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The role of calcium-phosphorus metabolism in hemodialysis patients in Baquba teaching hospital: clinical implications for bone health

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Abstract

Chronic kidney disease-mineral and bone disorder (CKD-MBD) is a serious complication among individuals who are receiving hemodialysis, and the dysregulation of calcium-phosphorus metabolism is one of the key pathophysiological mechanisms underlying outcomes related to the health of the bones. To investigate the pattern of calcium-phosphorus metabolism in hemodialysis patients of Baquba Teaching Hospital and identify their clinical impact on management of bone health. The study was a cross-sectional analytical study of 180 incidences of hemodialysis patients in the Baquba teaching hospital between January 2025 and June 2025. They were measured through serum calcium, phosphorous, intact parathyroid hormone (iPTH), alkaline phosphatase, and 25-hydroxyvitamin D. Dual-energy X-ray absorptiometry (DEXA) was the method used in measuring bone mineral density. The analysis was done by a statistical analysis with SPSS 28.0. The study population had a mean age of 52.3 +/- 14.2 years old, and their gender ratio was 58.9 percent male. Sixty seven and eight percent of patients had hyperphosphatemia and hypocalcemia respectively. Secondary hyperparathyroidism was noted in 73.3 percent of the patients. A high level of correlation was identified between the phosphorus observed and the bone mineral density ($r = -0.542$, $p < 0.001$). Patients having an ideal calcium- phosphorus product (<55 mg 2 / dL 2) exhibited better results in bone healthy when compared to those with higher levels. Disorders of calcium-phosphorus metabolism are extremely high in the prevalence of patients on hemodialysis and they have a profound effect on the bones. Multifaceted control methods that aim at managing these metabolic abnormalities are crucial in enhancing patient outcomes.

Keywords: Hemodialysis, Calcium-phosphorus metabolism, Bone health, Chronic kidney disease, Mineral bone disorder.

1. Introduction

Chronic kidney disease (CKD) is present in about 850 million people and end-stage renal disease (ESRD) and the need to receive renal replacement therapy is most advanced stage of this disease[1]. The most common type of renal replacement therapy is hemodialysis; more than 2.5 million patients worldwide are under this type of treatment[2]. Complicated pathophysiology of CKD prompts to the occurrence of numerous complications, and chronic kidney disease-mineral and bone disorder (CKD-MBD) is one of the critical issues in clinical care[3].

The spectrum of disorders entailed by CKD-MBD comprises calcium, phosphorus, parathyroid hormone (PTH), and vitamin D metabolic disorders, culminating with the occurrence of bone and cardiovascular complications[4].At the early stages of CKD development, the abnormalities related to calcium-phosphorus homeostasis are already characterized by abnormal values[5]. Such metabolic abnormalities are further aggravated in people on hemodialysis, where the process of dialysis has the potential of disrupting the balance of these minerals via diffusion and convection across a dialysis membrane[6].

Kidney plays a very important role in calcium-phosphorus homeostasis and the following are some of the mechanisms. In the kidney, about 70 percent of filtered phosphorus is reabsorbed by the proximal tubule which is regulated by fibroblast growth factor 23 (FGF-23) and PTH[7].It also produces the active form of vitamin D, calcitriol (1,25-dihydroxyvitamin D 3), that enhances calcium uptake in the intestine and binding to bone minerals[8].As the kidney fails, all these regulatory mechanisms fail, leading to phosphorus retention,

The pathophysiological pathway of CKD-MBD is initiated by the retention of phosphorus and inhibition of calcitriol production promoting the secretion of parathyroid hormone (PTH)[10].At first,

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such compensatory hyperparathyroidism allows maintaining of normal calcium levels in serum, but eventually results in the development of bone disease with high turnover, bone pain, and increase halts F of fracture[11]. Moreover, when used early in CKD, this increase of the FGF-23 level also leads to phosphaturia and inhibits the synthesis of calcitriol, the beginning of the vicious circle of disturbance of the mineral metabolism[12].

An abnormal calcium-phosphorus metabolism in hemodialysis patients has a wider clinical impact not confined to bone. There is a strong correlation between high levels of calcium-phosphorus product and cardiovascular complications such as vascular calcification and high risk of mortality[13]. To reduce such complications K/DOQI recommends that serum phosphorus should be maintained at a range of 3.5-5.5 mg/dL, serum calcium 8.4-9.5 mg/dL and the calcium-phosphorus product should be less than 55 mg 2 /dL 2[14,31].

Even with the improved knowledge concerning CKD-MBD pathophysiology, there is no optimal management still. The available modalities are dietary phosphorus restriction, phosphate binders, vitamin D analogs, and calcimimetic agents[15]; designed as individualized treatment regimens depending on multifaceted biochemical observations[16]. Cases of CKD are on the rise in Iraq, and they are caused by environmental conditions and endemic nephropathy[17]. The Baquba Teaching Hospital is a large referral center of patients undergoing hemodialysis in the Diyala Province, and it offers a good location to examine CKD-MBD trends among such patients. It is paramount to understand the peculiarities of calcium-phosphorus metabolism in patients of hemodialysis in Iraq with the aim of implementing specific therapeutic strategies and achieving better patient outcomes.

The study aim to holistically assess the trend among calcium-phosphorus metabolism in Baquba teaching hospital hemodialysis patients and then establish the clinical landscape and relevance of the same to bone health management.

Our aim will be to analyze the relationships between different biomarkers and the outcomes of bone health to add to the existing evidence of the need to individually approach the therapy of CKD-MBD.

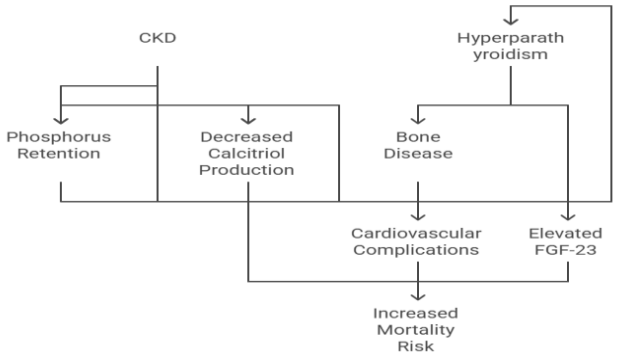

Figure 1. Pathophysiological pathways linking chronic kidney disease (CKD) to increased mortality risk via mineral and bone disorders (designed by the researcher).

2. Methodology

2.1 Study design and setting

The study was a cross- sectional analytical study carried out in the Hemodialysis Unit at the Baquba Teaching Hospital, Diyala Province, Iraq, within the period between January of the year 2025 to June 2025. The Ethics Committee of Baquba Teaching Hospital approved the study and was done in compliance with the Declaration of Helsinki. All of the participants signed the informed consent.

2.2 Study population

The patients in the study comprised of 180, who were under maintenance hemodialysis and had end stage renal disease. Criteria to include: (1) age was >18 years old, (2) was on hemodialysis treatment of at least 6 months, (3) the patient was in a stable clinical condition, and (4) the agreement to participate in the study. These exclusion criteria were (1) active malignancy, (2) pregnancy, (3) prior parathyroidectomy, (4) severe liver disease, (5) use of medications that affect bone metabolism with exception of CKD-MBD drugs, and (6) acute illness in the last month.

2.3. Data collection

A structured questionnaire was used to obtain demographic and clinical data such as age, gender, years on hemodialysis, the chief cause of kidney disease and medications that respondents were taking. Kt/V ratio that was calculated as pre-dialysis urea/pre-dialysis urea compared to post-dialysis

urea was used to measure the adequacy of hemodialysis.

2.4 Laboratory measurements

The blood samples were taken at the moment just before the mid-week session of the hemodialysis in a fasting state at night. Quantification of serum calcium, phosphorus, alkaline phosphatase, albumin, and creatinine were via normal automated chemistry analyzes. The level of intact parathyroid hormones (iPTH) was measured through the process of electrochemiluminescence immunoassay. The level of 25-hydroxyvitamin D [25(OH)D] was measured through liquid chromatography-tandem mass spectrometry. Laboratory measurements of all the samples were conducted in the central laboratory Department of the Baquba Teaching Hospital that is involved in the external quality assurance programmes.

2.5 Bone mineral density assessment

The test was conducted with the help of dual-energy X-ray absorptiometry (DEXA) of bone mineral density (BMD) at the lumbar spine (L1-L4) and the femoral neck. The t-scores were based on a population of the young healthy adults. Osteoporosis was considered to be a T-score of -2.5 or less and osteopenia as -1.0 and -2.5 and normal bone density as a T-score of -1.0 or more.

2.6 Statistical analysis

The statistical analysis was conducted with the help of SPSS version 28.0 (IBM Corp., Armonk, NY, USA). Continuous data were reported as mean +_standard deviation in case they were normally distributed and as median (interquartile range) in case of non-normally distributed data. Frequencies and percentages were reported to categorical variables. The relationships between the continuous variables were determined using Pearson correlation coefficient.

Two-sample tests were performed using independent t statistic or Mann-Whitney U statistic and multiple groups using one-way ANOVA or Kruskal-Wallis test. Multiple linear regression was also conducted in order to determine the independent predictors of bone mineral density. The statistical significance was set to a p-value < 0.05.

2.7. Ethical considerations

This study was accepted by the Institutional Review Board of Baquba Teaching Hospital. Each of the participants signed a written informed consent prior to enrollment. During the research patient confidentiality was observed, and any data were anonymized to analyze them.

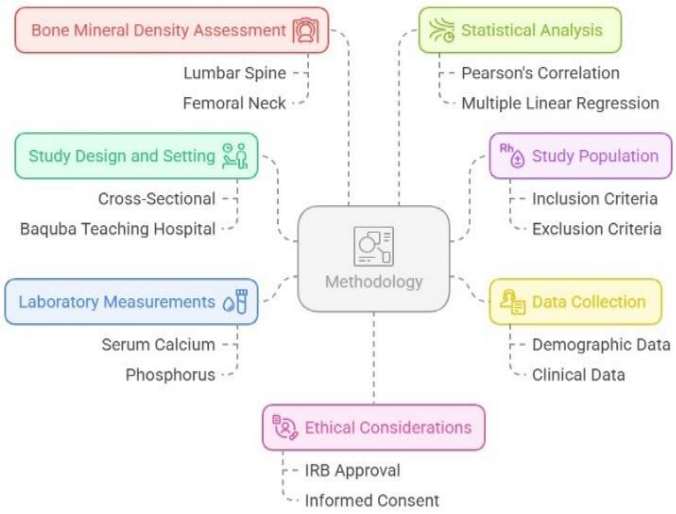

Figure 2. Methodological framework of the study on bone mineral density and biochemical markers (designed by the researcher).

3. Results

3.1. Parent characteristics

One hundred and eighty hemodialysis patients were used in the research. The age was 52.3 +/- 14.2 years, whereas there were 106 (58.9%) male and 74 (41.1%) female patients. Hemodialysis had the median duration of 36 months (range: 6-120 months).

Diabetic nephropathy, hypertensive nephrosclerosis and polycyclic kidney, glomerulonephritis and other causes were the major causes of kidney diseases contributing 45.6%, 23.3%, 8.9%, 12.2 and 10.0 percent, respectively.

The average Kt/V was 1.421.42 0.28 showing that there was sufficient dialysis in most of the patients.

3.2 Biochemical parameters

Table 1: Biochemical parameters of hemodialysis patients

Parameter	Mean ± SD	Normal Range	Outside Normal Range, n (%)
Serum Calcium (mg/dL)	8.2 ± 1.1	8.4-10.2	108 (60.0%)
Serum Phosphorus (mg/dL)	6.1 ± 2.3	2.5-4.5	122 (67.8%)
Intact PTH (pg/mL)	485 ± 312	15-65	132 (73.3%)
Alkaline Phosphatase (U/L)	142 ± 89	44-147	89 (49.4%)
25(OH)D (ng/mL)	18.2 ± 8.7	30-100	156 (86.7%)
Ca × P Product (mg^2/dL^2)	49.8 ± 18.6	<55	67 (37.2%)

The incidence of hyperphosphatemia (phosphorus > 5.5 mg/dL) was 122 (67.8%), hypocalcemia (calcium < 8.4 mg/dL) occurred in 82 (45.6%). Secondary hyperparathyroidism iPTH > 300 pg / mL was found in 132 patients (73.3%). The 156 patients (86.7%) had vitamin D deficiency (25(OH)D < 30 ng/mL).

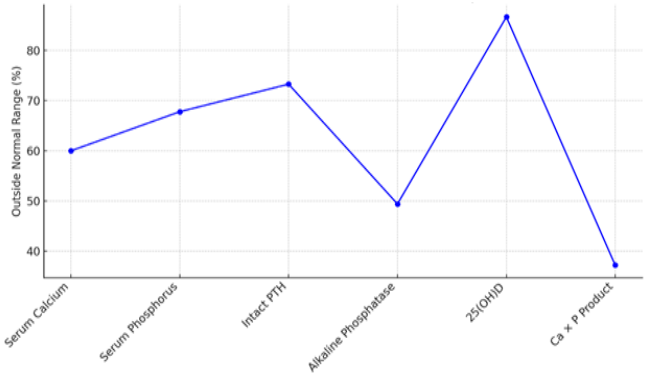

Figure 3. Patients with abnormal biochemical parameters (%).

3.3 Bone mineral density results

Table 2: Bone mineral density assessment

Site	T-Score (Mean ± SD)	Normal, n (%)	Osteopenia, n (%)	Osteoporosis, n (%)
Lumbar Spine	-2.1 ± 1.3	34 (18.9%)	89 (49.4%)	57 (31.7%)
Femoral Neck	-1.9 ± 1.2	42 (23.3%)	94 (52.2%)	44 (24.4%)

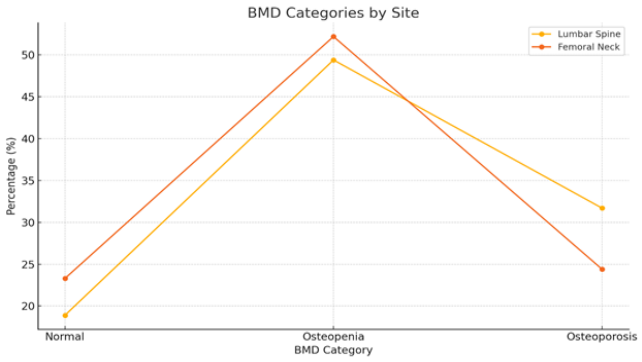

Figure 4. Comparison of bone mineral density categories by anatomical site

Patients had osteoporosis in 57 (31.7%) of them at the lumbar spine, and 44 (24.4%) of them at the femoral neck. Osteopenia was identified at the lumbar spine in 89 patients (49.4%) and on the femoral neck in 94 patients (52.2%).

3.4. Correlations between biochemical parameters and bone health

Table 3: Correlation analysis between biochemical parameters and bone mineral density

Parameter	Lumbar Spine T-Score	Femoral Neck T-Score
Serum Calcium	r = 0.234, p = 0.002	r = 0.198, p = 0.008
Serum Phosphorus	r = -0.542, p < 0.001	r = -0.487, p < 0.001
Intact PTH	r = -0.378, p < 0.001	r = -0.334, p < 0.001
Alkaline Phosphatase	r = -0.289, p < 0.001	r = -0.267, p < 0.001
25(OH)D	r = 0.312, p < 0.001	r = 0.298, p < 0.001
Ca × P Product	r = -0.456, p < 0.001	r = -0.423, p < 0.001

The results indicated strong negative correlations between serum phosphorus and bone mineral density including the lumbar spine ($r = -0.542$, $p < 0.001$) and femoral neck ($r = -0.487$, $p < 0.001$). There also were significant negative correlations between intact PTH and bone mineral density.

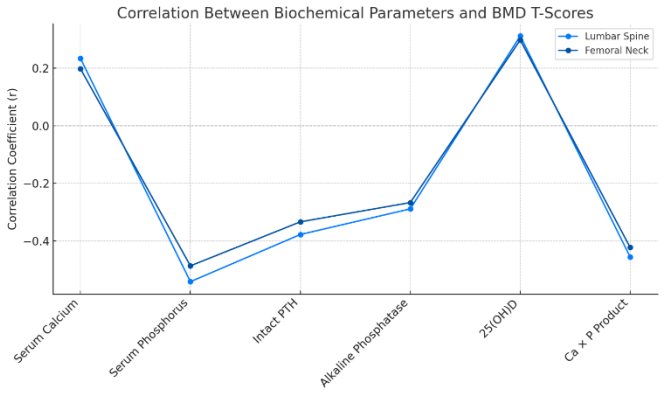

Figure 5. Correlation between biochemical parameters and t-scores at lumbar spine and femoral neck.

3.5 Impact of calcium-phosphorus product on bone health

Table 4: Bone Mineral Density by Calcium-Phosphorus Product Groups

Group	Lumbar Spine T-Score	Femoral Neck T-Score	Osteoporosis, n (%)
Group 1 (Ca × P < 45)	-1.6 ± 1.1	-1.4 ± 1.0	12 (17.9%)
Group 2 (Ca × P 45-55)	-2.2 ± 1.2	-1.9 ± 1.1	18 (39.1%)
Group 3 (Ca × P > 55)	-2.8 ± 1.4	-2.4 ± 1.3	32 (47.8%)
p-value	< 0.001	< 0.001	< 0.001

Patients with optimal calcium-phosphorus product levels (<45 mg^2/dL^2) demonstrated significantly better bone mineral density compared to those with elevated levels.

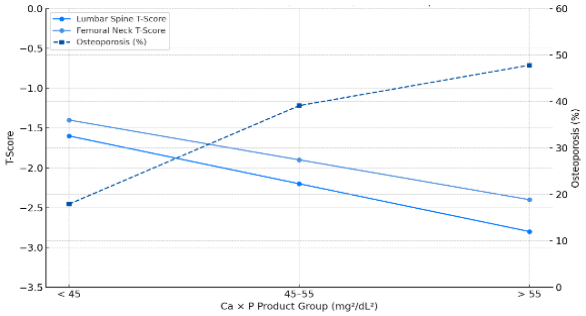

Figure 6. Association between calcium-phosphorus product levels, bone mineral density t-scores, and osteoporosis prevalence.

3.6 Multivariate analysis

Table 5: Multiple linear regression analysis for predictors of lumbar spine T-score

Variable	β Coefficient	95% CI	p-value
Age	-0.021	-0.035 to -0.007	0.003
Duration of HD	-0.012	-0.019 to -0.005	0.001
Serum Phosphorus	-0.287	-0.372 to -0.202	< 0.001
Intact PTH	-0.001	-0.002 to -0.0004	0.002
25(OH)D	0.034	0.018 to 0.050	< 0.001

The model accounted to 58.7 percent of the variance in lumbar spine T-score ($R^2 = 0.587$, $p < 0.001$). Serum phosphorus was the significant negative predictor, intact PTH and the duration of hemodialysis were significant negative predictors, and the 25(OH)D was positive predictors of the bone mineral density.

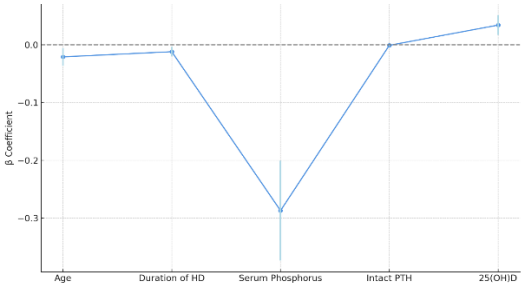

Figure 7. Regression coefficients and 95% confidence intervals for predictors of lumbar spine T-score.

3.7 Clinical outcomes

Table 6: Clinical outcomes by bone mineral density status

Outcome	Normal BMD (n=34)	Osteopenia (n=89)	Osteoporosis (n=57)	p-value
Bone Pain, n (%)	8 (23.5%)	42 (47.2%)	38 (66.7%)	< 0.001
Fracture History, n (%)	1 (2.9%)	8 (9.0%)	12 (21.1%)	0.012
Hospitalizations /year	1.2 ± 0.8	1.8 ± 1.2	2.4 ± 1.6	< 0.001

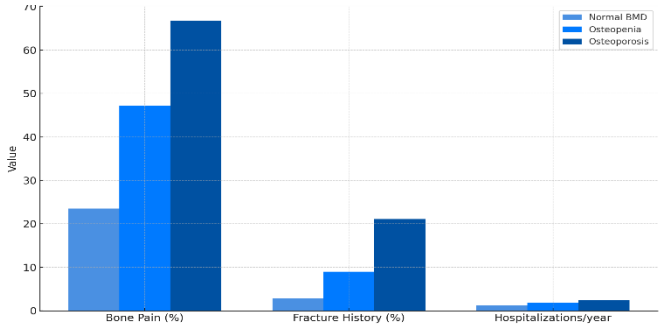

Figure 8. Clinical outcomes across bone mineral density categories

Osteoporotic patients showed a considerable increase in the occurrence of bone pain (66.7% vs 23.5%, $p < 0.001$), and fracture history (21.1% vs 2.9%, $p = 0.012$) as compared to those with normal bone mineral density.

4. Discussion

In our study of hemodialysis patients (N = 180) at Baquba Teaching Hospital, profound abnormalities were identified about calcium-phosphorus metabolism, and its grave consequences on bones.

The results indicate that CKD-MBD is extremely common among this group of patients with 67.8 percent of patients having hyperphosphatemia, and 73.3 percent displaying secondary hyperparathyroidism. The findings are consistent with recently published evidence in other countries and points out unique challenges Iraqi hemodialysis patients face.

The prevalence of hyperphosphatemia, taken as 67.8 percent in this population, compares well to international studies, where hyperphosphatemia is 60-70 percent in hemodialysis patients [18]. Our study has higher prevalence rates of hyperphosphatemia than some international studies and this can be attributed to the consumption of foods, the use of phosphate binders or the sufficiency of dialysis. Our study had average serum phosphorus of 6.1 mg/dl +/- 2.3 which is greater than the K/DOQI goal of 3.5-5.5 mg/dl and indicates that phosphorus is not being controlled. The incidence of hypocalcemia is high (45.69) in our cohort as compared with other populations. The relationship between hypocalcemia and secondary hyperparathyroidism is also well represented in our study where 73.3 percent of the patients had a raised level of iPTH [19].

Our rates of lack of vitamin D (86.7%) are extremely high and this is considerably higher than the reports in most studies that are being conducted across different parts of the world [20]. Such studies have indicated different levels of vitamin D deficiency occurring among patients under hemodialysis in various countries [21]. Our personal figure is bigger and this could be due to lack of access to sunlight, diet or inefficient supplementation procedures. This finding is of interest particularly with the premised uses of vitamin D on the bones and the immune systems. The results of the bone mineral density are of concern considering that 31.7 percent of the patients have osteoporosis in the lumbar spine and 24.4 percent in the neck of femur. These rates are compliant with international studies which revealed that there is high prevalence of osteoporosis in patients on hemodialysis [22]. The results of the close negative relationship between serum phosphorus and bone mineral density statistics ab -0.542 show the very significant role of phosphorus control in the bone.

The finding of correlation between calcium-phosphorus product and bone mineral density is reported in our study that has been of paramount clinical significance. Patients who maintained the best calcium-phosphorus product (<45 mg 2/dL 2) results were significantly improved in terms of bone

mineral density as only 17.09 percent of patients were recorded as being osteoporotic when compared to 47.8 percent of those with high results (>55 mg 2/dL 2). This finding supports those recommendations that suggest decreasing calcium-phosphorus product when it is advanced [23]. Our multivariate analysis showed that serum phosphorus level was the best predictor of bone mineral density and it was 58.7 percent of variance. This finding concurs with literature that indicate that hyperphosphatemia is independently linked to bone loss among hemodialysis patients [24]. Our findings that show an inverse correlation between PTH and BMD favor the evidence that secondary hyperparathyroidism is considered a risk factor to the integrity of the bones in CKD-MBD. Our study has observed protective impact of cadaveric levels of 25(OH)D on the bone mineral density, which is comparable with findings of other studies that reveal positive results concerning bone mineral density with vitamin D supplementation of hemodialysis patients [25]. However, it is still subject to disputes as to which levels of vitamin D are most ideal under such circumstances of hemodialysis as some studies indicate a higher cut-off especially in hemodialysis patients unlike those in the general population.

Clinical importance of CKD-MBD can be substantiated by the fact that incidence of bone pain (66.7%) and a history of fracture (21.1%) was also high in patients with osteoporosis. These findings are in agreement with studies that reported high incidence of fractures among patients under hemodialysis as a result of an abnormal mineral metabolism [26]. The importance of our research finding in which poor bone health and increased hospitalization are related proves the health care implications on a larger scale when it comes to poor management of CKD-MBD. The recent updates on the treatment of CKD-MBD include the prevention of binders to phosphate, which does not include calcium or selective activators of the vitamin D receptor [27]. Other studies have been effective in the treatment of CKD-MBD complications and have evidently seen the advantage of a number of treatment methods [28].

This tendency to develop certain abnormalities and their more prevalent occurrence in our Iraqi population may have a fraction of causality in the environmental peculiarities of this region. More severe aberrations in mineral metabolism may be due to endemic nephropathy that occurs in certain regions of Iraq, which might be as a result of environmental pollutants or water quality issues [29]. In addition, the cultural eating habits and access to certain drugs may also influence the observed patterns [30]. The present study has a number of limitations. The cross-sectional study design will not enable testing, and the study population is not varied, or it could affect applicability. Also, our measurements have not involved levels of FGF-23 that play a big role in phosphorus metabolism. Future directions of research include longitudinal studies with FGF-23 measurements, not to mention intervention studies involving the comparison of many therapeutic approaches.

Conclusion

and developing them are more able to create an environment of trust and cooperation between management and employees. There is a statistically significant correlation between SL and green HR practices, meaning that the SL style that focuses on serving and empowering others plays a significant role in promoting green HR practices within the organization. In other words, leaders who adopt a SL approach and who put employees' needs and aspirations first are more able to encourage and implement green HR practices more effectively. There is a statistically significant correlation between mutual trust between management and employees and green HR practices, meaning that mutual trust between management and employees plays a significant role in promoting green HR practices in the organization. In other words, the more trust and cooperation there is between management and employees, the more effective it will be to implement green HR practices. There is a statistically significant effect of SL on GHRs practices through the mediating role of mutual trust between management and This This thorough investigation shows that the rate of the calcium-phosphorus metabolism disorders is high among hemodialysis patients at Baquba Teaching Hospital which is accompanied by serious consequences in terms of bone health. The results indicate that 67.8 percent of patients are

hyperphosphatemia, and 73.3 percent of patients are secondary hyperparathyroidism, and 86.7 percent of patients are vitamin D insufficient. These metabolic disorders are directly related to bone mineral density poor results, and 31.7 percent of the patients show osteoporosis at the lumbar spines. The study shows that the level of serum phosphorus is the most, by far, significant predictor of bone mineral density, and it further illustrates the paramount need of phosphorus control in the management of CKD-MBD. Patients who had an ideal level of calcium-phosphorus product had much improved bone health outcomes and validate the present recommendations of keeping calcium-phosphorus product under 55 mg 2 /dL 2. The clinical consequences of these results are significant and patients with osteoporosis experience additional incidence of bone pain, a history of fractures, and hospitalization. This highlights the importance of holistic approaches to management which must cover all the areas of mineral metabolism disorders. The main recommendations that can be outlined based on the findings of this paper are: (1) a radical phosphorus-control regime integrating dietary counseling, proper dialysis, and a proper phosphate binder regimen; (2) improvement of the vitamin D supplementation system where most people are deficient; (3) periodic assessment of the bone mineral density that can determine a course of action in terms of therapy; and (4) the creation of a custom treatment plan depending on the thorough chemical examination. The results of the present study make part of the evidence base that proves the necessity of individual approaches to managing CKD-MBD. Future studies ought to be done on both longitudinal studies of the efficacy of various therapeutic interventions, and integration of new biomarkers, the most promising of which is probably FGF-23 into clinical practice. Managing CKD -MBD in hemodialysis patient needs to be multidisciplinary and involves nephrologists, endocrinologists, dietitians and pharmacists. Monitoring, patient education and the need to follow evidence based guidelines provide a key to the optimal outcomes and thus, decreasing the burden of bone disease in this vulnerable population.

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Author Contributions

Noor Dhehyaa Ibrahim: Project administration, methodology, data collection, analysis, writing, and conceptualization.

Conflict of Interest

The author has no conflict of interests.

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