Plant-Based Diets for Kidney Disease: A Guide for Clinicians

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In recent years, a growing body of evidence has emerged on the benefits of plant-based diets for the prevention and treatment of lifestyle diseases. In parallel, data now exist regarding the treatment of chronic kidney disease and its most common complications with this dietary pattern. Improving the nutrient quality of foods consumed by patients by including a higher proportion of plant-based foods while reducing total and animal protein intake may reduce the need for or complement nephroprotective medications, improve kidney disease complications, and perhaps favorably affect disease progression and patient survival. In this In Practice article, we review the available evidence on plant-dominant fiber-rich diet as it relates to kidney disease prevention, chronic kidney disease incidence and progression, metabolic acidosis, hyperphosphatemia, hypertension, uremic toxins, need for kidney replacement therapy including dialysis, patient satisfaction and quality of life, and mortality. Further, concerns of hyperkalemia and protein inadequacy, which are often associated with plant-based diets, are also reviewed in the context of available evidence. It is likely that the risks for both issues may not have been as significant as previously thought, while the advantages are vast. In conclusion, the risk to benefit ratio of plant-based diets appears to be tilting in favor of their more prevalent use.

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Clinical Vignette

A 57-year-old woman with essential hypertension, obesity, type 2 diabetes mellitus (T2DM), hyperlipidemia, and chronic kidney disease (CKD) presents to the clinic for a follow-up evaluation. She has a serum creatinine level of 1.6 to 1.8 mg/dL, which is equivalent to an estimated glomerular filtration rate (GFR) between 31 and 35 mL/min/1.73 m^2, serum potassium level of 4.8 to 5.2 mmol/L, and random urinary albumin-creatinine ratio of 323 mg/g, conferring a kidney disease classification of G3bA3. Her medications include calcium acetate, metformin, liraglutide, atorvastatin, lisinopril, amlodipine, glargine insulin, and sodium bicarbonate. She is currently not at goal in the treatment of her metabolic acidosis, hyperphosphatemia, hypertension, and T2DM. She states that she does not like "taking pills." She read online about the role of diets in kidney disease and is interested in learning more.

Introduction

Plant-based foods have been identified as a fundamental dietary component for health among a wide variety of eating patterns.[1] Plant-based diets are an umbrella term used to describe eating patterns that include a large proportion of plant-dominant foods. Examples of this include flexitarian, vegetarian, Mediterranean, and vegan diets (Box 1). Unrefined whole plant-based foods are recommended over their highly processed forms. The consumption of whole plant-based foods has been shown to be useful in the prevention and treatment of many of the lifestyle-related scourges of Western societies, including T2DM, obesity, hypertension, and hyperlipidemia.[2-4] In recent years, their utility for CKD and its resultant complications have become increasingly apparent.[5]

Plant-Based Diets and CKD Incidence and Progression

For those without pre-existing CKD, several observational studies have shown a beneficial association of plant-based foods with the development of CKD, including albuminuria. The Tehran Lipid and Glucose Study (TLGS) and the Multi-Ethnic Study of Atherosclerosis (MESA) are the largest cross-sectional studies, with about 5,000 participants each. In TLGS, those in the highest quartile of plant protein intake exhibited a 30% lower risk for CKD compared with those in the lowest quartile (odds ratio [OR], 0.70; 95% CI, 0.51-0.97).[6] Similarly, those in the highest quartile of animal protein intake had a 37% higher risk for CKD (OR, 1.37; 95% CI, 1.05-1.79) compared with the lowest. In MESA, consumption of a dietary pattern with a high amount of whole grains, fruits, vegetables, and low-fat dairy foods was associated with a 20% lower urinary albumin-creatinine ratio across quintiles (P for trend = 0.004).[7] In comparison, nondairy animal food consumption was associated with an 11% higher

In Practice is a focused review providing in-depth guidance on a clinical topic that nephrologists commonly encounter. Using clinical vignettes, these articles illustrate a complex problem for which optimal diagnostic and/or therapeutic approaches are uncertain.

Box 1. Examples and Descriptions of Various Plant-Based Diets

- **DASH Diet:** A specific dietary strategy designed to emulate the health-promoting effects of plant-based diet but allow for some animal-based foods, such as lean meat and low-fat dairy. Modern iterations have emphasized the unprocessed forms of fruits, vegetables, legumes, and grains (as opposed to fruit juices, refined grains, etc).
- **Mediterranean:** Although definitions and practices vary, particularly in time and place, the Mediterranean diet typically emphasizes whole plant foods from that area with moderate consumption of lean meats, dairy, and seafood. Added sugars, processed foods, and red meat are generally excluded but healthy fats such as olive oil are included. The recently updated KDOQI nutrition guideline gives a grade 2C recommendation for the potential of Mediterranean diets to improve lipid profiles in patients with nondialysis CKD.
- **Flexitarian:** Also commonly referred to as a "semi-vegetarian." Represents a diet that emphasizes plant-based foods but may periodically include meat and other animal-based foods.
- **Vegetarian:** A diet that excludes meat (beef, pork, chicken) but may include fish, dairy, or eggs and often specified as a pescatarian, lactovegetarian, or ovovegetarian, respectively. Combinations of these are possible.
- **Whole-Food Plant Based:** A diet that emphasizes the consumption of whole plant-based foods as opposed to refined or processed plant foods (such as potato chips or white bread) while still typically avoiding animal-based foods. It is also the diet most widely promulgated by health professionals recommending a plant-based diet.
- **Vegan:** A diet and in some cases a lifestyle that avoids the use of products derived from animals.
- **PLADO:** Plant-dominant low-protein diet for patients with kidney disease: 0.6-0.8 g/kg per day of dietary protein with >50% from plant-based sources, dietary sodium < 4 g/d (<3 g/d if uncontrolled hypertension or edema), and dietary energy of 30-35 Cal per kilogram of ideal body weight per day.

Abbreviations: CKD, chronic kidney disease; DASH, Dietary Approaches to Stop Hypertension; KDOQI, Kidney Disease Outcomes Quality Initiative.

urinary albumin-creatinine ratio across quintiles (P for trend = 0.03).

Prospective cohort studies have shown similar findings. The largest of these is the Singapore Chinese Health Study, which included 63,257 participants who were followed up for a median of 15.5 years.[8] In that study, red meat intake was strongly associated in a dose-dependent fashion with kidney failure. Those in the highest quartile of red meat intake had a 40% higher risk for developing kidney failure compared with the lowest (hazard ratio [HR], 1.40; 95% CI, 1.15-1.71). In a substitution analysis, replacing 1 serving of red meat per day with soy and legumes was associated with a 50% reduction in risk for kidney failure.

The longest follow-up within prospective cohort studies on this topic occurred in the Atherosclerosis Risk in Communities (ARIC) Study, which followed up approximately 12,000 individuals for a median of 23 years.[9] In ARIC, consumption within the highest quintile of nuts, legumes, and low-fat dairy was associated with 19% lower risk for CKD (HR, 0.81; 95% CI, 0.72-0.92) compared with the lowest. Inversely, consumption of red and processed meat was linked with a 23% higher risk for CKD (HR, 1.23; 95% CI, 1.06-1.42). Other observational studies of smaller sizes and shorter durations have also shown similar findings.[10-14]

For those with pre-existing CKD, observational evidence including the Nurses' Health Study (NHS) suggests a role of plant-based diets in secondary prevention.[15] The NHS was a prospective cohort study that followed up nearly 1,600 women with and without CKD for 11 years. Those with CKD had mildly reduced GFR at baseline (range, 55-80 mL/min/1.73 m^2); in this group, every 10 g of dietary protein consumed per day was associated with a borderline significant decline in GFR (−7.72; 95% CI, −15.52 to 0.08 mL/min/1.73 m^2). Further, among patients with pre-existing CKD, the consumption of every 10 g of protein per day from nondairy animal protein sources was significantly associated with a decline in kidney function (−1.21; 95% CI, −2.34 to −0.33 mL/min/1.73 m^2).

Although several randomized controlled trials (RCTs) have been conducted, only a few account for the total amount of protein ingested, which is an important confounder because those following animal-based diets tend to ingest more protein.[16] To our knowledge, only 3 trials control for this issue, thus allowing for a comparison of only protein quality and not quantity as well.[17-19] All 3 of these RCTs were done in patients with albuminuria and T2DM and were small (<50 participants each). These 3 RCTs, ranging in duration from 7 weeks to 5 years, found a statistically significant reduction in the amount of albuminuria with partial replacement of animal protein with plant protein.[17-19]

Putative mechanisms of diet on kidney health have been reviewed previously.[20-24] In brief, potential explanations for a protective effect of plant-based foods have included the presence of dietary fiber, phytochemicals, vitamins, minerals (such as potassium and magnesium), and antioxidants often found in plant-based foods, along with favorable changes in the microbiome. Substances common in animal-based foods that may have a detrimental effect on kidney health include saturated fats, sodium, phosphorus, dietary acid load (DAL), higher protein content (hyperfiltration), advanced glycation end products, heme iron, and carnitine and choline, which lead to trimethylamine-N-oxide (TMAO), a toxic compound that contributes to atherosclerotic cardiovascular disease and possibly kidney disease.[25]

Plant-Based Diets and the Complications of CKD

Metabolic Acidosis

A growing body of evidence suggests that an elevated DAL is detrimental for kidney health. Even in cases of a normal serum bicarbonate level, often occurring in the early stages

of CKD, an increasing DAL has been associated with increasing acid retention, as evidenced by reduced urinary citrate and/or reduced urinary ammonium secretion and increased plasma and urinary levels of endothelin 1 and aldosterone, which are mediators of progressive CKD in animal models.[26] The retention of acid by the body is associated with downstream effects of kidney progression and mortality. In the African American Study of Kidney Disease and Hypertension (AASK), lower urinary ammonium excretion was linked to increased risk for death or dialysis (HR, 1.36; 95% CI, 1.09-1.71) even in the absence of metabolic acidosis.[27]

The bulk of nonvolatile acid production in the body comes from diet, especially Western diets that favor animal-based acid-inducing foods. Animal protein is acid forming due to the presence of organic sulfur, which is found in the amino acids methionine and cysteine (common in animal proteins) and is oxidized to inorganic sulfate.[28] In contrast, plant-based foods have natural dietary alkali in the form of citrate and malate, which can be converted to bicarbonate. The average Western diet, being high in animal protein and low in natural alkali from plant foods, generates a DAL of ~1 mEq/kg per day, or about 50 to 75 mEq/d of DAL for the average person. In comparison, a vegan diet has a nearly neutral DAL.[28] In the Third National Health and Nutrition Examination Survey (NHANES III), analysis of the dietary and health records of nearly 1,500 adults showed that there was a significant association with increased risk for kidney failure for those in the highest tertile of DAL consumption (compared with the lowest tertile), even after adjusting for serum bicarbonate level (relative hazard, 3.04; 95% CI, 1.58-5.86).

In this light, it is not surprising that administration of alkali can reduce the DAL, acid retention, and kidney function decline.[26] In a 2-year RCT, those with CKD receiving alkali therapy in the form of oral sodium bicarbonate experienced a slowing of GFR decline from 5.93 to 1.88 mL/min/1.73 m^2 per year.[29] Alkali therapy typically occurs in the form of administering sodium bicarbonate but—though many are unaware of this—may also occur through diet. In a series of trials, Goraya et al[30-32] demonstrated the benefits of fruit and vegetable consumption for metabolic acidosis in those with CKD. In an RCT of 108 patients with CKD stage 3 of 3 years duration, administration of 2 to 4 cups of fruits and vegetables per day was comparable to oral sodium bicarbonate dosed at 0.3 mEq/kg per day (which was calculated to reduce DAL by 50%) in increasing serum bicarbonate levels for the treatment of metabolic acidosis.[30,33] GFR decline was attenuated in those receiving alkali therapy (either oral sodium bicarbonate or fruits and vegetables) compared with those not receiving alkali therapy. No difference in GFR decline was noted between the 2 groups receiving alkali therapy, suggesting that fruits and vegetables may be equivalent to sodium bicarbonate for this purpose. Further, the group receiving fruits and vegetables benefited from a mean 3.7-kg decrease in weight and a mean 7.4–mm Hg decrease in systolic blood pressure (BP) after 3 years compared with the sodium bicarbonate group. Similar findings were also noted in an RCT of 71 participants with CKD stage 4 lasting 1 year.[31]

Because of these findings, the recently updated Kidney Disease Outcomes Quality Initiative (KDOQI) nutrition guidelines "suggest that increased fruit and vegetable intake may decrease body weight, blood pressure, and net acid production" based on a grade 2C recommendation.[34]

Hypertension

Hypertension is an important cause and consequence of kidney disease. Hypertension is the second most common cause of kidney failure but it is also a common complication of kidney disease due to sodium retention and neurohormonal activation.[35] For those with and without kidney disease, plant-based diets have shown utility in the prevention and management of hypertension.[2]

Observations regarding the lower BPs of those eating plant-based foods in rural societies date back to nearly a century ago.[2] A meta-analysis of 32 observational studies involving 21,604 participants showed that plant-based diets were associated with a lower mean systolic (−6.9 [95% CI, −9.1 to −4.7] mm Hg) and diastolic (−4.7 [95% CI, −6.3 to −3.1] mm Hg) BP compared with omnivorous diets.[36] In the largest prospective study to date, researchers found that consumption of 1 or more serving per day of any animal-based flesh (red and processed meat, poultry, and/or seafood) was associated with a 30% increased risk for hypertension (HR, 1.30; 95% CI, 1.16-1.47) when compared with eating less than 1 serving per month.[37]

RCTs have shown similar findings. A meta-analysis of 9 RCTs demonstrated that consumption of a vegetarian diet was associated with a lower systolic (−4.8 [95% CI, −6.6 to −3.1] mm Hg) and diastolic (−2.2 [95% CI, −3.5 to −1.0] mm Hg) BP when compared with a diet inclusive of animal-based products.

The accumulation of substantial observational and experimental evidence of plant-based foods in hypertension led to the creation of the Dietary Approaches to Stop Hypertension (DASH) diet, which is a mostly plant-based diet with some animal-based foods. The rationale behind the individual components of the diet was to "have the blood pressure-lowering benefits of a vegetarian diet, yet contain enough animal products to make them palatable to nonvegetarians."[38] In a pair of seminal RCTs, the DASH diet and its low-sodium variation were shown to substantially reduce BP after 30 days.[39,40] The sodium-restricted DASH diet led to a mean reduction in systolic BP of 11.5 mm Hg in participants with hypertension. However, the biggest reduction was seen in those with the highest baseline BPs. In a secondary analysis, those in the highest stratum of evaluated BP (systolic, 150-159 mm Hg; diastolic, 90-95 mm Hg) had a reduction in BP of 20.8 (95% CI, −30.88 to −10.69) mm Hg systolic and 7.9 (95% CI, −10.28 to −5.45) mm Hg diastolic, which is comparable to the combined effects of 2 or more

antihypertensive medications.[41] It has been theorized that a higher proportion, or even exclusive use, of plant-based foods may have led to even more pronounced reductions.[2]

For those with CKD, as mentioned, Goraya et al[30,33] demonstrated that even a modest inclusion of plant-based foods (usually 2-4 cups of fruits and vegetables per day) was capable of reducing BP in those with CKD stage 3 when compared with those using oral sodium bicarbonate for supplemental alkali. A nearly equivalent decrease was seen when compared with a control group who did not receive any form of supplemental alkali, suggesting a benefit from the inclusion of these plant-based foods. Similarly, for those with CKD stage 4, the average reduction in systolic BP was 4.3 mm Hg after 1 year of including 2 to 4 cups of fruits and vegetables when compared with a group taking oral sodium bicarbonate for metabolic acidosis.[31]

The reasons for the reduction in BP in those eating plant-based foods are multifold.[2] A common explanation is the decrease in weight seen in those eating plant-based diets because weight loss is associated with a decrease in blood pressure. However, several observational studies have shown the persistence of an effect of plant-based diets on BP reduction even after adjusting for weight.[37,42,43] Based on data from the European Prospective Investigation Into Cancer and Nutrition (EPIC)-Oxford cohort, only half of the variation in BP may be attributable to weight.[42] Other potential mechanisms of BP reduction include a decrease in dietary sodium content, an increase in dietary potassium content, favorable changes in the microbiome, and reductions in oxidative stress, among others.[2]

Hyperphosphatemia

Elevated serum phosphate levels are an independent risk factor for mortality in both CKD and kidney failure.[44,45] Plant-based foods have been frequently avoided in patients with severe kidney disease due to concerns regarding their phosphate content, but their avoidance may be counterproductive. Although some plant foods may have a high phosphate content, such as nuts, seeds, and legumes, there is evidence that only a fraction of that phosphate content is absorbed. Phosphates found in plant-based foods are bound to phytate, limiting its bioavailability in humans, who lack the enzyme (phytase) necessary to release phytate. As such, the bioavailability of phosphates in plant-based foods ranges between 10% and 30%.[46] In contrast, phosphates in animal-based foods, such as meat, fish, dairy, and eggs, are typically between 40% and 60% bioavailable but can reach up to 80%.[47] Phosphate absorption in plant-based foods can be increased with industrial processing, such as exposure to heat >140 °C or the processing that occurs with industrially baked bread.[48] Home cooking does not typically affect phosphate bioavailability. Another reason that animal-based foods are higher in bioavailable phosphate is due to phosphate-containing food additives that are added for taste or preservation but can increase the amount of bioavailable phosphate by 7% to 100%.[49]

Studies of both animals and humans show reduced serum phosphate levels with the consumption of plant-based diets compared with animal-based diets despite having equal amounts of phosphate. In a rat model of kidney disease, rats fed grain-based diets had lower serum phosphorus levels, urinary phosphorus excretion, and serum FGF-23 (fibroblast growth factor 23) levels compared with rats fed an equivalent amount of phosphate from a casein-based diet.[50] In a subsequent crossover study with humans, patients with CKD stages 3-4 who were fed a vegetarian diet had lower serum phosphate levels, serum FGF-23 levels, and urinary phosphate excretion compared with those following a meat-based diet with an equivalent phosphate content.[51]

Another study with only partial replacement of animal-based protein from plant-based sources also resulted in a decrease in serum phosphate levels in patient with CKD.[17] Finally, prospective and retrospective cohort studies have shown that those eating plant-based foods, including vegetarians, had significantly lower serum phosphate levels in kidney failure.[52,53]

Uremic Toxins, Dietary Fibers, and the Microbiome

Dietary fiber has been known to reduce uremic toxin production for decades.[54] A meta-analysis of controlled feeding trials in CKD showed a reduction in urea and a dose-dependent reduction in creatinine levels with increasing fiber intake.[55] In those with normal kidney function, researchers measured on average 60% lower levels of the uremic toxins p-cresyl sulfate and indoxyl sulfate in vegetarians when compared with those eating omnivorous diets.[56] In a cross-sectional study of vegetarians and nonvegetarians undergoing hemodiafiltration, those consuming a strictly vegetarian diet were noted to have 47% and 67% lower levels of indoxyl sulfate and p-cresyl sulfate, respectively.[57] Other studies have demonstrated similar findings.[58,59]

This effect with dietary fiber is mainly derived from 2 important factors: the fiber itself and the replacement of animal protein. Dietary fiber consumption has been shown to decrease levels of urea, creatinine, and other toxins (such as p-cresyl sulfate and indoxyl sulfate) by improving intestinal motility (which decreases toxin absorption and increases fecal excretion), improving the integrity of tight junctions in the colonic epithelium (through the production of short-chain fatty acids such as butyrate), which reduces the permeability of toxins, and by facilitating the growth of a more favorable microbiome in the form of saccharolytic (instead of proteolytic) bacteria.[60,61] Because diet is a zero-sum game, the consumption of dietary fiber, which is found exclusively in plants, tends to result in a decrease in animal protein. Animal protein consumption, especially red meat, is associated with high production of uremic toxins such as TMAO, p-cresyl sulfate, and indoxyl sulfate by favoring the growth of proteolytic bacteria in the gut microbiome.[60]

Finally, uremic toxins have been linked to the progression of kidney disease, inflammation, insulin resistance, and cardiovascular disease, suggesting that lowering of these toxins through plant-based diets may result in

additional benefits.[22,62] Despite the potential benefits of dietary fiber, average intake of fiber in hemodialysis patients is 20% to 30% lower than for controls, ~11 g/d, and below recommended levels.[63]

Mortality

Patients with kidney disease are at increased risk for death compared with those without kidney disease. In observational studies, consumption of plant-based foods has been associated with a reduction in mortality in patients with both CKD and kidney failure. In a meta-analysis of 6 prospective cohort studies including 14,000 patients with CKD, Kelly et al[64] found that those eating a healthy dietary pattern that included more fruits, vegetables, cereals, whole grains, fiber, and fish and less red meat, salt, and refined sugars was associated with reduced risk for mortality (adjusted relative risk, 0.73; 95% CI, 0.63-0.83).

In a prospective study of patients with kidney failure receiving dialysis, more than 8,000 adult patients from 11 countries in Europe and South America were followed up with regard to fruit and vegetable consumption and mortality over a median follow-up of 2.7 years.[65] This study was notable for 2 reasons. First, patients consumed fruits and vegetables infrequently, with an average of 8 servings per week, which may be secondary to existing dietary recommendations to avoid these foods. Second, compared with those in the lowest tertile of consumption, those in the highest tertile experienced significantly lower risk for all-cause (HR, 0.80; 95% CI, 0.71-0.91) and non-cardiovascular (HR, 0.77; 95% CI, 0.66-0.91) mortality.

Plant-Based Diets and Potential Concerns

Hyperkalemia

One of the biggest concerns regarding the utility of plant-based diets in patients with kidney disease is hyperkalemia, which is not unfounded but likely overinflated. In a review of case reports of the dietary causes of hyperkalemia, including patients with and without CKD, plant-based items were a common culprit.[66] Although the review does not comment on patient baseline dietary habits, the bulk of hyperkalemic episodes from plant-based items in this series were related to the consumption of juices, sauces, or dried fruit, all of which uniquely increase the rate and amount of potassium consumed compared with their whole-food form. For example, although a person may not be inclined to eat 2 medium oranges in 1 sitting, a cup of orange juice can readily provide the potassium content of nearly 2 oranges.[67] Fruit- or vegetable-based sauces and dried fruit have similar issues in this regard. Further, juices and sauces also lack fiber, which may be an important factor in mitigating the possibility of hyperkalemia. Fiber increases stool quantity and frequency, which when excreted facilitates potassium excretion.

In contrast to the retrospective review of case reports, prospective observational and experimental studies, along with cross-sectional data, of patients consuming varying proportions of plant-based diets demonstrate only 1 patient with hyperkalemia, to our knowledge (Table 1). In that instance, the patient had a known pre-existing type IV renal tubular acidosis and was found to be consuming raw edamame, which is one of the most potassium-rich foods in existence (along with molasses and other types of raw legumes).[68] In this case, the hyperkalemia resolved when edamame was replaced by tofu. Notably, little to no association has been found between serum potassium level and dietary potassium in patients with kidney failure.[69,72]

Along with fiber, plant-based foods may have additional factors that temper any increase in serum potassium levels. For example, natural alkali in these foods may facilitate the intracellular movement of potassium, especially in metabolic acidosis. Other factors include improved insulin

Table 1. Selected Observational and Experimental Studies Examining Plant-Based Diets and Their Relationship to Serum Potassium

Study	Quantity of Plants Consumed	Size	Duration and Type	Hyperkalemia?	CKD Stage
Experimental Studies					
Goraya et al[32] (2012)	Typically 2-4 cups daily of fruits & vegetables	199	30-d controlled trial	No	1/2
Goraya et al[30] (2014)	Typically 2-4 cups daily of fruits & vegetables	108	3-y RCT	No	3
Tyson et al[70] (2016)	DASH diet[a]	10	2-wk controlled trial	No	3
Moorthi et al[68] (2014)	70% plant protein	13	4-wk controlled trial	Yes (1 patient[b])	3/4
Barsotti et al[71] (1996)	Vegetarian diet	37	3-mo controlled trial	No	3-5
Goraya et al[31] (2013)	Typically 2-4 cups daily of fruits & vegetables	76	1-y RCT	No	4
Observational Studies					
Wu et al[52] (2011)	Vegetarian diet	19	Cross-sectional	No	HD
St-Jules et al[69] (2016)	Increasing potassium intake	140	Cross-sectional	No	HD
Saglimbene et al[65] (2019)	Median 8 servings of fruits & vegetables per wk	8,078	Prospective observational (median, 2.8 y)	No	HD

Abbreviation: CKD, chronic kidney disease; DASH, Dietary Approaches to Stop Hypertension; HD, hemodialysis; RCT, randomized controlled trial.
[a]The DASH diet includes 8 to 12 servings of fruits and vegetables and 6 to 12 servings of grains (preferably whole grains) per day depending on caloric needs.[38]
[b]One patient with type IV renal tubular acidosis consuming a high-potassium food.

sensitivity and a reduction in the need for hyperkalemia-inducing medications (such as β-blockers, angiotensin II receptor blockers, and angiotensin-converting enzyme inhibitors) by treating hypertension. Finally, additional data suggest that the potassium in unprocessed plant foods may not be >60% absorbed.[73]

Based on these points, the risk for hyperkalemia may have been previously overstated, resulting in perhaps an opportunity lost for patients. It is likely that not all plant-based foods are the same in regard to their potential for hyperkalemia. Potential culprits, and substances to avoid, are juices, sauces, dried fruit, potassium-containing supplements, and foods unusually high in potassium (such as molasses and raw legumes). Despite all these considerations, it is reasonable to proceed with caution when introducing plant-based foods into the diet of patients with CKD or kidney failure.

Protein Adequacy and Beyond

Another common concern regarding the use of plant-based diets is protein inadequacy, either in quality or quantity. However, several studies have shown more than adequate levels of consumption in patients with and without kidney disease on varying degrees of plant-based diets, including vegan diets.[74] Although it is true that observational studies have shown lower levels of total protein consumption with plant-based diets, it does not preclude modifications of these diets to include more plant protein sources, such as legumes.[74] Typically those eating plant-based diets in CKD attain 0.7 to 0.9 g/kg per day of protein, which is not only closer to the recommended daily allowance but also avoids issues related to high-protein diets, such as hyperfiltration, which may hasten GFR decline.[74,75] The reduced protein content of plant-based diets may also help patients reach the lower protein targets (0.55-0.60 g/kg per day) recommended in the recently updated KDOQI nutrition guideline for those with CKD to reduce the risk for kidney failure or death.[34]

Those eating animal-based diets have been noted to have higher baseline GFRs, which is thought to be due to hyperfiltration from excess protein.[76] However, protein quality may also play a role. In one experimental study of participants consuming equivalent amounts of plant or animal protein for 3 weeks, those eating plant protein had significantly lower GFRs and renal plasma flows when compared with the animal protein group, suggesting that protein quality may also affect kidney function.[77]

Kidney Stones

The oxalate content of plant-based foods (and the theorized risk for a kidney stone) has been another cause for concern for years. There are instances of excess dietary oxalate intake leading to nephrolithiasis, especially when combined with other risk factors.[78] However, the association of dietary oxalate with urinary oxalate levels has not been consistent. Some studies have shown associations only with the consumption of high-oxalate–containing foods, such as spinach, rhubarb, nuts, and beets.[79] Other studies have shown that dietary oxalate restriction results in only a trivial reduction in urinary oxalate excretion.[80,81] A possible explanation for these findings is the recently discovered role of *Oxalobacter formigenes*, a bacterium that requires oxalate for survival and the presence of which is thought to reduce the amount of oxalate available for systemic absorption and ultimately excretion in urine.[82]

Although the evidence of vegan diets on the risk for nephrolithiasis is nearly nonexistent, it has been shown in observational studies that vegetarians have a lower risk for kidney stones.[83,84] This finding is likely attributable to several factors in vegetarian diets, including the omission of acid-prone animal-based proteins, the presence of natural alkali, the higher water content, and the reduced amounts of sodium within plant-based foods.[85-87]

Plant-Based Diets and T2DM

Although not within the scope of this review, patients with T2DM have benefited from the consumption of plant-based diets.[4] T2DM is the leading cause of both CKD and kidney failure, with about a quarter of diabetic patients having some form of CKD.[35] In a 74-week RCT of patients with T2DM, those consuming a plant-based diet had lower mean glycated hemoglobin levels than those consuming the American Diabetes Association's recommended diet for patients with T2DM.[36] Several meta-analyses, including those of RCTs, have shown reduced risk for developing T2DM and improved glycemic control for those who already have the disease with plant-based diets.[36,88] Finally, as discussed, several small RCTs have shown lower amounts of albuminuria with those consuming plant proteins, a finding that may be related to reduced hyperfiltration with plant-based diets.[17-19]

Review of Clinical Vignette and Conclusions

In the context of emerging evidence during recent years, the nephrologist for the patient described in the introductory vignette could discuss with her that healthy eating patterns generally have plant-based foods at their base and that these foods can not only be safely incorporated into the diets of those with CKD, but they may also help favorably with disease management.[1] The patient is motivated to make changes and finds support in a dietitian familiar with plant-based diets and CKD. She returns for a subsequent follow-up evaluation 3 months later and states that she has included more whole grains, fruits, vegetables, and legumes into her diet and reduced her consumption of processed foods, refined grains, added sugars and salts, and animal-based products. She states that her self-measured home BPs and glucose measurements, along with her weight, have decreased. Repeat blood work shows improvement in metabolic acidosis, proteinuria, and hyperphosphatemia without an increase in serum potassium levels. On subsequent encounters, the patient continues to show improvements, leading to reductions in her

Figure 1. Putative impact of plant-based and plant-dominant diets on the prevention and management of chronic kidney disease (CKD; see also Table 1 for more details). Abbreviation: eGFR, estimated glomerular filtration rate.

insulin requirements and discontinuation of her calcium acetate, sodium bicarbonate, and amlodipine treatments, while serum creatinine levels are unchanged.

Table 2. The Role of Plant-Based Diets in the Causes, Treatment, and Complications of Kidney Disease

	Role of Plant-Based Diet
Causes of Kidney Disease	
Hypertension	Well-established effect of rapid lowering in blood pressure with the consumption of plant-based foods
Type 2 diabetes mellitus	Combined effect of weight loss and improved insulin sensitivity with the consumption of plant-based foods
Obesity	Lower energy density and higher fiber content facilitates weight loss
Treatment of Kidney Disease	
Progression of disease	Plant-based diets tend to be lower in protein and tend to avoid protein excess, which may avoid hyperfiltration and temper the rate of GFR loss; treatment of complications (as listed below) may affect disease progression as well
Complications of Kidney Disease	
Metabolic acidosis	Plant-based foods have natural alkali
Hyperphosphatemia	Plant-based foods have lower bioavailability of phosphorus compared with animal-based and processed foods
Hypertension	Improved sodium to potassium ratio, weight loss
Cardiovascular disease	Plant-based diets may reduce the risk for several cardiovascular risk factors
Uremic toxins	Plant-based diets appear to generate fewer uremic toxins, which may be due to changes in the microbiome and fiber content

Abbreviation: GFR, glomerular filtration rate.

This clinical vignette illustrates the role of plant-based diets in the causes, treatment, and complications of kidney disease (Fig 1; Table 2). Plant-based diets should be viewed as being complementary to existing medical therapies and can help reduce the burden and cost of existing therapies to patients. However, in contrast to medications, dietary changes have the potential to address the root cause of lifestyle diseases for many patients and as a result may improve multiple disease processes simultaneously.

Although not discussed, the results seen from dietary changes can vary widely and depend on numerous factors, including patient adherence, provider support, and access to healthful foods, among other variables. Practical guidance for the inclusion of plant-based foods in the diets of patients with kidney disease are provided in Table 3 and Box 2. With certain exceptions, issues regarding hyperkalemia and protein inadequacy may have been overstated. The lower protein content of these diets may also help patients avoid protein excess, as suggested in the recently published KDOQI nutritional guideline for CKD.[34]

In this case, the patient was not only able to avoid additional medications but was able to reduce her existing medication burden, which is not uncommon in our experience. Further, she may have garnered additional benefits, such as altering the rate of her kidney function decline or her risk for mortality, although robust RCT-level data are limited. As such, future efforts should focus on additional research, including the funding and implementation of RCTs. In the meantime, the encouragement of patients with kidney disease to consume rather than avoid plant-based foods is certainly food for thought.

Table 3. A Practical Guide for the Inclusion of Plant-Based Foods in Patients With Kidney Disease

	Rationale
Daily Servings of Food Type	
2-4 servings of fruits	Unprocessed or minimally processed plant foods are the foundation of many healthy eating patterns due to their low caloric density, healthy fat content, fiber content, and high content of vitamins, minerals, and antioxidants. For patients with kidney disease, these foods tend to be low in sodium, have limited phosphate bioavailability, and have plant proteins, which may reduce hyperfiltration and uremic toxin production.
5+ servings of nonstarchy vegetables	
2+ servings of whole grains and starchy vegetables[a]	
3+ servings of legumes	
2-3 servings of nuts and seeds	
Foods to Exclude	
Fruit juices, vegetable sauces	Increase the rate of potassium ingestion (dried fruit may carry a similar risk); lack fiber; often prepared with added sugars.
Highly processed foods	Often contain added sodium and phosphorus. Calorically dense and nutritionally poor.
Meat	May worsen blood pressure, associated with adverse kidney-related outcomes, higher phosphate bioavailability.
Dairy	Higher phosphate bioavailability, calorically dense.

Data from Hever and Cronise.[89]
[a]Starchy vegetables are grouped with whole grains given their similar calorie density.

Box 2. Resources for Patients and Physicians Interested in Plant-Based Diets

- **www.kidney.org/atoz/content/plant-based:** An informative series of webpages created by the National Kidney Foundation to help educate patients and physicians alike on plant-based diets for the prevention and treatment of kidney disease, its causes, and its complications
- **www.nutritionfacts.org:** A not-for-profit website offering evidence-based information in the form of videos and articles on timely aspects of plant-based nutrition and other dietary issues
- **www.PCRM.org:** A not-for-profit organization focused on improving patient and societal health through the consumption of plant-based diets, offering free physician education, including CME, and patient education materials, such as starter kits and brochures
- **https://vegetariannutrition.net/:** The consumer/patient website of the Vegetarian Nutrition Dietetic Practice Group, a dietetic practice group of the Academy of Nutrition and Dietetics, offering patient-level information on plant-based diets
- **www.vndpg.org:** The professional website of the Vegetarian Nutrition Dietetic Practice Group, a dietetic practice group of the Academy of Nutrition and Dietetics, offering professional information for health care professionals, including registered dietitians

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