INSIGHTS-JOURNAL OF
HEALTH AND REHABILITATION

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

CORRELATION OF CAROTID INTIMA-MEDIA THICKNESS WITH CLINICAL AND BIOCHEMICAL PARAMETERS IN HEMODIALYSIS PATIENTS: A CROSS-SECTIONAL STUDY

Original Research

Muhammad Sufian Pasha[1]*, Khalid Mehmood Raja[1], Ramisha Arif[1], Muhammad Sulaiman Pasha[1], Ayesha Arif[1], Umair Ahmed[2]
[1]Department of Nephrology, CMH Multan, Pakistan.
[2]Resident Nephrology, CMH Lahore, Pakistan.
Corresponding Author: Muhammad Sufian Pasha, Department of Nephrology, CMH Multan, Pakistan, sufian.pasha@hotmail.com
Acknowledgement: The authors acknowledge the support of the Nephrology Department, Combined Military Hospital, Multan.

Conflict of Interest: None
Grant Support & Financial Support: None

ABSTRACT

Background: Cardiovascular disease remains the leading cause of mortality in patients with end-stage renal disease (ESRD), and carotid intima-media thickness (CIMT) has emerged as a non-invasive surrogate marker for subclinical atherosclerosis. In patients undergoing hemodialysis, chronic inflammation, metabolic abnormalities, and traditional risk factors may accelerate vascular changes. Early identification of such vascular alterations can guide timely interventions to reduce cardiovascular morbidity and mortality in this high-risk group.

Objective: To evaluate carotid intima-media thickness in patients on maintenance hemodialysis and investigate its association with clinical and biochemical parameters.

Methods: This cross-sectional study was conducted over six months at the Department of Nephrology, Combined Military Hospital, Multan. A total of 145 adult patients with ESRD undergoing hemodialysis for at least three months were enrolled. Patients with acute infections, inflammatory conditions, recent carotid surgery, or incomplete data were excluded. Demographic, clinical, and biochemical data were collected through structured questionnaires and laboratory assessments. CIMT was measured bilaterally at three predefined carotid artery sites using a GE Voluson E6 ultrasound machine. Data analysis was performed using SPSS version 20, with significance set at $p < 0.05$.

Results: Participants had a mean age of 46.3 ± 12.4 years, with 58.6% males. Hypertension (81.3%), lipid disorders (90.3%), and diabetes mellitus (52.4%) were prevalent. Elevated serum creatinine (6.8 ± 2.1 mg/dL), triglycerides (158 ± 82 mg/dL), and homocysteine (39.5 ± 28.4 µmol/L) were observed. Mean CIMT was 0.80 ± 0.15 mm (right) and 0.79 ± 0.14 mm (left), with increased CIMT (≥0.8 mm) seen in 72.4% and 69.0% of patients, respectively. CIMT was significantly correlated with age, CKD duration, dialysis time, hypertension, diabetes, lipid levels, creatinine, triglycerides, and homocysteine.

Conclusion: There is a high burden of subclinical atherosclerosis among hemodialysis patients, as indicated by increased CIMT and its strong associations with modifiable and disease-specific risk factors. Addressing hypertension, diabetes, and dyslipidemia may be critical to reducing cardiovascular complications in this population.

Keywords: Atherosclerosis, Carotid Intima-Media Thickness, Chronic Kidney Disease, Hemodialysis, Risk Factors, Ultrasonography, Vascular Stiffness.

INTRODUCTION

Chronic kidney disease (CKD) remains a pressing global health concern, affecting approximately 10%–15% of the population worldwide and contributing substantially to morbidity and premature mortality (1). In Pakistan, the burden is even more pronounced, with an estimated 20 million individuals—roughly 12%–15% of the population—living with CKD (2). This high prevalence is largely driven by the increasing incidence of diabetes mellitus and hypertension, affecting 26.7% and 40% of the adult population respectively, along with factors such as late-stage diagnosis and inadequate access to healthcare services (3). As CKD progresses to end-stage renal disease (ESRD), hemodialysis becomes the principal mode of treatment. While life-sustaining, hemodialysis is often accompanied by significant cardiovascular complications, which remain the leading cause of death in this patient population, accounting for nearly 50% of all-cause mortality (4). Notably, patients with CKD are 10–20 times more likely to die from cardiovascular disease (CVD) than from the progression to ESRD itself (4,5). Among the many methods used to assess cardiovascular risk, carotid intima-media thickness (CIMT) has emerged as a valuable, non-invasive indicator of subclinical atherosclerosis and arterial stiffness. Multiple studies have demonstrated that CIMT values are significantly elevated in CKD patients when compared to healthy individuals, with some reporting increases of 30%–50%, reflecting accelerated vascular aging and arterial rigidity (6,7).

The pathophysiological mechanisms underlying increased CIMT in CKD are complex and multifactorial. Uremia-induced systemic inflammation and oxidative stress have been identified as central contributors to endothelial injury and vascular remodeling (8). Mineral and bone disorders, commonly seen in CKD, further exacerbate vascular pathology through imbalances in calcium, phosphate, and parathyroid hormone levels—key drivers of arterial calcification and reduced vascular compliance (9). Moreover, the hemodialysis process itself imposes recurrent hemodynamic stress, perpetuating a cycle of inflammation, endothelial dysfunction, and oxidative damage, all of which may accelerate vascular changes (10). Biochemical markers such as elevated serum phosphate, parathyroid hormone (PTH), and C-reactive protein (CRP) have been consistently linked with increased CIMT in CKD populations. Clinical factors including the duration of dialysis, presence of diabetes, and hypertension also demonstrate significant associations with vascular thickening and stiffness (11). Despite growing recognition of these associations, there remains a need to deepen understanding of how biochemical and clinical parameters interact to influence vascular health in hemodialysis patients. Given the high cardiovascular risk burden among individuals receiving hemodialysis, and the prognostic potential of CIMT as a marker of subclinical vascular disease, it becomes imperative to explore these relationships more thoroughly. Therefore, the present study aims to evaluate carotid intima-media thickness in patients undergoing maintenance hemodialysis and to investigate its correlation with selected biochemical and clinical indicators.

METHODS

A cross-sectional study was conducted over a period of six months at the Department of Nephrology, Combined Military Hospital (CMH) Multan, to assess carotid intima-media thickness (CIMT) and its association with clinical and biochemical parameters among patients undergoing maintenance hemodialysis for end-stage renal disease (ESRD). The target population comprised adult ESRD patients receiving routine hemodialysis at the facility. Participation in the study was voluntary, and only patients who provided written informed consent were included, ensuring adherence to ethical standards. The study protocol was reviewed and approved by the institutional research and ethical committee. Participants were selected through non-probability consecutive sampling. Inclusion criteria required patients to be 18 years or older, diagnosed with ESRD, and undergoing regular hemodialysis for a minimum of three months. To maintain data quality and avoid confounding, individuals were excluded if they had active infections, recent inflammatory conditions, malignancies, a history of carotid artery surgery, or significant carotid stenosis. Pregnant women and patients with incomplete clinical or biochemical data were also excluded. The sample size was calculated using an online sample size calculator, based on a reported CKD prevalence of 10.5% among Pakistani adults, applying a 95% confidence interval ($Z = 1.96$) and a 5% margin of error. This resulted in a minimum sample size requirement of 145 patients (12). Demographic and clinical information, including age, sex, residential location, dialysis center, smoking status, and history of comorbidities such as hypertension, diabetes, and cardiovascular diseases, was collected using a structured questionnaire administered by trained personnel. Prior to the initiation of dialysis sessions, fasting blood samples were obtained by qualified healthcare staff. These samples were analyzed in a standardized hospital laboratory setting for

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

biochemical markers, including serum calcium, phosphate, magnesium, parathyroid hormone (PTH), vitamin D3, total cholesterol, triglycerides, creatinine, blood urea nitrogen (BUN), and albumin levels. All biochemical assays were conducted using calibrated equipment under uniform procedural protocols to ensure precision and inter-sample consistency.

Following the laboratory assessments, participants were referred to the hospital's radiology department for CIMT evaluation. Each patient was asked to rest quietly for 15 minutes to minimize stress-induced hemodynamic variability. They were then positioned supine with the head gently extended and turned contralaterally. A single experienced radiologist performed all CIMT measurements using a GE Voluson E6 ultrasound system equipped with a 12 MHz high-resolution linear array transducer. The bilateral carotid arteries were scanned at three predefined anatomical sites: 1.5 cm distal to the bifurcation of the common carotid artery, the carotid bifurcation, and the proximal internal carotid artery. Areas with visible plaques were avoided to ensure measurement validity. For each side, three readings were taken, and the average was computed; the higher of the two side-specific averages was used for further statistical analysis. Statistical analysis was carried out using SPSS software version 20. Quantitative data were expressed as mean ± standard deviation. Independent samples t-tests were applied to compare mean CIMT values across binary categorical variables, whereas one-way analysis of variance (ANOVA) was employed for comparisons among groups with more than two categories. Bivariate correlation analyses assessed associations between CIMT and continuous variables. Additionally, a univariate general linear model (GLM) was used to evaluate the combined effects of both categorical and continuous variables on CIMT, allowing for interaction analysis. A significance threshold of $p < 0.05$ was applied, and findings were presented using appropriate tables and graphical formats to facilitate interpretation.

RESULTS

The study included 145 patients with end-stage renal disease undergoing hemodialysis. The mean duration of CKD among participants was 4.8 ± 2.0 years, and 34.5% had been on dialysis for over 12 months. The sample showed a predominance of middle-aged (31.0%) and older adults (34.5%), with males comprising 58.6% of the population. Urban residents accounted for 65.5%. The majority of patients had a normal BMI (55.2%), while 34.4% were classified as overweight or obese. Active smoking was reported in 24.1% of cases. Common comorbidities included hypertension (81.3%), lipid disorders (90.3%), diabetes mellitus (52.4%), coronary artery disease (19.3%), and hyperuricemia (42.8%). The biochemical analysis revealed notable abnormalities. Mean hemoglobin was 10.9 ± 1.5 g/dL, indicating anemia across the sample. Serum creatinine was markedly elevated at 6.8 ± 2.1 mg/dL. Hyperphosphatemia was present, with a mean phosphorus level of 5.2 ± 1.4 mg/dL. Lipid profiling showed elevated triglycerides (158 ± 82 mg/dL), while HDL was within normal limits (86 ± 24 mg/dL). Vitamin D deficiency was observed, with mean levels of 38 ± 14 nmol/L. Inflammatory markers such as CRP (10.2 ± 14.3 mg/L) and fibrinogen (290 ± 78 mg/dL) were elevated, indicating a pro-inflammatory state. Parathyroid hormone was also significantly raised (24.7 ± 35.3 pmol/L), suggestive of secondary hyperparathyroidism.

Carotid intima-media thickness measurements showed mean values of 0.80 ± 0.15 mm on the right and 0.79 ± 0.14 mm on the left, both within the reference range (0.6–1.0 mm). The carotid bifurcation consistently exhibited the highest CIMT readings bilaterally. Increased CIMT (≥0.8 mm) was detected in 72.4% of patients on the right side and 69.0% on the left, demonstrating a high prevalence of subclinical atherosclerosis. Correlation analysis revealed that CIMT was strongly and positively associated with age ($r = 0.62$, $p < 0.001$), duration of CKD ($r = 0.55$, $p < 0.001$), and time on dialysis ($r = 0.50$, $p < 0.001$). Among clinical conditions, hypertension ($r = 0.42$, $p < 0.001$), diabetes ($r = 0.38$, $p < 0.001$), lipid disorders ($r = 0.47$, $p < 0.001$), and coronary artery disease ($r = 0.40$, $p < 0.001$) all showed significant positive associations with CIMT. Biochemical markers such as serum creatinine ($r = 0.50$, $p < 0.001$), triglycerides ($r = 0.48$, $p < 0.001$), homocysteine ($r = 0.55$, $p < 0.001$), CRP ($r = 0.50$, $p < 0.001$), and fibrinogen ($r = 0.45$, $p < 0.001$) demonstrated strong correlations with CIMT. In contrast, hemoglobin ($r = -0.25$, $p = 0.015$), HDL ($r = -0.22$, $p = 0.020$), and vitamin D ($r = -0.30$, $p = 0.004$) were inversely associated with CIMT, suggesting protective roles.

Table 1: Demographic and clinical characteristics of the study sample (n=145)

Variable	n (%) / Mean ± SD
Age Distribution (years)	
Young Adults (18–30)	25 (17.2)
Middle-Aged (31–45)	45 (31.0)
Older Adults (46–60)	50 (34.5)
Seniors (>60)	25 (17.2)

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

Variable	n (%) / Mean ± SD
Gender	
Male	85 (58.6)
Female	60 (41.4)
Residential Area	
Urban Residents	95 (65.5)
Rural Residents	50 (34.5)
CKD Duration (years)	4.8 ± 2.0
Time on Dialysis (months)	
<6 Months	40 (27.6)
6–12 Months	55 (37.9)
>12 Months	50 (34.5)
Body Mass Index (BMI)	
Low Weight (<18.5 kg/m²)	15 (10.3)
Normal Range (18.5–24.9 kg/m²)	80 (55.2)
Elevated BMI (25–29.9 kg/m²)	35 (24.1)
Obese (≥30 kg/m²)	15 (10.3)
Smoking Habits	
Active Smokers	35 (24.1)
Non-Smokers	110 (75.9)
Health Conditions	
Hypertensive	61 (81.3)
Diabetic Patients	38 (52.4)
Lipid Disorders	66 (90.3)
Increased Uric Acid	31 (42.8)
Heart Disease	9 (12.4)
Coronary Artery Disease	28 (19.3)

Table 2: Biochemical Parameters of the Study Participants (n=145)

Biochemical Parameter	Mean ± SD (Reference Range)
Hemoglobin (g/dL)	10.9 ± 1.5 (Female: 12.0–15.8, Male: 13.3–16.2)
Serum Creatinine (mg/dL)	6.8 ± 2.1 (0.8–1.2)
Serum Calcium (mg/dL)	9.2 ± 0.8 (8.5–10.0)
Serum Phosphorus (mg/dL)	5.2 ± 1.4 (3.5–5.5)
Triglyceride Level (mg/dL)	158 ± 82 (<150)
Total Cholesterol (mg/dL)	140 ± 30 (<200)
High-Density Lipoprotein (HDL) (mg/dL)	86 ± 24 (>40)
Low-Density Lipoprotein (LDL) (mg/dL)	28 ± 10 (<130)
Parathyroid Hormone (pmol/L)	24.7 ± 35.3 (0.8–3.9)
Serum Albumin (g/dL)	4.0 ± 0.6 (3.5–5.5)
Uric Acid (mg/dL)	5.8 ± 1.0 (Female: 2.5–6.0, Male: 3.1–7.5)
Homocysteine Level (µmol/L)	39.5 ± 28.4 (0–50)
C-Reactive Protein (CRP) (mg/L)	10.2 ± 14.3 (<5)
Fibrinogen Concentration (mg/dL)	290 ± 78 (50–400)
Vitamin D Levels (nmol/L)	38 ± 14 (50–125)

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

Table 3: Correlation of mean CIMT with demographic, clinical and biochemical characteristics of the study sample

Variable	Descriptive Statistics	Pearson Correlation Coefficient (r)	95% CI	p-value
Demographic Characteristics				
Age (years)	46.3 ± 12.4	0.62	0.49 to 0.72	<0.001
Gender (Male %)	58.6% Male	0.18	0.02 to 0.34	0.045
Residential Area (Urban %)	65.5% Urban	0.10	-0.06 to 0.26	0.210
Clinical Characteristics				
CKD Duration (years)	4.8 ± 2.0	0.55	0.42 to 0.66	<0.001
Time on Dialysis (months)	9.5 ± 4.2	0.50	0.36 to 0.62	<0.001
BMI (kg/m²)	24.3 ± 3.8	0.30	0.14 to 0.45	0.002
Smoking Habits (Active %)	24.1% Active Smokers	0.28	0.12 to 0.43	0.010
Hypertension (Yes %)	81.3%	0.42	0.27 to 0.56	<0.001
Diabetes Mellitus (Yes %)	52.4%	0.38	0.22 to 0.52	<0.001
Lipid Disorders (Yes %)	90.3%	0.47	0.33 to 0.60	<0.001
Increased Uric Acid (Yes %)	42.8%	0.35	0.19 to 0.50	0.005
Coronary Artery Disease (Yes %)	19.3%	0.40	0.24 to 0.54	<0.001
Biochemical Parameters				
Hemoglobin (g/dL)	10.9 ± 1.5	-0.25	-0.40 to -0.09	0.015
Serum Creatinine (mg/dL)	6.8 ± 2.1	0.50	0.36 to 0.62	<0.001
Serum Calcium (mg/dL)	9.2 ± 0.8	-0.18	-0.34 to -0.02	0.050
Serum Phosphorus (mg/dL)	5.2 ± 1.4	0.33	0.17 to 0.48	0.008
Triglyceride Level (mg/dL)	158 ± 82	0.48	0.34 to 0.61	<0.001
Total Cholesterol (mg/dL)	140 ± 30	0.40	0.24 to 0.54	<0.001
HDL (mg/dL)	86 ± 24	-0.22	-0.37 to -0.06	0.020
LDL (mg/dL)	28 ± 10	0.35	0.19 to 0.50	0.005
Parathyroid Hormone (pmol/L)	24.7 ± 35.3	0.25	0.09 to 0.40	0.012
Serum Albumin (g/dL)	4.0 ± 0.6	-0.15	-0.30 to 0.01	0.090
Uric Acid (mg/dL)	5.8 ± 1.0	0.30	0.14 to 0.45	0.003
Homocysteine Level (µmol/L)	39.5 ± 28.4	0.55	0.42 to 0.66	<0.001
C-Reactive Protein (CRP) (mg/L)	10.2 ± 14.3	0.50	0.36 to 0.62	<0.001
Fibrinogen Concentration (mg/dL)	290 ± 78	0.45	0.30 to 0.58	<0.001
Vitamin D Levels (nmol/L)	38 ± 14	-0.30	-0.45 to -0.14	0.004

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

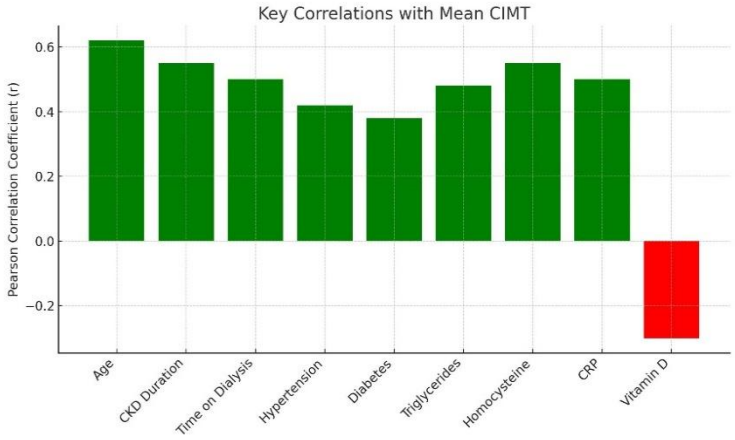

Figure 1 Key Correlations with Mean CIMT

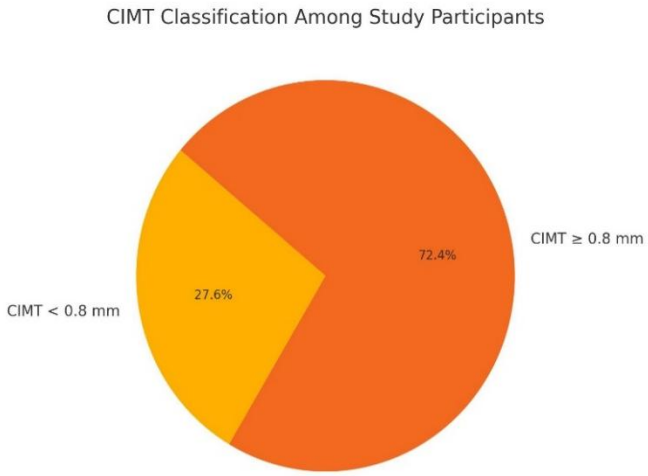

Figure 2 CIMT Classification Among Study Participants

DISCUSSION

The present study aimed to evaluate carotid intima-media thickness (CIMT) in patients undergoing maintenance hemodialysis and to explore its association with key clinical and biochemical variables. The findings demonstrated elevated CIMT values in a majority of participants, with increased CIMT (≥0.8 mm) present in over 70% of the cohort on both sides. These results are in line with prior evidence indicating an elevated burden of subclinical atherosclerosis and cardiovascular risk among individuals with chronic kidney disease (CKD) undergoing dialysis (13,14). The observed mean CIMT values also fell within the upper range of what is considered normal, reflecting underlying vascular remodeling and accelerated arterial aging in this population. Age showed a strong and statistically significant correlation with CIMT, affirming the role of vascular aging in the pathogenesis of atherosclerosis in CKD. Similar associations were found with CKD duration and dialysis vintage, supporting the cumulative vascular stress hypothesis and the role of prolonged hemodynamic alterations, chronic inflammation, and oxidative stress in driving arterial wall changes over time (15-17). Clinical comorbidities including hypertension, diabetes mellitus, and dyslipidemia were also significantly associated with increased CIMT, consistent with their well-established roles in promoting endothelial dysfunction, vascular stiffness, and atherogenesis in CKD patients (18,19). The positive associations between biochemical markers such as serum creatinine, triglycerides, homocysteine, and CIMT further reinforced the interplay between metabolic dysregulation and vascular pathology. Notably, homocysteine showed a strong correlation with CIMT, which is consistent with its known role as a mediator of endothelial injury and vascular inflammation in renal disease populations (20,21). In contrast, inverse correlations were observed between CIMT and serum hemoglobin as well as vitamin D levels, indicating potential protective effects of anemia correction and vitamin D sufficiency on vascular health (20,22). Although serum albumin exhibited a weak negative correlation with CIMT, the lack of statistical significance may reflect the relatively stable nutritional status of the study participants, evidenced by a normal mean BMI, suggesting that inflammation rather than malnutrition may be the predominant contributor to vascular alterations in this cohort.

The study adds valuable insight into the burden of vascular changes among Pakistani hemodialysis patients and highlights the utility of CIMT as a non-invasive surrogate marker for cardiovascular risk stratification in routine nephrology practice. One of the strengths of the study lies in the inclusion of a comprehensive panel of both clinical and biochemical parameters, along with standardized CIMT measurement protocols performed by a single experienced radiologist, which helped minimize measurement variability. However, several limitations merit consideration. The cross-sectional design precludes any inference of causality between risk factors and increased CIMT. The relatively modest sample size may have limited the statistical power to detect associations with weaker variables such as smoking and residence. Additionally, potential confounders such as physical activity, dietary intake, medication use, and dialysis adequacy were not captured, which could have influenced vascular outcomes. The study also did not perform multivariate regression analysis, which might have helped identify independent predictors of CIMT by controlling for interrelated variables. Despite these

INSIGHTS-JHR
INSIGHTS-JOURNAL OF HEALTH AND REHABILITATION

limitations, the findings underscore the high prevalence of subclinical atherosclerosis in hemodialysis patients and the importance of early identification of at-risk individuals through routine vascular screening. Future longitudinal studies with larger cohorts and more comprehensive data collection, including cardiovascular outcomes and therapeutic interventions, are warranted to establish predictive models and evaluate the impact of targeted interventions on vascular health in this vulnerable population.

CONCLUSION

The study concluded that carotid intima-media thickness (CIMT) is significantly associated with a range of clinical, biochemical, and demographic factors in patients undergoing maintenance hemodialysis. The observed correlations highlight the contribution of both traditional cardiovascular risk factors and CKD-specific metabolic disturbances to vascular changes in this population. The inverse relationships with hemoglobin and vitamin D levels further underscore the role of systemic inflammation, anemia, and nutritional deficiencies in vascular health. These findings reinforce the need for early identification and management of modifiable risk factors to mitigate cardiovascular complications and improve long-term outcomes in individuals receiving hemodialysis.

AUTHOR CONTRIBUTION

Author	Contribution
Muhammad Sufian Pasha*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Khalid Mehmood Raja	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Ramisha Arif	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Muhammad Sulaiman Pasha	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Ayesha Arif	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Umair Ahmed	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

REFERENCES

1. Kovesdy CP. Epidemiology of chronic kidney disease: an update 2022. Kidney international supplements. 2022 Apr 1;12(1):7-11.
2. Khan A, Cheema MF, Fatima R, Cheema SS, Butt Z, Gillani S, Ahmad A, Ullah MS, Jalal U, Cheema S. Prevalence of chronic kidney disease in a high-risk population in urban Lahore, Pakistan: a cross-sectional study. Cureus. 2024 Jun 27;16(6): e63296.
3. Ahmed J, Azhar S, ul Haq N, Hussain S, Stájer A, Urbán E, Gajdács M, Jamshed S. Awareness of chronic kidney disease, medication, and laboratory investigation among nephrology and urology patients of Quetta, Pakistan. International journal of environmental research and public health. 2022 Apr 20;19(9):5015.
4. Zoccali C, Mallamaci F, Adamczak M, de Oliveira RB, Massy ZA, Sarafidis P, Agarwal R, Mark PB, Kotanko P, Ferro CJ, Wanner C. Cardiovascular complications in chronic kidney disease: a review from the European Renal and Cardiovascular Medicine Working Group of the European Renal Association. Cardiovascular research. 2023 Aug;119(11):2017-32.
5. Wanyu K, Guangfeng G, Hua G. The effect of bone mineral metabolism disorder on cardiovascular events in uremia patients. Frontiers in Medical Science Research. 2023 Mar 10;5(3).
6. Fujii H. Is Oxidative Stress a Key Player for Progression of Cardiovascular Disease in Dialysis Patients? Journal of atherosclerosis and thrombosis. 2021 Mar 1;28(3):227-9.

7. Wang XR, Yuan L, Shi R, Li H, Wang DG, Wu YG. Predictors of coronary artery calcification and its association with cardiovascular events in patients with chronic kidney disease. Renal Failure. 2021 Jan 1;43(1):1172-9.
8. Naem M, Karem K, William V, Ghareeb M. Carotid Intima-Media Thickness as a Cardiovascular Risk Factor in Patients with Chronic Kidney Disease. QJM: An International Journal of Medicine. 2024 Jun 1;117(Supplement_1): hcae070-119.
9. Torres-Machorro A, Anaya-Ayala JE, Lopez-Mendez A, Martinez-Quesada JI, García-Alva JR, Cuen-Ojeda C, Lozano-Corona R, Luna L, Hinojosa CA. Multi-perspective ultrasound evaluation of Carotid Intima-Media thickness in hemodialysis access patients and its possible use to predict clinical outcomes. Vascular. 2024 May 31:17085381241258554.
10. Azouaou LT, Adnane M, Khelfi A, Ballouti W, Arab M, Toualbi C, Chader H, Tahae R, Seba A. Oxidative stress accelerates the carotid atherosclerosis process in patients with chronic kidney disease. Archives of Medical Science-Atherosclerotic Diseases. 2020 Sep 14;5(1):245-54.
11. Moosazadeh M, Ebrahimnejad P, Sohrab M, Rafiei A, Abastabar M, Khazaee-Pool M, Mahboubi S, Kheradmand M. Undiagnosed hypertension and diabetes mellitus in the Tabari cohort: a population-based study. BMC Public Health. 2024 Nov 18;24(1):3199.
12. Pan Q, Gao S, Gao X, Yang N, Yao Z, Hu Y, Miao L, Chen Z, Wang G. Relation of kidney function and homocysteine in patients with hypothyroidism. Endocrine Connections. 2021 May 1;10(5):502-10.
13. Wong SW, Rojas-Canales D, Tucker E, Mcnicholas K, Mehdron AS, Gleadle J. MICRORNA ANALYSIS OF GROWING KIDNEYS. InNephrology 2022 Oct 1 (Vol. 27, pp. 68-68). 111 RIVER ST, HOBOKEN 07030-5774, NJ USA: WILEY.
14. Kanda E. Protein Energy Wasting in Chronic Kidney Disease. Recent Advances of Sarcopenia and Frailty in CKD. 2020:35-55.
15. Huang Z, Fang J, Song A, Tong Y, Deng H, Wei S, Ji O, Hu C, Li P, Zhang C, Liu Y. The association between self-management ability and malnutrition-inflammation-atherosclerosis syndrome in peritoneal dialysis patients: a cross-sectional study. BMC nephrology. 2021 Dec; 22:1-9.
16. Hagemann R, Watanabe MT, Hueb JC, Martín LC, Silva VDS, Caramori J. Assessment of atherosclerosis and endothelial dysfunction risk factors in patients with primary glomerulonephritis. J Bras Nefrol. 2024;46(1):29-38.
17. Dragoș D, Timofte D, Georgescu MT, Manea MM, Vacaroiu IA, Ionescu D, et al. Cardiovascular Calcifications Are Correlated with Inflammation in Hemodialysis Patients. Medicina (Kaunas). 2023;59(10).
18. Zafar Mohtashami A, Hadian B, Heidarian M, Khalili P. Carotid Intima-media Thickness in Hemodialysis Patients and Related Biochemical and Clinical Factors. Iran J Kidney Dis. 2023;1(1):28-36.
19. Bolignano D, Greco M, Arcidiacono V, Presta P, Caglioti A, Andreucci M, et al. Circulating Omentin-1, Sustained Inflammation and Hyperphosphatemia at the Interface of Subclinical Atherosclerosis in Chronic Kidney Disease Patients on Chronic Renal Replacement Therapy. Medicina (Kaunas). 2022;58(7).
20. Moustafa B, Zekry H, Hashim RH, Salah DM, Abdelfattah AA, Sobhy R. Echocardiographic findings in children with chronic kidney disease. Saudi J Kidney Dis Transpl. 2020;31(6):1234-44.
21. Kara AV, Ozdemir R, Inan H, Ozdemir BO, Hayme S, Cosgun MS. Effect of serum magnesium level on carotid intima media thickness in hemodialysis patients. BMC Nephrol. 2025;26(1):270.
22. Karaer Büberci R, Öztekin PS, Duranay M. The relationship between apelin and carotid intima media thickness, and the presence of plaque in dialysis patients. Semin Dial. 2022;35(4):337-42.

