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ORIGINAL ARTICLE / ОРИГИНАЛНИ РАД

Relationship between serum AGE precursor levels, oxidative stress, and quality of life in patients receiving hemodialysis

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SUMMARY

Introduction/Objective The aim of this study was to determine the relationship between serum advanced glycation end product (AGE) precursors, oxidative stress levels, and quality of life in hemodialysis patients.

Methods A descriptive form and the Kidney Disease Quality of Life Form (KDQOL-36) were used in the study. Serum levels of AGE precursors [methylglyoxal (MGO) and glyoxal (GO)] and oxidative stress [malondialdehyde (MDA)] were determined in blood samples taken from the patients.

Results The KDQOL-36 subscale scores were 71.65 ± 17.76 for the symptoms/problems list, 66.35 ± 19.06 for the effect of kidney disease, 40.6 ± 24.01 for the kidney disease burden, 41.6 ± 9.83 SF-12 for physical health, and 37.83 ± 9.69 for SF-12 mental health. The serum levels were 3.96 ± 1.01 μmol/L for MDA, 1029.87 ± 314.43 ng/mL for GO, and 115.2 ± 75.54 ng/mL for MGO. A positive and significant correlation was detected between serum MGO and GO ($r = .285$, $p < 0.01$) and MDA ($r = 0.284$, $p < 0.01$). A positive correlation was noted between serum MDA and GO ($r = 1{,}000$, $p < 0.05$) and a negative correlation with kidney disease burden ($r = -0.205$, $p < 0.05$). A negative and significant correlation was detected between GO and kidney disease burden ($r = -0.204$, $p < 0.05$).

Conclusion Serum MGO, GO, and MDA levels were high in patients undergoing hemodialysis. High serum MDA levels are associated with high serum GO and MGO levels. High serum levels of MDA and GO had a negative impact on the quality of life of hemodialysis patients.

Keywords: hemodialysis; oxidative stress; serum advanced glycation end product precursor; quality of life

INTRODUCTION

Hemodialysis (HD) is a medical procedure used to treat end-stage renal disease (ESRD) by removing excess waste products, electrolytes, and fluids from the blood. This helps to maintain the electrolyte balance and acid-base status in the body and can also assist in regulating blood pressure. HD is one of the primary forms of renal replacement therapy for individuals with ESRD, along with peritoneal dialysis and kidney transplantation [1]. One consequence of renal insufficiency is a gradual increase in the levels of advanced glycation end-products (AGE), and renal functions decrease in proportion to this increase. The kidneys have an important role in AGE metabolism. As AGE levels increase in the plasma, the glomerular filtration rate decreases, thereby exacerbating the increase in AGE. The precursors of the most reactive AGE are glyoxal (GO) and methylglyoxal (MGO) [2].

Patients with HD are subjected to dietary recommendations (fruit and vegetable restrictions) to prevent the risk of hyperkalemia and the high prevalence of malnutrition. However, the recommended diet for HD patients impairs antioxidant defense mechanisms and increases oxidative stress by disrupting the rate of production and destruction of reactive oxygen species (ROS). In addition, every HD session causes more losses in antioxidant molecules (e.g., vitamins and trace elements), thereby suppressing the removal of ROS [3]. At excessive levels, ROS interact with many biomolecules, such as proteins, lipids, and nucleic acids, and may cause cellular damage, leading to negative effects on tissue function and structure [4]. The HD procedure itself is also known to trigger pro-oxidant mechanisms [5]. The presence of several interconnected factors, including oxidative stress, loss of important antioxidants, and chronic inflammation, are all critical factors that collectively contribute to a higher risk of cardiovascular disease and mortality in HD patients [6]. Consequently, AGE and oxidative stress levels, which cause many other known diseases, also have particularly adverse effects in HD patients [6].

HD treatment is a long-term therapy that can affect the quality of life of patients with ESRD [7]. The HD treatment guidelines highlight the importance of quality of life as a key outcome and recommend assessing quality of life via repetitive measures as a parameter for monitoring the quality of care given to HD

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patients [8]. Determination of the quality of life can help healthcare professionals assess the well-being of their patients and make decisions about the health care for those patients (e.g., new treatments and interventions) [7, 8]. In the current study, the relationships between serum AGE precursors, oxidative stress levels (i.e., MDA levels), and quality of life were investigated in HD patients.

METHODS

Study type

In this study, the aim was to assess whether a correlation exists between the serum levels of AGE precursors and MDA, as markers of oxidative stress and inflammation, and quality of life among individuals undergoing HD.

Location and time of study

The study was conducted in April 2021 with patients who were treated at two HD centers in Istanbul after obtaining the approval of the University Ethics Committee.

Population and sample of the participants in the study

A total of 170 patients who were treated at HD centers at the time of the study constituted the study population. Data were collected from 117 (68% participation) patients who met the following inclusion criteria: absence of communication problems (hearing, language, understanding, etc.), willingness to participate in the study, being 18 years old and over, and possessing the cognitive ability to answer the questions in the data collection tools. The G-Power 3.1.9.4 (Axel Buchner, Edgar Erdfelder, Franz Faul, Albert-Georg Lang; Heinrich Heine University Düsseldorf, Düsseldorf, Germany) program was used for *post hoc* power analysis to confirm that the sample size was sufficient (the effect size was 0.3 and the power was 0.9 at the 95% confidence interval, at a significance level of 0.05).

Data collection tools

Personal data form

Questions about sex, age, marital status, educational status, occupation, income level, and disease (duration of the disease, duration of HD, etc.) were prepared by the researcher to determine the socio-demographic and disease-related characteristics of the participating patients.

Kidney disease Quality of Life Scale (KDQOL-36)

This tool was developed to measure the quality of life of individuals with chronic kidney disease (CKD) who receive dialysis treatment. It provides an overall measure of the health status and outcomes of patients receiving dialysis treatment from their own perspectives. The KDQOL-36 questionnaire consists of 36 statements with five subscales. Two of the subscales measure the overall quality of life, while the other three measure the quality of life specific to patients with kidney disease. The general quality of life was measured using a short form of the general quality of life scale known as the SF-12. The subscales of the quality of life specific to kidney disease estimate the burden of kidney disease, the symptoms/problems of kidney disease, and the effects of kidney disease. Each dimension was scored according to the answers given to the related statements. Scores can be a minimum of 0 and a maximum of 100. A total score of 0 indicates the worst quality of life, while a total score of 100 indicates the best quality of life.

Measurement of serum AGE precursors

Blood samples were taken from the patients, and the levels of the AGE precursors MGO and GO were measured. Venous blood was collected in yellow-cap gel tubes and EDTA test tubes, and the plasma was separated by centrifugation at 3000 rpm for 30 minutes at 4°C. The plasma was aliquoted into polypropylene tubes and stored in a -80°C freezer until analysis.

Chemicals for AGE precursor analysis, including tetraethoxypropane, trichloroacetic acid (TCA), thiobarbituric acid (TBA), ethanol, GO (40%), MGO (40%), methanol, sodium acetate, 4-nitro-1,2-phenlenediamine, and acetonitrile, were purchased from Sigma-Aldrich (St. Louis, MO, USA).

Previously described extraction and high-performance liquid chromatography (HPLC) methods were used, with small modifications, for GO and MGO analysis in plasma samples. In brief, 0.5 mL of plasma sample was placed in a 10 mL glass tube, and 2 mL of TCA (10%) solution was added, followed by centrifugation at 8000 rpm for 5 minutes. A 1 mL aliquot of the supernatant was then removed and combined with 1 mL sodium acetate buffer (0.1 M, pH: 3) and 0.5 mL derivatization solution (4-nitro-1,2-phenlenediamine in 1% methanol). This mixture was incubated in a water bath for 20 minutes at 70°C and then passed through a cellulose acetate filter (0.45 μm) for injection into the HPLC.

The HPLC system consisted of a Shimadzu LC20AT pump and a Shimadzu SPD-20A UV/VIS detector (Shimadzu Corporation, Kyoto, Japan). The mobile phase consisted of a mixture of methanol, water, and acetonitrile (42:56:2, v/v/v). The detector wavelength was set at 254 nm. An Inertsil ODS-3 (250 × 4.6 mm, 5 μm) column was used for the separation of GO and MGO in the plasma samples. The flow rate was 1 mL/minute and the column oven temperature was 25°C.

Measurement of oxidative stress levels

The plasma samples of the patients were evaluated using MDA as a marker of oxidative stress.

A previous method for the extraction and HPLC analysis of MDA in plasma samples was used with small modifications. In brief, a 0.5 mL tetraethoxypropane standard

was placed in a 100 mL flask and made to 100 mL with ethanol. A 0.1 mL volume of this standard was placed in a 100 mL flask and made to 100 mL with TCA (10%). For MDA derivatization, a 0.5 mL plasma sample was placed in a 10 mL glass tube, 2 mL of TCA (10%) solution was added, and the tube was centrifuged at 8000 rpm for 5 minutes. A 1 mL sample of the supernatant was removed and combined with 1 mL TBA solution (0.67%) and incubated in a 90°C water bath for 30 minutes. The solution was then filtered through a 0.45-micron cellulose acetate filter into an amber vial for injection into the HPLC.

The HPLC system consisted of a Shimadzu Nexera-i pump and a Shimadzu RF-20A fluorescence detector (Shimadzu Corporation). The mobile phase was a mixture with 0.05M KH_2PO_4 buffer, methanol, and acetonitrile (72:17:11, v/v/v). The excitation and emission wavelengths of the fluorescence detector were set at 530 nm and 550 nm, respectively. MDA separation was achieved using an Inertsil ODS-3 (4.6 × 150 mm) column at a flow rate of 1 mL/minute and a column temperature of 25°C.

Data analysis

The IBM SPSS Statistics, Version 25.0 (IBM Corp., Armonk, NY, USA) package program was used for the statistical analysis of the results of this study. The descriptive statistics of the variables are presented as percentages, numbers, arithmetic standard deviations, and means.

The Mann–Whitney U test was used for the analysis of binary independent variables that did not have a normal distribution (between -2 and +2), as determined by the skewness and kurtosis values. Spearman's correlation analysis was used to determine the relationships between the variables. A p value < 0.05 was considered statistically significant.

Ethical considerations

Participation in this research was voluntary. The research aims were explained to the participants both verbally and in written form. Patient anonymity, confidentiality, and privacy of data were also explained in both verbal and written forms, and all data were guaranteed to be used only for research purposes. The study was performed according to the tenets of the Declaration of Helsinki. The study was approved by the Ethical Committee of the University (Nr 2020/11, 27.11.2020). Informed consent was obtained from all subjects involved in the study.

RESULTS

The average age of the patients was 60.32 ± 12.51 years, the duration of chronic kidney failure disease was 9.42 ± 8.12 years, and the duration of HD therapy was 6.53 ± 7.28 years. Overall, 31.6% of the patients were female, 66.7% were married, 46.2% had graduated from primary school, 66.7% were employed, 53.8% were retired, 35.9% had equal income–expense status, 76.9% did not smoke, 94.9% did not consume alcohol, and 44.4% exercised regularly (Table 1). All patients had a conventional HD regimen consisting of four-hour sessions three times weekly.

Table 1. Distribution of socio-demographic and health characteristics of the patients (n = 117)

Characteristics		Mean ± SD	Min–Max (median)
Age		60.32 ± 12.51	25–83 (62)
Disease Period of Chronic Renal Failure (Years)		9.42 ± 8.12	0.5–44 (8)
Application Period of Hemodialysis (Years)		6.53 ± 7.28	0.5–40 (4)
		n	%
Sex	Female	37	31.6
	Male	80	68.4
Marital status	Married	78	66.7
	Single	39	33.3
Educational status	Illiterate	8	6.8
	Literate	4	3.4
	Primary School	54	46.2
	Secondary school	31	26.5
	High school	15	12.8
	University and higher	5	4.3
Employment status	Yes	78	66.7
	No	39	33.3
Occupational status	Housewife	28	23.9
	Tradesman	9	7.7
	Worker	4	3.4
	Officer	5	4.3
	Retired	63	53.8
	Unemployed	8	6.8
Income status	Income exceeds expenses	39	33.3
	Income is equal to expenses	42	35.9
	Income is less than expenses	36	30.8
Smoking	Yes	27	23.1
	No	90	76.9
Alcohol use	Yes	6	5.1
	No	111	94.9
Regular exercising	Yes	52	44.4
	No	65	55.6

The mean CRP was 21.94 ± 45.02 mg/L, the mean HbA1C was 7.13 ± 1.62%, the mean KT/V ratio was 1.65 ± 0.3, the mean serum urea reduction ratio was 70.14 ± 11.07, the mean serum MDA level was 3.96 ± 1.01 μmol/L, the mean serum GO level was 1029.87 ± 314.43 ng/mL, and the mean serum MGO level was 115.2 ± 75.54 ng/mL (Table 2).

The KDQOL-36 sub-scale scores were as follows: the mean symptoms/problems list score was 71.65 ± 17.76, the mean effect of kidney disease score was 66.35 ± 19.06, the mean kidney disease burden score was 40.6 ± 24.01, the mean SF-12 physical health score was 41.6 ± 9.83, and the mean SF-12 mental health score was 37.83 ± 9.69 (Table 3).

The symptoms/problems list, effect of the kidney disease, kidney disease burden, and SF-12 physical health scores were higher in the non-diabetic group than in the diabetic group, and the differences were statistically significant (p < 0.05). The serum GO value was lower in the non-diabetic group than in the diabetic individuals (p = 0.001;

Table 2. Distribution of clinical and biochemical parameters of patients (n = 117)

Parameters	Mean ± SD	Min–Max (median)
Serum calcium (mg/dl)	13.05 ± 17.3	7.48–90 (9.2)
Serum phosphorus (mg/dl)	6.14 ± 7.05	2.1–49 (5.2)
Serum total protein (g/dl)	61.63 ± 102.14	5.1–660 (62.8)
Albumin (g/dl)	27.46 ± 18.44	3.6–49.6 (38.7)
Uric acid (mg/dl)	6.36 ± 1.22	1.8–8.5 (6.4)
C-reactive protein (mg/l)	21.94 ± 45.02	0.54–281.1 (11.4)
HbA1C (%)	7.13 ± 1.62	5.26–12.7 (6.8)
Total cholesterol (mg/dl)	169.11 ± 45.02	62.7–269.47 (159.7)
HDL (mg/dl)	44.01 ± 23.6	21.33–132 (36.8)
LDL (mg/dl)	93.34 ± 31.79	22.82–170 (91)
Triglyceride (mg/dl)	181.71 ± 116.94	45–565.8 (153.57)
Hemoglobin (mg/dl)	10.68 ± 1.55	6.8–13.1 (10.9)
Hematocrit (%)	31.87 ± 4.87	20.1–39.4 (32.6)
Serum iron (ug/dL)	61.93 ± 34.42	25–231 (54)
Total iron binding capacity (ug/dL)	207.54 ± 42.7	23.2–284 (202)
Ferritin (ng/mL)	570.48 ± 591.22	87.3–4130 (438)
KT/V	1.65 ± 0.3	0.93–2.32 (1.68)
URR	70.14 ± 11.07	18.5–85 (72)
Malondialdehyde (µmol/l)	3.96 ± 1.01	2.29–10.17 (3.74)
Glyoxal (ng/mL)	1029.87 ± 314.43	373–2019 (983)
Methylglyoxal (ng/mL)	115.2 ± 75.54	15–534 (97)

HDL – high-density lipoprotein; LDL – low-density lipoprotein; URR – urea reduction ratio

Table 3. Patients' mean scores for KDQOL-36 sub-scales (n = 117)

Sub-scales of KDQOL-36	Mean ± SD
Symptoms/problems list	71.65 ± 17.76
Effect of the kidney disease	66.35 ± 19.06
Kidney disease burden	40.6 ± 24.01
SF-12 physical health	41.6 ± 9.83
SF-12 mental health	37.83 ± 9.69

KDQOL-36 – kidney disease quality of life scale

Table 4. Comparison of KDQOL-36 sub-scales, serum AGE and oxidative stress levels measurements according to the presence of diabetes in patients (n = 117)

Sub-scales	Diabetes presence	n	Ort ± Ss	p
Symptoms/problems list	Non-diabetic individuals	77	75.36 ± 13.95	0.008*
	Diabetic individuals	40	63.63 ± 22.18	
Effect of the kidney disease	Non-diabetic individuals	77	68.95 ± 17.9	0.044*
	Diabetic individuals	40	60.73 ± 20.49	
Kidney disease burden	Non-diabetic individuals	77	44.61 ± 25.11	0.005*
	Diabetic individuals	40	31.93 ± 18.97	
SF-12 physical health	Non-diabetic individuals	77	42.86 ± 10.5	0.024*
	Diabetic individuals	40	38.88 ± 7.63	
SF-12 mental health	Non-diabetic individuals	77	38.48 ± 9.89	0.515
	Diabetic individuals	40	36.44 ± 9.21	
Glyoxal (ng/mL)	Non-diabetic individuals	77	963.59 ± 261.19	0.005*
	Diabetic individuals	40	1152.73 ± 367.4	
Methylglyoxal (ng/mL)	Non-diabetic individuals	77	105.32 ± 61.93	0.128
	Diabetic individuals	40	133.51 ± 93.95	
Malondialdehyde (µmol/l)	Non-diabetic individuals	77	4 ± 1.16	0.936
	Diabetic individuals	40	3.86 ± 0.68	

KDQOL-36 – kidney disease quality of life scale; Mann–Whitney U Test;
*p < 0.05

p < 0.05). No statistically significant differences in MDA and MGO values were observed according to diabetes status (p > 0.05) (Table 4).

A positive and significant correlation was found between the serum MGO and GO (r = 0.285, p < 0.01) levels and the serum MDA level (r = 0.284, p < 0.01) in the HD patients. A positive correlation was noted between MDA and GO (r = 1.000, p < 0.05), and a negative correlation was detected between MDA levels and kidney disease burden (r = -0.205, p < 0.05). A negative and significant correlation was detected between GO and kidney disease burden (r = -0.204, p < 0.05) (Table 5).

DISCUSSION

The aim of this study was to examine the relationship between serum AGE precursors, MDA serum levels, and quality of life in HD patients. The quality of life of the HD patients examined here was moderate in terms of the symptoms experienced and the effect of the disease, and their quality of life was low in terms of physical and mental health and disease burden. The reference ranges for MGO, GO, and MDA in healthy individuals were 6.5 ± 3.6 ng g^{-1}, 4.4 ± 2.9 ng g^{-1} [9], and 0.7 (0.69–0.72) µmol/L [10], respectively. The serum MGO, GO, and MDA levels were high. High serum MDA levels were associated with high GO and MGO levels, and our HD patients showed significant negative correlations between MDA and GO levels and renal disease burden. In addition, significant correlations were detected for the serum MDA and GO levels in diabetic and non-diabetic patients.

AGE are heterogenous compounds produced endogenously from the non-enzymatic glycation of proteins, lipids, and nucleic acids [11], and they play a role in the development of various chronic diseases, including diabetes-related complications, cardiovascular diseases, renal diseases, and neurodegenerative diseases [12]. Reactive carbonyl compounds are reported to accumulate during HD due to the interaction of ESRD and blood with the dialysis membrane, and both contribute to the formation of AGE [6]. Because the kidneys are the most important organ for AGE excretion, the relationship between CKD and AGEs is like a vicious cycle. As AGE increase, the glomerular filtration rate (GFR) decreases, and this exacerbates the AGE increase [13]. Increased plasma AGE levels also cause the activation of receptor of advanced glycation end-products (RAGE), and this generates inflammatory cascades and ROS production [14]. Renal and vascular AGE accumulation triggers AGE accumulation in all systems at levels that cause complications, largely due to increased oxidative stress [15].

Oxidative stress is defined as the imbalance that occurs in the rates of ROS production and destruction. Excess ROS interact with important biomolecules, such as proteins, lipids, and nucleic acids, and may cause cellular damage, with negative

Table 5. Correlation between patients' serum AGE and oxidative stress levels and KDQOL-36 sub-scales (n = 117)

Sub-scales		MDA	GO	MGO
Malondialdehyde (μmol/l)	r	1	1.000	0.284
	p		0.000*	0.002*
Glyoxal (ng/mL)	r	1.000	1	0.285
	p	0.000*		0.002*
Methylglyoxal (ng/mL)	r	0.284	0.285	1
	p	0.002*	0.002*	
Symptoms/Problems List	r	-0.077	-0.077	0.001
	p	0.411	0.411	0.989
Effect of the kidney disease	r	-0.089	-0.088	0.096
	p	0.342	0.348	0.304
Kidney disease burden	r	-0.205	-0.204	-0.137
	p	0.027*	0.027*	0.140
SF-12 physical health	r	-0.12	-0.119	-0.092
	p	0.197	0.202	0.326
SF-12 mental health	r	0.018	0.018	0.103
	p	0.849	0.848	0.268

MDA – malondialdehyde; MGO – methylglyoxal; GO – glyoxal;
*p < 0.05, Spearman's

effects on tissue function and structure [16]. In HD patients, comorbidities such as dyslipidemia, hypertension, metabolic syndrome, diabetes, senility, and atherosclerosis trigger pro-oxidant activity [3]. The resulting imbalance between the pro-oxidant and antioxidant systems in patients receiving HD causes an increase in oxidative stress related to both the pathophysiological mechanism underlying their ESRD and the physical stresses of HD itself. The end product of ROS interactions with polyunsaturated fatty acids is MDA, which can interact with proteins and nucleic acids to induce the pathogenesis of various disorders, including atherosclerosis [17]. In addition, uremic toxin accumulation can simultaneously activate the prooxidant system and inhibit the antioxidant system [18].

In the present study, the serum MDA levels in our HD patients were higher than those reported in an earlier study conducted on healthy individuals [12]. Miyagawa and Tateishi [19] reported that dialysis sessions increased oxidative stress and decreased antioxidant potential. Similarly, Coşkun et al. [20] detected that oxidative stress levels were higher in HD patients than in a control group. In addition, the oxidative stress levels in the patients increased more after the HD procedure [20]. The plasma levels of MDA, a biomarker of lipid peroxidation, were also significantly higher in HD patients after HD than before the HD treatment [5].

In the present study, the GO level was higher than the level previously reported in another study [17]. The MGO level was also higher than that stated in another study [18]. Luketin et al. [6] reported that the AGE levels were significantly higher in their HD group than in their control group. In addition, the AGE levels in the study population indicated a greater number of patients with high cardiovascular disease risk in the HD group than in the control group [6]. Another study that followed patients with CKD for 39 months reported a negative correlation between the estimated GFR (eGFR) and AGE levels, and high AGE levels were independently associated with all-cause mortality [21]. In patients with impaired renal function, serum AGE levels are higher than in patients with normal kidney function [15]. The MGO levels are also higher in patients with CKD than in the general population [22].

In this study, high MDA serum levels were associated with high GO and MGO levels. Studies have shown that AGE initiate intracellular oxidative stress by increasing ROS production [23]. AGE levels increase by the classical glycation pathway in CKD, but increases also occur by enhancements of oxidative stress and carbonyl stress. The clearance of reactive carbonyl compounds is reduced in CKD, leading to carbonyl stress, and a subsequent increase in serum AGE levels was also observed. In patients with a reduced capacity for renal activity, the plasma AGE levels are higher than in patients with normal kidney functions [15]. Increased plasma AGEs also cause the activation of RAGE, which then activates the production of inflammatory cascades and ROS [24]. AGEs cross-link to cell surface receptors or body proteins, and they cause oxidative stress and inflammation because they change the receptor or protein structure and function after binding. Glycated proteins, in turn, create an inflammatory response through their interaction with receptors, causing gene activation and various inflammatory diseases as a result of this activation [25].

In this study, high serum MDA levels had a negative impact on the quality of life of our HD patients. Silva et al. [26] examined the correlation between functional capacity and oxidative stress and inflammation biomarkers in patients receiving HD treatment and reported that oxidative stress and inflammation reduced patient functional capacity, and the negative effects on functional capacity caused limitations in daily activities and decreased patient quality of life. Oxidative stress has been shown to increase in the advanced stages of CKD, and it becomes more severe in HD patients [27]. Oxidative stress plays a role in the development of renal damage and uremic symptoms [28], while it also causes amyloidosis, immunologic disorders, coagulopathy, cataract, endothelial dysfunction, atherosclerosis, and cardiovascular complications in HD patients [19]. Inflammation may also be associated with an increase in resting energy expenditure while also negatively affecting the nutrition status of individuals. Anemia and bone-mineral disorder can also occur in patients due to inflammation [25, 26, 28]. As comorbidities increase, the level of dependency of individuals increases, and the quality of life is adversely affected [29].

Quality of life was also negatively affected by high GO levels in the present study, as high MGO levels reduced cognitive functions in our HD patients. A reduction in cognitive functions in these patients can decrease their quality of life and increase mortality [22]. In HD patients, AGE also function as uremic toxins, while vascular calcification of AGE causes endothelial dysfunction, myocardial changes, dysregulation of the immune system, and progression of atherosclerosis [30]. These changes can lead to further decreases in functional capacity and a worsening quality of life.

Limitations of the study

One limitation of the present study is that its results are valid only for the patients included in the study and, therefore, cannot be generalized to all patients. A second limitation is that the reliability of the data is also limited by the accuracy of the answers given by the patients in the study. Finally, since the duration of HD treatment, comorbidities, nutritional status, and many other parameters affect both oxidative stress and quality of life, examining only the correlation between quality-of-life parameters and a biomarker of oxidative stress may be insufficient and may not reflect the true picture of the relationship.

CONCLUSION

The quality of life of HD patients was moderate in terms of the symptoms experienced and the effects of the disease, but their quality of life was low in terms of physical and mental health and disease burden. The serum levels of MGO, GO, and MDA were high, and the high serum MDA levels were associated with high serum GO and MGO levels. A significant negative correlation was detected between the levels of MDA, GO levels, and renal disease burden. In addition, significant correlations were detected in the serum MDA and GO levels of diabetic and non-diabetic patients. Regular evaluations of symptom severity, quality of life, serum MDA levels, and serum AGE levels are recommended for HD patients, as are the development of strategies to increase the quality of life and reduce oxidative stress and the production of AGE in these patients.

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Однос између нивоа прекурсора *AGE* у серуму, оксидатног стреса и квалитета живота болесника који примају дијализу

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САЖЕТАК

Увод/Циљ Студија има за циљ да утврди везу између прекурсора крајњих продуката напредне гликације у серуму (*AGE*), нивоа оксидативног стреса и квалитета живота болесника на хемодијализи.

Методе У студији су коришћени дескриптивни облик и Упитник о квалитету живота са бубрежном болешћу (*KDQOL*-36). Нивои прекурсора *AGE* [метилглиоксала (МГО), глиоксала (ГО)] и оксидативног стреса [малондиалдехид (МДА)] болесника одређивани су у узорцима крви.

Резултати Утврђено је следеће: резултати подскале *KDQOL*-36 били су 71,65 ± 17,76 за листу симптома, 66,35 ± 19,06 за утицај болести бубрега, 40,6 ± 24,01 за оптерећење болешћу бубрега, 41,6 ± 9,83 за физичко здравствено стање према *SF*-12, 37,83 ± 9,69 за ментално здравствено стање према *SF*-12.

Утврђено је да МДА износи 3,96 ± 1,01 *μmol/l*, ГО 1029,87 ± 314,43 *ng/mL*, а МГО 115,2 ± 75,54 *ng/mL*. Уочена је позитивна и значајна корелација између МГО и ГО (r = 0,285, $p < 0,01$) и МДА ($r = 0,284$, $p < 0,01$) и између МДА и ГО ($r = 1,000$, $p < 0,05$), а негативна корелација са оптерећењем болешћу бубрега ($r = -0,205$, $p < 0,05$). Утврђено је да постоји негативна и значајна корелација између ГО и оптерећења болешћу бубрега ($r = -0,204$, $p < 0,05$).

Закључак Утврђено је да су нивои МГО, ГО и МДА били високи код болесника који су били на хемодијализи. Високи нивои МДА повезани су са високим нивоима ГО и МГО. Утврђено је да високи нивои МДА и ГО имају негативан утицај на квалитет живота болесника.

Кључне речи: хемодијализа; оксидативни стрес; прекурсори крајњих продуката узнапредовале гликације у серуму; квалитет живота