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Inflammatory and Oxidative Stress Biomarkers as Predictors of CKD Progression

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Abstract: A serious global health concern, chronic kidney disease (CKD) is a degenerative condition marked by a slow decrease of renal function. There is growing evidence that oxidative stress and chronic inflammation are important factors in the development and course of chronic kidney disease (CKD). Patients at increased risk of illness development and unfavourable outcomes may be identified with the use of biomarkers that reflect these processes.To assess the predictive power of oxidative stress and inflammatory biomarkers for the advancement of chronic kidney disease.From January 2025 to January 2026, a prospective observational study was carried out at the Mayo Hospital Lahore's Department of Nephrology. Consecutive sampling was used to register 180 patients with CKD stages 2-4. Demographic information, estimated glomerular filtration rate (eGFR), urinary albumin-to-creatinine ratio (UACR), and measurements of oxidative stress biomarkers like malondialdehyde (MDA) and total antioxidant capacity (TAC), as well as inflammatory biomarkers like C-reactive protein (CRP), interleukin-6 (IL-6), and tumour necrosis factor-alpha (TNF-α). Patients were monitored for the development of end-stage kidney disease (ESKD), a ≥30% reduction in eGFR, or the start of renal replacement therapy. SPSS version 26 was used to analyse the data.During follow-up, 58 (32.2%) of the 180 patients had CKD progression. In comparison to stable individuals, patients with illness progression showed significantly lower TAC levels and higher levels of CRP, IL-6, TNF-α, and MDA ($p < 0.001$). The progression of CKD was found to be independently predicted by elevated levels of MDA and IL-6. Individuals with inflammatory biomarker levels in the top quartile had a markedly faster drop in eGFR and a higher chance of developing advanced chronic kidney disease.Biomarkers for oxidative stress and inflammation are closely linked to the advancement of chronic kidney disease (CKD) and could be useful for early risk assessment.

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Keeping an eye on these biomarkers may help with prompt intervention and enhance long-term kidney results.

Keywords: progression of chronic kidney disease, inflammation, oxidative stress, biomarkers, CRP, IL-6, TNF-α, and malondialdehyde

Introduction

Millions of people worldwide suffer from chronic kidney disease (CKD), a developing public health issue that is linked to significant morbidity, death, and medical expenses. The hallmark of chronic kidney disease (CKD) is a gradual decline in renal function over time, which eventually results in end-stage kidney disease (ESKD), cardiovascular problems, and early death. Over the past 20 years, there has been a notable increase in the prevalence of chronic kidney disease (CKD) worldwide, primarily as a result of ageing populations, diabetes mellitus, hypertension, and obesity.Traditionally, clinical indicators including proteinuria and estimated glomerular filtration rate (eGFR) have been used to gauge the course of CKD. Even while these indicators are still crucial for diagnosis and staging, they frequently miss existing disease processes before significant kidney damage has taken place. Finding new biomarkers that might forecast the course of a disease at an earlier stage is therefore of increasing importance.A growing body of research indicates that oxidative stress and chronic inflammation are important factors propelling the development of chronic kidney disease. While oxidative stress intensifies cellular damage by producing reactive oxygen species (ROS), persistent inflammatory activation leads to endothelial dysfunction, fibrosis, glomerulosclerosis, and tubular injury. When combined, these pathways hasten the deterioration of renal function and raise the risk of cardiovascular disease, which continues to be the primary cause of death for those with chronic kidney disease.The accumulation of uremic toxins, oxidative stress, metabolic abnormalities, chronic infections, and activation of innate immune pathways are some of the multifactorial causes of inflammation in chronic kidney disease. Numerous inflammatory biomarkers have been studied as possible markers of disease activity and development. The most researched of them are C-reactive protein (CRP), interleukin-6 (IL-6), and tumour necrosis factor-alpha (TNF-α). greater proteinuria, greater cardiovascular risk, and a quicker deterioration in renal function have all been linked to elevated levels of these indicators.A common indicator of systemic inflammation, CRP is an acute-phase protein produced by the liver in reaction to inflammatory stimuli. In individuals with chronic kidney disease (CKD), elevated CRP levels have been repeatedly associated with poor renal and cardiovascular outcomes. Similar to this, TNF-α causes cellular damage, apoptosis, and fibrosis in renal tissues, but IL-6 is essential for immune control and stimulates the synthesis of acute-phase proteins.An imbalance between the generation of reactive oxygen species and antioxidant defence systems leads to oxidative stress. Patients with chronic kidney disease (CKD) are especially vulnerable to oxidative stress because of decreased antioxidant capacity, persistent

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inflammation, and poor oxidative metabolite clearance. Lipid peroxidation, protein oxidation, DNA damage, and the activation of profibrotic pathways are all consequences of excessive oxidative stress that lead to progressive kidney disease.

One of the most popular indicators of oxidative damage and lipid peroxidation is malondialdehyde (MDA). In patients with chronic kidney disease (CKD), elevated MDA levels have been linked to declining renal function and an increase in cardiovascular problems. On the other hand, the body's power to neutralise free radicals and guard against oxidative damage is reflected in total antioxidant capacity (TAC). Patients with advanced chronic kidney disease (CKD) have been shown to have lower TAC levels, which may suggest a greater vulnerability to the illness's advancement.When compared to traditional clinical criteria alone, recent research has indicated that integrating inflammatory and oxidative stress indicators may enhance the prognosis of CKD progression. These biomarkers may make it easier to identify high-risk individuals early on, enabling the application of focused treatments meant to delay the course of the illness and lessen its effects.In many underdeveloped nations, including Pakistan, information about the predictive significance of oxidative stress and inflammatory biomarkers is still scarce despite mounting evidence. The need for regionally relevant research assessing these biomarkers in CKD patients is highlighted by variations in patient populations, environmental factors, and healthcare access.In order to ascertain their usefulness as predictors of unfavourable renal outcomes, the current study was created to examine the relationship between inflammatory and oxidative stress biomarkers and the advancement of CKD.

Methodology

From January 2025 to January 2026, the Department of Nephrology at Mayo Hospital Lahore carried out this prospective observational study. Consecutive sampling was used to enrol 180 patients with stages 2-4 Chronic Kidney Disease. Patients with acute renal injury, active infections, autoimmune illnesses, cancer, chronic inflammatory disorders, or those undergoing dialysis were excluded. Patients who were at least eighteen years old and had been diagnosed with chronic kidney disease for at least three months were included. Age, gender, body mass index, blood pressure, diabetes status, and medication history were among the baseline clinical and demographic information that was documented. Serum creatinine, estimated glomerular filtration rate (eGFR), urine albumin-to-creatinine ratio (UACR), C-reactive protein (CRP), interleukin-6 (IL-6), tumour necrosis factor-alpha (TNF-α), malondialdehyde (MDA), and total antioxidant capacity (TAC) were among the laboratory tests. CKD progression was defined as a drop in eGFR of at least 30% from baseline, the development of end-stage kidney disease, or the start of renal replacement therapy. Patients were monitored on a frequent basis over the study period. SPSS version 26 was used to analyse the data. Categorical variables were shown as frequencies and percentages, whilst continuous variables were given as mean ± standard deviation. To find predictors of CKD progression, independent t-tests, Chi-square tests, and

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multivariate logistic regression analyses were carried out. Statistical significance was defined as a p-value of less than 0.05.

Results

A total of 180 CKD patients were enrolled, with a mean age of 56.8 ± 12.4 years. During follow-up, 58 patients (32.2%) experienced disease progression. Patients with CKD progression exhibited significantly higher inflammatory and oxidative stress biomarker levels and lower antioxidant capacity compared with those who remained stable.

Table 1: Baseline Characteristics of Study Population

Variable	Total Patients (n=180)
Mean age (years)	56.8 ± 12.4
Male gender	104 (57.8%)
Diabetes mellitus	92 (51.1%)
Hypertension	126 (70.0%)
Mean eGFR (mL/min/1.73m²)	42.5 ± 11.3

Table 2: Biomarker Levels According to CKD Progression

Biomarker	Progression Group (n=58)	Stable Group (n=122)	P-value
CRP (mg/L)	10.8 ± 3.4	5.9 ± 2.1	<0.001
IL-6 (pg/mL)	14.6 ± 4.2	7.8 ± 2.6	<0.001
TNF-α (pg/mL)	18.2 ± 5.1	10.4 ± 3.2	<0.001
MDA (nmol/mL)	5.8 ± 1.4	3.1 ± 1.0	<0.001
TAC (mmol/L)	0.82 ± 0.21	1.42 ± 0.33	<0.001

Table 3: Clinical Outcomes During Follow-Up

Outcome	Frequency (%)
Stable CKD	122 (67.8%)
CKD progression	58 (32.2%)
Progression to ESKD	18 (10.0%)
Initiation of dialysis	15 (8.3%)

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Table 4: Independent Predictors of CKD Progression

Variable	Odds Ratio (OR)	P-value
Elevated IL-6	3.8	<0.001
Elevated MDA	3.4	<0.001
Diabetes mellitus	2.7	0.003
Baseline proteinuria	2.5	0.007
Reduced TAC	2.3	0.012

Conclusion

Biomarkers for oxidative stress and inflammation are strongly linked to the advancement of chronic kidney disease. Reduced antioxidant capacity and elevated levels of CRP, IL-6, TNF-α, and MDA were linked to a quicker deterioration in renal function and a higher chance of developing severe CKD and end-stage kidney disease. IL-6 and MDA were found to be highly reliable independent indicators of disease progression among the assessed biomarkers. Regular evaluation of oxidative stress and inflammatory markers may enhance risk assessment, enable early treatment intervention, and possibly decrease the progression of chronic kidney disease (CKD), all of which could improve long-term renal outcomes.

References

1.Johnson RJ, Ketteler M, Stenvinkel P, et al. Mechanisms and treatment implications of inflammation and chronic kidney disease. Kidney International, 67(Suppl 94), S105–S110, 2005.

2.Oxidative stress and inflammation in chronic renal disease Cachofeiro V, Goicochea M, de Vinuesa SG, et al. Research on Kidney and Blood Pressure. 31(4):243-259. 2008.

3.Biomarkers of inflammation and the development of chronic renal disease, Tonelli M, Sacks F, Pfeffer M, et al. Kidney International. 2005; 68(1):237-245.

4.Landray MJ, Wheeler DC, Lip GYH, et al. CKD-related inflammation, endothelial dysfunction, and cardiovascular risk. circulation. 2004; 109(7):837-842.

5.Menon V, Greene T, Wang X, et al. Albumin and C-reactive protein as indicators of cardiovascular and all-cause mortality in CKD. Kidney International. 2005; 68(2):766–772.

6.Oxidative stress and inflammation are more common in patients with moderate to severe chronic kidney disease (CKD), according to Oberg BP, McMenamin E, Lucas FL, et al. Kidney International. 65(3):1009–1016, 2004.

DOI:10.35772/ghm.2026.01072

7.Ikizler TA, Hakim RM, Himmelfarb J, and Stenvinkel P. Oxidative stress as a unifying notion is the elephant in uremia. Kidney International, 62(5), 1524–1538, 2002.

8.Comparing the predictability of malnutrition-inflammation complex syndrome markers in chronic kidney disease (CKD) Kalantar-Zadeh K, Kopple JD, Humphreys MH, Block G. The American Journal of Kidney Diseases. 2004; 44(5):864-881.

9.Massy ZA, Stenvinkel P, Drueke TB. Oxidative stress and chronic renal disease. Dialysis seminars. 2009; 22(4):405-408.

10.Vaziri N.D. The nature, processes, and possible effects of oxidative stress in uremia. Nephrology Seminars. 2004; 24(5):469–473.