NEPHROLOGY

Nephrology **16** (2011) 582–587

Original Article

Nutritional status of vegetarians on maintenance haemodialysis

TAI-TE WU,[1]* CHIEH-YING CHANG,[1]* WEI-MIN HSU,[2] I-KWAN WANG,[3] CHIH-HAO HSU,[1] SHU-HWA CHENG,[1] CHIH-CHIA LIANG,[3] CHIZ-TZUNG CHANG[3] and CHIU-CHING HUANG[3]

[1]Chun-An Dialysis Centre, Taoyuan, [2]Zen-Ho Dialysis Centre and [3]Division of Nephrology, China Medical University Hospital and College of Medicine, Taichung, Taiwan

KEY WORDS:
body mass index, haemodialysis, nutrition, subjective global assessment, vegetarian.

Correspondence:
Dr Chiz-Tzung Chang, Department of Nephrology, China Medical University Hospital, 2 Yude Road, Taichung City, 40461 Taiwan.
Email: ma273737@yahoo.com.tw

Accepted for publication 23 March 2011.
Accepted manuscript online 1 April 2011.

doi:10.1111/j.1440-1797.2011.01464.x

*These authors contributed equally to this work.

SUMMARY AT A GLANCE

Wu *et al*. compared the nutritional status of 19 vegetarian *versus* 299 non-vegetarian stable HD patients and found that vegetarian patients have smaller BMI and require higher EPO usage, but their subjective global assessment score and functions of daily activity are similar to their non-vegetarian counterparts.

ABSTRACT:

Aim: **Vegetarian diets have long been thought of as beneficial to health. However, vegetarian diets are often low in protein, which is contradictory to the high protein diet guideline for uraemia patients. The purpose of the study was to investigate the impact of a vegetarian diet on the nutritional status of haemodialysis (HD) patients.**

Methods: **Patients on chronic HD for over 6 months were included in the study. The normalized protein catabolic rate (nPCR) was used to reflect daily protein intake. Biochemical markers of nutrition, anthropometric parameters, subjective global assessment (SGA) and functional activity of daily living were assessed to evaluate the nutritional status of vegetarians on chronic HD.**

Results: **Nineteen out of 318 HD patients were vegetarians. The nPCR was lower in the vegetarian group (1.20 ± 0.24 *vs* 1.10 ± 0.29 g/kg per day, non-Veg *vs* Veg, $P < 0.05$). The serum albumin and prealbumin were similar in vegetarian and non-vegetarian HD patients. The body mass index (BMI) and mid-arm muscular circumference (MAMC) were lower in vegetarian patients ($P < 0.05$). The haematocrit of vegetarians can be maintained at a level similar to that of non-vegetarian patients but erythropoietin doses needed were higher in vegetarian patients ($P < 0.05$). The muscle strength evaluated by the hand-grip test, SGA and activities of daily living were similar in vegetarians and non-vegetarians.**

Conclusion: **The present study revealed that HD patients on vegetarian diets might have a smaller BMI, but SGA and function of daily activities were similar to those of the non-vegetarians. The haematocrit of vegetarians can be maintained with a higher erythropoietin dose.**

Nutritional status is one of the most important predictors of mortality and morbidity in long-term haemodialysis (HD) patients. Malnutrition is a prevalent cause of death among these patients.[1] Protein energy wasting heralds the underlying systemic inflammatory disorder which usually leads to the fatal infectious or cardiovascular diseases in HD patients.[2]

Many serum biomarkers such as serum albumin, prealbumin or transferrin have long been used as predictors of the nutrition status of HD patients.[3] Physical anthropometric parameters like body mass index (BMI), triceps skin fold thickness (TSF) and mid-arm muscular circumference (MAMC) can also be used as indicators of nutrition.[4–6] Some subjective measurements like subjective global assessment (SGA) or activities of daily living are frequently used to assess nutrition performance of HD patients.[7]

To achieve the goal of biomedical and physical parameters, a diet rich in meat, poultry, fish or fresh pork are advocated for HD patients. A diet with 1.2 g protein/kg per bodyweight (BW) is suggested.[8] Normalized protein catabolic rate (nPCR) is often used to estimate daily protein intake of dialysis patients.[9] A high protein diet can increase protein nitrogen balance and lead to serum albumin and muscle mass increase. Increased serum albumin is associated with lower mortality in HD patients. High protein diets are, however, usually also high in saturated fat from animals. Long-term consumption of these foods raise the risk of coronary heart disease, diabetes, stroke and certain kinds of cancer.[10]

Vegetarian diets are either totally vegetarian diets which include only foods from plants or lacto-ovo-vegetarian diets which include plant foods plus diary products or eggs.[11] These vegetarian diets are low in animal products and they are usually lower in fat. Many studies have shown that vegetarians have a lower risk of cardiovascular disease, hypertension, diabetes and some forms of cancer.[12] Most vegetarian diets are frequently low in protein contents and are not compatible with current nutrition guidelines for HD patients.[13] Most HD patients consume high protein diets after starting dialysis therapy following the suggestion of physicians, nurses or nutritionists. There are, however, some HD patients consume vegetarian diets because of personal habits, personal beliefs or religious reasons. A cross-sectional study of patients on maintenance HD was performed and their nutritional status was studied and discussed.

METHODS

All chronic HD patients receiving dialysis therapy for at least 6 months in three different dialysis centres in central and northern Taiwan were included in the present study. A 24 h dietary recall method for 3 days was used for diet evaluation. Complete blood count, serum ferritin and transferrin saturation were checked. Biochemistry studies including serum albumin, prealbumin, cholesterol, triglyceride, aspartate aminotransferase (AST), alanine aminotransferase (ALT), blood urea nitrogen (BUN), creatinine, electrolyte and uric acid were measured using fasting blood. Intact parathyroid hormone (iPTH) was checked via the radioimmunoassay method. Adequate of dialysis Kt/V was calculated using the Daugirdas formula. A high-sensitivity C-reactive protein (hsCRP) test was measured using the nephelometry method. SGA based on medical physical history and physical examination was used to evaluate the nutrition status. Well-nourished people were rated as SGA A, moderately nourished SGA B and severely malnourished SGA C.[7] For fat and muscle study, TSF and MAMC were measured trice for each person. MAMC was calculated using the equation MAMC (cm) = MAC (mid-arm circumference) − 3.142 × TSF (cm).[14] The muscle strength was evaluated using a CWL-1 power handgrip (China Sports Science Research Institute, Beijing, China). For functional evaluation, patients who performed daily activities including eating, going to the toilet and ambulation independently were classified as 0. Patients who needed an orthosis (e.g. walking stick, walker, wheelchair) to perform daily activities were classified as 1. Patients who performed daily activities with the help of an orthosis or other people, and patients totally dependent on others to perform daily activities were classified as 2.

Statistical analysis

Continuous variables were expressed as mean ± standard deviation and categorical variables were expressed as the number or percentage for each item, unless otherwise stated. Data was routinely tested for normality of distribution and equality of standard deviations before analysis. For comparison of continuous variables, Student's *t*-test was used. For categorical variables, a cross-table with χ^2-test was used. For all statistical analyses, $P < 0.05$ was deemed significant.

RESULTS

Demography data

There were 318 patients enrolled in this study, including 299 non-vegetarians (non-Veg) and 19 (5.9%) vegetarians patients (Veg). Among the 19 Veg, six patients followed a vegetarian diet due to religious beliefs. Four patients followed strict vegetarian diets and 15 patients followed lacto-ovo-vegetarian diets. Most of the 19 Veg took vegetarian diets long before uraemia. Only three patients in the lacto-ovo-vegetarian subgroup started a vegetarian diet after initiation of HD therapy; one on a vegetarian diet for 11 years and the other two patients for 5 years. The important nutritional parameters of lacto-ovo-vegetarians were compared with those of the strict vegetarians. BMI, nPCR, serum albumin, serum cholesterol, uric acid and haematocrit were not different between these two vegetarian subgroups (Table 1). We therefore merged these two subgroups in our study. The ratio of male to female patients of the non-Veg and Veg were not statistically different (140:159 *vs* 9:10, non-Veg *vs* Veg, NS). The mean age of the non-Veg was 57.5 ± 1.2 and that of the Veg was 63.3 ± 2.6 years. There was no significant age difference between these two groups. The mean duration of HD of the non-Veg was not different from that of the Veg (70.1 ± 5.0 *vs* 71.5 ± 13.5 months, non-Veg *vs* Veg, NS). In the non-Veg, 79 patients (28.4%) had diabetes mellitus (DM); in the Veg, five patients (26.3%) had DM (Table 2).

Table 1 Anthropometric and biochemical parameters of lacto-ovo-vegetarian and strict vegetarian (Veg) haemodialysis patients

	Lacto-ovo Veg	Strict Veg
Number	15	4
BMI	20.1 ± 3.1	20.3 ± 3.6
nPCR	1.12 ± 0.26	0.99 ± 0.40
Albumin (g/dL)	3.81 ± 0.09	3.57 ± 0.18
Creatinine (mg/dL)	8.7 ± 1.1	8.8 ± 0.4
Haematocrit (%)	32.8 ± 1.1	32.1 ± 0.8
Cholesterol (mg/dL)	161.2 ± 13.8	152.1 ± 11.1
Uric acid (mg/dL)	6.3 ± 0.3	6.8 ± 0.3

BMI, body mass index; nPCR, normalized protein catabolic rate.

Table 2 Demographic characters of non-vegetarian (non-Veg) and vegetarian (Veg) haemodialysis (HD) patients

	Non-Veg	Veg
Number	299	19
Male : female	140:159	9:10
Age (years)	57.5 ± 1.2	63.3 ± 2.6
Duration of HD (months)	70.1 ± 5.0	71.0 ± 13.5
DM : non-DM	85:214	5:14

DM, diabetes mellitus.

Table 3 Biochemical parameters of non-vegetarian (non-Veg) and vegetarian (Veg) haemodialysis patients

	Non-Veg	Veg
Albumin (g/dL)	3.92 ± 0.03	3.76 ± 0.08
Pre-albumin (mg/dL)	33.1 ± 2.5	29.7 ± 1.8
BUN (mg/dL)*	70.4 ± 1.4	60.6 ± 3.2
Creatinine (mg/dL)*	10.0 ± 0.2	8.8 ± 0.5
nPCR (g/kg per day)*	1.20 ± 024	1.10 ± 029
Kt/V	1.40 ± 0.24	1.47 ± 0.27
Cholesterol (mg/dL)	170.7 ± 9.5	159.4 ± 16.8
Triglyceride (mg/dL)	169.0 ± 9.6	174.2 ± 19.7
Uric acid (mg/dL)*	7.2 ± 0.1	6.4 ± 0.3
AST (mg/dL)	22.6 ± 0.9	26.3 ± 3.3
ALT (mg/dL)	19.4 ± 1.0	217 ± 3.2

*$P < 0.05$. ALT, alanine aminotransferase; AST, aspartate aminotransferase; BUN, blood urea nitrogen; nPCR, normalized protein catabolic rate.

Biomarker

The nutritional markers were compared between the non-Veg and Veg groups. The daily calorie intakes were not different between these two groups (30.8 ± 1.8 *vs* 28.7 ± 1.9 kcal/kg per day, NS). The nPCR, an indicator of protein intake, was slightly lower in the Veg (1.20 ± 024 *vs* 1.10 ± 029 g/kg per day, non-Veg *vs* Veg, $P < 0.05$). Serum albumin (3.92 ± 0.03 *vs* 3.76 ± 0.08 g/dL, non-Veg *vs* Veg, NS) and serum prealbumin (33.1 ± 2.5 *vs* 29.7 ± 1.8 g/L, non-Veg *vs* Veg, NS) were not significantly different between these two groups. BUN (70.4 ± 1.4 *vs* 60.6 ± 3.2 mg/dL, non-Veg *vs* Veg, $P < 0.05$) and creatinine (10.0 ± 0.2 *vs* 8.8 ± 0.5 mg/dL, non-Veg *vs* Veg, $P < 0.05$) were significantly lower in the Veg. Unlike the results of BUN and creatinine, Kt/V was not different between these two groups (1.40 ± 0.24 *vs* 1.47 ± 0.27, non-Veg *vs* Veg, NS). There was also no statistical difference in cholesterol (170.7 ± 9.5 *vs* 159.4 ± 16.8 mg/dL, non-Veg *vs* Veg, NS) and triglyceride (169.0 ± 9.6 *vs* 174.2 ± 19.7 mg/dL, non-Veg *vs* Veg, NS). Serum uric acid was lower in the Veg (7.2 ± 0.1 *vs* 6.4 ± 0.3 mg/dL, non-Veg *vs* Veg, $P < 0.05$). Liver function test serum AST and ALT were not significantly different between these two groups (Table 3).

Haematological marker

Haemoglobin (10.5 ± 0.1 *vs* 10.1 ± 0.4 g/dL, non-Veg *vs* Veg, NS) and haematocrit (32.5 ± 0.4 *vs* 32.7 ± 1.0%, non-Veg *vs* Veg, NS) were not significantly different between non-Veg and Veg. White blood cell count (WBC) was lower in the Veg (6564 ± 168 *vs* 4990 ± 303/μL, non-Veg *vs* Veg, $P < 0.01$). Serum ferritin (396.4 ± 53.6 *vs* 5 05.5 ± 147.8 ng/mL, non-Veg *vs* Veg, NS) and Fe/total iron-binding capacity (35.6 ± 4.3% *vs* 36.7 ± 5.1%, non-Veg *vs* Veg, NS) were not different between these two groups. The weekly dose of erythropoietin (EPO) used was higher in the Veg (4488 ± 296 *vs* 5523 ± 423 U/week, non-Veg *vs* Veg, $P < 0.05$) (Table 4).

Table 4 Haematological parameters and erythropoietin (EPO) doses of non-vegetarian (non-Veg) and vegetarian (Veg) haemodialysis patients

	Non-Veg	Veg
Haemoglobin (g/dL)	10.5 ± 0.1	10.1 ± 0.4
Haematocrit (%)	32.5 ± 0.4	32.7 ± 1.0
WBC (/μL)**	6564 ± 168	4990 ± 303
Ferritin (ng/mL)	396.4 ± 53.6	505.5 ± 147.8
Fe/TIBC (%)	35.6 ± 4.3	36.7 ± 5.1
EPO (U/week)*	4488 ± 296	5523 ± 423

*$P < 0.05$; **$P < 0.01$. TIBC, total iron-binding capacity; WBC, white blood cells.

Table 5 Electrolyte and parathyroid hormone of non-vegetarian (non-Veg) and vegetarian (Veg) haemodialysis patients

	Non-Veg	Veg
K (mEq/L)	4.8 ± 0.12	5.0 ± 0.2
Ca (mg/dL)	10.7 ± 1.0	9.1 ± 0.3
P (mg/dL)*	4.8 ± 0.1	4.1 ± 0.2
iPTH (pg/mL)**	239.2 ± 32.1	111.0 ± 25.9
Alkaline phosphatase (IU/L)	117.5 ± 6.9	105.2 ± 8.8

*$P < 0.05$; **$P < 0.01$. iPTH, intact parathyroid hormone.

Serum electrolyte

Potassium level was not different between the non-Veg and Veg (4.8 ± 0.12 *vs* 5.0 ± 0.2 mg/dL, non-Veg *vs* Veg, NS). Serum calcium (10.7 ± 1.0 *vs* 9.1 ± 0.3 mg/dL, non-Veg *vs* Veg, $P < 0.05$) and serum phosphate were lower in the Veg (4.8 ± 0.1 *vs* 4.1 ± 0.2 mg/dL, non-Veg *vs* Veg, $P < 0.05$). Serum iPTH was also lower in the Veg (239.2 ± 32.1 *vs* 111.0 ± 25.9 pg/mL, $P < 0.01$). Alkaline phosphatase, however, was not significantly different between these two groups (117.5 ± 6.9 *vs* 105.2 ± 8.8 IU/L, non-Veg *vs* Veg, NS) (Table 5).

High sensitive CRP

Similar to WBC count results, another inflammatory marker hsCRP was lower in Veg patients (8.8 ± 0.4 *vs* 4.0 ± 0.3 mg/L, non-Veg *vs* Veg, $P < 0.05$).

Anthropometry study

Body mass index was lower in the Veg (22.7 ± 0.3 *vs* 20.2 ± 0.8 kg/m^2, $P < 0.05$). TSF (21.3 ± 0.7 *vs* 17.8 ± 2.1 mm, non-Veg *vs* Veg, $P < 0.05$) and MAMC were also lower in the Veg (26.2 ± 0.4 *vs* 23.6 ± 1.2 cm, non-Veg *vs* Veg, $P < 0.05$). For SGA of nutritional status, in the Veg group 10

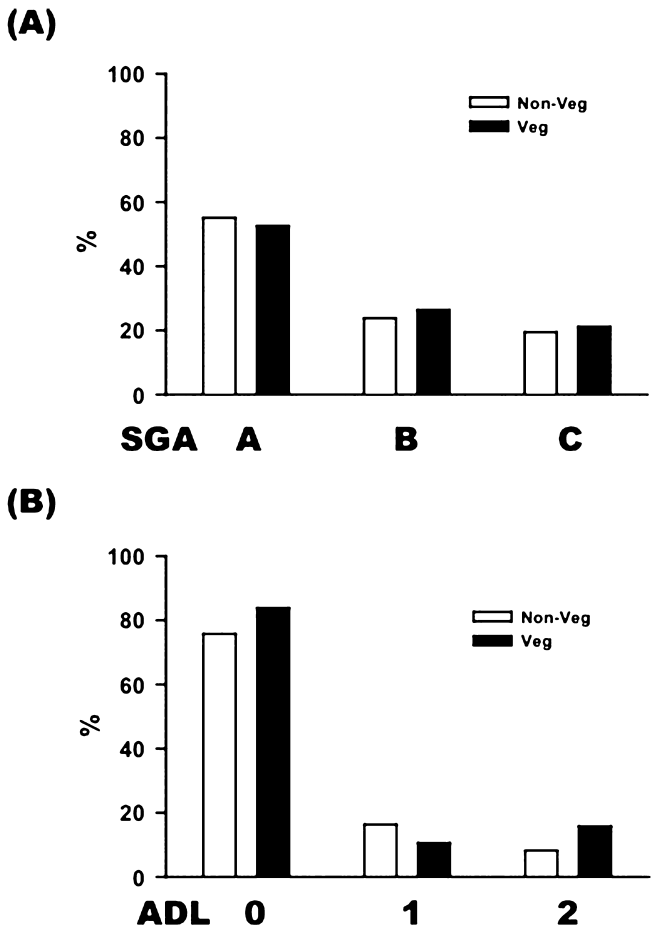

Fig. 1 (A) Rating of subjective global assessment (SGA) and (B) classification of functional activities of daily living (ADL) of non-vegetarian (non-Veg) and vegetarian (Veg) haemodialysis patients.

patients were rated as A (52.6%), five as B (26.3%), four as C (21.1%) in the 19 vegetarian patients; among the non-Vegetarians, 165 patients (55.2%) were rated as A, 76 (25.4%) as B and 58 (19.4%) as C. The results were not different from the SGA of the non-Veg (Fig. 1A).

Functional survey

A handgrip test was used to measure muscle strength of the dominant hand. For the non-Veg, the muscle power was 203.3 ± 9.8 N (Newton) and that of the Veg was 222.8 ± 24.8 N; there existed no statistical difference between these two groups. The performance of daily living activities was also comparable between these two groups. In the 19 Veg patients, only three (15.7%) people needed others' help for daily activities, two (10.5%) patients needed a walking stick and the remaining 14 (83.8%) could do daily activities without any help. For non-Veg, 226 (75.5%) could do daily activities freely, 49 (16.3%) needed the aide of orthosis and 24 (8.2%) needed the help of other people for daily activities (Fig. 1B). Patients' employment rate and hospital admission rate were also investigated, and 26.3% (5/19) of Veg HD patients and 24.7% (74/299) of non-Veg had regular jobs. These employment rates were not statistically different.

Two patients in the Veg had ever been hospitalized within 6 months before SGA evaluation; this rate was almost the same as that of the non-Veg (1.7 *vs* 2.0 per 100 patient-months, non-Veg *vs* Veg, NS).

DISCUSSION

Our study showed a vegetarian diet for HD patients might have impacts on nutritional and anthropometry markers without compromising the ability to perform daily activities. Patients on vegetarian diet had lower serum BUN, creatinine, muscle mass and BMI. BUN and creatinine have been used as a marker of store of muscle protein. Patients on a vegetarian diet have a lower protein intake as showed by lower nPCR. The lower protein intake decreases the nitrogen load and results in lower BUN, creatinine and the subsequent decreased muscle mass in vegetarian patients as presented by MAMC and BMI. However, with a lower muscle protein store, vegetarian patients still could maintain predialysis BUN in the 50–80 mg/dL range recommended for dialysis patients.[15] Albumin and prealbumin can serve as indicators of visceral protein store.[16] The most important protein sources of vegetarian patients are eggs, milk and tofu. Albumin and prealbumin were not different between the non-Veg and Veg groups. Studies in patients with uraemia implicated that albumin not only is an indicator of nutrition but also is an important indicator of inflammation. A lower protein diet lowers the ingredients for albumin synthesis. The lower WBC count and lower CRP value in the Veg group may implicate lower inflammation, which decreases the protein catabolism rate. The lower inflammation may help explain how Veg patients maintain their blood albumin and prealbumin levels. The results from albumin and prealbumin might indicate that visceral protein store can be maintained in vegetarians. The skeletal muscle store, however, is decreased in vegetarian patients as manifested by the decreased MAMC and BMI.

Serum uric acid level in HD patients can be affected by dialysis dosage, underlying gouty nephropathy, diet and the usage of uric acid lowering agents. Increased dialysis dosage reduces serum uric level. Increased protein intake or diets rich in bean products raise serum uric acid level. Our study, however, showed a higher uric acid level in non-Veg. Fourteen patients in the non-Veg had gouty nephropathy as the primary cause of uraemia and another 36 had hyperuricaemia on allopurinol therapy but denied gout attack episodes. There were no gouty nephropathy patients in Veg and only two patients in this group were receiving allopurinol. The non-significantly lower dialysis dosage (manifested by lower Kt/V), slightly higher increased protein intake (manifested

by higher nPCR) and slightly increased gouty nephropathy patients (4.6%) in the non-Veg may make serum uric acid of the non-Veg higher than that of the Veg. Bean product consumption, which may lead to hyperuricaemia and are the main dietary protein source before initiation of HD in vegetarians, may be partly replaced by milk products after HD because of less fluid and food restrictions. All the above-mentioned factors in the non-Veg and Veg in combination make the percentage of hyperuricaemia patients higher in the non-Veg. We did not, however, find significant correlation between uric acid and other nutritional status parameters in our study (data not shown).

Obesity and hyperlipidaemia are major reasons that people would follow a vegetarian diet in modern life. Serum triglyceride was insignificantly higher and cholesterol was insignificantly lower in the Veg group, but body fat content as manifested by TSF was statistically lower in the Veg group. Uraemia patients are prone to hypertriglyceridaemia and it is common for HD patients to receive fibrate therapy. There were 49 patients (16.4%) in non-Veg but only two patients (13.3%) in Veg receiving fibrate therapy. This may be the cause of non-significantly higher triglyceride seen in Veg patients. Cardiovascular disease is the main cause of death for uraemia patients. Only three out of the 19 vegetarian patients had ever been to clinics due to heart problems in the past 6 months. This may be a benefit of the vegetarian diet.

Haematocrit is another indicator of nutrition status.[17] Ferritin is associated with oxidative stress and inflammation, which then affect the nutritional status of non-dialysis people. Transferrin per se has long been used as an indicator of nutrition. Ferritin represents iron store and transferrin saturation represents iron availability. Ferritin and transferrin saturation can affect haemoglobin synthesis.[18] Patients of both groups had blood ferritin and transferrin saturation monitored every 3 months. Iron or vitamin C were given if ferritin was less than 300 ng/mL or transferrin saturation less than 30%.[19,20] There was no difference in ferritin and transferrin saturation in the non-Veg and Veg groups. Due to the frequent medical intervention and the co-existent high oxidative stress of HD patients, ferritin and transferrin may not be very good markers of nutritional status in dialysis patients.[21] Veg patients can maintain haematocrit levels comparable with those of the non-Veg group. The EPO dose, however, was higher in the Veg. Haemoglobin is the most abundant protein of red blood cell formed by bone marrow cells. EPO is an important growth factor that can promote erythropoiesis. Protein works as the ingredient of haemoglobin formation. As nPCR was lower in the Veg group, to compensate for the lack of the ingredient for haemoglobin synthesis, EPO requirement was increased in the Veg.[22] Some non-Veg patients can maintain haematocrit above 36% without using EPO. None of the Veg patients could do so without EPO and thus may help explain the higher dose needed in the Veg group.

Electrolyte imbalance, especially hyperkalaemia, is the most important concern for vegetarian dialysis patients. Dialysis patients were taught to soak vegetables in hot water and discard the soup before cooking vegetable dishes, helping to lower the potassium content of the diet. With adequate HD, Veg patients can maintain serum potassium levels similar to those of non-Veg patients. Only one of these 19 Veg patients had to use oral iron exchange resin to maintain potassium within normal range. PTH, serum calcium and phosphate are another concern. The serum calcium and phosphate of vegetarian patients was within the guideline suggested range, and had a mean value better than that of the non-Veg group in light of cardiovascular health.[23] To promote cardiovascular health is an important reason for the general population to consume a vegetarian diet; this inference suits HD patients as well. The number of Veg patients who had visited clinics due to heart problems within the past 6 months was only two (10.5%), a value lower than that of non-Veg patients (data not shown). PTH was an indicator of protein malnutrition.[24] Low protein diets can decrease the iPTH level but lower iPTH may also be associated with lower inflammation as seen in the Veg group. The mean iPTH in the Veg group was 110 pg/mL; a moderately low PTH level may be associated with good survival.[25]

Vegetarian patients can have muscle power no lower than non-Veg patients. SGA and functional daily activities were not different between these two groups. The employment rate for HD patients in Taiwan was approximately 20%, a value similar to our Veg and non-Veg group patients. The similar employment rate and hospital admission rate imply that HD patients can also enjoy a vegetarian diet.

In conclusion, HD patients on a vegetarian diet may compromise some nutrition status indicators like BMI or muscle mass without compromising patients' activities of daily living. A vegetarian diet may have the benefit of lower system inflammatory indicators. Dialysis adequacy can be maintained in vegetarian patients and haematocrit can be kept at a level similar to that of non-vegetarian patients with a slightly higher EPO dosage. Because only 19 patients were included in our studies, larger numbers of patients may be needed for further study.

REFERENCES

1. Herselman M, Esau N, Kruger JM, Labadarios D, Moosa MR. Relationship between body mass index and mortality in adults on maintenance hemodialysis: A systematic review. *J. Ren. Nutr.* 2010; **20**: 281–92, 287 p following 292.
2. de Mutsert R, Grootendorst DC, Axelsson J, Boeschoten EW, Krediet RT, Dekker FW. Excess mortality due to interaction between protein-energy wasting, inflammation and cardiovascular disease in chronic dialysis patients. *Nephrol. Dial. Transplant.* 2008; **23**: 2957–64.
3. Majchrzak KM, Pupim LB, Sundell M, Ikizler TA. Body composition and physical activity in end-stage renal disease. *J. Ren. Nutr.* 2007; **17**: 196–204.

4. Herselman M, Esau N, Kruger JM, Labadarios D, Moosa MR. Relationship between serum protein and mortality in adults on long-term hemodialysis: Exhaustive review and meta-analysis. *Nutrition* 2010; **26**: 10–32.
5. Huang CX, Tighiouart H, Beddhu S *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.
6. Oliveira CM, Kubrusly M, Mota RS, Silva CA, Choukroun G, Oliveira VN. The phase angle and mass body cell as markers of nutritional status in hemodialysis patients. *J. Ren. Nutr.* 2010; **20**: 314–20.
7. Fiedler R, Jehle PM, Osten B, Dorligschaw O, Girndt M. Clinical nutrition scores are superior for the prognosis of haemodialysis patients compared to lab markers and bioelectrical impedance. *Nephrol. Dial. Transplant.* 2009; **24**: 3812–7.
8. Ikizler TA, Hakim RM. Nutrition in end-stage renal disease. *Kidney Int.* 1996; **50**: 343–57.
9. Kalantar-Zadeh K, Supasyndh O, Lehn RS, McAllister CJ, Kopple JD. Normalized protein nitrogen appearance is correlated with hospitalization and mortality in hemodialysis patients with kt/v greater than 1.20. *J. Ren. Nutr.* 2003; **13**: 15–25.
10. Gonzalez CA, Riboli E. Diet and cancer prevention: Contributions from the european prospective investigation into cancer and nutrition (epic) study. *Eur. J. Cancer* 2010; **46**: 2555–62.
11. Lukaszuk JM, Robertson RJ, Arch JE, Moyna NM. Effect of a defined lacto-ovo-vegetarian diet and oral creatine monohydrate supplementation on plasma creatine concentration. *J. Strength Cond. Res.* 2005; **19**: 735–40.
12. Fraser GE. Vegetarian diets: What do we know of their effects on common chronic diseases? *Am. J. Clin. Nutr.* 2009; **89**: 1607S–12S.
13. Combe C, McCullough KP, Asano Y, Ginsberg N, Maroni BJ, Pifer TB. Kidney disease outcomes quality initiative (k/doqi) and the dialysis outcomes and practice patterns study (dopps): Nutrition guidelines, indicators, and practices. *Am. J. Kidney Dis.* 2004; **44**: 39–46.
14. Heymsfield SB, McManus C, Smith J, Stevens V, Nixon DW. Anthropometric measurement of muscle mass: Revised equations for calculating bone-free arm muscle area. *Am. J. Clin. Nutr.* 1982; **36**: 680–90.
15. Kopple JD. The national kidney foundation k/doqi clinical practice guidelines for dietary protein intake for chronic dialysis patients. *Am. J. Kidney Dis.* 2001; **38**: S68–73.
16. Holland DC, Meers C, Lawlor ME, Lam M. Serial prealbumin levels as predictors of outcomes in a retrospective cohort of peritoneal and hemodialysis patients. *J. Ren. Nutr.* 2001; **11**: 129–38.
17. Vannini FD, Antunes AA, Caramori JC, Martin LC, Barretti P. Associations between nutritional markers and inflammation in hemodialysis patients. *Int. Urol. Nephrol.* 2009; **41**: 1003–9.
18. Macdougall IC, Malyszko J, Hider RC, Bansal SS. Current status of the measurement of blood hepcidin levels in chronic kidney disease. *Clin. J. Am. Soc Nephrol.* 2010; **5**: 1681–9, p 484.
19. Daugirdas JT, Blake PG, Ing TS. Hematological abnormalities. In: Daugirdas JT (ed.). Philadelphia: Lippincott William & Wilkens, 2001; *Handbook of Dialysis*, 3rd edn. 477–94.
20. Jenq CC, Tian YC, Wu HH *et al*. Effectiveness of oral and intravenous iron therapy inhemodialysis patients. *Int. J. Clin. Prac.* 2008; **62**: 416–22.
21. Senol E, Ersoy A, Erdinc S, Sarandol E, Yurtkuran M. Oxidative stress and ferritin levels in haemodialysis patients. *Nephrol. Dial. Transplant.* 2008; **23**: 665–72.
22. Fisher JW. Erythropoitin: Physiology and pharmacology update. *Exp. Biol. Med. (Maywood)* 2003; **228**: 1–14.
23. Uhlig K, Berns JS, Kestenbaum B *et al*. Kdoqi us commentary on the 2009 kdigo clinical practice guideline for the diagnosis, evaluation, and treatment of ckd-mineral and bone disorder (ckd-mbd). *Am. J. Kidney Dis.* 2010; **55**: 773–99.
24. Blair D, Byham-Gray L, Lewis E, McCaffrey S. Prevalence of vitamin d [25(oh)d] deficiency and effects of supplementation with ergocalciferol (vitamin d2) in stage 5 chronic kidney disease patients. *J. Ren. Nutr.* 2008; **18**: 375–82.
25. Dukkipati R, Kovesdy CP, Colman S *et al*. Association of relatively low serum parathyroid hormone with malnutrition-inflammation complex and survival in maintenance hemodialysis patients. *J. Ren. Nutr.* 2010; **20**: 243–54.