Scholars Journal of Applied Medical Sciences
Abbreviated Key Title: Sch J App Med Sci
ISSN 2347-954X (Print) | ISSN 2320-6691 (Online)
Journal homepage: https://saspublishers.com

OPEN ACCESS

Nephrology Hemodialysis

Nutritional Management in Hemodialysis: Principles and Practical Overview

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DOI: https://doi.org/10.36347/sjams.2025.v13i10.015 | **Received:** 06.09.2025 | **Accepted:** 22.10.2025 | **Published:** 27.10.2025

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Abstract **Review Article**

Background: Malnutrition and protein-energy wasting (PEW) remain highly prevalent in patients receiving maintenance hemodialysis (HD) and are strong predictors of morbidity, hospitalization, and mortality. Nutritional care is a fundamental yet often underemphasized component of dialysis management. Understanding the metabolic alterations, dietary requirements, and evidence-based interventions is therefore essential for nephrology residents and trainees. ***Summary:*** This overview synthesizes current recommendations and practical principles for nutritional management in hemodialysis patients, drawing upon recent KDOQI, ESPEN, and KDIGO guidelines. It discusses the multifactorial pathophysiology of malnutrition, tools for nutritional assessment, and optimal targets for energy (30–35 kcal/kg/day) and protein intake (≥1.2 g/kg/day). Electrolyte and micronutrient management—including sodium, potassium, phosphorus, and water-soluble vitamins—is detailed, with emphasis on individualized approaches. The review also explores intradialytic and oral nutritional supplementation, the role of education and multidisciplinary teamwork, and the emerging shift from restrictive to personalized nutritional strategies. ***Key Messages:*** Effective nutritional care in HD improves survival, quality of life, and functional capacity. Early identification of at-risk patients, regular assessment, and integration of dietetic expertise into the dialysis team are critical. Training nephrology residents to approach nutrition as a core therapeutic component, rather than an adjunct, is essential for optimizing patient outcomes.

Keywords: Hemodialysis, nutrition, protein-energy wasting, dietary management, nephrology education, KDOQI, ESPEN.

INTRODUCTION

Malnutrition and protein-energy wasting (PEW) are among the most prevalent and prognostically significant complications in patients receiving maintenance hemodialysis (HD). Depending on the criteria used, the prevalence of PEW ranges from 20 % to 60 %, and is consistently associated with increased morbidity, infection rates, hospitalization, and all-cause mortality [1–3]. The etiology of malnutrition in dialysis patients is multifactorial—encompassing inadequate dietary intake, metabolic acidosis, chronic inflammation, and nutrient losses during dialysis—and is compounded by restrictive dietary prescriptions and comorbidities such as diabetes [4,5].

The last decade has witnessed major advances in understanding the metabolic and nutritional derangements of kidney failure. These include alterations in amino-acid turnover, anabolic resistance, insulin resistance, and changes in energy expenditure. Consequently, optimal nutrition in HD extends beyond protein restriction; it requires individualized dietary strategies that maintain muscle mass and metabolic stability while controlling electrolyte and mineral balance [6,7]. The KDOQI 2020 and ESPEN 2021 guidelines now emphasize early nutritional assessment, regular monitoring, and integration of dietitians into multidisciplinary dialysis teams [8,9].

Despite strong evidence linking nutritional optimization to survival benefits, nutritional care remains under-prioritized in daily HD practice and in nephrology training curricula [10]. Many residents are well-versed in dialysis prescriptions and laboratory targets but receive limited structured education in clinical nutrition. This review aims to provide nephrology trainees with a concise, practice-oriented synthesis of the principles of nutritional management in hemodialysis—bridging physiology, assessment, dietary targets, and modern interventions such as intradialytic and oral supplementation—based on current international guidelines and evidence-based recommendations.

Pathophysiology of Malnutrition in Hemodialysis

Malnutrition in hemodialysis (HD) results from a complex interplay between reduced nutrient intake, metabolic and hormonal disturbances, inflammation, and dialysis-related nutrient losses. The term protein-energy wasting (PEW), introduced by the *International Society of Renal Nutrition and Metabolism (ISRNM)*, more accurately reflects the multifactorial mechanisms that lead to the progressive depletion of protein and energy stores in end-stage kidney disease [1,2].

1. DECREASED NUTRIENT INTAKE

Patients with kidney failure frequently experience anorexia, nausea, and altered taste, all of which limit spontaneous food intake [3]. Uremic toxins suppress appetite through central and peripheral pathways, particularly via inflammatory cytokine activation and leptin dysregulation [4]. The restrictive nature of renal diets—particularly limits on potassium, phosphorus, and sodium—can inadvertently reduce caloric and protein consumption. Moreover, depression and fatigue, common in dialysis populations, further decrease overall intake [5].

2. METABOLIC AND HORMONAL DISTURBANCES

Hemodialysis patients exhibit anabolic resistance; wherein normal anabolic stimuli (dietary protein or exercise) fail to adequately stimulate muscle protein synthesis [6]. This resistance is exacerbated by insulin resistance, growth hormone–IGF-1 axis dysfunction, and metabolic acidosis, all of which promote proteolysis and inhibit protein synthesis [7,8]. Chronic kidney disease (CKD) also induces a pro-catabolic state characterized by increased resting energy expenditure and mitochondrial dysfunction. Collectively, these abnormalities lead to net negative nitrogen balance even in patients with adequate intake.

3. INFLAMMATION AND OXIDATIVE STRESS

Inflammation plays a central role in the malnutrition-inflammation-atherosclerosis (MIA) syndrome that typifies chronic dialysis [14]. Elevated cytokines such as interleukin-6 and TNF-α suppress appetite, accelerate muscle breakdown, and lower serum albumin independent of nutritional intake [5]. The bio-incompatibility of dialysis membranes, recurrent infections, and endotoxin exposure from dialysate can all sustain low-grade systemic inflammation [3]. Oxidative stress further amplifies this cycle, impairing nutrient utilization and protein synthesis.

4. DIALYSIS-RELATED NUTRIENT LOSSES

Hemodialysis itself contributes to nutrient depletion. Each session can remove 6–12 g of amino acids, 2–3 g of small peptides, and significant amounts of water-soluble vitamins (B-complex, vitamin C) and trace elements such as zinc and selenium [11]. Repeated losses without adequate replacement lead to cumulative deficits. Dialysis-induced catabolism is also augmented by fasting during HD sessions, as many units discourage eating due to aspiration or hypotension risk [21].

5. CONSEQUENCES

The downstream effects of these mechanisms include loss of muscle mass, hypoalbuminemia, immune dysfunction, and increased cardiovascular risk [15]. The convergence of decreased intake, inflammation, and dialysis-related losses underpins the high prevalence of PEW and the strong predictive value of low serum albumin and lean mass for mortality in HD cohorts [22,7].

Assessment of Nutritional Status in Hemodialysis

Accurate evaluation of nutritional status in hemodialysis (HD) patients is essential for early identification of protein-energy wasting (PEW) and for guiding individualized interventions. Because no single parameter captures the full nutritional profile, current guidelines advocate a multidimensional approach, combining anthropometric, biochemical, dietary, and functional indicators [1,2].

1. Anthropometric and Body Composition Measures

Traditional measures such as body weight, body mass index (BMI), triceps skinfold thickness, and mid-arm circumference remain widely used but must be interpreted with caution due to fluid shifts inherent to HD [3]. The post-dialysis “dry weight” is the preferred baseline for longitudinal monitoring.

Advanced tools—such as bioelectrical impedance analysis (BIA) and dual-energy X-ray absorptiometry (DEXA)—offer more accurate assessments of lean body mass, fat mass, and overhydration [4]. BIA-derived phase angle and lean tissue index have emerged as prognostic markers of mortality and inflammation in dialysis cohorts [5].

ESPEN recommends integrating body composition methods when available, while KDOQI underscores the importance of tracking weight change trends (>5% in 3 months) as a red flag for nutritional decline [2,6].

2. Biochemical and Laboratory Markers

Serum albumin remains the most widely used biochemical marker due to its strong association with mortality [7]. However, it is a negative acute-phase reactant, influenced by inflammation, hydration, and infection rather than nutrition alone [8]. Prealbumin (transthyretin), with a shorter half-life (~2 days), provides a more sensitive marker for acute changes but shares similar limitations.

Other useful indices include normalized protein catabolic rate (nPCR), which estimates dietary protein intake based on urea kinetics. An nPCR below 1.0 g/kg/day suggests inadequate protein intake, while values between 1.0–1.4 g/kg/day are considered optimal for HD patients [9,10]. Cholesterol, transferrin, and creatinine production rates can serve as adjunct markers, although their diagnostic accuracy is limited in isolation.

Inflammatory markers such as C-reactive protein (CRP) should be routinely assessed to distinguish malnutrition from inflammation-mediated hypoalbuminemia [5].

3. Dietary and Subjective Assessment Tools

Direct assessment of dietary intake through 24-hour recall, food diaries, or 3-day dietary logs remains fundamental [8]. These should ideally be reviewed by a renal dietitian to quantify energy and protein adequacy relative to recommendations (30–35 kcal/kg/day and ≥1.2 g protein/kg/day) [7].

Among composite tools, the Subjective Global Assessment (SGA) and Malnutrition Inflammation Score (MIS) are the most validated in dialysis populations [8,9].

- SGA classifies patients as well-nourished, moderately, or severely malnourished based on weight changes, dietary intake, and clinical findings (subcutaneous fat loss, muscle wasting, edema).
- MIS, a semi-quantitative extension of SGA, incorporates laboratory and inflammation parameters, providing a graded score (0–30) that correlates strongly with morbidity, hospitalization, and mortality risk [8, 9].

4. Functional and Performance-Based Assessment

Functional indicators, such as handgrip strength (HGS), gait speed, and frailty scales, are increasingly recognized as integral components of nutritional evaluation [7, 8]. Reduced HGS correlates with PEW and predicts adverse outcomes independent of biochemical indices [7,8]. KDOQI and ESPEN now recommend incorporating at least one functional or performance-based parameter into routine nutritional surveillance for HD patients [2,9].

5. Integrated Assessment and Monitoring

KDOQI 2020 proposes that nutritional screening be performed monthly in maintenance HD, with comprehensive assessment at least every 6 months, or earlier in patients with recent weight loss or intercurrent illness [2]. Effective assessment relies on multidisciplinary collaboration, combining physician, nurse, and dietitian input to contextualize findings and guide interventions.

Energy and Macronutrient Requirements

Adequate provision of macronutrients—energy, protein, fat, and carbohydrates—is central to preventing protein-energy wasting (PEW) in hemodialysis (HD) patients. Dialysis induces significant metabolic stress and nutrient losses, which, if uncorrected, contribute to muscle wasting, hypoalbuminemia, and poor clinical outcomes [1,2]. Nutritional targets should therefore be individualized according to age, comorbidities, physical activity, and dialysis adequacy, while adhering to standardized guideline ranges.

1. Energy Requirements

Hemodialysis patients have an energy expenditure similar to healthy individuals of comparable age, but catabolic stress during HD and chronic inflammation justify maintaining a slightly higher energy intake [3].

- **Recommended daily energy intake:**
  - <60 years: 35 kcal/kg/day (ideal body weight)
  - ≥60 years: 30–35 kcal/kg/day (4,5)

Energy should be distributed across three main meals and snacks, ideally providing at least 50–60% carbohydrates, 25–30% fats, and 15–20% proteins (6). For patients with reduced appetite or limited intake, intradialytic snacks or oral nutritional supplements (ONS) have been shown to improve energy balance and stabilize serum albumin [19,20].

Energy intake <25 kcal/kg/day for more than 1–2 weeks is associated with negative nitrogen balance and increased mortality risk [8].

2. Protein Requirements

Protein losses during a standard 4-hour HD session range between 6–12 grams, primarily as free amino acids and small peptides [11]. Therefore, HD patients require a higher protein intake compared to predialysis CKD populations.

- Recommended protein intake:
  - ≥1.2 g/kg/day (ideal body weight) for clinically stable HD patients [4,10]
  - Up to 1.4 g/kg/day in catabolic states, active infection, or inflammation [8,9]
  - At least 50% of total protein should be of high biological value (animal or dairy-based) to ensure sufficient essential amino acid content [8,9]

If spontaneous intake is inadequate, oral or intradialytic protein supplementation should be considered. The normalized protein catabolic rate (nPCR), derived from urea kinetics, serves as a proxy for dietary protein intake; target values are 1.0–1.4 g/kg/day [8].

3. Lipid Management

While fat intake represents an important energy source, dyslipidemia is highly prevalent in HD. ESPEN recommends maintaining 25–35% of total energy from fat, with preference for monounsaturated and polyunsaturated fatty acids, particularly omega-3s [14].

- Saturated fats should remain <10% of total energy intake, and trans fats should be avoided [9].
- Increasing omega-3 intake (fish oil, flaxseed, walnuts) may reduce inflammation and cardiovascular events [16].
- In diabetic dialysis patients, lipid control should align with general diabetic guidelines while ensuring adequate caloric intake.

4. Carbohydrate Requirements

Carbohydrates should provide approximately 50–60% of total caloric intake. Preference should be given to complex carbohydrates with a low glycemic index, including whole grains, legumes, and vegetables [9]. In diabetic HD patients, carbohydrate distribution should be individualized, balancing glucose control with prevention of undernutrition [7]. Artificial sweeteners such as sucralose or stevia can be used safely within recommended doses.

5. Clinical Considerations

- **Elderly HD patients** often have reduced appetite and energy needs but higher risk of sarcopenia; thus, prioritizing protein intake while avoiding excessive restriction is crucial [19].
- **Obese HD patients** with metabolic syndrome benefit from a balanced, calorie-appropriate plan emphasizing unsaturated fats and fiber, rather than caloric restriction that might aggravate PEW [16].
- **Intradialytic feeding** is safe in hemodynamically stable patients and helps attenuate protein catabolism, as confirmed by randomized trials [21].

Table 1: Summary of Macronutrient Recommendations in Hemodialysis Patients

Nutrient	Recommended Intake	Notes / Rationale	References
Energy	30–35 kcal/kg/day (<60 yrs: 35; ≥60 yrs: 30–35)	Maintain neutral/positive nitrogen balance	[4,5,8]
Protein	1.2–1.4 g/kg/day (≥50% HBV)	Compensate for HD losses; prevent PEW	[7–9,11]
Fat	25–35% total kcal	Emphasize MUFA/PUFA; reduce SFA & trans fats	[9,16]
Carbohydrates	50–60% total kcal	Prefer complex carbs; adjust for diabetes	[9,7]

Micronutrients and Electrolyte Management

Micronutrient and electrolyte control is a cornerstone of hemodialysis (HD) care. Inadequate management leads to cardiovascular, neuromuscular, and bone-mineral complications, whereas excessive restriction can worsen malnutrition and quality of life. A balanced, individualized plan should therefore aim to limit toxic accumulation while preventing deficiency [1, 2].

1. Sodium and Fluid Balance

Excessive sodium intake promotes thirst, interdialytic weight gain (IDWG), hypertension, and left-ventricular hypertrophy [8]. Restriction must be realistic to maintain dietary adherence.

- Recommended sodium intake: < 2 g/day (≈ 85 mmol/day).
- Target IDWG: < 4.5 % of dry body weight between sessions.
- Educate patients to avoid processed foods, cured meats, and salt-based seasonings; prefer herbs and spices instead (4).
- Excessive restriction (<1.5 g/day) is not advised because it may reduce appetite and caloric intake (16).

2. Potassium

Serum potassium reflects the balance between intake, dialysis clearance, and residual kidney function. Hyperkalemia remains a leading cause of cardiac death in HD [7,8].

- Recommended dietary potassium: 2–3 g/day (50–75 mmol/day), individualized according to predialysis levels and residual renal output [7].
- Encourage patients to avoid potassium salts and leach high-K foods (boiling vegetables, double-cooking potatoes).
- For patients with hypokalemia (often due to poor intake or over-restriction), a liberalized diet is appropriate [8].
- Frequent counseling with a renal dietitian helps balance safety and variety.

3. Phosphorus and Calcium

Hyperphosphatemia drives secondary hyperparathyroidism, vascular calcification, and mortality in HD populations [17]. Phosphorus management requires a combination of dietary restriction, phosphate binders, and dialytic removal.

- Recommended phosphorus intake: 800–1000 mg/day, preferably from non-additive, organic sources [8].

- Processed foods containing phosphate additives should be strictly limited, as their absorption rate exceeds 90 % [12].
- Maintain serum phosphorus 3.5–5.5 mg/dL and corrected calcium 8.4–9.5 mg/dL, with a Ca × P product < 55 mg^2/dL^2 [17].
- Calcium-based binders should be used cautiously, particularly in adynamic bone disease or vascular calcification; sevelamer or lanthanum are preferred alternatives [17].

4. Vitamins

Hemodialysis removes significant amounts of water-soluble vitamins, whereas fat-soluble vitamins may accumulate [8].

- **Supplementation recommended for :**
  - Vitamin C: 60–100 mg/day (avoid > 250 mg to prevent oxalate accumulation).
  - Vitamin B-complex (B1, B6, B12, folate): daily renal multivitamin preparations are safe and effective [8].
  - Vitamin D: use active analogs (calcitriol, alfacalcidol, paricalcitol) based on PTH and calcium–phosphate balance, not routine multivitamins [17].
- Avoid supplementation of vitamin A and E unless deficiency is proven, due to risk of toxicity [8].

5. Trace Elements

Losses of zinc, selenium, copper, and iron occur via dialysate and reduced dietary intake [8].

- Zinc deficiency can impair taste and appetite; supplementation (25–50 mg elemental Zn/day) improves both [8].
- Selenium is often low; 50–100 µg/day supplementation may restore antioxidant capacity [8].
- Iron balance should follow anemia-management protocols; oral iron may be poorly absorbed, so IV formulations are preferred when indicated [7].

6. Practical Summary

Parameter	Recommended Intake/Range	Clinical Rationale	Key Refs
Sodium	< 2 g/day (85 mmol)	Control BP & thirst	[8,4,16]
Fluid gain	< 4.5 % dry weight	Prevent overload	[8]
Potassium	2–3 g/day (50–75 mmol)	Avoid hyper-/hypokalemia	[7,8]
Phosphorus	800–1000 mg/day	Control Ca×P product	[8,12,17]
Calcium	800–1000 mg/day (total)	Maintain normal Ca & PTH	[17]
Vitamin C	60–100 mg/day	Replace dialysis loss	[8]
Vitamin B-complex	Daily renal multivitamin	Prevent megaloblastosis	[8]
Vitamin D (active)	Per PTH status	Bone & Ca homeostasis	[17]
Zinc	25–50 mg/day	Improve taste & appetite	[8]
Selenium	50–100 µg/day	Antioxidant support	[8]

Special Dietary Considerations

Nutritional management in hemodialysis (HD) must be individualized to account for comorbidities, dietary preferences, and cultural factors. Certain populations—including diabetic, elderly, vegetarian, and malnourished patients—require specific adjustments to optimize outcomes while preventing protein-energy wasting (PEW) and metabolic complications [1,2].

1. Diabetic Hemodialysis Patients

Diabetes mellitus is the leading cause of end-stage kidney disease (ESKD) worldwide, and up to 40–50% of HD patients are diabetic [8]. Their nutritional management aims to balance glycemic control with adequate energy and protein intake.

- Energy and protein goals remain similar to non-diabetic HD patients (30–35 kcal/kg/day and ≥1.2 g protein/kg/day) [4].
- Carbohydrates: should comprise 50–55% of total energy, emphasizing low-glycemic-index complex carbohydrates (whole grains, legumes, vegetables) [9].
- Simple sugars and sweetened beverages should be minimized.
- Fats: emphasize mono- and polyunsaturated fatty acids (MUFA/PUFA), with <10% saturated fats [9].
- Glycemic targets should be individualized; HbA1c goals around 6.5–7.5% are reasonable in HD to reduce hypoglycemia risk [7].

Intradialytic feeding with small carbohydrate- and protein-rich snacks can stabilize glucose levels and prevent catabolism during long sessions [21]. Coordination between nephrologists and diabetes educators is essential to adapt insulin regimens to the dialysis schedule.

2. Elderly Hemodialysis Patients

Elderly HD patients (>65 years) often exhibit sarcopenia, frailty, and anorexia of aging, compounded by comorbidities and polypharmacy [9]. Strict dietary restriction may worsen malnutrition and increase mortality.

- Energy needs: 30–35 kcal/kg/day, though often reduced due to decreased activity [8].
- Protein intake: should remain ≥1.2 g/kg/day, even in the presence of moderate hyperphosphatemia, as the benefits of maintaining muscle mass outweigh phosphate load risk [9].
- Liberalized diets with small, frequent meals are preferred to improve adherence and prevent anorexia.
- Oral nutritional supplements (ONS) or intradialytic nutrition are strongly recommended in this population [19,20].
- Frailty assessment (handgrip, gait speed) should guide nutritional interventions [8].

3. Vegetarian and Vegan Patients

Plant-based diets may offer cardiovascular and anti-inflammatory benefits but can predispose to protein and micronutrient deficiencies in HD patients if not carefully planned [16].

- Protein intake: should remain ≥1.2 g/kg/day, but at least 50% should be from high-biologic-value sources, such as soy, tofu, seitan, quinoa, and legumes combined with cereals [9].
- Phosphorus bioavailability from plant sources is lower (~40–50%), which may reduce phosphate burden; however, care is needed to ensure adequate protein and zinc [9].
- Vitamin B12, iron, and zinc supplementation are mandatory in strict vegans [9].
- Vitamin D deficiency is common; active vitamin D analogs should be prescribed according to standard CKD-MBD guidelines [17]. Dietitian involvement is critical to balance plant-based protein quality with renal-specific restrictions.

4. Malnourished or Catabolic Patients

Patients with established PEW or catabolic illness (infection, hospitalization, postoperative state) require intensified nutritional support [19].

- Protein targets: 1.4–1.6 g/kg/day, with energy intake ≥35 kcal/kg/day [9].
- Oral supplements (20–30 g protein/serving) or intradialytic parenteral nutrition (IDPN) may be indicated when oral intake remains <60% of needs [18].
- Anti-inflammatory therapy, exercise programs, and correction of acidosis enhance the anabolic response [15].
- Frequent nutritional reassessment (monthly) and monitoring of serum albumin and weight trends are recommended until recovery.

5. Practical Summary

Patient Group	Key Adjustments	Main Risks / Goals	References
Diabetic HD	Low-GI carbs, MUFA/PUFA, maintain kcal/protein	Hypoglycemia, catabolism	[3–8]
Elderly HD	Small frequent meals, liberalize diet, ONS	Frailty, sarcopenia	[9–13]
Vegetarian/Vegan HD	Ensure essential AA, supplement B12, Zn, Fe	Protein & micronutrient deficiency	[14–18]
Malnourished/Catabolic HD	↑ Protein (1.4–1.6 g/kg), consider IDPN	PEW, infection, inflammation	[19–22]

Nutritional Interventions and Monitoring

Nutritional care in hemodialysis (HD) should be dynamic, multidisciplinary, and evidence-based. It integrates dietitian-led counseling, individualized dietary planning, and ongoing evaluation of nutritional and functional status. Early and structured intervention improves survival, reduces hospitalizations, and enhances quality of life [8,9].

1. The Role of the Dietitian and Multidisciplinary Team

Nutrition management is most effective when embedded within a multidisciplinary HD care model. Dietitians specialized in renal nutrition play a pivotal role in assessing intake, educating patients, and tailoring plans to clinical and cultural contexts [3].

- Frequency of contact: KDOQI recommends monthly review of dietary intake and body weight, with comprehensive reassessment every 6 months or after intercurrent illness [4].
- Education focus: individualized guidance on protein and phosphorus sources, food label interpretation, and practical cooking strategies.
- Communication: close collaboration between nephrologists, dietitians, and nurses ensures early detection of nutritional deterioration and adjustment of dialysis prescriptions [5].
  Multidisciplinary rounds, including a nutrition discussion, are associated with higher albumin levels and improved patient adherence [6].

2. Oral Nutritional Supplements (ONS)

When spontaneous intake is insufficient (<60–70% of estimated needs), oral nutritional supplementation (ONS) is first-line therapy [8,9].

- **Composition**: renal-specific ONS provide 10–30 g protein and 200–400 kcal per serving, with reduced potassium and phosphorus content.

- **Timing**: may be administered intradialytically to counteract protein catabolism during HD and improve tolerance [21].
- **Efficacy:** Randomized controlled trials have demonstrated improvements in serum albumin, prealbumin, and lean mass after 3–6 months of ONS, with no adverse effects on potassium or phosphorus [19,20].
- **Adherence:** flavor variation, patient education, and intradialytic administration significantly enhance compliance [10,19,20].

ONS should be monitored via weight trends, nPCR, and inflammatory markers to avoid overfeeding or electrolyte imbalance.

3. Intradialytic Parenteral Nutrition (IDPN)

IDPN is reserved for severely malnourished patients unable to meet requirements orally or enterally [12].

- **Indications:** persistent PEW, anorexia, gastrointestinal dysfunction, or catabolic states unresponsive to ONS.
- **Formulation:** amino acids (0.8–1.1 g/kg/session), glucose, and lipid emulsions infused during HD via the venous line [13].
- **Outcomes:** trials report gains in lean body mass, serum albumin, and survival in selected patients [14].
- **Limitations:** cost, nursing workload, and infection risk restrict routine use; therapy should be reassessed monthly [15].

4. Enteral and Combined Nutrition

For patients with neurologic impairment or severe anorexia, enteral feeding via nasogastric or gastrostomy routes may be necessary. Energy-dense renal formulas help maintain caloric and protein goals while limiting electrolytes (16). Combination of enteral feeding + intradialytic supplementation can be implemented in refractory PEW cases (17).

5. Monitoring and Follow-up

Systematic follow-up ensures early detection of nutritional deterioration and therapy adjustment.

Recommended monitoring parameters:

- Monthly: weight, BMI, interdialytic weight gain, serum albumin, nPCR, CRP.
- Every 3–6 months: SGA/MIS score, handgrip strength, dietary recall, lipid profile.
- Annually: body composition (BIA or DEXA) and micronutrient levels (vitamin D, iron, zinc, selenium).

Indicators of improvement include ≥0.2 g/dL rise in serum albumin, stabilization of body weight, or improved SGA/MIS class [8].

6. Practical Algorithm for Nutritional Care in Hemodialysis

Below is a conceptual flowchart (Figure 2) summarizing the management pathway.

Baseline Evaluation → Identify at-risk patient (BMI <23, albumin <3.8, ↓ intake)
↓
Comprehensive Assessment (SGA/MIS, labs, diet recall)
↓
Adequate intake?
↙ Yes ↘ No
Monitor monthly Initiate nutrition intervention
↓
Start individualized ONS (oral/intradialytic)
↓
Reassess after 3 months → Improved?
↙ Yes ↘ No
Continue plan Evaluate for IDPN/enteral
↓
Monthly team review & adjust plan

Figure 2: Nutritional Care Algorithm in Maintenance Hemodialysis

7. Integration with Dialysis Prescription

Nutritional strategies must align with the dialysis prescription:

- Increase dialysate magnesium or bicarbonate to correct metabolic contributors to catabolism.
- Extend session duration or frequency in hypercatabolic patients to optimize nutrient utilization.
- Coordinate meal timing with dialysis schedule to minimize post-dialysis fatigue and anorexia [7].

Clinical Outcomes and Evidence

Nutritional status in maintenance hemodialysis (HD) is a powerful determinant of clinical outcomes, influencing survival, hospitalization, inflammation, and functional capacity. Malnutrition and protein-energy wasting (PEW) are independently associated with two- to three-fold increases in mortality and hospitalization risk [1,2]. Conversely, nutritional rehabilitation—through oral supplementation, intradialytic nutrition, or individualized counseling—has consistently shown positive effects on biochemical, functional, and survival endpoints [3,4].

1. Nutritional Status and Survival

Serum albumin, prealbumin, and lean body mass are among the strongest predictors of survival in HD patients. Observational data from over 50,000 HD patients in the Dialysis Outcomes and Practice Patterns Study (DOPPS) revealed that serum albumin <3.8 g/dL is associated with a 40–50 % higher mortality risk, independent of dialysis adequacy [22]. Similarly, prealbumin levels <30 mg/dL predict early mortality and hospitalization [7].

Body composition studies show that preservation of muscle mass, rather than body weight alone, is critical for longevity. Low appendicular lean mass and reduced phase angle by bioimpedance are strong prognostic markers of all-cause mortality [7,8]. Importantly, moderate overweight (BMI 24–30 kg/m²) confers a survival advantage—a phenomenon termed the "reverse epidemiology" of dialysis patients, emphasizing the protective role of adequate energy and protein reserves [9].

2. Nutritional Interventions and Clinical Outcomes

Several interventional trials and meta-analyses confirm that nutritional support improves outcomes in HD populations:

- Oral Nutritional Supplements (ONS): Randomized trials demonstrate increases in serum albumin (≈ +0.2–0.3 g/dL) and body weight after 3–6 months, with parallel reductions in hospitalization days [19]. A meta-analysis of 15 studies including >1,000 patients showed a 25 % mortality reduction among those receiving ONS compared to usual care [20].
- Intradialytic Parenteral Nutrition (IDPN): Improves nitrogen balance and lean body mass in malnourished patient's refractory to oral intake [12]. Gains in serum albumin and survival have been documented in prospective cohorts [13].
- Exercise and Anabolic Support: Combined nutritional supplementation and intradialytic resistance exercise augment muscle protein synthesis and improve physical performance indices [14,15].
- Dietitian-Led Education: Structured nutrition counseling programs significantly increase energy and protein intake, improve albumin, and enhance adherence to phosphate and potassium control [10].

3. Inflammation, Hospitalization, and Quality of Life

Chronic inflammation amplifies PEW and cardiovascular risk in HD. Nutritional interventions—especially those rich in omega-3 fatty acids and antioxidants—can modulate inflammatory cytokines such as IL-6 and TNF-α [16]. Trials supplementing oral fish oil or α-lipoic acid showed modest reductions in CRP and improved nutritional indices [18].

Patients receiving consistent dietitian follow-up demonstrate fewer hospitalizations, shorter hospital stays, and better health-related quality of life (HRQoL) scores on the KDQOL-36 and SF-36 surveys [19,20]. Improvements in appetite, energy, and functional independence are frequently reported with intradialytic nutrition and protein supplementation [21].

4. Long-Term Implications

The collective evidence underscores nutrition as a modifiable determinant of outcomes comparable in importance to dialysis adequacy and anemia management. Maintenance of serum albumin ≥4.0 g/dL, nPCR ≥1.0 g/kg/day, and stable lean body mass are now recognized key quality indicators of dialysis care [22]. Integrating systematic nutritional screening, early supplementation, and exercise-nutrition synergy is central to reducing morbidity and mortality in the HD population [23].

Challenges and Future Perspectives

Despite clear evidence linking optimal nutrition to improved outcomes, implementation of nutritional care in hemodialysis (HD) remains inconsistent globally. Barriers include economic constraints, insufficient training, cultural dietary limitations, and lack of structured interdisciplinary integration [1,2].

1. Practical and Systemic Challenges

Resource and staffing limitations

In many dialysis centers—particularly in low- and middle-income settings—dietitian-to-patient ratios remain inadequate, limiting individualized follow-up and dietary adaptation [3]. Even in high-resource countries, dietitian involvement in HD rounds is often sporadic, despite KDOQI and ESPEN recommendations for monthly contact [4].

Cultural and socioeconomic barriers

Food insecurity, cost of protein-rich renal foods, and cultural food patterns (high potassium or phosphate traditional dishes) hinder adherence to prescribed diets [5,6]. Counseling approaches that fail to consider local cuisines often result in poor compliance and dietary monotony, which further exacerbate anorexia and malnutrition [7].

Restrictive and outdated prescriptions

Historically, renal diets emphasized strict potassium, phosphorus, and protein restrictions to control uremic symptoms. This restrictive approach, while useful in predialysis CKD, may be detrimental in HD, promoting PEW and poor appetite [8]. Modern guidelines advocate liberalized, individualized diets that prioritize adequate energy and protein intake over uniform restriction [9].

Lack of standardization in nutritional assessment.

Heterogeneous use of nutritional screening tools (SGA, MIS, nPCR, BIA) across centers complicates data comparison and clinical auditing [10]. Furthermore, laboratory markers like albumin and prealbumin are influenced by inflammation and hydration status, often leading to misclassification of nutritional risk [11].

2. Emerging Directions and Future Perspectives

Toward personalized and liberalized nutrition.

Recent ESPEN and KDIGO updates emphasize moving from “one-size-fits-all” prescriptions to personalized nutrition plans integrating patient phenotype, residual renal function, comorbidities, and cultural background [12]. This includes targeted use of intradialytic snacks, plant-based proteins, and energy-dense supplements, as well as redefining potassium and phosphorus thresholds for each individual.

Integration of digital and AI-based nutrition support.

The rise of AI-powered diet-tracking applications and tele-nutrition platforms enables real-time dietary monitoring and feedback, facilitating adherence and early identification of undernutrition [13]. Pilot programs have demonstrated that automated image-based food tracking and personalized feedback improved protein intake and reduced hospitalization in HD cohorts [14].

Exercise-nutrition synergy.

Combining intradialytic resistance training with nutritional supplementation amplifies anabolic response and functional recovery [15]. This integrative model, often referred to as the “exercise as medicine” paradigm, is likely to become a future standard of HD rehabilitation.

Research and policy priorities.

Future research must focus on large-scale randomized trials testing liberalized dietary models, real-world cost-effectiveness of ONS and IDPN, and validation of novel biomarkers (e.g., phase angle, bioimpedance-derived lean mass). On the policy side, dialysis quality metrics should include nutritional adequacy indicators, ensuring reimbursement for dietitian services and intradialytic nutrition [16,17].

Education and resident training.

Nutrition remains underrepresented in nephrology curricula. Incorporating structured modules on dietary management, case-based teaching, and interdisciplinary simulation into residency programs will prepare future nephrologists to view nutrition as a therapeutic cornerstone rather than a peripheral concern [18].

3. Outlook

The future of renal nutrition lies in precision and integration—precision through data-driven personalization and integration through team-based care that aligns nutrition with dialysis, pharmacotherapy, and psychosocial support. As the field moves toward value-based dialysis care, nutritional optimization will become a defining marker of quality and a key determinant of patient-centered outcomes.

CONCLUSION

Optimal nutritional management is a cornerstone of high-quality hemodialysis (HD) care. Malnutrition and protein-energy wasting (PEW) remain highly prevalent, yet largely preventable contributors to morbidity and mortality in the dialysis population. Understanding the metabolic alterations of kidney failure, accurately assessing nutritional status, and applying evidence-based dietary prescriptions are essential skills for every nephrology trainee.

Current recommendations from KDOQI, ESPEN and KDIGO converge on a unified principle: restrictive, “one-size-fits-all” renal diets must be replaced by personalized, liberalized, and patient-centered approaches. Achieving adequate energy (30–35 kcal/kg/day) and protein (≥1.2 g/kg/day) intake, while maintaining electrolyte and micronutrient balance, significantly improves survival, functional capacity, and quality of life. Regular screening—using Subjective Global Assessment (SGA), Malnutrition Inflammation Score (MIS), and nPCR—allows early intervention before irreversible PEW develops.

Nutritional rehabilitation should be viewed as a therapeutic intervention, not merely an adjunct. Incorporating dietitians as core members of the dialysis team, implementing oral or intradialytic nutritional support, and integrating exercise-nutrition synergy represent practical strategies with proven outcome benefits.

For nephrology practitioners, mastery of nutritional care is both a clinical and educational imperative. Recognizing that nutrition directly influences cardiovascular stability, inflammation, and dialysis adequacy transforms how we approach the HD patient: from a purely biochemical focus to a holistic, physiology-driven model of care.

The future of dialysis medicine will increasingly rely on precision nutrition, digital monitoring tools, and value-based metrics that prioritize patient well-being. By embedding nutrition into every stage of HD management, clinicians can meaningfully extend survival, enhance recovery, and restore the dignity and vitality of life on dialysis.

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