Nutrition Management of Children on Dialysis

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No Disclosures

Learning Objectives

- Describe approaches to achieve optimal nutritional status in children on dialysis
- Review aspects of diet requiring modification, and management strategies
- Develop appreciation for the many challenges faced by caregivers trying to feed a child on dialysis

Focus of Nutrition Care

- " Maintenance of an optimal nutritional status (i.e.. achievement of a normal pattern of growth and body composition by intake of appropriate amounts and types of nutrients). "
- "Avoidance of uremic toxicity, metabolic abnormalities, and malnutrition
- "Reduction of the risk of chronic morbidities and mortality in adulthood"

NKF, Am J Kidney Dis. 2009

Phases of Growth

	Fetal	Infant	Child	Pubertal
From	Conception to Birth	Birth to 18 months	18 months to 12 years	Onset of Puberty
% of total growth	30	15	40	15
Dependent on	Nutrition Placenta	Nutrition Good health	Growth hormone Thyroid hormone Good health	Growth hormone Testosterone /Estrogen Good Health

Growth Pattern and Dietary Intake of Children with CRI

>80% DRI - **normal** growth

<80% DRI - **reduced** growth velocity

<40%IDRI - **cessation** of growth

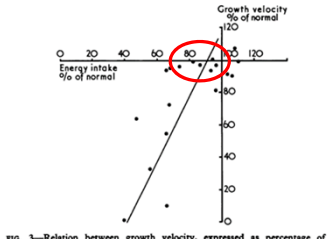


FIG. 3—Relation between growth velocity, expressed as percentage of expected 50th centile velocity, and energy intake, expressed as percentage of that recommended for same age. ($r=0.72$; $P<0.001$.)

Betts & Magrath, BMJ 1974

Growth Pattern and Dietary Intake of Children with CRI

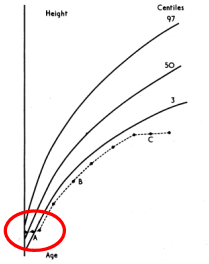


FIG. 6—Schematic representation of growth of children with renal insufficiency dating from infancy. A, B, and C represent periods of growth.

Betts & Magrath, BMJ 1974

Indications for Nutritional Intervention

- Impaired ingestion or tolerance
- Documented inadequate provision or tolerance
- Increased requirements
- BMI <5%ile OR > 85%ile
- Acute Wt loss ≥10%
- Inadequate Wt gain, Lt/Ht less than – 2SD, or significant decrease in usual growth %ile
- Abnormality in nutrition-related biochemistry

NEONATES

- Low birth Wt (< 2500 g)
- Birth Wt z-score less than -2SD for Gestational Age
- Polyuria, inability to concentrate urine

NKF, Am J Kidney Dis. 2009

Nutrition Assessment

Length (<2 yrs) or Height for Age or SDS

Wt for Lt (<2 yrs)
BMI (> 2 yrs) adjusted to Ht Age or SDS

Head Circumference for Age or SDS (up to 3 yrs)

Intake Diary
3 days
3 x 24 hr recalls

Dry Weight for Age or SDS

nPCR = normalized protein catabolic rate (adolescents on dialysis)

NKF, Am J Kidney Dis. 2009; Sgambat, Ped Neph 2018

Nutrition Assessment Frequency

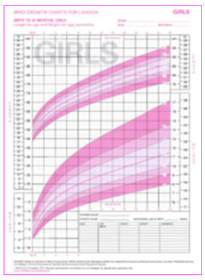
Table 1. Recommended Parameters and Frequency of Nutritional Assessment for Children with CKD Stages 2 to 5 and 5D

	Minimum Interval (mo)									
	Age 0 to <1 y			Age 1-3 y			Age >3 y			
Measure	CKD 2-3	CKD 4-5	CKD 5D	CKD 2-3	CKD 4-5	CKD 5D	CKD 2	CKD 3	CKD 4-5	CKD 5D
Dietary intake	0.5-3	0.5-3	0.5-2	1-3	1-3	1-3	6-12	6	3-4	3-4
Height or length-for-age percentile or SDS	0.5-1.5	0.5-1.5	0.5-1	1-3	1-2	1	3-6	3-6	1-3	1-3
Height or length velocity-for-age percentile or SDS	0.5-2	0.5-2	0.5-1	1-6	1-3	1-2	6	6	6	6
Estimated dry weight and weight-for-age percentile or SDS	0.5-1.5	0.5-1.5	0.25-1	1-3	1-2	0.5-1	3-6	3-6	1-3	1-3
BMI-for-height-age percentile or SDS	0.5-1.5	0.5-1.5	0.5-1	1-3	1-2	1	3-6	3-6	1-3	1-3
Head circumference-for-age percentile or SDS	0.5-1.5	0.5-1.5	0.5-1	1-3	1-2	1-2	N/A	N/A	N/A	N/A
nPCR	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1*

Abbreviation: N/A, not applicable.
*Only applies to adolescents receiving HD.

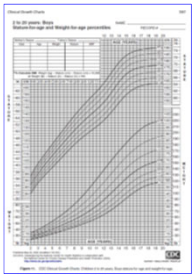
NKF, Am J Kidney Dis. 2009

Plotting Growth



WHO "Growth Standards"

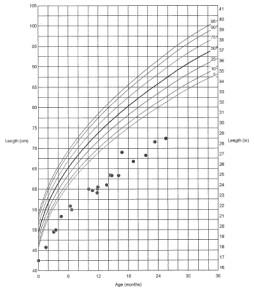
Birth to 2 years



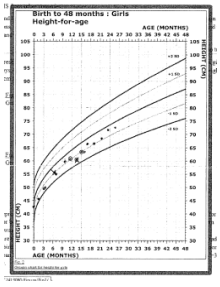
CDC Reference Curves

2-20 years

Plotting Growth



CDC Reference Curve



Wolff-Hirschhorn Chart

Nutrition Assessment

Other Tools:

- Bio-electric Impedance Analysis (BIA)
- Bioimpedance Spectroscopy (BIS)
- Mid Upper Arm Circumference (MUAC) – validated as marker of nutrition status in general pediatric population
- Waist-to-Ht Ratio (>0.49)
- Subjective Global (Nutrition) Assessment (SGA/SGNA)
- Nutrition Focused Physical Exam (NFPE)

Mastrangelo, Ped Neph 2013; Eng, NDT 2017; Addo, AJCN 2016; Modi, J Nutr 2015;Secker, AJCN 2007; Steiber, JRN 2007; Steiber, JRN 2004; Steiber, JRN 2004; Secker, JAND 2012; Secker, JRN 2011; Corkins, NCP 2015; Corkins, NCP 2016; Esper, NCP 2015

Obesity

Obesity, Dyslipidemia – modifiable risk factors for CVD

- Multi-factorial
- Excess energy intake
- Inactivity
  - 10% of non-school hours in activity
  - Up to 1000 hr/year transit or dialysis treatment

CKiD Data

- 13% met activity goal
- 98% exceed recommended screen time

NKF, Am J Kidney Dis. 2009; Hui, Ped Neph 2017;Weaver, Semin Neph 2018; Schaar, Ped Neph 2019, Clark, Ped Neph 2015

Protein Energy Wasting (PEW)

Also called uremic failure to thrive in pediatrics

- 7-20% of children with CKD demonstrate PEW
- May be more common in dialysis population

Hormonal milieu

- Unable to utilize fat
- Breaks down lean tissue

Overly aggressive nutrition does not correct body composition abnormalities

Overweight/Obese children may have PEW picture

Nourbakhsh, Ped Neph 2014; Abraham, Ped Neph 2014; Ayestaran, Ped Neph 2016; Ku, JASN 2015; Mak, Curr Opin Supp Pall Care 2016;

Feeding Challenges

- Dysmotility, reflux, nausea and vomiting
- Intolerance to calorically dense feeds
- Fluid restrictions or goals
- Increased abdominal pressure
- Feeding interruptions
- Medications
- Altered taste
- Elevated cytokines
- Behavioral component

Ruley, Ped Neph, 1989; Ravelli, Arch Dis Child, 1992,; Mak et al, Kid Intern 2006; Armstrong et al, Ped Neph 2010

Feeding Interventions

- Non-nutritive sucking, Oral Stimulation
- Formula manipulations
- Positioning
- Use of small, frequent, thick feeds
- Prokinetics, acid blocking meds, PPI
- Supportive feeding
- Age appropriate introduction of solids
- Feeding specialists (OT, ST)
- Return to oral feeding
- Appetite stimulants

Ruley, Ped Neph, 1989; Ravelli, Arch Dis Child, 1992; Mak et al, Kid Intern 2006; Armstrong et al, Ped Neph 2010; IPPN Network, 2007-2009

Estimating Energy Requirements

- 100% of the EER for chronological age
- Adjusted for PAL and body size

- Further adjustment based on rate of weight gain or loss

NKF, Am J Kidney Dis. 2009; Anderson, Ped Neph 2015

Estimating Energy Requirements

Table 2. Equations to Estimate Energy Requirements for Children at Healthy Weights

Age	Estimated Energy Requirement (EER) (kcal/d) = Total Energy Expenditure + Energy Deposition
0-3 mo	EER = [89 × weight (kg) − 100] + 175
4-6 mo	EER = [89 × weight (kg) − 100] + 56
7-12 mo	EER = [89 × weight (kg) − 100] + 22
13-35 mo	EER = [89 × weight (kg) − 100] + 20
3-8 y	Boys: EER = 88.5 − 61.9 × age (y) + PA × [26.7 × weight (kg) + 903 × height (m)] + 20
	Girls: EER = 135.3 − 30.8 × age (y) + PA × [10 × weight (kg) + 934 × height (m)] + 20
9-18 y	Boys: EER = 88.5 − 61.9 × age (y) + PA × [26.7 × weight (kg) + 903 × height (m)] + 25
	Girls: EER = 135.3 − 30.8 × age (y) + PA × [10 × weight (kg) + 934 × height (m)] + 25

There are equations that estimate energy needs for patients who are obese.

NKF, Am J Kidney Dis. 2009

Recommended Dietary Protein Intake

Table 12. Recommended Dietary Protein Intake in Children with CKD Stages 3 to 5 and 5D

	DRI				
Age	DRI (g/kg/d)	Recommended for CKD Stage 3 (g/kg/d) (100%-140% DRI)	Recommended for CKD Stages 4-5 (g/kg/d) (100%-120% DRI)	Recommended for HD (g/kg/d)*	Recommended for PD (g/kg/d)†
0-6 mo	1.5	1.5-2.1	1.5-1.8	1.6	1.8
7-12 mo	1.2	1.2-1.7	1.2-1.5	1.3	1.5
1-3 y	1.05	1.05-1.5	1.05-1.25	1.15	1.3
4-13 y	0.95	0.95-1.35	0.95-1.15	1.05	1.1
14-18 y	0.85	0.85-1.2	0.85-1.05	0.95	1.0

*DRI + 0.1 g/kg/d to compensate for dialytic losses.
†DRI + 0.15-0.3 g/kg/d depending on patient age to compensate for peritoneal losses.

Ad lib eaters typically consume adequate protein intake.

NKF, Am J Kidney Dis. 2009; Chen, Ped Neph 2017; Quan, Ped Neph 1996

Infants

Breast Feeding or Expressed Human Milk	Low Electrolyte and Mineral Formula	Introduction of Solids
Naturally low in electrolytes and minerals. **Fortify with formula powder or modular products.**	**Whey protein promotes gut emptying.** **Concentrate formula or fortify with modular products.**	**Age appropriate. Low electrolytes and minerals.** **Provide oral stimulation even with supportive feeding.**

Dextrose absorbed from dialysate may need to be considered for infants and children who are gaining weight more quickly than expected.

Young Children

Oral Diet + Supplements	Oral Diet + Supportive Feeds	Eating Competency and Return to Oral Feeding
Choose oral formula based on age, needs, tolerance, contribution from oral diet.	**Choose route, feeding pattern, and formula based on age, needs, tolerance, contribution from oral diet.**	**Continue oral stimulation.** **Involve feeding therapy.** **School experience.**

Lum, Child, Care Health Dev 2017; Ellyn Satter Institute

Supportive Feeding

- Majority of infants on dialysis will need enteral feeding support
- Tube feeds provide as much as 61% of intake in children with gastrostomy
- Up to ½ of feedings may be lost to emesis

NKF, Am J Kidney Dis. 2009; Coleman NDT 1998; Rees, Peds Neph 2009

Nutrition Support Study

IPPN (International Pediatric PD Network)

2007-2009

To analyze growth in infants on PD <2 yrs

150 infants:

- 32 % NG
- 25% PEG
- 22% oral supplements
- 21% no supplemental feeding

Results:

- PEG /NG had significantly higher Ht and BMI SDS
- Ht velocity was greater in the enterally-fed infants

Conclusion:

- Early institution of enteral feeding improves longitudinal growth in infants receiving chronic PD

Rees et al, JASN 2011

Return to Complete Oral Feeding

- Multiple studies have demonstrated the success with which infant and children return to complete oral feeding post transplant.

Warady Adv Perit Dial 1990; Coleman, Adv Perit Dial 1998; Dello Strologo, Ped Neph 1997; Kari, Kidney Int 2000; Pugh, Adv Perit Dial 2006

Comparison of Common Formulas

100 kcal Source (std kcal/oz)	ml	Prot (g)	Na+ (mg)	K+ (mg)	Ca2+ (mg)	Phos (mg)
Cow's Milk	159	5.1	79	248	200	148
Human Milk (20)	142	1.5	25	75	46	20
Similac PM 60/40 (20)	147	2.2	23	80	56	28
Nephea Kids (37)	82	1.3	41	4	31	5
Kindergen (30)	100	1.5	46	24	22	19
Renastart (30)	100	1.6	49	22	21	19
Suplena (54)	56	2.5	44	63	59	40
Nepro (54)	56	4.5	59	59	59	40
Renalcal (60)	50	1.7	3	4	3	5

Modular Energy and Protein

Product	Nutrient	Form
Duocal	Carbohydrate/Fat	Powder
Microlipid	Fat	Emulsified Oil
MCT Oil	MCT Oil	Liquid
Liquid Protein	Protein	Liquid
Beneprotein	Protein	Powder

Distribution of Macronutrients

Table 7. Acceptable Macronutrient Distribution Ranges

Macronutrient	Children 1-3 y	Children 4-18 y
Carbohydrate	45%-65%	45%-65%
Fat	30%-40%	25%-35%
Protein	5%-20%	10%-30%

It is important to consider the source and type of carbohydrates and fats used.

NKF, Am J Kidney Dis. 2009; Moe, CJASN 2011; Tian, Exper Therap Medi 2017; Khurana, Ped Neph 2015

Managing Potassium and Phosphorus in Formulas

Potassium

- Treatment of formula with sodium polystyrene sulfonate
  - Electrolyte derangements
- Use of adult renal formulas in infants

Phosphorus

- Treat breast milk, dairy with Sevalamer HCl and Carbonate

Potassium and Phosphorus

- Pretreat renal formulas with SPS and binders
  - Alters nutrient profiles

Bunchman, Ped Neph 1991; Le Palma, Clin Kid J 2018; Hobbs, JRN 2010; Raajmakers, Perit Dial Int 2013; Taylor, Ped Neph 2015

Older Children and Adolescents

Oral Diet + Supplements	Oral Diet + Supportive Feeds	IDPN or Lipids
Age appropriate oral diet. Low electrolytes and minerals.	**Age appropriate oral diet.**	**Age appropriate. Low electrolytes and minerals.**
Age appropriate formula. Low in Electrolytes and minerals.	**Choose access. Formula choice, feeding plan.**	**Nutrient choice.**

Intradialytic Nutrition Therapies

- Intradialytic Parenteral Nutrition (+PO)
  - Amino acids
  - Dextrose
  - Lipids
- ↑ Wt, BMI, %IBW
- ↑ oral caloric intake
- Albumin unchanged
- Costly
- Adverse events
  - Hyperglycemia
  - Lipid intolerance
  - Hypophosphatemia

- Intradialytic Lipid Infusion
  - Lipids
- ↑ albumin, preHD BUN, nPCR
- Cholesterol, TG no significant change
- Less costly

Krause, JRN 2002; Goldstein, Ped Neph 2002; Orellana, JRN 2005; Haskin, JRN 2017

Growth Hormone

Correct factors that contribute to poor growth starting with optimizing nutrition

"Renal" Diet

Modifications to:

- Minerals: **phosphorus**
- Electrolytes: **sodium** , **potassium**
- **Fluid**

- Energy
- Protein
- Calcium
- Vitamins
- Minerals

"Renal" Diet

There is no "one size fits all"

- Be as liberal as possible to start
- Implement restrictions as indicated
- Individualize for:
  - age,
  - stage of development,
  - food preferences
  - biochemistry
- More liberal if RRF, on PD or daily HD

"Renal" Diet

What **are** children with CKD actually eating?

CKiD Data

- Consuming more Energy, Protein, Sodium, Phosphorus than recommended
- Milk largest contributor to kcal, protein, phosphorus, potassium
- Fast foods largest contributors to fat and sodium, and 3rd largest contributors to phosphorus and potassium

Hui, Ped Neph 2017; Chen, Ped Neph 2017

Sodium and Fluids

Polyuria & Na+ Wasting

- Obstructive uropathies
- Renal dysplasia
- Na+ depletion in infants on PD

Goals:

- Adequate hydration
- Na+ supplementation
- ✓ Promote muscle development, bone mineralization
- ✓ Prevent growth retardation

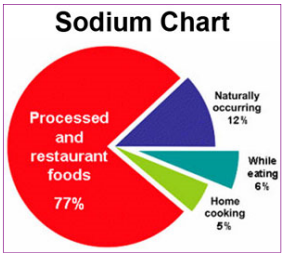
Na+ & Fluid Retention

- Primary glomerular disease
- Oliguric or anuric

Goals:

- Fluid restriction
- Na+ restriction
- ✓ Prevent volume overload, HTN
- ✓ Decrease risk of CVD and LVH

Sodium and Fluids



- Infant formula ~90%
- Enteral formula 70-85%
- 80 % from drinking
- 20% from foods
- Consider all food "liquid" at room temperature

Sodium and Fluids

Sodium

- Processed → Fresh
- Restaurants → Home prepared
- Salt → Herbs and no Na+ spices
- Limit Na+ to 1500-2000 mg daily (based on age)
- Read food labels
  - Choose low Na+ items
    - < 140 mg/serving

Fluid

- Limit Na+ intake
- Count obvious and hidden fluids
- Small amounts divided through day.
- Freshen mouth without drinking fluids

Potassium

- Levels usually controlled until GFR < 15 ml/min/1.73 m2
- K+ may be high despite preserved renal function
- Medications
- Clinical condition
- Volume contraction (Na+ losers)
- Increased losses with PD
- Impaired muscle function
- Cardiac arrhythmia and death

Potassium

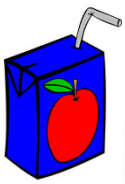
Food	mg K+ /serving
Blueberries ½ c	65
Tomato 1 med	273
Milk 1cup	422
Banana 1 medium	451
Orange juice 1 cup	496
Salt substitute 1/4 tsp	595
Avocado 1/2 med	645
Potato 1 medium	844

Potassium

Fruit Juice	mg K^+/ 125 ml	Drinks	mg K^+/ 125 ml
Cranberry	30	Cola/sprite	0
Apple	148	Koolaid	0
Grape	167	Iced Tea	10
Orange	248	Gatorade	15
Tomato	270	Lemonade	17
Prune	354	Milk	221

Potassium

Think portion size!



Think cumulative!

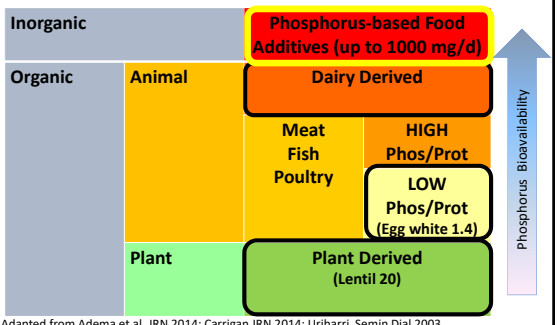
Phosphorus

Early nutrition intervention key to addressing CKD-MBD and consequences

- Cardiovascular disease
- Poor transplant outcomes
- Bone damage post transplant

KDIGO CKD-MBD Update Work Group, Kidney Int 2017; Wesseling-Perry CJASN 2012; Wesseling-Perry NDT 2011

Sources of Phosphorus



Adapted from Adema et al, JRN 2014; Carrigan JRN 2014; Uribarri, Semin Dial 2003

Phosphorus to Protein Ratio

Food	mg Phosphorus /g Protein	Ratio adjusted for digestibility/absorption
Egg white	1.4	1
Meat	9	6
Tofu	12	7
Egg whole	14	10
Legumes	17	10
Lentils	20	12
Nuts	25	15
Milk	29	21
Seeds	50	29

1998, Vegetarian Diets in Renal Disease article in Nutrition Update, DGP Newsletter.

Phosphorus Intake

Recommended Phosphorus Intake mg/d			
Age (y)	DRI (mg/d)	High PTH Normal Phos	High PTH High Phos
0-6 mo	100	<100	<80
7-12 mo	275	<275	<225
1-3	460	<460	<370
4-8	500	<500	<400
9-18	1250	<1250	<1000

NKF, Am J Kidney Dis. 2009

Phosphorus Management

Decrease Phosphorus Intake

Offer low phosphorus formulas. Delay introduction of cow's milk.	Limit intake of dairy Offer low phosphorus proteins	Limit or avoid sources of inorganic phosphorus (food additives)

Adjust phosphorus binder dose and timing to meals, snacks, tube feeds

Which of the following statements about phosphorus is true?

1	To help achieve and maintain a normal serum phosphorus level, avoid high phosphorus foods, including potatoes, bananas, tomatoes & avocado.
2	A study of the typical US diet found food additives alone typically add <100 mg of phosphorus/day, over and above what is naturally found.
3	The primary intervention for a high phosphorus is an ad-lib diet, and adjustment of the binder to the amount of phosphorus in meals.
4	To control serum phosphorus: use low phosphorus formulas and foods; avoid phosphorus-based additives; take binder as prescribed.
5	The effects of an elevated phosphorus level are limited to the immediate bone structure damage done when the level is above normal.

Which of the following statements about phosphorus is true?

https://api.cvent.com/polling/v1/api/polls/sp-8cwtd0

Calcium

Important role in bone health in children

Adequate is necessary
Excess should be avoided

- KDOQI: Goal intake 100% DRI for age – max 200%
- Consider Calcium burden from diet, formulas, medications

NKF, Am J Kidney Dis. 2009; KDIGO CKD-MBD Update Work Group, Kidney Int 2017; Goodman, NEJM 2000

Calcium Intake

Age	DRI (mg/d)	Upper Limit for Calcium (Dietary + Phosphate Binders)
0-6 mo	210	≤420
7-12 mo	270	≤540
1-3 yr	500	≤1000
4-8 yr	800	≤1600
9-18 yr	1300	≤2500

NKF, Am J Kidney Dis. 2009

Calcium

Phosphorus Binder	Elemental Ca2+ (% of total)	Elemental Ca2+ (mg/dose)	Phosphorus Bound mg (mg per 100 mg Ca2+ delivered)
Calcium Acetate (667 mg)	25	167	45 (27 mg P/100 mg Ca2+)
Calcium Carbonate (1250 mg)	40	500	39 (8 mg P/100 mg Ca2+)

Vitamin D

High prevalence of Vit D insufficiency in children with CKD

Current KDOQI Guidelines:

- measure 25-hydroxy vitamin D annually
- if <30 ng/ml (75 mmol/L) supplement with D2 or D3
- in the repletion phase, check PO4 and Ca levels x 1 month
- when replete, supplement continuously and monitor yearly

NKF, Am J Kidney Dis. 2009

Vitamins

Requirements = 100% DRI

Increased risk of deficiency

- intake limited by anorexia,
- diet restrictions
- losses via dialysis
- interference with absorption, excretion, metabolism

NKF, Am J Kidney Dis. 2009;

Vitamins

Children with CKD stage 5D should receive a water-soluble vitamin supplement

Adult renal formulas provide 100% of requirements without supplement

Diet + Supplement < tolerable upper intake level (UL)

NKF, Am J Kidney Dis. 2009;

Vitamins

Vitamin A
- Elevated in 77 and 94% of CKD and Dialysis patients
- Vitamin A supplements contraindicated

Vitamin E
- Elevated in 87% children on dialysis
- Insufficient evidence to recommend supplementation

Vitamin K
- Depleted with Antibiotic use
- Monitor for signs of deficiency

NKF, Am J Kidney Dis. 2009; Fassinger, JRN 2010; Manichkavasagar, Ped Neph 2015; Joyce, Ped Neph 2018;

Minerals

Magnesium
- Elevated levels found in dialysis patients

Fluoride
- Supplementation contraindicated in pediatric dialysis patients

Copper
- High and low levels found
- No clear recommendations for supplementation

Ponton-Vazquez, JRN 2017; Zwolinska, Ped Neph 2006; Filler, Ped Neph 2013; Tonelli, BMC Med 2009; Esmaeili, JRN 2019; Mekahli, CJASN 2009;

Minerals

Zinc
- Commonly low in children on dialysis
- Varying response to supplementation

Selenium
- Commonly low in children on dialysis

Ponton-Vazquez, JRN 2017; Zwolinska, Ped Neph 2006; Filler, Ped Neph 2013; Tonelli, BMC Med 2009; Esmaeili, JRN 2019; Mekahli, CJASN 2009; Ortac, Ped Neph 2006;

Education and Counseling

Education with first intervention
Frequent Re-education
- Be positive – focus on allowances
- Incorporate personal preferences
- Provide pleasure with food

Role of cognitive function and developmental stage

Health Literacy – child and caregivers

NKF, Am J Kidney Dis. 2009; Lum, Child, Care Health Dev 2017; Ellyn Satter Institute; Beto, Int J Neph and Renovasc Dis, 2016; Morris, J Ren Care 2015; Chen, CJASN 2018;

Education and Counseling

Learning styles

Motivational Interviewing

Teach Back Method

Creative Strategies
- Technology, Game-based learning
- Incentive programs
- Multidisciplinary approach

NKF, Am J Kidney Dis. 2009; Lum, Child, Care Health Dev 2017; Beto, Int J Neph and Renovasc Dis, 2016; Morris, J Ren Care 2015; Chen, CJASN 2018; BMC Med Educ 2013; Dinh, JBI Database 2016

Education and Counseling

Don't get discouraged
Remember

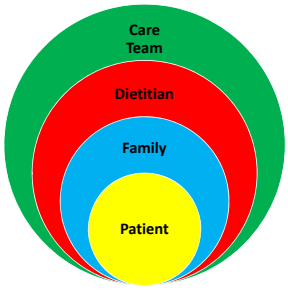
Knowledge

⇌

Improved Self Management

Youssef, Kid Dis Trans 2015; Abercrombie, JRN 2010

Nutrition Management of Children on Dialysis



Thank you