Published in final edited form as:

J Ren Nutr. 2007 September ; 17(5): 305–313. doi:10.1053/j.jrn.2007.06.005.

Chronic Kidney Disease Mineral Bone Disorder (CKD-MBD) and Health-Related Quality of Life among Incident ESRD Patients

Kirsten L. Johansen, MD^{1,2} and Glenn M. Chertow, MDMPH¹

¹ Department of Medicine, Division of Nephrology, University of California, San Francisco

² Nephrology Section, San Francisco VA Medical Center

Abstract

Objective—To determine the extent to which chronic kidney disease mineral bone disorder (CKD-MBD) is associated with HRQOL among incident dialysis patients.

Design—Cross-sectional analysis

Setting—United States Renal Data System Dialysis Morbidity and Mortality Study (DMMS), Wave 2

Patients—2590 adult participants in DMMS Wave 2 for whom quality of life and laboratory data were available

Methods—We stratified patients according to their serum concentrations of phosphorus, calcium, and parathyroid hormone (PTH) and compared HRQOL as a function of these indicators in analyses adjusted for demographic, clinical, and other laboratory variables.

Main Outcome Measures—Physical Component Summary (PCS) and Mental Component Summary (MCS) scores and the Symptom score of the KDQOL.

Results—Both high and low serum phosphorus concentrations were associated with lower PCS (−1.25 to −1.48 points compared to the reference category), as was low PTH (−1.49 points). Low serum phosphorus was associated with more severe symptoms of kidney disease (−3.88 points) but there were no associations between high phosphorus or either extreme of PTH and the Symptom score. Serum calcium concentration and the calcium × phosphorus product were unassociated with PCS or Symptom scores. There were no associations among phosphorus, calcium, or PTH and MCS. Analyses simultaneously controlling for serum phosphorus, calcium, and PTH showed similar results.

Conclusions—High and low serum phosphorus and low PTH are associated with slightly poorer self-reported physical functioning. Clinical trials will be necessary to determine whether and to what extent improvement in health status may occur with correction of selected disorders of mineral metabolism.

Corresponding author contact information: Kirsten L. Johansen, MD, Nephrology Section, 111J, San Francisco VA Medical Center, 4150 Clement Street, San Francisco, CA 94121, Telephone: 415-221-4810, ext. 3598, Fax: 415-750-6949, kirsten.johansen@ucsf.edu.

Potential conflicts of interest: Dr. Johansen and Dr. Chertow have received research support from Amgen, Inc. Dr. Johansen has received research support from Abbott Laboratories. Dr. Chertow has received research support from Genzyme, Inc. and served on advisory boards for Amgen, Inc. and Genzyme, Inc.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Keywords

end-stage renal disease (ESRD); chronic kidney disease mineral bone disorder (CKD-MBD); quality of life; health status

Introduction

Patients with end-stage renal disease (ESRD) requiring dialysis have low health-related quality of life in the physical functioning domains when compared to individuals of similar age distribution without kidney disease.^{1–6} Thus, there has been considerable interest in elucidating the determinants of poor self-reported physical functioning. Demographic factors such as age, race, and sex are associated with differences in self-reported physical functioning in this population,^{2–4, 7} but these are not potential targets for intervention. The anemia that accompanies ESRD is a potentially-modifiable factor, and the advent of treatment with recombinant erythropoietin resulted in higher hemoglobin concentrations that were associated with dramatic improvements in health-related quality of life.⁸ However, it is less clear that increases in hemoglobin beyond current targets (generally 11 to 12–13 g/dL) will result in any material improvement in health-related quality of life.⁹ Moreover, there is some evidence to suggest that strategies aimed to normalize hemoglobin concentrations could be harmful.^{10, 11}

Therefore, other potential strategies to optimize health-related quality of life in the ESRD population must be explored. A large randomized trial comparing higher dialysis dose (expressed as equilibrated Kt/V_{urea}) with the standard recommended dose showed that higher dialysis dose within the current thrice-weekly paradigm resulted in minimal improvements in health status.¹² Recent studies have shown that high serum phosphorus and parathyroid hormone levels are associated with increased mortality and cause-specific hospitalization among hemodialysis patients.^{13, 14} Thus, it is plausible that disordered mineral metabolism could be associated with reduced health-related quality of life and could be modifiable. However, the association among disorders of mineral metabolism and health status has received little attention. To test the hypothesis that selected disorders of mineral metabolism were associated with health status, we evaluated data from the United States Renal Data System (USRDS). We hypothesized that high and low serum phosphorus concentrations; high and low parathyroid hormone concentrations; and hypercalcemia would be associated with lower self-reported physical functioning and worse symptoms related to kidney disease. We hypothesized that these parameters of mineral metabolism would not be associated with self-reported mental health.

Subjects and Methods

Study Population

Data were obtained from the Dialysis Morbidity and Mortality Study (DMMS) Wave 2 Standard Analytic File of the USRDS. The DMMS was an observational study in which data on demographics, comorbidity, laboratory values, treatment, socioeconomic factors, and insurance were collected for a random sample of US dialysis patients, using dialysis records. Wave 2 was a prospective study of incident hemodialysis and peritoneal dialysis patients for 1996 and some incident patients entering the ESRD program in the first part of the 1997 calendar year.¹⁵ Patients were enrolled in the study and data collected 60 days after initiation of regular dialysis. The current analyses were approved by the Committee on Human Research of the University of California, San Francisco.

Predictor Variables

Predictor variables included serum phosphorus, calcium, parathyroid hormone (PTH) concentrations, and the product of serum calcium and phosphorus. These values were obtained by review of the dialysis chart. The value closest to the study start date (from 3 months before to one month after) was entered. Because of suspected data entry errors, serum calcium or phosphorus concentrations were set to missing under the following conditions: phosphorus greater than 20 mg/dL (5.17 mmol/L, n=5), and calcium <4 mg/dL (1.0 mmol/L, n=1) or >15 mg/dL (12 mmol/L, n=8). Because relations among predictor and outcome variables were not hypothesized to be linear, predictor variables were divided *a priori* into categories that included approximately 10–50% of patients and that we considered clinically meaningful. Specifically, phosphorus was divided into the following categories: missing, <1.13 mmol/L, 1.13 to <1.78 mmol/L, 1.78 to <2.42 mmol/L, and ≥ 2.42 mmol/L (<3.5 mg/dL, 3.5 to <5.5 mg/dL, 5.5 to <7.5 mg/dL, and ≥ 7.5 mg/dL). Adjusted serum calcium concentrations were adjusted for low serum albumin concentration according to the following equation: adjusted calcium = calcium + (4.0 – serum albumin) * 0.8.¹⁶ Serum calcium was then divided into categories, including missing, <1.875 mmol/L, 1.875 to <2.215 mmol/L, 2.215 to <2.375 mmol/L, and ≥ 2.375 mmol/L (<7.5 mg/dL, 7.5 to <8.5 mg/dL, 8.5 to <9.5 mg/dL, and ≥ 9.5 mg/dL). Calcium $\times$ phosphorus product was divided into the following categories: <35, 35 to <45, 45 to <55, 55 to <70, and ≥ 70 . Finally, PTH was divided into: missing, <150 ng/L, 150 to <300 ng/L, 300 to <600 ng/L, and ≥ 600 ng/L (<150 pg/ml, 150 to <300 pg/ml, 300 to <600 pg/ml, and ≥ 600 pg/ml).

Health-Related Quality of Life

The Kidney Disease Quality of Life (KDQOL) instrument was given to all patients in the DMMS Wave 2 at the time of study enrollment as part of the Dialysis Patient Questionnaire.¹⁷ Patients were asked to complete the questionnaire on their own in the dialysis unit, if possible. If assistance was needed, dialysis unit staff members were encouraged to provide it. If dialysis unit staff were unavailable, patients needing assistance were encouraged to seek help from a capable family member, preferably at the dialysis unit but, if necessary, at home.¹⁵

The KDQOL includes 36 items known as the RAND-36 that are identical to those included in the Medical Outcomes Study 36-Item Short Form, or SF-36. These items were designed for use across diverse populations and healthcare settings and include eight scales of self-reported health status: physical functioning (PF), role functioning/physical (RP), bodily pain (BP), general health (GH), vitality (VT), social functioning (SF), role functioning/emotional (RE), and mental health (MH).¹⁸ These scales are scored from 0 to 100, with higher scores indicating better function. Two normalized scores representing overall physical (Physical Component Summary, PCS) and mental (Mental Component Summary, MCS) functioning are calculated using the dimensions related to physical and mental functioning.¹⁹ In addition, the KDQOL includes a Symptom score that incorporates information related to several kidney disease specific symptoms. The SF-36 and KDQOL have been used extensively in the dialysis population.^{1–6} We scored the instrument according to the recommendations of its developers, i.e., using the RAND method of scoring.^{20, 21}

Statistical Analysis

Baseline characteristics for those in the Wave 2 study with and without SF-36 data were compared using unpaired t-tests for continuous variables and using Chi square tests for categorical variables.

Multiple linear regression was used to determine whether categories of phosphorus, calcium, PTH, and calcium $\times$ phosphorus product were associated with health status and to explore the structure of the association. The reference categories were defined to roughly match current targets according to clinical practice guidelines:¹⁶ phosphorus 3.5 to 5.5 mg/dL, calcium 7.5

to 8.5 mg/dL, PTH 150 to 300 pg/mL, and calcium $\times$ phosphorus product 45 to 55 mg²/dL². The models were adjusted for demographic, clinical, and laboratory predictor variables. Demographic variables included age, sex, race (Caucasian, African American, Asian or Pacific Islander, or other race), ethnicity (Hispanic or other), employment status, and marital status. Clinical variables included body mass index (BMI), dialysis modality, tobacco use, systolic and diastolic blood pressures, administration of intravenous 1,25-dihydroxyvitamin D (yes or no), and the presence or absence of the following comorbidities: coronary artery disease, diabetes, cerebrovascular disease, peripheral vascular disease, amputation, and cancer. Body mass index was calculated as weight in kilograms divided by height in meters squared and was divided into the following categories: <19 kg/m², 19 to <25 kg/m², 25 to <30 kg/m², and $\geq$ 30 kg/m². These categories were chosen to conform to World Health Organizations classifications of underweight, normal weight, overweight, and obese.²² Blood pressures represented the average of the last three blood pressure recordings prior to the date of study entry. Predialysis blood pressures were used in the case of hemodialysis patients. Laboratory variables included serum albumin and creatinine concentrations and hematocrit. These laboratory studies were recorded as the nearest predialysis values within 3 months before or up to one month after study enrollment. Missing data for serum creatinine (N=175 or 4.7%) were replaced with the mean. Missing values of hematocrit were replaced with three times the hemoglobin level if hemoglobin was available. The mean value of hematocrit was used for subjects missing data for both hemoglobin and hematocrit (N= 100 or 2.7%). Because serum albumin was missing for a substantial number of patients (N=353 or 9.5%), albumin was entered into the models as a categorical variable using quartiles of serum albumin and a missing category (<31 g/L, 31 to <35 g/L, 35 to <38 g/L, and $\geq$ 38 g/L).

Outcome variables included the Physical Component Summary (PCS) and Mental Component Summary (MCS) scores of the SF-36 and the Symptom score of the KDQOL (kidney disease-specific symptoms). Initially, each predictor variable was modeled separately, adjusting for all covariates. Then, to determine whether observed associations were independent of each other, the analyses were repeated with phosphorus, calcium, and PTH categories in a single model. Multiplicative interaction terms were used to evaluate effect modification for selected variables. Two-tailed P-values <0.05 were considered significant. Statistical analyses were conducted using SAS 9.2 (Cary, NC).

Results

A total of 3938 patients over the age of 18 years were enrolled in the DMMS Wave 2 study. Health-related quality of life data were available for 2590 of these patients (66%). Of the patients with available health-related quality of life data, 142 were missing phosphorus values, 141 were missing values for serum calcium, and 561 lacked information on PTH. Table 1 shows the patient characteristics for the groups with and without health-related quality of life data. Patients with available health-related quality of life data were similar in age to those who did not provide health-related quality of life data. However, on average, those who responded to the KDQOL were healthier in the sense that their average serum albumin was slightly but significantly higher and they were less likely to have several comorbidities, including diabetes, cerebrovascular disease, and peripheral vascular disease. In addition, respondents were more likely to be Caucasian, married, employed, and on hemodialysis rather than peritoneal dialysis.

The mean PCS score was 33.0 ± 10.2 , Symptom score was 71.8 ± 16.6 , and MCS score was 45.5 ± 11.8 for the whole cohort, similar to other studies in the hemodialysis population. After adjusting for covariates, both low and high serum phosphorus concentrations were associated with worse PCS, as hypothesized (Table 2), although the association with low phosphorus did not reach statistical significance. Low phosphorus was associated with more severe symptoms of kidney disease but high phosphorus was not. Neither high nor low serum phosphorus

concentration was associated with MCS score. Neither serum calcium nor the calcium $\times$ phosphorus product was associated with any measure of health-related quality of life. Low PTH was associated with worse PCS scores, but PTH was not associated with kidney disease-related symptoms or with MCS (Table 3). Since PTH concentrations tend to be higher in African Americans compared with Caucasians,²³ we tested PTH category $\times$ race interaction terms in companion models; none were statistically significant (data not shown).

Multivariable analysis confirmed several known or expected associations with PCS, such as lower scores in older individuals, women, patients at both extremes of BMI, and patients with several comorbidities, including diabetes, coronary artery disease, and cerebrovascular disease, as well as higher scores among patients starting peritoneal dialysis.⁷ Adjustment for serum phosphorus, calcium, and PTH in the same model did not alter the results (Table 4), suggesting that the observed associations between serum phosphorus and health-related quality of life and between PTH and health-related quality of life were independent of each other.

Discussion

We have shown that both low and high serum phosphorus concentrations were associated with worse self-reported physical functioning in this cohort, as was low PTH. Only low phosphorus was significantly associated with worse symptoms related to kidney disease. The associations of PTH and phosphorus with these measures of health status appear to be independent of each other. Possible reasons for these observed associations might include nutritional status, vascular calcification, or bone disease.

Nutritional status is a likely explanation for the association between low phosphorus and poor self-reported functioning. Low serum phosphorus is associated with poor nutritional intake, which can lead to wasting, with loss of muscle mass and strength and ultimately worse physical functioning. Although our models adjusted for serum albumin as a marker of nutritional status, we did not adjust for other markers, such as serum cholesterol, nor for any direct measure of nutritional intake. Thus, it is likely that low serum phosphorus was associated with poorer nutritional status even after adjustment for serum albumin and body size.

High phosphorus, on the other hand, would be expected to be associated with more severe bone disease and has been previously associated with higher rates of fracture-related hospitalization.¹⁴ Thus, a negative impact on physical functioning on the basis of the bone effects of hyperphosphatemia is plausible. In addition, vascular calcification could diminish physical functioning by causing exercise limitations due to coronary or peripheral vascular disease. Our models adjusted for a history of overt vascular disease, but it is entirely possible that disorders of mineral metabolism might result in subclinical vascular disease, due to vascular calcification with arteriosclerosis, or could contribute to symptomatology in persons with existing atherosclerotic or arteriosclerotic vascular disease. It has recently been recognized that vascular calcification is an active process, more complex than the notion of passive precipitation related to a high calcium $\times$ phosphorus product and supersaturated plasma.^{24, 25} Rather, calcification appears to be a regulated process that can be initiated by hyperphosphatemia, exacerbated by expression of many factors involved in regulation of bone matrix production, and abrogated or attenuated by inhibitors of calcification such as fetuin A.^{25, 26}

It is likely that the association between missing PTH values and poor self-reported physical functioning was related to the reasons for missing the dialysis sessions in which PTH was to be drawn. Hospitalization and nonadherence to dialysis treatment are two of the more likely reasons why patients might have been unavailable to have PTH levels drawn. Since both of these are likely to lead to poorer physical functioning, the association between missing PTH and low physical functioning is not surprising.

Surprisingly, neither hyperphosphatemia nor high PTH was associated with more severe symptoms related to kidney disease. The symptom score is derived from responses to questions about the extent to which patients were bothered by 12 symptoms. Among these, lack of appetite and nausea or upset stomach may have been associated with poor nutritional status with low phosphorus. The lack of association between high phosphorus or PTH and symptoms could be related to the fact that the questionnaire does not ask patients about bone or joint pain, although questions about muscle soreness, itchy skin and dry skin are included.

It should be noted that the differences in health-related quality of life that we observed in association with different levels of serum phosphorus or PTH, although statistically significant, were relatively small. There has been considerable debate about the magnitude of a minimally clinically important difference (MCID) in health-related quality of life. A recent review concluded that the MCID for the PCS is a standardized effect size of 0.2, where standardized effect size is equal to the absolute difference between two groups divided by the standard deviation of the group as a whole.²⁷ This difference is similar to the estimated effect of hypertension on PCS score in the original Medical Outcomes Study.²⁸ By this standard, the observed associations between serum phosphorus and PTH and PCS fall just short of the MCID. However, it is noteworthy that the association between low PTH and PCS is similar in magnitude to that of diabetes and greater than that of 10 years of age, on average (Table 4). Furthermore, the limitations of the available data would tend to underestimate associations because categorization of phosphorus and PTH was based on a single set of laboratory values. Since serum concentrations of phosphorus and PTH may change over relatively short time periods, single measurements may not accurately reflect time averaged concentrations over the period during which patients were asked to report on their physical functioning and health-related quality of life. In addition, there were several PTH assays in use throughout the United States during the study period (1996–1997). Thus, some misclassification probably occurred. While our conversion of PTH data to categories rather than reliance on continuous PTH values would mitigate the tendency for misclassification, the multiple assays would nevertheless tend to reduce the magnitude of any association between PTH and health status. Any potential associations between health status and serum calcium concentrations could have been blunted by the single measurements used in this study and by the fact that some albumin values were missing, limiting the precision with which serum calcium could be adjusted for albumin concentration.

The cross-sectional nature of the study also limited the conclusions that can be drawn regarding causality. Although we observed that patients with hyperphosphatemia reported lower physical functioning on average, we cannot assume that high serum phosphorus causes poor physical functioning, nor can we infer that treatment to lower serum phosphorus will result in improved functioning. Although we adjusted for IV vitamin D administration, a further limitation of this study is the lack of available data regarding treatment of hyperphosphatemia or dose of dialysis. It is possible that the association observed between low serum phosphorus and PCS scores was confounded by binder therapy or dialysis dose, although adjustment for serum calcium concentration did not affect the association. The potential confounding effects of dialysis dose are difficult to predict, since underdialysis could lead to poorer control of serum phosphorus or, on the other hand, could lead to reduced phosphorus intake because of impaired appetite.

It is possible that longitudinal or interventional studies will show a link between phosphorus, PTH and health-related quality of life and that appropriate treatment of these derangements according to current practice guidelines will result in improved functioning. On the other hand, the small magnitude of the associations observed in this study should serve to highlight the need to pursue other means of improving functioning.

Acknowledgments

Funding source: This study was supported by contract N01-DK-1-2450 from the National Institutes of Health, National Institute of Diabetes, Digestive and Kidney Diseases.

This study was supported by contract N01-DK-1-2450 from the National Institutes of Health, National Institute of Diabetes, Digestive and Kidney Diseases. The authors are responsible for the content of this article. This article does not represent government policy.

References

1. Diaz-Buxo JA, Lowrie EG, Lew NL, et al. Quality-of-life evaluation using Short Form 36: comparison in hemodialysis and peritoneal dialysis patients. *Am J Kidney Dis* 2000;35:293–300. [PubMed: 10676729]
2. Lopes AA, Bragg-Gresham JL, Satayathum S, et al. Health-related quality of life and associated outcomes among hemodialysis patients of different ethnicities in the United States: the Dialysis Outcomes and Practice Patterns Study (DOPPS). *Am J Kidney Dis* 2002;41:605–615. [PubMed: 12612984]
3. Dwyer JT, Larive B, Leung J, et al. Nutritional status affects quality of life in hemodialysis (HEMO) study patients at baseline. *J Ren Nutr* 2002;12:213–223. [PubMed: 12382213]
4. Chiang CK, Peng YS, Chiang SS, et al. Health-related quality of life of hemodialysis patients in Taiwan: A multicenter study. *Blood Purif* 2004;22:490–498. [PubMed: 15523175]
5. Lowrie EG, Curtin RB, LePain N, et al. Medical outcomes study short form-36: a consistent and powerful predictor of morbidity and mortality in dialysis patients. *Am J Kidney Dis* 2003;41:1286–1292. [PubMed: 12776282]
6. Kutner NG, Zhang R, Brogan D. Race, gender, and incident dialysis patients' reported health status and quality of life. *J Am Soc Nephrol* 2005;16:1440–1448. [PubMed: 15800127]
7. Johansen KL, Kutner NG, Young B, et al. Association of body size with health status in patients beginning dialysis. *Am J Clin Nut* 2006;83:543–549.
8. Evans RW, Rader B, Manninen DL. The quality of life of hemodialysis recipients treated with recombinant human erythropoietin. Cooperative Multicenter EPO Clinical Trial Group. *JAMA* 1990;263:325–330.
9. Parfrey PS, Foley RN, Wittreich BH, et al. Double-blind comparison of full and partial anemia correction in incident hemodialysis patients without symptomatic heart disease. *J Am Soc Nephrol* 2005;16:2180–2189. [PubMed: 15901766]
10. Besarab A, Bolton K, Browne JK, et al. The effects of normal as compared with low hematocrit values in patients with cardiac disease who are receiving hemodialysis and epoetin. *N Engl J Med* 1998;339:584–590. [PubMed: 9718377]
11. Strippoli GFM, Craig JC, Manno C, et al. Hemoglobin targets for the anemia of chronic kidney disease: A meta-analysis of randomized, controlled trials. *J Am Soc Nephrol* 2004;15:3154–3165. [PubMed: 15579519]
12. Unruh M, Benz R, Greene T, et al. Effects of hemodialysis dose and membrane flux on health-related quality of life in the HEMO Study. *Kidney Int* 2004;66:355–366. [PubMed: 15200444]
13. Block GA, Hulbert-Shearon TE, Levin NW, et al. Association of serum phosphorus and calcium $\times$ phosphate product with mortality risk in chronic hemodialysis patients: A national study. *Am J Kidney Dis* 1998;31:607–617. [PubMed: 9531176]
14. Block GA, Klassen PS, Lazarus JM, et al. Mineral metabolism, mortality, and morbidity in maintenance hemodialysis. *J Am Soc Nephrol* 2004;15:2208–2218. [PubMed: 15284307]
15. United States Renal Data System. Researcher's Guide to the USRDS Database. National Institutes of Health, National Institute of Diabetes and Digestive and Kidney Diseases; Bethesda, MD: 2004.
16. National Kidney Foundation. K/DOQI clinical practice guidelines for bone metabolism and disease in chronic kidney disease. *Am J Kidney Dis* 2003;42:S1–S201. [PubMed: 14520607]
17. Hays RD, Kallich JD, Mapes DL, et al. Development of the kidney disease quality of life (KDQOL) instrument. *Qual Life Res* 1994;3:329–338. [PubMed: 7841967]
18. Ware, JE. SF-36 Health Survey Manual and Interpretation Guide. Nimrod Press; Boston, MA: 1993.

19. Ware, JE.; Kosinski, M. SF-36 Physical and Mental Health Summary Scales: A Manual for Users of Version 1. QualityMetric Incorporated; Lincoln, RI: 200.
20. Hays, RD.; Kallich, JD.; Mapes, DL., et al. Kidney Disease Quality of Life Short Form (KDQOL-SF), Version 1.3: A Manual For Use and Scoring. RAND; Santa Monica, CA: 1997.
21. The KDQOL Working Group. <http://www.gim.med.ucla.edu/kdqol/>
22. World Health Organization. Obesity: preventing and managing the global epidemic. (WHO Technical Report Series, No. 894). Geneva: World Health Organization; 1997.
23. Aloia JF, Feuerman M, Yeh JK. Reference range for serum parathyroid hormone. *Endocr Pract* 2006;12:137–144. [PubMed: 16690460]
24. Derici U, El Nahas AM. Vascular calcifications in uremia: old concepts and new insights. *Semin Dial* 2006;19:60–68. [PubMed: 16423183]
25. Moe SM, Chen NX. Pathophysiology of vascular calcification in chronic kidney disease. *Circ Res* 2004;95:560–567. [PubMed: 15375022]
26. Ketteler M, Wanner C, Metzger T, et al. Deficiencies of calcium-regulatory proteins in dialysis patients: a novel concept of cardiovascular calcification in uremia. *Kidney Int Suppl* 2003;84:S84–S87. [PubMed: 12694317]
27. Samsa G, Edelman D, Rothman ML, et al. Determining clinically important differences in health status measures: a general approach with illustration to the Health Utilities Index Mark II. *Pharmacoeconomics* 1999;15:141–155. [PubMed: 10351188]
28. Stewart AL, Greenfield S, Hays RD, et al. Functional status and well-being of patients with chronic conditions. Results from the Medical Outcomes Study. *JAMA* 1989;262:907–913. [PubMed: 2754790]

Table 1

Baseline Characteristics by Availability of Quality of Life Information

Variable	KDQOL (n=2590)	No KDQOL (n=1348)	P-value
Age	58.4 ± 15.5	59.4 ± 15.4	0.07
Sex (% male)	46.4	48.0	0.35
Race (%)			
Caucasian	63.9	59.3	0.005
African American	27.3	29.6	0.13
Asian	2.3	4.0	0.002
Other	6.5	7.0	
BMI, kg/m ²	25.8 ± 5.6	25.1 ± 5.2	0.005
Peritoneal dialysis (%)	47.0	51.7	0.005
Diabetes (%)	47.4	50.8	0.04
Coronary artery disease	31.1	31.2	0.98
Cerebrovascular disease	8.6	12.2	0.0002
Peripheral vascular disease	15.2	17.7	0.05
Amputation	4.1	5.6	0.03
Cancer	8.2	8.2	0.99
Marital status (% married)	56.4	51.0	0.001
Employment status (% employed)	13.7	0.1	<0.0001
Smoker	13.5	12.7	0.49
Serum albumin, g/L	35 ± 6	34 ± 6	<0.0001
Serum creatinine, mg/dL	672 ± 265	654 ± 265	0.12
Hematocrit, %	30.4 ± 6.0	30.5 ± 6.1	0.53
Systolic blood pressure	147.6	145.3	0.002
Diastolic blood pressure	79.7	79.1	0.12
Vitamin D	16.3	19.0	0.04

* Abbreviations: KDQOL, Kidney Disease Quality of Life Questionnaire; BMI, body mass index. To convert serum albumin in g/L to g/dL, divide by 10; to convert serum creatinine in mmol/L to mg/dL, divide by 88.4.

Table 2
Associations between phosphorus and Health-Related Quality of Life*

Phosphorus	PCS			Symptoms			MCS		
	Adjusted mean	Coefficient	P-value	Adjusted mean	Coefficient	P-value	Adjusted mean	Coefficient	P-value
Missing (n=142)	32.41	0.17	0.86	67.00	-0.96	0.55	44.83	-0.06	0.96
< 1.875 mmol/L (n=227)	32.24	-1.25	0.08	67.96	-3.88	0.001	44.89	-0.35	0.69
1.875 to < 2.215 mmol/L (referent; n=1105)	33.53	0		71.88	0		45.26	0	
2.215 to < 2.375 mmol/L (n=780)	32.48	-1.09	0.02	71.39	-0.52	0.51	45.74	0.51	0.37
≥2.375 mmol/L (n=336)	32.09	-1.48	0.02	71.10	-0.77	0.47	45.33	0.17	0.83

* Abbreviations: PCS, Physical Component Summary Score; MCS, Mental Component Summary Score. Results are adjusted for age, sex, race, body mass index, blood pressure, primary cause of kidney disease, dialysis modality, marital and employment status, smoking status, intravenous vitamin D therapy, history of diabetes, coronary artery disease, cerebrovascular accident, peripheral vascular disease, amputation, cancer, serum albumin and creatinine concentrations, and hematocrit. To convert phosphorus in mmol/L to mg/dL, divide by 0.3229.

Table 3
Associations between PTH and Health-Related Quality of Life*

PTH category	PCS				Symptoms				MCS			
	Adjusted mean	Coefficient	P-value		Adjusted mean	Coefficient	P-value		Adjusted mean	Coefficient	P-value	
Missing (n=561)	30.22	-2.20	0.0002		69.68	-1.29	0.21		44.59	-0.97	0.20	
<150 ng/mL (n=767)	32.42	-1.49	0.007		70.97	-0.51	0.59		45.29	-0.21	0.76	
150 to <300 ng/L (referent; n=526)	33.99	0			71.42	0			45.56	0		
300 to <600 ng/L (n=457)	33.56	-0.45	0.46		72.14	0.51	0.63		45.30	-0.28	0.72	
≥600 ng/L (n=279)	33.29	-0.73	0.31		72.28	0.79	0.53		46.78	1.19	0.19	

* Abbreviations: PTH, parathyroid hormone; PCS, Physical Component Summary Score; MCS, Mental Component Summary Score. Adjusted for age, sex, race, body mass index, blood pressure, primary cause of kidney disease, dialysis modality, marital and employment status, smoking status, intravenous vitamin D therapy, history of diabetes, coronary artery disease, cerebrovascular accident, peripheral arterial occlusive disease, amputation, cancer, serum albumin and creatinine concentrations, and hematocrit. Abbreviations: PTH, parathyroid hormone. To convert PTH in ng/L to pg/ml, multiply by 1.

Table 4

Multivariate regression results*

Variable	PCS Coefficient	P-value	Symptoms Coefficient	P-value	MCS Coefficient	P-value
Age, per 10 years	-0.42	0.01	0.78	0.006	0.36	0.09
Sex (female)	-1.53	0.0002	-2.88	<0.0001	-0.67	0.19
Race/ethnicity						
White	Referent					
Black	-0.68	0.17	-0.88	0.30	1.19	0.05
Asian	0.19	0.88	-2.79	0.21	-2.07	0.19
Other	2.95	0.26	5.88	0.17	-2.46	0.45
Hispanic	1.26	0.06	-2.12	0.07	-2.91	0.0006
BMI, kg/m ²						
<19	-2.45	0.001	-1.30	0.31	-0.91	0.33
19 to <25	Referent		Referent		Referent	
25 to <30	0.23	0.61	0.06	0.93	0.65	0.26
≥30	-1.44	0.008	-2.05	0.03	0.47	0.48
Primary cause of kidney disease						
Hypertension	Referent		Referent		Referent	
Diabetes	0.05	0.95	-0.80	0.52	0.71	0.44
Glomerulonephritis	1.90	0.01	-0.04	0.97	0.45	0.63
Other or unknown	0.39	0.49	-0.70	0.48	1.33	0.06
Modality (PD)	1.15	0.01	2.07	0.009	2.25	<0.0001
Diabetes	-1.31	0.06	-0.95	0.42	-0.85	0.32
Coronary artery disease	-1.95	<0.0001	-3.11	<0.0001	-1.15	0.05
Cerebrovascular disease	-2.03	0.003	-0.53	0.65	-0.95	0.27
Peripheral vascular disease	-1.40	0.03	-0.29	0.79	0.12	0.88
Amputation	-0.92	0.40	2.05	0.28	1.70	0.22
Cancer	-1.97	0.005	-0.43	0.72	-0.40	0.65
Employed	5.64	<0.0001	4.38	<0.0001	3.88	<0.0001
Married	-0.95	0.02	-0.94	0.18	-0.75	0.14
Smoker	-0.61	0.29	-2.28	0.02	-2.68	0.0002

Variable	PCS		Symptoms		MCS	
	Coefficient	P-value	Coefficient	P-value	Coefficient	P-value
Serum albumin, mg/dL						
Missing	0.61	0.45	1.71	0.22	1.62	0.11
< 31 g/L	Referent		Referent		Referent	
31 to < 35 g/L	0.38	0.54	2.29	0.03	1.27	0.10
35 to < 38 g/L	0.13	0.84	1.55	0.15	0.55	0.48
≥ 38 g/L	2.07	0.001	3.13	0.003	1.91	0.01
Creatinine, per 0.011 mmol/dL						
	0.16	0.05	−0.04	0.79	−0.02	0.81
Hematocrit	−0.01	0.85	−0.07	0.22	0.01	0.82
Vitamin D	0.25	0.64	0.93	0.31	−0.97	0.15
Systolic blood pressure	0.01	0.65	0.03	0.24	0.04	0.02
Diastolic blood pressure	0.06	0.02	0.02	0.60	−0.07	0.02
Phosphorus						
Missing (n=142)	1.68	0.44	5.01	0.17	3.97	0.14
< 1.875 mmol/L (n=227)	−1.18	0.10	−3.77	0.002	−0.28	0.75
1.1875 to < 2.215 mmol/L (referent; n=1105)	Referent		Referent		Referent	
2.215 to < 2.375 mmol/L (n=780)	−1.15	0.01	−0.56	0.48	0.53	0.36
≥ 2.375 mmol/L (n=336)	−1.49	0.02	−0.89	0.42	0.20	0.80
PTH						
Missing (n=561)	−2.23	0.0002	−1.34	0.19	−0.95	0.21
< 150 ng/L (n=767)	−1.58	0.004	−0.62	0.52	−0.13	0.85
150 to < 300 ng/L (n=526)	Referent		Referent		Referent	
300 to < 600 ng/L (n=457)	−0.44	0.48	0.35	0.74	−0.33	0.67
≥ 600 ng/L (n=279)	−0.79	0.28	0.63	0.61	1.20	0.18

Abbreviations: PCS, Physical Component Summary Score; MCS, Mental Component Summary Score; BMI, body mass index; PD, peritoneal dialysis; PTH, parathyroid hormone. To convert phosphorus in mmol/L to mg/dL, divide by 0.3229. To convert PTH in ng/L to pg/ml, multiply by 1.