# Nutritional Management for Dogs and Cats with Chronic Kidney Disease

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**KEYWORDS**

• Dysrexia • Phosphorus • Protein • Body condition score • Proteinuria • Potassium • Vitamin D

**KEY POINTS**

- Dogs and cats with kidney disease commonly develop dysrexia and exhibit weight loss.
- Body composition measurements (ie, body weight, body condition score) can have diagnostic and prognostic implications for dogs and cats with kidney disease.
- The optimal nutritional management of kidney disease varies by disease type (eg, chronic kidney disease, protein-losing nephropathy).
- Assisted enteral nutrition can alleviate the stress that owners feel with hyporexic animals and can allow for the provision of optimal nutritional support.

## INTRODUCTION

Nutritional management is a crucial component of veterinary care provided to dogs and cats with kidney disease. It has the potential to slow progression of disease and also prolong survival. This article reviews the nutritional goals for dogs and cats with chronic kidney disease (CKD) and protein-losing nephropathy (PLN). Beyond the impressive body of evidence already in existence to support these recommendations, additional research will continue to refine and enhance the ways in which we provide optimal nutrition to our patients.

## CHRONIC KIDNEY DISEASE

### *Body Composition*

An animal's body composition (body weight [BW], body condition score [BCS], and muscle condition score)[1] may yield clues about the impending diagnosis of CKD, and it has also been shown to affect survival in dogs and cats with CKD. A loss of BW may precede a diagnosis of CKD in cats by up to 3 years, and weight loss often increases after diagnosis.[2] Cats with CKD and a BW of less than 4.2 kg at diagnosis

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had a shorter survival than cats with CKD that had a BW of 4.2 kg or more.[2] Thin dogs (BCS of <4/9) with CKD had a shorter survival than dogs with a BCS of 4 or more out of 9,[3] and overweight dogs (ie, BCS of >5/9) had longer survival than ideal and underweight dogs.[4]

Muscle loss seen in patients with CKD is likely multifactorial, related to (1) sarcopenia, an age-related loss of muscle; (2) cachexia, muscle loss affected by inflammatory cytokines; and/or (3) decreased protein and amino acid (AA) intake, whether owing to specific dietary manipulation and/or decreased caloric intake.[5,6] Protein-energy wasting, a cachectic state characterized by nutritional and metabolic derangements, is commonly identified in people with CKD, and it contributes to decreased quality of life and increased morbidity and mortality[7,8] (**Fig. 1**). Dogs with CKD that had normal muscle mass scores had longer survival than dogs with muscle loss.[4]

Research is ongoing in both human and veterinary medicine to better identify and understand cachexia in a variety of conditions. Several studies have validated the usefulness of ultrasound examination and computed tomography scans to measure muscle mass in dogs and cats, which may have greater clinical usefulness compared with other research methods.[9–12] If we can better define cachexia and its effects on morbidity and mortality, we may be able to identify methods by which to lessen cachexia or its deleterious effects.

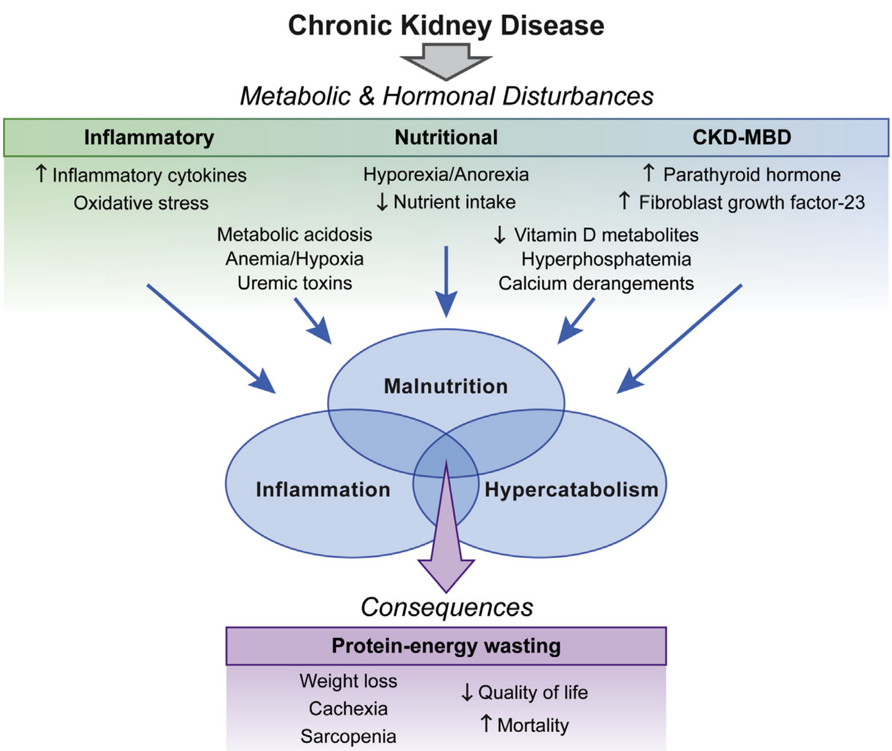


**Fig. 1.** Contributors and consequences of protein–energy wasting (PEW) syndrome associated with CKD. CKD-MBD, CKD–mineral and bone disorder. (Reproduced with permission of The Ohio State University.)

Maintaining adequate caloric intake is imperative to maintaining BW, BCS, and muscle condition scores. Some animals will maintain weight eating their resting energy requirement – $70 \times BW_{kg}^{0.75}$; however, others will require multiplication of a maintenance energy requirement factor.[13] If an animal is losing weight despite eating more than 2 times the resting energy requirement, it should be evaluated for other diseases that can contribute to increased energy needs (eg, hyperthyroidism), maldigestion (eg, exocrine pancreatic insufficiency), or malabsorption (eg, inflammatory bowel disease).

## Appetite Dysregulation

Animals with CKD are often hyporexic or anorexic, reported in up to 92% of cats.[2] It can be helpful to offer a variety of both dry and canned diet options to increase intake. Medications to ameliorate nausea may be useful (eg, maropitant, ondansetron); however, the bioavailability and efficacy of these drugs is variable across species.[14,15] Acid-reducing agents are not generally recommended because dogs and cats rarely develop uremic gastropathy.[16,17] The exception to this would be if there is evidence of gastrointestinal bleeding,[18] which is more common in advanced CKD.[19]

Appetite stimulants can be useful in dogs and cats with CKD. Capromorelin, a ghrelin receptor agonist, has been approved by the US Food and Drug Administration for both dogs and cats. It is labeled to increase appetite and body weight in dogs[20] and for management of weight loss in cats, respectively.[21] Mirtazapine can be effective in both oral and transdermal forms to aid in weight gain, decrease vomiting, and improve appetite in cats.[22,23] The transdermal form has been approved by the US FDA for weight gain. Anecdotally, many animals respond well to these medications. See **Table 1** for medications and dosages.

## Assisted Enteral Nutrition

When an animal will not eat enough to maintain BW, the placement of a feeding tube may be a viable option to provide enteral nutritional support and a good route for additional water and medications.[24] The feeding tube will likely be in place for the remainder of the animal's life; thus, placement of either esophagostomy or gastrostomy tubes is appropriate.[25,26] With proper maintenance, these tubes can be used for months to years.[24,26] Canned veterinary therapeutic renal diets can be blended with water (or a liquid enteral diet designed for kidney disease) to achieve appropriate consistency to be fed via tubes (**Box 1**).

## Nutritional Modification

### Phosphorus

There is strong evidence for dietary modification in dogs and cats with CKD. Feeding a veterinary therapeutic renal diet can prolong survival and decrease the risks of uremic crises in dogs and cats with naturally occurring CKD.[4,27–29] The primary nutrient of concern for CKD is dietary phosphorus. Decreasing dietary phosphorus intake slowed the progression of renal disease and prolonged survival in dogs with induced CKD.[30] Hyperphosphatemia is related to reduced survival in cats with CKD.[31–33] In 1 study, for every 1 mg/dL (0.32 mmol/L) increase in serum phosphorus, there was an 11.8% increased risk of death.[32] The plasma phosphate concentration is a potent stimulator of fibroblast growth factor-23 (FGF-23), a phosphatonin that affects the development of CKD mineral and bone disorder (CKD-MBD).[34,35] Feeding a reduced phosphorus diet decreased plasma phosphate and FGF-23 in cats with CKD.[36]

The 2019 International Renal Interest Society treatment guidelines suggest maintaining plasma (or serum) phosphate concentrations in dogs and cats with CKD between 2.7 and 4.6 mg/dL (0.87–1.49 mmol/L), although a target of less than 5.0 mg/dL

**Table 1**
**Medications and supplements commonly prescribed for dogs and cats with CKD and PLN**

| Medication or Supplement | Canine Dose | Feline Dose | Comments |
|---|---|---|---|
| Appetite stimulants | | | |
| Capromorelin | 3 mg/kg PO q24 h | 2 mg/kg PO q24 h | Hypersalivation may be observed with administration in dogs and cats. |
| Mirtazapine | 3.75–30 mg per dog q12–24 h<br>1 mg/kg PO q12–24 h | 1.88 mg per cat PO q48 h<br>~2 mg (1.5-inch strip TD q24–48 h | The half-life of mirtazapine is prolonged in cats with CKD and/or liver disease.<br>Cats that exhibit excitation may require dose reduction.<br>Prokinetic effect observed in healthy dogs dosed with 2.0 mg/kg PO once. |
| Antiemetics | | | |
| Maropitant | 1 mg/kg SC or IV q24 h<br>2 mg/kg PO q24 h | 1 mg/kg IV or PO q24 h | Refrigeration may reduce pain associated with SC injection. |
| Ondansetron | 0.2–0.5 mg/kg IV or SC q6-12h<br>0.5–1.0 mg/kg PO q6–8h | 0.2–0.5 mg/kg IV or SC q6–12h<br>0.5–1.0 mg/kg PO q6–8h | Oral bioavailability is low (<10%) in dogs.<br>Oral bioavailability is moderate (32%) in cats.<br>Half-lives are short in dogs and cats, with SC half-life longest in cats (3.2 $\pm$ 0.5 h).[15]<br>Oral ondansetron is rarely cost-effective in larger dogs.<br>Give 30 min before meals. |
| Antihypertensive and antiproteinuric medications | | | |

| | | | |
|---|---|---|---|
| Telmisartan (antihypertensive and antiproteinuric) | 0.5–1.0 mg/kg PO q24 h, up to 3.0 mg/kg/d | 0.5–1.0 mg/kg PO q24 h, up to 3.0 mg/kg/d | Labeled for cats to initially start with a higher dose (1.5 mg/kg PO q12 h × 14 d), then taper to minimum dose of 0.5 mg/kg PO q24 h.<br>Monitor for azotemia, hyperkalemia, and hypotension. |
| Amlodipine (antihypertensive) | 0.1–0.5 mg/kg PO q12–24h, up to 1.0 mg/kg PO q12 h | 0.625–1.25 mg per cat PO q12–24 h | |
| Enalapril (antihypertensive and antiproteinuric) | 0.5–1.0 mg/kg PO q12–24 h | 0.25–0.5 mg/kg PO q12–24 h | Monitor for azotemia, hyperkalemia, and hypotension. |
| Benazepril (antihypertensive and antiproteinuric) | 0.5 mg/kg PO q12–24 h, up to 2.0 mg/kg PO/d | 0.5–1.0 mg/kg mg/kg PO q12–24 h, up to 2.0 mg/kg/d | |
| Acid-reducing medications | | | |
| Famotidine | 1 mg/kg PO q12 h<br>1 mg/kg IV loading dose, then 8 mg/kg/d IV CRI (up to 3 d) | 1 mg/kg PO q12 h | Famotidine has poor potency relative to proton pump inhibitors. |
| Omeprazole | 1 mg/kg PO q12 h | 1 mg/kg PO q12 h | Only indicated if overt evidence of GI bleeding.<br>Prolonged administration of acid suppressants have been associated with calcium and parathyroid hormone derangements in humans. |
| Phosphate binders | | | |
| Aluminum hydroxide | 30–100 mg/kg/d PO | 30–100 mg/kg/d PO | Must be given with food. |
| Lanthanum carbonate | 10-40 mg/kg/d PO | 30 mg/kg/d PO, up to 95 mg/kg/d PO | Divide daily dose into multiple meals. Titrate to effect. |
| Sevelamer | 30–50 mg/kg PO q8 h | 30–50 mg/kg PO q8 h<br>40–80 mg/kg PO q12 h | Monitor for ionized hypercalcemia with use of calcium salts. |
| Calcium carbonate<br>Calcium acetate | 60–90 mg/kg/d PO 90–150 mg/kg/d PO | 60–90 mg/kg/d PO<br>90–150 mg/kg/d PO | |
| Epakitin (8% chitosan, 10% calcium carbonate) | 1 g per 5 kg BW PO q12 h | 1 g per 5 kg BW PO q12 h | |
| Erythropoietic medication | | | |

(*continued on next page*)

**Table 1**
**(*continued*)**

| Medication or Supplement | Canine Dose | Feline Dose | Comments |
|---|---|---|---|
| Darbepoetin | 0.25–1.0 μg/kg SC per week until target PCV attained | 0.25–1.0 μg/kg SC per week until target PCV attained | Monitor packed cell volume, blood pressure.<br>Once target PCR met, increase dose interval to once every 2–3 wk OR decrease dose to maintain PCV.<br>Give iron dextran: 50 mg per cat OR 10 mg/kg (dog) IM once to ensure adequate iron stores. |
| Antithrombotic medication | | | |
| Clopidogrel | 1–5 mg/kg PO q24 h | 18.75 mg per cat PO q24 h | Recommended to reduce hypercoagulability associated with proteinuria. |
| Vitamins and minerals | | | |
| Potassium gluconate, potassium citrate | 2 mEq per 4.5 kg q12 h | 1–4 mEq per cat q12 h | Titrate based on individual animal's response. |
| Calcitriol | 2–2.5 ng/kg PO q24 h, up to 5 ng/kg/d | 1.5–3.5 ng/kg PO q24 h | Monitor for ionized hypercalcemia.<br>Use cautiously in animals with hyperphosphatemia. |
| Calcifediol | | | Not currently labeled for use in dogs or cats. |

| | | | |
|---|---|---|---|
| | | | Providing ~2 μg/kg PO 3 times weekly increased 25(OH) and 1,25$(OH)_2$D concentrations in dogs with CKD. |
| Vitamins C and E | | | Supplementation with antioxidants may reduce renal oxidative stress.<br>Use caution with vitamin C in animals prone to calcium oxalate urolithiasis production.<br>Dogs with CKD had higher concentrations of plasma vitamin C and several B vitamins, and no difference in plasma vitamin E compared with healthy dogs. |
| Additional supplements | | | |
| Fish oil (EPA and DHA) | 140 mg/kg $BW^{0.75}$<br>66 mg/kg/d | 200–300 mg EPA/DHA per cat per day | Liquid (eg, pump) and twist-off capsule options are useful for cats who cannot ingest larger capsules.<br>Double or triple strength capsules are useful for large dogs to reduce the number of capsules, and subsequent calories, provided. |
| Azodyl (symbiotic) | 1–3 capsules per day | 1–2 capsules per day | Capsules should be given whole.<br>Limited evidence for use in azotemic animals. |

*Abbreviations:* GI, gastrointestinal; IV, intravenously; PO, by mouth; SC, subcutaneously.

**Box 1**
**Equation to determine caloric density of blended canned diet**

$$\frac{(\text{kcal per can} + \text{kcal liquid added})}{\text{mL of can} + \text{mL added liquid}} = \frac{\text{kcal}}{\text{mL}}$$

Example: Blend (1) 5.5 oz (156 g) can of Hill's Prescription Diet k/d with Chicken (177 kcal per can). Because 1 g is approximately equal to 1 mL, assume that 1 can = 156 mL. Through some trial and error, by adding small increments of water at a time, if you determine that it takes 25 mL water to achieve a smooth consistency to be fed via a 14-F esophagostomy feeding tube, that means the following:

$$\frac{177\text{ kcal }(1\text{ can k/d}) + 0\text{ kcal (water)}}{156\text{ mL }(1\text{ can k/d}) + 25\text{ mL (water)}} = \frac{177\text{ kcal}}{181\text{ mL}} = 0.98\text{ kcal per mL}$$

* If a higher caloric density were required, a liquid enteral diet appropriate for feline CKD could be substituted for water. For example, if Royal Canin Veterinary Diet Feline Renal Support Liquid (0.9 kcal/mL) were used to blend the canned Hill's Prescription Diet k/d diet, it would add an additional 22.5 kcal, increasing the resultant kcal/mL to 1.10 kcal/mL. However, when only a small volume of water is required to prepare a canned diet for provision via a feeding tube, this difference is fairly insignificant, and the cost-to-benefit ratio is low.

* Commercial formulas, caloric density, and consistency of diets may change. Thus, the caloric density of a diet should always be confirmed, and the amount of liquid needed to blend with the diet may vary over time to ensure the consistency of the slurry remains appropriate.

(1.62 mmol/L) for patients with stage 3 CKD and less than 6.0 mg/dL (1.94 mmol/L) for patients with stage 4 CKD was deemed more realistic.[37] Controlling the circulating phosphate concentrations is first addressed by decreasing the dietary phosphorus intake, then adding oral phosphate binders with food, if needed.[38] Currently available canine and feline veterinary therapeutic renal diets are shown in **Tables 2** and **3**.

Evidence suggests that not only the amount of phosphorus, but also the form of dietary phosphorus, as well as the dietary calcium:phosphorus ratio, may influence renal health.[39–42] Phosphorus from organic sources (eg, meat, bone meal, grains) is less bioavailable than phosphorus from certain inorganic sources (eg, sodium or potassium phosphate salts). Feeding these highly available phosphate salts, especially in a diet with too little calcium, resulted in renal damage in previously healthy cats.[39,41,42] Some of this damage is alleviated by maintaining a dietary calcium:phosphorus intake of 1.0 or more.[42]

### *Protein*

It is controversial if and/or when protein should be restricted in animals, especially cats, with CKD.[43–45] In people with CKD, providing adequate protein, including essential AAs, can decrease the risk of the development of protein-energy wasting and loss of lean body mass (LBM).[7,46,47] In dogs and cats, dietary protein intake has been shown to influence LBM.[48,49] In dogs with CKD, feeding a diet with protein concentration of more than 51 g/Mcal (>5.1 g/100 kcal) better allowed dogs to maintain body condition.[50] Feeding higher protein diets may then be preferable, because it has been shown that dogs with CKD and a BCS of 4 or more out of 9 had longer survival than dogs with a thin BCS.[3,4]

Protein requirements have conventionally been determined based on the maintenance of nitrogen balance.[51,52] This factor differs from using maintenance of LBM as a marker of protein adequacy. To maintain nitrogen balance in 20 healthy cats,

**Table 2**
**Comparison of selected nutrients of concern (per 100 kcal) for currently available veterinary therapeutic renal diets for dogs**

| Canine Renal Diets | Calories (kcal) | Phosphorus (mg) | Protein (g) | Potassium (mg) | Sodium (mg) | Vit D (IU) | Calcium (mg) | EPA & DHA (mg) |
|---|---|---|---|---|---|---|---|---|
| Royal Canin Canine Renal Support + Hydrolyzed Protein (dry) | 385/cup | 50 | 3.4 | 150 | 90 | 19.5 | 70 | 120 |
| Royal Canin Canine Renal Support A (dry) | 352/cup | 50 | 3.5 | 150 | 90 | 25.0 | 100 | 120 |
| Hill's Prescription Diet k/d Canine Chicken & Vegetable Stew (5.5 or 12.5 oz can) | 158 or 358/can | 61 | 3.6 | 226 | 35 | 16.3 | 170 | 156 |
| Hill's Prescription Diet k/d Canine (13 oz can) | 422/can | 62 | 3.6 | 201 | 45 | 18.9 | 180 | 129 |
| Hill's Prescription Diet k/d Canine with Lamb (13 oz can) | 421/can | 64 | 3.6 | 204 | 45 | 19.2 | 184 | 132 |
| Hill's Prescription Diet k/d + Mobility Canine (dry) | 496/cup | 65 | 3.5 | 155 | 43 | 33.5 | 140 | 157 |
| Hill's Prescription Diet k/d Canine Beef & Vegetable Stew (5.5 or 12.5 oz can) | 145 or 330/can | 65 | 3.8 | 235 | 38 | 19.0 | 188 | 136 |
| Royal Canin Canine Renal Support S (dry) | 365/cup | 70 | 3.1 | 150 | 90 | 24.8 | 140 | 120 |
| Royal Canin Canine Renal Support E (13.5 oz can) | 598/can | 70 | 3.5 | 160 | 80 | 20.1 | 110 | 100 |
| Hill's Prescription Diet k/d + Mobility Canine Chicken & Vegetable Stew (12.5 oz can) | 352/can | 72 | 3.6 | 217 | 40 | 37.5 | 171 | 417 |
| Hill's Prescription Diet k/d Canine (dry) | 402/cup | 73 | 3.5 | 186 | 40 | 30.4 | 188 | 117 |
| Hill's Prescription Diet k/d Canine with Lamb (dry) | 459/cup | 74 | 3.6 | 154 | 38 | 30.5 | 165 | 120 |
| Royal Canin Canine Renal Support F (dry) | 356/cup | 80 | 3.4 | 150 | 90 | 25.3 | 150 | 110 |
| Purina Pro Plan Veterinary Diets NF Kidney Function Canine Formula (dry) | 478/cup | 80 | 3.4 | 170 | 60 | 31.8 | 150 | 120 |

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**Table 2**
**(*continued*)**

| Canine Renal Diets | Calories (kcal) | Phosphorus (mg) | Protein (g) | Potassium (mg) | Sodium (mg) | Vit D (IU) | Calcium (mg) | EPA & DHA (mg) |
|---|---|---|---|---|---|---|---|---|
| Royal Canin Canine Renal Support + Advanced Mobility Support (dry) | 332/cup | 80 | 3.5 | 150 | 100 | 25.3 | 150 | 150 |
| Royal Canin Canine Renal Support T (13.5 oz can) | 595/can | 80 | 3.8 | 160 | 90 | 22.0 | 160 | 110 |
| Purina Pro Plan Veterinary Diets NF Kidney Function Canine Formula (13.3 oz can) | 483/can | 80 | 4.1 | 230 | 40 | 36.1 | 160 | 120 |
| Royal Canin Canine Renal Support Liquid (237 mL bottle) | 1.3/mL | 90 | 3.7 | 160 | 100 | 16.0 | 140 | 110 |
| BLUE Natural Veterinary Diet KS Kidney Support (dry) | 404/cup | 90 | 4.0 | 220 | 50 | 39.5 | 110 | 190 |
| Royal Canin Canine Renal Support + Advanced Mobility Support (13 oz can) | 374/can | 100 | 4.0 | 170 | 100 | 19.6 | 160 | 100 |
| BLUE Natural Veterinary Diet KS Kidney Support (12.5 oz can) | 354/can | 100 | 4.7 | 480 | 50 | 17.4 | 230 | 120 |
| Royal Canin Canine Renal Support D (13.5 oz can) | 344/can | 110 | 4.0 | 170 | 100 | 19.1 | 160 | 100 |
| Royal Canin Renal Support Early Consult (5.2 oz can) | 156/can | 120 | 6.0 | 170 | 90 | 19.4 | 160 | 110 |
| Royal Canin Renal Support Early Consult (dry) | 316/cup | 130 | 5.7 | 150 | 90 | 25.1 | 200 | 130 |
| 2020 AAFCO Canine adult maintenance minimum | | 100 | 4.5 | 150 | 20 | 12.5 | 125 | – |
| 2020 AAFCO Canine adult maintenance maximum | | 400 | – | – | – | 75.0 | 625 | – |

Diets are listed by ascending phosphorus concentrations. Association of American Feed Control Officials (AAFCO) minimum and maximum (when applicable) nutrient requirements for canine adult maintenance are provided for reference.

*Note that nutrient profiles can change approximately every 6 to 12 mo.

**Table 3**
**Comparison of selected nutrients of concern (per 100 kcal) for currently available veterinary therapeutic renal diets for cats**

| Feline Renal Diets | Calories (kcal) | Phosphorus (mg) | Protein (g) | Potassium (mg) | Sodium (mg) | Vit D (IU) | Calcium (mg) | EPA & DHA (mg) |
|---|---|---|---|---|---|---|---|---|
| Royal Canin Feline Renal Support D (3 oz can) | 98/can | 80 | 6.8 | 190 | 80 | 17.8 | 130 | 140 |
| Royal Canin Feline Renal Support Liquid (237 mL bottle) | 0.9/mL | 80 | 7.5 | 180 | 90 | 31.2 | 130 | 150 |
| Purina Pro Plan Veterinary Diets NF Early Care (dry) | 494/cup | 90 | 9.0 | 350 | 70 | 86.0 | 150 | 120 |
| Purina Pro Plan Veterinary Diets NF Advanced Care (dry) | 536/cup | 90 | 6.9 | 350 | 70 | 79.0 | 150 | 120 |
| Purina Pro Plan Veterinary Diets NF Advanced Care (5.5 oz can) | 165/can | 90 | 6.7 | 370 | 80 | 24.8 | 160 | 110 |
| Royal Canin Feline Renal Support E (5.1 oz can) | 151/can | 90 | 7.0 | 180 | 90 | 23.2 | 150 | 130 |
| Royal Canin Feline Renal Support S (dry) | 397/cup | 100 | 5.9 | 210 | 100 | 16.7 | 170 | 100 |
| Royal Canin Feline Renal Support + Hydrolyzed Protein (dry) | 402/cup | 100 | 6.3 | 220 | 90 | 19.4 | 160 | 100 |
| Royal Canin Feline Renal Support T (3 oz can) | 82/can | 100 | 6.6 | 190 | 100 | 26.0 | 160 | 140 |
| Hill's Prescription Diet k/d Feline with Tuna (5.5 oz can) | 170/can | 104 | 6.6 | 247 | 56 | 26.3 | 174 | 140 |
| Hill's Prescription Diet k/d + Mobility Chicken & Vegetable Stew (2.9 oz can) | 68/can | 108 | 6.6 | 234 | 54 | 43.4 | 198 | 180 |
| BLUE Natural Veterinary Diet KM Kidney + Mobility Support (5.5 oz can) | 156/can | 110 | 6.1 | 560 | 50 | 55.0 | 160 | 150 |

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**Table 3**
**(*continued*)**

| Feline Renal Diets | Calories (kcal) | Phosphorus (mg) | Protein (g) | Potassium (mg) | Sodium (mg) | Vit D (IU) | Calcium (mg) | EPA & DHA (mg) |
|---|---|---|---|---|---|---|---|---|
| Purina Pro Plan Veterinary Diets NF Early Care (5.5 oz can) | 162/can | 110 | 9.7 | 380 | 100 | 22.3 | 150 | 120 |
| Royal Canin Feline Renal Support A (dry) | 347/cup | 110 | 5.8 | 230 | 90 | 20.3 | 210 | 100 |
| Royal Canin Feline Renal Support F (dry) | 376/cup | 110 | 6.5 | 230 | 100 | 22.5 | 160 | 100 |
| Hill's Prescription Diet k/d Feline Chicken & Vegetable Stew (2.9 oz can) | 70/can | 111 | 6.8 | 239 | 53 | 44.2 | 176 | 133 |
| Hill's Prescription Diet k/d + Mobility Feline (dry) | 483/cup | 115 | 6.6 | 188 | 63 | 17.5 | 160 | 191 |
| Hill's Prescription Diet k/d Vegetable & Tuna Stew (2.9 oz can) | 77/can | 115 | 7.1 | 247 | 57 | 36.8 | 193 | 145 |
| Hill's Prescription Diet k/d Feline (dry) | 541/cup | 116 | 6.8 | 169 | 58 | 28.8 | 163 | 115 |
| Hill's Prescription Diet k/d Feline with Ocean Fish (dry) | 444/cup | 118 | 6.7 | 168 | 59 | 43.3 | 167 | 131 |
| Hill's Prescription Diet k/d Feline with Chicken (5.5 oz can) | 177/can | 120 | 7.6 | 279 | 61 | 28.3 | 215 | 155 |
| Royal Canin Feline Renal Support Early Consult (3 oz can) | 82/can | 120 | 8.4 | 180 | 90 | 17.8 | 160 | 170 |
| Hill's Prescription Diet k/d Early Support Feline Chicken (dry) | 536/cup | 127 | 7.7 | 170 | 57 | 23.7 | 170 | 112 |
| BLUE Natural Veterinary Diet KM Kidney + Mobility Support (dry) | 425/cup | 130 | 6.9 | 220 | 70 | 43.4 | 140 | 220 |
| Royal Canin Feline Renal Support Early consult (dry) | 299/cup | 130 | 7.3 | 210 | 100 | 20.9 | 180 | 200 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Hill's Prescription Diet k/d Early Support Feline Chicken, Vegetable & Rice Stew (2.9 oz can) | 79/can | 133 | 7.6 | 210 | 61 | 31.5 | 198 | 174 |
| 2020 AAFCO Feline adult maintenance minimum | | 125 | 6.5 | 150 | 50 | 7.0 | 150 | – |
| 2020 AAFCO Feline adult maintenance maximum | | – | – | – | – | 752 | – | – |

Diets are listed by ascending phosphorus concentrations. Association of American Feed Control Officials (AAFCO) minimum and maximum (when applicable) nutrient requirements for feline adult maintenance are provided for reference.

*Note that nutrient profiles can change approximately every 6 to 12 mo.

1.5 g protein per kilogram BW (2.1 g/kg BW)$^{0.75}$ was needed. However, to maintain LBM, 5.2 g protein per kilogram BW (7.8 g/kg BW)$^{0.75}$ was required.[49] Another consideration is that dietary AA profiles can differ between diets even if crude protein is similar.[48,53] Diets enhanced with essential AAs may be able to better maintain LBM.[53,54]

There are diets available that provide lower phosphorus concentrations (ie, <1.00–1.35 g/Mcal; <100–135 mg/100 kcal) and higher protein concentrations, which may be preferable in some instances (eg, to better allow the maintenance of LBM, for young dog with renal dysplasia). For both dogs and cats, there may be additional diets that are not specifically marketed for kidney disease that meet these nutritional goals (**Table 4**).

One exception to feeding a higher protein diet is when proteinuria is present. Proteinuria can be diagnosed in dogs and cats with kidney disease as a primary disease process, most commonly glomerular disease or as a sequela of tubulointerstitial kidney disease. Typically the term PLN is reserved for cases of glomerular disease, and most clinicians consider a urine protein:creatinine ratio of 2.0 or more to be significant. Recommendations for when to initiate therapy for dogs and cats with proteinuria may vary depending on the presence of azotemia, but the importance of addressing proteinuria should be apparent, because it has been associated with decreased survival in dogs and cats with kidney disease.[31,33,55–59] Although most of the veterinary literature on PLN relates to dogs, cats may also be diagnosed with significant proteinuria.[60] The management of proteinuria relies on both medical and dietary interventions, including decreasing protein intake.[61]

The goal of nutritional modification with PLN is to decrease dietary protein enough to decrease proteinuria, but not so much as to contribute to LBM loss. The proposed mechanism for the benefit of protein restriction is a decreased glomerular filtration rate and subsequent decrease in structural damage to the remaining glomeruli.[62] Given the tremendous variability in protein concentration among commercially available diets, the recommended degree of protein reduction is highly dependent on the individual animal's diet. It is extremely important to obtain a complete and thorough diet history, including information about treats, dietary supplements, and foods used for medication administration. If the animal's diet is very high in protein when PLN is diagnosed, it may be unnecessary to transition that animal to a veterinary renal diet. If the animal is receiving a large percentage of calories from high-protein treats (eg, chicken breast, rawhides, dental chews), modification of the treats alone may sufficiently decrease the animal's protein intake.[63]

This author recommends initially decreasing the total dietary protein by 25% to 50%, depending on the severity of proteinuria, azotemia, and clinical signs. Dietary protein restriction typically results in a decrease in proteinuria within 1 month. If the animal's diet already is low to moderate in protein concentration (near the AAFCO minimum recommendation for adult maintenance), it may be preferable to allow medical management time to decrease proteinuria before further restricting dietary protein.

A possible approach to optimize dietary restriction of protein without contributing to LBM loss is to strategically supplement AAs. In people with PLN, feeding low-protein diets with concurrent supplementation of keto acids or essential AAs is advantageous because it can improve protein status while minimizing nitrogen load.[64–67] This concept is related to the ability of keto acids to stimulate protein synthesis while inhibiting protein breakdown. This dietary regimen can improve hypoalbuminemia and decrease proteinuria.[64]

Dogs with PLN have decreased concentrations of several AAs as compared with healthy controls.[68] Oral essential AA supplementation for 4 to 8 weeks in dogs with

**Table 4**
**Nonrenal diets that may be appropriate for dogs and cats with CKD**

| | Calories (kcal) | Phosphorus (mg) | Protein (g) | Sodium (mg) | Potassium (mg) | Vitamin D (IU) | Calcium (mg) | EPA and DHA (mg) |
|---|---|---|---|---|---|---|---|---|
| **Canine Diets** | | | | | | | | |
| Hill's Prescription Diet t/d Canine (dry) | 248/cup | 107 | 4.5 | 58 | 173 | 15.2 | 157 | 1 |
| Hill's Prescription Diet g/d Canine (can) | 388/can | 109 | 4.9 | 56 | 188 | 53.9 | 200 | 3 |
| Hill's Prescription Diet g/d Canine (dry) | 361/cup | 110 | 4.6 | 50 | 179 | 25.2 | 149 | 6 |
| Royal Canin Canine Hepatic (14.4 oz can) | 527/can | 110 | 4.6 | 60 | 200 | 12.7 | 170 | 80 |
| Hill's Prescription Diet j/d Canine (dry) | 353/cup | 117 | 4.6 | 47 | 190 | 14 | 151 | 200 |
| **Feline diets** | | | | | | | | |
| Royal Canin Feline Health Nutrition Aging 12+ thin slices in gravy (3 oz) | 71/can | 115 | 11.0 | 94 | 178 | 23.0 | 146 | 167 |
| Royal Canin Feline Health Nutrition Aging 12+ loaf in sauce (5.8 oz) | 139/can | 116 | 10.5 | 105 | 2.00 | 22.1 | 158 | 158 |
| Hill's Science Diet Adult Tender Tuna Dinner Cat Food (5.5 oz can) | 162/can | 127 | 10.1 | 117 | 172 | 79.6 | 194 | 187 |
| Hill's Science Diet Adult 7+ Tender Tuna Dinner Cat Food (5.5 oz) | 152/can | 129 | 9.9 | 112 | 174 | 78.4 | 203 | 50 |
| Hill's Science Diet Adult 11+ Healthy Cuisine Seared Tuna and Carrot Medley Cat Food (2.8 oz) | 66/can | 135 | 8.9 | 90 | 213 | 45.3 | 187 | 152 |

Diets are listed by ascending phosphorus concentrations. Nutrients are listed on a per 100 kcal basis. This is not an all-inclusive list.
*Note that nutrient profiles can change approximately every 6 to 12 mo.

renal proteinuria resulted in increased serum albumin concentrations and BW with no effect on the urine protein:creatinine ratio.[69] It remains unclear whether the lack of decrease in the urine protein:creatinine ratio is clinically as important as the increase in albumin and BW.

### Potassium

Serum potassium concentrations may be abnormal owing to underlying kidney disease, dietary intake, acid–base abnormalities, gastrointestinal complications, or medications. It is reported that 20% to 30% of cats with CKD will develop hypokalemia.[70,71] Hypokalemia may result in muscle weakness, polyuria, polydipsia, and constipation.[72] There is a wide range of potassium currently available in veterinary renal diets (see **Tables 1** and **2**). Thus, if hypokalemia is present, it may be helpful to offer a higher potassium-containing diet or oral potassium supplementation with either potassium gluconate or potassium citrate.[73,74]

Dogs with CKD can develop either hypokalemia or hyperkalemia.[74,75] Medications that influence the renin–angiotensin–aldosterone system (eg, angiotensin-converting enzyme inhibitors, angiotensin receptor antagonists) may contribute to hyperkalemia and the doses may need to be adjusted.[61] Additionally, the dietary intake of potassium may exceed renal excretory capability. In these cases, choosing a lower potassium-containing diet may alleviate the hyperkalemia. If feeding a commercial diet is ineffective, then a decreased potassium home-prepared diet may be considered.[75] It is also important to ensure that pseduohyperkalemia (eg, from thrombocytosis) is not falsely affecting therapeutic recommendations.[76]

### Sodium

The role of dietary sodium restriction for dogs and cats with CKD is controversial. Studies in people and experimental canine models suggest that high sodium intake contributes to hypertension, nephrotoxicity, and progression of proteinuria.[77,78] In 1 study that included 6 cats with renal insufficiency, feeding a high sodium diet (2.9 g/Mcal; 290 mg/100 kcal), increased the serum concentrations of creatinine, urea nitrogen, and phosphorus. There was no effect noted on blood pressure.[79] Given these findings, it has generally been recommended to avoid high sodium intake in dogs and cats with CKD. Conversely, in other larger long-term studies, there have been no adverse effects on renal function noted in cats fed high sodium diets (2.9–3.1 g/Mcal; 290–310 mg/100 kcal).[80,81]

In contrast, there are several studies in rats, dogs, and cats that demonstrate adverse effects from excessive restriction of sodium, including activation of the renin–angiotensin–aldosterone system and subsequent kaliuresis.[82–84] Some evidence in people suggests that the dietary sodium to potassium ratio plays a larger role in determination of hypertension or relative risk of CKD than either nutrient alone.[85,86] An inverse relationship between hypokalemia and systemic hypertension has been documented in cats,[87] and consideration is given to the prevalence of a relative or absolute hyperaldosteronism contributing to both.[88]

One of the biggest issues with regards to recommendations for dietary sodium intake is the lack of standardization for what is considered a high, moderate, or low sodium intake. Diets that are typically promoted as reduced in sodium for dogs and cats can provide up to 2 to 5 times the AAFCO minimums for cats and dogs, respectively. This author does not currently specifically aim to feed a reduced sodium diet to animals with CKD; however, this is often a moot point because all veterinary therapeutic renal diets exceed AAFCO minimums (see **Tables 2** and **3**).

### *Metabolic acidosis*

Metabolic acidosis is a common complication observed with CKD.[70,89] In people, metabolic acidosis decreases the glomerular filtration rate, induces muscle wasting, and decreases muscle protein synthesis.[90] In cats, overt metabolic acidosis may not be recognized until late-stage disease, and there are minimal data to specifically suggest that metabolic acidosis precedes worsening renal function.[91] It is likely, however, that the blood pH is remaining normal in many animals with CKD at the expense of bone health because increased dietary acid loads cause bone to resorb calcium.[92] In dogs and cats with CKD, bone quality is affected, likely owing to a complex relationship between metabolic acidosis and other hormonal derangements observed with CKD-MBD (eg, hyperparathyroidism, increased FGF-23).[93,94] Veterinary therapeutic renal diets are typically fortified with alkalinizing agents (eg, potassium citrate). For animals that develop metabolic acidosis, treatment with additional potassium citrate or sodium bicarbonate may be considered.[89]

### *Vitamin D*

Derangements in vitamin D metabolism are commonly identified in dogs and cats with CKD. Dogs with both CKD and nonazotemic PLN tend to have lower serum 25-hydroxyvitamin D (25[OH]D) and 1,25-dihydroxyvitamin D (1,25[OH]$_2$D; calcitriol) concentrations than healthy dogs.[95,96] These metabolites decrease with increasing International Renal Interest Society stage.[95] Cats with CKD have lower calcitriol concentrations than healthy cats, and cats with end-stage CKD show significantly lower concentrations than cats with compensated disease.[97] Derangements in vitamin D metabolism likely influence the development of CKD-MBD (**Fig. 2**).[35]

For several decades, calcitriol treatment has been recommended to reduce parathyroid hormone concentrations and improve quality of life in dogs and cats with CKD.[98,99] However, the cost, monitoring, and potential for toxicity (eg, hypercalcemia) are sometimes limiting factors for pet owners. Additional research is needed to determine the manner in which supplementation with various forms of vitamin D influences vitamin D repletion, parathyroid hormone, and FGF-23 concentrations, quality of life, preservation of renal function, and survival.

There does not seem to be a clear relationship between dietary vitamin D$_3$ (ie, cholecalciferol) intake and subsequent serum 25(OH)D concentrations in dogs[100,101]; thus, simply increasing cholecalciferol intake is not likely by itself to improve vitamin D status based on 25(OH)D concentration. However, in 1 study that investigated the usefulness of cholecalciferol supplementation for treatment of canine atopy, very high doses (range, 300–2700 IU/kg) did increase serum 25(OH)D concentrations by 250% (a mean increase of 80 μg/mL).[102] It is important to note that these doses exceed the AAFCO maximum recommendations for vitamin D intake.

Providing an extended-release formulation of 25(OH)D (calcifediol) to dogs with CKD rapidly increased serum 25(OH)D concentrations.[103] Additional studies are underway to elucidate appropriate dosing recommendations and to determine effects on the complex pathophysiology of CKD-MBD. It has yet to be determined if increased 25(OH)D concentrations will translate to improved survival or quality of life for dogs with CKD.

### *Calcium*

Dogs and cats with CKD may develop derangements in calcium homeostasis.[95,97,104,105] There is a risk of soft tissue mineralization when the calcium × phosphorus product exceeds 60 to 70 mg$^2$/dL.[106] An increased calcium × phosphorus product has been associated with decreased survival in dogs with CKD.[59,106] Ionized hypercalcemia is often present in cats with CKD.[105] Some cats may have concurrent

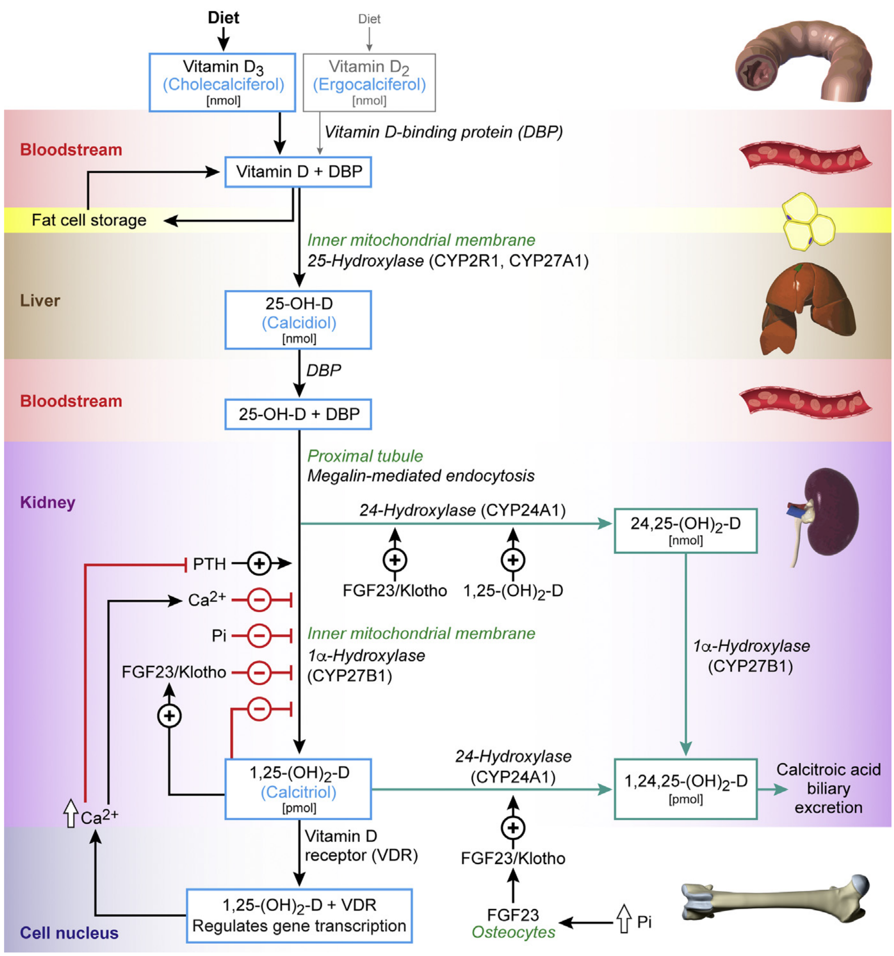


**Fig. 2.** Comprehensive overview of vitamin D metabolism, starting with dietary intake and progressing through hepatic and renal transformation. Also notice the influences of phosphate (Pi), ionized calcium ($Ca^{2+}$), FGF-23, Klotho, and parathyroid hormone (PTH). CYP, cytochrome P450. (Reproduced with permission of The Ohio State University.)

CKD and idiopathic hypercalcemia; however, there may be additional pathophysiologic mechanisms by which cats with CKD develop ionized hypercalcemia. Feeding a reduced phosphorus diet may contribute to the development of ionized hypercalcemia, and hypercalcemia may subsequently be managed by feeding a higher phosphorus diet and by manipulating the dietary calcium to phosphorus ratio.[107] Several other nutritional strategies have been suggested for addressing ionized hypercalcemia in cats (eg, increasing fiber, decreasing dietary calcium intake, and limiting the intake of vitamins A and D).[108] However, additional research is needed to understand the pathophysiology and treatment of hypercalcemia in CKD.

### *Omega-3 fatty acids and supplement use*

Many pet owners have the desire to provide additional dietary supplements and nutraceuticals to their pets with CKD. In 1 study, 38% of pet owners administered vitamins, minerals, or other supplements to their cats with CKD.[109] There are a plethora of supplements marketed for patients with kidney disease. Careful selection of type, dose, and brand is important to avoid toxicities or lack of efficacy.[110] This process entails a consideration of the specific brand (eg, reputable, tested by an independent company), potential benefits (research driven vs hypothetical), risks (known or hypothetical), and interaction with other medications and supplements. Some supplements provide unwanted calories and added nutrients that may be nominal or, alternatively, toxic. Additionally, for an animal that is already wary of taking its necessary medication(s), forcing it to take unnecessary (or even potentially harmful) supplements may add undue stress.

This author routinely recommends omega-3 fatty acid supplementation with eicosopentaenoic acid (EPA) and docosahexaenoic acid (DHA) for their anti-inflammatory properties. In experimental models, EPA/DHA supplementation reduced proteinuria; however, this finding has not been demonstrated clearly in naturally occurring disease. Although an optimal dose of EPA/DHA for animals with kidney disease has not been determined, general dose recommendations for dogs include 50 to 75 mg/kg or up to 140 mg EPA and DHA/kg $(BW)^{0.75}$.[111,112] Many veterinary therapeutic renal diets have added EPA/DHA, and the amounts provided should be determined based on the pet's caloric intake (ie, mg EPA/DHA per 100 kcal ingested daily). It can then be decided whether or not to add to the total dose.

### *Other diet options*

If the animal will not eat, or if the owner is unwilling to feed, any available veterinary therapeutic renal diet options, there may be some other diets (either veterinary therapeutic diets marketed for other diseases or over-the-counter commercial diets) that still provide acceptable nutrient profiles. The author typically considers phosphorus as the primary nutrient of concern for CKD, and subsequently aims to provide less than 1.5 g phosphorus/Mcal (150 mg/100 kcal) to dogs and cats with CKD (see **Table 4**). Not all senior diets are appropriate options for animals with CKD, and careful attention must be paid to specific nutrient profiles.

### *Comorbid patients and home-cooked diets*

Choosing an appropriate diet for dogs and cats with comorbid conditions can be challenging, because each patient's needs are unique. Nutritional management goals must be identified and prioritized to achieve the results most favorable to the patient's overall health and quality of life. For example, in the case of a dog with relatively mild CKD and chronic, recurrent pancreatitis, there may be preference to prioritize feeding a low fat diet that is moderate in phosphorus (eg, <2.0 g/Mcal; 200 mg/100 kcal). In a cat with concurrent CKD and inflammatory bowel disease, feeding a low to moderate phosphorus limited antigen diet would be recommended. Even when appropriate commercial diet options are available, pet owners may elect to feed home-prepared diets to their pets.

Studies have shown that most recipes that pet owners will find online or in books, including those designed for pets with CKD, do not provide complete and balanced nutrition.[113–115] Thus, for owners who prefer to feed a home-prepared diet, or if a suitable diet cannot be identified, a board certified veterinary nutritionist should be consulted (http://acvn.org). It is imperative that owners follow instructions closely to avoid contributing to nutritional deficiencies or toxicities. Many pet owners have trouble following explicit instructions over time, so monitoring is important.[116]

## SUMMARY

Dogs and cats are affected by different forms of kidney disease, and nutritional management will vary accordingly. It is best practice when determining a nutritional plan for any dog or cat to consider that animal as an individual. The animal's energy needs and specific nutrients of concern should be determined first. Using that information, appropriate diet options can be chosen and offered. Maintaining adequate energy intake is of utmost importance in CKD patients. Concurrent medical management may be required in many cases, and assisted enteral nutritional support can offer sustenance for hyporexic patients.

## CLINICS CARE POINTS

- Dogs and cats with kidney disease commonly develop dysrexia and exhibit weight loss.
- Body composition measurements (ie, BW, BCS, MCS) can have diagnostic and prognostic implications for dogs and cats with kidney disease.
- Optimal nutritional management of kidney disease varies by disease type (eg, CKD, PLN).
- Assisted enteral nutrition can alleviate the stress that owners feel with hyporexic animals and can allow for provision of optimal nutritional support.

## DISCLOSURE

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