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Original article

The association of monocyte-to-lymphocyte and neutrophil-to-lymphocyte ratios with CIMT in HD and CAPD populations

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ABSTRACT

BACKGROUND: Chronic kidney disease (CKD) carries a high risk of cardiovascular complications due to atherosclerosis, which is exacerbated by chronic inflammation. The neutrophil-to-lymphocyte ratio (NLR) and monocyte-to-lymphocyte ratio (MLR) are emerging inflammatory markers with potential to predict atherosclerotic risk.

OBJECTIVES: To evaluate the association between NLR and MLR values with carotid intima-media thickness (CIMT) in CKD patients undergoing hemodialysis and continuous ambulatory peritoneal dialysis (CAPD).

METHODS: This observational cross-sectional study was conducted at Dr. Saiful Anwar General Hospital, Malang, between July and December 2024. Data on baseline characteristics, laboratory results, and CIMT were obtained from medical records and carotid ultrasonography. Statistical analyses included t-tests, Mann-Whitney tests, and Pearson or Spearman correlation tests, depending on data distribution.

RESULTS: A total of 97 CKD patients were included (45 on CAPD and 52 on hemodialysis). NLR values were significantly higher in the CAPD group compared to the hemodialysis group ($p = 0.0253$), while MLR did not differ significantly. CIMT was significantly higher in the hemodialysis group ($p = 0.0035$). In the CAPD group, MLR was significantly correlated with CIMT ($r = 0.3543$; $p = 0.0169$), whereas no significant correlation was observed in the hemodialysis group. NLR was not significantly associated with CIMT in either group. Subgroup and ROC analyses indicated that neither NLR nor MLR could accurately differentiate elevated CIMT from normal.

CONCLUSION: MLR is associated with CIMT in patients undergoing CAPD, while NLR does not show a significant association with CIMT in either dialysis group.

KEYWORDS: Chronic kidney disease; hemodialysis; continuous ambulatory peritoneal dialysis; chronic inflammation.

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INTRODUCTION

Chronic kidney disease (CKD) is a major global health challenge, associated with high morbidity and mortality rates, primarily due to cardiovascular complications. Cardiovascular disease in CKD patients is closely linked to atherosclerosis triggered by chronic inflammation.[1] Chronic inflammation in CKD is characterized by elevated inflammatory cytokines and an excessive increase in circulating monocytes and neutrophils, all contributing to systemic inflammation and oxidative stress. Monocytes, neutrophils, and lymphocytes play critical roles in the inflammatory process and are involved in CKD-induced oxidative pathogenesis in patients undergoing hemodialysis and continuous ambulatory peritoneal dialysis (CAPD).[2] The neutrophil-to-lymphocyte ratio (NLR) and monocyte-to-lymphocyte ratio (MLR) are emerging inflammatory markers that are non-invasive, cost-effective, and can be

easily calculated from routine blood tests. Compared to traditional inflammatory markers such as high-sensitivity C-reactive protein (hs-CRP), NLR and MLR exhibit more stable and representative kinetic patterns.[3]

MLR reflects monocyte activity, which are precursors to macrophages and directly involved in atherosclerotic plaque formation. Meanwhile, NLR is closely associated with the expression of inflammatory mediators and serves as an important prognostic indicator of broader systemic inflammation.[4] Literature suggests that MLR may be a more sensitive predictor of cardiovascular disease than NLR, given the direct role of monocytes in atherosclerosis development.[5] Additionally, increased MLR is linked to higher lymphocyte apoptosis and elevated infection risk.[6] Dialysis patients, whether on hemodialysis or CAPD, face heightened inflammatory risk due to bloodstream infections related to catheters, access site infections, pathogen overgrowth in the gut, and potential exposure to bacteria-contaminated dialysis water.[7] Higher cytokine production observed in hemodialysis patients compared to CAPD is likely due to the use of synthetic membranes in hemodialysis, which are more prone to inducing inflammation, whereas CAPD uses the natural peritoneal membrane.[8] Both hemodialysis and CAPD increase the risk of atherosclerotic complications in CKD patients.[9] The progression of atherosclerosis can be evaluated by measuring carotid intima-media thickness (CIMT), a reliable, safe, and non-invasive technique for detecting subclinical atherosclerosis and assessing cardiovascular risk.[10] This study aims to investigate the association between MLR and NLR values with CIMT in CKD patients undergoing hemodialysis and CAPD, with the hope that the findings may support the development of targeted strategies to reduce cardiovascular risk in this population.

METHODS

Study design

This observational cross-sectional study was conducted at Dr. Saiful Anwar Hospital, Malang, from July to December 2024. The study aimed to assess the relationship between MLR and NLR with CIMT in CKD patients undergoing hemodialysis and CAPD. The study protocol was developed and implemented following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.[11]

Ethical approval

Ethical approval was obtained from the Ethics Committee of Dr. Saiful Anwar Hospital (approval number: 400/269/K.3/102.7/2024). All procedures were conducted in accordance with the principles outlined in the Declaration of Helsinki.[12] Prior to participation, all subjects were thoroughly informed about the study's purpose, potential risks, and benefits. Participation was voluntary, with written informed consent obtained from each participant. Participants had the right to withdraw at any time without any consequences. No incentives were provided.

Participants and eligibility criteria

Sample size was calculated using a retrospective sample size formula for quantitative variables (one-sided method),[13] resulting in 45 CAPD patients and 52 hemodialysis patients. Inclusion criteria were male or female patients aged over 18 years, undergoing hemodialysis or CAPD for at least 3 months, with hemodialysis frequency of at least twice per week, and in physically independent condition. Exclusion criteria included patients with acute infections, critically ill patients (e.g., severe infections or acute pulmonary edema), and pregnant women.

Table 1. Baseline characteristics of patients in our study

Characteristics	CAPD (n = 45)	HD (n = 52)	p
Age, years, mean ± SD	41.87 ± 12.06	52.83 ± 11.25	<0.0001
Age group			
17-25 years	4 (8.89)	0 (0.00)	0.0281
26-35 years	10 (22.22)	5 (9.62)	0.0868
36-45 years	12 (26.67)	8 (15.38)	0.1708
46-55 years	14 (31.11)	17 (32.69)	0.8677
56-65 years	4 (8.89)	17 (32.69)	0.0045
>65 years	1 (2.22)	5 (9.62)	0.1317
Gender, n (%)			
Male	24 (53.33)	27 (51.92)	0.8897
Female	21 (46.67)	25 (48.08)	0.8897
Last education level, n (%)			
No formal education	0 (0.00)	4 (7.69)	0.0574
Elementary school	4 (8.89)	6 (11.54)	0.6687
Junior high school	10 (22.22)	12 (23.08)	0.9201
Senior high school	15 (33.33)	17 (32.69)	0.9466
Diploma / Bachelor's degree	16 (35.56)	13 (25.00)	0.2574
Marital Status, n (%)			
Married	39 (86.67)	48 (92.31)	0.3622
Single	6 (13.33)	4 (7.69)	0.3622
Comorbidities, n (%)			
Hypertension	42 (93.33)	46 (88.46)	0.4095
Diabetes mellitus	5 (11.11)	10 (19.23)	0.1882
Duration of dialysis, median (IQR)	4.00 (3.00)	3.50 (3.25)	0.5405
Dialysis duration group			
1 - 5 years	35 (77.78)	43 (82.69)	0.5430
6 - 10 years	6 (13.33)	8 (15.38)	0.7743
>10 years	4 (8.89)	1 (1.92)	0.1218
Body weight, kg, median (IQR)	61.40 (14.00)	59.00 (21.50)	0.2594
Height, cm, median (IQR)	160.00 (11.00)	160.00 (12.00)	0.6848
BMI, kg/m2, mean ± SD	24.53 ± 4.32	22.79 ± 4.12	0.0453
BMI Category			
<18,5 kg/m2	2 (4.44)	9 (17.31)	0.0463
18,5-24,99 kg/m2	25 (55.56)	28 (53.85)	0.8661
25-29,99 kg/m2	13 (28.89)	13 (25.00)	0.6663
>30 kg/m2	5 (11.11)	2 (3.85)	0.1679
Laboratory parameters			
Hemoglobin, gr/dl, median (IQR)	8.43 (1.93)	9.63 (2.33)	0.0002
RDW, median (IQR)	0.13 (0.01)	0.14 (0.01)	0.0005
Albumin, gr/dl, median (IQR)	3.74 (0.51)	4.05 (0.45)	0.0005
Urea, mg/dl, median (IQR)	96.30 (27.97)	109.30 (16.33)	0.0006
Creatinine, mg/dl, median (IQR)	12.43 (3.37)	11.77 (2.07)	0.0870
eGFR, median (IQR)	4.05 (1.01)	4.83 (0.81)	0.0050
Serum iron, median (IQR)	65.66 (34.67)	63.93 (20.15)	0.1198
Transferrin saturation, median (IQR)	0.33 (0.18)	0.31 (0.11)	0.2174
Natrium, median (IQR)	136.67 (3.33)	135.82 (3.67)	0.0639
Kalium, median (IQR)	3.48 (0.64)	4.04 (0.63)	<0.0001
Chloride, median (IQR)	94.30 ± 3.44	98.83 ± 2.52	<0.0001
Calcium, median (IQR)	7.97 (1.24)	8.75 (0.47)	<0.0001
Phosphorus, mean ± SD	4.70 ± 1.22	4.20 ± 1.09	0.0350
Parathyroid hormone, median (IQR)	451.80 (388.20)	282.00 (305.80)	0.0010

Notes, CAPD, continuous ambulatory peritoneal dialysis; HD, hemodialysis; BMI, body mass index; RDW, red cell distribution width; eGFR, estimated glomerular filtration rate.

Data collection

Data collection was conducted at Dr. Saiful Anwar Hospital from July to December 2024. Baseline participant characteristics and laboratory data were obtained from medical records, while CIMT measurements were performed using carotid ultrasonography. Data collection was performed by FB, NS, and ESW. Any discrepancies or inconsistencies in the data were resolved through group discussion to ensure data consistency.

Covariates

Dialysis modality, consisting of hemodialysis and CAPD, was considered the predictor variable. Outcome variables included CIMT, MLR, and NLR.

Table 2. Comparison of NLR, MLR, and CIMT in CAPD versus hemodialysis patients.

Variables	CAPD (n = 45)	HD (n = 52)	MD	95%CI	p
NLR	3.68 (2.05)	3.05 (1.45)	0.63	0.07 - 1.15	0.0253
MLR	0.34 (0.18)	0.36 (0.18)	[-0.02]	[-0.05] – [0.06]	0.9469
CIMT	0.05 (0.02)	0.07 (0.03)	[-0.02]	[-0.02] – [0.00]	0.0035

Notes, CAPD, continuous ambulatory peritoneal dialysis; HD, hemodialysis, NLR, neutrophil-to-lymphocyte ratio; MLR, monocyte-to-lymphocyte ratio; CIMT, carotid intima-media thickness.

Statistical analysis

Categorical variables were presented as frequencies and percentages (n, %), while numerical variables were expressed as mean ± standard deviation (SD) if normally distributed or median (interquartile range, IQR) if not. Normality was assessed using the Kolmogorov-Smirnov test, with p-values > 0.05 indicating normal distribution. Differences in categorical variables between CAPD and hemodialysis groups were analyzed using the chi-square test. For numerical variables, group comparisons employed the t-test for normally distributed data or the Mann-Whitney test for non-normal data. Differences in MLR, NLR, and CIMT between CAPD and hemodialysis groups were analyzed similarly. Effect estimates were reported as mean differences (MD) for normal data or median differences for non-normal data. Correlations between MLR or NLR and CIMT within each dialysis group were evaluated using Pearson's correlation for normally distributed data or Spearman's correlation for non-normal data. Correlation results were presented as correlation coefficient (r) with 95% confidence intervals (95% CI). Subgroup analyses comparing NLR or MLR between patients with increased CIMT and normal CIMT in CAPD or hemodialysis populations were performed using t-tests for normal data or Mann-Whitney tests for non-normal data. Receiver operating characteristic (ROC) analysis was conducted to determine the sensitivity and specificity of NLR and MLR. The area under the curve (AUC) with 95% CI was reported as the effect estimate. If significant differences were observed, the Youden index was calculated to determine the optimal cutoff values for NLR and MLR between groups with increased and normal CIMT in CAPD or hemodialysis populations. All analyses were conducted using GraphPad Prism (GraphPad Software, Inc., California, USA).

RESULTS

Basic characteristics of study participants

From July to December 2024, a total of 97 CKD patients were enrolled in this study. Among them, 45 patients underwent CAPD, while 52 patients received hemodialysis. The distribution of patients between the CAPD and hemodialysis groups was analyzed to evaluate differences in baseline characteristics, including age, sex, highest education level, marital status, comorbidities, dialysis duration, anthropometric data, and

laboratory parameters. Detailed comparisons of baseline characteristics between CKD patients receiving CAPD and hemodialysis are presented in Table 1. Categorical variables such as sex, education level, marital status, and comorbidities are presented as counts and percentages (n, %). Numerical variables including age, body weight, height, body mass index (BMI), dialysis duration, and laboratory parameters are reported as mean ± SD if normally distributed or median (IQR) if non-normally distributed. Normality was tested using the Kolmogorov-Smirnov test. Age, BMI, and phosphorus levels demonstrated normal distribution ($p > 0.05$), whereas dialysis duration, body weight, height, hemoglobin, red cell distribution width (RDW), albumin, urea, creatinine, estimated glomerular filtration rate (eGFR), serum iron, transferrin saturation, sodium, potassium, chloride, calcium, and parathyroid hormone levels were non-normally distributed ($p < 0.05$).

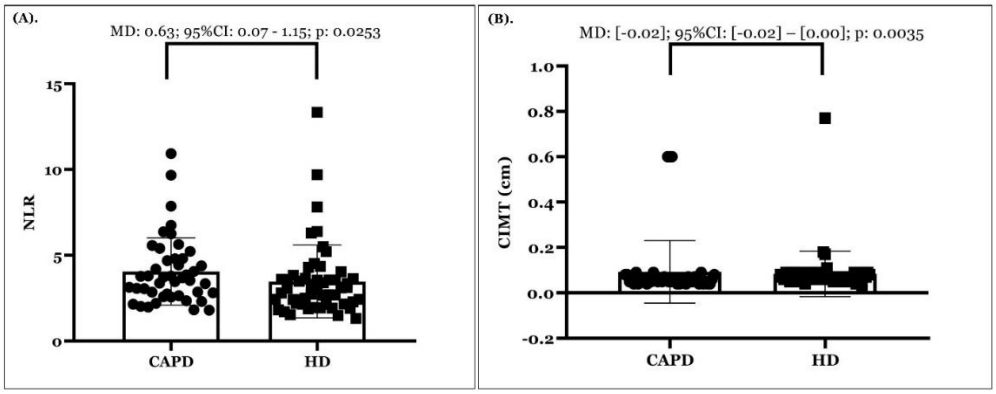

Figure 1. A) Comparison of Neutrophil-to-Lymphocyte Ratio (NLR) between CKD patients undergoing CAPD and hemodialysis (MD: 0.63; 95% CI: 0.07–1.15; p = 0.0253). B) Comparison of Carotid Intima-Media Thickness (CIMT) between CKD patients receiving CAPD and hemodialysis (MD: –0.02; 95% CI: –0.02 to 0.00; p = 0.0035).

Based on Table 1, the hemodialysis group was significantly older than the CAPD group. Age category data showed a higher proportion of CAPD patients in the 17–25 years age range compared to hemodialysis patients, while hemodialysis patients were more prevalent in the 56–65 years age group. No significant differences ($p > 0.05$) were found between CAPD and hemodialysis groups in terms of sex, education level, marital status, and comorbidities. Dialysis duration also did not differ significantly between groups in either numeric or categorical analyses. Regarding anthropometric data, no differences were observed in body weight or height between groups. However, BMI was significantly higher in the CAPD group compared to the hemodialysis group. Categorical BMI data showed that the hemodialysis group had a higher frequency of BMI <18.5 kg/m² than the CAPD group. Laboratory analysis revealed no significant differences in creatinine, serum iron, transferrin saturation, and sodium between groups. Significant differences were observed in hemoglobin, RDW, albumin, urea, eGFR, potassium, chloride, calcium, phosphorus, and parathyroid hormone levels.

Assessment of NLR variation between CAPD and hemodialysis in CKD patients

The median NLR was 3.68 (IQR 2.05) in the CAPD group and 3.05 (IQR 1.45) in the hemodialysis group. The Kolmogorov-Smirnov test indicated non-normal distribution; therefore, the Mann-Whitney test was used to compare NLR values. CKD patients undergoing CAPD had significantly higher NLR values than those on hemodialysis (MD: 0.63; 95%CI: 0.07–1.15; p = 0.0253) (Figure 1A). Detailed analysis results are presented in Table 2.

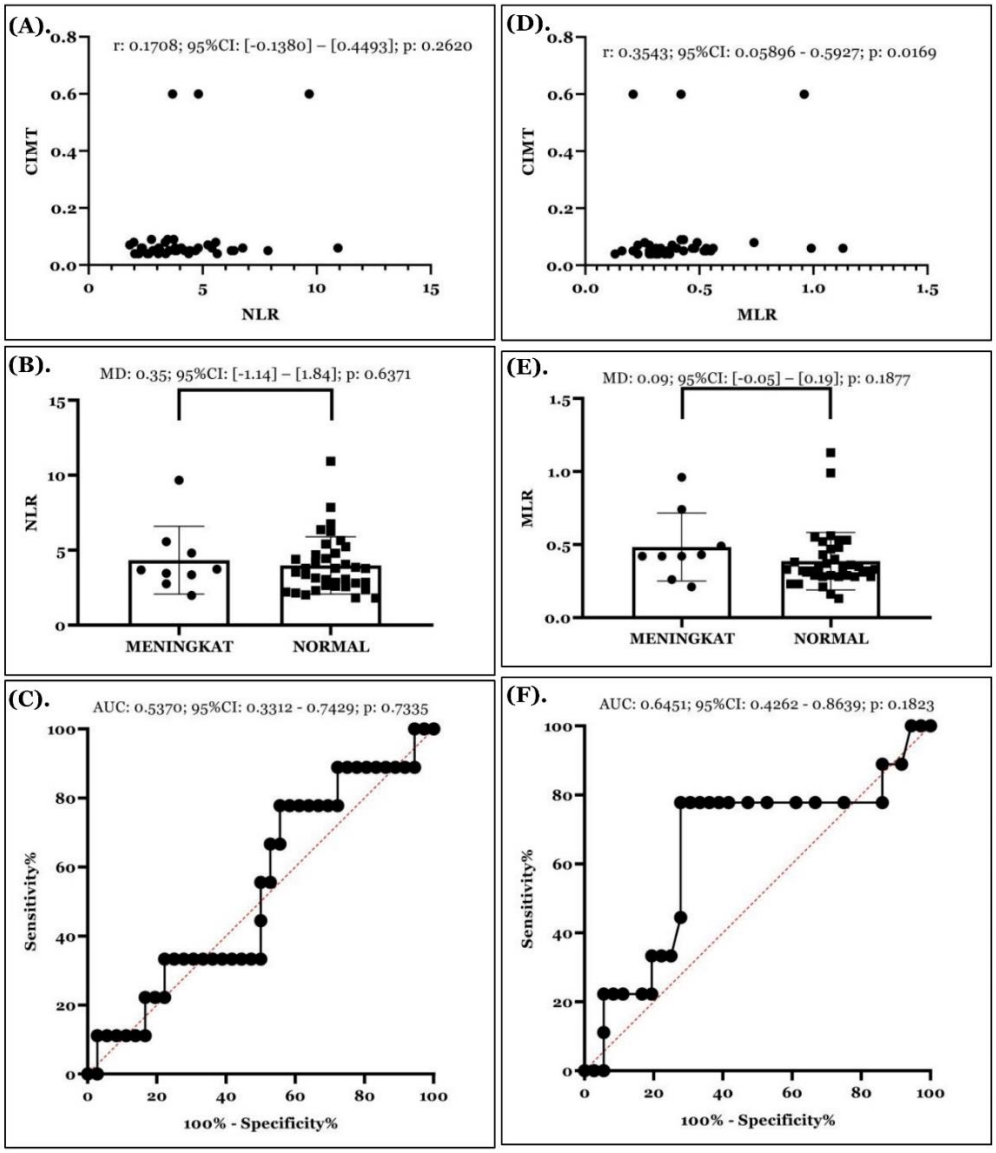

Figure 2. A) Correlation between NLR and CIMT in CKD patients undergoing CAPD (r = 0.1708; 95% CI: –0.1380 to 0.4493; p = 0.2620). B) Comparison of NLR between patients with increased CIMT and normal CIMT in the CAPD group (MD: 0.35; 95% CI: –1.14 to 1.84; p = 0.6371). C) ROC curve of NLR for distinguishing increased CIMT from normal CIMT in CAPD patients (AUC: 0.5370; 95% CI: 0.3312–0.7429; p = 0.7335). D) Correlation between MLR and CIMT in CKD patients undergoing CAPD (r = 0.3543; 95% CI: 0.05896–0.5927; p = 0.0169). E) Comparison of MLR between patients with increased CIMT and normal CIMT in the CAPD group (MD: 0.09; 95% CI: –0.05 to 0.19; p = 0.1877). F) ROC curve of MLR for distinguishing increased CIMT from normal CIMT in CAPD patients (AUC: 0.6451; 95% CI: 0.4262–0.8639; p = 0.1823).

Assessment of MLR differences between CAPD and hemodialysis in CKD patients

The median MLR was 0.34 (IQR 0.18) in CAPD patients and 0.36 (IQR 0.18) in hemodialysis patients. Normality testing confirmed non-normal distribution; thus, the Mann-Whitney test was applied. There was no significant difference in MLR between CAPD and hemodialysis groups (MD: -0.02; 95% CI: -0.05 to 0.06; p = 0.9469). Further details are shown in Table 2.

Assessment of CIMT differences between CAPD and hemodialysis in CKD patients

The median CIMT was 0.05 cm (IQR 0.02) in CAPD patients and 0.07 cm (IQR 0.03) in hemodialysis patients. Normality tests indicated non-normal distribution; therefore,

the Mann-Whitney test was used for comparison. CIMT values were significantly higher in the hemodialysis group compared to CAPD (MD: -0.02; 95% CI: -0.02 to 0.00; p = 0.0035) (Figure 1B). Full statistical results are detailed in Table 2.

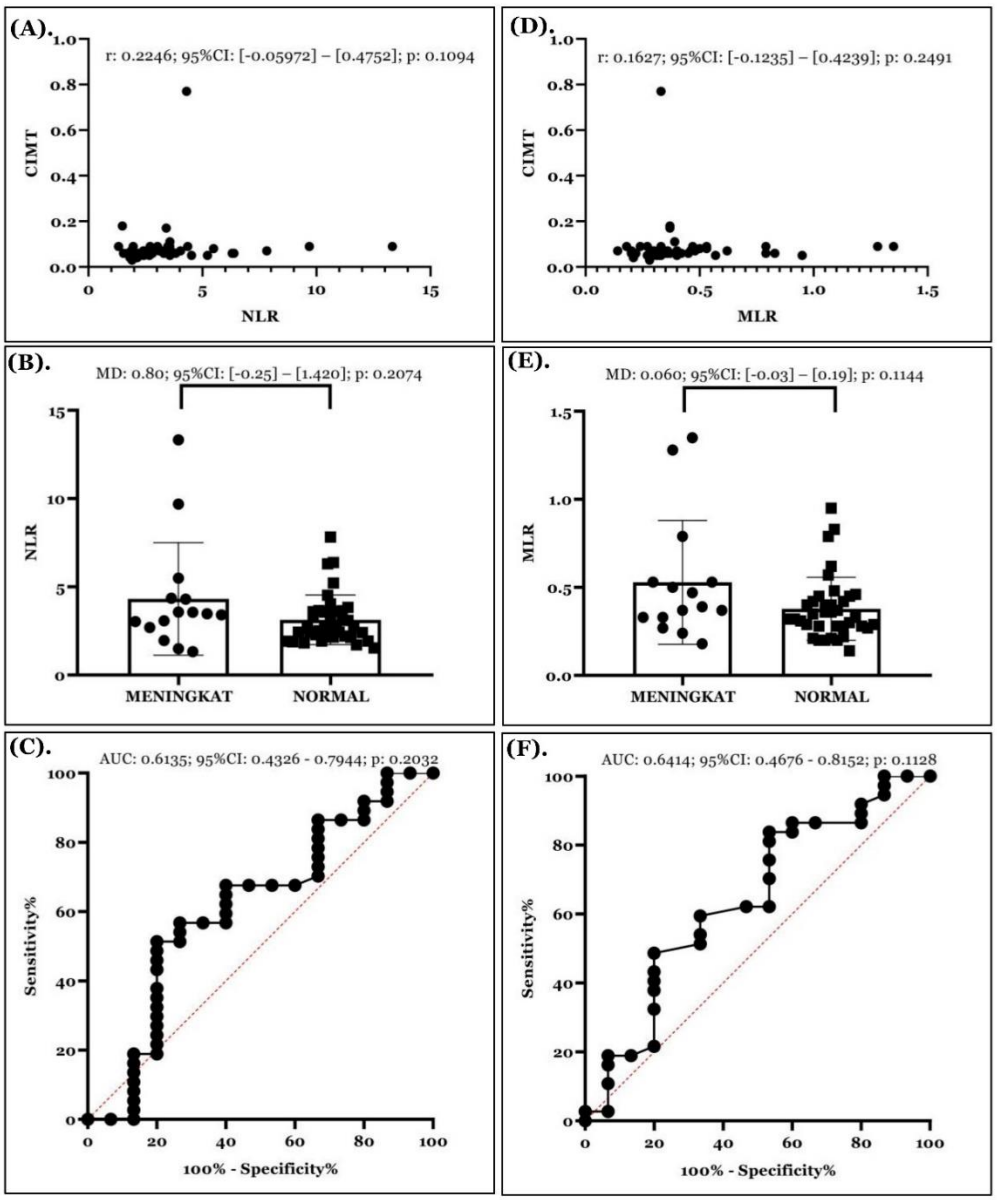

Figure 3. A) Correlation between NLR and CIMT in CKD patients undergoing hemodialysis (r = 0.2246; 95% CI: –0.05972 to 0.4752; p = 0.1094). B) Comparison of NLR between patients with increased CIMT and normal CIMT in the hemodialysis group (MD: 0.80; 95% CI: –0.25 to 1.42; p = 0.2074). C) ROC curve of NLR for distinguishing increased CIMT from normal CIMT in hemodialysis patients (AUC: 0.6135; 95% CI: 0.4326–0.7944; p = 0.2032). D) Correlation between MLR and CIMT in CKD patients undergoing hemodialysis (r = 0.1627; 95% CI: –0.1235 to 0.4239; p = 0.2491). E) Comparison of MLR between patients with increased CIMT and normal CIMT in the hemodialysis group (MD: 0.06; 95% CI: –0.03 to 0.19; p = 0.1144). F) ROC curve of MLR for distinguishing increased CIMT from normal CIMT in hemodialysis patients (AUC: 0.6414; 95% CI: 0.4676–0.8152; p = 0.1128).

NLR and MLR differences and correlations by CIMT status in CAPD patients

In the CAPD group, median NLR and CIMT were 3.68 (IQR 2.05) and 0.05 cm (IQR 0.02), respectively. Both variables were non-normally distributed. Spearman correlation revealed no significant correlation between NLR and CIMT (r = 0.1708; 95%

CI: -0.1380 to 0.4493; p = 0.2620) (Figure 2A). Subgroup analysis showed no significant difference in NLR between CAPD patients with increased CIMT and those with normal CIMT (MD: 0.35; 95% CI: -1.14 to 1.84; p = 0.6371) (Figure 2B). ROC analysis indicated poor discriminatory ability of NLR for CIMT status in CAPD patients (AUC = 0.537; 95% CI: 0.3312–0.7429; p = 0.7335) (Figure 2C). Consequently, Youden index calculation was not performed.

Median MLR in CAPD patients was 0.34 (IQR 0.18), with CIMT median 0.05 cm (IQR 0.02). Both variables were non-normally distributed. Spearman correlation analysis revealed a significant positive correlation between MLR and CIMT (r = 0.3543; 95% CI: 0.059–0.593; p = 0.0169) (Figure 2D). Subgroup comparison showed no significant difference in MLR between patients with increased and normal CIMT (MD: 0.09; 95% CI: -0.05 to 0.19; p = 0.1877) (Figure 2E). ROC analysis showed moderate discriminatory ability of MLR for CIMT status (AUC = 0.645; 95% CI: 0.4262–0.8639; p = 0.1823) (Figure 2F), but Youden index was not calculated.

NLR and MLR in relation to CIMT status in hemodialysis patients with CKD

In the hemodialysis group, median NLR and CIMT were 3.05 (IQR 1.45) and 0.07 cm (IQR 0.03), respectively. Both variables were non-normally distributed. Spearman correlation showed no significant association between NLR and CIMT (r = 0.2246; 95% CI: -0.0597 to 0.4752; p = 0.1094) (Figure 3A). Subgroup analysis revealed no significant difference in NLR between increased and normal CIMT groups (MD: 0.80; 95% CI: -0.25 to 1.42; p = 0.2074) (Figure 3B). ROC analysis did not demonstrate significant discriminatory ability (AUC = 0.6135; 95% CI: 0.4326–0.7944; p = 0.2032) (Figure 3C). Youden index calculation was not performed.

Median MLR in hemodialysis patients was 0.36 (IQR 0.18), with CIMT median 0.07 cm (IQR 0.03). Both variables were non-normally distributed. Spearman correlation showed no significant association between MLR and CIMT (r = 0.1627; 95% CI: -0.1235 to 0.4239; p = 0.2491) (Figure 3D). No significant difference in MLR was found between increased and normal CIMT subgroups (MD: 0.06; 95% CI: -0.03 to 0.19; p = 0.1144) (Figure 3E). ROC analysis also showed no significant difference (AUC = 0.6414; 95% CI: 0.4676–0.8152; p = 0.1128) (Figure 3F). Therefore, Youden index was not calculated.

DISCUSSION

In this study, no significant difference in MLR was found between patients undergoing hemodialysis and those on CAPD. Hematological parameters such as MLR are influenced by various factors, including age, sex, ethnicity, diet, environment, altitude of residence, timing of sample collection, and measurement methods. Variations in these factors across populations may lead to differences in reference values for inflammatory markers.[14] Several studies report that sex, smoking habits, hypertension, diabetes, BMI, hemoglobin, urea, creatinine, bicarbonate, calcium, phosphorus, parathyroid hormone, and ferritin do not significantly correlate with MLR.[15,16] Conversely, age, dialysis duration, CRP, NT-proBNP, and leukocyte count show positive correlations with MLR.[17] The acute impact of hemodialysis on proinflammatory cytokine levels remains controversial, with mixed results reported regarding changes in IL-1, TNF-α, IL-6, and IL-18 levels.[18] Some studies indicate no change in plasma cytokine levels post-stimulation, while others suggest that hemodialysis can enhance proinflammatory cytokine transcription.[18,19] Furthermore, although hemodialysis is known to trigger a stronger acute inflammatory response than CAPD (evidenced by elevated hs-CRP levels), parallel decreases in lymphocyte counts in both groups may neutralize MLR values.[20] Another potential confounding

factor is the malnutrition-inflammation complex syndrome (MICS), commonly observed in both hemodialysis and CAPD patients.[21]

This study demonstrated that CKD patients undergoing CAPD have significantly higher NLR values compared to those receiving hemodialysis, with a MD of 0.63 (95% CI: 0.07–1.15; p = 0.0253). NLR is an established inflammatory marker and an important prognostic factor for various conditions including cardiovascular diseases, malignancies, and inflammatory bowel diseases. NLR correlates negatively with lymphocyte count, hemoglobin, and serum albumin, and positively with neutrophil count.[22] In this study, clinical history factors such as systemic infections or central catheter infections in hemodialysis patients that may influence NLR were not precisely known. Additionally, the duration and frequency of hemodialysis can affect NLR, considering the chronic inflammatory process induced by repeated contact with the dialysis machine, triggering bio-incompatibility mechanisms. Repeated blood contact with machine components activates immune cells such as monocytes, lymphocytes, and others, promoting immune complex release.[23] NLR is associated with CKD progression and endothelial dysfunction in these patients. Recent studies indicate that elevated NLR in CAPD patients correlates with increased mortality risk and CKD progression.[24,25] In this study, 46.67% of CAPD patients had NLR values exceeding 3.6, indicating vulnerability to chronic infection and inflammation. CAPD patients also tended to have lower hemoglobin and albumin levels, contributing to higher NLR values.

Our findings show no significant correlation between NLR or MLR and CIMT in the hemodialysis group. Confounding factors may affect the relationship between NLR, MLR, and CIMT in hemodialysis patients. Previous studies suggest that while NLR and MLR serve as inflammatory markers, their correlation with arterial wall thickening depends heavily on the specific pathological context of the underlying disease.[26,27] MLR may increase in other inflammatory conditions, but its role related to carotid artery thickness requires further clarification. Chronic inflammation can alter hematological responses linked to cardiovascular risk evaluation, complicating the relationship between inflammatory parameters like NLR and MLR with CIMT.[28] One possible explanation for the lack of independent association between NLR, MLR, and CIMT is the influence of hemodialysis duration, dialysis frequency, as well as lifestyle and environmental factors varying among patients.[29] Existing literature on NLR-CIMT relationships has also shown inconsistent results. The heterogeneity of components within the NLR ratio might affect its predictive validity, and independent associations between neutrophil count, lymphocyte count, and carotid atherosclerosis have not been established.

Conversely, in the CAPD group, NLR was not correlated with CIMT, whereas MLR showed a significant positive correlation with CIMT (r = 0.3543; 95% CI: 0.059–0.593; p = 0.0169). Differences in CIMT between groups may reflect distinct physiological mechanisms specific to each dialysis modality. CIMT and carotid plaque presence are positively associated with systemic inflammatory diseases and chronic inflammatory conditions, which increase cardiovascular risk. Elevated monocyte markers have also been strongly correlated with CIMT.[30] Proteomic analyses indicate that CIMT correlates mainly with proteins involved in chemotaxis rather than other inflammatory proteins.[31] Neutrophils and monocytes play crucial roles in interleukin-6 (IL-6) production during immune responses. Neutrophils, as first responders to infection or injury, rapidly produce IL-6 upon activation but have a short lifespan, limiting the duration of IL-6 production. In contrast, monocytes can produce IL-6 over a longer

period, especially as they differentiate into macrophages. IL-6 production by monocytes is influenced by other cytokines, growth factors, and the surrounding microenvironment. Macrophages derived from monocytes are key players in chronic inflammation and are major cellular components in atherosclerotic plaque formation.[32]

This study has several limitations. The cross-sectional design captures data at a single time point and cannot establish causal relationships between variables. Variability in CIMT measurement may affect accuracy due to operator skill and image analysis software dependency. Additionally, the study was conducted at a single center, Rumah Sakit dr. Saiful Anwar in Malang, during a specific period, limiting generalizability to other populations or settings.

CONCLUSION

This study demonstrated significant differences in NLR and CIMT between CKD patients undergoing CAPD and those receiving hemodialysis. CAPD patients exhibited higher NLR values, whereas hemodialysis patients showed greater CIMT measurements. Although MLR values did not differ significantly between the two groups, a positive correlation between MLR and CIMT was observed in CAPD patients, indicating that increased MLR is associated with carotid artery wall thickening. Conversely, no significant relationship was found between NLR or MLR and CIMT in hemodialysis patients. These findings suggest that the inflammatory mechanisms involved in these two dialysis modalities may differ, and that MLR could serve as a potential marker for assessing subclinical atherosclerosis, particularly in CAPD patients. Further longitudinal studies with larger populations are warranted to confirm the role of MLR as a vascular inflammatory biomarker in CKD patients.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The protocols of our study have been approved by local ethical committee.

CONFLICTS OF INTEREST

We have no conflict of interest

FUNDING SOURCES

We have no source of funding

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None

AUTHOR CONTRIBUTION

Conceptualization: FB, NS, ESW; Data Curation: FB, NS, ESW; Formal Analysis: FB, NS, ESW; Investigation: FB, NS, ESW; Project Administration: FB, NS, ESW; Resources: FB, NS, ESW; Methodology: FB, NS, ESW; Software: FB, NS, ESW; Visualization: FB, NS, ESW; Supervision: NS; Validation: NS; Writing – Original Draft Preparation: FB, NS, ESW; Writing – Review & Editing: NS All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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