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Inflammation, Malnutrition, and Oxidative Stress as Predictors of Mortality in Advanced Chronic Kidney Disease (CKD) and Hemodialysis Patients

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Abstract

Cardiovascular disorders arise with high frequency among individuals suffering from chronic kidney disease and constitute the predominant cause of death within this group. The objective of this investigation was to explore the influence of inflammatory processes, nutritional deficits, and oxidative imbalance in subjects managed with long-term hemodialysis, kidney allograft recipients, or those classified with advanced chronic kidney disease (CKD), along with corresponding outcomes tracked over a 38-month observation window. The cohort comprised 137 participants with impaired renal function (48 were CKD-stage patients, 29 were transplant recipients, 60 CKD subjects were treated with hemodialysis [HD], and 39 healthy volunteers served as the reference group; average age 49 ± 20 years, 96 men and 80 women). Every renal-compromised participant underwent dialysis three times per week, with each session lasting 4 to 5 hours (treatment commenced in March 2017 and extended over 38 months). Biochemical markers, Paraoxonase (PON)-1 function, and indicators of inflammation were quantified following established institutional procedures. Cumulative survival among CKD participants was estimated using the Kaplan–Meier method, with log-rank testing. Individuals of advanced age had a greater probability of developing CKD than the reference group ($P < .001$). Serum albumin, body mass index, and total cholesterol were lower, whereas triglyceride concentrations were elevated in the HD subgroup ($P < .05$ across all comparisons). The HD subgroup demonstrated greater PON-1 enzymatic function than the kidney transplant subgroup ($P < .001$). The healthy reference group exhibited superior PON-1 function compared with the HD, CKD-only, and transplant subgroups ($P < .001$ for all contrasts). Throughout the 38-month observation of 16 CKD individuals, 15 HD-treated participants died owing to cardiovascular events, and a single individual underwent kidney transplantation. At the 8- to 10-month follow-up, the survival rate reached 85%. With advancing illness, the survival rate fell to 30%, a decline attributed to nutritional depletion among CKD participants. Lipid peroxidation and the malnutrition–inflammation complex are linked across the different stages of CKD. As renal disease advances, biomarkers reflecting lipid peroxidation and malnutrition–inflammation display a consistent upward trajectory.

Keywords: Oxidative stress, Malnutrition, Inflammation, Chronic kidney disease, Hemodialysis

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Introduction

Throughout the previous decades, the societal toll of renal illness has escalated, contributing substantially to health-attributable fatal outcomes, while complications have

proliferated worldwide. Congruent with this pattern, the frequency of chronic renal impairment diagnoses has climbed steadily year by year. Upon entry into the multiple decisive phases of chronic kidney disease (CKD), an affected individual carries a pronounced likelihood of fatal outcomes before transitioning into terminal renal failure. Cardiovascular disorders are a very common occurrence in patients with CKD [1]. The contribution of established predisposing conditions, namely hypertension, dyslipidemia, and diabetes mellitus, underlies the fatal burden imposed by cardiovascular disorders. In the modern context, other non-classical predisposing conditions, notably inflammatory activation and redox imbalance, substantially quicken the emergence of cardiovascular disorders among CKD sufferers [2]. Aberrations in circulating lipid profiles are commonly encountered in CKD populations, a condition referred to as dyslipidemia, characterized by elevated triglyceride concentrations, elevated very low-density lipoprotein cholesterol, and diminished high-density lipoprotein cholesterol (HDL-C).

In contrast, low-density lipoprotein cholesterol parameters remain within reference limits. Moreover, the heightened burden of oxidative agents, derived primarily from inflammatory responses and dialytic procedures, combined with nutritional inadequacy, significantly weakens the antioxidant defense machinery and can foster a pro-oxidative milieu in CKD patients. Defensive enzymes, such as Paraoxonase (PON)-1 that circulates in association with HDL particles, are particularly liable to functional modifications inside a pro-oxidative setting [3], and their foremost duty is to safeguard LDL particles from peroxidative damage. This enzymatic family comprises three members—PON-1, PON-2, and PON-3; among them, PON-1 and PON-3 are expressed in humans, synthesized primarily in hepatic tissue, and are predominantly associated with HDL-C in the bloodstream. The cardinal role of both enzymes is to modulate oxidative burden and inflammatory cascades to restrain atherosclerotic progression in patients with renal disease. Published findings indicate diminished PON-1 function among patients with CKD [4]. However, to the best of our knowledge, no dataset on PON-3 in the CKD population has been reported to date. It must be underscored that nutritional deficits, inflammatory activation, and oxidative imbalance hold the capacity to perturb the reduction–oxidation condition of lipoproteins in these individuals [5].

The herein described prospective inquiry was designed to scrutinize the repercussions of diverse states—namely, inflammatory activation, nutritional inadequacy, and oxidative imbalance (compromised antioxidant protective apparatus)—in subjects with renal functional impairment (managed with long-term hemodialysis or/and/or kidney allograft recipients or individuals with late-phase CKD), along with the sequential ramifications, over a 38-month longitudinal surveillance span.

Materials and Methods

Ethical approval and consent to participate

The institutional review panel at Ningbo Yinzhou No. 2 Hospital granted approval and evaluated the investigative plan (Approval no. 1547NY2H; December 15, 2016), and authorization was obtained from each examined individual before study initiation. The investigative plan was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki, as amended in 2008. Informed consent was documented for every participant.

Inclusion criteria

Individuals carrying a diagnosis of renal functional impairment and necessitating dialytic intervention were enrolled. For those receiving dialytic treatment, a minimum of 3 months of hemodialysis (HD) was required. Subjects were required to have surpassed the 3-month milestone following kidney transplantation (where applicable; the initial 3-month interval corresponds to the phase of most intense immunosuppressive therapy). No enrolled subject had been administered any pharmaceutical agent or bioactive compound recognized to modulate their stress-related physiological condition.

Exclusion criteria

Individuals afflicted by autoimmune disorders, rheumatoid arthritis, and diabetes mellitus were not admitted into the present study. Subjects whose HD vintage fell below 3 months, and those under pharmacotherapy aimed at lipid reduction, were likewise not included.

Collection of blood samples

Venous whole blood specimens were drawn into EDTA-containing tubes (Nanjing Superfit I & E Co. Ltd., Nanjing, Jiangsu, China) following an overnight fasting interval; plasma was isolated via ultracentrifugation at 1500 × g over 10 minutes at 4 ºC, partitioned into fractional aliquots, and maintained at −80 ºC pending subsequent assays. Participants underwent evaluation monthly.

Lipid status determination

Serum concentrations of total cholesterol (TC), triglyceride (TG), and HDL-C were measured according to conventional institutional protocols on an ILAB-600 bioassay analyzer (Instrumentation Laboratory Company, Bedford, MA). The low-density lipoprotein cholesterol

fraction in the CKD cohort was calculated by applying the Friedewald formula [6]. Nephelometric detection (Turbidimeter Model 850, Confab Instrumentation, San Diego, CA) was employed to quantify high-sensitivity heat shock protein (hs-CRP), apolipoprotein A-1, and lipoprotein levels. The antigen-antibody complex method was used to determine albumin concentrations on an ILAB-600 bioassay analyzer.

Enzymatic determination of PON-1

PON-1 catalytic velocity was established in plasma specimens with paraoxon and diazoxon serving as substrates (Chem Service, Inc., West Chester, PA). Circulating interleukin (IL)-6 levels were determined via a sandwich-ELISA kit (cat. no. c-Kit Elisa LS-F25956) procured from the Bioassay Technology Laboratory, Birmingham, UK. Concentrations of further biochemical variables were ascertained from the harvested blood samples.

In addition to these biochemical variables, further clinically significant parameters—namely, the ferric-reducing ability of plasma (FRAP) and plasma malondialdehyde (MDA)—were quantified.

Risk factor evaluation

Predisposing conditions, specifically malnutrition, were recognized in subjects whose albumin measurements fell under the conventional boundary (<38 g/L) when set against the overall study sample (n = 137), and also in subjects whose body mass index (BMI) fell beneath the antecedent BMI threshold (22 kg/m²), in line with the reports of Kirushnan *et al*. [7] and Hwang *et al*. [8] An inflammatory condition was considered established when IL-6 concentrations exceeded 5 pg/mL across the study sample (n = 137). This event triggers the synthesis of acute-phase proteins at the inflammatory locus. Lipid degradation was judged to have taken place when the assayed antioxidant enzyme values of PON (>122 U/L) and diazoxonase (DZOase) (5966 U/L) in plasma lay beneath the respective normal reference intervals.

Statistical analysis

The entire statistical analysis of the research dataset was conducted in Minitab (version 19, National Bureau of Statistics, China). The Kolmogorov–Smirnov test was used to verify whether continuous variables followed a Gaussian distribution. Between-group contrasts of parametric continuous variables were drawn using the unpaired Student t test or one-way analysis of variance (ANOVA). For non-parametric continuous variables, the Kruskal–Wallis test was employed. Post hoc examinations were conducted using either the Tukey or Dunn test. Chi-squared (χ^2) tests were applied to evaluate numerical or categorical variables. The outcome measures were time-to-death appraisals recorded in months. The Kaplan–Meier technique, in combination with the log-rank test, was used to estimate survival (from illness identification through to demise or confirmation of survival) among CKD participants. In the present study, the assessment of the scrutinized predisposing factors was based on the joint presence of malnutrition, oxidative stress, and inflammation. A threshold of $P < .05$ was regarded as indicative of a statistically noteworthy divergence.

Results and Discussion

Study population

Spanning January 15, 2016, to December 1, 2016, a collective of 154 adult (>18 years) subjects were identified as having renal functional impairment and needing dialytic management at the nephrology unit of Ningbo Yinzhou No. 2 Hospital, Ningbo, Zhejiang, P.R. China, in addition to other partnering dialysis centers. Out of the full set of screened subjects, 2 were afflicted by autoimmune pathology, 3 by rheumatoid arthritis, and 12 by complications linked to diabetes mellitus. As a result, these individuals (n = 17) were omitted from the current study. The final investigation included 137 participants with defective renal function, together with 39 healthy volunteers (normal controls). A flowchart outlining the participant enrollment pathway is provided in **Figure 1**.

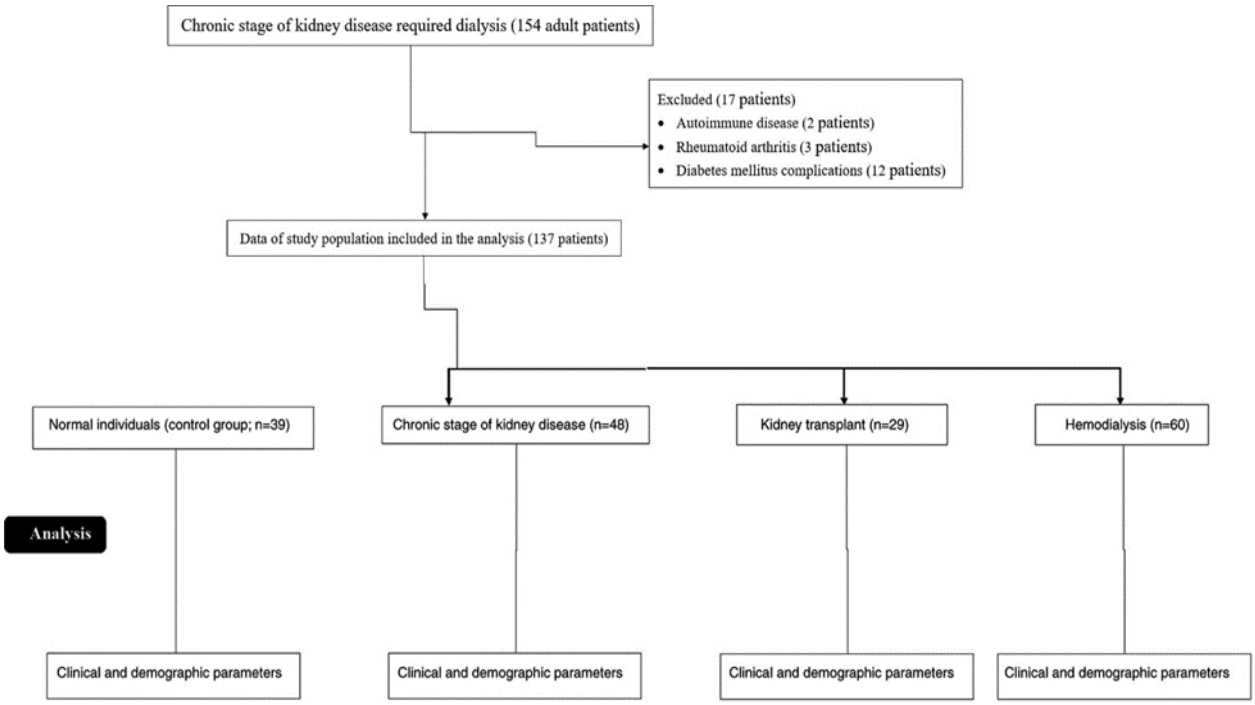

Figure 1. Flow chart of the study inclusion process for patients in the present study.

Demographic characteristics

The mean participant age was 49 ± 20 years, with a sex distribution of 96 males and 80 females. Dialysis treatments began in March 2017 and lasted 38 months. Every renal-impaired participant was dialyzed three times weekly, each session lasting 4 to 5 hours, while receiving corticosteroids or alternative immunosuppressive agents, in strict compliance with the standard clinical operational directives of the principal institutions and associated dialysis facilities (these directives are not yet disseminated). CKD subjects exhibiting anemia were counseled to use recombinant products such as erythropoietin, whereas no participant had externally received any hypolipidemic medication. Within the 137 subjects suffering from renal functional decline, 48 corresponded to CKD cases, 29 to kidney transplant cases, and 60 CKD subjects were managed with HD (the hemodialyzed group also bore a diagnosis of CKD). The HD-managed subset was characterized by greater age and a higher predisposition to CKD onset compared with the control group ($P < .0001$; one-way ANOVA/Tukey test); accordingly, age had to be factored in. Information on variables such as sex-based differences, BMI, cigarette smoking history, and blood pressure readings was comparable across all investigated groups ($P > .05$ for each; data not displayed). Furthermore, details on parameters, including HD vintage and the distribution of subcategorical disease entities among CKD subjects, are presented in **Table 1**.

Table 1. Representation of parameters, such as hemodialysis and sub-categorical disease occurrence in patients with CKD.

Variable	Hemodialysis patients (n = 60)	Kidney transplant recipients (n = 29)	CKD patients (n = 48)	Control group (n = 39)	Between-group comparison
Age (years), mean ± SEM	54.87 ± 1.49	42 ± 2.16	37.5 ± 1.99	51.7 ± 2.24	< 0.0001 (one-way ANOVA); degrees of freedom: 175
Sex, n (%)					0.4288 (χ^2 test of independence); degrees of freedom: 3
Male	29 (48)	19 (66)	25 (52)	23 (59)	
Female	31 (52)	10 (34)	23 (48)	16 (41)	
CKD/HD duration (months), mean ± SEM	111 ± 10.07	33.8 ± 15.91	42.9 ± 3.81	Not applicable	< 0.0001 (one-way ANOVA)*; degrees of freedom: 175

Variables are depicted as the mean ± SEM or frequencies (percentages).
Abbreviations: ANOVA = analysis of variance, CKD = chronic kidney disease, HD = hemodialysis, SEM = standard error of the mean.
Among patients with CKD, Kidney transplant patients, and patients undergoing hemodialysis.

Clinical characteristics

A reduction was observed in albumin concentration ($P < .05$, one-way ANOVA/Tukey test), BMI ($P < .05$, one-way ANOVA/Tukey test), and TC ($P < .05$, one-way ANOVA/Tukey test), alongside an elevation in TG values ($P < .001$, one-way ANOVA/Tukey test) within the cohort receiving HD. Circulating IL-6 amounts were noticeably augmented among CKD participants ($P < .05$, one-way ANOVA/Tukey test) as well as kidney transplant (Tk) recipients ($P < .01$, one-way ANOVA/Tukey test). However, the IL-6 burden in CKD participants remained below that observed in the HD cohort ($P < .05$, one-way ANOVA/Tukey test). Plasma MDA together with FRAP readings were suppressed, yet hs-CRP concentrations in plasma rose in the HD cohort versus the healthy comparator arm ($P < .05$ for each, one-way ANOVA/Tukey test). Additionally, the HD cohort demonstrated greater PON-1 enzymatic activity than the kidney transplant arm (Tk; $P < .05$, one-way ANOVA/Tukey test). Healthy comparator individuals outperformed the HD, kidney transplant, and CKD cohorts in PON-1 enzymatic activity ($P < .05$ for each). A comprehensive summary of clinical attributes across the four arms is laid out in **Table 2**.

Table 2. Analysis of general biochemical parameters, antioxidant enzyme paraoxonase-1 activity, and inflammatory marke concentrations across CKD patients, hemodialysis patients, kidney transplant recipients, and control groups.

Group parameters	Patients undergoing hemodialysis (n = 60)	Kidney transplant patients (T_k, n = 29)	Patients with CKD (n = 48)	Control group (n = 39)
Body mass index (kg/m^2)	21.91 ± 3.99^{a,b,c}	23.19 ± 4.66^{a}	23.19 ± 4.63^{a}	29.4 ± 5.69
Albumin (g/L)	40.8 ± 3.09^{a,c}	41.6 ± 3.16	41.4 ± 6.23^{a}	42.6 ± 3.81
Urea (mmol/L)	21.3 ± 3.46^{aaa,b,c}	11.2 ± 5.66^{aaa,b}	19.7 ± 9.22^{aaa}	4.66 ± 1.46
Creatinine (µmol/L)	877 ± 166^{aaa,bbb,cc}	185.4 ± 163.58^{aaa,bb}	323.6 ± 245.88^{aaa}	65.5 ± 13.68
GFR (mL/min/1.73 m^2)	<6^{aaa,bbb,ccc}	38.8 ± 14.0^{aaa}	31.8 ± 25.7^{aaa}	98 ± 15
TC (mmol/L)	4.71 ± 1.1^{aa,bb,ccc}	5.52 ± 1.05	5.27 ± 1.35^{a}	5.32 ± 1.10
TG (mmol/L)	2.13 ± 1.300^{aaa,c}	1.97 ± 0.958^{b}	2.33 ± 0.072^{aaa}	1.55 ± 0.864
LDL-C (mmol/L)	2.81 ± 0.894^{aaa,bbb,ccc}	3.45 ± 0.934	3.64 ± 1.244	3.59 ± 1.09
HDL-C (mmol/L)	1.09 ± 0.313^{aaa,ccc}	1.32 ± 0.357^{b}	1.19 ± 0.246^{a}	1.22 ± 0.345
MDA (µM/L)	6.61 ± 0.31^{aaa,ccc}	6.79 ± 0.55^{b}	6.65 ± 0.41^{a}	6.69 ± 0.45
FRAP (µM/L)	927 ± 17^{aaa,ccc}	931 ± 19^{b}	951 ± 20^{a}	1055 ± 22
hs-CRP (mg/L)	3.18 (2.293–4.565)^{aaa,bbb,cc}	1.31 (0.767–1.928)^{b}	1.28 (0.374–1.760)^{a}	1.18 (0.877–1.49)
IL-6 (pg/mL)	3.83 (3.150–4.734)^{aaa,b}	4.11 (3.340–4.830)^{aa,b}	2.37 (1.867–3.356)^{a}	1.58 (1.251–1.984)
POase activity (U/L)	241 (201–310)^{aa,b,c}	232 (191–292)^{aa,b}	339 (267–501)^{a}	361 (301–489)
DZOase activity (U/L)	7159 (6566–8152)$^{\alpha,\beta\beta\beta,\gamma\gamma\gamma}$	14,128 (12,651–15,979)$^{\alpha\alpha}$	13,998 (10,890–15,738)$^{\alpha}$	9877 (8829–12,013)

Variables are depicted as the mean ± standard deviation or median (Q1–Q3).

[a]Group differences from the control group,

[b]Group differences from CKD,

[c]Group differences from Tk based on one-way ANOVA or the Kruskal–Wallis test, Tukey's, or Dunn's post hoc test. $^{a,b,c}P < .05$, $^{aa,bb,cc}P < .01$, $^{aaa,bbb,ccc}P < .001$.

Geometric means and confidence intervals (CIs) for hs-CRP, IL-6, and POase activity are shown.

The P-value for comparing all groups was <.05 for all parameters.

Abbreviations: CKD = chronic kidney disease, DZOase = diazoxonase, FRAP = ferric-reducing ability of plasma, GFR = glomerular-filtration rate, IL = interleukin, MDA = plasma malondialdehyde, POase = paraoxonase, TC = total cholesterol, TG = triglyceride.

Non-parametric analysis of survival functions in patients undergoing HD

A result emerging from this 38-month inquiry was that, among the 16 CKD subjects available for continued observation (only 16 were successfully traceable), 15 individuals under HD care met a fatal outcome (mortality). In contrast, a single individual proceeded to renal transplantation. The foremost driver of fatality across these 15 HD-treated participants stemmed from cardiovascular pathologies (cardiac arrest, myocardial infarction, thrombotic, and hemorrhagic stroke), accounting for 10/15 (67%), malignant disease (cancer) for 3/15 (20%), and unobtainable documentation for the final 2/15 (13%) participants.

Risk factor evaluation

The survival function graph portrayed in **Figure 2** reveals that subjects living with renal disorders faced an amplified probability of death driven by multiple predisposing elements. Compared with the reference arm, the divergent predisposing factors operating in these subjects substantially shortened the survival function (log-rank = 12.03; $P < .0071$). The synergistic burden exerted by two predisposing elements—namely, oxidative stress and inflammation—became detectable around the 8- to 10-

month time point of the observation period. At that moment, an 85% survival function was documented. As pathological decline continued, the survival function plummeted to 30%, an event unfolding under the influence of merely a solitary predisposing element—namely, malnutrition.

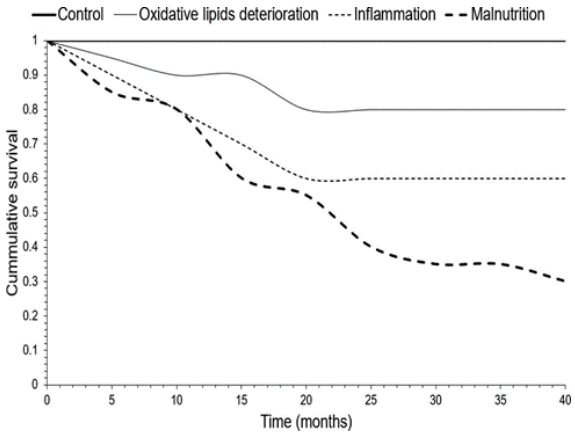

Figure 2. The survival plot. A range of predisposing conditions was associated with the survival trajectory of renally impaired subjects, as monitored throughout the 38-month observation period (Kaplan–Meier curve; log-rank = 12.03; P < .0071). Those burdened by renal dysfunction faced a heightened probability of fatal outcomes driven by assorted predisposing conditions. Participants in the malnutrition cluster had shorter survival than those experiencing oxidative stress or inflammatory states. Oxidative compromise was appraised solely through PON 1 measurement, inflammatory status was discerned exclusively via IL-6 quantification, and nutritional depletion was estimated strictly from albumin concentrations. Survival: duration spanning from pathological diagnosis until either fatal endpoint or verification of continued survival.

In this investigation, malnutrition was identified through assessment of serum albumin and body mass index, with both measures showing lower values in the HD-treated cohort. Prior work has established that hs-CRP and IL-6 biomarker concentrations are markedly elevated in CKD subjects with severe nutritional deficits and inflammatory activation [9]—a condition that is common among those receiving HD therapy.

In the present analysis, HD-treated subjects exhibited depressed TC levels and elevated TG concentrations, a biochemical picture suggesting the simultaneous presence of oxidative imbalance and inflammatory activity. This observation is consistent with earlier findings from Hopewell *et al*. [10] who reported that the accumulation of HDL-C within the circulation expedited the clearance of apolipoprotein A-1, consequently lowering the HDL-C concentration and blunting the enzymatic action of lecithin-cholesterol acyl-transferase, thereby impairing HDL-C maturation [11] as a secondary manifestation of disturbed lipid handling. At the same time, HD-treated subjects who harbor oxidatively damaged and structurally aberrant protein products possess a notably elevated antioxidative reserve compared with the healthy reference group, a circumstance ascribed to blunted SOD catalytic performance and a scarcity of total sulfhydryl (-SH) groups provided in insufficient quantity along the intra-chain segments of aberrant protein products [12]. A compensatory rise in the functional capacity of antioxidant systems may occur in HD-treated subjects, alongside a suppression of SOD enzymatic activity.

The collected data indicated that CKD subjects and renal allograft recipients alike showed a meaningfully increased IL-6 burden. Yet, the IL-6 burden in CKD subjects remained below that observed in the HD-managed group [13]. Correspondingly, circulating inflammatory surrogate markers, typified by plasma MDA and hs-CRP, are elevated in the HD-treated group. In contrast, FRAP values decline relative to the healthy reference arm. In line with the proposal of Kirushnan *et al*. [7], malnutrition, inflammatory processes, and cardiovascular incidents are triggered by oxidative imbalance, a phenomenon particularly evident in the CKD setting. The HD-treated group may face a predisposition toward cardiovascular incidents.

In agreement with a prospective cohort study [12], HD-treated subjects showed significantly higher PON-1 enzymatic activity than Tk recipients. By contrast, other groups [14] have shown that the enzymatic activities of both PON and glutathione peroxidase endow HDL-C with antioxidant protection and anti-inflammatory properties, especially during the later phases of renal deterioration. It has additionally been recognized that the augmented actions of PON-1 and DZOase (ApoA-1) carried on HDL-C safeguard LDL particles from oxidative assault mounted by phagocytic cells such as macrophages, and concurrently facilitate the macrophage-cholesterol efflux pathway [15]. In the present work, however, PON-1 activity was higher in HD-treated participants than in renal allograft recipients, suggesting that the former have not progressed to a degree of kidney collapse comparable to that of the latter group.

As articulated previously, [2] growing focus has fallen upon further sequelae, such as the advancement of atherosclerosis, most characteristically among subjects living with renal pathology, driven by both traditional and non-traditional predisposing elements for cardiovascular conditions. Nutritional deficit was recognized among participants whose serum albumin had sunk beneath 38 g/L and whose BMI registered 22 kg/m²; whose IL-6 burden surpassed 5 pg/mL across the full set of participants; and whose antioxidative enzymatic readings for PON-1 stood above 122 U/L, together with DZOase

activity measured at 5966 U/L, both concurrently reduced. Moreover, a reciprocal relationship has been reported between PON-1 status and lipid indices, exemplified by VLDL, particularly in populations with renal pathology [16]. The VLDL subclass deserves particular consideration, as it is the principal precursor of LDL particles and plays a pivotal role in the atherosclerotic cascade [17]. In the present analysis, the combined effect of two predisposing elements—namely, oxidative imbalance and inflammatory activation—was observed around the 10-month mark of the observational period, coinciding with an 85% survival function. Approaching the concluding phase of this investigation, survival figures declined below 60% in the HD-treated arm owing to the combined burden of malnutrition and oxidative imbalance, a pattern consistent with earlier published evidence [18, 19]. With the deterioration of renal performance proceeding among HD-treated subjects, a single predisposing element—namely malnourishment—emerges as the driving force behind the progression of cardiovascular incidents; a shift into a critical renal failure phase also supervenes, at which stage a bare 30% survival proportion is witnessed. The present study establishes that all evaluated participants' arms showed impaired antioxidative defense, with the deficit most pronounced in the HD-treated arm. At the intermediate stage of renal pathology, inflammatory activation and oxidative imbalance, as reflected by elevated IL-6 and hs-CRP levels, have been corroborated by earlier reports [20, 21]. The HD-treated group bears a heightened risk of fatal outcomes.

Certain limitations of this work deserve explicit mention. The study comprised a constrained set of participant categories, in keeping with its nature as a preliminary exploration. A variety of predisposing elements accelerate complications such as cardiovascular incidents among subjects living with renal pathology; accordingly, subsequent research ought to concentrate particularly on nutritional indices or antioxidant-based interventions designed to mitigate such predisposing elements in CKD populations. A weakness inherent to this investigation is the small sample size (16 CKD subjects).

Conclusion

This observational study examined the interrelationships among malnutrition, inflammatory activation, and oxidative imbalance by enrolling 137 subjects with renal impairment and 39 healthy individuals as the comparator group. The surveillance phase lasted 38 months. Drawing upon the results obtained, it was reasoned that malnourishment, inflammatory activation, and the oxidative breakdown of lipids were collectively associated with an elevated mortality hazard in renally impaired subjects, with malnourishment exerting a distinct part in the pronounced mortality hazard characteristic of the advanced phase of chronic kidney disease. The pathophysiological cascades by which malnourishment, inflammatory activation, and oxidative imbalance modulate survival length in individuals living with chronic kidney disease have yet to be charted. This report maps the relationships between lipid peroxidation and malnutrition/inflammation across the different phases of chronic kidney disease. As chronic kidney disease progresses, surrogate markers of lipid peroxidation and malnutrition/inflammation follow an upward trajectory. The present investigation provides insight into the interrelationships among the predisposing factors of malnutrition, inflammatory activation, and oxidative imbalance in subjects with renal functional decline.

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Conflict of interest: None

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