

Assessment of dietary acid burden in adult patients with end-stage renal disease undergoing dialysis: a pilot study

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Key words: dialysis, dietary acid load, acid-base balance, nutritional value of diet, end-stage kidney disease.

Abstract

Introduction: Literature data clearly indicate that consumption of an acid-forming diet by renal failure patients on dialysis can worsen acid-base balance parameters by lowering serum bicarbonate levels. Conversely, consumption of an alkaline-forming diet while controlling potassium and phosphorus intake may be helpful in maintaining predialysis bicarbonate levels within reference values.

Aim of the research: Evaluate the nutritional value of daily rations of patients with renal failure treated with dialysis in terms of balancing the intake of acid- and alkaline-forming components.

Material and methods: Fifty-four patients (35 men, 19 women) with end-stage renal failure undergoing dialysis therapy were enrolled in the study. A dietary history of 3 non-dialysis days of the week was collected from the subjects. Nutrient intake was assessed using Aliant software (Anmarsoft).

Results: The results of the in-house analysis showed that as many as 48 of the 54 participating patients (88.9%) consumed an acid-forming diet. It was observed that the unfavourable nature of the rations of the studied patients was mainly influenced by the low intake of alkaline-forming components, such as calcium and magnesium, and in the group of men also by a higher-than-recommended intake of phosphorus. The median PRAL index (potential renal acid load) of the analysed rations was 9.49 and was significantly higher in males.

Conclusions: Observations made in the study, related to the improper dietary balance of dialysis patients, indicate the need to intensify nutrition education as an element in the routine care of dialysis patients in order to increase the effectiveness of patients' adherence to an alkaline-forming diet.

Introduction

Patients with renal failure (RF) experience reduced bicarbonate production in the distal tubules and impaired reabsorption of HCO_3^- in the renal tubules, as well as loss of the ability to remove excess H^+ ions with the urine [1–3]. Moreover, complications accompanying RF, such as anaemia (resulting in impaired haemoglobin buffering) or an inflammatory response (resulting in increased kidney damage and disease progression), also contribute to blood pH abnormalities [2, 4–6]. The disorders described above result in the accumulation of hydrogen ions in the body with a subsequent decrease in blood pH and the development of metabolic acidosis [2, 3]. The results of epidemiological studies available in the literature indicate that the average prevalence of metabolic acidosis among patients with RF, regardless of the stage of the disease, is 17–20% [1, 4]. In patients in advanced stages of chronic kidney disease, this result is higher: 39–60%, and the incidence of acidosis increases with the progression of RF [1, 4, 7]. In dialysis-treated patients, the prevalence of metabolic acidosis is lower than the prevalence among non-dialysis patients in advanced stages of chronic kidney

disease; however, the result remains high and indicates the significance of the problem. The problem of metabolic acidosis affects nearly 40% of haemodialysed patients, and some sources report an even higher percentage, i.e. 73% [1, 7, 8].

Various methods are available in the literature to assess the nature of the diet consumed (acid and alkaline milli-equivalent method, PRAL index, NEAP index). The NEAP index (net acid production) determines the total amount of acid excreted, while the PRAL index (potential renal acid load) determines the amount of acids and bases produced according to the nutrient profile of the diet. The results of studies available in the scientific literature indicate that high NEAP and PRAL values, suggesting the acid-forming nature of the diet, are associated with a decrease in glomerular filtration rate and reduced serum bicarbonate levels [9–12]. On the other hand, reduction of renal acid load by supplying an alkaline-forming diet resulted – among patients with chronic kidney disease coexisting with metabolic acidosis – in slowing the progression of renal dysfunction and reducing the risk of RF [13]. In addition, the results of available

studies indicate that consumption of an alkalinising diet correlates with increased HCO_3^- levels in renal failure patients and increased predialysis bicarbonate levels in dialysis patients [14, 15].

Aim of the research

The aim of this study was to evaluate the nutritional value of daily rations of patients with renal failure treated with dialysis in terms of balancing the intake of components affecting parameters of acid-base balance.

Material and methods

Patients of the Department of Nephrology, Internal Medicine, and Hypertension with the Dialysis Station and Outpatient Dialysis Clinic of the Dr. Antoni Ju-rasz SU No. 1 in Bydgoszcz were eligible for the study. Approval for the study (KB 343/2022) was granted by the Bioethics Committee at the Medical University of Torun, CM in Bydgoszcz on 21 June 2022. The inclusion criteria for the study group were as follows: informed consent to participate in the study, age > 18 years, haemodialysis 3 times a week (every other day), and duration of dialysis treatment > 6 months.

As part of the study, anthropometric measurements (measurement of weight and height) and biochemical tests (albumin and creatinine levels) were performed to assess the nutritional status of the patients studied. To assess the nutritional value and acid/base-forming nature of the diet, a dietary history of 3 days was collected using the running note method. The interview included 2 non-consecutive days during the work week and one weekend day.

Written consent to participate in the study was given by 105 patients who met the inclusion criteria. However, only 60 patients returned a completed dietary history form. After verifying the correctness of completion of the received 3-day dietary history forms, 6 patients who provided incorrectly recorded dietary intake data were excluded from the study. Finally, after taking into account all the inclusion criteria and the correctness of completion of the returned dietary history form, 54 patients were included in the study group, including 35 men and 19 women. The age of the participating patients ranged from 27 to 92 years ($\text{Me} = 69.5$).

The nutritional value of the rations was assessed by analysing the collected 3-day dietary history in Aliant (Anmarsoft). The resulting individual dietary intake was compared with recommendations for dialysis patients developed by the Working Group of the Polish Society of Nephrology [16]. The PRAL and NEAP indices were used to estimate the acid- or alkaline-forming nature of the diet. The formulas developed by Remer [17] were used to calculate the PRAL and NEAP index.

$$\text{PRAL (mEq/day)} = (0.49 \times \text{protein g/day}) + 0.037 \times \text{phosphorus mg/day} - (0.021 \times \text{potassium mg/day}) - (0.026 \times \text{magnesium mg/day}) - (0.013 \times \text{calcium mg/day}).$$

$$\text{NEAP} = \text{PRAL} + \text{OAest}.$$

$$\text{OAest} = (0.007184 \times \text{height [cm]} + 0.725 \times \text{weight [kg]} - 0.425) \times 41/1.73.$$

PRAL values above 0 were interpreted as an acid-forming diet, while values below 0 were interpreted as an alkaline-forming diet.

Statistical analysis

Statistical analyses were performed using Statistica 13 (StatSoft). The normality of the distribution of the variables was tested using the Shapiro-Wilk test. Student's *t*-test and Mann-Whitney *U* tests were used to test for differences between 2 groups, depending on the distribution of the variables. ANOVA and Tukey's HSD test for unequal numbers and Kruskal-Wallis ANOVA test were used to test differences between more than 2 groups. Results with $p < 0.05$ were considered statistically significant.

Results

The causes of end-stage renal failure in the group of patients studied were: glomerulonephritis ($n = 20$; 37%), diabetic nephropathy ($n = 15$; 28%), and hypertensive nephropathy ($n = 8$; 15%). In the remaining 11 (20%) eligible patients, the pathogenetic factors of end-stage renal disease were polycystic renal degeneration, systemic vasculitis, monoclonal gammopathy, lupus nephritis, or atherosclerotic ischaemic nephropathy.

The study group was mostly represented by haemodialysis patients ($n = 39$), with the rest of the study patients undergoing haemodiafiltration ($n = 9$) and peritoneal dialysis ($n = 6$). The average duration of dialysis treatment in the study group overall was 3.2 years, in the women's group it was 2.7 years, while in the men's group it was 3.6 years (Table 1). No statistically significant differences ($p = 0.6658$) in terms of duration of dialysis treatment were observed between the women and men studied.

Participating men and women also did not differ statistically significantly in albumin and creatinine levels. Analysis of anthropometric measurements showed, as expected, statistically significantly lower values for body weight and height in the women's group ($p < 0.0001$).

Analysis of the energy value of daily rations in the study group overall and by gender

The calculated average energy intake among the studied patients was in line with the recommended range of intake per kilogram of body weight (25–35 kcal/kg IBW) and amounted to 29.0 kcal/kg

Table 1. Characteristics of the study group overall and by gender

Parameter	All (<i>n</i> = 54)		Women (<i>n</i> = 19)		Men (<i>n</i> = 35)		<i>P</i> -value
	Me (<i>x</i> ± <i>SD</i>)	Q1; Q3 (min.–max.)	Me (<i>x</i> ± <i>SD</i>)	Q1; Q3 (min.–max.)	Me (<i>x</i> ± <i>SD</i>)	Q1; Q3 (min.–max.)	
Age [year]	69.5	52.0–75.0	62.6 ±16.8	40.0–89.0	71.0	61.0–75.0	0.5178
Height [cm]	167.7 ±10.1	145.0–185.0	159.0 ±9.0	145.0–175.0	172.5 ±7.1	154.0–185.0	< 0.0001
Weight [kg]	74.1 ±14.8	40.9–102.0	63.0 ±12.5	40.9–85.3	80.4 ±12.2	55.0–102.0	< 0.0001
TBW [%]	55.6 ±4.5	46.7–64.7	52.3 ±3.8	47.2–59.9	57.5 ±3.8	46.7–64.7	< 0.0001
BMI [kg/m ²]	26.3 ±4.3	19.0–40.5	24.8 ±3.9	19.4–31.5	27.0 ±4.4	19.0–40.5	0.0774
Albumins [mg/dl]	4.00	3.75–4.20	3.95 ±0.28	3.30–4.30	3.93 ±0.45	2.80–4.80	0.8737
Creatinine [mg/dl]	7.59 ±2.89	1.17–13.80	7.55 ±2.67	1.17–12.87	7.61 ±3.04	2.76–13.80	0.9385
Dialysis therapy time [year]	3.2	1.7–7.0	2.7	1.7–13.5	3.6	1.4–5.3	0.6658

Me – median, TBW – total body water, BMI – body mass index.

IBW in the female group and 28.3 kcal/kg IBW in the male group. Male subjects had a statistically significantly higher energy intake compared to females (1767.3 vs. 1374.3 kcal, *p* = 0.026) (Table 2).

The analysis of individual values carried out as part of the study showed that of the 54 patients included in the study, 21 (38.9%) consumed a diet of insufficient caloric intake, while 12 (22.2%) patients consumed a diet of caloric intake above the upper limit of the norm.

Analysis of acid-forming ingredient intake in the study group overall and by gender

Analysis of the average intakes of acid-forming nutrients showed that the dietary rations of the participating renal failure patients on dialysis were improperly balanced due to their phosphorus content (Table 2). The average phosphorus intake in the men's group (1126.3 ±406.8 mg) translated into realisation of the norm at 124%. The mean phosphorus intake in the women's group (*x* = 886.4 ±360.8 mg) was statistically significantly lower compared to men (*p* = 0.036) and was within the recommended values (97.4% of the norm).

Analysis of total protein intake by class of realisation of the norm showed that 22 of the 54 participating patients (40.7%) consumed insufficient protein, while 11 (20.4%) patients consumed protein above the upper limit of the norm.

The men surveyed consumed statistically significantly more protein than the women (77.0 ±25.4 g vs. 60.1 ±20.6 g, *p* = 0.016).

Analysis of intake of alkaline-forming components in the study group overall and by gender

Analysis of the intake of alkaline-forming nutrients showed an improper balance of diets of dialysis patients mainly in terms of calcium and magnesium

(Table 2). The average calcium intake in the total study group was 456.6 mg. This value realised the standard in only 28.5%. Moreover, an analysis of individual intake showed that the diets of 98.1% of the patients (*n* = 53) contained calcium in amounts below the norm. When discussing the issue of calcium intake, it should be noted that 42 out of 54 patients taking part in the study were on therapy with preparations containing calcium carbonate. The average dose of calcium taken by patients in the form of a drug was 6.3 ±3.67 g/24 h.

The average magnesium intake of participating patients was 219.1 mg, realising the standard in only 53%. The vast majority of the subjects (87.0%, *n* = 47) consumed magnesium below the recommended values. The calculated average potassium intake was at the normal level, but only for 23 (42.6%) of the participating patients was the intake recorded within the normal range. For 22.2% of patients, potassium intake was reported to be too high. The remaining 35.2% of dialysis patients (*n* = 19) had a potassium intake below normal.

Analysis of PRAL and NEAP index values in the study group overall and by gender

The median value of the PRAL index in the total study group was 9.49 mEq, indicating the acid-forming nature of the diet (Table 2). Analysis of the individual values of the PRAL index, calculated for 3-day intake, showed that as many as 88.9% of the subjects (*n* = 48) consumed an acid-forming diet. It was shown that the average PRAL value calculated for the men's group was almost 3 times higher (11.90 mEq) than the value calculated for the women's study group (4.24 mEq) (*p* = 0.007). An alkaline-forming diet was consumed by only 2 women and 4 men.

The mean value of the NEAP index in the total study group was 53.06 ±14.65 mEq. Also, the value of this index was statistically significantly (*p* < 0.0001)

Table 2. Energy and nutrient intake, % coverage of the standard, and PRAL and NEAP values in the study group overall and by gender

Nutrient [units per day]	All (n = 54)			Women (n = 19)			Men (n = 35)			P-value
	Me (x ± SD)	Q1; Q3 (min.–max.)	% of norm	Me (x ± SD)	Q1; Q3 (min.–max.)	% of norm	Me (x ± SD)	Q1; Q3 (min.–max.)	% of norm	
Energy [kcal]	1775.5 ± 595.7	734.3–3290.7	89.6	1374.3	1106.0–2153.2	96.8	1767.3	1573.7–2260.3	94.2	0.0262
Acid-producing nutrients										
Protein [g]	71.1 ± 25.0	21.6–134.4	95.7	60.1 ± 20.6	29.9–107.5	93.5	77.0 ± 25.4	21.6–134.4	96.9	0.0161
Plant protein [g]	21.2 ± 6.9	7.9–35.7	–	18.1 ± 6.5	7.9–32.9	–	22.9 ± 6.6	9.2–35.7	–	0.0143
Animal protein [g]	49.6 ± 19.8	12.4–98.7	96.3	41.8 ± 16.5	14.5–74.5	97.1	53.9 ± 20.3	12.4–98.7	94.7	0.0302
Phosphorus [mg]	1041.9 ± 404.7	331.6–2127.1	114.6	886.4 ± 360.8	463.8–1701.7	97.4	1126.3 ± 406.8	331.6–2127.1	123.9	0.0361
Base-producing nutrients										
Potassium [mg]	2399.3 ± 867.4	885.0–5261.7	95.8	2179.4 ± 761.4	1197.0–3764.0	87.0	2518.7 ± 907.8	885.0–5261.7	100.6	0.1721
Calcium [mg]	456.6	273.0–644.1	28.5	355.1	203.7–603.9	22.2	466.4	391.8–650.5	29.1	0.1434
Magnesium [mg]	219.1	156.2–273.3	53.4	182.5	127.7–232.7	60.0	221.3	179.0–285.9	52.7	0.0617
Dietary acid load indexes										
PRAL [mEq]	9.49	3.82–14.67	–	4.24	2.96–10.59	–	11.90	7.60–16.93	–	0.0073
NEAP [mEq]	53.06 ± 14.65	10.56–84.53	–	43.01	38.71–49.46	–	57.56	49.04–65.56	–	< 0.0001

Me – median, PRAL – potential renal acid load, NEAP – net endogenous acid production.

higher in men compared to women (57.56 mEq vs. 43.01 mEq, respectively).

Discussion

The analysis of clinical studies available in the Polish literature allows us to conclude that the present paper is the first one in which the authors present the results of the evaluation of the nutritional value of daily food rations of patients with RF treated with dialysis in terms of acid-/alkaline-forming character. The results of the authors' own analysis showed that as many as 48 of the 54 participating patients (88.9%) consumed an acid-forming diet. It was observed that the unfavourable nature of the study patients' rations was mainly influenced by the low intake of alkaline-forming components, such as calcium (28.5% of the norm) and magnesium (53.4% of the norm), and in the group of men also a higher-than-recommended intake of phosphorus (123.9% of the norm). The inadequacies shown in the authors' own work in balancing the diet of dialysis patients are consistent with results published by other authors [18–23]. In the study by Bogacka *et al.* haemodialysis patients were characterised by a low intake of alkaline-forming components: calcium (214.8–431.2 mg, which realised the norm in the range of 17.2–34.5%) and magnesium (172.3–217.9 mg; 41.0–68.1% of the norm) [18]. Insufficient intakes of calcium (24.1–43.3% of the norm) and magnesium (48.3–90.2%) in a group of haemodialyzed patients were also reported by Kardasz *et al.* [19]. Similarly, Tokarska *et al.* demonstrated insufficient intake of both calcium (39.3–45.4% of the norm) and magnesium (78.2–85.0%) in a group of 36 haemodialyzed patients [20].

The median value calculated in our own work for the PRAL index in the total study group was 9.49 mEq, and the mean value of the NEAP index was 53.06 ± 14.65 mEq, indicating an acid-forming character of the diets analysed. The values of PRAL and NEAP indices most similar to those observed in our own work were obtained by Ikizler *et al.*, in a study performed in a group of 42 patients with CKD in stages 3–5 under the care of nephrology clinics in Seattle (9.7 ± 18.4 mEq and 58.2 ± 24.3 mEq, respectively) [15]. Comparing the nutritional value of the diets analysed in our own work with the nutritional value calculated by Ikizler *et al.*, it can be observed that patients from Washington state consumed more acid-forming protein (77.3 g vs. 71.1 g) and phosphorus (1202.1 mg vs. 1041.9 mg). At the same time, U.S. patients were characterised by almost twice the intake of alkaline-forming calcium (812.3 mg vs. 456.6 mg) [15].

Lower – but still indicative of acidogenicity – values of PRAL and NEAP indices were also obtained by 2 other research teams [21, 22]. The average PRAL index value calculated for the rations consumed by the 100 renal failure patients described in the study by Angeloco *et al.* was 6.8 mEq, while the NEAP index value

was 53.1 mEq [11]. In contrast, RF patients participating in a study published by Machado *et al.* consumed less acid-forming rations, with PRAL and NEAP values of 4.8 mEq and 49.5 mEq, respectively [22]. Different results related to the alkaline-forming nature of the diet were published by Moghari *et al.* [14]. In the cited study, PRAL and NEAP values calculated for a group of 122 RF patients treated with haemodialysis in Kashan, Iran were at the following level: PRAL = −2.8 mEq and NEAP = 42.7 mEq. In addition, the authors of the cited study showed a statistically significant negative correlation between PRAL values and serum bicarbonate levels before dialysis ($\beta = -0.38$; $p < 0.0001$). Moghari *et al.* noted that consumption of vegetables such as lettuce, tomato, cucumber, spinach, as well as dried fruits, low-fat milk, and natural yogurt was associated with higher predialysis blood HCO_3^- levels [14].

The observations made in this study, which are related to poor dietary balance, indicate the need to intensify the process of nutritional care, including nutrition education among dialysis patients to increase the effectiveness of their adherence to dietary recommendations. The Working Group of the Polish Nephrological Society stated that early nutritional education can be crucial for preventing common renal dietary mistakes made by end-stage kidney disease patients undertaking dialysis therapy [16]. For patients undertaking maintenance haemodialysis, clinical practice guidelines advise the need for dietary interview and nutritional counselling at least every 3 months or even more often in the case of high risk of malnutrition [23, 24]. The results of scientific papers available in the literature confirm that the implementation of nutrition education among dialysis patients results in improved balance of rations [20, 24]. Visiedo *et al.* showed that a nutrition intervention program (NIP) based on individualised counselling, implemented in a group of dialysis patients during routine follow-up examinations, significantly improved nutritional status and quality of life, and prolonged survival [24]. Similarly, Tokarska *et al.* observed improved ration balance in a group of dialysis patients enrolled in a nutrition education program [20].

The main limitation of the present study is the relatively small size of the study group and the evaluation and interpretation of nutritional value based on menus from only 3 days and additionally collected from patients during the summer (July-August). This approach does not take into account possible differences in nutrition related to the seasonality of certain food products.

Conclusions

In the present study, the values of the PRAL and NEAP indicated the acid-forming nature of the diet. It is advisable to provide nutritional education, aimed at improving the balance of the diet and its nature by introducing more alkalising products, such as vegeta-

bles and fruits or lean dairy products, provided that serum potassium levels are in the normal range.

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Ethical approval

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Conflict of interest

The authors declare no conflict of interest.

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