Carbon Emissions From Different Dialysis Modalities: A Life Cycle Assessment

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Rationale & Objective: As the health impacts of climate change intensify, the health care sector faces growing pressure to minimize its carbon footprint. Achieving this goal requires understanding of the carbon impact of widely used medical treatments. This study evaluated and compared the carbon footprints of in-center hemodialysis, home hemodialysis, automated peritoneal dialysis (APD), and continuous ambulatory peritoneal dialysis (CAPD).

Study Design: Comparative life cycle assessment.

Setting & Participants: In-center hemodialysis, home-based hemodialysis, CAPD, and APD treatments provided by the Royal Melbourne Hospital Kidney Care Service, Melbourne, Victoria, Australia.

Outcome: Carbon emissions in kilograms of carbon dioxide equivalents (kg CO_2e) from the annual provision of dialysis to a single patient.

Analytical Approach: Attributional process-based comparative life cycle assessment methodology was used to identify the sources and extent of carbon emissions for all dialysis modalities.

Results: In-center hemodialysis had the highest annual per patient carbon impact, at 4,814 kg CO2e. In comparison, emissions from home hemodialysis were 41% lower (2,938 kg CO2e), APD 29% lower (3,339 kg CO2e), and CAPD 59% lower (1,969 kg CO2e). Across all 4 modalities, consumables were the largest source of emissions. For in-center hemodialysis, patient travel was the main factor contributing to its higher carbon footprint compared with home-based dialysis options.

Limitations: Single dialysis provider in an urban setting.

Conclusions: In-center hemodialysis has a substantially higher carbon footprint than all home dialysis options, informing the choice of home dialysis when feasible and appropriate for individual patients.

Visual Abstract online

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In recent years, the world has witnessed increasingly severe and frequent climate-related extreme weather events with devastating effects on human health and livelihoods.[1-4] Paradoxically, health care itself is responsible for approximately 5% of annual global carbon emissions,[5] which is nearly 3 times greater than emissions from all aviation.[6] Health care is thus one of the most carbon-intensive service sectors in the industrialized world[7] and a major contributor to climate change.

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Recognizing the urgent need for health care to reduce its emissions, 84 countries have formally committed to developing low-carbon health systems, with 43 of these pledging to achieve net-zero emissions by 2050.[8] To date, however, limited research has been conducted on the carbon impacts of clinical care, making informed decisions about lower carbon alternatives challenging.

Recent estimates suggest dialysis for kidney failure is undertaken by over 3 million people globally, with this number likely to nearly double by 2030.[9] The vast majority of individuals receiving dialysis do so in health care facilities, but there is a growing push toward home-based care—both home hemodialysis and peritoneal dialysis (PD)—due to potential improvements in health, well-being and quality of life, and budgetary concerns.[10] However, no comparative studies have been conducted on the carbon footprints of these modalities.

Accordingly, this study compared the carbon impacts associated with all the currently used dialysis modalities, namely, in-center (facility-based) hemodialysis, home hemodialysis, automated peritoneal dialysis (APD), and continuous ambulatory peritoneal dialysis (CAPD).

Methods

Overview of Methods

Life cycle assessment quantifies carbon emissions associated with the whole life cycle of products, processes, or services from raw material extraction through to disposal at end of life (the grave) (Fig 1). The method to conduct and report life cycle assessments has been internationally standardized (ISO 14040-44), with these standards in turn forming the foundation of major carbon footprinting standards and protocols.[11] We used attributional process-based life cycle assessment in accordance with ISO14040:2000[12] to identify the source and extent of carbon emissions for all dialysis modalities.

Study Design and Outcome Measure

The functional unit of the life cycle assessment was the annual provision of dialysis to a single patient. The system boundary, showing the study inclusions and exclusions, is

PLAIN-LANGUAGE SUMMARY

As climate change intensifies, there is growing pressure on health care systems to reduce their greenhouse gas emissions. To do this effectively, it is important to understand the carbon footprint of different treatment options and identify key areas where emissions are highest. This study compared greenhouse gas emissions from 4 types of dialysis: hemodialysis performed in a health care facility (in-center hemodialysis), home hemodialysis, automated peritoneal dialysis (APD), and continuous ambulatory peritoneal dialysis (CAPD). We found that in-center hemodialysis had the highest carbon footprint, primarily due to the impact of patient travel. Among the home therapies, APD was responsible for higher emissions than home hemodialysis while CAPD had the lowest carbon footprint. Across all treatment types, consumables were the largest source of carbon emissions.

shown in Figure 2. The study excluded both facility and home heating and cooling to make the results generalizable to any location or time of year. The impacts of manufacturing the reverse osmosis generator and the hemodialysis and APD machines were also excluded because detailed information on their respective components was not available. Additionally, this equipment is long-lasting, so the carbon footprint associated with its manufacture was assumed to be minimal when distributed across individual treatment sessions (<2% of the total carbon footprint).[13] The primary outcome was carbon emissions in kilograms of carbon dioxide equivalents (kg CO_2e).

Data Collection and Study Setting

All data were collected between December 2019 and August 2024. Dialysis treatment-related consumable use was recorded for a convenience sample of 16 patients receiving in-center hemodialysis, 10 patients receiving home-based hemodialysis, and 5 patients each receiving CAPD, and APD, all managed by the Royal Melbourne Hospital (RMH) Kidney Care Service in Melbourne, Victoria, Australia. Both hemodialysis and PD consumables were supplied by Baxter Healthcare. The in-center hemodialysis data were obtained via direct observation of treatments, and the home hemodialysis and PD data were obtained through the examination of medical records and supply inventories. All consumables used and their associated packaging were analyzed to determine their material compositions and weighed using a Testel electronic scale with a resolution of 0.01g.

Aggregated consumable usage for hemodialysis and PD treatments is shown in Tables S1-S4. This was used to determine an "average" treatment for each modality (Table 1), with all data assumptions available in Tables S5-S9.

For hemodialysis salts and concentrates, ion concentrations were modeled using publicly available Baxter data sheets.[14] For PD fluids, data on the total mass of water, sugars, and salts used when manufacturing each formulation were obtained from Baxter Healthcare.

Information regarding the makes and models of dialysis equipment used for in-center and home hemodialysis and APD are shown in Table 2. Within the in-center hemodialysis facility, power usage of central reverse osmosis generator was obtained using a Hioki PW3365-20 3-phase power logger, with a measurement obtained every 15 minutes for a period of 2 weeks, as detailed elsewhere.[15] Water usage by the reverse osmosis plant was measured via a water meter installed into the incoming cold-water supply, also over 2 weeks. For the single-phase power usage of the in-center hemodialysis machines, 4 were sampled over 2 weeks using a Cabac Power-Mate PM10AHDS, with a measurement obtained every minute. Power usage by the home hemodialysis machine and reverse osmosis generator and the APD machine were measured from a single piece of each equipment using a Watts Up Pro power meter (Vernier) connected to Logger Pro 3.14.1.0 (Vernier), with a measurement obtained every 30 seconds for a period of 5 days. Additional measurements were undertaken to determine the impact of reducing the dialysate flow rate to 300 mL/min (the rate used during extended-hour home hemodialysis) on machine power usage. Water consumption by the home hemodialysis reverse osmosis generator was obtained from manufacturer data.

For overseas shipping of consumables, distances between seaports were obtained from sea-distances.org. Google Maps was used to calculate road distances from ports to state warehouses and dialysis facilities (for in-center hemodialysis) and patient homes (for home hemodialysis, APD, and CAPD), with patient postcodes obtained from the Australia and New Zealand Dialysis and Transplant Registry.[16] Google Maps was also used to calculate distances traveled by patients to receive in-center hemodialysis.

Data Analysis

For the primary analysis comparing the carbon impact of the 4 dialysis modalities, both in-center and home hemodialysis were assumed to occur via arteriovenous fistulae over 4 hours, 3 times a week, with a dialysate flow rate of 500 mL/min. Both APD and CAPD were assumed to occur daily, with APD using 14 L of fluid (12 L of 2.5% dextrose and 2 L of icodextrin) and CAPD using 8 L of fluid (6 L of 2.5% dextrose and 2 L of icodextrin). These regimens were selected because they were the most commonly used by the RMH Kidney Care Service.

We also examined the impacts of 4 alternative home hemodialysis regimens: 3 times per week dialysis for 6 hours with a dialysate flow rate of 300 mL/min; alternate daily dialysis for 4 hours with a dialysate flow rate of 500 mL/min; alternate daily dialysis for 8 hours with a flow rate of 300 mL/min; and 6 nights per week of dialysis for 8 hours, also with a flow rate of 300 mL/min.

Additionally, because patients receiving home-based dialysis through the RMH Kidney Care Service generally

Figure 1. Stages of a life cycle assessment.

live farther from metropolitan Melbourne than those treated in-center, we conducted a sensitivity analysis excluding individuals living more than 100 km away. This approach allowed for a comparison of carbon emissions between the therapies while minimizing the confounding impact of distance.

The life cycle inventory of the energy and transport used and the weights and compositions of all consumables was modeled using SimaPro 9.4 LCA software (PRé Sustainability). Background data containing the carbon emissions of all the individual materials in the life cycle inventory such as plastics, salts and sugars were obtained from the APOS version of the ecoinvent 3.10 APOS database (Ecoinvent)[17] and AusLCI 2.2 database for Australian specific emissions.[18] The impact assessment method used was SimaPro's 2021 Intergovernmental Panel on Climate Change (IPCC) 100-year global warming potentials.

Ethics

Project approval was obtained from the Melbourne Health Human Research and Ethics Committee.

Results

The annual per-patient carbon impact and source of emissions for each modality are shown in Table 3 and Figure 3. Emissions were highest for in-center hemodialysis (4,814 kg CO_2e). Comparatively, the carbon impact of home hemodialysis was 41% lower (2,835 kg CO_2e), APD was 29% lower (3,339 kg CO_2e), and CAPD was 59% lower (1,969 kg CO_2e). The equivalent emissions from driving a passenger car are shown in Table 3.

Across all dialysis modalities, consumables were the largest source of emissions. For in-center hemodialysis, patient transport had the second highest impact; for home hemodialysis, it was the electricity consumption of dialysis equipment. For both APD and CAPD, the second-largest contributor was the transport of consumables from manufacturing sites to patients' homes.

Scenario Analyses

The impact of alternative home hemodialysis regimens compared with a 3 times per week 4-hour regimen with dialysate flow rate of 500 mL/min are shown in Table 4. Increasing the treatment frequency to alternate days resulted in a 17% (499 kg CO_2e) increase in emissions. Reducing the dialysate flow rate to 300 mL/min reduced hemodialysis machine power usage by 0.035 kW per hour, or 0.14 kWh over a 4-hour treatment session. Extending the treatment duration to 6 hours with dialysate flow rate of 300 mL/min increased the carbon footprint by 2% (kg CO_2e) from the standard regime. Maintaining a

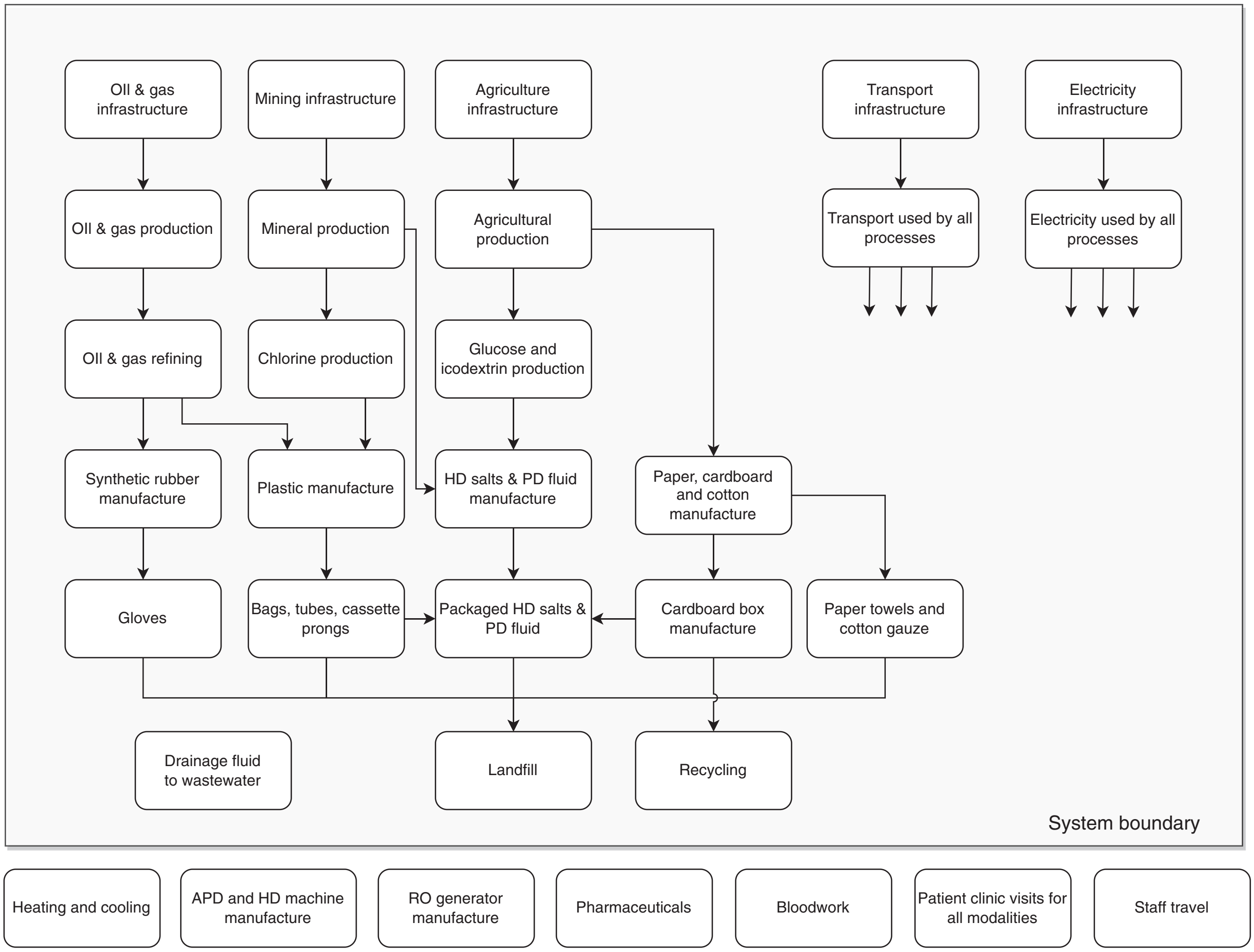

Figure 2. System boundary, showing included and excluded processes. Abbreviations: APD, automated peritoneal dialysis; HD, hemodialysis; PD, peritoneal dialysis; RO, reverse osmosis.

dialysate flow rate of 300 mL/min but increasing treatment frequency to alternate days resulted in a 17% (499 kg CO_2e) increase. Alternate daily treatments for 8 hours led to a 24% (695 kg CO_2e) increase whereas the 6-nights-per-week, 8-hour regimen resulted in a 112% (3,274 kg CO_2e) increase above standard 3 times per week 4-hour dialysis with a flow rate of 500 mL/min.

Sensitivity Analysis

In-center hemodialysis patients lived an average of 14.5 km from the dialysis unit (range: 1-41 km) whereas 52 of the 94 PD patients (55%) and 20 of the 63 home hemodialysis patients (32%) lived more than 100 km away (PD range: 120-678 km; home hemodialysis range: 104-539 km). When individuals who lived more than 100 km away were excluded from the calculations, the carbon footprint of APD, CAPD, and home hemodialysis decreased to 2,913 kg CO_2e, 1,684 kg CO_2e, and 2,804 kg CO_2e, respectively. This represents reductions of 39%, 65%, and 42%, respectively, compared with in-center hemodialysis.

Discussion

To our knowledge, this study is the first to compare the carbon footprint of all currently available dialysis modalities. It demonstrated a substantially higher carbon footprint from in-center hemodialysis compared with home hemodialysis (using the same prescription) and both forms of PD. Among the home-based options, APD had higher emissions than home hemodialysis, and CAPD had the lowest carbon impact.

The greater carbon footprint of in-center hemodialysis was primarily driven by patient travel, which accounted for 36% of total emissions—nearly 18 times the emissions associated with transporting consumables to patients for home hemodialysis. Emissions from electricity were also significantly greater, almost 2-fold higher than for home hemodialysis and 4-fold higher than for APD. The higher emissions from APD compared with home hemodialysis were due to the greater carbon impact of the fluids and consumables as well as their transport. APD was responsible for higher emissions than CAPD due to the electricity

Table 1. Consumable Usage for the "Average" Treatment Session for Each Dialysis Modality

In-Center Hemodialysis	Home Hemodialysis
Bloodline (Novaline)	Bloodline (Novaline)
Dialyser (Polyflux 210H)	Dialyser (Polyflux 210H)
Bicart	Bicart
C298 Softpac	C298 Softpac
Fistula pack	Fistula pack
0.5 × CleanCart	CleanCart
1,000 mL saline	2 × 1,000 mL saline
2 × injection pad	2 × injection pad
200 cm Yu-ki ban tape	100 cm Yu-ki ban tape
2 × plastic apron 10 × nitrile gloves 2 × 10 mL Saline vial	—
2 × 10 mL syringe	—
2 × 18 g drawing up needle	—
2 × paper towel	—
Yellow bag	—
2 × chlorohexidine swab	—
10 × Clinell wipe	—
Bluey	—
Cotton wool ball	—
Total consumable weight: 6.4 kg	*Total consumable weight:* 7.3 kg

APD	CAPD
2 × 6 L dextrose solution 2.5%	3 × 2 L dextrose solution 2.5%
1 × 2 L icodextrin solution	1 × 2 L icodextrin solution
C15 L cycler drainage bag	—
HomeChoice Automated PD Set	—
Minicap with povidone-iodine	4 × Minicap with povidone-iodine
Opticap	—
10 × paper towel	20 × paper towel
50 cm Yu-ki ban tape	100 cm Yu-ki ban tape
Primapore dressing	Primapore dressing
2 × cotton gauze	5 × cotton gauze
Total consumable weight: 15.7 kg	*Total consumable weight:* 9.2 kg

Abbreviations: APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; PD, peritoneal dialysis; RO, reverse osmosis.

usage by the APD machine, higher fluid and consumable requirements and thus carbon impacts, and the greater mass of APD consumables, resulting in greater transport emissions.

Table 2. Dialysis Equipment

Equipment	Make and Model
In-center RO plant	Two Gambro CWP800R01 RO units in series
In-center hot water unit	Gambro CWP800HW
Home HD RO units	Gambro WRO300H
HD machines (in-center and home)	Baxter AK98
APD machines	Baxter Homechoice Claria

Abbreviations: APD, automated peritoneal dialysis; HD, hemodialysis; RO, reverse osmosis.

Six previous studies have examined the carbon impact of in-center hemodialysis, reporting annual emissions estimates ranging from 3,800 to 10,200 kg CO_2e.[19-24] However, comparing these studies is challenging due to differences in both the emissions contributors considered and the life cycle assessment methodologies used. For instance, 2 of the studies included the carbon impact of pharmaceuticals,[19,23] and the others, including ours, did not. One study considered the total electricity usage of the facility rather than just the electricity consumed by dialysis equipment,[22] and 3 used economic costs instead of material components to estimate certain emissions,[9-21] relying on environmentally extended input-output (EEIO) models, which generally yield less reliable estimates.[25] Our estimate of 4,814 kgCO_2e is considerably lower than a previous estimate from an Australian dialysis center (10,200 kgCO_2e)[19]; however, pharmaceuticals (calculated using EEIO) were the largest contributor to total greenhouse gas emissions in the earlier study (37%), and these were excluded from our estimate.

Home hemodialysis offers patients greater autonomy over their treatment, along with lifestyle benefits such as flexible scheduling and treatment duration. Limited trial data also suggest that longer or more frequent dialysis sessions—most easily facilitated in the home setting—may provide clinical benefits, although the evidence remains mixed.[26] To date, only 1 other study has assessed the carbon footprint of home hemodialysis. Conducted in the United Kingdom over a decade ago, it reported annual per-patient carbon emissions ranging from 3,900 to 7,200 kg CO_2e, depending on the treatment regimen.[21] Consistent with our findings, treatment frequency had a greater carbon impact than duration, primarily due to increased consumable use.

In our study, extending treatment length to 6 hours resulted in a 2% increase in the annual carbon footprint if the dialysis flow rate was simultaneously reduced to 300 mL/min. By contrast, alternate-day home hemodialysis led to a 17% increase. Meanwhile, a regimen of 6 nights per week at 8 hours per session—a 4-fold increase in treatment hours compared with the standard—resulted in just over double the carbon footprint. This discrepancy between treatment hour increases and carbon footprint highlights that longer treatment durations can be achieved with a relatively smaller increase in carbon emissions. This information could support more environmentally sustainable dialysis prescriptions, while still accommodating patient care needs.

There is a similar paucity of data in the literature regarding the carbon footprint of PD. A study from the People's Republic of China showed that CAPD was responsible for 1,400 kg CO_2e emissions annually;[27] however, the impacts of PD fluid and consumable transportation from manufacturer to recipient were not included. Our group previously showed that the carbon impact of PD can vary significantly depending on transport distances,[13] with related emissions accounting for up to

Table 3. Annual Carbon Impact for Each Dialysis Modality

	In-Center Hemodialysis kg CO_2e	Home Hemodialysis kg CO_2e	APD kg CO_2e	CAPD kg CO_2e
RO electricity	499 (10.3%)	277 (9.8%)	—	—
Dialysis machine electricity	320 (6.6%)	170 (6%)	191 (5.7%)	—
Consumable manufacture and disposal	2,213 (46.0%)	2,292 (80.8%)	2,152 (64.4%)	1,351 (68.6%)
Patient transport	1,764 (36.6%)	—	—	—
Consumable transport	18 (0.37%)	96 (3.4%)	1,055 (31.6%)	618 (31.4%)
Total kg CO_2e	4,814	2,835	3,339	1,969
Passenger car km[a]	12,305	7,247	8,688	5,033

Values are percentage of total unless otherwise indicated. The higher RO plant electricity use in-center is due to the lower efficiency of the centralized RO system compared with the individual RO units used at home. Dialysis machine energy consumption is higher in-center because the machines remain switched on for extended periods to accommodate multiple patients throughout the day and more frequent machine disinfections. Abbreviations: APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; kg CO_2e, kilograms of carbon dioxide equivalent emissions; RO, reverse osmosis.
[a]From Ecoinvent: Transport, passenger car, medium size EURO 4[17] | market for| APOS, U.

50% of PD's total footprint when distances are large. We have also demonstrated the large carbon savings achievable using incremental PD prescriptions,[13] where appropriate and in keeping with International Society of Peritoneal Dialysis guidelines.[28]

In this study, we conducted a sensitivity analysis excluding home dialysis patients residing far from metropolitan Melbourne. This approach allowed for a direct comparison between in-center and home-based dialysis therapies, minimizing the confounding influence of outliers. Our analysis revealed that the carbon footprint of home hemodialysis was 41% lower than in-center hemodialysis and the carbon impacts of APD and CAPD were 29% and 59% lower, respectively. These findings provide valuable insights for patients and clinicians in urban areas, supporting informed decision making regarding treatment modality.

Consistent with other health care carbon footprint studies,[20,29,30] we show that for all dialysis modalities the majority of the carbon footprint derives from the supply chain, specifically from the consumables used during treatments. This underscores a critical need for "green procurement," which involves prioritizing the purchase of goods with minimal environmental impact. To facilitate this shift, the kidney care community must demand that suppliers publicly disclose the carbon intensity of their products, enabling easy comparisons. Additionally, there should be a greater emphasis on environmental sustainability in the evaluation criteria for purchasing decisions and advocacy for innovation to develop more environmentally friendly consumables. We previously showed that significant carbon savings may be achievable in dialysis through polyvinyl chloride recycling.[13]

Strategies to address the substantial travel emissions associated with in-center hemodialysis should include encouraging patients to use public and active transport and engage in carpooling. To enable this, new hemodialysis facilities should be integrated with urban planning to ensure accessibility and sustainability. Additionally, there is a need for broad investment in zero-emission vehicles, both for personal use and across the commercial transport and health care sectors. For the emissions associated with

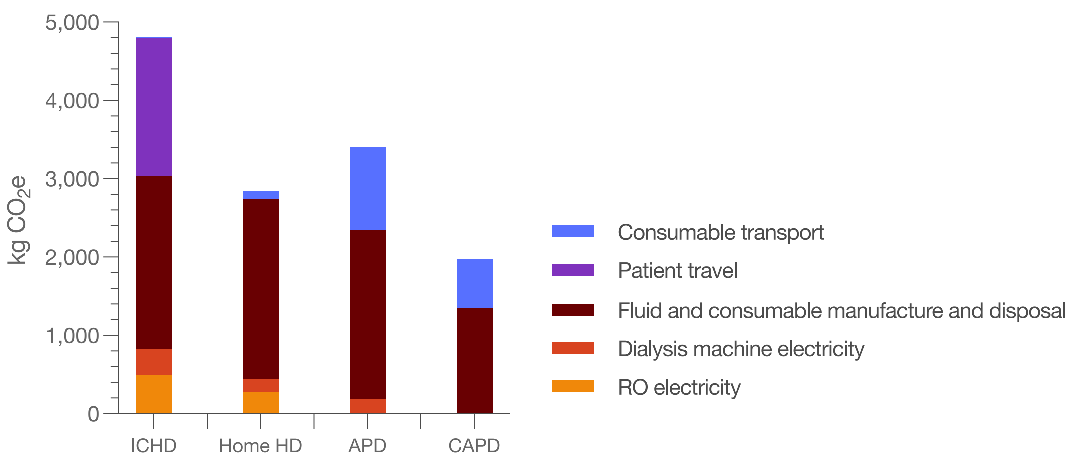

Figure 3. Annual carbon impact, in kg CO_2e, for each dialysis modality. Abbreviations: APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; HD, hemodialysis; ICHD, in-center hemodialysis; kg CO_2e, kilograms of carbon dioxide equivalent emissions; RO, reverse osmosis.

Table 4. Impact of Different Home Hemodialysis Treatment Regimens

Scenario	Annual kg CO_2e	Additional kg CO_2e (% Change Compared With Standard)
Standard: 3 times/wk for 4 h; Qd 500 mL/min	2,835	—
3 times/wk for 6 h; Qd 300 mL/min	2,903	68 (2%)
Alternate days for 4 h; Qd 500 mL/min	3,317	482 (17%)
Alternate days for 8 h; Qd 300 mL/min	3,513	678 (24%)
6 nights/wk for 8 h; Qd 300 mL/min	6,006	3,171 (112%)

Abbreviations: kg CO_2e = kilograms of carbon dioxide equivalent emissions; Qd = dialysate flow rate.

the transport of PD consumables to patients, novel dialysis systems with point-of-care dialysate generation offer a significant opportunity.[31,32]

A zero-cost way to reduce emissions from electricity use in hemodialysis is to optimize the operation times of reverse osmosis plants and the disinfection schedules of hemodialysis machines.[33] Additionally, priority should be given to purchasing the most energy-efficient equipment during upgrades; for stand-alone hemodialysis facilities, local solar power generation should be considered. Beyond these measures, the impact of electricity use should gradually decrease to zero over time by virtue of energy system decarbonization (renewable electricity generation). Once this occurs, the difference in carbon emissions between home hemodialysis and APD compared with CAPD will narrow.

Our study has several limitations. We modeled a single dialysis provider in an urban setting, including in-center and home hemodialysis and PD. Due to variations in dialysis equipment, consumable usage, and energy sources between providers, our data may not be generalizable to other health care settings or dialysis providers either in Australia or internationally.

The transport impacts observed in this study are influenced by the local manufacture of PD fluids by Baxter in Australia and our country's geography. Different impacts would be expected if fluids were manufactured overseas and in countries with shorter distribution distances. Similarly, the patient travel impact in our study is specific to the local context, where the dialysis facility serves patients across a relatively broad geographic area.

The carbon impact of medication use was not included due to lack of available proprietary data. This means our results are likely an underestimate, given the major contribution of the pharmaceutical sector to carbon emissions,[29] but this is likely to affect all dialysis modalities equally in our analysis.

We excluded emissions from the production, installation, and maintenance of hemodialysis and APD machines. Notably, hemodialysis machines serve multiple patients in-center but only 1 patient at home. Manufacturer guidelines for machine replacement differ, but in some cases they specify that machines are replaced after a set period (eg, 7 years), regardless of prior operational hours. If this impact were included in carbon footprint calculations, the carbon benefit of home hemodialysis over in-center hemodialysis would be reduced. Similarly, including the carbon impact of APD machine manufacture would increase the carbon impact of APD relative to CAPD. This said, as noted earlier, because dialysis machines have a long life span, the bias introduced is likely to be minimal when distributed across individual treatment sessions.[13]

We excluded facility heating and cooling from the system boundary because our goal was to assess the carbon impact of dialysis procedures rather than the building's energy use and to ensure our results were generalizable to other climates and times of year. However, it is worth noting that if facility heating and cooling had been included, in-center hemodialysis would have further emerged as the kidney replacement therapy with the highest carbon impact.

We did not assess the impact of hemodiafiltration or central venous catheter use. No prior studies have addressed the differential carbon impact of these factors, but we suspect that the carbon impact of a central venous catheter—a single piece of plastic—would be low. By contrast, hemodiafiltration may incur a higher carbon footprint than hemodialysis due to the additional requirements for replacement fluid and tubing for its infusion.

Including routine clinical visits supplementary to the provision of dialysis and the resulting patient travel required were beyond the scope of this analysis and were assumed to be equal between modalities. This said, it is feasible that some clinical assessments could, and should, be coordinated with dialysis visits for those receiving in-center treatment, thus reducing associated travel emissions. For in-center dialysis, we extrapolated travel distances using ANZDATA records and assumed all travel was by car, without conducting individual patient travel surveys to identify alternative modes of transport.

Finally, we did not include the noncarbon environmental impacts of dialysis provision in our analysis. Expanding future research to encompass these factors will be essential for gaining a more comprehensive understanding of, and ultimately mitigating, the environmental footprint of dialysis.

To note, using our data as a proxy, we estimate that all forms of dialysis account for approximately 0.3% of health care–related emissions in Australia, based on the 15,518 patients currently receiving treatment.[34] Although this represents a small percentage, the impact remains significant due to projected growth in dialysis populations both in Australia and globally,[9,35] and because dialysis stands out as one of the most resource-intensive health care interventions on a recurrent per capita basis.[36] Furthermore, our data suggest that receiving dialysis increases the average Australian individual's CO_2 emissions by 20%-35%,[37] which is substantial.

In conclusion, in-center hemodialysis is responsible for higher carbon emissions than all the home-based dialysis options. Of the home therapies, APD is more carbon intensive than home hemodialysis, and CAPD has the lowest footprint. The choice of dialysis modality should always be grounded in shared decision making between patients, caregivers, and health care providers, guided by the patients' clinical condition and other key factors such as their preference for independence, proximity to a dialysis center, transplantation prospects, and available resources.[38] However, when combined with knowledge that home-based dialysis can provide comparable survival rates and improved quality of life to in-center dialysis, often at lower cost,[10,39] our study provides additional rationale for prioritizing home dialysis where feasible. Indeed, our findings underscore the need for practice and public policy changes to promote growth in the relative amounts of home versus in-center dialysis use in Australia and elsewhere to support the health care sector's transition toward net-zero carbon emissions.

Supplementary Material

Supplementary File (PDF)

Table S1: Consumables used per session for in-center hemodialysis, n = 16 patients.

Table S2: Consumables used per session for home hemodialysis, n = 10 patients.

Table S3: Consumables used per session for APD, n = 5 patients.

Table S4: Consumables used per session for CAPD, n = 5 patients.

Table S5: Life cycle inventory assumptions for in-center hemodialysis consumables per session.

Table S6: Life cycle inventory assumptions for home hemodialysis consumables per session.

Table S7: Life cycle inventory assumptions for APD fluid and consumables used per session.

Table S8: Life cycle inventory assumptions for CAPD fluid and consumables used per session.

Table S9: Transport.

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The Carbon Footprint of Dialysis Therapies: A Life-Cycle Assessment

Setting

Single-center in Melbourne, Australia

Life-cycle assessment:
Carbon emissions associated with the whole life cycle of products, processes or services, from raw material extraction through disposal at end of life

Analysis

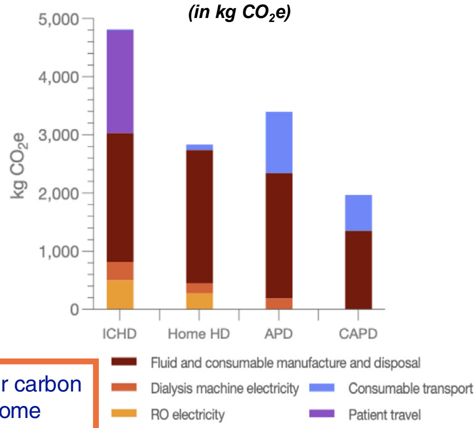
Comparison of Dialysis Modalities:

- In-center hemodialysis (ICHD)
- Home hemodialysis
- Automated peritoneal dialysis (APD)
- Continuous ambulatory peritoneal dialysis (CAPD)

Outcome:
Carbon emissions in kilograms of carbon dioxide equivalents (kg CO_2e) from annual provision of dialysis to a single patient

Results

Annual Carbon Impact
(in kg CO_2e)



CONCLUSION: In-center hemodialysis has a substantially higher carbon footprint than all home dialysis options, informing the choice of home dialysis when feasible and appropriate for individual patients.

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