Biochemical Correlations with Other Biomarkers in ESRD Hemodialysis Short Title: Biomarkers in ESRD Hemodialysis

Barat Yusubov, MD* Mirkhalig Javadov, MD** Khanbaba Huseynov, MD*** Muradali Bakhshiyev, MD****

ABSTRACT

ESRD patients on HD have elevated FGF23, iPTH, and Hcy and have been individually linked to disordered mineral metabolism and CVD risk. This study evaluated the associations between FGF23, iPTH, Homocysteine, and routine biochemical parameters in CKD HD patients to bridge the literature gap. This cross-sectional observational study was conducted on 103 adult CKD patients receiving maintenance HD. The detailed baseline information of biochemistry laboratory parameters included Hg, CRP, Glucose, Creatinine, eGFR, K, Na, Ca, P, ALT, AST, iPTH, Hcy, and FGF-23. In the sample, 65 were male (63.1%), and 38 were female (36.9%), with the mean age, height, and weight of 64±13.64, 170 ± 6.85, and 79 ± 13.07. FGF23 levels were positively correlated with phosphorus (r=0.78, p=0.01), creatinine (r=0.78, p=0.01), iPTH (r=0.61, P=0.01), and homocysteine (r=0.65, p=0.01). It was negatively correlated with GFR (r=-0.64, p=0.01). No statistically significant correlation was found with Ca values (r=-0.12, p>0.05). Changes in FGF23, iPTH, and homocysteine levels together and in correlation with other biochemistry laboratory parameters are the earliest markers for HD patients. These parameter values can be used to guide strategies for prognostic issues and early treatment management.

Keywords: Chronic Kidney Disease, End-Stage Renal Disease, Fibroblast Growth Factor 23, Homocysteine, İntact Parathyroid Hormone, Mineral Metabolism

INTRODUCTION

Patients with end-stage renal disease (ESRD) undergoing hemodialysis (HD) face a higher risk of mortality due to chronic kidney disease-related mineral bone abnormalities (CKD-MBD) and cardiovascular disease (CVD) complications such as cardiorenal syndrome[1]. The reason behind increased CVD risk factors in CKD patients is pathologically changed phosphocalcic metabolism. CKD-MBD syndrome is characterized by an imbalance of mineral values and bone metabolism changes, including abnormal calcium (Ca), phosphorus (P) metabolism, and intact parathyroid hormone (iPTH)[2].

Fibroblast growth factor 23 (FGF23) is one of the major phosphate metabolism regulators secreted from the osteocytes. High levels of FGF23 are associated with mortality in ESRD patients with HD[3]. Bouma-de Krijger, et al.[4] reported no association between a single value of FGF23 and all-cause mortality. However, increasing FGF23 was associated with mortality risk. This is because FGF23 inhibits PTH secretion and active vitamin D3 synthesis and consequently inhibits the reabsorption of P by the renal tubules, resulting in limiting intestinal P absorption[3,4].

FGF23 also plays an important role in CVD pathological processes, including left ventricular hypertrophy, myocardial injury, coronary atherosclerosis, vascular calcification, etc[5]. Vázquez-Sánchez, et al.[6] reported direct FGF23 effects on the heart myocardium, and FGF23 elevated plasma levels have been related to negative CVD results such as arrhythmias and heart failure, etc. The feedback of persistent hyperphosphatemia and deficiency of the co-factor Klotho explains the mechanism. The relation between FGF23 levels and CVD, such as cardiorenal syndrome and MBD in hemodialysis patients, is unclear[7].

Renal hyperparathyroidism (rHPT) develops during the early stages of renal failure with high risks of bone fractures, CVD, and death. PTH and FGF23 increase as kidney function declines when patients reach kidney failure and fail to exert their phosphaturic effects. This process leads to hyperphosphatemia and further elevations of both hormones. FGF23 levels should be measured in clinical practice, targeting the control of it just as with PTH levels. The target range levels for intact PTH (iPTH) remain debatable. Furthermore, research is needed to determine optimal iPTH level ranges in ESRD HD patients[8,9].

Chen, et al.[10] showed high Homocysteine (Hcy) levels in CKD HD patients. Hyperhomocysteinemia (Hhcy) was recognized as an independent risk factor for developing CVD with an 85-90% rate, especially in combination with biochemical parameters such as creatinine, albumin, Calcium, and CRP. Thus, it is argued as a prognostic and predictive biomarker in ESRD, and it is recommended to monitor Hcy levels in all CKD HD patients.

* Department of Nephrology,
Yeni Klinika Hospital, Baku,
Azerbaijan.
** Department of General Surgery and Transplantation,
Yeni Klinika Hospital, Baku, Azerbaijan
Email: dr.mjavadov@gmail.com
*** Department of Extracorporeal Detoxification and Hemodialysis,
Scientific Surgical Center named after Academician M. Topchubashov,
Baku, Azerbaijan.
**** Department of Internal Medicine, Azerbaijan Medical University,
Baku, Azerbaijan.

Currently, no biomarker alone can be used to predict and follow up on the prognosis of CKD progression. GFR and creatinine are follow-up markers for kidney failure, along with early detection of CKD[2,11]. Therefore, this study aims to analyze the correlation of FGF23, iPTH, and Homocysteine with other biochemistry parameters to determine the predictive and prognostic markers for ESRD HD patients. There is a literature gap as there is limited research that simultaneously maps the biochemical interrelationships among FGF23, iPTH, Homocysteine, CRP, lipids, and mineral metabolism markers in ESRD patients with chronic HD. Thus, this study contributes significantly to this field of discussion.

MATERIALS AND METHOD

Study Design: This is a cross-sectional, observational study conducted in Azerbaijan. The Institutional Ethics Committee approved the study (research protocol code 012, number 012/24).

Sample Size

ESRD patients who underwent dialysis for a minimum of 3 months were approached, and data was collected from 103 patients who agreed to participate in the study. These patients were divided into two groups: the main group (with high FGF23 and homocysteine levels) and the control group (with no increase in Homocysteine and FGF23 levels). The planned examinations were performed for both groups.

Selection Criteria

Inclusion criteria

- Adult patients diagnosed with ESRD on maintenance HD
- Absence of primary cardiovascular disease (CVD)

Exclusion criteria

- Presence of primary CVD or acute cardiovascular events
- Acute renal failure
- History of recent surgery (within the past 2 months)
- Hemodialysis due to non-ESRD etiologies (e.g., autoimmune or oncological diseases)

Assessment ***Parameters***

i. Demographic information, including age, gender, primary disease, and comorbid diseases, was collected.
ii. Data were collected for classic biochemistry laboratory parameters using standard procedures, including creatinine, urea, sodium, potassium, Calcium, Phosphorus, AST, ALT, and CRP, along with the target parameters such as FGF23, iPTH, and homocysteine levels.
iii. Cardiac evaluation of all HD patients was performed using Color Doppler Echocardiography and Electrocardiogram (ECG).

Glomerular filtration rates (GFR) ml/min were calculated to assess renal function by using the CKD-EPI formula. Renal function was classified using the K/DOQI guidelines, where GFR stages were defined as >90, 60-89, 30-59, 15-29, and <15 ml/min/1.73 m^2 [12].

Biomarker Measurement and Reference Values: Blood samples were collected before HD and then centrifuged for serum fluid collection. Enzyme-linked immunosorbent assay (ELISA) was used for FGF23 serum level measurement. The human FGF23 ELISA kits utilized in this study were manufactured by Immutopics International (San Clemente, CA, USA; #60-6600). For FGF23, normal value reference measurements were 10.84-23.72 pg/mL, which were determined by taking the mean value of FGF23 (17.28 ± 6.44) from 28 healthy volunteers. Electrochemiluminescence immunoassay (ECLIA, PTH Cobas®, Roche) was used to measure iPTH levels in the normal range of 15-65 pg/ml. The Fluorescence Polarization Immunoassay (FPIA) method was used for total Hcy concentration measurement. The normal reference range for total Hcy was 5-15 µmol/L. The target reference range for Phosphorus (1.13-1.78 mmol/l), Calcium (2.1-2.4 mmol/l), and iPTH (150-300 pg/ml) in CKD patients were evaluated (K/DOQI guidelines)[13-15].

Statistical Analysis: Descriptive statistics and frequency analysis were used to describe demographic and clinical features. The Chi-square (χ^2) test was performed to compare groups based on their categorical variables.The Shapiro-Wilk test showed that the data did not follow a normal distribution, so non-parametric methods were chosen. Mann–Whitney U test was employed to contrast clinical parameters between the focus and control groups. Spearman's rank correlation was chosen to assess the relationship between FGF23 and numerous other chemical markers. All tests used statistical significance with $p < 0.05$. All statistical analyses were done using IBM SPSS Statistics version 25.0.

RESULTS

The study involved 103 patients who were receiving maintenance hemodialysis because of ESRD. Table 1 shows that both groups had more male patients than female patients, as 63.1% of the whole group were male, 67% in the focus group, and 54% in the control group. This gender imbalance might imply that males face higher risks of biochemical imbalances leading to ESRD.

Table 1. Baseline clinical and laboratory characteristics (n=103).

Parameters			**Patient no = 103, n%**
Gender (n%)	Male	Control	15 (54%)
		Focus	50 (67%)
		Total	65 (63.1)
	Female	Control	13 (46%)
		Focus	25 (33%)
		Total	38 (36.9)
			Mean ± SD
Age (year)			64 ±13.64
Height (cm)			170 ±6.9
Weight (kg)			79 ±13.04
Vital Parameters			
Systolic blood pressure (mm/Hg)			140 ±17.83
Diastolic blood pressure (mm/Hg)			80 ± 6.13
Pulse (per minute)			83 ± 11.3
Laboratory parameters			
HGB (g/dl)			9.3 ± 11.9
HT (%)			30.4 ± 6.36
CRP (mg/L)			12.31 ± 18.67
eGFR (ml/min/1.73m2)			11 ± 5.78
Creatinine (umol/l)			599 ± 242.2
Glucose (mmol/l)			6.2 ± 3.2
Urine protein (mg/dl)			150 ± 85.8
Potassium (mmol/l)			4.1 ± 0.57
Sodium (mEq/l)			142 ± 3.32
Calcium (mmol/l)			2.34 ± 3.17
Phosphorus (mmol/l)			1.69 ± 1.94
ALT (U/l)			22.1 ± 13.06
AST (U/l)			22.4 ± 12.56
FGF-23 (pg/ml)			876 ± 584.8
İPTH (pg/ml)			153 ± 93.7
Homocysteine (umol/ml)			20 ±7.42

The average age of all patients was 64 (±13.64), which is common for patients suffering from CKD. The standard group had an average height of 170 cm (±6.9) and weighed around 79 kg (±13.04). It was

discovered that the systolic blood pressure was 140 mmHg on average (with a typical variation of 17.83 mmHg) and diastolic blood pressure was 80 mmHg (with a normal variation of 6.13 mmHg), both consistent with hypertension that is normally seen in patients undergoing dialysis. The mean pulse rate was 83 bpm (±11.3), which fell within the normal range for humans.

The table also reveals the laboratory biomarkers. The mean HGB level was 9.3 g/dL, and the HT rate was 30.4%, both revealing that chronic disease anemia often affects patients on dialysis. According to the data, patients in this group had a mean CRP level of 12.31 mg/L (±18.67), higher than normal, suggesting an inflamed state that can lead to greater cardiovascular risk.

Observations from renal function tests made it clear that the disease involved severe progression. The mean eGFR level observed was 11 mL/min/1.73m² (±5.78), which matches the criteria for Stage 5 CKD. The serum creatinine value of 599 µmol/L (+/-242.2) indicated substantial kidney damage. Blood glucose (6.2 mmol/L) and urine protein (150 mg/dL) were found in the proper ranges for adults with diabetes and proteinuric nephropathy, which are among the main reasons for ESRD.

The serum electrolyte test revealed potassium at 4.1 mmol/L and sodium at 142 mEq/L, which is acceptable for dialysis patients. The serum calcium level was 2.34 mmol/L (±3.17), and the phosphorus level was 1.69 mmol/L (±1.94). Even though these values are close to or within the recommended range, the wide deviations in these results make it difficult to manage the mineral balance in Huntington's disease patients. Measurement of ALT and AST showed no significant liver damage, with means at 22.1 U/L (±13.06) and 22.4 U/L (±12.56) for most patients.

Both the FGF23 and iPTH levels were significantly abnormal, supporting a diagnosis of secondary hyperparathyroidism and abnormal mineral metabolism. While the iPTH level is near the lower limits of the target for HD, it hints at a changed parathyroid function. Moreover, the average homocysteine level was 20 µmol/L (±7.42), higher than the normal range and confirming its importance as a cardiovascular risk factor for people with diabetes.

Table 2 showed that the eGFR ranged from 4 to 35 mL/min/1.73 m². Creatinine values ranging from 106 to 1300 µmol/L point to severe kidney dysfunction. Blood phosphate levels varied between 0.8 and 9 mmol/L, indicating that some patients had hypophosphatemia and others had hyperphosphatemia. Ca levels varied from 1.7 to 9.84 mmol/L, and the higher readings suggest an imbalance or overload of Calcium. The iPTH levels, which range from 101 to 480 pg/mL, are associated with differing degrees of secondary hyperparathyroidism. Patients had very high or very low levels of FGF23 (108-5550 pg/ml), indicating significant imbalances in phosphate management. The Hcy levels measured were 7 to 44 µmol/L, and several individuals had abnormal levels, suggesting that Hcy may be a marker of heart risks here.

According to K/DOQI guidelines, the target reference range for Phosphorus was 1.13-1.78 mmol/l, for Calcium is 2.1-2.4 mmol/l, and for iPTH is 150-300 pg/ml. The figure 1 illustrates the distribution of patients in the two groups by their biochemical and demographic characteristics. Compared to the control group, a much greater percentage of patients in the main group had increased P levels (78.7%) than patients with low levels of P (5.3%), and more patients in the control group had low P levels (26.7%) than those in the main group (18%). Likewise, there was a larger percentage of low Ca in main group patients (67.9%) compared to control group patients (32.1%),

Table 2. Minimum and maximum values of biochemical parameters

Min-Max	eGFR (ml/min/1.73m²)	Crea (umol/l)	P (mmol/l)	Ca (mmol/l)	iPTH (pg/ml)	FGF23 (pg/ml)	Hcy (umol/ml)
Minimum	4	106	0.8	1.7	101	108	7
Maximum	35	1300	9	9.84	480	5550	44

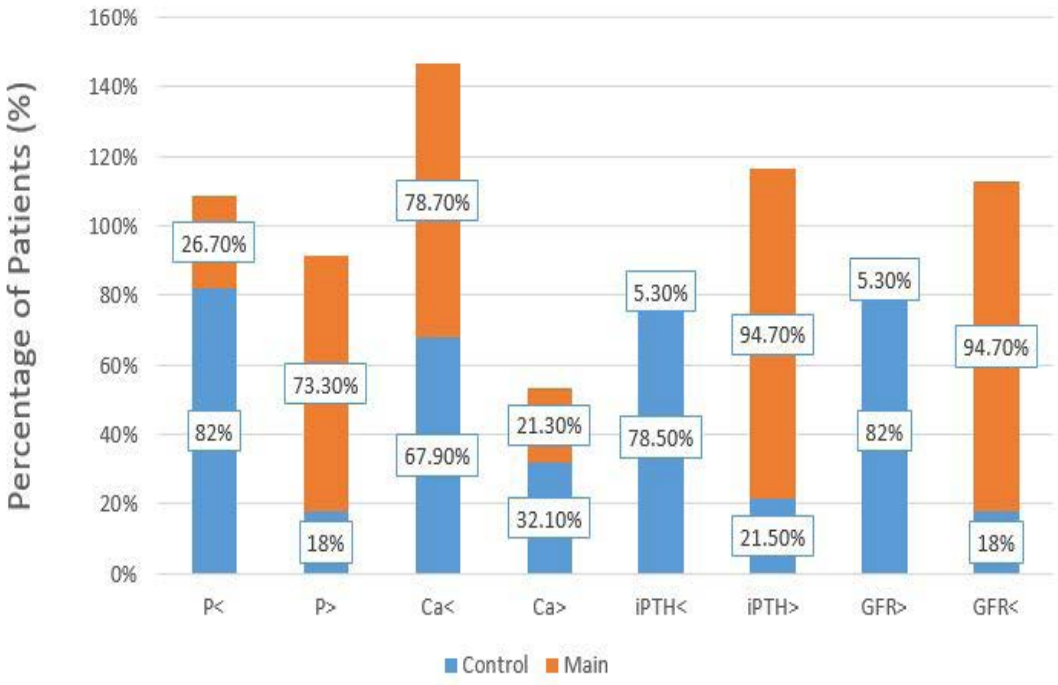

Figure 1. Comparison of percentage of patients for each laboratory characteristics between groups

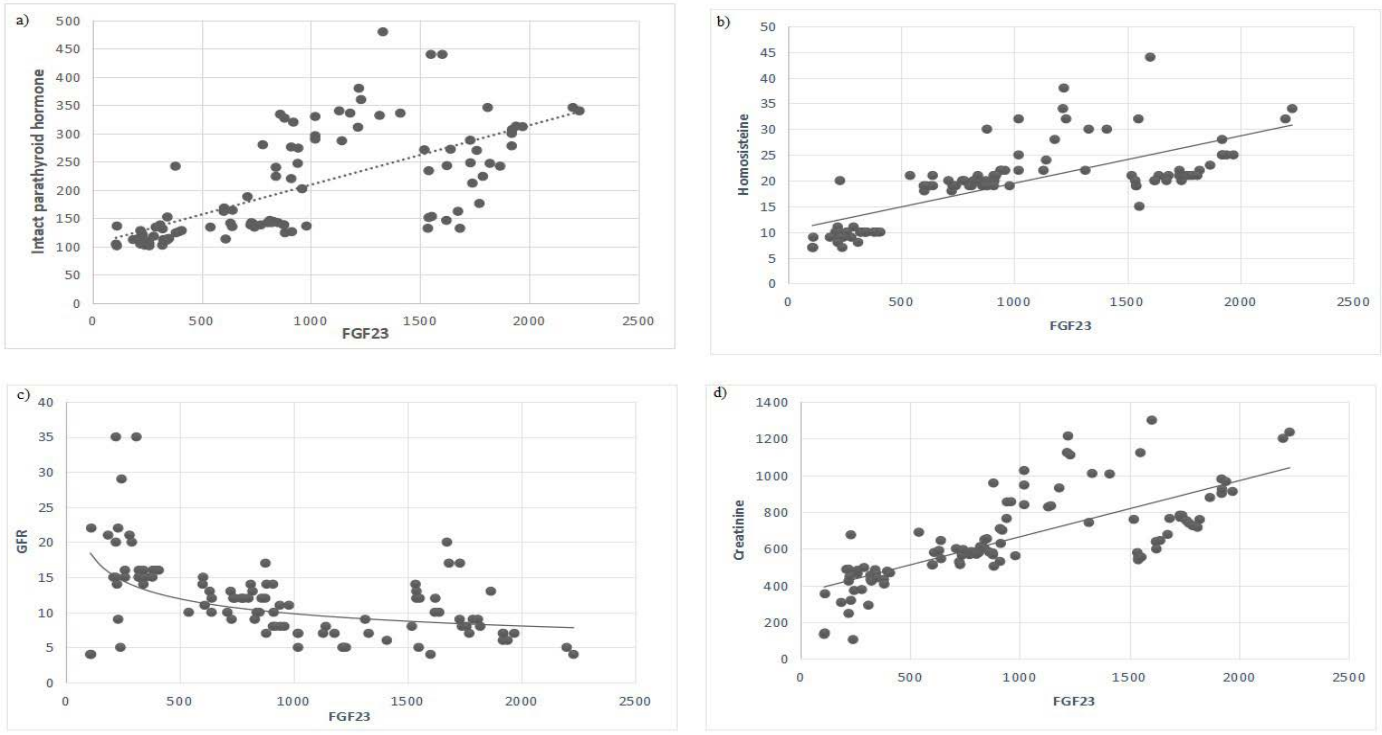

Figure 2. Correlation of serum levels of fibroblast growth factor 23 with intact parathyroid hormone (a), serum homocysteine rate (b), glomerular filtration (c), and (d) Creatinine

showing that hypocalcemia was much higher in the main group. The control group (21.3%) had a higher rate of elevated Ca than the main group (5.3%).

Most (94.7%) of the main group patients had high iPTH, compared to just 21.5% of the control group. People in the control group were much more likely to have low iPTH (78.5%), suggesting that focus patients had more serious secondary hyperparathyroidism. About 94.7% of the main group had low GFR values, but only 18% of controls were found to be in the same category, meaning the main group had much more serious renal issues.

Table 3. Spearman Correlation Analysis between the changes in FGF-23 and other biochemistry laboratory parameters in the groups

Group		FGF-23
Control (n=28)	Crea	0.25*
	Ca	-0.18
	P	-0.31
	iPTH	-0.28
	GFR	-0.11
Main (n=75)	Crea	0.78*
	Ca	-0.12
	P	0.78*
	iPTH	0.61*
	GFR	-0.64*

Table 3 shows the Spearman correlation analysis where FGF-23 had a different connection pattern with key biochemical factors in the control and main groups. The control group showed that FGF-23 had a slight positive relationship with creatinine ($r = 0.25$, $p < 0.05$), but its connections with Ca, P, iPTH, and GFR were weak and not statistically significant, meaning FGF-23 and these other variables interacted very little in patients with lower FGF-23 and Hcy.

The main group demonstrated that FGF-23 increases strongly with increased creatinine ($r = 0.78$, $p < 0.05$) and phosphorus concentration ($r = 0.78$, $p < 0.05$), suggesting that FGF-23 rises greatly as renal function and phosphorus levels worsen. FGF-23 and iPTH displayed a moderate positive association ($r = 0.61$, $p < 0.05$), indicating that they affected bone and mineral metabolism. Interestingly, a strong negative relationship was found between FGF-23 and GFR ($r = -0.64$, $p < 0.05$), meaning that an increase in FGF-23 often goes with a decrease in GFR, which suggests that FGF-23 is a good marker of kidney function in advanced CKD. There was no strong link between FGF-23 and Calcium in the tested group.

Figure 2a indicates that there is a moderate positive correlation between FGF23 and iPTH levels (r=0.61, p=0.01). Both factors work together to disrupt mineral metabolism in ESRD patients. It confirms their function in supporting phosphate balance in the body. Figure 2b shows a positive association between FGF23 and Homocysteine (r=0.65, p=0.01). Figure 2c shows that FGF23 is negatively associated with GFR, indicating that FGF23 can reveal early signs of kidney problems. Figure 2d shows that there is a strong positive relationship between FGF23 and creatinine. Therefore, FGF23 is useful for detecting different stages of CKD.

Table 4. Mann-Whitney U Analysis of creatinine, calcium, Phosphorus, PTH, and GFR levels in groups

Parameters	Patient group (n=103)		p**
	Control (n=28)	Main (n=75)	
	X±SD	X±SD	
Crea 1	389.73±113.43	748.87±201.49	0.01*
Crea 2	515.46±209.16	697.6±191.98	0.01*
Crea 3	484.21±184.95	661.45±211.91	0.01*
Crea 4	489.18±204.52	646.11±204.98	0.01*

Ca 1	4.35±3.16	5.1±3.18	0.09
Ca 2	4.03±3.01	4.93±3.23	0.34
Ca 3	4.79±3.49	5.8±3.42	0.11
Ca 4	4.18±3.18	6.00±3.05	0.06
P 1	2.22±1.78	2.71±2.04	0.01*
P 2	1.90±1.46	3.04±2.59	0.01*
P 3	2.08±1.15	2.77±2.10	0.01*
P 4	2.27±1.55	2.90±2.27	0.01*
GFR 1	17.21±7.27	9.83±3.38	0.01*
GFR 2	13.50±7.24	10.60±4.42	0.04*
GFR 3	14.00±13.22	10.74±4.52	0.03*
GFR 4	13.57±13.28	10.75±3.73	0.04*
iPTH1	121.54±27.06	235.23±90.97	0.01*
iPTH 2	124.25±31.16	242.76±98.41	0.01*
iPTH 3	135.46±57.67	250.27±105.28	0.01*
iPTH 4	133.32±43.79	257.51±112.29	0.01*

Table 4 shows the results of the Mann-Whitney U test. Crea, GFR, and iPTH had significantly high levels at all-time points ($p < 0.05$). No differences in Ca levels were found between the groups at any time ($p > 0.05$). However, the main group had higher mean Ca levels. Figure 3 shows a visual comparison of the mean values of these biomarkers between control and main group.

DISCUSSION

There is a lack of studies that propose a correlation of FGF23, Homocysteine, and iPTH with other biochemistry laboratory parameters in ESRD HD patients. In this study, the correlation between FGF23, Hcy, and iPTH with P, Ca, and GFR is evaluated. The clinical and laboratory results of the participants are typical for ESRD, with challenges like anemia, inflammatory signs, mineral imbalances, and a higher risk of cardiovascular disease. FGF23 is a promising biomarker in CKD, especially regarding prognosis and morbidity in ESRD HD patients[6]. Electrolyte imbalances, such as hyperkalemia, hyperphosphatemia, and hypercalcemia, are usually the result of CKD-MBD, which have been associated with elevated levels of FGF23 and PTH[16].

Nakagawa and Komaba[9] proposed that elevated levels of PTH and FGF23 can cause multiple organ damage with advanced CKD. This study's results confirm this, as patients in the main group showed more serious disruptions in mineral metabolism (of phosphate and Calcium), PTH regulation, and renal function with high levels of FGF23. Finding that FGF23 and iPTH are positively related agrees with other research suggesting an influence of FGF23 on the parathyroid glands[11]. Because FGF23 is strongly related to P levels, it is clear that FGF23 helps regulate phosphate balance, and Almquist, Isaksson and Clyne[8] also noted its increased levels reflect the body's reaction to phosphate

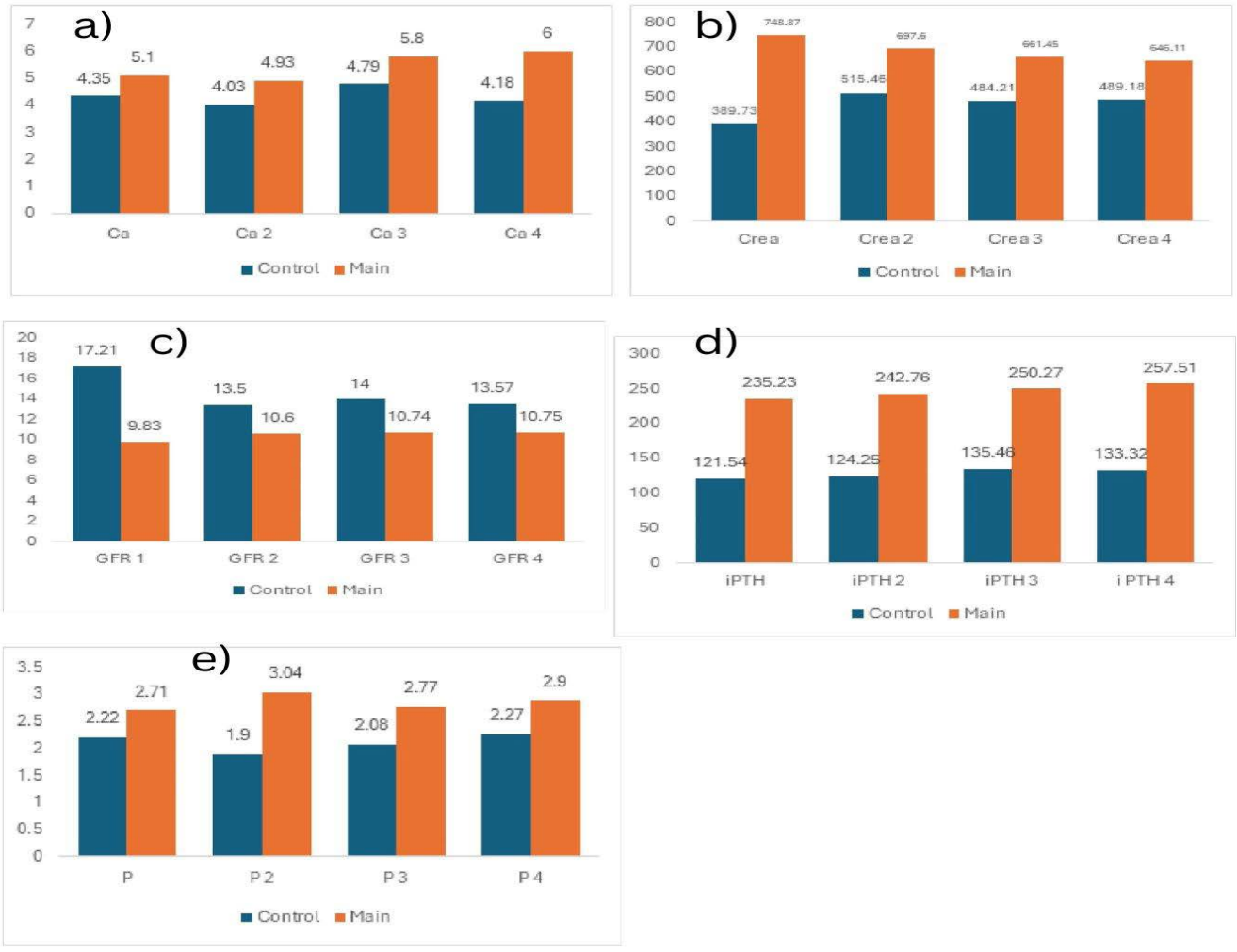

Figure 3. Comparison of creatinine, calcium, Phosphorus, PTH, and GFR levels between groups

accumulation. In this study, FGF23 and GFR revealed an inverse correlation, suggesting that rising FGF23 levels as kidney function declines can contribute to additional kidney and heart complications.

Zeng et al.[2] investigated FGF23 concentrations in 107 CKD patients and found an association with serum PTH and Ca levels in CKD HD patients. However, no correlation was found with P levels. Contrarily, this study found that patients with higher FGF23 and Hcy demonstrated markedly increased Crea, P, and iPTH levels alongside reduced GFR. These results reinforce the pathophysiological relevance of FGF23 and Hcy as markers of disease severity and potential contributors to CKD-related complications. This study also highlights the significant association between elevated levels of FGF23 and Hcy with impaired renal function and disrupted mineral metabolism in patients with advanced CKD. Monitoring these parameters may provide valuable insights into disease progression and guide more individualized treatment strategies. Similarly[17], showed Hcy as a predictive and prognostic marker for CKD HD patients. Hcy levels have been elevated in chronic renal failure patients.

Elevated PTH controlling synthesis of FGF23 in bones and decreased renal Klotho expression increases serum P load, which also induces the production of FGF23. Elevated FGF23 plasma levels are related to impaired renal functions as represented by higher levels of creatinine and estimated glomerular filtration rate (eGFR) < 60 mL/min/1.73 m^2 [18]. This study also found a negative correlation of FGF23 with eGFR.

This research urges that FGF23, iPTH, and Hcy should always be tracked along with regular testing in HD CKD patients. These findings suggest that FGF23 and Hcy serve not only as markers of disease progression but also as potential therapeutic targets. FGF23 concentration reduction can be one of the major targets for therapies in everyday follow-up clinical practice of HD CKD patients to achieve a goal of dietary phosphate restriction and using phosphate binders for keeping lower FGF23 concentrations. Non-calcium-containing phosphate binders, calcimimetics, and HDF are effective ways to decrease FGF23 levels for patients with HD[19]. A recent study by Yang, et al.[20] proposed a KHA-200 hemoperfusion device in HD patients and showed that targeting blood urea nitrogen, Crea, uric acid, potassium, P, PTH, and Hcy, significantly improved the patient's health. Therefore, other parameters focused in this study, including FGF23, should be focused in future treatment research.

Limitations: This work did not report on outcomes like heart issues, bone fractures, or death, which are typical problems linked to having too much FGF23 and Hcy. The study did not control for factors such as phosphate binders, vitamin D analogs, and changes in nutritional status, so these might have influenced the results.

Recommendations: Other studies are required to see if FGF23 and Hcy can truly cause damage and to check if their value predicts future outcomes for these patients. Further clinical trials should focus on using therapies to lower FGF23 and Hcy in patients to see if they can slow kidney damage and improve patient health. Since these findings have been demonstrated with FGF23 and Hcy, their inclusion in CKD management guidelines, with a focus on bone-mineral changes and cardiovascular risk, is advised.

CONCLUSIONS

High level of FGF23 and Hcy is associated with abnormal renal function and mineral imbalance. There is a strong correlation of FGF23 with increased Crea, P, and iPTH levels alongside reduced GFR. These parameters can be used to monitor the disease progression and as potential markers of disease severity in CKD HD patients. GFR and creatinine are not only follow-up markers for renal failure prediction, but together, these parameters can be used to guide strategies for prognostic issues and early treatment management in patients with CKD.

Authorship Contribution: All authors share equal effort contribution towards (1) substantial contributions to conception and design, acquisition, analysis and interpretation of data; (2) drafting the article and revising it critically for important intellectual content; and (3) final approval of the manuscript version to be published. Yes.

Potential Conflicts of Interest: None

Competing Interest: None

Acceptance Date: 26 September 2025

REFERENCE

1. K.S. Aman, A.S. Ahaithmi, Pattern of Cardio-Renal Syndrome Amongst End Stage Renal Disease Patients on Maintenance Hemodialysis, YJMHR, 10 2021.
2. D. Zeng, A. Zha, Y. Lei, et al., Correlation of Serum FGF23 and Chronic Kidney Disease-Mineral and Bone Abnormality Markers With Cardiac Structure Changes in Maintenance Hemodialysis Patients, Evid Based Complement Alternat Med, 2023 2023, 6243771.
3. C. Rodelo-Haad, M.E. Rodríguez-Ortiz, A. Martin-Malo, et al., Phosphate control in reducing FGF23 levels in hemodialysis patients, PLoS One, 13 2018, e0201537.
4. A. Bouma-de Krijger, C.L. de Roij van Zuijdewijn, M.J. Nubé, et al., Change in FGF23 concentration over time and its association with all-cause mortality in patients treated with haemodialysis or haemodiafiltration, Clin Kidney J, 14 2021, 891-7.
5. E. Memmos, A. Papagianni, New insights into the role of FGF-23 and Klotho in cardiovascular disease in chronic kidney disease patients, Curr Vasc Pharmacol, 19 2021, 55-62.
6. S. Vázquez-Sánchez, J. Poveda, J.A. Navarro-García, et al., An overview of FGF-23 as a novel candidate biomarker of cardiovascular risk, Front Phys, 12 2021, 632260.
7. A.C. Heijboer, E. Cavalier, The measurement and interpretation of fibroblast growth factor 23 (FGF23) concentrations, Calcif Tissue Int, 112 2023, 258-70.
8. M. Almquist, E. Isaksson, N. Clyne, The treatment of renal hyperparathyroidism, Endocr Relat Cancer, 27 2020, R21-R34.
9. Y. Nakagawa, H. Komaba, Roles of parathyroid hormone and fibroblast growth factor 23 in advanced chronic kidney disease, Endocrinol Metab, 39 2024, 407-15.
10. W. Chen, J. Feng, P. Ji, et al., Association of hyperhomocysteinemia and chronic kidney disease in the general population: A systematic review and meta-analysis, BMC nephrology, 24 2023, 247.
11. H. Komaba, Roles of PTH and FGF23 in kidney failure: a focus on nonclassical effects, Clin Exp Nephrol, 27 2023, 395-401.
12. A.S. Levey, L.A. Stevens, C.H. Schmid, et al., A new equation to estimate glomerular filtration rate, Ann Intern Med, 150 2009, 604-12.
13. P. Rout, I. Jialal, Hyperphosphatemia, StatPearls [Internet], StatPearls Publishing2023.
14. X. Zhou, Y. Guo, Y. Luo, The optimal range of serum intact parathyroid hormone for a lower risk of mortality in the incident hemodialysis patients, Ren Fail, 43 2021, 599-605.
15. C. Heybeli, S.G. Tan, R. KAZANCIOĞLU, et al., Prevalence of Electrolyte Impairments Among Outpatient Elderly Subjects, 2022.

16. S. Yamada, T. Nakano, Role of chronic kidney disease (CKD)–mineral and bone disorder (MBD) in the pathogenesis of cardiovascular disease in CKD, J Atheroscler Thromb, 30 2023, 835-50.
17. M.P. Kruglova, A.V. Ivanov, A.N. Fedoseev, et al., The diagnostic and prognostic roles played by homocysteine and other aminothiols in patients with chronic kidney disease, Journal Clin Med, 12 2023, 5653.
18. Y. Kuwatsuru, T. Hirano, R. Wakabayashi, et al., Changes in renal function over time in outpatients with eGFR≥ 30 mL/min/1.73 m2: implication for timing of renal function testing before contrast-enhanced CT imaging, Jpn J Radiol, 41 2023, 994-1006.
19. K. Takkavatakarn, T. Wuttiputhanun, J. Phannajit, et al., Effectiveness of fibroblast growth factor 23 lowering modalities in chronic kidney disease: a systematic review and meta-analysis, Int Urol Nephrol, 2022, 1-13.
20. Q. Yang, G. Liu, M. Guo, et al., The clinical efficacy evaluation of the KHA-200 hemoperfusion device in the treatment of end-stage renal disease patients undergoing blood purification therapy, Kidney Diseases, 11 2025, 270-82.