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Research Article

Improvement of Hyperphosphatemia in Patients Undergoing Chronic Hemodialysis Relying on Internet Online Dietary Guidance

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Abstract

Object: To explore the effect of Internet online dietary guidance on improving serum phosphate levels in hemodialysis patients.

Methods: A prospective cohort study enrolled 70 patients undergoing chronic hemodialysis from April 01, 2019 to May 31, 2019. The enrolled patients entered Intellkidney Nutrition WeChat Mini Program and uploaded their photographs of three meals a day. The nutritionists carried out online assessment and intervention in a timely manner. After the 6-month follow-up period, improvement of hyperphosphatemia had been assessed due to different compliance.

Results: The average serum phosphorus level was 2.4±0.6 mmol/L at baseline. After median 6-month follow-up, the prevalence of hyperphosphatemia was 75.8% and the average serum phosphorus level was 2.3±0.7 mmol/L ($P=0.017$). Compared to the general compliance group, the patients in the good compliance group presented a seemed higher level of serum phosphorus (2.6±0.6 versus 2.3±0.5mmol/L, $P=0.055$) at baseline but the levels of serum phosphorus and daily average dietary phosphorus intake were significantly reduced during follow-up. Adjusted gender, dietary parameters, serum iPTH and use of phosphorus-reducing drugs during follow-up, the multivariate Logistic analysis indicated that the decrease of daily average calorie intake (per 1 Kcal/Kg/d, OR 3.003, 95%CI, 1.014-8.897, P=0.047) was independently associated with improvement of hyperphosphatemia.

Conclusion: Our preliminary research indicated that effective online dietary guidance and good compliance to diet control were helpful to decrease the prevalence of hyperphosphatemia in hemodialysis patients.

Keywords: Hemodialysis, Hyperphosphatemia, Serum phosphorus, Internet, Dietary guidance, Compliance

Introduction

According to the latest DOPPS data, the incidence of mineral and bone metabolism abnormalities (CKD-MBD) is more severe in hemodialysis patients in China compared with those in Europe, North America and Japan. Wherein, the compliance rate of serum phosphorus (serum phosphorus level of 3.5~5.5 mg/dl) was only 39%, the proportion of hyperphosphatemia (serum phosphorus level > 5.5 mg/dl) was 55%, and the incidence of severe hyperphosphatemia (serum phosphorus level > 7.0 mg/dl) is up to 27%. [1].

The clinical strategies for hyperphosphatemia is mainly based on 3D principle. The 3D principles include diet control, phosphorus-reducing drugs, low calcium dialysate and adequate dialysis [2,3]. From the above 3D principles, we can see that diet control, especially phosphorus intake control, is of great importance to prevention and therapy hyperphosphatemia in CKD5D-stage patients.

The traditional dietary guidance mainly refers to routine patient education by medical personnel, including dietary mold propaganda and education, kidney communication meeting, and on-the-spot dietary guidance. However, in fact, it is still difficult even for the patients requiring routine hemodialysis at the hospital for 2-3 times a week to effectively control phosphorus intake in their diet due to their differences in self-management ability and limited understanding of phosphorus content in different foods, as well as the lack of pertinence and monitoring feedback in the above-mentioned patient education mode. Therefore, the traditional and conventional propaganda and education mode needs to be improved.

With the continuous development of Internet concepts and technologies, our goal is how to apply Internet technologies to patient education, carry out high-quality patient propaganda and implement targeted dietary guidance so that the patients could carry out their daily diet according to the dietary plan adjusted by specialized medical personnel or nutritionists to reduce phosphorus intake and the incidence of hyperphosphatemia. Up to now, few researchers, especially nurses in the dialysis room, have payed attention to Internet online dietary guidance and patient education. We planned to carry out assessment and feedback for the patients' diet by the online specialized nutritionist in a real-time manner, so as to timely adjust the dietary plan, improve the operability of dietary therapy, improve the compliance of the patients with dietary therapy, and therefore reduce the incidence of hyperphosphatemia.

Materials and Methods

Patients Selection

Patients undergoing chronic hemodialysis from April 01, 2019 to May 31, 2019 in our three research centers were screened. Those who presented with age ≥18 years old, time on dialysis ≥3 months, dialysis frequency ≥2 times per week, hyperphosphatemia (defined as serum phosphorus level ≥1.78 mmol/L), clear consciousness, certain reading ability and initiative intent to join the program of Internet online dietary guidance were included. Patients who had a history of serious surgery or comorbidities in the past one month, such as organ failure, malignant tumor and severe malnutrition; who had secondary hyperparathyroidism and got parathyroidectomy; were excluded. Patients who were unable to receive at least 3-month follow-up or unwilling to cooperate with blood examination were deemed to have withdrawn from the research. There were 70 eligible patients enrolled in this study.

Ethical considerations

All the three participating centers followed the Blood Purification

Standard Operating Procedure of Guangdong, China, and had passed the medical quality training and tests of the Guangdong Medical Association. The study was conducted in accordance to the principles of Good Epidemiology Practices and Declaration of Helsinki. All patients provided written informed consent.

Clinical characteristics

Demographic information contained gender, age, education, time on dialysis, height, weight. Clinical variables included serum phosphorus, hemoglobin, serum albumin, serum uric acid, serum creatinine, serum urea nitrogen, serum potassium, serum calcium, and serum parathyroid hormone (iPTH). In principle, the blood examination was performed every 3 months and all the samples were measured after an overnight fast before dialysis in the morning. Data in the first month as baseline and that in the last month as follow-up values recorded. Use of medications for CKD-MBD were also recorded during our research.

Internet online dietary guidance and dietary parameters

With the platform of "Intellkidney Nutrition Management System" , the enrolled patients entered Intellkidney Nutrition WeChat Mini Program by scanning the QR code and finished registration, and each day, uploaded their photographs of three meals a day. The nutritionists carried out dietary assessment and formulated individualized assessment report (to estimate the dietary phosphorus intake in diet) and intervention plan, carried out online assessment and intervention in a timely manner, and made written summary and dietary adjustment every week. Then the patients implemented the adjusted dietary plan and uploaded their dietary photographs; the nutritionists undertook assessment (to estimate the phosphorus intake in diet), made continuous and timely feedback and carried out an new intervention.

Follow-up assessment

Assessment indexes include: times of uploading dietary photograph (total times the patients actively uploaded their photographs of three meals a day during follow-up), times of viewing dietary assessment comments (total times the patients view the nutritionist's comments on their dietary photographs uploaded during follow-up), daily average protein intake (g/Kg/d), daily average high-quality protein intake (g/Kg/d), daily average calorie intake (Kcal/Kg/d), and daily dietary phosphorus intake (mg/d). The daily dietary phosphorus intake was calculated by 128 (mg) + protein intake in diet (g) ×14 (mg/g). (10) High-quality protein, was defined as the food protein whose amino acid pattern is closer to that of human protein; for example, egg, milk, meat, fish and soybean protein. The above four dietary parameters were recorded in the first month as baseline and the last month as follow-up.

- Follow-up time: 6 months.

Clinical outcome during follow-up: improvement of hyperphosphatemia (serum phosphorus<1.78 mmol/L at the end of follow-up).

Statistics analysis

- Study design: a multi-center prospective cohort research

Data description and analysis: for quantitative variables, if symmetric distribution, mean ± standard deviation (SD) for statistical description, student's t test for statistical inference in the independent variables and paired t-test for comparison of the variables between baseline and follow-up; and if asymmetric distribution, median (Q25, Q75) for description and Mann-Whitney test or paired Wilcoxon rank test for inference. For qualitative variables, frequency for description and Chi-square test or Fisher's exact test for inference.

Logistic regression model was used for multivariate analysis to identify the associated factors of improvement of hyperphosphatemia (serum phosphorus<1.78 mmol/L at the end of follow-up).

Statistical analysis was performed using SPSS Statistics version 20.0 for Windows (IBM Corp., Armonk, NY, USA). All P-values were two-sided; $P < 0.05$ was considered to be statistically significant.

Results

Patient and clinical characteristics at baseline

A total of 108 patients were included in this research, among whom, 37 had stopped following Internet online dietary guidance service and 1 failed to cooperate with the blood examination.

Therefore, 70 patients were finally enrolled in the analysis. Baseline demographic and clinical characteristics were shown in Table 1 and the average serum phosphorus level was 2.4±0.6 mmol/L.

Clinical characteristics during follow-up

Of all the 70 patients, only 7 patients completed 3-month follow up, 63 patients had finished the total 6-month follow-up visit. The median follow-up time was 6 (6, 6) months. At the end of the study, the frequency of hyperphosphatemia in patients with chronic hemodialysis patients was 47, with the prevalence of 75.8%. Table 2 shows that, the average serum phosphorus level decreased to 2.3±0.7 mmol/L during follow-up (P=0.017). Hemoglobin and

Table 1: Clinical characteristics of the enrolled patients at baseline

Variable	Value n=70
Demographics	
Gender, male [n(%)]	39(55.7)
Age (years)	46.9±10.9
Education [n(%)]	
≤Primary school	23(32.9)
Middle school	44(62.9)
≥College	3(4.3)
Body mass index (Kg/m^2)	22.1±3.5
Time on dialysis (months)	48.5(19.8,73.5)
Clinical parameters	
Serum phosphorus (mmol/L)	2.4±0.6
Hemoglobin (g/L)	101.7±20.4
Serum albumin (g/L)	35.9±5.4
Serum uric acid (μmol/L)	482.5±92.9
Serum creatinine (μmol/L)	1092.1±298.1
Serum urea nitrogen (mmol/L)	26.8±8.3
Serum potassium (mmol/L)	4.9±0.9
Serum calcium (mmol/L)	2.2±0.2
Serum parathyroid hormone (pg/ml)	358.6(132,757.2)
Medications	
Calcium [n(%)]	29(41.4)
Sevelamer [n(%)]	9(12.9)
Calcitriol [n(%)]	21(30)
Paricalcitol [n(%)]	4(5.7)
Calcimimetics [n(%)]	6(8.6)
Dietary contents	
Daily average protein intake (g/Kg/d)	0.9±0.2
Daily average high-quality protein intake (g/Kg/d)	0.5±0.2
Daily average calorie intake (Kcal/Kg/d)	25.4±5.2
Daily dietary phosphorus intake (mg/d)	802.5±181.0

Table 2: Comparison of the clinical and dietary parameters between baseline and follow-up

Variable	Baseline n=70	Follow-up n=70	P-value
Body mass index (Kg/m^2)	22.1±3.5	22.2±3.2	0.778
Serum phosphorus (mmol/L)	2.4±0.6	2.3±0.7	0.017
Hemoglobin (g/L)	101.7±20.4	107.5±15.3	0.167
Serum albumin (g/L)	35.9±5.4	38.1±3.6	0.068
Serum uric acid (μmol/L)	482.5±92.9	482.6±117.3	0.747
Serum creatinine (μmol/L)	1092.1±298.1	1104.4±269.4	0.994
Serum urea nitrogen (mmol/L)	26.8±8.3	26.5±7.1	0.701
Serum potassium (mmol/L)	4.9±0.9	5.0±0.8	0.555
Serum calcium (mmol/L)	2.2±0.2	2.2±0.2	0.601
Serum parathyroid hormone (pg/ml)	358.6(132,757.2)	476.1(200,716.2)	0.039
Calcium [n(%)]	29(41.4)	29(41.4)	1.000
Sevelamer [n(%)]	9(12.9)	8(11.4)	0.862
Calcitriol [n(%)]	21(30)	21(30)	1.000
Paricalcitol [n(%)]	4(5.7)	4(5.7)	1.000
Calcimimetics [n(%)]	6(8.6)	6(8.6)	1.000
Daily average protein intake (g/Kg/d)	0.9±0.2	0.8±0.3	0.046
Daily average high-quality protein intake (g/Kg/d)	0.5±0.2	0.5±0.2	0.644
Daily average calorie intake (Kcal/Kg/d)	25.4±5.2	24.5±5.5	0.102
Daily dietary phosphorus intake (mg/d)	802.5±181.0	754.4±159.5	0.009

Table 3: Comparison of the clinical and dietary parameters in patients with different compliance

Variable	Good compliance n=34	General compliance n=36	P-value
Times of uploading dietary photographs [n(%)]	36.5(18.8,84.3)	1(0,3)	<0.001
Times of viewing dietary assessment comments [n(%)]	36(17.8,81.5)	0(0,2)	<0.001
Gender, male [n(%)]	14(41.2)	25(69.4)	0.017
Age (years old)	45.6±11.0	48.1±10.9	0.343
Education [n(%)]			0.684
≤Primary school	10(29.4)	13(36.1)	
Middle school	23(67.6)	21(58.3)	
≥College	1(2.9)	2(5.6)	
Time on dialysis (months)	60(26,79)	35(13.5,69)	0.086
Serum phosphorus (mmol/L)			
Baseline	2.6±0.6	2.3±0.5	0.055
Follow-up	2.2±0.7††	2.4±0.6	0.308
Hemoglobin (g/L)			
Baseline	106.6±15.6	96.9±23.6	0.051
Follow-up	109.3±14.5	105.3±16.1	0.309
Serum albumin (g/L)			
Baseline	36.8±3.6	35.2±6.3	0.251
Follow-up	38.7±2.8	37.4±4.5	0.243
Serum uric acid (μmol/L)			
Baseline	500.4±73.6	465.7±106.4	0.136
Follow-up	479.2±102.0	486.3±133.9	0.815
Serum creatinine (μmol/L)			
Baseline	1159.6±283.2	1026.5±301.6	0.067
Follow-up	1134.0±237.6	1071.7±301.5	0.371
Serum urea nitrogen (mmol/L)			
Baseline	29.1±8.7	25.3±7.7	0.174
Follow-up	26.7±7.0	26.2±7.4	0.818
Serum potassium (mmol/L)			
Baseline	5.1±0.8	4.8±0.9	0.248
Follow-up	5.0±0.8	4.9±0.7	0.606
Serum calcium (mmol/L)			
Baseline	2.2±0.3	2.2±0.2	0.378
Follow-up	2.2±0.2	2.2±0.2	0.237
Serum parathyroid hormone (pg/ml)			
Baseline	169.6(109.1,463)	380.2(190.4,768.4)	0.223
Follow-up	482.7(227.1,907.8)	458.0(188.0,621.6)	0.322
Body mass index (Kg/m^2)			
Baseline	21.7±3.6	22.4±3.5	0.397
Follow-up	22.0±2.4	22.6±4.5	0.285

Daily average protein intake (g/Kg/d)			
Baseline	0.9±0.3	1.0±0.1	0.549
Follow-up	0.8±0.3†	1.0±0.2	0.564
Daily average high-quality protein intake (g/Kg/d)			
Baseline	0.5±0.2	0.6±0.1	0.460
Follow-up	0.5±0.2	0.6±0.2	0.493
Daily average calorie intake (Kcal/Kg/d)			
Baseline	25.4±5.4	24.7±5.3	0.849
Follow-up	24.4±5.6	25.2±5.9	0.861
Daily dietary phosphorus intake (mg/d)			
Baseline	803.1±190.2	796.5±180.8	0.962
Follow-up	753.2±166.1†	766.4±101.0	0.915

Note: †, for in this group, comparison of the variable between baseline and follow-up with P valne < 0.05; ††, for in this group, comparison of the variable between baseline and follow-up with P valne < 0.01.

serum albumin seemed increased from the baseline. Daily average protein intake and daily average dietary phosphorus intake had decreased, but there was no changed in daily average high-quality protein intake, daily average calorie intake or drugs for CKD-MBD.

Internet online dietary guidance

During median 6-month follow-up period, of the 70 patients included in this research, the median times of actively uploading the dietary photographs was 7.5 (1, 36.25), and the median times of viewing the diet assessment comments was 7 (0, 36).

The patients' compliance was assessed according to the times of viewing the nutritionist's comments on the dietary photographs actively uploaded by the patients. The median times of viewing the dietary assessment comments as mentioned above was assumed as 7. The patients with times of viewing the dietary assessment comments ≤ 7 were defined as good compliance group and the patients with times of viewing the dietary assessment comments ≤ 7 were defined as general compliance group.

Clinical characteristics in different compliance to Internet online dietary guidance

As shown in Table 3, the median times of viewing the dietary assessment comments in good compliance group was 36, but that in general compliance group was 0, P< 0.001. Compared to the general compliance group, the patients in the good compliance group showed a lower proportion in male, a seemed longer time on dialysis and a seemed higher level of serum phosphorus at baseline. There was no significant differences in the clinical and dietary parameters during follow-up between the two groups. (Table 3)

For patients in the good compliance group, compared to the baseline data, the levels of serum phosphorus (2.2±0.7mmol/L versus 2.6±0.6mmol/L at baseline, P=0.001), daily average protein intake (0.8±0.3g/Kg/d versus 0.9±0.3g/Kg/d, P=0.015) and daily average dietary phosphorus intake (753.2±166.1mg/d versus 803.1±190.2 mg/d, P=0.015) were significantly reduced. At the end of follow-up visit, the levels of serum uric acid, serum creatinine, serum urea nitrogen, serum potassium and daily average calorie intake showed a decreasing trend in the patients with good compliance; the levels of hemoglobin, serum albumin, serum iPTH and BMI showed an increasing trend in this group.

Associated factors of improvement of hyperphosphatemia

In the further research, we explored the associated factors of improvement of hyperphosphatemia (serum phosphorus<1.78 mmol/L) at the end of follow-up. Adjusted gender, dietary parameters, serum iPTH and use of CKD-MBD drugs during follow-up, the multivariate Logistic analysis indicated that the decrease of daily average calorie intake (per 1 Kcal/Kg/d, OR 3.003, 95%CI, 1.014-8.897, P=0.047) was independently associated with improvement of hyperphosphatemia.

Table 4: Associated factors of improvement of hyperphosphatemia (serum phosphorus<1.78 mmol/L at the end of follow-up)

Variable	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Gender (male:female)	0.631(0.210,1.891)	0.411		
Serum creatinine at the end of follow-up (↑ 1 μmol/L)	0.997(0.995,1.000)	0.042	0.999(0.991,1.007)	0.823
iPTH at the end of follow-up (↑ 1 pg/ml)	0.999(0.997,1.001)	0.176		
Use of phosphorus-reducing drugs during follow-u^p a	1.004(0.336,3.001)	0.994		
Good compliance[b]	1.726(0.571,5.222)	0.334		
Decrease in daily average protein intake (↑ 1 g/Kg/d)	1.149(0.947,1.394)	0.158		
Decrease in daily average high-quality protein intake (↑ 1 g/Kg/d)	1.116(0.934,1.334)	0.225		
Decrease in daily average calorie intake (↑ 1 Kcal/Kg/d)	1.016(1.002,1.030)	0.027	3.003(1.014,8.897)	0.047
Decrease in daily dietary phosphorus intake (↑ 1 mg/d)	1.010(0.996,1.024)	0.158		

Discussion

The preliminary research indicated that effective online dietary guidance was helpful to reduce the serum phosphorus level and decrease the prevalence of hyperphosphatemia in the patients undergoing chronic hemodialysis.

For the 70 hyperphosphatemia patients included in the analysis, the average serum phosphorus level was 2.4±0.6 mmol/L. According to the requirement for the target of serum phosphorus in CKD5D-stage patients to be controlled within 1.13-1.78 mmol/L [8], and the serum phosphorus level above 2.42 mmol/L was deemed as severe hyperphosphatemia, we had to do more to control hyperphosphatemia. And we began from the first D of the above 3D principles.

K/DOQI suggested that the protein intake in the maintenance hemodialysis patients should be 1.2 g/Kg/d, and the dietary phosphorus should be controlled at 800-1000 mg/d. In fact, more and more clinical researchers observed that the protein intake of 1.2 g/Kg/d was already excessive for hemodialysis patients [4]. Some studies had pointed out that low protein intake (0.8 g/Kg/d), low phosphorus intake (500 mg/d) and compound α-keto acid therapy could effectively reduce serum phosphorus in maintenance hemodialysis patients while the nutritional status of such patients was remained stable. In our research, at baseline, the daily average protein intake was 0.9±0.2 g/Kg/d and the daily average dietary phosphorus intake was 802.5±181.0 mg/d. On the other hand, the average hemoglobin level was 101.7±20.4 g/L and the average serum albumin level was 35.9±5.4 g/L [5]. According to the criteria of target hemoglobin in hemodialysis patients for 100-120 g/L [6] and the recommended target of serum albumin in hemodialysis patients for 40g/L [7], the data indicated that the hemoglobin and serum albumin in our patients barely reached the minimum level required by the target. But why the level of serum phosphorus was still higher? Was that due to incorrect components of diet? We speculated whether protein intake and high-quality protein intake should be more strictly controlled for Chinese hemodialysis patients.

Patient education, especially nursing education intervention, played an important role in reducing complications and improving prognosis of hemodialysis patients. With the continuous development of Internet concepts and technologies in the information age and the emerging of smart city construction, it has become a new trend to use Internet, Internet of Things and data information technology to improve the physical and mental follow-up visit of the hemodialysis or peritoneal dialysis patients [8]. This real-time and updated follow-up visit mode could not only improve dialysis quality, but also help improve the psychological state of such patients. In this research, we, relying on the platform of Internet of Things Data Company, planned to carry out assessment and feedback for the patients' diet by the online specialized nutritionist in a real-time manner, so as to timely adjust the dietary plan, improve the operability of dietary therapy, improve the compliance of the patients with dietary therapy, and therefore reduce the incidence of hyperphosphatemia [9-11].

Our research indicated that with online dietary guidance, the prevalence of hyperphosphatemia was decreased from 100% to 75.8% under the condition of no significant change in use of drugs for CKD-MBD. Patients in good compliance group presented a lower proportion of male, younger, a relatively longer time on dialysis at baseline; decreased in daily average total protein, phosphorus and calorie intake, increased in hemoglobin, serum albumin and BMI, but no changed in high-quality protein intake during follow-up. This showed that with systematic and specialized dietary guidance, the patients had adjusted their dietary structure and reduced the intake of phosphorus-containing food on the premise of ensuring the calorie and nutritional status. The online dietary guidance could ensure sufficient and effective nutrition support, and reduce the intake of unfavorable compositions, including controlling the intake of foods containing phosphorus, potassium and purine, which was helpful for the patients to have a deeper understanding of food compositions and master the diet collocation in future life.

This study had used the platform of "Intellkidney Nutrition Management System", which belong to Internet and Internet of Things program and is not suitable for elder or illiterate people. Consistent with previous reports [12,13], hyperphosphatemia was more common in young adults with maintained hemodialysis in our center. So we had focused the group of patients who had a much higher prevalence of hyperphosphatemia. Also there was no significant differences in the levels of education among the patients with different compliance according to our results.

However, our research still has some disadvantages. Firstly, the median times of actively uploading the dietary photographs was 7.5, and the median times of viewing the dietary assessment comments was 7. Such data indicates that during 6 months of follow-up, the patients have made effective contact and interaction with the online nutritionist once a month on average, which indicates that the compliance of such patients still need to be improved. Secondly, this was an one-armed study with small sample size and short follow-up visit period. According to this preliminary results, we need to strengthen a long-time follow-up in the future research, and include a controlled group that is in traditional dietary education to track the effect of online dietary adjustment on hyperphosphatemia management.

In conclusion, our preliminary research indicated that effective online dietary guidance and good compliance to diet control were helpful to reduce the serum phosphorus and decrease the prevalence of hyperphosphatemia in the hemodialysis patients.

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Conflicts of interest

No potential conflict of interest relevant to this article was reported by the authors. The authors alone are responsible for the content and writing of the paper.

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