© 2008 Órgano Oficial de la Sociedad Española de Nefrología

Nutritional aspects in renal failure

D. de Luis* and J. Bustamante**

**Unidad de Apoyo a la investigación. H. Universitario del Río Hortega. Instituto de Endocrinología y Nutrición Clínica. **Servicio de Nefrología. H. Clínico Universitario y Dept. Medicina. Facultad de Medicina de Valladolid.*

Nefrología 2008; 28 **(3)** 339-348

INTRODUCTION

Kidney function plays a role in regulation of the acid-base balance, water and electrolyte balance, calcium and phosphorus metabolism, and nitrogen balance. Hence, acute (ARF) or chronic renal failure (CRF) particularly affect the nutritional metabolic state of patients.[1,2]

Patients with CRF have a high prevalence of protein-calorie malnutrition, with an impaired fat and protein compartment, as well as a marked change in serum proteins. Different studies have shown the relationship between maintenance of a good nutritional status and a decreased morbidity in these patients.[3,4] Even if patients have a good nutritional status, they should be monitored every 6 months if they are younger than 50 years and every 3 months if older than 50 years. Protein-restricted diets have been used for decades to relieve uremic symptoms, and have also proved to be able to decrease progression of kidney function loss. Development of haemodialysis and peritoneal dialysis has resulted in an increased survival in these patients, with a clear improvement in quality of life. These advances have led to recommend specific nutritional requirements as a function of treatment received.[5]

Nutritional problems in patients with ARF and CRF will be successively reviewed, as well as tools used to assess them and dietary and advanced nutritional support recommendations published in the literature.

MALNUTRITION AND NUTRITIONAL ASSESSMENT IN RENAL FAILURE

A hypercatabolic state occurs in ARF, causing an increased glucose consumption. If there is no adequate glucose supply in diet, a gluconeogenesis phase starts when hepatic glycogen deposits are depleted.[3,6] Uptake of new glucose molecules from visceral and skeletal muscle proteins causes an unfavourable metabolic situation. On the other hand, proteolysis causes metabolic acidosis, which in turn promotes protein catabolism, leading to an increasing muscle mass and impairment of the nutritional status of the patient. In addition, accumulation in blood of nitrogenated products causes anorexia and nausea, maintaining the catabolic state by not allowing an adequate intake. To sum up, it is important to maintain an adequate energy supply, with a good supply of carbohydrates to maintain nitrogen balance.

In patients with *chronic renal failure*, protein-calorie malnutrition[7] results from failure of kidney function itself, causing increases in neuroendocrine factors and cytokines. This hormonal change causes hypertriglyceridemia and an impaired carbohydrate metabolism, with insulin resistance that may lead to diabetes. Increased levels of nitrogen products and electrolyte changes cause gastrointestinal disorders that reduce intake, with nausea and vomiting. On the other hand, treatments received by these patients also have an impact on their nutritional status. One of the most common dietary recommendations is protein restriction in diet, that reduces progression of nephropathy.[5] However, this dietary change may induce in uremic patients a decrease in their calorie intake due to their poor compliance with changes required in nutritional habits.[8] *Dialysis* may also condition the nutritional status. It should not be forgotten that patients on haemodialysis have a higher protein consumption than those on peritoneal dialysis, and also a greater risk of deficiency of water soluble vitamins and iron.

In order to achieve a good protein and calorie intake and maintain and adequate nutritional state, appropriate assessment tools are therefore required. Different parameters to assess the nutritional state of these patients[9] and protocols to evaluate the different tools used[10] have been traditionally employed, and it has been concluded that the most useful tools are those integrating parameters related to different fields of nutritional evaluation (subjective, anthropometric, and biochemical parameters, etc.).

The most important among these include data derived from physical examination using anthropometric data (current weight, ideal weight, usual weigh, dry weight, oedema-free adjusted weight, skin folds, arm circumference).

The precise definition of the different procedures to assess body weight should be known to avoid errors:

1. Current weight, the weight seen at that given time.
2. Ideal weight, or weight obtained from reference tables.
3. Usual weight, or historical weight of the patient.
4. Dry weight, or weight found after dialysis.

Correspondence: *Daniel de Luis Román*
Perales, 16 (Urb. Las Aceñas)
47130 Valladolid
dadluis@yahoo.es

5. The oedema-free adjusted weight is calculated as (dry weight – (ideal weight – dry weight) x 0.25)

Body mass index (BMI) is another commonly used anthropometric parameter. The results of a study with a cohort of more than 10,000 patients conducted in the USA and Europe[11] showed that mortality significantly decreased in patients with a higher BMI. Another study (Dialysis Outcomes and Practice Patterns Study)[9] showed that a BMI decrease greater than 3.5% was associated to a higher mortality. The significance of this parameter in nutritional monitoring of these patients has also been evaluated in our setting.[12]

As regards biochemical data, albumin has been used as a parameter to assess the protein-calorie status of patients on dialysis.[13] In the abovementioned study (DOPPS),[9] a 1.38% increase in mortality was seen in patients with albumin levels lower than 3.5 g/dL. Prealbumin has also been shown to be a predictor of mortality in patients at the start of dialysis therapy.[9]

Among integrated nutritional assessment methods, the Subjective Global Assessment (SGA) test is the most commonly used. The SGA is a simple method for assessing and monitoring the nutritional status of patients using a number of nutritional, clinical, and anthropometric data that are easy to obtain. This method has been shown to be of value in renal failure patients (fig. 1).[11]

Questionnaires to evaluate food intake may also be used for detecting deviations from the recommendations that will subsequently be analysed[14] or from those of other diets, such as the Mediterranean diet.[15,16] These questionnaires should be administered with some regularity and in several different days because of the inherent variability of the results obtained and the possibility that the intake level of patients may be modified by multiple intercurrent factors.

Other more sophisticated techniques may be used, such as single or multiple frequency impedanciometry (including vectorial analysis), X-ray absorptiometry, or neutron activation analysis.

Subjective Global Assessment
(Tick the adequate category or write the numerical value after #)

A. Clinical history

1. Change in weight
Weight loss in the past 6 months Total: #_____ kg, % lost#_____
Change in the past 2 weeks: _____ increase,_____ no change,_____ decrease

2. Changes in food intake (as compared to usual intake)
_____ no change
_____ change _____ duration = # _____ weeks
_____ type: _____ suboptimal solid diet _____ liquid diet
_____ low-calorie fluids _____ fasting

3. Gastrointestinal symptoms (> 2 weeks in duration)
_____ none, _____ nausea, _____ vomiting, _____ diarrhoea, _____ anorexia

4. Functional capacity
_____ no dysfunction
_____ dysfunction _____ duration = # _____ weeks
_____ type: _____ working suboptimal
_____ ambulatory
_____ bedridden

5. Disease and its relationship to energy requirements
Primary diagnosis (especify): _____
Metabolic demand (stress): _____ no stress, _____ low stress
_____ moderate stress, _____ high stress

B. Physical examination (specify for each: 0 = normal, 1 = mild, 2 = moderate, 3 = severe)

_____ loss of subcutaneous fat tissue (triceps, chest)
_____ loss of muscle mass (quadriceps, deltoid)
_____ ankle oedema
_____ sacral oedema
_____ ascites

C. Subjective Global Assessment (grading)

_____ A = well nourished
_____ B = moderate or suspected undernutrition
_____ C = severely undernourished

Figure 1. Subjective global assessment test.

DIETARY REQUIREMENTS IN RENAL FAILURE

Energy requirements may be calculated by formulas used for nutritional evaluation in general patients (with no renal failure), such as the Harris-Benedict formula[17] or other special formulas[18] (table I).

However, various authors use approximations to facilitate daily practice ranging from 35-40 calories per kg and day in chronic kidney disease.[19] Once energy requirements are calculated, *nutrient distribution*[20] in the diet should be balanced. The recommended proportions are 10%-15% of protein, 55%-70% of carbohydrates, and 20%-30% of lipids. The widespread recommendation of protein restriction to 0.6-0.8 g/kg/day has only been shown to be beneficial for patients with CRF receiving conservative treatment (evidence A), because it slows progression of kidney disease to its end stage.[21] However, patients on replacement therapy need 1-1.2 g/kg when on haemodialysis and 1-1.5 g/kg when on peritoneal dialysis.[3,19]

After calculating energy and protein supply, *water requirements* of our patients should be considered. Water balance should be calculated, taking into account the residual urine output of patients. Fluid intake should usually be approximately 500-600 mL, added to the residual urine output of patients.

Mineral and electrolyte requirements are marked by the nutritional status and the degree of renal failure of the patient. In highly malnourished patients, mineral requirements may be increased due to the anabolism they experience when adequate oral diet and/or a nutritional support procedure are started, so that an excessive and/or rapid supply of calories and proteins may lead to a refeeding syndrome with a sudden decrease in potassium and phosphorus levels and severe heart failure. Kidney function should also be taken into account. For instance, oligoanuric patients (urine output < 500 mL/day) excrete little or no sodium, potassium, magnesium, or phosphate, which should therefore be restricted in the diet. A finer adjustment of minerals, based on measurement of electrolytes and minerals in urine and creatinine clearance, may be considered, particularly in patients with preserved urine output, having widely variable requirements. On the other hand, because of the deficient hydroxylation of vitamin D at the 1-hydroxy position, calcium supply should be increased up to a minimum of 1 gram daily. An increased intake of foods rich in vitamin D could involve complications because these are a usual source of protein (fish, milk products, etc.).

Another important issue is the metabolic acidosis suffered by patients. Administration of bicarbonate as oral supplements to maintain pH > 7.2 or serum bicarbonate levels > 17 mEq/L is therefore recommended. A possible dietary measure is to recommend intake of bicarbonate waters, though most patients require oral bicarbonate at different doses.

Vitamin requirements also depend on treatment received by patients.[20] For instance, patients who follow restrictive dietary recommendations as a conservative measure in their treatment plan should receive supplements of water soluble vitamins and active vitamin D as 1,25 dihydroxyvitamin D. However, for patients on dialysis (peritoneal or haemodialysis), vitamin A, D, and B_{12} supplements are recommended because these vitamins are bound to proteins and, thus, easily removed at dialysis sessions. Decreased levels are also seen of water soluble vitamins such as vitamins C and B1 and folic acid. However, supplements of vitamin C and folic acid are only required.

Iron is one of the minerals that should be paid special attention.[21] The general population requires 10-15 mg/day of iron, but patients with renal failure and ferritin levels < 100 mg/dL should receive supplements of at least 60 mg/day of ferrous sulphate. Concomitant intake of iron with a citrus juice, promoting iron absorption together with vitamin C, may be recommended.

Table I. Formulas to calculate energy expenditure

Harris Benedict formula[17]:

Males. Energy expenditure = 66 + (13.7 x weight) + (5 x height) - (6.8 x age)
Females. Energy expenditure = 655.1 + (9.6 x weight) + (1.8 x height) - (4.7 x age)

Special formulas[18]:

De Luis.
Males: Energy expenditure = 58.6 + (6.2 x weight) + (1,023 x height) - (9.5 x age)
Females: Energy expenditure = 1,272.5 + (9.8 x weight) - (61.6 x height) - (8.2 x age)

Schofield.
Males
- 18-30 years: Energy expenditure = 15.3 x weight + 679
- 30-60 years: Energy expenditure = 11.6 x weight + 879
- > 60 years: Energy expenditure = 13.5 x weight + 487

Females
- 18-30 years: Energy expenditure = 14.7 x weight + 496
- 30-60 years: Energy expenditure = 8.7 x weight + 829
- > 60 years: Energy expenditure = 10.5 x weight + 596

SPECIAL NUTRITIONAL ASPECTS IN ARF

ARF causes a wide variety of changes in intermediate metabolism, the most sever of which is a severe hypercatabolism.[22,23] The primary *nutritional objective* in these patients is to accelerate kidney function recovery and preserve lean mass.

As regards energy requirements (table II), 30-40 kcal/kg body weight are recommended, with a protein supply of 0.8-1 g/kg ideal weight, that is increase as glomerular filtration rate normalises. Potassium intake should be limited to 30-50 mEq/day and sodium intake to 20-40 mEq/day in the oliguric phase, with replacement of losses in the diuretic phase. In order to apply these electrolyte recommendations, diets with fixed menus may be used, or tables are routinely used to limit electrolyte intake. It should also be reminded that removal of water used to cook vegetables and legumes may decreased potassium content by up to 40%. However, this also results in a substantial loss of water soluble vitamins. Fluid intake should consist of daily expenditure plus an additional 500 mL.

However, many patients are unable to cover the abovementioned nutritional requirements because of their clinical status, therefore requiring advanced nutritional support. The European Society of Parenteral and Enteral Nutrition (ESPEN)[24] recently prepared guidelines listing all requirements of patients with ARF. Non-protein energy requirements range from 20-30 kcal/kg/day, and 3-5 g/kg/day of carbohydrates and 0.8-1.2 g/kg/day of fat should be administered. Protein supply may range from 0.6 g/kg/day in patients on conservative treatment and up to 1.5 g/kg/day in patients on extracorporeal treatment.

Despite these recommendations, various studies have shown[23,25,26] the difficulty for achieving an adequate protein intake with the artificial formulas available in the market. This problem is more marked in the subgroup of patients requiring dialysis. An alternative measure consists of supplementing the nutritional supply with parenteral amino acids.[27] Standard amino acid solutions are recommended to maintain a neutral balance. Non-essential amino acids have been shown[28] to play an essential role in certain stress conditions in ARF patients. Only in cases where avoidance of dialysis is intended, use of solutions containing essential amino acids as the only source, at doses of 0.3-0.5 g/kg, and for less than three weeks would be indicated. Finally, the ESPEN guidelines provide a number of recommendations for this type of patients:

1. Macronutrient requirements are not so much determined by ARF as by the severity of the condition triggering it, the type and intensity of extracorporeal renal replacement therapy, and the nutritional status and associated complications *(Evidence C)*.
2. Extracorporeal treatments induce losses of micronutrients which should be supplemented *(Evidence C)*.
3. Micronutrient level should be monitored to prevent supplementation from resulting in toxic levels *(Evidence C)*.
4. In ARF patients in intensive care units, electrolytes contained in an enteral formula providing 1,500-2,000 calories are usually adequate. However, individual requirements may differ, and monitoring is required. Special care should be taken to avoid hypokalemia and/or hypophosphoremia after starting enteral nutrition (refeeding syndrome) *(Evidence C)*.
5. In patients with uncomplicated ARF, enteral nutrition should be used if requirements are not met with oral supplements (shakes) *(Evidence C)*.
6. In ARF patients in critical care units, enteral nutrition should be started early (within 24 hours) *(Evidence C)*.
7. In patients with uncomplicated ARF, when spontaneous oral feeding is insufficient, oral supplements (shakes) should be used *(Evidence C)*.
8. The nasogastric tube should be the access route of choice for enteral nutrition. Jejunal access is indicated in conditions causing a severe impairment in gastrointestinal motility.
9. In cases where nutritional requirements are not met using enteral support, parenteral support should be used *(Evidence C)*.
10. Standard enteral formulas are the products of choice in most cases *(Evidence C)*.
11. In ARF patients with water and electrolyte disturbances, special nephrological nutritional formulas may be useful *(Evidence C)*.

Table II. Summary of dietary recommendations in acute renal failure

Nutrients	Amounts
Protein	0.8-1 g/kg ideal weight, increased on normalisation of glomerular filtration rate.
Energy	30-40 kcal/kg body weight.
Potassium	30-50 mEq/day in oliguric phase, replace losses in diuretic phase.
Sodium	20-40 mEq/day in oliguric phase, replace losses in diuretic phase.
Fluid	Replace daily urine output plus 500 mL.
Phosphorus	Limit as required.

Table III. Nutritional support requirements in patients with acute renal failure (protein-free calorie supply)

Energy	20-30 kcal/kg/d
Carbohydrates	3-5 (max. 7) g/kg/d
Fat	0.8-1.2 (max. 1.5) g/kg/d
Protein (essential and non-essential amino acids)	
Conservative therapy	0.6-0.8 (max. 1.0) g/kg/d
Extracorporeal therapy	1.0-1.5 g/kg/d

As regards the last recommendation, table IV shows that various nutritional oral supplements have changes in their composition for patients with acute renal failure.

However, these recommendations may be qualified taking into account the guidelines published in *Nutrición Hospitalaria* (the official journal of the Spanish Society of Enteral and Parenteral Nutrition):[26]

1. ARF patients should receive 3-5 g/kg/day of glucose, i.e. a similar amount as in other clinical conditions *(Evidence C)*.
2. Fat infusion should be limited to 1 g/kg/day, and lipid supply should be discontinued if triglyceride levels higher than 300 mg/dL are reached *(Evidence C)*.
3. Protein supply should be adapted to the clinical situation and to the catabolic state, as assessed by the occurrence of urea nitrogen. Urea nitrogen occurring is the sum of urinary urea nitrogen plus urea nitrogen in dialysis fluid plus change in the organic urea pool *(Evidence B)*.

4. Amino acids formulas consisting only of a mixture of essential amino acids should not be used *(Evidence A).*
5. Amino acids such as tyrosine, histidine, taurine, and branched amino acids should be provided in amounts higher than recommended for other patients *(Evidence C.)*
6. Use of glutamine is recommended *(Evidence B).*
7. Protein supply should be increased in patients with ARF on haemodialysis *(Evidence C).*
8. Assessment of vitamin A, C, and D supply is important *(Evidence A).* At least 60-100 mg/day of vitamin C are recommended. Minimum supplies of pyridoxine (5-10 mg) and folic acid (1 mg/day) are also recommended.
9. Use of standard enteral nutrition diets poses no problem if patients are being treated with clearance techniques *(Evidence B).*
10. Enteral diets adapted to renal failure could be indicated for patients with multiorgan failure who are being treated with clearance techniques *(Evidence C).*
11. Clearance techniques could be used for providing nutrients *(Evidence C).*

SPECIAL NUTRITIONAL ASPECTS IN CRF

In CRF patients, *nutritional objectives* include achieving an adequate nutritional status, helping control azotemia and its effects to improve quality of life, and delaying progression of renal failure.

With regard to the first objective, various series have shown an improved prognosis in these patients when they are well nourished.[19,28-31] As to the delay in progression of kidney function loss, there are also general recommendations on the matter, even with an *Evidence A.*[17] In most studies, protein- and phosphorus-restricted diets delay reduction of glomerular filtration rate and progression to end-stage renal disease in renal failure patients in general and type 1 diabetics in particular, in the latter irrespective of glucose control.[16] Thus, CARI guidelines (Caring for Australasians with Renal Impairment) give the following recommendations:[32]

1. A protein-controlled diet (0.75-1 g/kg/day) should be prescribed to all patients with CRF. Low protein diets (< 0.6 g/kg/day) are not justified because they minimally improve glomerular filtration rate and their impact on the nutritional status advises against their use *(Evidence A).*
2. In children, reduction of protein intake to the minimum levels recommended by the World Health Organisation (0.8-1.1 g/kg/day depending on patient age) has not been shown to decrease progression of chronic renal failure, and should therefore not be recommended.

For the group of diabetic patients, the American Diabetes Association (ADA) guidelines*33* specifically recommend, with an *Evidence B,* reduction of protein intake to 0.8-1 g/kg/day in patients with diabetes and early stages of CRF, and to 0.8 g/kg/day in patients in the final stages of CRF. The Cochrane Collaborative Group[34] showed that a small reduction in protein intake resulted in a slight but not statistically significant decrease in progression to renal failure. However, because of the great individual variability of pa-

Table IV. Nephrological nutritional formulas

	Nepro®	Suplena®	Nutrison low sodio®	Nefronutril®	Resource 2.0®	Novasource renal®
How supplied (mL)	236	236	500 mL	91 g sachet	200	237
Kcal/mL	2	2	1	1	2	2
Protein (g/L) (TCV* percentage)	68.9 14	29.6 6	40 16	27 11	90 18	73.4 17.4
Lipids (g/L) (TCV percentage)	95.8 43	95.6 43	39 35	18.5	87 39	100 45
Carbohydrates (g/L) (TCV percentage)	215 43	255 51	123 49	181 73	214 43	200 40
Na (mg/L)	830	784	250	257	600	1,000
K (mg/L)	1,056	1,116	1,500	78	1,600	840
PO4 (mg/L)	686	728	720	126	900	650
Mg (mg/L)	210	210	230	16	300	200
Ca (mg/L)	1,372	1,386	800	128	1,900	1,300

TCV: Total caloric value.

tients, a therapeutic trial of protein restriction for 6 months may be started in all patients, continuing treatment in only those patients with a favourable response.

As shown, great doubts exist about the true effectiveness of this type of diets because of poor patient adherence.[35] However, use of diet as a therapeutic tool must always be our first option, as it may be useful even for management of complications of CRF such as osteodystrophy.[36]

Despite dietary recommendations, some patients with CRF required advanced nutritional support. As a general recommendation, nutritional support should be given when a 5-7 day fasting period is expected or when oral intake does not meet patient requirements. The first step consists of use of oral nutritional supplements (table III), which have been shown to improve the course of disease.[17,37] The nutritional support type and requirements depend on the treatment received by the patient.[19,24] Two possibilities should be distinguished: nutritional support for CRF patients on conservative treatment-predialysis, and nutritional support for patients on dialysis treatment (haemodialysis and/or peritoneal dialysis).

Nutrition in CRF patients on conservative treatment

According to recommendations by the National Kidney Foundation[38] (table V), the goal is to achieve the normal weight for the patient. An energy supply of 35 kcal/kg/day, to be adjusted based on the nutritional state of the patient, is recommended. As regards protein supply, this organisation gives different objectives depending on stage of kidney disease:

a) For patients with more than 50% kidney function (plasma creatinine levels less than 2 mg/dL or glomerular filtration rate > 70 mL/min), 0.8-1 g/kg/day of protein of a high biological value should be provided, plus an additional 1 g per g of proteinuria.
b) For patients with 20%-50% kidney function (plasma creatinine levels 2-5 mg/dL or glomerular filtration rate 25-70 mL/min), protein intake must be reduced to 0.6 g/kg/day, the amount considered minimum for a healthy adult. Sixty percent of protein should be of high biological value.
c) For patients with less than 20% kidney function (plasma creatinine levels higher than 8 mg/dL or glomerular filtration rate < 25 mL/min), protein must be restricted to 0.30 g/kg/day.
d) Patients with more reduced kidney function (glomerular filtration rate < 10 mL/min) are amenable to extrarenal clearance. Only in the event that clearance is not possible, a protein-free diet would be used, supplemented with essential amino acids or their keto analogues.

As regards carbohydrates, they should represent the main energy source (approximately 60%) and consist of complex carbohydrate because of protein restriction. Fat represents 30% of calorie supply, and consists of at least 10% saturated fats and more than 10% monounsaturated fats. The recom-

Table V. Nutritional requirements in renal failure

	Predialysis	Haemodialysis	Peritoneal dialysis
Energy kcal/day	30-35	35	35
Fluids (mL)	Water balance	Water balance + 500 mL	Water balance
Protein (g/kg/day)	0.6-0.8 based on GFR*	1.2-1.4	1.5
Electroytes			
Na	RDA**	60-100	Según tolerancia
K	RDA	1 mEq/kg/day	2-3 g/day
Minerals			
Ca (g/day)	1.5-2	1-1.5	RDA
P (mg/kg/d)	5-10	17	RDA
Iron	If EPO	If EPO	If EPO
Trace elements	RDA	RDA	RDA
Vitamins (mg/day)			
Pyridoxine	5	10	10
Vit C	30-50	30-60	100
Folic acid	0.25	100	100

*GFR: Glomerular filtration rate. See text.
**RDA (Recommended dietary allowance).
(reference 38) According to Kidney Foundation.

mended daily amount of cholesterol is less than 300 mg. As regards electrolytes, sodium intake should be limited to 1,000 mg/day, and potassium intake to 40-60 mEq/day.

Mineral and vitamin provision to these patients is essential. Patients have a deficient intestinal absorption of calcium due to vitamin D3 deficiency, and should therefore receive calcium supplements (1,500-2,000 mg/day). By contrast, phosphorus intake should be restricted to 5-10 mg/kg/day, limiting consumption of milk products, eggs, meat, and some vegetables, because increased phosphorus levels contribute to hyperparathyroidism and kidney function impairment. Iron should be provided to patients treated with erythropoietin. In these patients, supplementation is recommended with the following vitamins: vitamin B_6, 5 mg/day; vitamin D(1,25-dihydroxyvitamin D), 0.25 micrograms/day; vitamin C, 30-50 mg/day. Multivitamin complexes are generally used (table VI).

The ESPEN also provided a number of recommendations in patients having some unique characteristics:

1. Energy intake should be approximately 35 kcal/day in patients with stable CRF and weights within ± 10% of ideal weight *(Evidence A).*
2. Energy supply should be adjusted in patients with obesity or low weight.
3. With an *evidence* B, a protein intake of 0.55-0.6 g/kg/day (2/3 of high biological value) is recommended in patients with creatinine clearance ranging from 25-70 mL/min, and 0.55-0.6 g/kg/day (2/3 of high biological value) or 0.28 and the rest as essential amino acids.
4. Mineral intake should be 600-1000 mg/day of phosphorus, 1500-2500 mg/day of potassium, and 1.8-2.5 g/day of sodium *(Evidence B).*
5. Enteral nutrition should be started when requirements are not met despite diet and oral supplements (shakes). *Evidence C.* The main indications for this dietary modality would be in patients with CRF and some comorbid condition in which oral intake is not possible, i.e. patients in whom dietary recommendations cannot be met using the oral route alone. In these cases, the procedure of choice is enteral support by night using nasogastric tube, maintaining oral intake during the day. Finally, elderly patients with CRF are a group with a high nutritional risk.
6. The recommended type of formula is a standard formula *(Evidence C).*
7. In patients receiving enteral nutrition for more than 5 days, special formulas with modified electrolyte contents (table V) may be used *(Evidence C).*
8. Essential amino acids and their keto analogues, in association with enteral formulas low in protein, may preserve kidney function *(Evidence B).*

Nutrition in CRF patients on haemodialysis and peritoneal dialysis

In these patients, calorie requirements are 35 kcal/kg/day under baseline conditions (table V). The goal is to achieve a protein supply of 1.2-1.4 g/kg/day (2/3 of high biological value).. Water requirements depend on residual urine output, to which 500-800 mL/day may be added. If protein-calorie requirements are not covered by the normal diet, oral nutritional supplements and even parenteral nutrition may be given during haemodialysis.

Intradialysis parenteral nutrition is administered during the dialysis session using the high flow of the arteriovenous fistula. This allows for administration of a hyperosmolar solution, thus minimising the volume overload from haemodialysis itself.[39] Approximately 16 kcal/kg and 0.08 g of nitrogen per kg of weight are provided. Despite its initial advantages, intradialysis parenteral nutrition has a number of disadvantages:

Table VI. Multivitamin complexes

	A IU	D3 IU	E IU	K1 mg	C mg	B_1 mg	B_2 mg	B_6 mg	B_{12} ug	Folate ug	Biotin ug	Pantothenate mg
Multicentrum	2,666	200 (5 ug)	14.9	30	60	1.4	1.6	2	1	200	150	6
Micebrina complex	1,500	400	30		150	10	5	6	12	400	45	15
Micebrina	1,500	400	30		100	10	5	2	3			10
Micebrina ginseng	1,500	400	30		60	1.5	1.7	2	3	400	45	10
Supradyn	800 retinol and 400 carotene	200	10 mg	30	60	1.4	1.6	2	1	200	150	6
Dayamineral	5,000	1,667			83.33	2.5	2	0.83				
Hidropolivit	2,500	500	1 mg	100	40	2	1	1	2	100	250	2
Rochevit	2,500	400	15 mg		100	1.6	1.8	2.6	4	400	250	10

1. Administration of a great amount of nutrients in a very short time causes hyperglycemia and hyperlipidemia.
2. In addition, nutrition is provided two or three times per week, only during the dialysis session, so that it should be considered a nutritional supplementation method, rather than a total nutritional support.
3. As compared to other possibilities of nutritional support, intradialysis parenteral nutrition has a high economic cost.

It should therefore be carefully indicated, being reserved to patients with severe malnutrition and hypoalbuminemia[40] or to very special situations.[41] The main criteria for administration of intradialysis parenteral nutrition reported in the literature[38-41] include:

- Predialysis serum creatinine levels < 8 mg/dL for 3 months.
- Predialysis serum albumin levels < 3.4 g/dL for 3 months.
- > 10% loss of ideal weight.
- Protein intake < 0.8 g/kg/day and calorie intake < 25 kcal/kg.
- Grade C Subjective Global Assessment (severe malnutrition).

The presence of three of the previous criteria plus impossibility to increase oral intake or failure of oral supplements or rejection of enteral nutrition. There are also criteria for discontinuation of intradialysis parenteral nutrition:

- Achievement of predialysis serum albumin levels > 3.8 g/dL for 3 months.
- Achievement of predialysis serum creatinine levels > 10 mg/dL for 3 months.
- Dry weight increase.
- Subjective Global Assessment A or B.
- Increase in protein intake to > 1 g/kg/day and in calorie intake to > 30 kcal/kg.

The presence of three of the previous criteria plus occurrence of complications or intolerance to parenteral nutrition or no improvement after 6 months of parenteral nutrition.

The following supplements of vitamins and minerals are recommended:[38] vitamin C, 30-60 mg/day; vitamin B_6, 10-20 mg/day; folic acid, 1 mg/day. Vitamin B1 supplementation is considered optional. No more than 60-100 mEq/day of sodium should be provided. In anuric patients on haemodialysis, water and sodium should be limited to a minimum during week ends to limit interdialytic weight gain and prevent volume overload. As regards potassium, 1 mEq/kg/day should not be exceeded in patients in acidosis or with no urine output. Iron should be provided to patients receiving erythropoietin. Calcium requirements are 1-1.5 g/day. Phosphorus requirements are approximately 17 mg/kg/day.

ESPEN recommendations for this type of patients are similar:[24]

1. In patients with acute disease in a regular haemodialysis programme, nutritional requirements should be similar to those for ARF patients.
2. Protein requirements are 1.2-1.4 g/kg/day (> 50% of high biological value) in stable patients on haemodialysis and 1.2-1.5 g/kg/day (>50% of high biological value) in patients on peritoneal dialysis. With an energy supply of 35 kcal/kg/day, taking into account the glucose contained in the dialysis fluid for patients on peritoneal dialysis *(Evidence B).*
3. Mineral requirements of metabolically stable patients include 800-1,000 mg/day of phosphate, 2,000-2,500 mg/day of potassium, 1.8-2.5 g/day of sodium. Fluid requirements are 1,000 mL/day plus urine output. Dialysis sessions cause loss of vitamins, particularly water soluble vitamins, which should be supplemented as follows: folic acid, 1 mg/day; pyridoxine, 10-20 mg/day; vitamin C (30-60 mg/day). Vitamin D should be supplemented depending on calcium, phosphorus, and parathyroid hormone levels. Loss of trace elements with haemodialysis is minimal, but depleted patients should be administered 15 mg/day of zinc and 50-70 µg/day of selenium (*Evidence B).*
4. Advanced nutritional support should be indicated for undernourished patients on haemodialysis. Undernutrition is defined as a body mass index < 20 kg/m^2, a weight loss greater than 10% in 6 months, serum albumin levels lower than 3.5 g/L, and prealbumin levels lower than 300 mg/L *(Evidence C).* The following patients deserve special attention:

   a) Patients on haemodialysis with acute concomitant diseases causing catabolism and in whom adequate nutritional support is not possible.
   b) Stable patients on haemodialysis not reaching the recommended oral requirements.
   c) Unconscious haemodialysis patients, e.g. with neurological disease, in nursing homes.

5. The first nutritional support measure are oral supplements *(Evidence A).*
6. If diet and oral supplements are of no value, nasogastric tube support should be used *(Evidence C).*
7. In patients with gastroparesis and who do not respond to prokinetics, a nasojejunal tube should be the procedure of choice *(Evidence C).*
8. In patients who will receive nutritional support for a long time, endoscopic gastrostomy or jejunostomy should be used *(Evidence C).*
9. Standard formulas are recommended for nutritional support using oral supplements. However, specific formulas (taking into account phosphorus and potassium requirements) are recommended for patients with nasogastric tube nutrition *(Evidence C).*

Patients on peritoneal dialysis have a number of unique requirements.[24,38] Protein requirements are higher, approxima-

tely 1.5 g/kg/day. Calories from carbohydrates, approximately 60% of the total amount, should include the glucose contained in the dialysis fluid. There are studies evaluating the effect of use of amino acid-based peritoneal dialysis solutions. Results failed to show a significant improvement in serum protein levels, but there was a trend to an improvement.[42] No differences were seen in the incidence of peritonitis, hospital stay, and mortality. Another essential difference was a more liberal diet in these patients, as they undergo daily dialysis. For instance, potassium intake may be increased to 2000-3000 mg/day. Losses of water soluble vitamins are less striking. Provision of 10 mg/day of vitamin B_6 and 100 mg/day of vitamin C is recommended. If patients are receiving treatment with erythropoietin, iron supplements should be given as in all other case.

REFERENCES

1. Star R. Treatment of acute renal failure. *Kidney Int* 1998; 54: 1817-1831
2. Galindo P, Pérez de la Cruz A, Cerezo S, Martínez T, López P, Asensio C. Malnutrition and mortality in hemodialyzed patients. *Nutr Hosp* 2001; 16: 27-30.
3. Steffee W. Nutritional support in renal failure. *Surg Clin N Am* 1981; 61: 661-670.
4. Osorio Moratalla JM, Osuna Ortega A, Feliú Roig F, Orduña Espinosa RM, Bravo Soto J, Arrebola Nacle JA, Asensio Peinado C, Pérez de la Cruz AJ. An evaluation of the nutritional status of patients with chronic kidney failure on hemodialysis via rapid-turnover proteins. *Nutr Hosp* 1992; 7: 52-7.
5. Pérez VO, Hernández EB, Bustillo GG, Penié JB, Porbén SS, Borrás AE, González CM, Martínez AA. Nutritional status in chronic renal failure patients assisted at the hemodialysis program of the «Hermanos Ameijeiras» Hospital. *Nutr Hosp* 2007; 22: 677-94.
6. López Martínez J, Sánchez Castilla M, García de Lorenzo y Mateos A. New prospects in the treatment of acute kidney failure. *Nutr Hosp* 1996; 11: 82-93.
7. Bristrian B. Role of the systemic inflammatory response syndrome in the development of protein calorie malnutrition in ESRD. *Am J Kidney Dis* 1998; 32: S113-S117.
8. Orzáez Villanueva MT, Rodríguez Cisneros A, Morales Ruiz E, Martinéz Rincón C. Determination of factors conditioning adherence and accomplishment of renal protection diet in patients with chronic renal failure: pilot study for the elaboration of a dietary guideline. *Nutr Hosp* 2006; 21: 145-54.
9. Combe C, McCullough KP, Asano Y, Ginsberg N, Maroni BJ, Pifer TB. Kidney Diseases Outcomes Quality Initiative (K/DOQI) and the Dialysis Outcomes and Practice Patterns Study (DOPPS): Nutrition Guidelines, Indicators, and Practices. *Am J Kidney disease* 2004; 44: S39-S46.
10. Hecking E, Bragg-Gresham JL, Rayner HC, Pisoni RL, Andreucci VE, Combe C et al. Hemodialysis prescription, adherence and nutritional indicators in five European countries: results from the Dialysis Outcomes and Practice Patterns Study (DOPPS). *Nephrol Dial Transplant* 2004; 19: 100-107.
11. Leavey SF, McCullough K, Hecking E, Goodkin D, Port FK, Young EW. Body mass index and mortality in «healthier» as compared with «sicker» haemodialysis patients: results from the Dialysis Outcomes and Practice Patterns Study (DOPPS). *Nephrol Dial Transplant* 2001; 16: 2368-2394.
12. Palomares Bayo M, Quesada Granados JJ, Osuna Ortega A, Asensio Peinado C, Oliveras López MJ, López G de la Serrana H, López Martínez MC. Longitudinal study on the body mass index (BMI) of dialysis patients. *Nutr Hosp* 2006; 21: 155-62.
13. Kaysen GA, Stevenson FT, Depner TA. Determination of albumin concentration in hemodialysis patients. *Am J Kidney disease* 1997; 29: 658-668.
14. Lou LM, Gimeno JA, Paúl J, Sanz París A, Gutiérrez Dalmau A, Gómez Sánchez R, Pérez Pérez J, Boned B. Evaluation of food intake in hemodialysis using a food consumption and appetite questionnaire. *Nefrología* 2002; 22 (5): 438-47.
15. Lou LM, Campos B, Gimeno JA, Caverní A, Boned B. Nutrient intake and eating habits in hemodialysis patients: comparison with a model based on mediterranean diet. *Nefrología* 2007; 27 (1): 38-45.
16. Pérez Bañasco V, Gil-Cunquero JM, Borrego FJ, Grassó M, Segura P, Warletta F, Lozano JL, Costa LA, Torres J, Gaforio JJ, Villarrubia VG. [Preliminary study on efficacy and tolerance of a «coupage» of olive oil in patients with chronic kidney disease. Nutritonal evaluation] *Nefrología* 2007; 27 (4): 472-81.
17. Harris JA, Benedict FG. A biometric study of basal metabolism in man. Washington DC: Canergie Institute of Washington, 1919: 40-44.
18. De Luis DA, Aller R, Izaola O, Romero E. Prediction equation of resting energy expenditure in an adult spanish population of obese adult population. *Ann Nutr Metab* 2006; 50: 193-196.
19. Kopple J. Dietary protein and energy requirements in ESRD patients. *AM J Kidney Dis* 1998; 32: 97-104.
20. Amler C, Kopple JD. Nutrition support for patients with renal failure. En: Merrit RJ et al. (eds.) ASPEN. Nutrition Support Practice Manual. Silver Spring, MD. American Society for Parenteral and Enteral Nutrition 1998; 16: 1-16.
21. Zarazaga A, García de Lorenzo L, García-Luna PP, García Peris P, López Martínez J, Lorenzo V, Quecedo L, Del Llano J. Nutricional support in chronic renal failure: systematic review. *Clinical Nutrition* 2001; 20: 291-299.
22. Kopple JD. The nutrition management of the patient with acute renal failure. *JPEN* 1996; 20: 3-12.
23. Fiaccadori E, Maggiore U, Giacosa R, Rotelli C, Picetti E, Sagripanti S et al. Enteral nutrition in patients with acute renal failure. *Kidney International* 2004; 65: 990-1008.
24. Cano N, Fiaccadori E, Tesinsky P, Toigo G, Druml W et al. ESPEN Guidelines on enteral nutrition: acute renal failure. *Clinical Nutrition* 2006; 25: 295-310.
25. Ortiz A, Arduán MJ. Artificial nutrition in kidney failure. *Nutr Hosp* 1991; 6: 267-75.
26. Jiménez Jiménez FJ, López Martínez JA, Sánchez-Izquierdo Riera J. Artificial nutrition in acute renal failure. *Nutr Hosp* 2005; 20: 18-21.
27. Abel RM, Beck CH Jr, Abbott WM, Ryan JA Jr, Barnett GO, Fischer JE. Improved survival from acute renal failure after treatment with intravenous essential L-amino acids and glucose: results of a prospective, double-bind study. *N England J Med* 1973; 288: 695-699.
28. Suleiman M, Zaloga G. Renal failure and nutrition. En: Zaloga G (ed.) Critical Care. St Louis: Mosby; 1994: 661-684.
29. Fernández-Reyes MJ, Álvarez-Ude F, Sánchez R, Mon C, Iglesias P, Vázquez A. Nutritional status, comorbidity, and inflammation in hemodialysis. *Nefrología* 2000; 20: 540-9.
30. Raimundo P, Ravasco P, Proença V, Camilo M. Does nutrition play a role in the quality of life of patients under chronic haemodialysis? *Nutr Hosp* 2006; 21 (2): 139-44.
31. Ayúcar Ruiz de Galarreta A, Cordero Lorenzana ML, Martínez-Puga y López E, Gómez Seijo A, Escudero Álvarez E. Nutrition and chronic renal failure. *Nutr Hosp* 2000; 15: 101-13.
32. Harris D, Thomas M, Johson D, Nicholls K, Gillin A. Prevention of progression of kidney disease. The Cari Guidelines. April 2006. Online publication.
33. Executive summary: Standards of medical care in diabetes 2008. *Diabetes Care* 31 S1: s3-s11.
34. Robertson L, Waugh N, Robertson A. Protein restriction for diabetic renal disease. The Cochrane Library 2007, issue 4.
35. García Valderrama FW, Fajardo C, Guevara R, Gonzáles Pérez V, Hurtado A. Poor adherence to diet in hemodialysis: role of anxiety and depression symptoms. *Nefrología* 2002; 22 (3): 244-52.
36. Martínez I, Saracho R, Ocharán J, Muñoz RI, Montenegro J. Role of diet in the management of osteodystrophy during progressive renal insufficiency. *Nefrología* 2003; 23 Supl. 2: 57-63.
37. Montes-Delgado R, Guerrero Riscos MA, García-Luna PP, Martín Herrera C, Pereira Cunill JL, Garrido Vázquez M. Tratamiento con dieta hipoproteica y suplementos calóricos en pacientes con insuficiencia renal crónica en prediálisis. Estudio comparativo. *Rev Clin Esp* 1998; 198: 580-586.

38. National kidney Foundation. Kidney Disease Outcomes Quality Initiative. Clinical Practice Guidelines for Nutrition in Chronic Renal Failure. I. Adult guidelines. B. Advanced chronic renal failure without dialysis. *Am J Kidney Dis* 2000; 35 (Supl. 2): S56-S65.
39. Foulk Ch J. An evidence. Based evaluation of intradialytic parenteral nutrition. *Am J Kidney Dis* 1999; 33: 186-192.
40. Lazarus JM. Recomended criteria for initiating and discontinuing intradialitic parenteral nutrition therapy. *Am J Kidney Dis* 1999; 33: 211-215.
41. Martínez P, Sánchez-Vilar O, Picón J, Gonzalo A, De Villar N, Riobó P. Parenteral nutrition in a case of renal insufficiency due to amyloidosis. *Nutr Hosp* 1999; 14: 96-8.
42. Li F, Chan L, Woo J, Ho S, Lo W, Lai K. A year, prospective, randomized, controlled study on amino acid dialysate in patients on CAPD. *Am J Kidney Dis* 2003; 42: 173-183.