Nutritional management of acute kidney injury in the critically ill: a focus on enteral feeding

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Abstract

Optimal nutritional management of critically ill patients who present with acute kidney injury (AKI) is paramount. The management of this patient population is probably more complicated than that of chronic care haemodialysis (HD) patients as AKI patients have significant protein catabolism, insulin resistance (abnormal carbohydrate metabolism) and an altered fat metabolism, and AKI patients on continuous renal replacement therapy (RRT) are at greater risk of protein and micronutrient losses. The primary goals of nutritional management of AKI patients are to attenuate protein (muscle) catabolism, and to replace micronutrient losses, specifically folic acid, thiamine and selenium, while being mindful of the potentially harmful effects of excessive vitamin C and vitamin A in retinol form. Hence, it is prudent, if standard enteral feeds are used, that the latter are considered, especially if the patient is on RRT. The majority of intensive care units (ICUs) in South Africa do not have scale beds or Bluetooth bed scales to accurately measure body weight, which is required to accurately determine fluid and nitrogen balance. Nitrogen balance is required for the calculation of the appropriate prescription of protein. Hence, critically ill AKI patients on RRT are at possible risk of the provision of either insufficient or excessive protein. Insufficient protein intake in catabolic AKI patients is associated with an increased mortality risk. A good understanding of the classification of patients with AKI, the types of RRT used in the management of these patients, the specialised macronutrient and micronutrient requirements, and appropriate fluid management is required for the appropriate dietary management of critically ill AKI patients. The aim of this review is to address all of these. To achieve optimal nutritional management of AKI patients in the ICU, especially those on RRT in South Africa, it is critically important that the lack of ICU scale beds and ready-to-hang specialised dialysis enteral feeds is addressed.

Introduction

The appropriate management of critically ill patients who present with acute kidney injury (AKI) is paramount. The management of this patient population is probably more complicated than that of chronic care haemodialysis (HD) patients, as AKI patients have significant protein catabolism, insulin resistance (abnormal carbohydrate metabolism) and an altered fat metabolism, and AKI patients on continuous renal replacement therapy (CRRT), such as continuous venovenous haemofiltration (CVVH), are at greater risk of protein and micronutrient losses. The primary goals of nutritional management of AKI patients are to attenuate protein (muscle) catabolism and to replace micronutrient losses, while being mindful of the potential harmful effects of excessive vitamin C and vitamin A in retinol form.[1]

The majority of intensive care units (ICUs) in South Africa do not have scale beds to accurately determine actual body weight which is required to calculate fluid and nitrogen balance. The calculation of nitrogen balance (an adapted formula for AKI) is required for the calculation of the appropriate dose of protein (patient-specific prescription). A grade E recommendation [supported by level IV (nonrandomised, historical controls) or level V evidence (case series, uncontrolled studies and expert opinion)] has been proposed for patients with AKI. It states that "in ICU patients with AKI, standard ICU recommendations for energy and protein should be followed, and (these patients) should receive a standard enteral formulation. Unless electrolyte abnormalities exist or develop, a specialised renal formulation may be considered".[2] The focus of this review will be on the nutritional management of AKI patients requiring renal replacement therapy (RRT), i.e. AKI patients requiring more specialised dietary management. Until recently, few HD oral enteral feeds (high protein, with low electrolytes and limited volume) were available in South Africa. Currently, specialised HD ready-to-hang enteral feeds tube feeding for AKI patients on RRT in ICU are not available in South Africa. Decanting the oral feeds for tube feeding is labour intensive for the nursing staff, and such practice lacks the sterility of a closed system (personal observation). Some of the

enteral feeds, not necessarily the HD-specific feeds, used for HD patients in ICUs in South Africa, are too high in vitamin C and the retinol form of vitamin A, and too low in folic acid.

A good understanding of the classification of patients with AKI, the types of RRT used in the management of these patients, the specialised macronutrient and micronutrient requirements, and appropriate fluid management of AKI patients is required for appropriate dietary management of critically ill AKI patients. The aim of this review is to address these.

Definitions

There are over 35 different definitions of acute renal failure; referred to as AKI in recent years. [3] AKI is an abrupt and sustained reduction in kidney function, defined as:

- An increase in serum creatinine by 50% within seven days, or
- An increase in serum creatinine by 0.3 mg/dl (26.5 umol/l) within two days, or
- Oliguria. [4]

AKI may be due to isolated kidney dysfunction, or it may be a complication of severe illness. [5]

Classification of acute kidney injury

Patient groups based on severity of disease

Valencia et al[5] have classified AKI in three patient group categories according to level of catabolism and disease severity.

Group 1

Group 1 comprises patients without excess catabolism and a urea nitrogen appearance (UNA) of 6 g or less nitrogen loss than the nitrogen intake per day. AKI is mainly caused by nephrotoxins (aminoglycosides, contrast media and mismatched blood transfusions) in this group. In most cases, these patients are fed enterally and the prognosis for renal function recovery and survival is excellent. [5]

Group 2

Group 2 comprises patients with moderate catabolism and a UNA of 6-12 g nitrogen loss more than the nitrogen intake per day. This group of patients frequently has complicating infections, peritonitis or moderate injury, in association with AKI. Patients require enteral feeding or total parenteral nutrition (TPN), and usually dialysis or haemofiltration to limit waste product accumulation. [5]

Group 3

Group 3 comprises patients with severe catabolism and a UNA of more than 12 g nitrogen loss than the nitrogen intake per day. This group of patients frequently has severe trauma, burns or overwhelming infection, in association with AKI. Treatment strategies are usually complex and include parenteral nutrition, haemofiltration (intermittent or continuous), as well as blood pressure and ventilatory support. [5]

To reduce catabolism and avoid protein depletion in group 3 patients, nutrient requirements, specifically protein, are high, and dialysis is used to maintain fluid balance and blood urea nitrogen (BUN) below 100 mg/l. Mortality in this group is high (60-80%), mainly due to a combination of renal dysfunction, hypercatabolism, inflammatory reaction and the severity of the underlying illness. [5]

The RIFLE and Acute Kidney Injury Network classifications

Currently, the most widely used classification for AKI is the RIFLE model (risk, injury, failure, loss and end-stage renal disease), which was proposed by the Acute Dialysis Quality Initiative group. [6] A second model that is commonly used is the Acute Kidney Injury Network (AKIN) staging system, which is a modification of the RIFLE classification. Both models are based on serum creatinine and urine output, and both have been validated. In a recent study conducted by Joannidis et al, [7] it was observed that the RIFLE criteria failed to detect 9% of AKI that was detected by the AKIN criteria, while the AKIN criteria failed to detect 26.9% of AKI cases detected by RIFLE. Despite the validation of both models, in clinical practice, oliguria appears to be the main factor that is considered by clinicians when deciding whether or not to initiate RRT. As demonstrated in the study conducted by Bellomo et al, [8] the decision to initiate RRT was based on oliguria in 60% of the patients.

RIFLE classification

The RIFLE classification is defined in Table I. [5]

Table I: RIFLE classification of renal failure[5]

Class	Serum creatinine or GFR criteria	Urine output criteria
Risk (stage 1)	Serum creatinine x 1.5 or GFR decreased by > 25%	< 0.5 ml/kg/hour for 6 hours
Injury (stage 2)	Serum creatinine x 2 or GFR decreased by > 50%	< 0.5 ml/kg/hour for 12 hours
Failure (stage 3)	Serum creatinine x 3 or serum creatinine ≥ 4 mg/dl (354 mmol/l) with an acute rise > 0.5 mg/dl (44 mmol/l)	< 0.3 ml/kg/hour for 24 hours, or anuria for 12 hours
Loss	Persistent acute renal failure equals complete loss of kidney function (> 4 weeks)	
End-stage kidney disease	End-stage kidney disease (> 3 months)	

GFR: glomerular filtration rate

Acute Kidney Injury Network criteria

The AKIN criteria have similar urine output criteria to the RIFLE classification, but differ in the serum creatinine levels, as defined in Table II.

The proposed staging system is a highly sensitive interim staging system, and is based on recent data indicating that a small change in serum creatinine influences outcome. Only one criterion (creatinine or urine output) has to be fulfilled to qualify for a stage.

Table II: Acute Kidney Injury Network staging system[9]

Stage	Serum creatinine	Urine output
1*	An increase in serum creatinine of more than or equal to 0.3 mg/dl (≥ 26.4 µmol/l), or an increase to more than or equal to 150-200% (1.5 to 2-fold) from baseline	Less than 0.5 ml/kg/hour for more than six hours
2	An increase in serum creatinine to more than 200-300% (> 2- to 3-fold) from baseline	Less than 0.5 ml/kg/hour for more than 12 hours
3**	An increase in serum creatinine to more than 300% (> 3-fold) from baseline, or serum creatinine of more than or equal to 4 mg/dl (≥ 354 µmol/l) with an acute increase of at least 0.5 mg/dl (44 µmol/l)	Less than 0.3 ml/kg/hour for 24 hours or anuria for 12 hours

*Modified from the RIFLE (risk, injury, failure, loss and end-stage kidney disease) criteria
**Given the wide variation in indications and the timing of the initiation of renal replacement therapy, individuals who receive renal replacement therapy are considered to have met the criteria for stage 3, irrespective of the stage at which they are in at the time of renal replacement therapy

Table III: Common causes of acute kidney injury[3]

The most common causes of acute kidney injury	Other common causes of acute kidney injury
• Sepsis (most common) • Major surgery • Low cardiac output • Hypovolaemia • Medications	• Hepatorenal syndrome • Trauma • Cardiopulmonary bypass • Abdominal compartment syndrome • Rhabdomyolysis (breakdown of muscle cells) • Obstruction

Common causes of acute kidney injury

The most common causes of AKI include sepsis, major surgery, low cardiac output and hypovolaemia. Other common causes of AKI are listed in Table III. [3]

Common nephrotoxins that cause acute kidney injury

Both exogenous and endogenous nephrotoxins cause AKI in critically ill patients.

Exogenous nephrotoxins

Exogenous nephrotoxins include:
- *Radiocontrast dye:* For example, that used for angiograms.
- *Ingestions:* For example, ethylene glycol (found in anti-freeze brake fluid, coolants and solvents) and paracetamol. These ingestions are examples of those taken by parasuicide patients.
- *Medications:* Chemotherapeutic agents, nonsteroidal anti-inflammatory drugs, antimicrobial medicines, aminoglycoside agents (gentamycin), amphotericin, penicillin and acyclovir.[3]

Endogenous nephrotoxins

Endogenous nephrotoxins include:
- Rhabdomyolysis.
- *Haemolysis:* Haemolytic uraemic syndrome and thrombotic thrombocytopenic purpura.
- Tumour lysis syndrome.[3]

Onset of acute kidney injury

It was observed in a retrospective study on 5 383 ICU patients that the majority of patients developed AKI in ICU. However, in some cases AKI occurred post discharge from the ICU.[10]

Types of dialysis

There are three types of RRT; peritoneal dialysis (PD), HD and CRRT, which is administered continuously over 18-24 hours. There are two modes of HD, namely intermittent HD which is usually performed every second day for 4-6 hours, and sustained low-efficiency dialysis which is performed for 8-12 hours, 5-6 days a week.[11] There are two types of CRRT, namely CVVH and continuous venovenous haemodiafiltration (CVVHDF). It is important to have a good understanding of the various forms of renal replacement therapy, as each has a varying impact on the nutritional requirements for critically ill AKI patients.[12]

AKI requiring dialysis in critically ill patients is associated with a mortality of 40-70%, and the disease itself is an independent risk factor for death.[12]

Intermittent HD is perhaps the most commonly used form of RRT in critically ill patients. Intermittent HD is less expensive than CRRT and has similar efficacy.[13] CRRT is used for patients who require dialysis, but who are haemodynamically unstable, and/or fluid overloaded, and hence cannot afford to have a rapid change in total fluid volume.[6] It was observed in a study carried out by Salahudeen et al[11] that more aggressive and early nutritional support may be important to survival in patients on CRRT.

Continuous venovenous haemofiltration circuit

The patient's blood is pumped and anticoagulated before passing to the haemofilter. A drip chamber acts as a bubble trap before the blood is returned to the patient. The ultrafiltration rate and resultant solute convection are dependent upon the speed of the blood pump and consequent transmembrane pressure generated. Multiple pressure sensors assist in monitoring transmembrane pressure, for example. CVVH blood flow is 0-300 ml per minute. The ultrafiltration rate is 0-35 ml/kilogram body weight/hour. However, in clinical practice, the average rate used is usually 20-35 ml/kg/hour. A calculated proportion of ultrafiltrate is replaced with replacement fluid to achieve the desired fluid balance, except in patients with fluid overload or cardiopulmonary dysfunction, when a negative fluid balance needs to be achieved.[12]

Continuous venovenous haemodiafiltration circuit

A CVVHDF circuit is similar to CVVH, but with the addition of a counter-current dialysate fluid flow through the haemofilter. This

allows for both convective and diffuse flow to occur, and hence an increase in the rate of solute clearance. [12]

Intermittent haemodialysis circuit

Intermittent HD depends on diffusive solute clearance owing to the counter-current flow of dialysate fluid through the haemofilter. The blood flow rate within the circuit is higher, and high dialysate flow produces large filtration volumes. Unlike CVVH, no replacement fluid is required as rapid solute removal is achieved with less total fluid loss from the patient.[12] The average human has a total blood volume of five litres.[14]

Absolute indications for renal replacement therapy

The following are absolute indications for RRT:
- *Uraemic complications:* Encephalopathy, pericarditis and bleeding.
- Serum urea $\geq$ 36 mmol/l.
- Potassium > 6 mmol/l or electrocardiogram abnormalities.
- Serum pH $\leq$ 7.15.
- Urine output less than 200 ml/12 hours or anuria.
- Diuretic-resistant organ oedema, especially pulmonary oedema, in the presence of AKI.[15]

Goals of nutritional support

The goals of nutritional support in AKI are the following:
- To prevent protein energy wasting.
- To preserve lean body mass and nutritional status.
- To avoid further metabolic derangement.
- To avoid complications.
- To improve wound healing.
- To support immune function.
- To minimise inflammation.
- To improve antioxidant activity.
- To improve endothelial function.
- To reduce or prevent mortality.[16]

Energy requirements

Internationally, the recommended guideline for calculating energy requirements for AKI is 25-35 Kcal/kg/day (total energy). [4] However, in practice, 20-30 Kcal/kg/day is more achievable.[2,17] Energy expenditure in critically ill patients with AKI rarely exceeds 1.3 times the basal energy requirements.[16,18] Fiaccadori et al[16] reported that benefit was not shown in the nitrogen balance if more than 35 Kcal/kg/day was administered.

Protein requirements

Whole body protein synthesis increases by 15-37% in critically ill patients. However, protein breakdown increases by 41-79%, resulting in net protein catabolism. Unabated protein catabolism during critical illness, because of inadequate nutrition therapy, will result in impaired immunity, increased risk of infection and might worsen mortality risk.[19]

In addition to stress mediators, immobility and physical inactivity are key determinants of anabolic resistance in critically ill patients. The

development of mobility protocols in the ICU should be promoted to enhance the efficacy of nutrition.[20]

Pathogenesis of protein catabolism in acute kidney injury

Multiple factors can potentially aggravate the pathogenesis of protein catabolism in AKI, namely:
- An inadequate supply of nutrients.
- Uraemic toxins.
- Endocrine factors.
- A defective response to insulin (resistance).
- The increased secretion of catabolic hormones (glucagon, catecholamines and glucocorticoids).
- Resistance to, or suppression of, growth or anabolic factors.
- Acute phase response or systemic inflammatory response (cytokines).
- Metabolic acidosis.
- Proteases (the ubiquitine-proteasome system).
- Loss of nutritional substrates during RRT.[16]

Approximately 0.2 g amino acid is lost per litre of filtrate in CRRT, resulting in a total loss of 10-15 g amino acid (protein) per day. An additional 5-10 g of protein is lost per day depending on the type of therapy and dialyser membrane.[2]

The optimum protein requirement for intermittent HD is 1.2-1.5 g/kg ideal body weight.[17] The optimum protein requirement for CRRT and hypercatabolic patients is 1.7 g/kg/day.[4] Fiaccadori et al[22] recommend a maximum of 2 g/kg/day for hypercatabolic AKI patients and/or those who are on CRRT. In practice, the latter recommendation is difficult to implement practically, especially if a fluid restriction (due to severe fluid overload and cardiopulmonary failure) is required in such patients (personal observation). The recommended protein requirement in AKI patients who are not yet on RRT varies from 0.6-0.8 g[2,13] and 0.8-1 g protein/kg/day.[4,22] Refer to Table IV for a case example of the protein requirements for an AKI patient, either not on RRT, or on intermittent HD or on CRRT.

Assessment of adequacy of protein prescribed

The standard nitrogen balance calculation method usually utilised for critically ill patients requires a creatinine clearance of 50 ml/minute/1.73m^2, and is hence not reliable for AKI. In AKI, UNA and protein catabolic rate (PCR) are more accurate.

The formulae for calculating UNA and PCR are provided below: [17]

UNA g/day = UUN + [(BUN2 − BUN1) x 0.6 x BWI] + (BW2 − BW1) x BUN2]
PCR g/day = UNA x 6.25

BUN1: Initial collection of blood urea nitrogen, post dialysis (g/l)
BUN2: Final collection of blood urea nitrogen, pre-dialysis (g/l)
BW1: Post-dialysis weight (kg)
BW2: Pre-dialysis weight (kg)
UUN: Urinary urea nitrogen (g/day).[13]

Table IV: Case example of the protein requirements for an acute kidney patient patient, either not on renal replacement therapy, or on intermittent haemodialysis or on continuous renal replacement therapy

The calculation of protein requirements for a patient weighing 70 kg:
- *Not on RRT:* 0.6-1 g x 70 kg = 42-70 g protein/day.
- *Intermittent dialysis*: 1.2-1.5 g (1.3 g) x 70 kg = 84-105 g protein/day.
- *CRRT:* 1.7-2 g x 70 kg = 119-140 g protein/day.

A UNA of 5-10 g per day suggests moderate catabolism, while a UNA of greater than 10 g per day suggests severe catabolism.[18] A practical limiting factor in determining UNA and PCR is that an accurate pre- and post- dialysis actual body weight are required. If an ICU scale bed or Bluetooth bed scale is not available to accurately measure actual body weight, the UNA and PCR cannot be calculated, and hence individualised protein requirements cannot be accurately determined.

Carbohydrate requirements

Carbohydrate requirements have not yet been accurately established for critically ill patients. The theoretical estimation of the maximum oxidation rate of glucose is 4-7 mg/kg/minute (or 400-700 g/day for a 70 kg patient). The latter should not be confused with ideal carbohydrate requirements for ICU patients, required to achieve blood sugar levels between 4.5 mmol/l and 6.1mmol/l, which have been shown to reduce mortality rates in ICU patients. To meet the requirements of the brain, the minimum daily requirement of glucose is estimated to be 100-120 g per day.[21] Carbohydrate, in the form of citrate, glucose and lactate from intravenous fluids, as well as from dialysate or haemofiltration solutions, also needs to be considered with regard to the total carbohydrate and energy daily intake to ensure normoglycaemia.[22]

Avoiding hyperglycaemia

Stress-induced hyperglycaemia in critically ill patients occurs due to the impairment of insulin-mediated glucose uptake in the skeletal muscles and the failure of insulin to suppress hepatic gluconeogenesis.[18] Patients with AKI are more prone to have exacerbated insulin resistance due to losses of renal gluconeogenesis and hormonal clearances (mainly insulin and glucagon).[23] Under normal conditions, 30% of insulin catabolism occurs in the kidneys.[18] Some studies have suggested a better outcome for AKI patients with tighter blood sugar control, using insulin infusion protocols.[3,21] Hence, it would be prudent to be more cautious regarding the amount of carbohydrate prescribed and to ensure that the administration rates of high carbohydrate enteral feeds or TPN (especially if greater than 250 g/day) are administered at a lower rate, to aid more stringent glycaemic control (personal observation). Infusion insulin therapy which targets plasma glucose at 6.1-8.3 mmol/l is recommended in critically ill AKI patients with elevated blood sugar. Tight glycaemic control has been shown to reduce the incidence of severe AKI.[4]

Fat requirements

AKI patients are prone to elevated plasma triglyercides (TGs) and elevated very low-density lipoprotein (LDL) levels, as well as, decreased levels of total cholesterol, LDL and high-density lipoprotein (HDL). Impaired lipolysis is the most important cause of plasma changes in AKI, as both peripheral lipoprotein lipase and hepatic triglyceride lipase are reduced by approximately 50%, and lipoprotein lipase activity is further inhibited if acidosis coexists in patients with AKI.[18]

Ideally, 30-35% of total energy should be provided in the form of fat. A further more specific suggested dose of fat (intravenously) per day been recommended, i.e. 0.8-1.2 g per kilogram body weight. It is important to monitor serum TGs, and to reduce or stop fat intake if the TGs exceeds 400 mg/dl (4.5 mmol/l). The provision of fat in the form of a combination of medium-chain TGs and long-chain TGs may aid in preventing elevated TGs in AKI.[18]

Special micronutrient requirements

Patients with AKI on RRT have specific micronutrient requirements. Excessive amounts of vitamin C and retinol, for example, may be deleterious to these patients, while they may also be at greater risk of folic acid, thiamine, selenium and copper deficiencies, and require greater amounts of these nutrients than the standard daily allowance.[2,16]

Vitamin C

Vitamin C is converted to oxalate, a renal toxin in renal failure. Oxalate is not adequately removed by RRT, accumulates in the renal tubules, and thus exacerbates the existing AKI and potentially limits renal recovery. Hence, it is paramount to limit vitamin C to 100 mg in intermittent HD and 100-200 mg for CRRT.[2,17,18]

Table V: Enteral feed product micronutrient and fibre nutritional profiles

Nutrient	Suplena®*	Nepro® with Carb Steady**	NovoSource® Renal**	Renilon® 7.5	Peptamen® AF	Survimed® HN
Volume	1 000 ml	1 000 ml	1 000 ml	1 000 ml	1 000 ml	1 000 ml
Sodium	779 mg	1 060 mg	1 600 mg	590 mg	1 000 mg	1 350 mg
Potassium	1 119 mg	1 060 mg	1 100 mg	220 mg	2 300 mg	2 600 mg
Phosphorus	740 mg	720 mg	650 mg	30 mg	840 mg	720 mg
Fibre	0 g	4.2 g		0 g	0g	0 g
L-carnitine	162 mg	265 mg	270 mg	150 mg	-	0 mg
Folic acid	426 µg	1 060 µg	1 000 µg	1 000 µg	400 µg	400 µg
Vitamin C	106 mg	105 mg	80 mg	60 mg	180 mg	120 mg
Vitamin A (retinol)	315 µg (RE)	954 µg (RE)	990 µg (RE)	0 µg	1 480 µg	105 µg
Beta-carotene	Not specified	Not specified	Not specified	4.5 µg	220 µg	200 µg

*Was recently discontinued in South Africa, and replaced with Nepro® Low Protein
**Currently not available in ready-to-hang format, and only available in sip-feed format, in South Africa

During CRRT, approximately 100 mg of vitamin C is lost per day in the ultrafiltrate.[24] Refer to Table V for the vitamin C content of specific enteral feeds used in the management of ICU AKI patients on dialysis.

Folic acid

Approximately 265 µg of folic acid per day is lost in the ultrafiltrate during CRRT.[24] Supplementation with 1 mg per day of folic acid is recommended in ischaemic heart disease and CRRT.[17] Some of the specialised renal enteral feeds contain 1 mg folic acid per litre, and hence additional supplementation is unnecessary, while other specialised renal enteral products only contain 400 µg (personal observation). Refer to Table V for the folic acid content of various enteral feeds used to treat patients undergoing RRT.

Thiamine and selenium

Prolonged CRRT also results in increased selenium and thiamine losses.[24] Supplementation with 25-100 mg of thiamine per day is recommended in AKI patients on CRRT.[2] Supplementation with 1.5 times the normal daily requirement for selenium, or 100 µg/day, is recommended for AKI patients on CRRT.[16,17]

Vitamin D

Vitamin D deficiency has been reported to be significantly associated with an increase in AKI in the critically ill population. The risk of mortality is 1.4 times higher in the vitamin D-insufficient, and 1.6 times higher in the vitamin D-deficient critically ill, patient group.[25]

Vitamin D deficiency is defined by a serum 25-hydroxvitamin D [25(OH)D] below 20 ng/ml (50 nmol), and vitamin D insufficiency as a serum 25(OH)D of 20-30 ng/ml (50-75 nmol/l). Normal vitamin D status is defined as above 30 ng/ml (75 nmol/l). 1,25-dihydroxyvitamin D [1,25(OH)D] (calcitriol), the active form of vitamin D levels, is regulated by the parathyroid hormone, and reflects renal hydroxlase activity, but not body vitamin D stores. The 1,25(OH)D levels may remain within the normal range until a severe degree of vitamin D deficiency is reached.[26]

Vitamin D has an important role in calcium and phosphorus homeostasis, and also in cell growth and regulation, immune function, renin-angiotensin and neuromuscular regulation, as well as the up- and downregulation of over 2 000 genes.[26]

The daily dose of intravenous 200 IU vitamin D_2 (cholecalciferol) usually prescribed for hospitalised patients has been shown to be ineffective in normalising vitamin D concentrations in patients who are vitamin D deficient. Recent studies in which high-dose vitamin D therapy [60 000 IU 25(OH)D x two doses] was administered to critically ill patients, demonstrated significant increases in serum 25(OH)D.[25]

The risks of vitamin D supplementation (> 10 000-40 000 IU per day) taken for an extended period, include hypercalcaemia, hypercalciuria and acute renal failure. Optimal vitamin D supplementation in critically ill patients with AKI has not yet been established. Further research is required to establish whether or not vitamin D supplementation improves organ function and mortality in critically ill patients.[26]

Vitamin A

Vitamin A toxicity (hypervitaminosis A) due to increased plasma retinol levels as a result of the loss of renal degradation of retinal-binding protein in renal failure, occurs in patients on prolonged RRT.[16] It is recommended that the retinol administered to AKI patients (especially in prolonged AKI) is limited to 700-900 µg per day.[17] Refer to Table V for the retinol content of various enteral feeds used to treat patients undergoing RRT.

Phosphorus

The incidence of hypophosphataemia is prevalent in ICU patients, and can be further aggravated by prolonged RRT. Severe hypophosphataemia has been associated with respiratory muscle weakness and phosphate depletion, ventilator failure, myocardial dysfunction and encephalopathy. A bolus intravenous treatment dose of 20-30 mmol parenteral sodium phosphorus can be added to replacement or dialysate solutions.[17,22] However, prescribed phosphorus should be limited to 10-15 mg per kilogram per day, to prevent hyperphosphataemia.[27]

Copper

Approximately 400 µg of copper is lost during CRRT, and hence an intake of 300-500 µg per day is recommended. However, copper should be withheld from nutritional support when the total bilirubin is greater than 3 mg/dl.[17]

Zinc

A positive zinc balance may occur during CRRT from zinc contaminant in CRRT replacement fluid and may be due to the citrate anticoagulant used in CRRT. Hence, standard nutrition doses are recommended, unless significant gastrointestinal losses occur.[17]

Fluid management

The kidneys usually receive 25% of the total cardiac output, and hence are very sensitive to hypoperfusion or hypovolaemia.[3] Fluid overload is associated with an increased risk of death.[13] Trends demonstrate improved outcomes with more stringent maintenance of fluid intake and output daily balances. The management of the critically ill is a dynamic process, and requires frequent assessment and adjustment to fluid volumes. Synthetic colloids, i.e. hydroxethyl starches and dextrans, are still widely used despite concerns regarding renal outcomes.[3]

Route of feeding

Enteral feeding of critically ill AKI patients may be challenging because of impaired gastrointestinal motility and the decreased absorption of nutrients secondary to bowel oedema. AKI is a major risk factor for gastrointestinal haemorrhage. Hence, enteral feeding may potentially exert a protective effect in reducing the risk of stress ulcers or bleeding.[2] Enteral nutrition has been shown to augment renal plasma flow and improve renal function in experimental AKI.[28]

When sufficient enteral feeding cannot be achieved, a combination of enteral and parenteral feeding may be required to achieve successful nutritional support. Hence, the two routes of feeding should be considered as complementary, and not mutually exclusive.[22] Current available clinical practice guidelines recommend enteral nutrition as the preferential route in the first 24-48 hours upon ICU admission, and if adequate enteral nutrition cannot be achieved from day 3-5, parenteral nutrition should be introduced.[2]

Conclusion

The evolution of more optimal and individualised dietary intervention in critically ill AKI patients will only progress in South Africa when ICU scale beds or Bluetooth bed scales are available in all of the ICUs in the country, especially those which provide RRT. The accurate measurement of actual body weight would also allow for tighter fluid management and more accurate measurement of nitrogen balance, so that adequate protein can be administered to AKI patients. It is also paramount that the appropriate (in terms of both macronutrients and micronutrients, especially protein, vitamin C, folic acid and vitamin A) specialised ready-to-hang (one-litre) enteral feeds for patients on HD and CRRT are made available in South Africa.

References

1. Casaer MP, Mesotten D, Schetz MRC. Bench-to-bedside review: metabolism and nutrition. Crit Care. 2008;12(4):222.
2. McCarthy MS, Phipps SC. Special nutrition challenges: current approaches to acute kidney injury. Nutr Clin Pract. 2014;29(1):56-62.
3. Dennen P, Douglas IS, Anderson R. Acute kidney injury in the intensive care unit: an update and primer for the intensivist. Crit Care Med. 2010;38(1): 1-15.
4. Kidney Disease Improving Global Outcomes. KDIGO clinical practice guideline for acute kidney injury. Kidney International Supplements. 2012;2(1):2.
5. Valencia E, Marin A, Hardy G. Nutritional therapy for acute renal failure. Curr Opin Clin Metab Care. 2009;12(3):241-244.
6. Honore PM, Jacobs R, Joannes-Boyau O, et al. Septic AKI in ICU patients. Diagnosis, pathophysiology, and treatment type, dosing, and timing: a comprehensive review of recent and future developments. Ann Intensive Care. 2011;1(1):32.
7. Joannidis M, Metnitz B, Bauer P, et al. Acute kidney injury in critically patients classified by AKIN versus RIFLE using the SAPS 3 database. Intensive Care Med. 2009;35(10):1692-1702.
8. Bellomo R, Cass A, Cole L, et al. Intensity of continuous renal replacement therapy in critically ill patients. N Engl J Med. 2009;361(17):1627-1638.
9. Mehta RL, Kellum JA, Shah SV, et al. Acute Kidney Injury Network: report of an initiative to improve outcomes in acute kidney injury. Crit Care. 2007;11(2):R31.
10. Hoste EA, Clermont G, Kersten A, et al. RIFLE criteria for acute kidney injury are associated with hospital mortality in critically ill patients: cohort analysis. Crit Care. 2006;10(3):R73.
11. Salahudeen AK, Kumar V, Madan N, et al. Sustained low efficiency dialysis in the continuous mode (C-SLED): dialysis efficacy, clinical outcomes and survival predictors in critically ill cancer patients. Clin J Am Soc Nephrol. 2009;4(8):1338-1346.
12. Hall NA, Fox AJ. Renal replacement therapies in critical care. Contin Educ Anaesth Crit Care Pain. 2006;6(5):197-202.
13. Lameire NH, Bagga A, Cruz D, et al. Acute kidney injury: an increasing global concern. Lancet. 2013;382(9887):170-179.
14. Blood. World book encyclopedia. Chicago: World Book, 1998; p. 407.
15. Ricci Z, Ronco C. Timing, dose and mode of dialysis in acute kidney injury. Curr Opin in Crit Care. 2011;17(6):556-561.
16. Fiaccadori E, Regolisti G, Cabassi A. Specific nutritional problems in acute kidney injury, treated with non-dialysis and dialytic modalities. NDT Plus. 2010;3:1-7.
17. Gervasio JM, Cotton AB. Nutrition support therapy in acute kidney injury: distinguishing dogma from good practice. Curr Gastroenterol Rep. 2009;11(4):325-331.
18. Fiaccadori E, Parenti E, Maggoire U. Nutritional support in acute kidney injury. J Nephrol. 2008;21(5):645-666.
19. Dickerson RN, Pitts SL, Maish GO, et al. A reappraisal of nitrogen requirements for patients with critical illness and trauma. J Trauma Acute Care Surg. 2012;73(3):549-557.
20. Biolo G. Protein metabolism and requirements. World Rev Nutr Diet. 2013;105:12-20.
21. Singer P, Berger MM, van den Berghe, et al. J Clin Nutr. 2009;28(4):387-400.
22. Fiaccadori E, Regolisti G, Maggiore U. Specialized nutritional support interventions in critically ill patients on renal replacement therapy. Curr Opin Clin Nutr Metab Care. 2013;16(2):217-224.
23. Wiesen P, van Overmeire L, Delanaye P, et al. Nutrition disorders during acute renal failure and renal replacement therapy. JPEN J Parenter Enteral Nutr. 2011;35(2):217-222.
24. Cano N, Fiaccadori E, Tesinsky P, et al. ESPEN guidelines on enteral nutrition: acute renal failure. Clin Nutr. 2006;25(2):295-310.
25. Massey K, Dickerson RN, Brown RO. A review of vitamin D deficiency in the critical care population. Pharmacy. 2014;2:40-49.
26. Amrein K, Venkatesh B. Vitamin D and the critically ill patient. Curr Opin Clin Nutr Metab Care. 2012;15(2):188-193.
27. Cano NJM, Aparicio M, Brunori G, et al. ESPEN guidelines on parenteral nutrition: acute renal failure. Clin Nutr. 2009;28(4):401-414.
28. Druml W. The renal failure patient. World Rev Nutr Diet. 2013;105:126-135.