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Pediatric Nephrology (B Dixon and E Nehus, Section Editors)

Nutritional Management of the Pediatric CKD Patient

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Abstract

Purpose of Review Children with chronic kidney disease (CKD) have unique nutritional needs related to decreased kidney function. This review discusses outcomes related to nutritional status in children with CKD. It reviews recommendations specific to children with CKD including nutritional assessment, energy needs, and macro- and micronutrient requirements. In addition, other considerations including supplemental feeding and potential barriers are briefly summarized.

Recent Findings While malnutrition has been long associated with CKD, obesity is increasingly being recognized in CKD and may contribute to progression of disease. The practice of dietary potassium restriction is being questioned. Education regarding phosphorus management should include inorganic sources from food additives and preservatives in addition to the usual organic sources of phosphorus. There are emerging options for formula alternatives including blenderized diets that meet the dietary restrictions of this population. Recognizing and addressing food insecurity and providing guidance on cooking techniques may enhance adherence.

Summary The nutritional management of children with CKD is complex. An individualized approach by a multi-disciplinary team can help educate and promote success in these lifelong dietary modifications.

Introduction

Chronic kidney disease (CKD) usually refers to abnormal kidney function persisting for more than 3 months. Whatever the underlying cause, kidney function may worsen over time which can lead to a variety of complications. Children with progressive CKD require complex dietary management to ensure appropriate nutritional intake as well as control electrolyte disorders. Dietary modifications are needed to mitigate not only the immediate effects of impaired renal function and electrolyte abnormalities but also the long-term consequences of malnutrition and obesity. The purpose of this review is to highlight unique nutritional management considerations for children with CKD.

Nutritional status and outcomes in CKD

The traditional focus of nutritional management in children with CKD has been avoiding malnutrition. Potential consequences of malnutrition include impaired growth, more frequent hospitalizations, and a greater risk of mortality [1]. In the Chronic Kidney Disease in Children (CKiD) study, a large North American prospective cohort study of children with CKD, unintentional weight loss worsened with progression of CKD and those with significant weight loss were more likely to develop end-stage kidney disease (ESKD) [2••]. Another study of the CKiD cohort investigated the association of fragility indictors with patient outcomes. Fragility indicators included objective measurements of growth, muscle mass, fatigue, and inflammation. Children with greater than 3 fragility indicators had 3-fold increased odds of developing infections or hospitalizations [3••]. Given the significant association between poor nutrition, CKD progression, and adverse events, these studies indicate appropriate evaluation and treatment of malnutrition is needed in children with CKD to improve long-term outcomes.

However, high caloric consumption leading to obesity may also occur in children with CKD and has been a topic of recent focus. In the CKiD cohort, 33% of participants were classified as either overweight or obese [4]. Obesity remains a concern post renal transplant as many transplant recipients have excessive weight gain after transplant. The incidence of obesity has been shown to increase by as much as 29% with the majority of weight gain occurring within the first 6 months after transplant [5]. Even more concerning is that obesity at the time of kidney transplantation is associated with decreased long-term allograft survival [6].

Similar to malnutrition, obesity should also be avoided or treated as emerging evidence suggests that obesity can lead to progression of CKD via a number of proposed mechanisms [7••, 8, 9]. The goal of nutritional management is to prevent growth failure and malnutrition while making sure patients are not overnourished leading to obesity, as both a large decrease and increase in body mass index (BMI) are associated with increased mortality risk [10]. Finding the right balance for patients with CKD is challenging. The most effective way to accomplish this is with individualized management and education tailored to each patient. Helping patients and families adapt their current diet and lifestyle to make

them fit within their CKD diet can help increase adherence to dietary recommendations [11].

Nutritional assessment

The National Kidney Foundation Kidney Disease Outcomes Quality Initiative (KDOQI) Clinical Practice Guideline for Nutrition in Children with CKD recommends monitoring nutritional status and growth parameters in infants and children with CKD at least twice as frequently as in healthy children of the same age. The nutritional assessment includes dietary intake, laboratory values, and anthropometric data to evaluate growth. In infants under 1 year of age with stage 2–4 CKD, the KDOQI guideline suggests monitoring anthropometrics every 2 to 6 weeks. For children aged 1–3 years, it is recommended to be monitored every 1–3 months. Children older than 3 years of age should be monitored every 1–6 months depending on the degree of CKD. Patients on chronic dialysis typically require more frequent nutritional evaluation, usually on a monthly basis [12].

To standardize the identification and diagnosis of infant and pediatric malnutrition, the Academy of Nutrition and Dietetics along with the American Society for Parenteral and Enteral Nutrition (ASPEN) recommends an assessment of anthropometric data and dietary intake [13]. For infants and children up to 2 years of age, it is recommended to monitor weight, length, weight for length, and head circumference *z*-scores for age using the World Health Organization growth charts. Patients over 2 years of age can have their weight, height, BMI, and growth velocity monitored utilizing the Center for Disease Control 2–20 year growth charts. A child with BMI between the 85th and 95th percentiles is classified as overweight and with BMI greater than the 95th percentile is considered obese [14].

Dietary intake can be evaluated using either food frequency questionnaires which are completed by the family or by utilizing a 3-day dietary recall collected by a dietitian. Food frequency questionnaires are validated surveys that assess intake of various nutrients by tallying intake of different food groups. It is also vital that a renal dietitian meets with the patient and/or caregiver to review dietary intake. For dietary recall, there are several smart phone applications available specifically tailored to kidney health that can be used to electronically record dietary intake instead of traditional tracking on paper. The subjective global nutrition assessment (SGNA) is a nutrition assessment tool that can be utilized along with a nutrition-focused physical exam assessing fat and muscle wasting to provide a standardized approach [13]. The SGNA can be used in either the inpatient or outpatient setting.

Nutritional requirements

Energy and caloric needs

The basal metabolic rate of children with CKD is generally similar to that of healthy children [15]. For infants and children under age 3, we recommend using the dietary reference intakes (DRI) for energy to estimate caloric needs. For children 3 years of age and older, the estimated energy requirements (EER) will estimate energy needs based on age, sex, weight, height, and physical

activity level [16]. The caloric intake goal may need to be individually tailored to each child with CKD taking into consideration the nutritional status (malnourished vs overweight/obese). Table 1 provides a summary of estimated energy needs based on gender and age.

The caloric intake of children with CKD is often less than the recommended amount due to decreased appetite, especially as kidney function worsens [17]. The KDOQI guideline recommends supplemental nutritional support if children with CKD fail to meet their energy requirements or are not gaining weight or growing as expected [12]. Some children will need a nasogastric tube or gastrostomy tube to administer supplemental nutritional formula due to inadequate oral intake. Formulas for children and adults with decreased kidney function who require low solute loads (e.g., potassium and phosphorus) are commercially available and are discussed in further detail below. For most overweight or obese children with CKD, we favor a staged approach of increasing intensity to weight management [18].

Macronutrients

Protein

Dietary protein intake (DPI) in children with CKD frequently exceeds the usual recommended amount by DRI [19, 20]. A randomized trial in children with stage 3 and 4 CKD did not demonstrate a difference in CKD progression or growth in the lower protein group who received 125% of the protein intake recommended by the World Health Organization compared with the control group who had a higher mean protein intake of 181% of the recommended amount [19]. Thus, protein restriction is not recommended to slow CKD

Table 1. Estimated energy needs based on gender and age

Calculating energy needs	
	Dietary reference intakes for energy (kcal/kg/day)
Age	
0–6 months	108
6–12 months	98
1–3 years	102
	Estimated energy requirements (kcal/day)
Males	
3–8 years	88.5 – (61.9 × Age [years]) + PA[¥] × (26.7 × Weight [kg]) + (903 × Height [m]) + 20
9–18 years	88.5 – (61.9 × Age [years]) + PA[¥] × (26.7 × Weight [kg]) + (903 × Height [m]) + 25
Females	
3–8 years	135.3 – (30.8 × Age [years]) + PA[¥] × (10 × Weight [kg]) + (934 × Height [m]) + 20
9–18 years	135.3 – (30.8 × Age [years]) + PA[¥] × (10 × Weight [kg]) + (934 × Height [m]) + 25

kcal kilocalories, *kg* kilograms, *m* meter, *PA* physical activity coefficient
[¥]PA coefficient varies depending on sex and level of physical activity [12]
Adapted from DRI and EER guidelines [16]

progression. Instead, the goal is to ensure enough protein intake to maintain adequate growth and nutritional status while limiting potential adverse effects of protein intake including accumulation of nitrogen waste products, acid overload, and phosphorus overload. The recommended DPI varies by age, CKD stage, and type of dialysis therapy [12]. The recommended DPI in stage 3 CKD is 100–140% of the DRI which decreases to 100% of the DRI for children on chronic dialysis [12]. However, an extra allowance for protein and amino acid losses with chronic dialysis therapy (typically higher with peritoneal dialysis compared with hemodialysis) is usually needed to maintain a net intake of 100% DRI. In the hemodialysis population, a normalized protein catabolic rate can provide an objective measure of protein intake; however, it does not provide information about body composition or body protein stores [21]. Table 2 contains a summary of recommended DPI based on age and CKD stage including dialysis.

Protein energy wasting (PEW) is described as low serum albumin, reduced BMI, reduced muscle mass, and poor growth as demonstrated by height less than 3rd percentile and/or growth velocity less than 10th percentile. PEW is exacerbated by chronic inflammation, acidosis, defective insulin signaling, and abnormal appetite regulation seen in CKD [22]. A CKiD study found that PEW diagnosis in children with CKD ranges from 7 to 20% [23]. The combination of decreased DPI and PEW can lead to growth delay and short stature. If the child is not meeting his or her recommended DPI, protein supplements or supplemental formula should be prescribed [24]. The choice of formula will depend on the patient age and electrolyte considerations.

Carbohydrates and fats

The KDOQI guideline does not recommend limiting carbohydrate or fat consumption beyond what is recommended for children without chronic disease. Children aged 1–18 years old are recommended to have carbohydrates composing 45–65% of their caloric intake. Fat intake should comprise 30–40% of total calories in children 1–3 years old and 25–35% of total caloric intake in children 4–18 years old [12].

Table 2. Recommended protein intake based on age and CKD stage

Dietary protein intake recommendations					
Age	**Healthy children (g/kg/day)**	**CKD stage 3 (g/kg/day)**	**CKD stage 4–5 (g/kg/day)**	**Hemodialysis (g/kg/day)**	**Peritoneal dialysis (g/kg/day)**
0–6 months	1.5	1.5–2.1	1.5–1.8	1.6	1.8
7–12 months	1.2	1.2–1.7	1.2–1.5	1.3	1.5
1–3 years	1.05	1.05–1.5	1.05–1.25	1.15	1.3
4–13 years	0.95	0.95–1.35	0.95–1.15	1.05	1.1
14–18 years	0.85	0.85–1.2	0.85–1.05	0.95	1.0

CKD chronic kidney disease, *g* gram, *kg* kilogram
Reprinted with permission from KDOQI clinical practice guideline for nutrition in children with CKD: 2008 update [12]

Micronutrients

Sodium

Sodium has many functions in the body. Not only is sodium necessary for vital cell functions and maintaining intravascular volume, it is needed for muscle development, bone mineralization, and overall growth [25]. The KDOQI guideline recommends meeting at least the age-related DRI of sodium and chloride [12]. Obtaining a stable sodium balance can be challenging depending on the etiology of CKD. Congenital anomalies of the kidney and urinary tract (including renal hypodysplasia and obstructive uropathy) are the most common underlying cause of pediatric CKD, accounting for approximately 50% of the CKiD cohort [26]. This segment of the CKD population is prone to renal salt and water losses and often requires sodium supplementation, especially during infancy. Infants on peritoneal dialysis often have increased sodium requirements due to sodium loss into the dialysate. Infants who require sodium supplementation in addition to their dietary sodium intake may receive sodium chloride and/or sodium citrate depending on their chloride and acid-base needs. For patients without salt wasting, dietary sodium restriction may be an important strategy for blood pressure control, particularly in children with glomerular causes of CKD [27].

Potassium

Like sodium, potassium plays a critical role in many cell functions including nerve excitation and muscle contraction. Some patients with CKD may be at risk for hypokalemia due to the underlying kidney disease or medications and may require increased dietary potassium intake or supplementation. While mild to moderate hypokalemia is usually asymptomatic, more severe hypokalemia can present with extremity cramps, weakness, or even paralysis [28]. Hyperkalemia causes more significant risks, primarily arrhythmias and cardiac arrest with no predisposing symptoms [29].

As urinary excretion is the primary mode of removing excess potassium, children with CKD are at an increased risk for hyperkalemia [12], especially in the presence of more severe CKD and/or additional risk factors for hyperkalemia besides decreased kidney function. The traditional approach to children and adolescents with CKD who have hyperkalemia or increased risk for hyperkalemia is dietary restriction of foods with high potassium content. The KDOQI guideline suggests starting with 40–120 mg/kg/day (1–3 mmol/kg/day) of potassium intake for infants and young children [12]. For older children and adolescents, a potassium restriction of 30–40 mg/kg/day (approximately 0.8–1 mmol/kg/day) with a maximum of 2000–3000 mg/day may be a reasonable starting point [12]. Unfortunately, not all nutrition labels disclose potassium content. A food is considered to be high in potassium if it is has more than 200 mg per serving [12]. Rather than prescribing a potassium restriction by milligrams per day, our practice is to recommend restriction to one high-potassium and four moderate-potassium foods per day. Table 3 lists common foods that are both high and moderate in potassium content. More exhaustive lists of foods containing potassium are available [30].

Table 3. Common foods with significant potassium and phosphorus content

Common foods			
High potassium	**Moderate potassium**	**Organic phosphorus**	**Inorganic phosphorus**
Avocado	Apple	Beans	Cereals
Banana	Blueberries	Cheese	Enhanced meats
Beans	Broccoli	Chocolate	Fast foods
Beets	Carrots	Cottage cheese	Frozen meals
Corn	Cherries	Cow's milk	Processed cheeses
Mushrooms	Garlic	Deli meats	Protein bars
Orange	Lettuce	Nuts and seeds	Sodas
Pear	Onion	Oatmeal	Sports and flavored drinks
Peas	Spaghetti squash	Pancakes	
Potatoes	Summer squash	Pizza	
Raisins	Zucchini	Tofu	
Sweet potatoes		Waffles	
Tomato		Whole eggs	
		Yogurt	

Adapted from references [30, 31]

It is important to note that the common practice of dietary potassium restriction in CKD is being questioned. Observational studies at varying levels of CKD in adults have found higher risk of death or CKD progression associated with markers of lower potassium intake. Diets with cardiovascular benefits such as the Mediterranean diet and Dietary Approaches to Stop Hypertension (DASH) are rich in potassium. Restricting potassium intake may result in denying patients the potential benefits of potassium-rich foods such as fruits and vegetables. In addition, the evidence that dietary potassium restriction significantly lowers serum potassium concentration or avoids hyperkalemia is weak [32••]. We do not recommend preemptive potassium restriction in patients with no history of hyperkalemia, but it may still be indicated in patients with chronic or recurrent hyperkalemia.

Some patients continue to develop hyperkalemia despite dietary restriction. Certain resins including sodium polystyrene sulfonate (SPS), patiromer, and sodium zirconium cyclosilicate act as cation exchangers in the intestine to remove potassium, thus decreasing risk of hyperkalemia. SPS exchanges sodium for potassium and is approved by the United States Food and Drug Administration (FDA) for use in the pediatric population [33]. Patiromer is a sodium-free polymer that exchanges calcium for potassium [34] and sodium zirconium cyclosilicate is a nonabsorbable compound that exchanges both sodium and hydrogen for potassium; however, neither drug is FDA approved for children. Infants and older children dependent on formula for nutritional intake may continue to develop hyperkalemia despite use of low solute formulas. SPS can be used to pretreat formula or breastmilk in order to reduce its free potassium

content and lower risk for hyperkalemia. For more information on how to properly prepare SPS-treated formula/breastmilk, please view the following link: https://youtu.be/_X0UCBJZdv0. Given the association between lower potassium intake and adverse outcomes, an unresolved question is whether using a potassium binder before dietary restriction is more beneficial.

Phosphorus

Hyperphosphatemia is a common complication of moderate to severe CKD and is associated with increased risk for vascular calcification and cardiovascular disease which is the leading cause of death in CKD [35]. The KDOQI guideline recommends limiting phosphorus to 100% of the DRI when the serum parathyroid hormone (PTH) level is elevated with a normal serum phosphorus concentration. When both the PTH and serum phosphorus are elevated, it is recommended to reduce intake to 80% of the DRI [12]. In addition to a phosphorus-restrictive diet, administration of a phosphate binder with food may be necessary.

There are different sources of phosphorus including both organic (plant and animal) sources and inorganic (food additives) sources. Organic phosphorus has varying absorption rates ranging from 10–30% for plant-based organic phosphorus to 30–60% for animal sources of organic phosphorus [36]. On the other hand, inorganic phosphorus has an absorption rate greater than 90% [36, 37] and can greatly affect the serum phosphorus levels. Phosphorus-containing additives or inorganic phosphorus in processed food products can be difficult to identify as they are not always listed on the nutrition facts label. Common organic sources of phosphorus and processed foods that often contain inorganic phosphorus are listed in Table 3 [31].

For chronic dialysis patients, controlling phosphorus is often challenging and difficult to achieve with sustained adherence. However, phosphorus level can be reduced with education. A study with 279 adult patients with ESKD found that counseling and providing education on avoiding foods with phosphorus additives resulted in a modest decline in serum phosphorus levels compared with the control group [38]. Unfortunately, there is a paucity of pediatric trials investigating how to effectively treat hyperphosphatemia.

Calcium

As CKD progresses, calcitriol production by the kidney decreases, thus impairing intestinal calcium absorption which can lead to hypocalcemia and secondary hyperparathyroidism. The KDOQI guideline suggests that children with CKD have a calcium intake 100–200% of the DRI for age with a maximum dose of 2500 mg of elemental calcium [12]. Elemental calcium is present in some commonly used phosphate binders and should be included in the daily intake calculation. Calcium supplementation should be considered when the DRI is not met [12] and the patient has hypocalcemia. Supplementation with calcitriol or a synthetic vitamin D analog such as paricalcitol can help maintain normocalcemia and prevent secondary hyperparathyroidism but can also result in hypercalcemia. A meta-analysis of randomized control studies comparing calcitriol with paricalcitol in dialysis patients showed that both medications result in similar reductions of parathyroid hormone as well as serum

concentrations of calcium, phosphorus, alkaline phosphatase, and episodes of hypercalcemia [39•].

Iron

Anemia in children with CKD is usually multifactorial but is mainly secondary to decreased production of erythropoietin [40]. Iron deficiency is also common and can arise from multiple causes including decreased dietary iron intake, poor absorption of dietary iron intake, inhibited release of iron stores (functional iron deficiency), increased blood loss, and increased red blood cell turnover [41]. As a result, dietary iron intake often requires additional iron supplementation to help correct the hemoglobin. Oral or intravenous iron is often necessary when erythropoietin-stimulating agents (ESA) are prescribed to prevent iron storage depletion and ESA resistance while trying to achieve target hemoglobin concentrations [29].

Vitamins

Due to abnormal renal metabolism, dialysis-related losses, and decreased gastrointestinal absorption, children with CKD are at risk for vitamin and mineral deficiencies [12]. It is recommended by the KDOQI guideline that the diet should provide 100% of the DRI for vitamins A, B, C, E, and K as well as copper and zinc. If not met by dietary intake alone, supplemental vitamins to achieve the DRI are suggested. Given the removal of water-soluble vitamins and trace elements by hemodialysis and peritoneal dialysis, chronic dialysis patients should receive a water-soluble vitamin supplement which is mainly comprised of the B vitamins including folate.

Nutritional management issues

Supplemental nutrition

Specialized formulas for CKD

For children and adolescents with CKD who require formula supplementation, there are limited commercially available options. In the USA, there are one infant formula (Similac PM 60/40®), one pediatric formula (Vitaflo Renastart™), and three adult formulas (Abbott Suplena® with Carbsteady®, Abbott Nepro®, Nestle Novasource® Renal) developed for patients with CKD. These formulas differ from traditional nutritional supplements as they have lower contents of potassium, phosphorus, and vitamin A. The pediatric formula also has a lower osmolality. A limitation of Vitaflo Renastart™ is low protein content. The adult formulas are more calorically dense and therefore require less volume to meet caloric needs. Pediatric patients may therefore need a combination of formulas and additives or an adult formula at reduced strength. Common tolerance issues in children with CKD include gastrointestinal reflux, delayed gastric emptying, and emesis.

Blenderized diets

Blenderized diets have recently emerged as an alternative to standard enteral formulas in patients with CKD or ESKD as a way to manage formula intolerance

or multiple food allergies. Blenderized diets refer to either homemade or commercially made blended foods using mixtures of intact foods and nutrients and are used for tube feedings. In the USA, there are several commercially made blenderized formulas but only select Real Food Blends® products fit within the parameters of a low-potassium and low-phosphorus diet. It is important to monitor for hypervitaminosis A and hyponatremia after starting blenderized diets in children with CKD.

Barriers to adherence

Despite the recognized importance of good nutritional intake, adherence to nutritional guidelines is frequently difficult to achieve. Despite counseling and education, a cross-sectional survey using the food frequency questionnaire in the CKiD cohort revealed higher than recommended consumption of sodium, phosphorus, protein, and calories in all age groups [42••]. When counseling patients and families, it is important to consider several potential barriers to adherence including food insecurity, housing stability, cooking skills, literacy, and numeracy. Some organizations have started offering grocery store tours for families to help them learn to read food labels and choose healthy foods.

Food insecurity

Food insecurity refers to a condition of limited or uncertain access to nutritionally adequate food in the household. Food insecurity includes both reduced food intake and reduced variety or quality of consumed food. In 2017, nearly 16% of all households with children and nearly 35% of households with children and incomes below 185% of the federal poverty level were food insecure [43•]. Food insecurity is associated with worse health outcomes. A recent study utilizing data of 29,341 children (2–17 years of age) from the National Health Interview Survey found that children in food-insecure households were more likely to delay medical care due to cost and were more likely to need but be unable to afford medical care [44•].

Recently, a study examined food insecurity in a pediatric nephrology clinic which surveyed a total of 118 children/families and found that nearly 35% lived in food-insecure households. After the survey, families who screened positive for food insecurity were contacted and 24% of them reported that available food resources were inappropriate for their child's specific nutritional needs [45••]. Among their ESKD patients undergoing chronic dialysis, the prevalence of food insecurity was higher at 64% and those with food insecurity had increased healthcare utilization [46].

Cooking techniques

Our dialysis team has started focusing on helping patients learn to cook and choose recipes for common foods that are compatible with CKD nutritional requirements. For example, boiling potatoes and root vegetables that are cut into small pieces in a large volume of water will decrease potassium content [47]. Phosphorus can be reduced in beef by slicing prior to cooking or by preparing in a pressure cooker [48]. Boiling chicken for at least 20 min has been shown to reduce phosphorus content [49]. These techniques will not affect

the protein content in the meats. Soaking legumes prior to boiling will reduce both the potassium and phosphorus contents [50].

Conclusions

The nutritional goals required for children with CKD are complex and can be taxing on the whole family. Counseling should include what can be consumed in addition to what cannot be consumed. Helping families learn how to prepare snacks and foods while meeting their dietary prescription may improve adherence. Using individualized goals and having the support of an interdisciplinary team can help some patients take better control of their health. In addition to the physician and renal dietitian, our dialysis team also involves psychology, social work, nursing staff, school teacher, child life, and therapeutic recreation to support patients and families as they try to achieve their nutritional goals.

Compliance with Ethical Standards

Conflict of Interest
Jason Thomas declares that he has no conflict of interest.
Jessica Nieves declares that she has no conflict of interest.
Hiren P. Patel declares that he has no conflict of interest.

Human and Animal Rights and Informed Consent
This article does not contain any studies with human or animal subjects performed by any of the authors.

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- • Of importance
- •• Of major importance

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