using the intraclass correlation index with a 95% CI.

RESULTS

A total of 320 patients with stable CAD (poor CCC group 150 patients and good CCC group 170 patients) were included in the study. Baseline characteristics and coronary angiographic findings are presented in Table 1. Both groups were similar in terms of age, sex, hypertension, smoking, the location of occluded vessel and the number of diseased vessels. Compared with good CCC group, the poor CCC group had a significantly higher frequency of DM ($P = .020$).

In Table 2, levels of creatinine (Cr), ALT, AST, total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, and triglyceride were similar in both the groups. Levels of fasting blood glucose ($P = .020$), WBC count ($P = .044$), neutrophil-to-lymphocyte ratio (NLR) ($P = .031$), C-reactive protein (CRP) ($P = .041$) and NPAR ($P = .008$) were significantly higher in patients with poor collateral than good collateral. On the other hand, level of albumin ($P = .023$) was significantly higher in patients with good collateral than poor collateral. An inverse stepwise relation was present between NPAR and collateral scores (Figure 1).

Table 1. Baseline Characteristics and Coronary Angiographic Findings

	All (n = 320)	Poor CCC (n = 150)	Good CCC (n = 170)	*P*
Age, years	66 (48-76)	68 (56-76)	65 (48-72)	.782
Gender, female (%)	140 (44)	65 (43)	75 (44)	.664
Hypertension, n (%)	160 (50)	79 (53)	81 (48)	.122
Diabetes, n (%)	198 (62)	121 (81)	77 (45)	.020
Smoking, n (%)	152 (48)	79 (53)	73 (43)	.074
1 vessel disease, n (%)	42 (13)	18 (12)	24 (14)	.586
2 vessel disease, n (%)	98 (31)	46 (31)	52 (31)	.944
3 vessel disease, n (%)	180 (56)	82 (55)	98 (58)	.744
Occluded LAD, n (%)	46 (14)	18 (12)	28 (16)	.326
Occluded CX, n (%)	44 (14)	19 (13)	25 (15)	.686
Occluded RCA, n (%)	230 (72)	103 (69)	127 (75)	.094

CCC, coronary collateral circulation; CX, left circumflex artery; LAD, left anterior descending artery; RCA, right coronary artery.

Table 2. Comparison of Laboratory Parameters Between Poor and Good CCC Groups

	Poor CCC (n = 150)	Good CCC (n = 170)	*P*
Glucose, mg/dL	134 (68-488)	109 (59-224)	.020
Creatinin, mg/dL	0.98 ± 0.38	0.92 ± 0.26	.864
AST, U/L	24 ± 4.6	30 ± 6.4	.222
ALT, U/L	32 ± 6.6	36 ± 6.9	.346
Total cholesterol, mg/dL	204 ± 28.8	182 ± 19.7	.742
LDL-C, mg/dL	138 ± 34.4	120 ± 30.2	.640
HDL-C, mg/dL	32.8 ± 9.4	34.6 ± 8.8	.686
Triglyceride, mg/dL	142 ± 23.3	134 ± 16.6	.564
WBC, $\times 10^3/mm^3$	9.4 ± 2.4	8.6 ± 2.7	.044
Hemoglobin, g/dL	13.1 (11.7-15.9)	12.7 (10.8-14.8)	.122
Platelet count, $\times 10^3/mm^3$	259 ± 31.1	247 ± 27.6	.142
NLR	3.75 ± 1.1	2.92 ± 1.3	.031
Albumin, g/dL	3.89 ± 0.98	4.55 ± 1.8	.023
CRP, mg/dL	2.9 (0.9-5.5)	1.9 (1.1-4.4)	.041
NPAR	18.8 ± 3.2	12.1 ± 2.9	.008

ALT, alanine aminotransferase; AST, aspartate aminotransferase; CCC, coronary collateral circulation; CRP, C-reactive protein; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; NLR, neutrophil-to-lymphocyte ratio; NPAR, Neutrophil percentage-to-albumin ratio; WBC, white blood cell.

In the univariate binary logistic regression analysis, DM, WBC, fasting blood glucose, hemoglobin, platelet count, CRP, NLR, albumin, and NPAR were evaluated. Variables with $P < .10$ were included in the multiple binary logistic regression analysis. The results indicated that NPAR (OR = 0.702, 95% CI: 0.614-0.802, $P < .001$), fasting blood glucose (OR = 0.995, 95% CI: 0.991-0.999, $P = .014$), and CRP (OR = 0.991, 95% CI: 0.984-0.998, $P = .009$) were independent predictors of poor CCC (Table 3).

ROC analysis revealed that NPAR had an optimal cutoff value of 16.4 for predicting poor CCC, with 68% sensitivity and 74% specificity. The AUC was 0.740, $P < .001$, 95% CI: 0.690-0.790 (Figure 2).

DISCUSSION

In this study, an independent association was demonstrated between levels of NPAR and the quality of collateral circulation in CTO patients. These findings also demonstrated a significant association between inadequate CCC and elevated levels of inflammatory markers, including fasting blood glucose, WBC, NLR, and CRP in patients with stable CAD.

Percutaneous coronary intervention (PCI) for CTO lesions is technically challenging, with lower success rates and a higher risk of complications. The retrograde approach has been developed and used worldwide recently, especially in challenging CTO lesions. Brilakis et al[12] have proposed a treatment algorithm for CTO PCI, suggesting that a primary

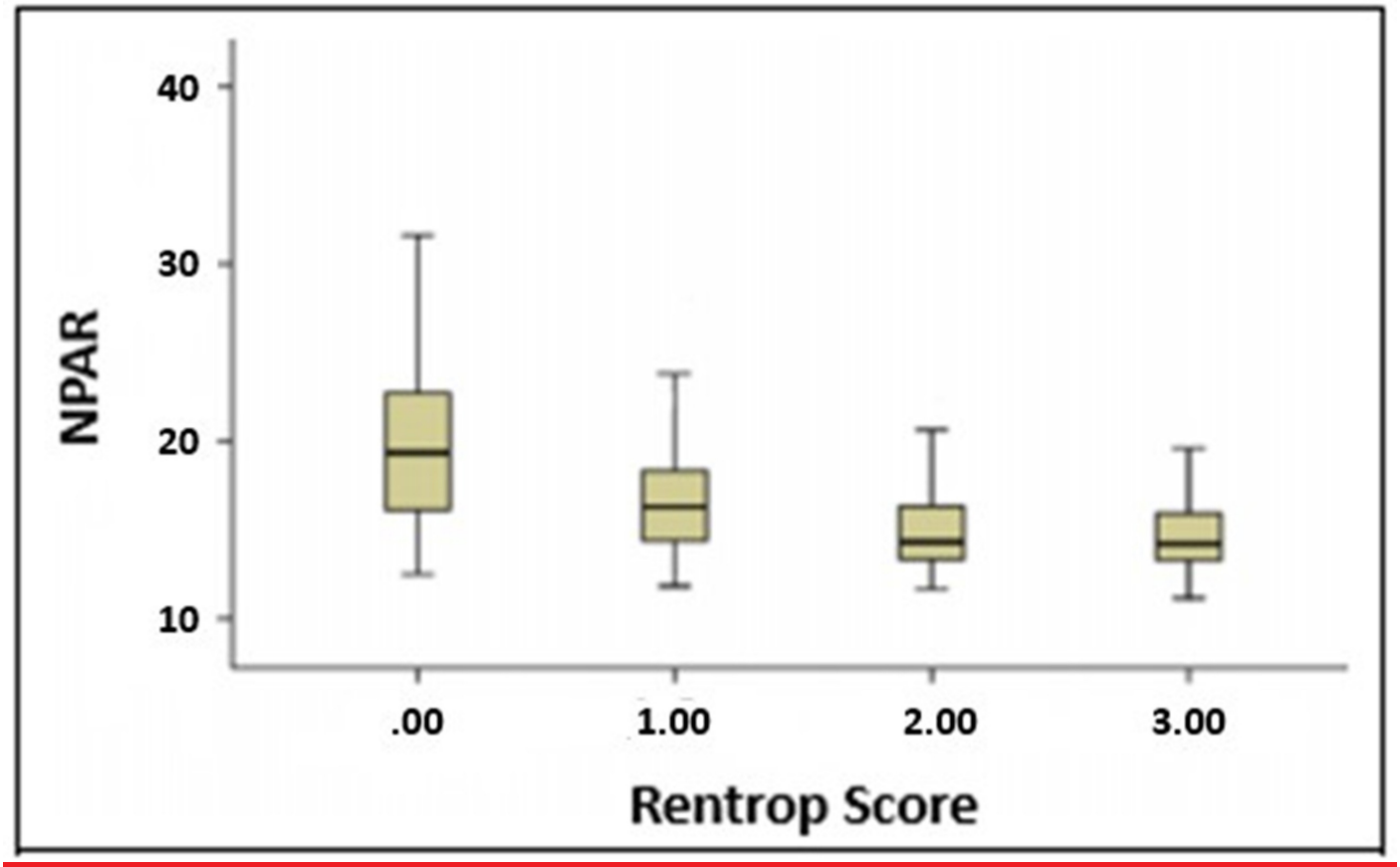


Figure 1. Relationship between neutrophil percentage-to-albumin ratio and Rentrop score (error bars: 95% confidence interval [CI]). Box plot showing the relationship between neutrophil percentage-to-albumin ratio and Rentrop score in patients with chronic total occlusion (CTO). Neutrophil percentage-to-albumin ratio values were significantly higher in patients with lower Rentrop scores (indicating poor collateral circulation).

retrograde approach may be reasonable in specific scenarios, such as cases with an ambiguous proximal cap, poor distal target, or the presence of interventional collaterals. The first and most important step for the successful completion of the retrograde procedure is the correct identification and monitoring of adequate CCC. In the retrograde cohort study, the size, tortuosity, and distal segment diameter of the collateral vessel were determined as independent variables related to procedural success.[13] In another study, collateral filling with a Rentrop score less than 2 was determined as an independent risk factor for technical failure.[14]

Many studies showed that the development of CCC was a pathophysiological process involving multiple mechanisms, including oxidative stress, systemic hypoxia, inflammation, and vascular endothelial function.[15,16] In this study,

Table 3. Results of Multivariate Logistic Regression

	Univariate		Model 1 Multivariate		Model 2 Multivariate	
Variables	**OR (95% CI)**	***P***	**OR (95% CI)**	***P***	**OR (95% CI)**	***P***
Fasting glucose	0.990 (0.986-0.994)	.003	0.995 (0.991-0.999)	.014	0.995 (0.991-0.999)	.014
Diabetes	0.689 (0.402-0.966)	.044	0.789 (0.431-1.438)	.388	0.789 (0.431-1.438)	.388
Albumin	0.991 (0.985-0.997)	.024	0.997 (0.995-1.000)	.066	–	–
CRP	0.988 (0.980-0.996)	.004	0.991 (0.984-0.998)	.009	0.991 (0.984-0.998)	.009
Hb	0.766 (0.388-1.242)	.568	0.704 (0.357-1.322)	.682	0.704 (0.357-1.322)	.682
Plt	0.744 (0.392-1.364)	.766	0.722 (0.384-1.356)	.724	0.722 (0.384-1.356)	.724
WBC	0.946 (0.906-0.986)	.048	0.976 (0.896-1.062)	.411	0.976 (0.896-1.062)	.494
NLR	0.990 (0.893-0.997)	.038	0.993 (0.986-1.000)	.058	–	–
NPAR	0.788 (0.696-0.880)	.003	–	–	0.702 (0.614-0.802)	.001

CRP, C-reactive protein; DM, diabetes mellitus; Hb, hemoglobin; NLR, neutrophil-to-lymphocyte ratio; NPAR, neutrophil percent-to-albumin ratio; Plt, platelet; WBC, white blood cell.

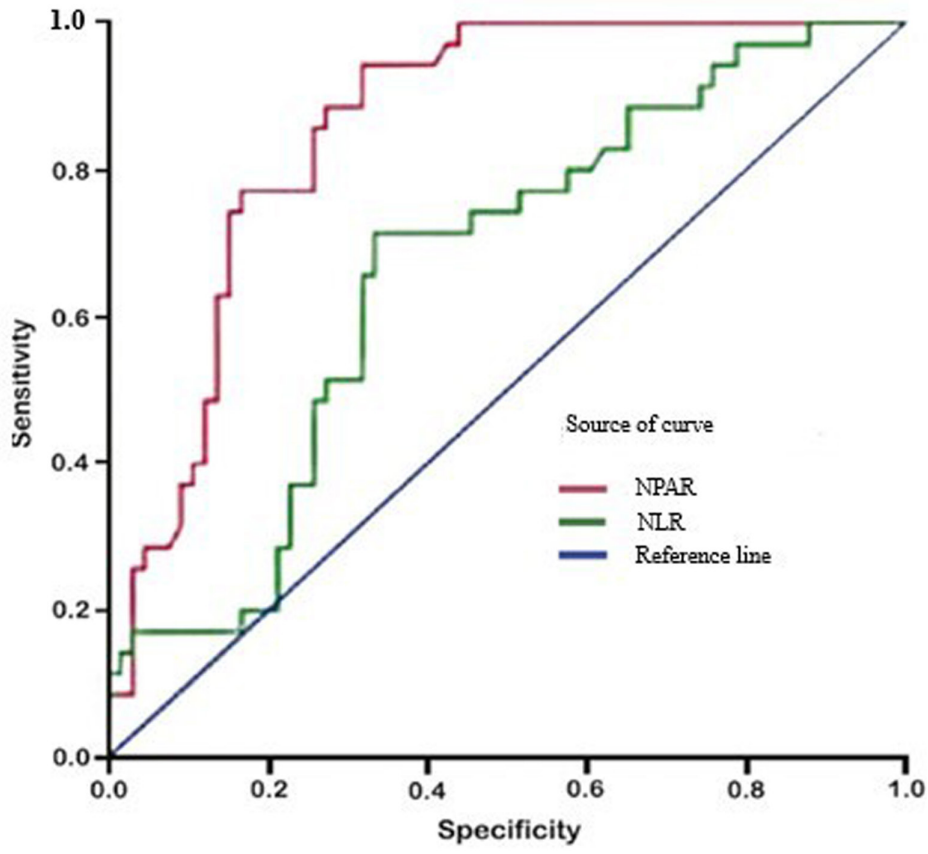


Figure 2. Receiver–operating characteristic curve analysis for neutrophil percentage-to-albumin ratio (NPAR) and NLR for the prediction of poor collateral. Figure 2 displays ROC curves demonstrating that NPAR levels (AUC = 0.74, 95% CI: 0.69-0.79, *P* < .001) exhibited comparable predictive ability for poor CCC to NLR levels (AUC = 0.62, 95% CI: 0.57-0.67, *P* < .01).

inadequate CCC was observed in patients with high fasting blood glucose levels and in individuals with diabetes in accordance with previous studies.[17]

Inflammation plays a central role at all stages of atherosclerosis, and it is now known that inflammation plays an essential role in CCC formation apart from traditional risk factors.[7,18] White blood cell, neutrophil, and lymphocyte counts are important markers in systemic inflammation processes. During the inflammatory response, there is an increase in the number of neutrophils and a decrease in the number of lymphocytes. This leads to a significant increase in NLR. Studies in the literature have demonstrated that NLR and Platelet Lymphocyte Ratio (PLR) are reliable indicators for assessing the presence and severity of systemic inflammation.[19,20] Neutrophil-to-lymphocyte ratio was significantly higher in patients with hemodynamically significant coronary artery stenosis.[21] The relationship between NLR and the development of CCC in CAD has not been consistently demonstrated in the literature. Although studies have shown that NLR is a marker of inflammation, they have yielded conflicting results regarding its effect on the development of CCC.[22,15] Contrary to expectations, elevated serum monocyte and adiponectin levels were associated with well-developed CCC in patients with acute coronary syndrome. This finding suggests the complex nature of systemic inflammation and that its effects on coronary collateral development may be different than expected.[6,23] Akın et al[24] suggested that an elevated level of NLR is independently associated with a significant impairment in coronary collateralization. Similarly, in this study, it was found that elevated levels of WBC and NLR were associated with inadequate CCC.

C-reactive protein, an important marker of vascular inflammation, is a frequently used biomarker in this regard.[25-27] In the literature, increased nitric oxide (NO) production has been reported to promote endothelial cell proliferation and migration. However, CRP-mediated inflammation has been suggested to inhibit NO production, which plays a critical role in angiogenesis.[28,29] Vascular endothelial growth factor (VEGF) is known to be a potent regulator of endothelial cell proliferation. In 1 study, CRP was shown to inhibit VEGF-mediated endothelial cell migration.[30] A negative correlation has been found between high CRP levels and the development of CCC.[31] In a study, Zorkun et al[32] demonstrated that male gender, prior statin usage, and higher hs-CRP levels are determinants of coronary collaterals in patients with coronary artery disease. Kelesoglu et al[33] showed that patients who had poor CCC had higher CRP, NLR, and CRP to Albumin Ratio (CAR) levels compared with those who had satisfactory CCC.

Neutrophils are cells that play an important role in inflammation processes.[34] Serum albumin is a protein that indicates the state of nutrition in the body and can change under the influence of inflammation.[35] Low serum albumin levels are associated with poor clinical outcomes in patients with CAD, mainly due to malnutrition and inflammation.[36] Low serum albumin can lead to physiological changes that contribute to the development of cardiovascular diseases. Low serum albumin levels increase long-term all-cause mortality in ST-segment elevation myocardial infarction (STEMI) patients.[37] Decreased albumin levels were found to predict a higher risk of all-cause mortality after percutaneous transluminal coronary intervention.[36] In a study by Topal et al[38] it was stated that gamma-glutamyl transferase to albumin ratio can independently predict the presence, extent, and severity of CAD.

NPAR, the ratio of neutrophil percentage and serum albumin concentration, is a combination of 2 important clinical indicators. A high NPAR value suggests an elevated neutrophil count and/or a reduced serum albumin level. The calculation of the NPAR can make the changes of these 2 indicators more apparent. In particular, in some cases, clinicians may overlook the importance of these 2 indicators, for example, even if the neutrophil ratio is high and albumin is low, both may be within the normal range. Neutrophil percentage-to-albumin ratio is a simple, cost-effective, and timely assessment tool that combines 2 key clinical parameters. Cui et al[39] found that NPAR was independently correlated with in-hospital mortality in patients with STEMI. Dai et al[40] showed that NPAR is a good indicator for predicting free wall rupture. Also, Yu et al,[41] Sun et al,[10] Lin et al,[42] and Hu et al[43] have independently established the significance of NPAR in predicting mortality in various critical and cardiac patient populations. Similar to the above studies, in this study, NPAR was associated with inadequate CCC in CTO patients, indicating a higher likelihood of complications.

In addition to inflammatory parameters such as WBC, CRP, and NLR, NPAR value was found to be significantly higher in patients with poor collateral circulation. According to the results of multivariate analysis, high NPAR levels were identified as an independent marker of poor collateral circulation.

To the best of the authors' knowledge, this is the first study to examine the relationship between NPAR, a popular and effective inflammatory parameter, and the level of collateral circulation. By assessing the quality of collateral circulation in patients with CTO using NPAR, a simple and powerful inflammatory parameter, this study offers the potential to predict the mortality risk of these patients and determine their suitability for percutaneous intervention.

Study Limitations

This study has some limitations. Firstly, the number of patients was relatively small and the study was single-centre and retrospective. Therefore, it can be stated that the selected population may not represent the whole patient group. The lack of measurement of other important parameters such as NO and VEGF, which play a role in coronary collateral development, is a deficiency that prevents one from better understanding the mechanisms of NPAR in this process.

CONCLUSION

NPAR may be a simple, measurable and inexpensive inflammatory marker that can be used to predict the risk of poor CCC in CTO patients. In this way, it will be possible to predict the prognosis and success of percutaneous revascularization in patients with CTO. A larger-scale, prospective, multicenter case-control study is required to validate these results and establish the clinical utility of NPAR in predicting outcomes in patients with CTO.

Ethics Committee Approval: This study was approved by the Malatya Turgut Özal University Ethics Committee on October 1, 2023, with decision number 2023/23.

Informed Consent: Due to the retrospective nature of the study, written informed consent from patients was unattainable.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – İ.A., H.A.B.; Design – İ.A., M.K.; Supervision – İ.A.; Resources – İ.A., H.A.B.; Materials – İ.A.; Data Collection and/or Processing – İ.A.; Analysis and/ or Interpretation – İ.A., M.K.; Literature Search – İ.A., H.A.B.; Writing – İ.A., M.K.; Critical Review – İ.A., M.K.

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REFERENCES

1. Yamane M. Current percutaneous recanalization of a coronary chronic total occlusion. *Rev Esp Cardiol (Engl Ed)*. 2012;65(3):265-277. [CrossRef]
2. Popma JJ. Coronary Angiography and intravascular imaging. In: Libby P, Bonow RO, Mann DL, Zipes DP, eds. *Heart Disease: A Textbook of Cardiovascular Medicine*. 8th ed. Philadelphia: Elsevier Saunders; 2008.
3. Fukai M, Ii M, Nakakoji T, et al. Angiographically demonstrated coronary collaterals predict residual viable myocardium in patients with chronic myocardial infarction: a regional metabolic study. *J Cardiol*. 2000;35(2):103-111.
4. Sabia PJ, Powers ER, Ragosta M, Sarembock IJ, Burwell LR, Kaul S. An association between collateral blood flow and myocardial viability in patients with recent myocardial infarction. *N Engl J Med*. 1992;327(26):1825-1831. [CrossRef]
5. Soehnlein O. Multiple roles for neutrophils in atherosclerosis. *Circ Res*. 2012;110(6):875-888. [CrossRef]
6. Kocaman SA, Arslan U, Tavil Y, Okuyan H, Abaci A, Cengel A. Increased circulating monocyte count is related to good collateral development in coronary artery disease. *Atherosclerosis*. 2008;197(2):753-756. [CrossRef]
7. Kerner A, Gruberg L, Goldberg A, et al. Relation of C-reactive protein to coronary collaterals in patients with stable angina pectoris and coronary artery disease. *Am J Cardiol*. 2007;99(4):509-512. [CrossRef]

8. Liu CF, Chien LW. Predictive role of neutrophil-percentage-to-albumin ratio (NPAR) in nonalcoholic fatty liver disease and advanced liver fibrosis in nondiabetic US adults: evidence from NHANES 2017-2018. *Nutrients*. 2023;15(8):1892. [CrossRef]
9. Chen Z, Xie D, Li Y, et al. Neutrophil albumin ratio is associated with all-cause mortality in stroke patients: a retrospective database study. *Int J Gen Med*. 2022;15:1-9. [CrossRef]
10. Sun T, Shen H, Guo Q, et al. Association between neutrophil percentage-to-albumin ratio and all-cause mortality in critically ill patients with coronary artery disease. *BioMed Res Int*. 2020;2020:8137576. [CrossRef]
11. Imhof BA, Aurrand-Lions M. Angiogenesis and inflammation face off. *Nat Med*. 2006;12(2):171-172. [CrossRef]
12. Brilakis ES, Grantham JA, Rinfret S, et al. A percutaneous treatment algorithm for crossing coronary chronic total occlusions. *JACC Cardiovasc Interv*. 2012;5(4):367-379. [CrossRef]
13. Chai WL, Agyekum F, Zhang B, et al. Clinical prediction score for successful retrograde procedure in chronic total occlusion percutaneous coronary intervention. *Cardiology*. 2016;134(3):331-339. [CrossRef]
14. Galassi AR, Boukhris M, Azzarelli S, Castaing M, Marzà F, Tomasello SD. Percutaneous coronary revascularization for chronic total occlusions: a novel predictive score of technical failure using advanced technologies. *JACC Cardiovasc Interv*. 2016;9(9):911-922. [CrossRef]
15. Uysal OK, Turkoglu C, Sahin DY, et al. The relationship between neutrophil-to-lymphocyte ratio and coronary collateral circulation. *Clin Appl Thromb Hemost*. 2015;21(4):329-333. [CrossRef]
16. Jamaiyar A, Juguilon C, Dong F, et al. Cardioprotection during ischemia by coronary collateral growth. *Am J Physiol Heart Circ Physiol*. 2019;316(1):H1-H9. [CrossRef]
17. Abacı A, Oğuzhan A, Kahraman S, et al. Effect of diabetes mellitus on formation of coronary collateral vessels. *Circulation*. 1999;99(17):2239-2242. [CrossRef]
18. Balta S, Aparci M, Ozturk C, Demir M, Celik T. Neutrophillymphocyte ratio may predict the degree of coronary collateral circulation. *Clin Appl Thromb Hemost*. 2015;21(6):586-587. [CrossRef]
19. Zahorec R. Ratio of neutrophil to lymphocyte counts-rapid and simple parameter of systemic inflammation and stress in critically ill. *Bratisl Lek Listy*. 2001;102(1):5-14.
20. Yüksel M, Yıldız A, Oylumlu M, et al. The association between platelet/lymphocyte ratio and coronary artery disease severity. *Anatol J Cardiol*. 2015;15(8):640-647. [CrossRef]
21. Akyel A, Yayla Ç, Erat M, et al. Neutrophil-to-lymphocyte ratio predicts hemodynamic significance of coronary artery stenosis. *Anatol J Cardiol*. 2015;15(12):1002-1007. [CrossRef]
22. Çil H, İslamoğlu H,Yavuz C. Association between neutrophil/lymphocyte ratio and coronary collateral circulation. *J Clin Exp Immunol*. 2012;3(1):29-32.
23. Soydinc S, Davutoglu V, Sari I. High serum levels of adiponectin improve coronary collateral development in patients with coronary artery disease. *Tohoku J Exp Med*. 2007;211(4):347-352. [CrossRef]
24. Akın F, Ayça B, Çelik Ö, Şahin C. Predictors of poor coronary collateral development in patients with stable coronary artery disease: neutrophil-to-lymphocyte ratio and platelets. *Anatol J Cardiol*. 2015;15(3):218-223. [CrossRef]
25. Casas JP, Shah T, Hingorani AD, Danesh J, Pepys MB. C-reactive protein and coronary heart disease: a critical review. *J Intern Med*. 2008;264(4):295-314. [CrossRef]
26. Calabró P, Willerson JT, Yeh ET. Inflammatory cytokines stimulated C-reactive protein production by human coronary artery smooth muscle cells. *Circulation*. 2003;108(16):1930-1932. [CrossRef]
27. Venugopal SK, Devaraj S, Jialal I. Macrophage conditioned medium induces the expression of C-reactive protein in human aortic endothelial cells: potential forparacrine/autocrine effects. *Am J Pathol*. 2005;166(4):1265-1271. [CrossRef]
28. Ziche ML, Morbidelli L, Masini E, et al. Nitric oxide mediates angiogenesis in vivo and endothelial cell growth and migration in vitro promoted by substance P. *J Clin Invest*. 1994;94(5):2036-2044. [CrossRef]
29. Verma S, Wang CH, Li SH, et al. A shelfful filling prophecy: C-reactive protein attenuates nitric oxide production and inhibits angiogenesis. *Circulation*. 2002;106(8):913-919. [CrossRef]
30. Schneeweis C, Gräfe M, Bungenstock A, Spencer-Hänsch C, Fleck E, Goetze S. Chronic CRP-exposure inhibits VEGF induced endothelial cell migration. *J Atheroscler Thromb*. 2010;17(2):203-212. [CrossRef]
31. Gulec S, Ozdemir AO, Maradit-Kremers H, Dincer I, Atmaca Y, Erol C. Elevated levels of C-reactive protein are associated with impaired coronary collateral development. *Eur J Clin Investig*. 2006;36(6):369-375. [CrossRef]
32. Zorkun C, Akkaya E, Zorlu A, Tandoğan I. Determinants of coronary collateral circulation in patients with coronary artery disease. *Anadolu Kardiyol Derg*. 2013;13(2):146-151. [CrossRef]
33. Kelesoglu S, Yilmaz Y, Elcık D. Relationship between C-reactive protein to albumin ratio and coronary collateral circulation in patients with stable coronary artery disease. *Angiology*. 2021;72(9):829-835. [CrossRef]
34. Libby P, Ridker P, Maseri A. Inflammation in atherosclerosis. *Arterioscler Thromb Vasc Biol*. 2012;32(9):2045-2051. [CrossRef]
35. Don BR, Kaysen G. Serum albumin: relationship to inflammation and nutrition. *Semin Dial*. 2004;17(6):432-437. [CrossRef]
36. Wada H, Dohi T, Miyauchi K, et al. Impact of serum albumin levels on long-term outcomes in patients undergoing percutaneous coronary intervention. *Heart Vessels*. 2017;32(9):1085-1092. [CrossRef]
37. Plakht Y, Gilutz H, Shiyovich A. Decreased admission serum albumin level is an independent predictor of longterm mortality in hospital survivors of acute myocardial infarction. Soroka acute myocardial infarction II (SAMI-II) project. *Int J Cardiol*. 2016;219:20-24. [CrossRef]
38. Topal S, Kızıltunç E, Sezenöz B, et al. Gamma-glutamyl transferase to albumin ratio can predict severity of coronary artery disease detected by coronary computed tomography angiography. *Anatol J Cardiol*. 2021;25(9):653-660. [CrossRef]
39. Cui H, Ding X, Li W, Chen H, Li H. The neutrophil Percentage to Albumin Ratio as a New Predictor of In-Hospital Mortality in Patients with ST-Segment Elevation myocardial infarction. *Med Sci Monit*. 2019;25:7845-7852. [CrossRef]
40. Dai K, Li Z, Luo Y, et al. Neutrophil percentage-to-albumin ratio and monocyte-to-lymphocyte ratio as predictors of free-wall rupture in patients with acute myocardial infarction. *J Clin Lab Anal*. 2022;36(1):e24136. [CrossRef]
41. Yu Y, Liu Y, Ling X, et al. The neutrophil per centage-to-albumin ratio as a new predictor of all-cause mortality in patients with cardiogenic shock. *BioMed Res Int*. 2020;2020:7458451. [CrossRef]
42. Lin Y, Lin Y, Yue J, Zou Q. The neutrophil percentage-to-albumin ratio is associated with all-cause mortality in critically ill patients with acute myocardial infarction. *BMC Cardiovasc Disord*. 2022;22(1):115. [CrossRef]
43. Hu Z, Wang J, Xue Y, et al. The Neutrophil-to-Albumin Ratio as a new predictor of All-Cause mortality in patients with heart failure. *J Inflamm Res*. 2022;15:701-713. [CrossRef]