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From Infusion to Push: Implementation of an Intravenous Iron Administration Quality Improvement and Waste Reduction Initiative in the Hemodialysis Unit

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Abstract

Healthcare contributes to environmental harm, with Hemodialysis (HD) among the most resource-intensive treatments. Intravenous (IV) iron sucrose is routinely administered by infusion in HD units despite product monographs permitting direct ("push") administration. IV infusion generates avoidable plastic waste. We conducted a quality improvement initiative across a regional kidney program in Canada to switch IV iron sucrose to push administration. A literature-informed safety and workflow review, supplemented by peer experience and prospective time trial on nursing time guided implementation. Safety events, nursing feedback, and consumable waste were evaluated. The pilot period prevented 36 kg of consumable waste, with estimated annual reduction of 1,548 kg. Consumable supply costs decreased by 75% following program-wide implementation. Transitioning iron sucrose from IV infusion to IV push is safe, feasible, and well accepted in HD settings, while substantially reducing waste and costs. This initiative demonstrates how evidence-based changes to practices can support environmentally sustainable kidney care.

Introduction

Healthcare systems, dedicated to improving health, are recognized to have significant environmental impacts. The Canadian health sector has among the highest per capita healthcare emissions globally[1] and is responsible for 5.2% of national total greenhouse gas emissions.[2] Canada is one of the nearly 100 countries that has committed to low-carbon, sustainable health systems,[3] and increasingly healthcare organizations are accelerating the implementation of environmentally sustainable care as a component of healthcare quality.[4-8]

Pharmaceuticals and chemicals contribute a significant portion of total health system Greenhouse Gas (GHG) emissions,[9] comprising nearly 20% of England's National Health Service emissions.[10] Kidney care has disproportionately high environmental impacts across the spectrum of care, with in-centre Hemodialysis (HD) being one of the most resource-intensive treatments, accounting for annual emissions ranging from 2,700 to 10,200 kilograms (kg) of carbon dioxide equivalents (CO_2e) in previous studies.[11-13] Consumables are consistently one of the largest source of emissions in these studies, constituting up to 50% of HD emissions in one Australian study, responsible for 4,814 kg CO_2e annually.[12] Some of the most frequently used consumables include Intravenous (IV) tubings and minibags, which are composed of polyvinyl chloride (PVC), a type of synthetic plastic polymer. PVC is among the most carbon-intensive polymers used in healthcare, with life cycle assessments estimating emissions of 7.8 kg CO_2-equivalent per kilogram of PVC produced, driven by energy-intensive manufacturing and chlorine-based chemistry.[14]

Many pharmaceuticals, many of which have multiple dosage forms, are mainstays of HD management. Due to sterility requirements, packaging, and supplies necessary for their administration, parenteral medications have a higher environmental impact than their oral formulations, with IV infusion having a higher carbon footprint than other parenteral administration forms, such as IV direct and subcutaneous.[15,16]

Since IV iron was introduced, it has become the mainstay in adjunctive anaemia treatment in people with Chronic Kidney Disease (CKD), especially in those who undergo HD.[17] Early forms of IV iron, such as iron dextran (which was introduced in the 1950s), had significant risk of allergic reactions and other adverse events including bronchospasm, fever, hypotension, arthralgia, and flushing. As such, appropriate precautions arose regarding administration.[17-19] Reactions persisted, though less frequently, after the reformulation of iron dextran in the 1990s

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and early 2000s. Newer forms of IV iron, commonly formulated as a carbohydrate complex such as iron sucrose and ferric gluconate, have considerably improved safety profiles. Despite the lower risk of adverse events with these newer formulations, prolonged IV infusion remains the preferred method of administration in most centres.[18,20] Though iron sucrose was first approved by the U.S. Food and Drug Administration (FDA) in 2020, it had been used in other regions for much longer.[21] Nonetheless, iron sucrose is considered a newer class of IV iron that has an improved safety record.

The Canadian product monograph of iron sucrose states that a 100 mg dose can be intravenously administered undiluted over 2 to 5 minutes.[22] In facilities within British Columbia (BC), Canada, however, despite local parenteral drug therapy approval for administration by IV direct ("IV push"), a 1-hour IV infusion remains the commonest form of practice for administration of a 100 mg iron sucrose dose. IV infusion requires the injection of the pharmaceutical into a mini bag (100 millilitre (mL) of sodium chloride 0.9% most commonly), with subsequent infusion to the HD circuit via a tubing set.[23] By contrast, IV direct involves withdrawing the solution from a glass vial into a syringe.[24] As such, IV infusion, compared to IV push, incurs additional practitioner steps to administer, as well as significant supply use hence cost and plastic waste generation. We therefore aimed to review our process of administering IV iron sucrose and assess the feasibility of switching from IV infusion to IV push for better healthcare stewardship at the HD facilities of a regional health authority in BC.

Materials and Methods

This quality improvement initiative was conducted and scaled across three in-centre HD units and five community HD dialysis units (CDUs) in the health authority. Given the quality improvement nature of this study, ethics approval was not required; hence, an exemption was granted by the institutions' ethics board. The study was conducted in accordance with institutional guidelines and principles, with strict adherence to data privacy and confidentiality.

Workflow and Safety Review

A literature search regarding the safety of IV iron sucrose administration, by both infusion and push, was initially undertaken using Medline and Google Scholar (from inception to February 1, 2023) with the following keywords: iron sucrose, intravenous iron, adverse events, infusion reaction, hypersensitivity reaction, allergic reaction, anaphylaxis, intravenous infusion, and intravenous direct. Information on comparative adverse event rates between the available forms of IV iron as well as the different methods of administration were reviewed.

The experiences of two Canadian institutions with HD units where IV iron sucrose push administration had been previously implemented were sought. Renal pharmacists and nurse educators at these sites were contacted via a combination of email and video conference. Their practical experience informed our education materials and rollout planning.

A time trial was designed to capture the total active nursing time from the beginning of nurses gathering supplies to prepare for iron sucrose administration to completion of its administration and, if required, the removal of the infusion pump to a storage area. The time during the IV infusion, outside of infusion pump alarms, was excluded as nurses would not need to actively tend to the infusion pump. Given that IV push administration requires a minimum of 2 minutes,[22] with an estimated 1 minute of preparation common to both methods and an additional 1 minute to accommodate workflow variability, we established a threshold of ≥4 minutes of active infusion time to indicate that switching to IV push would not increase nursing workload.

Education, Pilot Site Selection, and Rollout

Project leadership (program leadership, nursing educators, and a clinical pharmacy specialist) were involved with the selection of the initial site for a 1-month pilot, using the following operational criteria: (1) relatively high historical IV iron utilization (to allow rapid accumulation of experience and data), (2) on-site pharmacy accessibility (for immediate troubleshooting, if necessary), and (3) a nursing leadership team supportive of practice change and education. This targeted selection facilitated close observation, rapid feedback, and efficient resolution of early implementation issues. A review of nursing satisfaction, safety events review, and medical waste reduction was planned at the end of the trial.

Education and competency supports were delivered in a multimodal fashion:

- Four in-person didactic sessions were conducted at each site by a clinical pharmacy specialist, covering literature evidence, adverse-event rates, monitoring, and step-by-step nursing procedure for IV push administration.
- Nursing huddles incorporated short practical refreshers and question and answer sessions delivered by clinical nurse educators.
- Slide decks and stepwise guides were disseminated via email and placed on the unit resource drives for asynchronous access.
- During the first 2 weeks of each site's rollout, a renal pharmacist and/or clinical nurse educator were physically present as on-site resources to support staff and address questions.

In-person didactic sessions were not mandatory, however, attendance was tracked; supplementary materials were available for those who could not attend. A brief staff survey was administered after the pilot to capture nursing acceptance, perceived workload changes, and qualitative feedback. The survey instrument is available by contacting the corresponding author.

Patients with prior precautions with iron sucrose (e.g., previous adverse reactions and special instructions for prolonged infusions) were also reviewed. A renal pharmacist and/or clinical nurse educator was always on site as resources for the first 2 weeks of the rollout for each site.

Subsequent rollout at the remaining sites was planned after the review. The education and rollout process were conducted in the same fashion as described above; however, we additionally included the experiences and results from the staff survey from the initial trial site in the subsequent rollout. All adverse events were documented and reviewed by the clinical pharmacy specialist. Rollout timeline is summarized in Figure 1.

Medical Waste and Cost Analysis

A prospective calculation of medical waste was planned at the end of the 1-month in-centre HD site pilot using chart data. Medical waste was calculated as the sum of the weight of IV tubing and minibag (Figure 2), minus the weight of the fluid inside the minibag, multiplied by the number of IV iron sucrose doses. Medical waste reduction was quantified to one year via the number of treatments received using data from the billing information from the community pharmacy partner responsible for supplying iron sucrose to the HD units, as well as from Patient Records and Outcome Management Information System (PROMIS), a provincial clinical information database used by all dialysis facilities in our province.[25] The community pharmacy partner supplies iron sucrose doses based on the iron sucrose orders documented in PROMIS, which accurately reflects any order changes for each of the patients.

Cost analysis was calculated by the billing records of the medical supplies expected to be reduced, that is, IV tubing and minibag. Cost was trended based on fiscal year.

Results

Literature Review on Safety of IV Iron Administration

Five studies (1 open-label randomized controlled trial (RCT), 4 prospective) reported on administering IV iron sucrose as push between 2 and 5 minutes; 3 studies involved HD patients, 2 studies involved pre-dialysis CKD patients.[18,26-29] The RCT was a comparison of oral ferrous sulfate and iron sucrose 200 mg IV over 5 minutes; thus, there were no studies that directly compared iron sucrose IV infusion and push. No serious adverse drug events were reported from all five studies, which are summarized in Table 1. Two epidemiological studies were also reviewed. Nathell et al., using the centralized European safety surveillance database EudraVigilance, reported severe hypersensitivity reactions to iron sucrose at a rate of 0.12 per 100,000 daily doses between 2014 and 2017.[20] Bailie et al, utilizing surveillance data from the Food and Drug Administration (FDA) between January 1997 and September 2002, reported an anaphylaxis rate of 0.0 per million 100 mg iron sucrose dose equivalents, and a rate of anaphylactoid reaction of 0.0 per million 100 mg dose equivalent.[30]

Workflow Impacts

Time trials were conducted across multiple sites from July to August 2023 with several observations collected per site. The active nursing time required for IV infusion, defined as preparation, pump setup, and takedown, ranged from 5 to 7 minutes. One outlier measurement of 10 minutes was attributed to the unavailability of an infusion pump. Based on the predefined threshold of 4 minutes of active infusion time, these observations indicated that switching to IV push would not increase nursing workload. No safety concerns were identified in the workflow review or from the two external programs consulted.

One-Month Pilot and Subsequent Rollout

A 1-month pilot was conducted at one in-centre site in November 2023 (Figure 1). At the pilot site, the majority (>60%) of day-shift nurses attended at least one live session. A total of 490 doses of iron sucrose were administered via IV push during the pilot period, which represent 100% of the doses of iron sucrose scheduled. No anaphylactic or anaphylactoid reactions were observed during this pilot. Two patients with a prior special instruction to receive iron sucrose via prolonged

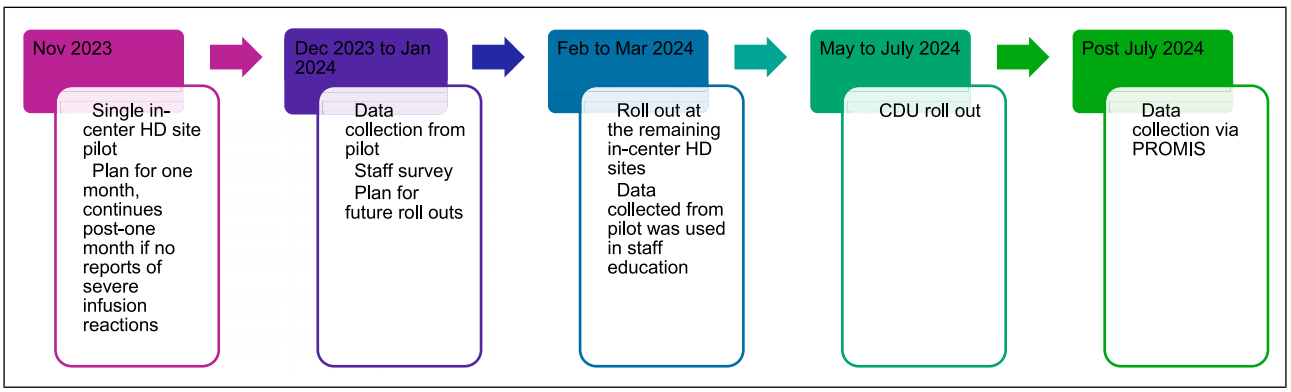

Figure 1. Roll out timeline. Abbreviations: CDU: community dialysis unit; HD: hemodialysis; PROMIS: Patient Records and Outcome Management Information System

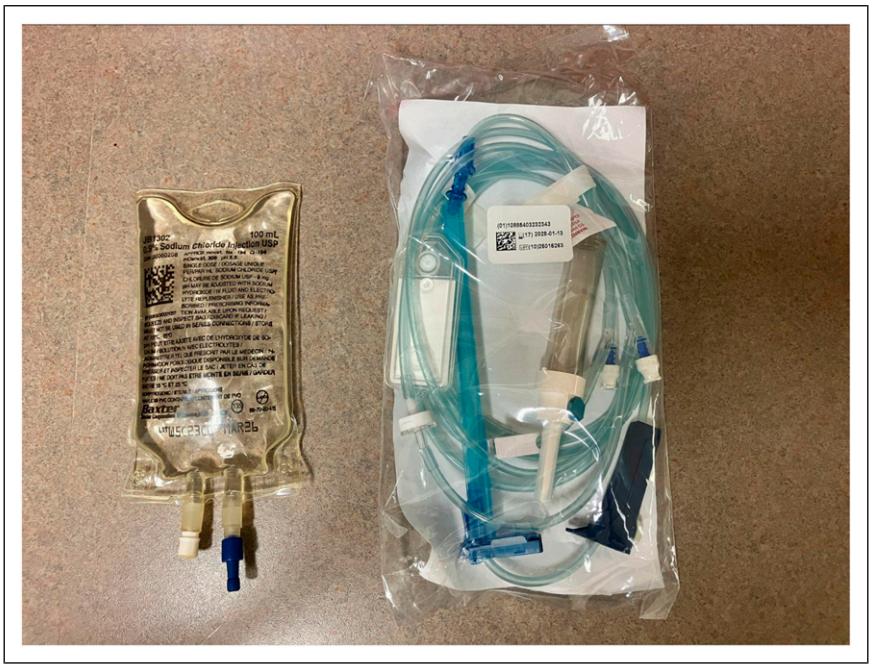

Figure 2. Intravenous infusion tubing set and sodium chloride 0.9% minibag 100 mL used in a single IV iron sucrose infusion dose

infusions (2 hours or greater) were reviewed. No history of anaphylaxis or anaphylactoid reactions to IV iron sucrose were found on these patient's charts. Both patients consented to receiving iron sucrose as IV push, and both patients tolerated the administration without incident.

Post-pilot staff survey feedback was positive. Nurses highlighted time savings, ease of administration, reduced need to obtain a clean infusion pump, and decreased plastic use as key advantages. There were questions on more detailed process of the administration through the survey, which were subsequently addressed with staff huddle and email communication. These questions from the survey also informed our roll outs in other units. After reviewing safety outcomes, workflow findings, and survey responses, the initiative was expanded. Rollout to the remaining in-centre HD sites occurred from February to March 2024, followed by implementation in CDUs from May to July 2024. Each site received the same multimodal education package and 2-week on-site pharmacy and educator support (Figure 1).

Medical Waste and Cost Analysis

A total of 36 kg of medical waste was prevented during the 1-month pilot period. Based on the yearly IV iron sucrose usage in our institution from the PROMIS database, this initiative is expected to result in reduction of 1,548 kg of plastic waste annually across our health authority.

Based on the hemodialysis units billing records, there was approximately a CAD $300,000 savings from IV tubings and minibags annually, representing 75% in cost reduction, compared with baseline scenario of all IV iron sucrose doses being administered by IV infusion, each year.

Discussion

This quality improvement initiative demonstrated that switching the IV administration of iron sucrose from infusion to push in a regional hemodialysis program was feasible, safe, and well accepted by staff, while reducing cost and a large amount of medical plastic waste. Importantly, this practice change was undertaken within existing regulatory allowances for IV push administration, and was implemented while maintaining highest standards of patient safety. With additional consideration of workflow, practice culture, institutional policy, and staff engagement, we were able to successfully shift a long-standing practice norm across multiple dialysis sites.

Implementing IV push eliminated the need for infusion tubing and minibags, resulting in a substantial reduction in medical waste and environmental impact in anemia management for patients receiving HD. The estimated annual reduction of 1,548 kg, equivalent to enough waste to fill 77 standard garbage cans, in eight HD units in one health region by this safe and accessible practice change underscores the cumulative impact that small, frequently repeated clinical processes can have on the environmental footprint of dialysis care. In addition to direct waste reduction, there are indirect sustainability gains likely occurring but not formally quantified in this project. Reduced dependence on infusion pumps may decrease the use of cleaning supplies (single use sodium hypochlorite wipes), reduce space required for consumables and IV pump storage, and reduce time spent on pump preparation and disinfection. These small operational improvements, when scaled across multiple HD shifts and sites, can meaningfully

Table 1. Summary of Studies Reporting on Iron Sucrose Push Safety

Study	IV iron dose and rate	Adverse reactions
Haddad et al. 2009 (Jordan),[29] n = 15, all HD Prospective cohort	Iron sucrose: 100 mg 5-10 min push	No reactions reported
Charytan et al. 2001 (USA),[27] n = 77, all HD Open-label, single-arm, prospective	Iron sucrose: 100 mg 5 min push. No test dose	No serious ADR, anaphylaxis, or drug discontinuation due to drug-related adverse events
Charytan et al. 2004 (USA),[42] n = 130, all HD Review	Combination of 4 prospective clinical trials with iron sucrose (includes Charytan, 2001 study): 3 studies—100 mg IV 5 min push or over 15-30 min 1 study—100 mg IV 2 min push or 200 mg over 5 min Median cumulative dose received: 1,000 mg, no test dose	No serious ADR 14 non-serious ADR in 8 patients attributed to iron sucrose, none which resulted in discontinuation of therapy • Severe diarrhoea: 1 • Moderate nausea: 2 • Moderate hypotension: 1 • Mild taste disturbances: 3 • Moderate vomiting: 1 • Constipation, dry mouth, and skin irritation: 1 • One patient experienced 7 of these events, yet nevertheless was able to tolerate continued iron sucrose therapy
Charytan et al. 2005 (USA),[28] N = 96 open-label RCT, CKD non-HD	Ferrous sulfate PO 325 mg TID vs. iron sucrose 200 mg IV over 5 min weekly (total 5 doses) x 1 month	Patients were assessed up to 14 days from last dose of intervention medication: • Frequent of AEs similar in both groups • GI AEs more common in PO vs. IV: Constipation, 35.4 vs. 12.5% Nausea, 10.4 vs. 4.2% Vomiting, 8.3 vs. 0% Diarrhoea, 6.3 vs. 0% • Taste disturbances more common in IV vs. PO (8.4 vs. 0% oral) • No serious AEs or deaths • No hypersensitivity reaction, treatment-related hypotension, or required slowing of the rate of IV drug administration
MacDougall et al. 2006 (UK),[18] n = 657 (total of 2297 doses administered), all CKD non-HD Prospective cohort	Iron sucrose: 200 mg 2 min push	Transient metallic taste: 17.9% No case of phlebitis Acute anaphylactoid reaction: 7 in 2,297 injections; 5 episodes received hydrocortisone, diphenhydramine, and metoclopramide; 2 episodes resolved spontaneously after 10 and 20 min
Van Wyck et al. 2000 (USA),[26] n = 23, all HD Open-label, single-arm, prospective	Iron sucrose: 100 mg 5 min push. No test dose These pts had a previous severe reaction to iron dextran (but not anaphylaxis)	No serious adverse drug reactions, anaphylaxis, withdrawals, or drug discontinuation Three adverse events: metallic taste (2 events in 1 patient) Pruritus: 4, in 1 patient it resolved by switching to infusion; the other 3 had pruritus in pre-administration period Hypotensive episodes: 8 patients in treatment period; all deemed not related to iron sucrose

Abbreviations: ADR: adverse drug reactions; AEs: adverse events; CKD: chronic kidney disease; GI: gastrointestinal; HD: hemodialysis; IV: intravenous; PO: orally; RCT: randomized controlled trial; TID: three times daily.

contribute to workflow efficiency, staff satisfaction, and resource stewardship.

In addition to environmental benefits, this practice change was associated with substantial direct cost savings related to reduced use of consumables. Based on billing data for IV minibags and IV infusion tubing, total annual expenditures decreased by 75%. These estimates reflect only direct costs captured within the kidney program budget and do not include potential downstream savings related to reduced cleaning supply use or changes in infusion pump utilization; the reported cost savings are therefore likely conservative. Taken together, these findings support that environmentally

sustainable practice changes can align with both environmental stewardship and cost containment, particularly when targeting high-volume, single-use consumables in routine care.

Our findings also reinforce existing literature showing that newer formulations of IV iron, such as iron sucrose, have a favourable safety profile and a low incidence of serious hypersensitivity reactions, including when administered as IV push. While evidence supporting safe IV push administration predated our initiative, the demonstration of real-world safety within our own program helped build staff confidence while addressing concerns rooted in historical experiences with older iron formulations. This highlights how perceptions of risk may persist even when underlying evidence evolves, and how structured education combined with local validation can facilitate practice change.

Beyond safety and workflow considerations, this initiative contributes to an emerging body of work examining the environmental impact of medication administration practices. Although environmental impact assessments in nephrology have largely focused on dialysis consumables, water use, and energy requirements,[12] pharmacy-related emissions are increasingly recognized as a major contributor to healthcare's carbon footprint.[31-33] A recent scoping review on existing environmental sustainability interventions in nephrology had noted pharmaceuticals stewardship being underexplored compared to water or energy efficiency.[34] Our findings illustrate how reviewing routine medication processes through a sustainability lens can reveal targeted opportunities for reduction in materials use, waste generation, and downstream resource requirements, without requiring new technologies or significant capital investment.

Our estimated annual waste reduction of 1,548 kg of waste, based on an estimated emission of 7.8 kg CO_2-equivalent per kilogram of PVC produced, would equate to a reduction of 12,074 kg CO_2-equivalent of carbon emission. In addition, plasticisers used in PVC to improve flexibility remain a significant risk for patients and the environment.[35] Phthalate plasticisers may leach into the human body and the environment, and studies have shown phthalates can impair human placental function, disrupt the endocrine system, gives rise to transgenerationally inherited reproductive defects, and many other effects throughout the lifespan.[36] Although recycling can reduce the carbon footprint of PVC products, effective recycling pathways for contaminated medical plastics remain limited in most healthcare systems. By eliminating the routine use of PVC-based tubings and minibags for iron sucrose administration, this practice change represents a targeted, upstream approach to reducing both plastic waste and the carbon emissions embedded within routine HD care.

This work is aligned with broader strategic efforts within BC Renal, and similar movements internationally,[37-41] highlighting a growing global consensus that environmental stewardship should be embedded within standard renal practice. Yasar et al. emphasized the urgency to incorporate sustainability into routine nephrology care and to share sustainability practice improvements between care networks to broadly enhance uptake, thereby accelerating the transition to sustainable and low-carbon health systems.[34]

Limitations

Our initiative is not without limitations. As mentioned above, we were unable to quantify several indirect forms of waste reduction, such as the decreased use of wipes, gloves, and cleaning products resulting from reduced pump cleaning, or staff time saved from less equipment handling. We plan a dedicated assessment of these processes by life cycle assessment. Additionally, although staff feedback was positive, our assessment of nursing experience relied on a short post-pilot survey and did not include a detailed time and motion analysis or long-term follow-up. Patient perspectives were also not systematically captured, and future work should explore patient experience, preferences, or perceived differences in care. While our safety findings in the real-world setting were reassuring, our sample size remains insufficient to estimate extremely rare events, and continuous monitoring is ongoing. Finally, although the intervention was a simple change in route of medication administration, implementation was time consuming. Successful adoption required considerable change management, organizational readiness, and coordination among program leadership, nursing educators, frontline staff, and pharmacy, as well as the development and delivery of education, workflow assessment, and ongoing on-site support. These considerations may pose challenges for smaller programs with more limited infrastructure, underscoring the importance of sharing implementation strategies and lessons learned to support broader adoption of sustainability-focused practice improvements.

Implications for Leaders

Health leaders have an important role in identifying opportunities where evidence-based practice changes can simultaneously improve environmental sustainability, operational efficiency, and resource stewardship. This quality improvement initiative demonstrates that transitioning iron sucrose from IV infusion to IV push can be implemented safely and feasibly across diverse hemodialysis settings while reducing consumable waste and costs. By aligning clinical evidence with operational practice, the project illustrates how environmentally informed prescribing can advance sustainability without compromising patient safety, workflow, or staff acceptance. Future directions include broader application of environmentally informed prescribing principles to other parenteral medications used in dialysis units, life cycle assessments to quantify greenhouse gas impacts of specific medication workflows, and integration of environmental metrics into routine quality dashboards. Collectively, these strategies foster a culture that embraces environmental stewardship as an integral component of both patient care and operational practices.

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Ethical Approval

Given the quality improvement nature of this study, ethics approval was not required, hence an exemption was granted by the institution's ethics board.

Author Contributions

All authors contributed to the study conception, design, and manuscript draft. Final approval of the manuscript was approved by all authors.

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Declaration of Conflicting Interests

The authors declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: CS is the medical lead for the BC Renal Planetary Health committee (remunerated role), the chair of Canadian Society of Nephrology Sustainable Nephrology Action Planning committee (nonremunerated role), and a member of the International Society of Nephrology GREEN-K Steering committee (nonremunerated role).

Data Availability Statement

The data that support the findings of this study are available upon reasonable request from the corresponding author, Ada Chiu. The data are not publicly available due to patient confidentiality and privacy restrictions.

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