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Predialysis Urea Nitrogen Is a Nutritional Marker of Hemodialysis Patients

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End-stage renal disease (ESRD) patients on hemodialysis have poor nutritional status and associated problems such as inflammation and sarcopenia. Blood urea nitrogen (BUN) is an important measure of uremic toxins, and urea reduction is a marker of hemodialysis efficacy. However, a low protein diet for lower BUN could aggravate malnutrition in patients, and optimal pre-dialysis BUN is not defined. We investigated the association of pre-dialysis BUN with patients' comorbidities and the relationship between pre-dialysis BUN and serum albumin as a nutrient marker. Among the 67 patients, the average pre- and post-dialysis BUN were 59.2 and 15.0 mg/dL, respectively, serum creatinine was 10.1 mg/dL, and the average serum albumin was 4.0 g/dL. Patients' age was negatively correlated with serum creatinine ($r=-0.277$, $p<0.05$) and albumin ($r=-0.453$, $p<0.001$). Predialysis BUN showed a significant positive correlation with serum albumin ($r=0.287$, $p<0.05$) and creatinine ($r=0.454$, $p<0.001$). However, the predialysis BUN was not significantly related to diabetes, coronary artery disease, congestive heart failure, or cerebrovascular disease. Hemodialysis patients with high pre-dialysis BUN and high serum creatinine could be regarded as having good nutritional status. The significance of this study lies in the potential utility of pre-dialysis blood urea nitrogen as an indicator of the nutritional status of patients. Liberal protein intake might be recommended to adequately dialyzed patients.

Key Words: *Malnutrition; Blood Urea Nitrogen; Renal Dialysis*

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INTRODUCTION

End-stage renal disease (ESRD) patients on dialysis have higher morbidity and mortality than the general population.[1] They tend to have poor nutritional status and many malnutrition-associated problems such as inflammation and sarcopenia.[2-4] Various studies have been conducted to predict malnutrition-related problems in dialysis patients. In some studies that evaluated nutritional status through serum chemistry battery, anthropometry, and subjective global assessment, the prevalence of malnutrition in older dialysis patients was 51%.[5] Older patients can be malnourished due to social, economic, psychological, or physical factors. Malnutrition in older patients with kidney disease requires investigation, as malnutrition increases the risk of infectious and cardiovascular deaths.[6,7]

Blood urea nitrogen (BUN) is an important measure of uremic toxins, and urea reduction is a marker of hemodialysis efficacy.[8] Dialyzer clearance rate (Kt/V) and Urea reduction ratio (URR) using BUN quantify the efficacy of dialysis by measuring the reduction in BUN during dialysis.[9] Since BUN is used to evaluate dialysis adequacy, the evaluation of pre-dialysis urea nitrogen has also become important. Several studies have suggested that dialysis adequacy (measured through differences in post-pre dialysis BUN) impacts long-term survival.[10-13]

However, increasing dialysis efficiency with a low protein diet to lower BUN may aggravate into malnutrition of patients,[14-16] and optimal pre-dialysis BUN is still not

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defined. Therefore, in this study, we test the assumption that higher pre-dialysis blood urea nitrogen (by a restrictive diet) may improve long-term survival because of higher nutritional status. Also, we investigate the association between pre-dialysis urea nitrogen and patients' comorbidities and the correlation of pre-dialysis urea nitrogen with serum albumin as a nutritional marker.

MATERIALS AND METHODS

1. Study design

We included 73 ESRD patients older than 19 years who had been on chronic dialysis for at least 3 months and were receiving maintenance hemodialysis 3 times a week at the outpatient hemodialysis unit of Chungbuk National University Hospital. Patients who underwent one or two dialysis sessions per week, who were hospitalized, or who had a dialysis period of less than 3 months were excluded. Patients underwent three 3.5- to 4-hour sessions of hemodialysis weekly using bicarbonate-buffered dialysate. The dialyzer was composed of Fresenius Medical Care 5008S, Baxter ARTIS and GAMBRO AK 98. The dialysis membrane used in all patients was composed of POLYFLUX 170H, 210H, or FMC FX100, depending on the patient's condition. Most patients were administered recombinant human erythropoietin and anti-hypertensive medication (angiotensin-converting enzyme inhibitors, calcium-channel blockers, and B-blockers or vasodilators), as well as other drugs commonly used in chronic hemodialysis patients, such as phosphate and potassium binders and soluble vitamin supplements. We evaluated all scheduled routine laboratory parameters performed in each month of 2019 (from January to December 2019) and investigated risk factors via medical record review. Routine procedures included complete blood cell counts, serum electrolytes assessment, and serum chemistry tests (BUN, creatinine, cholesterol, and albumin). Estimation of BUN was done using Berthelot's method, while serum creatinine was estimated by alkaline Jaffe's Picrate method (Owen et al., 1954).[17] This research was approved by the Institutional Research Board (IRB) of Chungbuk National University Hospital (IRB No: 2020-03-039).

2. Statistical Analyses

Data are presented as mean±SD (standard deviation) or median and range, as appropriate, with P less than 0.05 indicating statistical significance. Blood levels are presented as the mean of 12 monthly values and evaluated against risk factors including diabetes, coronary artery disease, heart failure, and cerebrovascular disease using the independent t-test. Pearson's correlation was used for comparing correlations among risk factors and blood chemistry values. All data were analyzed by SPSS (VER. 25).

RESULTS

1. Patient Characteristics

Of the 67 hemodialysis patients who agreed to participate in the study, 33 (49.3%) were male, 34 (50.7%) were female, and the average age was 61.7 years old. The average dialysis duration was 78.7 months. 36 patients (54%) had diabetes mellitus (DM), 22 (33%) had coronary artery disease, 7 (10%) had congestive heart failure, and 11 (16%) had a cerebrovascular accident. Average pre- and post-dialysis BUN were 59.2 mg/dL and 15.0 mg/dL; average serum creatinine, potassium, total CO_2, albumin and hemoglobin were 10.1 mg/dL, 5.0 mg/dL, 22.5 mmol/L, 4.0 g/dL, and 10.2 g/dL, respectively (Table 1).

2. Correlations between predialysis BUN and nutritional parameters

Patients' age was negatively correlated with serum creatinine ($r=-0.277$, $p<0.05$) and albumin ($r=-0.453$, $p<0.001$), which implied decreased muscle mass and nutrition via aging. Also, pre-dialysis BUN showed significant correlations with serum albumin ($r=0.287$, $p<0.05$) and creatinine ($r=0.454$, $p<0.001$) (Table 2, Fig. 1).

3. Correlations between pre-dialysis BUN and other variables

Age and pre-dialysis BUN showed no significant rela-

TABLE 1. Baseline clinical characteristics of the patients who underwent hemodialysis

Characteristic	Mean (n=67)±SD
Median age (range, yr)	61.69 (31.1-83.6)±12.5
Sex - no. (%)	
Male	33 (49.3)
Female	34 (50.7)
Comorbidity	
DM - no. (%)	36 (53.7)
CAD - no. (%)	22 (32.8)
CHF - no. (%)	7 (10.4)
CVA - no. (%)	11 (16.4)
Dialysis vintage (month)	78.7±60.3
Variable laboratory	
Pre BUN (mg/dL)	59.2±12.3
Post BUN (mg/dL)	15.1±4.8
Creatinine (mg/dL)	10.08±1.99
Cholesterol (mg/dL)	128.0±23.8
Albumin (g/dL)	4.02±0.28
Potassium (mg/dL)	5.04±0.52
Hemoglobin (g/dL)	10.25±0.65
Total CO_2 (mmol/L)	22.5±1.9
Delta urea nitrogen (mg/dL)	44.2±9.6
URR (%)	74.69±5.54

Pre BUN: pre-dialysis blood urea nitrogen, Post BUN: post-dialysis blood urea nitrogen, DM: diabetes mellitus, CAD: coronary artery disease, CHF: congenital heart failure, CVA: cerebrovascular accident, URR: urea reduction ratio.

tionship (p=0.534). None of the other results showed statistical significance except for albumin, creatinine, dialysis duration, potassium, total CO_2 and hemoglobin, which were significantly related to age. In particular, serum albumin was significantly related (p=0.025). When patients' ages were 65 years or older, albumin was 3.93 g/dL, and when ages were less than 65 years, albumin was 4.08 g/dL. Significant differences were also found for creatinine (9.46 mg/dL vs 10.54 mg/dL, p=0.028), dialysis duration (56.0 months vs 96.0 months, p=0.028), and potassium (4.94 mg/dL vs 5.13 mg/dL, p=0.028) (Table 3).

We also investigated the differences between higher and lower pre-dialysis BUN groups. The higher pre-dialysis BUN group showed higher serum albumin, creatinine, and post dialysis BUN. Especially, serum albumin showed a significant difference between groups (4.09 mg/dL vs. 3.94 mg/dL, p=0.021) which was not associated with age (p=0.074). Patients with higher BUN have higher serum creatinine and potassium, implying higher dietary intake and muscle mass (Table 4).

TABLE 2. Predialysis BUN and nutritional parameters

	Age		Pre-dialysis BUN	
	R	p-value	R	p-value
Creatinine (mg/dL)	−0.277	0.023	0.454	0.0001
Albumin (g/dL)	−0.453	0.0001	0.287	0.018
Pre BUN (mg/dL)	−0.205	0.097	1.000	1.000
Cholesterol (mg/dL)	−0.149	0.229	0.011	0.930
Hemoglobin (g/dL)	0.098	0.432	0.113	0.363
URR (%)	0.060	0.628	−0.070	0.575

Pre BUN: pre-dialysis blood urea nitrogen, URR: urea reduction ratio, R: Pearson's Correlation Coefficient.

4. Nutritional parameters with coronary disease and DM

Dialysis patients with coronary artery disease were older (67.1 vs. 59.0 y, p<0.05) and had lower total cholesterol (118.3 vs. 132.8 mg/dL, p<0.05). Serum creatinine was lower in the patients with DM (9.25 vs. 11.04 mg/dL, p<0.001) and with coronary artery disease (9.24 vs. 10.49 mg/dL, p<0.05) which might imply inflammation and malnutrition.

However, the pre-dialysis BUN showed no significant difference among the DM, coronary artery disease, congestive heart failure, or cerebrovascular accident groups. When we compared the DM and non-DM groups, pre-dialysis BUN showed no significant difference (p=0.480). Only

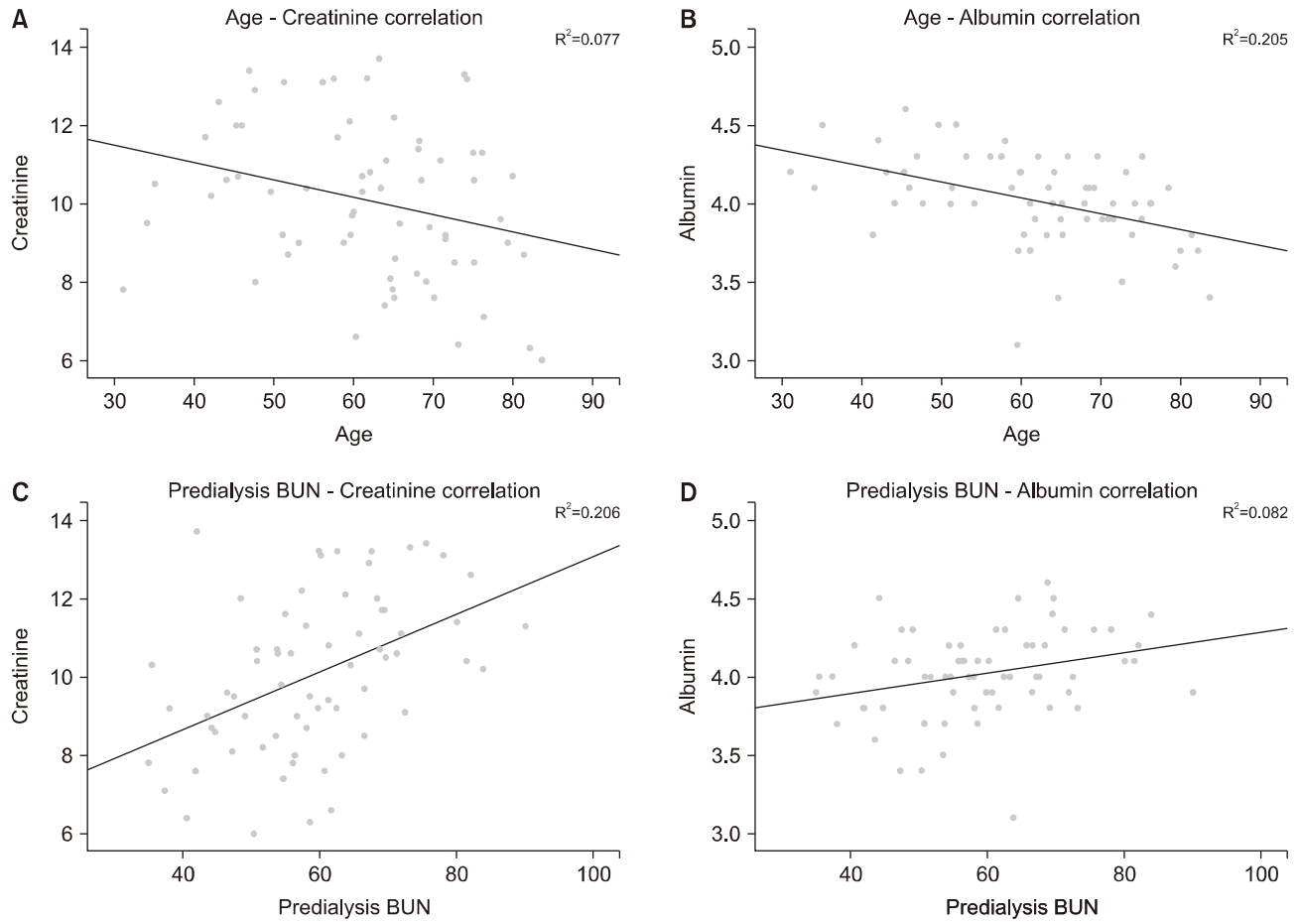

FIG. 1. Simple linear regression graphs for (A) Age - Creatinine (p<0.05), (B) Age - Albumin (p<0.001) and (C) Pre-dialysis BUN - Creatinine (p<0.001), (D) Pre-dialysis BUN - Albumin (p<0.05). BUN: blood urea nitrogen.

TABLE 3. Dialysis patients with age

	Age≥65 y (n=29)	Age<65 y (n=38)	p-value
Albumin (g/dL)	3.93±0.22	4.08±0.30	0.025
Creatinine (mg/dL)	9.47±1.98	10.54±1.89	0.028
Pre BUN (mg/dL)	58.1±12.4	60.1±12.4	0.534
Post BUN (mg/dL)	14.2±5.0	15.7±4.7	0.226
Cholesterol (mg/dL)	124.7±20.2	130.6±26.1	0.318
Hemoglobin (g/dL)	10.45±0.56	10.10±0.69	0.030
URR (%)	75.71±5.60	73.92±5.44	0.191
Delta urea nitrogen (mg/dL)	43.9±9.7	44.4±9.7	0.843
Dialysis duration -month	56.0±28.1	96.0±71.9	0.006
Potassium (mg/dL)	4.94±0.41	5.13±0.58	0.141
Total CO_2 (mmol/L)	23.3±1.5	21.9±1.9	0.001

Pre BUN: pre-dialysis blood urea nitrogen, Post BUN: post-dialysis blood urea nitrogen, DM: diabetes mellitus, CAD: coronary artery disease, URR: urea reduction ratio.

TABLE 4. Dialysis patients with pre-dialysis blood urea nitrogen

	BUN≥60 mg/dL (n=33)	BUN<60 mg/dL (n=34)	p-value
Albumin (g/dL)	4.10±0.28	3.94±0.26	0.021
Creatinine (mg/dL)	10.95±1.82	9.23±1.78	0.000
Post BUN (mg/dL)	17.9±4.8	12.3±2.8	0.000
Delta urea nitrogen (mg/dL)	51.2±7.3	37.4±6.0	0.000
Cholesterol (mg/dL)	129.3±22.9	126.8±24.9	0.676
Hemoglobin (g/dL)	10.12±0.63	10.37±0.66	0.119
URR (%)	74.11±6.41	75.26±4.56	0.400
AGE	58.91±11.83	64.39±12.77	0.074
Dialysis duration -month	71.2±47.5	85.9±70.5	0.322
Potassium (mg/dL)	5.22±0.50	4.87±0.48	0.004
Total CO_2 (mmol/L)	21.5±1.8	23.5±1.3	0.000

Pre BUN: pre-dialysis blood urea nitrogen, Post BUN: post-dialysis blood urea nitrogen, DM: diabetes mellitus, CAD: coronary artery disease, URR: urea reduction ratio.

TABLE 5. Dialysis patients with comorbidity

	CAD (n=22)	Non-CAD (n=45)	p-value	DM (n=36)	Non-DM (n=31)	p-value
Age (yr)	67.13±11.87	59.03±12.10	0.012	63.46±11.47	59.63±13.56	0.214
Dialysis duration (month)	75.55±61.70	80.20±60.23	0.769	72.61±56.71	85.71±64.41	0.379
Creatinine (mg/dL)	9.24±2.00	10.49±1.86	0.014	9.25±1.74	11.04±1.84	0.000
Albumin (g/dL)	3.92±0.21	4.06±0.30	0.051	4.01±0.28	4.03±0.29	0.700
Pre BUN (mg/dL)	58.1±14.5	59.8±11.3	0.599	58.2±13.1	60.4±11.5	0.480
Post BUN (mg/dL)	14.4±5.5	15.3±4.5	0.479	14.9±5.0	15.3±4.6	0.747
Cholesterol (mg/dL)	118.3±17.2	132.8±25.2	0.018	125.5±20.7	131.0±26.9	0.345
Hemoglobin (g/dL)	10.46±0.78	10.15±0.56	0.068	10.11±0.70	10.42±0.57	0.054
Delta urea nitrogen (mg/dL)	43.6±10.8	44.5±9.1	0.741	43.4±9.5	45.1±9.8	0.458
URR (%)	75.43±5.35	74.33±5.65	0.452	74.76±4.97	74.62±6.22	0.921

Pre BUN: pre-dialysis blood urea nitrogen, Post BUN: post-dialysis blood urea nitrogen, DM: diabetes mellitus, CAD: coronary artery disease, URR: urea reduction ratio.

creatinine was significantly higher in the non-DM group (p=0.000) (Table 5).

DISCUSSION

In this study, through the correlations between blood urea nitrogen, creatinine, and albumin, we confirmed that blood urea nitrogen could also be used as an indicator to evaluate the nutritional status of patients. Pre-dialysis blood urea nitrogen was positively correlated with serum albumin and creatinine, which are indicators of muscle mass and nutritional status. In other words, 'maintaining

high pre-dialysis BUN' is equivalent to 'maintaining the patient's nutritional status well'.

The independence of BUN as an indicator supports the argument of the study. Pre-dialysis BUN levels were not related to URR. In other words, it was confirmed through linear regression analysis that pre-dialysis BUN did not affect URR. These results may support the argument that increasing BUN by increasing protein intake does not affect dialysis adequacy.

This study also showed that pre-dialysis BUN did not differ significantly among patients with DM, coronary artery disease, congestive heart failure, and cerebrovascular disease. When divided into DM and non-DM groups, creatinine showed significantly higher values in the non-DM group. However, there was no significant difference between the DM and non-DM groups for any other blood chemistry values or pre-dialysis BUN.

Since pre-dialysis BUN did not differ based on age or DM, it can be the basis for judging the independent status of blood urea nitrogen as a nutritional index.

Several previous studies suggest that pre-dialysis creatinine and interdialytic creatinine changes between dialysis are closely related to the nutritional status and mortality in hemodialysis patients. Desmeules et al.[18] (2004) reported that pre-dialysis creatinine levels were related to patient muscle mass and that high creatinine levels were associated with high muscle mass, which had a significant impact on patient survival. Another study (Huang et al.[19] (2010)) demonstrated that muscle mass was related to overall mortality. This study demonstrated that decreased muscle and fat masses were significantly associated with higher overall mortality. In addition, another study (Srinivasan Beddhu et al. (2003)) described the effect of body size and composition in dialysis patients on their survival.[19] This study demonstrated that patients with high body mass index (BMI) had a low risk of death. Based on these studies, it can be deduced that a "high creatinine level" is associated with "high body mass," which can be an important factor in patient survival.

Meanwhile, previous studies (Friedman et al.[20] (2010)) show that assessing the albumin level of a hemodialysis patient can determine the nutritional status of the patient. In addition, albumin can be used to predict patient mortality (Owen et al.[21] (1993), Msaad et al.[22] (2019)), and there have been studies showing that the higher the albumin, the better the patient's survival (Dwyer et al.[23] 2005). Based on these studies, it can be inferred that high serum creatinine and albumin levels significantly affect survival in hemodialysis patients.

In a previous study, BUN was found to be related to mortality through the URR; it was confirmed that a lower URR was associated with a higher risk of death (Owen et al. (1993)).[21] However, studies on the relationship between pre-dialysis BUN level and mortality are limited. A small number of studies have found that high pre-dialysis BUN is beneficial for patient survival.

Degoulet et al.[24] (1982) reported that low pre-dialysis BUN levels were associated with an increase in overall mortality and cardiovascular mortality. On the other hand, other studies provide evidence that high pre-dialysis BUN is detrimental to patients' survival. In a study limited to pregnant women, it was reported that lower pre-dialysis BUN optimizes birth weight and gestational age (Asamiya et al. 2009).[25] In addition, a study reported that metabolic acidosis was significantly progressed in the patient group with high pre-dialysis BUN (Gao et al. 2000).[26]

The limitations of the present study are the small number of patients, the short study duration, and that the factors affecting pre-dialysis BUN were not clear. It is not clear whether pre-dialysis BUN could be reduced or increased by dietary restrictions alone or whether it could have been altered by diet as well as other factors. In addition, the relationship between comorbidity and diet (esp. protein) is limited because diet composition varies by country and region. Therefore, further studies such as large-scale randomized control trials and comparative analyses between different races and countries may be needed.

Despite these arguments about pre-dialysis BUN, the significance of this study is that it shows that pre-dialysis BUN can be used as an indicator to evaluate the nutritional status of patients. Appropriate management is required because the need for kidney replacement therapy in patients with ESRD is constantly increasing, and the mortality rate is significantly higher than that in the general population. Currently, the BUN is mainly used to calculate Kt/V of urea, a surrogate indicator of dialysis appropriateness in patients with terminal renal failure, because it is easy to measure even if it is not the most important toxic uremic substance. However, it is not possible to evaluate dialysis appropriateness and the patient's health status simply with Kt/V of urea. A comprehensive evaluation is required, with not only clinical symptoms but blood pressure, anemia, nutritional status, inflammation, acid-base balance, and mineral metabolism, including calcium and phosphorus. Further trials are needed to improve the long-term survival rate and quality of life of patients with ESRD.

In conclusion, we suggest that the pre-dialysis BUN is not only a marker of dialysis adequacy but also could be an indicator of nutritional status in ESRD patients.

CONFLICT OF INTEREST STATEMENT

None declared.

REFERENCES

1. Avram MM, Blaustein D, Fein PA, Goel N, Chattopadhyay J, Mittman N. Hemoglobin predicts long-term survival in dialysis patients: a 15-year single-center longitudinal study and a correlation trend between prealbumin and hemoglobin. Kidney Int Suppl 2003;64:S6-11.
2. Honda H, Qureshi AR, Axelsson J, Heimburger O, Suliman ME, Barany P, et al. Obese sarcopenia in patients with end-stage renal

disease is associated with inflammation and increased mortality. Am J Clin Nutr 2007;86:633-8.
3. Kim JK, Choi SR, Choi MJ, Kim SG, Lee YK, Noh JW, et al. Prevalence of and factors associated with sarcopenia in elderly patients with end-stage renal disease. Clin Nutr 2014;33:64-8.
4. Ikizler TA, Cano NJ, Franch H, Fouque D, Himmelfarb J, Kalantar-Zadeh K, et al. Prevention and treatment of protein energy wasting in chronic kidney disease patients: a consensus statement by the International Society of Renal Nutrition and Metabolism. Kidney Int 2013;84:1096-107.
5. Cianciaruso B, Brunori G, Traverso G, Panarello G, Enia G, Strippoli P, et al. Nutritional status in the elderly patient with uraemia. Nephrol Dial Transplant 1995;10 Suppl 6:65-8.
6. Stenvinkel P, Heimbürger O, Paultre F, Diczfalusy U, Wang T, Berglund L, et al. Strong association between malnutrition, inflammation, and atherosclerosis in chronic renal failure. Kidney Int 1999;55:1899-911.
7. Ikizler TA, Wingard RL, Harvell J, Shyr Y, Hakim RM. Association of morbidity with markers of nutrition and inflammation in chronic hemodialysis patients: a prospective study. Kidney Int 1999;55:1945-51.
8. Waikar SS, Bonventre JV. Can we rely on blood urea nitrogen as a biomarker to determine when to initiate dialysis? Clin J Am Soc Nephrol 2006;1:903-4.
9. Leypoldt JK. Urea standard Kt/V(urea) for assessing dialysis treatment adequacy. Hemodial Int 2004;8:193-7.
10. Charra B, Calemard E, Ruffet M, Chazot C, Terrat JC, Vanel T, et al. Survival as an index of adequacy of dialysis. Kidney Int 1992;41:1286-91.
11. National Kidney Foundation. KDOQI Clinical Practice Guideline for Hemodialysis Adequacy: 2015 update. Am J Kidney Dis 2015;66:884-930. Erratum in: Am J Kidney Dis 2016;67:534.
12. Stolic R, Trajkovic G, Stolic D, Peric V, Subaric-Gorgieva G. Nutrition parameters as hemodialysis adequacy markers. Hippokratia 2010;14:193-7.
13. Combe C, Chauveau P, Laville M, Fouque D, Azar R, Cano N, et al. Influence of nutritional factors and hemodialysis adequacy on the survival of 1,610 French patients. Am J Kidney Dis 2001;37(1 Suppl 2):S81-8.
14. Rocco MV, Paranandi L, Burrowes JD, Cockram DB, Dwyer JT, Kusek JW, et al. Nutritional status in the HEMO study cohort at baseline. Hemodialysis. Am J Kidney Dis 2002;39:245-56.
15. Piccoli GB, Capizzi I, Vigotti FN, Leone F, D'Alessandro C, Giuffrida D, et al. Low protein diets in patients with chronic kidney disease: a bridge between mainstream and complementary-alternative medicines? BMC Nephrol 2016;17:76.
16. Wang AY, Sanderson J, Sea MM, Wang M, Lam CW, Li PK, et al. Important factors other than dialysis adequacy associated with inadequate dietary protein and energy intakes in patients receiving maintenance peritoneal dialysis. Am J Clin Nutr 2003;77: 834-41.
17. Owen JA, Iggo B, Scandrett FJ, Stewart CP. The determination of creatinine in plasma or serum, and in urine; a critical examination. Biochem J 1954;58:426-37.
18. Desmeules S, Lévesque R, Jaussent I, Leray-Moragues H, Chalabi L, Canaud B. Creatinine index and lean body mass are excellent predictors of long-term survival in haemodiafiltration patients. Nephrol Dial Transplant 2004;19:1182-9.
19. Huang CX, Tighiouart H, Beddhu S, Cheung AK, Dwyer JT, Eknoyan G, et al. Both low muscle mass and low fat are associated with higher all-cause mortality in hemodialysis patients. Kidney Int 2010;77:624-9.
20. Friedman AN, Fadem SZ. Reassessment of albumin as a nutritional marker in kidney disease. J Am Soc Nephrol 2010;21:223-30.
21. Owen WF Jr, Lew NL, Liu Y, Lowrie EG, Lazarus JM. The urea reduction ratio and serum albumin concentration as predictors of mortality in patients undergoing hemodialysis. N Engl J Med 1993;329:1001-6.
22. Msaad R, Essadik R, Mohtadi K, Meftah H, Lebrazi H, Taki H, et al. Predictors of mortality in hemodialysis patients. Pan Afr Med J 2019;33:61.
23. Dwyer JT, Larive B, Leung J, Rocco MV, Greene T, Burrowes J, et al. Are nutritional status indicators associated with mortality in the Hemodialysis (HEMO) Study? Kidney Int 2005;68: 1766-76.
24. Degoulet P, Legrain M, Réach I, Aimé F, Devriés C, Rojas P, et al. Mortality risk factors in patients treated by chronic hemodialysis. Report of the Diaphane collaborative study. Nephron 1982;31:103-10.
25. Asamiya Y, Otsubo S, Matsuda Y, Kimata N, Kikuchi KAN, Miwa N, et al. The importance of low blood urea nitrogen levels in pregnant patients undergoing hemodialysis to optimize birth weight and gestational age. Kidney Int 2009;75:1217-22.
26. Gao H, Lew SQ, Bosch JP. Moderate metabolic acidosis and its effects on serum parameters in hemodialysis patients. Nephron 2000;86:135-8.