Home-delivered meals as an adjuvant to improve volume overload and clinical outcomes in hemodialysis

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ABSTRACT

Patients on chronic hemodialysis are counseled to reduce dietary sodium intake to limit their thirst and consequent interdialytic weight gain (IDWG), chronic volume overload and hypertension. Low-sodium dietary trials in hemodialysis are sparse and mostly indicate that dietary education and behavioral counseling are ineffective in reducing sodium intake and IDWG. Additional nutritional restrictions and numerous barriers further complicate dietary adherence. A low-sodium diet may also reduce tissue sodium, which is positively associated with hypertension and left ventricular hypertrophy. A potential alternative or complementary approach to dietary counseling is home delivery of low-sodium meals. Low-sodium meal delivery has demonstrated benefits in patients with hypertension and congestive heart failure but has not been explored or implemented in patients undergoing hemodialysis. The objective of this review is to summarize current strategies to improve volume overload and provide a rationale for low-sodium meal delivery as a novel method to reduce volume-dependent hypertension and tissue sodium accumulation while improving quality of life and other clinical outcomes in patients undergoing hemodialysis.

Keywords: dietary sodium, hemodialysis, interdialytic weight gain, kidney failure, meal delivery, nutrition, quality of life, volume overload

INTRODUCTION

Chronic volume overload is a persistent and challenging problem in kidney failure patients undergoing chronic hemodialysis (HD) therapy, with an estimated prevalence of 40-60% [1-4]. However, volume overload is rarely quantified in an objective manner, as there are several assessment techniques but no universal standard diagnosis for volume overload in either clinical practice or research [5]. Chronic volume overload contributes to a poor quality of life, caused in part by edema, fatigue, impaired breathing and poor dialysis treatment tolerance [6]. Chronic volume overload also contributes to hypertension and left ventricular hypertrophy, which are leading causes of morbidity and mortality in patients undergoing HD [7-10].

Volume overload and hypertension are managed through a combination of pharmacological therapy, dialysis therapy and...
lifestyle modifications that include dietary sodium restriction [11]. Dietary sodium intake, which stimulates thirst and subsequent fluid intake, is a primary cause of volume overload in HD patients with minimal to no residual kidney function [12]. However, antihypertensive medications are typically the first-line approach for treating hypertension aside from the prescribed dialysis treatment [13]. This is perhaps because modifying a patient’s dietary sodium and fluid intake demands behavioral intervention strategies that require more effort than most clinicians are able to provide or that are sustainable [14]. Nonetheless, the limitations of pharmacological and dialysis therapy make sodium restriction critical to preventing and treating volume overload and hypertension in HD patients [15].

Seminal work in the USA from the 1960s [16–19], as well as more recent studies in Tassin, France [20] and Izmir, Turkey [21] have shown that blood pressure (BP) can be controlled in many HD patients nonpharmacologically using comprehensive volume control strategies that include significant restrictions in dietary sodium intake (e.g. <2000 mg/day) in conjunction with gradual or progressive ultrafiltration and reduced reliance on antihypertensive medications [2, 22]. These data suggest that sodium restriction is key to successful volume control and improving patients’ quality of life and cardiovascular risk. This is further illustrated by single-intervention therapies, such as pharmacotherapy or altering dialysis parameters (e.g. increasing ultrafiltration rate and reducing dialysate sodium), that have shown limited efficacy in treating volume overload when not coupled with sodium restriction [21, 23–25]. Unfortunately, non-pharmacological lifestyle approaches to managing volume and hypertension in patients undergoing HD do not appear to be the primary focus and effort of clinical practice today [26].

One likely reason that comprehensive volume control protocols are not widely practiced is because it is challenging to reduce dietary sodium intake, a vital component of volume control. Low-sodium dietary trials in HD are sparse and mostly indicate that dietary education and behavioral counseling are ineffective in reducing sodium intake and interdialytic weight gain (IDWG) [27]. These research gaps suggest that new strategies for reducing dietary sodium intake are needed. One sodium reduction strategy that has shown promise in patients with hyperlipidemia, hypertension and heart failure is providing patients with low-sodium, home-delivered meals [28–30]. These comorbidities are often prevalent in patients on HD, which furthers the rationale for utilizing this approach in HD. Until recently [31], studies have not evaluated the efficacy of this approach to reduce sodium intake in HD patients.

Another reason to reduce excess sodium consumption is to potentially reduce sodium accumulation in soft tissues, which is elevated in patients on HD compared with healthy controls [32, 33]. Excess tissue sodium may contribute to cardiovascular complications, including hypertension, left ventricular hypertrophy and congestive heart failure [34, 35]. Although tissue sodium may be reduced to some extent during dialysis [33], studies have not investigated whether reducing dietary sodium intake can lead to reductions in the tissue sodium storage of HD patients.

Reduction of dietary sodium intake through low-sodium, home-delivered meals may lower tissue sodium accumulation and improve chronic volume overload, both factors that have been associated with hypertension, left ventricular hypertrophy and mortality in individuals on HD. Importantly, home meal delivery could bypass many of the barriers associated with a low-sodium diet in patients on HD. Home-delivered meals also have the potential to be formulated to be low in phosphorus and potassium, which could have secondary benefits in the context of highly complex renal dietary restrictions [36]. The objective of this review is to summarize current strategies to improve volume overload and provide a rationale for low-sodium meal delivery as a novel method to reduce volume-dependent hypertension and tissue sodium accumulation while improving quality of life and other clinical outcomes in individuals undergoing HD.

Rationale for sodium restriction as the primary focus of volume control

The prevalence of volume overload is difficult to determine as clinical assessment relies on different subjective, objective and proxy measures of volume status [37]. Although many of these assessment techniques have different benefits and drawbacks, IDWG is arguably a highly informative and practical measure of fluid intake and retention (i.e. acute volume overload) in clinical practice [38]. To prevent volume overload, patients undergoing HD are often advised to reduce both their sodium (<2.3 g/day) [39] and fluid intake to limit IDWG. However, adherence to these recommendations is low [40]. Some researchers have argued that sodium restriction should be the central focus of volume reduction strategies rather than fluid restrictions, due to ethical concerns [38, 41] and clinical consequences of advising patients not to consume fluid when thirsty, including xerostomia and periodontal disease [42].

This ideological shift could be based on the rationale that dietary sodium intake is a driver of thirst, fluid intake and fluid retention [43]. A major consequence of kidney failure is the inability to concentrate and produce urine to remove both fluid and electrolytes, leaving thirst as the major osmoregulatory mechanism, which is higher in patients on HD compared with healthy controls [44]. Studies by Kusaba et al. [45] and Kim et al. [46] have demonstrated that those with kidney disease generally have less sodium taste sensitivity (i.e. are less able to recognize salty tastes) than healthy controls. Osmolutes other than sodium, such as urea and glucose, may also drive excessive thirst and studies have shown that patients with diabetes on HD have greater thirst than those without diabetes [47]. Finally, both xerostomia and thirst have been positively associated with IDWG [48, 49].

Reduction of tissue sodium

A relatively new concept in sodium regulation is the non-osmotic storage of sodium in tissues such as the skin and skeletal muscle [50]. Extrarenal sodium regulation, in the form of vascular vasodilation and lymphatic expansion, has been proposed to mobilize fluid and electrolytes throughout the body while clearing sodium storage reservoirs [51]. Recent studies indicate that tissue sodium accumulation is positively associated with age, diabetes, BP and left ventricular hypertrophy [34, 35]. Thus it appears that tissue sodium may be linked to both volume overload and hypertension. In kidney failure, non-osmotic sodium regulation may be the sole remaining buffering mechanism for dietary intake and homeostasis [51, 52]. Thus extrarenal storage and regulation provide further rationale for limiting exogenous sources of sodium and attenuating tissue sodium accumulation. To date, however, few studies have examined the relationship between tissue sodium levels and clinical outcomes in patients on HD.

A recent study by Dahlmann et al. [33] demonstrated that patients on HD have excessive sodium in their skin and skeletal muscle compared with age-matched healthy controls. This
the USA.

A caveat to the Tassin approach is that patients typically dialyze 50%, as well as IDWG, volume overload and BP [53–55]. However, Tassin dialysis centers have reduced mortality rates by nearly 40% compared with other HD centers in the USA [21]. Despite the reduced dialysis treatment times, they were able to achieve similar results, including normal BP without antihypertensive medications in up to 95% of patients [2, 56–59]. One example of this was a cross-sectional comparison of two dialysis clinics in Turkey conducted by Kayikcioglu et al. [57]. One center-controlled BP using a comprehensive volume control strategy that included intensive ultrafiltration and dietary sodium restriction, while the second center-controlled BP with antihypertensive medications. Both centers had improvements in BP, but the comprehensive volume reduction strategy significantly reduced IDWG, hypertension and left-ventricular mass index.

Notably, both Tassin and Izmir achieved significant reductions in BP without antihypertensive medications in the majority of patients [59]. Comprehensive volume reduction strategies, combining sodium restriction and increased ultrafiltration, are not novel and were originally recommended in the early decades of dialysis [16–18]. However, there are few examples outside of Izmir and Tassin where this approach is being successfully applied today. Raimann et al. [60] conducted a pilot volume control intervention in the USA, modeled after the Izmir protocol. While they showed reductions in IDWG and BP, the study was presented as an abstract at a professional conference but was never published in a peer-reviewed journal, so it is difficult to draw definitive conclusions from the data.

Unfortunately, these studies are also lacking data on important clinical outcomes such as dietary intake and dietary patterns and objective measures of volume overload. To address this gap in knowledge, our group conducted a pilot volume control intervention that included dietary sodium restriction as part of a comprehensive volume control intervention [61]. Our findings included modest reductions in sodium intake and markers of volume overload (dialysis weights, extracellular fluid and calculate volume overload), as well as improved BP control. These data are generally consistent with recent studies demonstrating small changes in dietary sodium intake and IDWG in patients on HD provided with weekly nutritional education and counseling (Table 1) [61]. However, the benefits are modest compared with the robust improvements in BP and volume overload demonstrated in the studies in Tassin and Izmir. The failure to fully replicate these findings in the USA suggests that novel strategies to reduce sodium intake are needed. These modest improvements may also be a reflection of the US food supply, with high availability of ultra processed foods high in sodium, which makes it much more difficult to adhere to lower sodium intakes compared with other regions. However, salt and sodium intake may be similar or even higher in other countries as evidenced by population studies in Turkey [62].

### Limited efficacy of dietary sodium interventions

Sodium restriction in patients on HD is recognized as an important strategy to reduce fluid intake, IDWG, volume overload and hypertension [63]. Many studies in HD patients have indicated that dietary sodium consumption exceeds the recommendations [39], with intakes that typically range from 2 to 14 g/day of sodium [64–71]. Unfortunately, strategies to reduce dietary sodium intake in patients undergoing HD have had little success [27]. Renal dietitians provide regular counseling to patients on HD to reduce their dietary sodium and fluid intake, but patient adherence to these recommendations remains low [14, 72]. This is further highlighted by several dietary education

| Author | Results |
|--------|---------|
| Charra et al. [54] | 98.4% BP controlled  
98.4% BP medication free  
Highest global HD survival rate |
| Kayikcioglu et al. [57] | 82% BP controlled  
93% BP medication free  
Reduced IDWG (~1.0 kg/day)  
Reduced LVH (~15 g/m²) |
| Ozkahya et al. [58] | 96% BP controlled and medication free  
Reduced IDWG (~5.1 kg/day)  
Reduced LVM (~70 g/m²)  
Reduced CTI (~11%)  
Reduced hypotensive events |
| Ozkahya et al. [56] | Reduced systolic BP (16 ± 5 mmHg)  
Reduced diastolic BP (7.2 ± 2.6 kg)  
Reduced pre-HD weight (3.9 ± 2.6 kg)  
Reduced post-HD weight (3.8 ± 2.6 kg)  
Reduced BP medication free (maintained) |
| Perez et al. [61] | Trend for reduced 1 to 2-month IDWG (P = 0.05)  
Reduced EDW (mean −2.3 ± 3.9 kg)  
Reduced volume overload (mean −1.3 ± 1.8 L)  
Reduced BP medications (mean −1 ± 1)  
No significant BP changes (maintained) |

All included studies consisted of a low-sodium diet, progressive ultrafiltration and conventional (4-h) dialysis, with the exception of 8-h dialysis in Charra et al. [54]. Statistically significant (P < 0.05). LVH, left ventricular hypertrophy; LVM, left ventricular mass index; CTI, cardiothoracic index; EDW, estimated dry weight.

study also reported that HD treatment may acutely reduce tissue sodium levels by 19–27% [33]. Yet, studies have not yet examined the impact of diet or reduced sodium intake on tissue sodium storage. Currently there is an unclear relationship between tissue sodium accumulation and other factors impacting HD patients’ excessive cardiovascular disease risk, including hypertension, chronic volume overload, arterial stiffness and systemic inflammation.

### Sodium restriction as a cornerstone of comprehensive volume control

Comprehensive volume control is generally defined as any combination of gradual reductions in target dialysis weights, minimization of antihypertensive prescriptions, standardized dialysate sodium and weekly intradialytic counseling on dietary sodium intake and IDWG. While it appears that single-therapy interventions aimed at reducing volume overload and hypertension in HD have had limited success [23, 24], some studies have demonstrated success when sodium restriction has been included as a cornerstone in comprehensive volume control intervention strategies. These strategies also included stringent management of ultrafiltration rates and reduced reliance on BP medications (Table 1) [53–55]. Dialysis centers in Tassin, France have long practiced strict sodium restriction, which appears to result in improved outcomes. Compared with clinics in the USA, Tassin dialysis centers have reduced mortality rates by nearly 50%, as well as IDWG, volume overload and BP [53–55]. However, a caveat to the Tassin approach is that patients typically dialyze up to 8 hours, as opposed to 3 to 4-hour dialysis sessions in the USA.

In contrast, dialysis centers in Izmir, Turkey adopted a similar strategy, albeit with thrice-weekly, 4-hour HD, as is common in the USA [21]. Despite the reduced dialysis treatment times, they were able to achieve similar results, including normal BP without antihypertensive medications in up to 95% of patients [2, 56–59]. One example of this was a cross-sectional comparison of two dialysis clinics in Turkey conducted by Kayikcioglu et al. [57]. One center-controlled BP using a comprehensive volume control strategy that included intensive ultrafiltration and dietary sodium restriction, while the second center-controlled BP with antihypertensive medications. Both centers had improvements in BP, but the comprehensive volume reduction strategy significantly reduced IDWG, hypertension and left-ventricular mass index.

Notably, both Tassin and Izmir achieved significant reductions in BP without antihypertensive medications in the majority of patients [59]. Comprehensive volume reduction strategies, combining sodium restriction and increased ultrafiltration, are not novel and were originally recommended in the early decades of dialysis [16–18]. However, there are few examples outside of Izmir and Tassin where this approach is being successfully applied today. Raimann et al. [60] conducted a pilot volume control intervention in the USA, modeled after the Izmir protocol. While they showed reductions in IDWG and BP, the study was presented as an abstract at a professional conference but was never published in a peer-reviewed journal, so it is difficult to draw definitive conclusions from the data.

Unfortunately, these studies are also lacking data on important clinical outcomes such as dietary intake and dietary patterns and objective measures of volume overload. To address this gap in knowledge, our group conducted a pilot volume control intervention that included dietary sodium restriction as part of a comprehensive volume control intervention [61]. Our findings included modest reductions in sodium intake and markers of volume overload (dialysis weights, extracellular fluid and calculate volume overload), as well as improved BP control. These data are generally consistent with recent studies demonstrating small changes in dietary sodium intake and IDWG in patients on HD provided with weekly nutritional education and counseling (Table 1) [61]. However, the benefits are modest compared with the robust improvements in BP and volume overload demonstrated in the studies in Tassin and Izmir. The failure to fully replicate these findings in the USA suggests that novel strategies to reduce sodium intake are needed. These modest improvements may also be a reflection of the US food supply, with high availability of ultra processed foods high in sodium, which makes it much more difficult to adhere to lower sodium intakes compared with other regions. However, salt and sodium intake may be similar or even higher in other countries as evidenced by population studies in Turkey [62].

### Limited efficacy of dietary sodium interventions

Sodium restriction in patients on HD is recognized as an important strategy to reduce fluid intake, IDWG, volume overload and hypertension [63]. Many studies in HD patients have indicated that dietary sodium consumption exceeds the recommendations [39], with intakes that typically range from 2 to 14 g/day of sodium [64–71]. Unfortunately, strategies to reduce dietary sodium intake in patients undergoing HD have had little success [27]. Renal dietitians provide regular counseling to patients on HD to reduce their dietary sodium and fluid intake, but patient adherence to these recommendations remains low [14, 72]. This is further highlighted by several dietary education
or behavioral interventions that have not achieved or sustained significant reductions in both dietary sodium intake and IDWG (Table 2) [67–71].

Notably, Maduell et al. [67] and Rigby et al. [68] conducted two small studies that demonstrated successful reductions in both dietary sodium intake and IDWG, yet neither has been published as a full-text original article (i.e. short communication and abstracts only). Importantly, Rigby et al. [68] provided a strict shopping list, daily diet plan and low-sodium foods throughout the intervention to increase adherence. The provision of food in these examples supports meal provision as a method to increase dietary adherence among patients with CKD. Such an approach also addresses concerns about patient food security and the costs of purchasing fresh foods or produce. Though some previous studies have reported on general barriers to low-sodium dietary adherence [73], few have studied or reported on cultural food barriers and food fatique that may also play an important role in dietary adherence. Epidemiological data suggest that IDWG is positively associated with both dietary sodium intake and poor health outcomes, yet few trials have successfully managed to reduce dietary sodium consumption in patients on HD [74–77]. Thus there is a critical need to develop new strategies that produce robust reductions in sodium intake and subsequent reductions in IDWG to improve volume overload and reduce cardiovascular mortality.

The rationale for providing home-delivered meals to patients on HD

Patients on HD face a plethora of barriers that make it extremely challenging for them to adhere to recommendations to significantly restrict their dietary sodium intake [12, 38, 78]. Commonly cited barriers include time constraints, fatigue related to dialysis treatments [78] and socioeconomic factors such as food cost and availability (Table 3) [79]. Many patients on HD may also lack cooking equipment, physical function and/or social support, which reduces their ability to cook their own food [78]. Poor nutrition and health literacy, an inability to track nutrients and feelings of deprivation also contribute to low adherence to the renal diet [78, 80]. Given all these barriers, it is clear why attempts to restrict dietary sodium intake through enhanced education and counseling alone have had limited success (Table 2) [67–71]. In contrast, providing home-delivered kidney-friendly meals may help mitigate many of the barriers to eating a low-sodium diet.

To examine the initial efficacy of this approach, we recently conducted a pilot study that provided home-delivered renal meals to 20 HD patients [31]. Participants were followed for a 4-week observational period followed by a 4-week interventional home-meal delivery period. In this study, HD patients who were provided the home-delivered meals had reductions in IDWG, ultrafiltration, BP, and volume overload. In secondary analyses of this study (unpublished), during the observation period, participants frequently consumed high-sodium, ultra-processed and processed foods and there was a high proportion of meals consumed away from the home [81]. The largest contributors to dietary sodium intake also contributed to higher phosphorus and potassium intakes. This could be secondary to the concurrent use of phosphorus, sodium and potassium additives in ultra-processed foods, though the studies did not capture these data. Participants may have also changed their consumption of animal-based food products or dairy consumption, which needs to be further evaluated in future studies. We also found several deficits in sodium knowledge. However, participants generally scored high on most assessed educational areas. These data agree with a recent study by Betz et al. [82] finding that dietary knowledge was not associated with dietary intake. A common reported behavioral challenge was the HD diet and

Table 2. Studies investigating the effect of low-sodium/salt diet on IDWG in HD patients

| Author, Year | Design, N | Intervention | Result (change) | Effect Size (Cohen’s d) |
|-------------|-----------|-------------|----------------|-----------------------|
| Perez et al. [31], 2020 | Single arm, 20 | Usual diet followed by low-sodium delivered meals, 4-weeks pre versus 4-weeks post | Na intake Δ: −1.6 ± 0.3 g/day,* IDWG Δ: −0.8 ± 0.1 kg* | Na: 1.71, IDWG: 0.53 |
| Sakai et al. [71], 2017 | Single arm, 48 | Usual diet followed by counseling, 48-months pre versus 48-months post | Na intake Δ: −0.6 ± 0.2 g/day,* IDWG (kg) not reported | Na: 0.60 |
| Sevick et al. [70], 2016 | RCT, CON: 86 INT: 93 | Counseling or counseling + technology support, 16 weeks | No Δ: dietary Na intake, No Δ: IDWG | Na: 0.00, IDWG: 0.18 |
| Rodriguez-Telini et al. [69], 2014 | RCT, CON: 18 INT: 21 | Usual diet or usual diet less 2 g/Na/day, 16 weeks | Na intake Δ: −2.5 ± 0.4 g/day,* No Δ: IDWG | Na: 1.92, IDWG: 0.24 |
| Maduell et al. [67], 2000 | Case-control, 15 | Nutritional counseling | Na intake Δ: −1.2 ± 1.2 g/day,* IDWG Δ: −0.5 ± 0.6 kg* | Na: 1.07, IDWG: 0.82 |
| Rigby et al. [68], 1999 | RCCCT, 28 | Usual diet or 0.5 g/Na/day, 1 week | Na intake Δ: −2.7 ± 0.2 g/Na/day,* IDWG Δ: −0.8 ± 0.2 kg* | Na: 3.30, IDWG: 0.77 |

*Statistically significant (P < 0.05). aWithin-subjects statistical comparison non significant (P > 0.05) or not reported. All values standardized from salt intake to Na content. Smallest effect size calculated based the lowest reported change values. Adapted from Bossola et al. [27]. Na, sodium; RCT, randomized control trial; RCCCT, randomized control cross-over trial; IDWG, interdialytic weight gain; CON, control group; INT, intervention group.
fluid restrictions. In contrast, participants were generally confident in limiting salt shaker usage and salt intake overall despite nearly all being above dietary sodium recommendations (∼2.3 g/day/sodium) [39].

**Evidence from other clinical populations**

Low-sodium meal provision has shown promise in individuals with hyperlipidemia, hypertension [28] and heart failure [29]. Troyer et al. [28] provided seven home-delivered meals per week for 12 months to older adults with cardiovascular disease. The primary finding was that providing meals adopting the Dietary Approach to Stop Hypertension (DASH) diet increased DASH adherence (adherence), indicating that this was both a feasible and efficacious approach. In patients with heart failure, Hummel et al. [29] randomized patients to usual care or three DASH meals per day for 4 weeks to post discharge patients with heart failure. Meal provision in this study appeared to improve the survey-evaluated clinical status, rate of rehospitalization and duration of rehospitalizations. Similarly, Kalogeropoulos et al. [30] randomized patients with heart failure to 1500 or 3000 mg sodium home-delivered meals for 12 weeks. The primary finding was that the meals were generally well tolerated without adverse safety or quality-of-life signals. Overall, these studies suggest that providing meals may be a practical method to achieve dietary adherence that may also translate to improved clinical outcomes in clinical populations. Both Hummel et al. [29] and Kalogeropoulos et al. [30] used the commercial vendor Pur-Foods (Ankeny, IA, USA; www.purfoods.com), which also provides meal options for HD patients. In our pilot trial in HD, with a similar home-delivered approach, participants had generally good meal adherence and improvements in some clinical outcomes such as IDWG, volume overload and BP [31]. To date, however, studies have not widely explored the efficacy of a meal-provision approach to manage sodium intake and clinical outcomes in HD patients.

**Clinical benefits**

In addition to helping overcome barriers to a low-sodium diet, home-delivered meals may also yield clinical benefits relevant to HD patients (Table 3). First, reducing sodium intake could reduce thirst, sodium and fluid retention (Figure 1). This decrease in thirst may, in turn, lead to reduced IDWG, volume overload and hypertension, which in the long term may translate into reductions in left ventricular hypertrophy, congestive heart failure and cardiovascular mortality. Second, reductions in IDWG may reduce complications from aggressive dialysis ultrafiltration such as intradialytic hypotension, cardiac stunning, peripheral organ ischemia, cramping and fatigue [83]. Reduction of intradialytic hypotension, as well as these complications, may improve mortality and improve patients’ quality of life. Notably, dialysis centers in Tassin, France reduced mortality due to a drastic reduction in hypertensive episodes attributed to slower ultrafiltration rates [20].

Moreover, a low-sodium diet may also reduce tissue sodium levels and thus further reduce cardiovascular risk in HD patients. Some commercial vendors [29, 84] also provide kidney-friendly meal options that are low in potassium and phosphorus. Therefore, home-delivered meals may also help prevent and treat hyperkalemia and hyperphosphatemia through the reduction of highly bioavailable phosphate and potassium additives. These meals can also be formulated to provide both consistent and adequate energy and protein intake to promote reductions in protein-energy wasting. Similarly, the meals can be formulated to contain adequate amounts of dietary fiber from plant-based foods, which may be beneficial for the gastrointestinal microflora, leading to lower production of microbiota-derived uremic toxins [85, 86]. Diabetes- and heart-healthy options may be available for patients with these comorbidities. Lastly, meal-provision may represent a method to provide more plant-based, Mediterranean or DASH-type foods, which has been described as a research priority in HD to reduce intradialytic symptoms and the risk of fluid overload [87].

**Concerns and costs**

There are a number of concerns with home-delivered meals that need to be considered. One obvious concern is the up-front costs associated with providing these meals. Typically, most home-delivery meal services charge ~$6–$14 per meal [84, 88], although this may vary significantly depending on the provider and/or type of meal provided. If a healthcare or insurance

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### Table 3. Potential benefits and concerns of home-delivered meals in kidney failure

| Benefits | Concerns |
|----------|----------|
| **Adherence and barriers:** | **Adherence and barriers:** |
| Less reliance on the need for shopping and cooking | Not eating provided meals and meal fatigue |
| Improved food security | Consumption of high-Na food in addition to the meals provided |
| Promote changes in salt-taste sensitivity/preference to promote short- or long-term behavior change | Reduced cooking self-efficacy and storage requirements |
| **Clinical benefits:** | Reduced patient autonomy for meal decisions |
| Reduced Na, K, P and thirst/fluid intake | Culturally appropriate meals may not be available |
| Reduced volume overload, HTN, hyperkalemia, hyperphosphatemia | Clinical consequences |
| Improved HD treatment efficacy and reduced HD adverse effects | Meals may not meet entire nutritional needs: energy, protein, micronutrients |
| Diabetes- and heart-healthy meals could be formulated | Need for additional oral nutritional supplements |
| Long-term cost-effectiveness: | **Up-front costs:** |
| Reduced antihypertensive medications, phosphate binders, K binders and hospitalizations | Several hundred dollars/month/patient |
| Improved treatment compliance/fewer missed dialysis shifts | Safe weight reduction to improve kidney transplantation eligibility |
| Safe weight reduction to improve kidney transplantation eligibility | **Concerns and costs** |

*Na*, sodium; *K*, potassium; *P*, phosphorus; *QOL*, quality of life; *HTN*, hypertension.
suggests that priming strategies may improve specific nutrition behavior. A small body of literature involves providing exposure to environmental cues that may for ‘priming’ behavior change. Priming in this context would improve volume-dependent hypertension. Low-potassium and low-phosphorus meals could improve hyperkalemia and hyperphosphatemia, in turn improving cardiac alterations and bone mineral disorders. CVD, cardiovascular disease; CHF, congestive heart failure; CKD-MBD, chronic kidney disease—mineral bone disorder; QOL, quality of life.

provider were to provide only two meals/patient/day, it would cost roughly $360–$840/patient/month, which is a significant cost outlay for a dialysis provider or insurance agency. However, home-delivered meals could also provide significant healthcare cost savings, especially if the reduced sodium intake helps manage chronic volume overload. Unfortunately, some parts of the world may not have insurance or dialysis providers to cover these costs. Individual patients would have to absorb these costs in these cases, which may not be possible for people with lower incomes. Nonetheless, an added benefit of meal provision is that there may be less need for some medications. For example, euvoletic patients may require fewer antihypertensive medications, while patients adhering to lower potassium and phosphorus intakes may need fewer intestinal potassium and phosphorus binders. And most significantly, reduced volume overload, hyperkalemia and hyperphosphatemia should ideally lead to fewer hospitalizations. However, future long-term studies should assess the cost-effectiveness of this approach.

Three home-delivered dialysis-friendly meals would represent a minimum cost of ~$587/month [89]. A proposed comparison of these costs would be approximately $6000 for a cardiovascular-related hospitalization, $300 for additional dialysis treatment and <$100/month for each pharmaceutical medication (antihypertensive agent, phosphate binder, potassium binder), though the cost-effectiveness of these treatments may be highly variable [90–96]. Meal provision could in theory also aid with weight loss in patients with obesity and in turn improve eligibility for kidney transplantation, which could help make the approach cost effective [97]. Overall, these effects could hypothetically also improve both quality and quantity of life, a benefit that could be desired by patients, healthcare providers, dialysis providers and insurance providers alike. But all of these hypotheses should be studied in a systematic way.

**Patient receptiveness and practical considerations**

Not all individuals will be equally receptive to home-delivered meals, nor will meals be equally beneficial to all patients. An important outcome in evaluating these hypotheses will be which HD patients may need this service long term versus those that may learn to change habits when provided low-sodium meals. Meal provision could be an effective method for ‘priming’ behavior change. Priming in this context would involve providing exposure to environmental cues that may help modify long-term behavior. A small body of literature suggests that priming strategies may improve specific nutrition behaviors, but this has not been studied as a strategy to reduce dietary sodium intake, particularly in HD patients [88]. This approach could assist patients in visualizing and controlling portion sizes to further aide in dietary sodium reduction. Some studies indicate that it may take several weeks to months on a low-sodium diet to change salt sensitivity and preferences [99]. As a result, providing home-delivered low-sodium meals for a short time (~2–4 months) may help facilitate long-term changes in sodium intake and be less cost prohibitive. Nonetheless, it is important to investigate the midterm and long-term efficacy, benefits and cost-effectiveness of home-delivered meals.

Another concern with home-delivered meals is that most commercial vendors provide limited meal options that are appropriate for the ‘renal diet’, including meals low in sodium, phosphorus and potassium. The limited variety of meals may not be palatable for some patients, may not be culturally relevant, and even if they are, meal fatigue may become an issue over time. Some patients may also consume significant amounts of high-sodium foods in addition to home-delivered meals. However, Hummel et al. [29] reported 77% overall adherence with home-delivered meals and Troyer et al. [28] also reported increased adherence (reported as accordance) to the DASH diet. Another drawback is that providing meals may not help patients learn cooking skills that will help them sustain these dietary changes. An alternative approach would be to provide fresh produce, foods or meal kits in a manner similar to Goraya et al. [100] in individuals with earlier stages of CKD.

There are potential concerns that meal provision may discourage patients from taking behavioral responsibility, becoming increasingly reliant on another provider. However, provided home-delivered meals may be coupled with educational approaches to change short- or long-term behavior. Meal provision could demonstrate examples of healthy or desired dietary choices and lead to positive taste changes. These meals could also alleviate food insecurity and the regular consumption of processed or fast food [101] among patients on dialysis. Furthermore, the total calories and protein content of provided meals may be lower than recommended for HD patients. If so, these patients may simply require additional healthy snacks or oral nutrition supplements to meet energy and protein requirements, which is already common clinical practice. Finally, providing meals in this manner could have similar benefits for patients with earlier stages of CKD or on peritoneal dialysis, who often exhibit volume overload as well [102]. The reduction of sodium intake and volume-dependent hypertension in earlier stages of kidney disease could reduce cardiovascular

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**FIGURE 1:** Potential benefits of home-delivered meals in patients with CKD. This figure depicts the potential benefits of kidney-friendly home-delivered meals. Meals can be formulated to be calorie dense and high protein to prevent protein energy malnutrition and wasting. Low-sodium meals may reduce thirst and fluid intake to improve volume-dependent hypertension. Low-potassium and low-phosphorus meals could improve hyperkalemia and hyperphosphatemia, in turn improving cardiac alterations and bone mineral disorders. CVD, cardiovascular disease; CHF, congestive heart failure; CKD-MBD, chronic kidney disease—mineral bone disorder; QOL, quality of life.
risk, which contributes to the progression of CKD. By the time individuals reach end-stage kidney disease and dialysis, nearly 75% of patients present with left ventricular hypertrophy [103].

CONCLUSIONS

In summary, while the long-term efficacy of home-delivered meals in patients undergoing chronic HD needs to be evaluated, there are a number of potential benefits that make this an intriguing idea to explore. If dietary sodium can be effectively controlled, chronic volume overload may be effectively reduced and this may translate into improvements in cardiovascular-related outcomes. To date, many studies have failed to show that dietary education and counseling produce sustained changes in sodium intake in HD patients. This is not surprising, given the ubiquitous presence of sodium in our food supply and the plethora of barriers that HD patients face when trying to limit their sodium intake. Home-delivered, low-sodium meal delivery services may help HD patients overcome many of these barriers. Clinical trials, quality improvement programs and other studies need to investigate the efficacy of meal provision in HD to demonstrate this approach is a cost-effective and sustainable model to achieve sodium restriction. Importantly, low-sodium meal delivery may improve both clinical outcomes and patient quality of life, which should be welcomed by both healthcare providers and patients alike.

CONFLICT OF INTEREST STATEMENT

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