OPEN

The Carbon Footprint of Peritoneal Dialysis in Australia

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Key Points

- Automated peritoneal dialysis (APD) had a higher carbon impact than continuous ambulatory peritoneal dialysis (CAPD).
- This was due to higher emissions from the manufacture and disposal of APD consumables, and their higher weight, meaning greater transport emissions.
- Polyvinyl chloride recycling can partially mitigate peritoneal dialysis–associated emissions.

Abstract

Background As climate change escalates with increasing health impacts, health care must address its carbon footprint. The first critical step is understanding the sources and extent of emissions from commonly utilized clinical care pathways.

Methods We used attributional process-based life-cycle analysis to quantify CO_2 equivalent emissions associated with the delivery of Baxter's HomeChoice automated peritoneal dialysis (APD) and continuous ambulatory peritoneal dialysis (CAPD) in Australia.

Results The annual per-patient carbon emissions attributable to the manufacture and disposal of peritoneal dialysis (PD) fluids and consumables were 1992 kg CO_2 equivalent emissions for APD and 1245 kg CO_2 equivalent emissions for CAPD. Transport impacts varied depending on the distance between the site of manufacture of PD fluids and consumables and the state of origin of the patient. Therefore, the total impact of providing PD also differed by Australian state, ranging from 2350 to 4503 kg CO_2 equivalent emissions for APD and from 1455 to 2716 kg CO_2 equivalent emissions for CAPD. Recycling of polyvinyl chloride (PVC) could reduce emissions by up to 14% for APD and 30% for CAPD depending on the distance between the site of PVC waste generation and the recycling center.

Conclusions This study demonstrated higher per-patient carbon emissions from APD compared with CAPD, owing to both higher fluid and consumable requirements and the consequent higher transport impacts. PVC recycling can partially mitigate PD-associated carbon emissions.

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Introduction

According to the World Health Organization, climate change is unequivocally a health crisis.[1] This is not a future problem: Nearly half of the world's population is already impacted by it.[1] Simultaneously, health care emits vast greenhouse gases and so contributes to climate change. Indeed, if global health care were a country, it would be the world's fifth largest emitter.[2]

Increasingly, the health sector is being called upon to transition to sustainable, efficient, and zero emission models of care to safeguard health. However, efforts are currently hindered by a lack of evidence regarding the carbon impact of common clinical care pathways. More data are needed to enable targeted mitigation strategies.

In 2021, approximately 3.8 million people worldwide were treated with dialysis for kidney failure. By 2030, this number is expected to rise to 6.1 million[3] owing to aging population, an increase in lifestyle diseases such as hypertension and diabetes, and greater access globally to health care.[4] Currently, 89% of those undertaking dialysis receive hemodialysis (HD) and 11% receive peritoneal dialysis (PD).[5] However, PD has numerous potential advantages over HD, including reduced need for trained staff, greater feasibility of use in remote places, greater capacity for patient travel, lower risk of acquiring communicable diseases such as coronavirus disease 2019, and generally lower cost.[5] In addition, while PD outcomes vary widely around the world, studies suggest that patients treated with PD have better preservation of residual kidney function, increased employment, and comparable survival compared with in-center HD patients.[5,6] Because of this, numerous countries around the world, including Australia, have introduced strategies and policies that prioritize the use of PD unless a medical contraindication is present.[5,7]

One previous study has examined the carbon impact of PD.[8] However, it did not consider key elements, including the impacts of PD fluid manufacture, transportation of fluids and consumables from the manufacturer to the recipient, and a detailed inventory, and hence impact analysis, of consumables used. Furthermore, it examined only continuous automated peritoneal dialysis (CAPD), and not ambulatory peritoneal dialysis (APD).

Accordingly, the aim of this study was to quantify all the carbon impacts associated with the provision of both CAPD and APD using Baxter fluids and consumables in Australia.

Methods

Study Design

Life-cycle analysis (LCA) quantifies emissions of the whole life cycle of products or services, including raw material extraction, manufacture, transport, use, and end of life. We used attributional process-based LCA to identify the source and extent of carbon emissions of PD in accordance with the International Organization for Standardization 14040 principles and framework.[9] The functional unit of the LCA was the annual provision of either home APD or CAPD to a patient in Australia. The system boundary, showing the study inclusions and exclusions, is shown in Figure 1. The primary outcome was carbon emissions in kilogram CO_2 equivalents (kg CO_2 equivalent emissions).

Process Flow

Baxter PD fluid for Australia is manufactured by Baxter Healthcare at its manufacturing plant in Sydney, New South Wales. During the manufacture process, water, salts, and sugars are mixed and filled into polyvinyl chloride (PVC) bags that are then steam sterilized before being protected by a high-density polyethylene (HDPE) over pouch and packaged into cardboard boxes and warehoused. Operations at Baxter's facility are powered using a trigeneration system, with natural gas–driven generators providing steam for sterilizers, chilled water for cooling, and electricity, with supplemental grid electricity provided when required. All other consumables used for PD are manufactured overseas and sea freighted to Australia.

For distribution, fluid and consumables are transported by road using 28-ton semitrailer trucks from the manufacturing plant to warehouses in capital cities in the Australian states of New South Wales, Victoria, South Australia, and Queensland (Figure 2). To reach the state of Tasmania, fluid and consumables are first trucked to Melbourne and then placed on a ferry across Bass Strait before continuing by road to Hobart. For the Northern Territory, fluid and consumables are transported from the South Australian warehouse. Deliveries of fluid and consumables from the warehouse to patient homes typically occur using 6- to 8-ton trucks.

Because fluid and consumables for PD in Western Australia are supplied by Fresenius rather than Baxter, Western Australia was not included in this study. Fresenius PD fluids are manufactured in Singapore and Germany and air freighted to Australia.

Cardboard boxes packaging the fluids and consumables were assumed to be recycled, with all other materials disposed to landfill. Drainage fluid was assumed to be disposed *via* wastewater.

Data Collection

All data were collected between December 2019 and May 2021. Dialysis prescription and treatment-associated consumable use were recorded from a convenience sample of 22 patients undergoing CAPD and 45 patients undergoing APD through four kidney care services in Australia. Two of these were located in the Australian state of Victoria and one each in New South Wales and South Australia. The higher number of APD patients included was due to a higher proportion of patients undertaking APD compared with CAPD at the study sites. Each patient used standard, commercially available Baxter PD consumables, with Baxter's HomeChoice machines used for APD delivery. Information about their treatments was obtained *via* examination of medical records and supply inventories as well as observations made by PD nursing staff (*i.e.*, there was no involvement of the patients themselves). All consumables used (*e.g.*, dialysis fluid bags, drainage bags, cassette prongs, cotton gauze, *etc.*) had their material compositions determined and were weighed using a Tester electronic scale with a resolution of 0.01 g.

Annual 2020 manufacturing data for PD fluid were obtained from the Baxter Healthcare Sydney plant. These data included the total mass of water, sugars, and salts used for each formulation, along with the respective mass of the associated PVC bags and HDPE over pouches. As it was not possible to isolate the electricity and gas used for

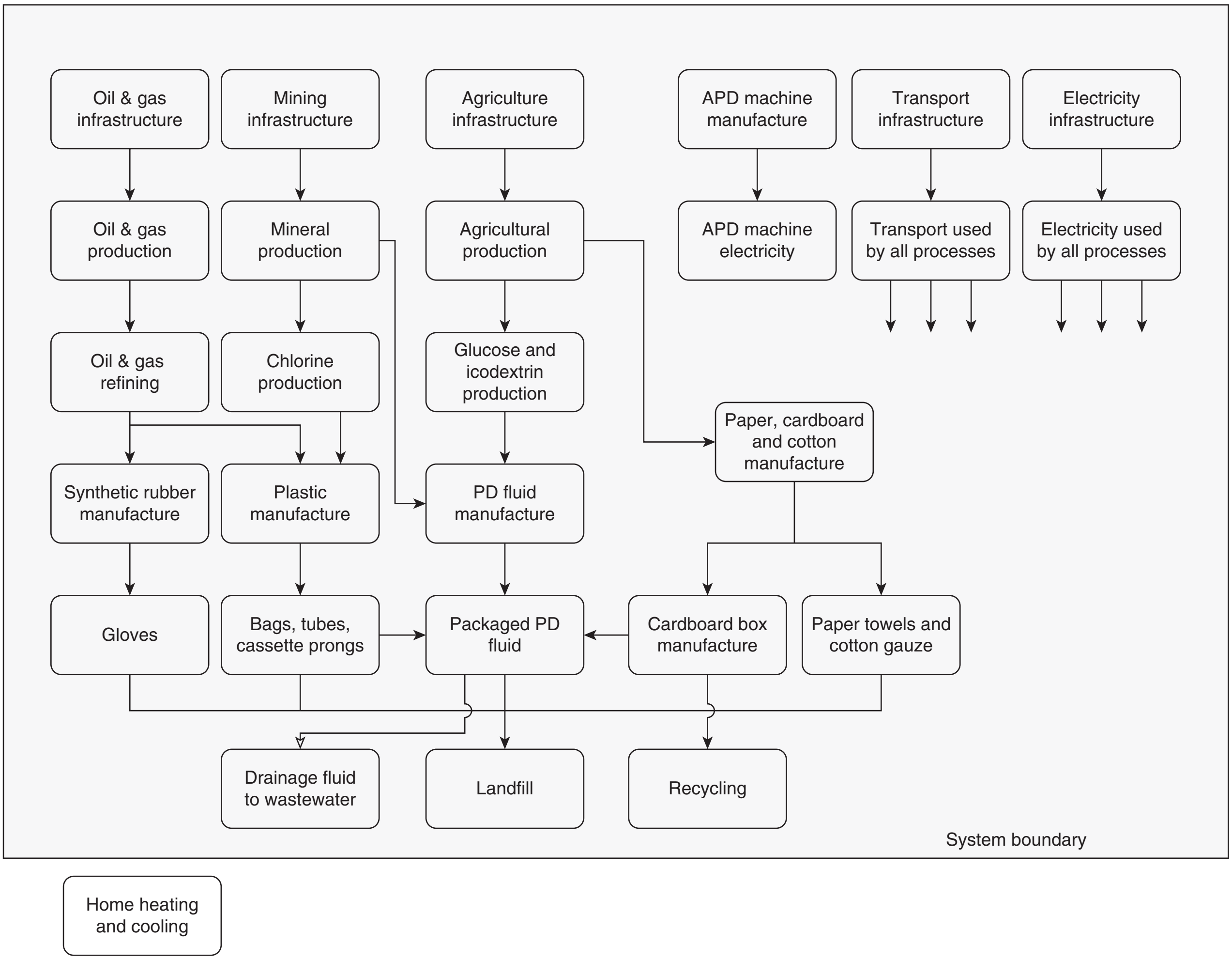

Figure 1. System boundary, showing included and excluded processes. APD, ambulatory peritoneal dialysis; PD, peritoneal dialysis.

manufacturing PD fluids from the other fluids produced at Baxter's plant (*e.g.*, 0.9% saline), usage was estimated based on the volume of fluids manufactured by Baxter in 2020. As PD fluids were 4.8% of the total volume of fluids manufactured, they therefore had 4.8% of total electricity and gas use attributed to them on a per-liter basis.

As we were unable to obtain a detailed breakdown of the components of the APD machine, we estimated APD machine manufacture combining the physical requirements of a low-cost APD machine designed by Rivero-Urzua *et al.* (*e.g.*, pumps) with electronics based on a desktop computer without a screen, as obtained from the ecoinvent 3.06 allocation at the point of substitution (APOS) LCA database (Supplemental Table 1).[10,11] Power usage of an APD machine during operation was measured using a Watts Up Pro Power Meter (Vernier, OR) connected to Logger Pro 3.14.1.0 (Vernier) with a sample obtained every 30 seconds for a period of 5 days.

For transport of fluid and consumables, road distances from the Sydney factory to state warehouses were obtained from Google Maps. For sea transport to Tasmania's warehouses, and for shipping of consumables from overseas, shipping distances were obtained from sea-distances.org. The postcodes of patients receiving PD were obtained from the Australia and New Zealand Dialysis and Transplant Registry.[12] Road distances between patients' postcodes and the state warehouse were determined with Google Maps.

Data Analysis

The life-cycle inventory of the weights and compositions of all consumables, energy, and transport used was modeled using SimaPro 9.4 LCA software (PRé Sustainability, Amersfoort, The Netherlands). The background data containing the environmental impacts 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 3.6 APOS database (ecoinvent, Zurich, Switzerland)[11] and the AusLCI 2.2 database for Australia's specific emissions.[13] Impacts from electricity were modeled from 2020 Australian Energy Statistics.[14] The impact assessment method used was SimaPro's 2021 Intergovernmental Panel on Climate Change 100-year global warming potentials.[15]

Ethics

Project approval was obtained from the institutional research ethics review board at each participating site.

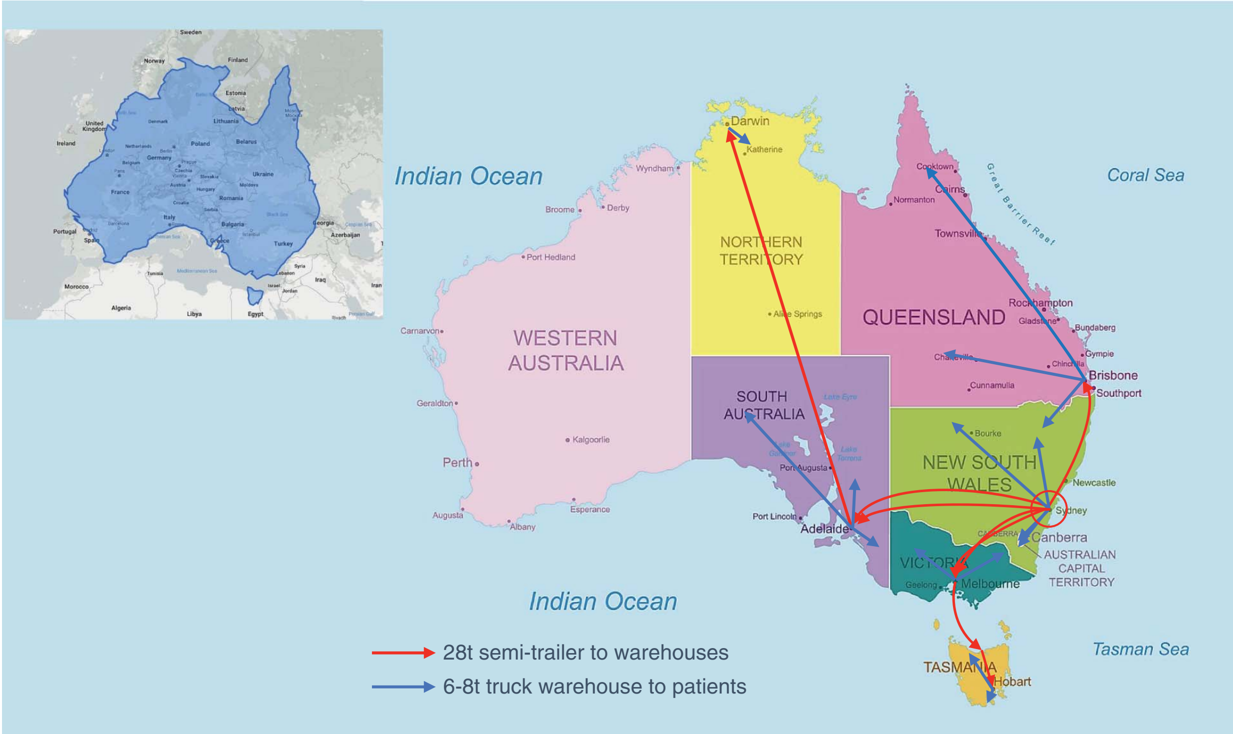

Figure 2. Transport of fluid to patients, with inset showing the size of Australia relative to Europe (from thetruesize.com).

Results

Consumable and Fluid Impacts

Aggregated consumable and fluid usage for the 45 APD and 22 CAPD patients is shown in Supplemental Tables 2 and 3. This usage was used to determine an "average" patient for each modality (Table 1), with all data assumptions available in Supplemental Tables 1, 4, and 5. Given the majority of patients used only 2.5% glucose, or used a combination of 1.5% and 2.5% glucose, we used 2.5% glucose for the "average" patient. Similarly, since the majority of patients included an icodextrin fluid bag as part of their PD regimen, it was included for the "average patient."

Annual per-patient carbon emissions attributable to the consumables utilized for PD (*e.g.*, fluids and packaging, prongs, tubes, drainage bags, gloves, and electricity usage for APD) were 1992 kg CO_2 equivalent emissions for APD and 1245 kg CO_2 equivalent emissions for CAPD. The difference in emissions between APD and CAPD arose primarily from the 15-L cycler drainage bag, the APD 4 prong cassette, and the electricity needed to run the APD machine (Figure 3 and Table 2).

Although APD had higher annual per-patient carbon emissions from consumables than CAPD, the impact from glucose-based PD fluids was higher for CAPD (818 versus 656 kg CO_2 equivalent emissions) despite the use of only half the fluid volume per day (6 versus 12 L). This was due to a greater impact from packaging in CAPD (PVC bags, HDPE over pouches, polypropylene ports, and cardboard boxes), which itself was due to a decreased surface area-to-volume ratio with increasing bag size, meaning two 6-L bags of glucose-based fluids for APD required less PVC packaging than three 2-L bags for CAPD.

Transport Impacts

Average transport distances for fluids and consumables from state warehouses to patients are shown in Table 3. Of note is the average distance of 563 km in Queensland owing to the Brisbane warehouse supplying patients in Cairns and the average distance of 2856 km in the Northern Territory owing to supply from the Adelaide warehouse. All data assumptions for transport are shown in Supplemental Tables 6–9.

Table 1. Consumable usage by the "average" patient for automated peritoneal dialysis and continuous ambulatory peritoneal dialysis per day

APD	CAPD
2×6 L 2.5% dextrose solution	3×2 L 2.5% dextrose solution
1×2 L icodextrin solution	1×2 L icodextrin solution
C15L cycler drainage bag	
4-prong PD cassette	
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
Machine operation—814.6 min per day	No machine required
Total weight (excluding APD machine)—15,656 g	Total weight—9167 g

APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; PD, peritoneal dialysis.

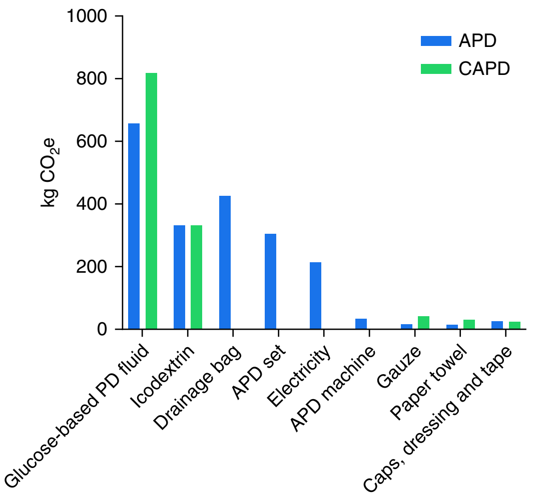

Figure 3. Annual greenhouse gas impacts per patient by source for automated peritoneal dialysis and continuous ambulatory peritoneal dialysis. CAPD, continuous ambulatory peritoneal dialysis; CO_2e, carbon dioxide equivalent.

Average carbon emissions for each state from transport are shown in Table 4. The higher transport emissions from APD compared with CAPD are due to the approximately 52% greater mass of APD fluids and consumables.

Of note, we were unable to calculate an annual impact per kilometer owing to the nonlinear relationship between transport distance and impact (APD: 1.5–33 kg CO_2 equivalent emissions/km, CAPD: 0.95–20 kg CO_2 equivalent emissions/km), with longer distance having the least impact. This is because at shorter distances, each kilometer has a greater proportion of the consumable and fluid impact attributed to it (*e.g.*, at a distance 1 km from the factory, the impact per kilometer would be total annual consumable/fluid impact). In addition, the larger trucks used to transport fluid and consumables to the warehouse have lesser associated emissions per kilometer compared with the smaller trucks used to transport them to individual patients.

Table 2. Annual greenhouse gas impacts per patient by source for automated peritoneal dialysis and continuous ambulatory peritoneal dialysis

Component	APD (kg CO_2e Emissions)	CAPD (kg CO_2e Emissions)
2×6 L 2.5% dextrose solution	656	—
3×2 L 2.5% dextrose solution	—	818
2 L icodextrin solution	331	331
C15L cycler drainage bag	425	—
4-prong PD cassette	304	—
Minicap with povidone-iodine	3	11
Opticap	11	—
Paper towel	15	31
Yu-ki ban tape	2	4
Primapore dressing	9	9
Gauze	17	42
APD machine	34	—
Electricity, Australian average	213	—
Total	1992	1245

APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; CO_2e, carbon dioxide equivalent; PD, peritoneal dialysis.

Table 3. Average transport distance from state warehouses to patients

State	No. of Patients	Average Distance to Patient, km
New South Wales	989	126
Victoria	673	82
Queensland	585	563
South Australia	179	95
Tasmania	43	176
Northern Territory	55	2856

Total Impacts

The combined annual impacts (consumables and fluids and transport) for the provision of PD are shown in Figure 4 and Table 5. The impact of providing APD to patients ranged from 2350 to 4503 kg CO_2 equivalent emissions depending on the patient's state of origin, while for CAPD, emissions ranged from 1455 to 2716 kg CO_2 equivalent emissions. The higher impact of APD compared with CAPD was due to both higher emissions from the manufacture and disposal of APD consumables, along with the greater weight of the fluids and consumables for APD, resulting in greater transport emissions.

Sensitivity Analysis

We investigated the impact on emissions if the PVC fluid bags were recycled. Currently, in Australia, the only flexible PVC recycling plant is situated in Victoria,[16] so the impacts from trucking PVC waste material from different states to be recycled negates some of the benefits from recycling. Comparing Victoria with Queensland, the furthest state from Victoria, PVC recycling for APD conferred a benefit of 389 versus 315 kg CO_2 equivalent emissions per patient annually (leading to a 14% versus 8% reduction in total emissions, respectively). Greater benefits were apparent for CAPD, owing to greater PVC use in CAPD (510 versus 457 kg CO_2 equivalent emissions per patient annually, leading to a 30% versus 18% reduction in total emissions, respectively).

We also investigated the impact of prescribing a lower dose of PD. Using the example of New South Wales,

Table 4. Average transport impact per patient per annum by state

State	APD (kg CO_2e Emissions)	CAPD (kg CO_2e Emissions)
New South Wales	357	209
Victoria	737	431
Queensland	2106	1233
South Australia	1073	628
Tasmania	1194	699
Northern Territory	2511	1470

APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; CO_2e, carbon dioxide equivalent.

Table 5. Annual greenhouse gas impacts per patient of the provision of automated peritoneal dialysis and continuous ambulatory peritoneal dialysis by state

State	APD (kg CO_2e Emissions)	CAPD (kg CO_2e Emissions)
New South Wales	2350	1455
Victoria	2729	1677
Queensland	4099	2479
South Australia	3065	1874
Tasmania	3186	1944
Northern Territory	4503	2716

APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; CO_2e, carbon dioxide equivalent.

removing the icodextrin exchange (*i.e.*, omitting the daytime dwell for APD or using only three glucose exchanges for CAPD) led to a reduction in per-patient annual APD emissions from 2350 kg to 1968 kg CO_2 equivalent emissions, while for CAPD patients, they fell from 1455 kg to 1072 kg CO_2 equivalent emissions. Undertaking PD 5 instead of 7 days per week reduced the per-patient annual APD emissions from 2350 kg to 1675 kg CO_2 equivalent emissions, while for CAPD patients, they fell from 1455 kg to 1041 kg CO_2 equivalent emissions. Using 9-L instead of 12-L APD fluid reduced the per-patient annual APD emissions from 2350 kg to 1777 kg CO_2 equivalent emissions, while performing only a single 2-L glucose CAPD exchange per day reduced the per-patient annual emissions from 1455 kg to 429 kg CO_2 equivalent emissions.

The impact in other states for both APD and CAPD is shown in Supplemental Tables 10–13, with the differences between states owing to varying emissions from transport.

Discussion

We undertook a comprehensive LCA of the carbon impact of Baxter PD in Australia. While there has been one prior study of this kind,[8] ours is the first to consider the full range of contributors to carbon emissions from those associated with PD fluid manufacture through to transportation of fluids and other consumables to the patient. It is also the first to examine both APD and CAPD modalities.[17] The number of individuals choosing APD has been steadily increasing over recent decades.[18] This is primarily because it can be performed overnight, thereby providing patients and/or caregivers greater freedom to undertake their usual daytime activities. Indeed, for lifestyle reasons, APD is now the most common modality of PD for patients in most high-income countries, including Australia, and will likely remain so.[19]

The impact of PD was high, ranging from 2350 to 4503 kg CO_2 equivalent emissions per year for APD and from 1455 to 2716 kg CO_2 equivalent emissions per year for CAPD. This equates to between 12%–24% and 8%–14% of the total annual per-person emissions in Australia for the two PD modalities, respectively.[20] When compared with mean per-person emissions globally, emissions from APD and CAPD equate to between 50%–96% and 31%–58% of the annual total, respectively.[20] Considered another way, the lower bound annual emission estimates are equivalent to driving a passenger vehicle 6107 km for APD and 3817 km for CAPD.

APD had substantially greater carbon impacts from consumables than CAPD, primarily owing to the 15-L cycler drainage bag, the APD 4-prong cassette, and the electricity needed to run the APD machine. The greater mass of APD fluids and consumables compared with CAPD also meant higher APD emissions from transport.

One option to mitigate emissions in APD is to avoid the single-use cycler drainage bag and instead utilize a reusable reservoir (for instance, a 25-L plastic drum with a tap, as shown in Figure 5). These can be commonly found in hardware stores for a one-off cost of around AUD$30, such that their use would be expected to lead to financial and carbon savings (Table 6). While a limited number of dialysis services in Australia are offering this option to patients currently, there is significant opportunity for expanded promotion and uptake.

By comparison, there are limited opportunities to decrease emissions associated with the plastic cassette beyond reducing its overall mass. For the impact from the power consumption of the APD machine, this should steadily move to zero over time as renewable energy in the electricity grid increases.

Regardless though, emissions from APD will likely always remain higher than those of CAPD owing to its higher consumable requirements. This should factor into decision making about PD modality, particularly at the system level, as do cost considerations.

The differences in carbon emissions observed between states for each PD modality were attributable to differing emissions from fluid and consumable transport. For instance, in New South Wales, the state in which Baxter's manufacturing plant is located, transport distances were relatively short, such that transport emissions accounted for only 15% of PD's total carbon footprint. By contrast, in Queensland and the Northern Territory, states located far from the manufacturing plant and where high proportions of patients live long distances from major urban centers,

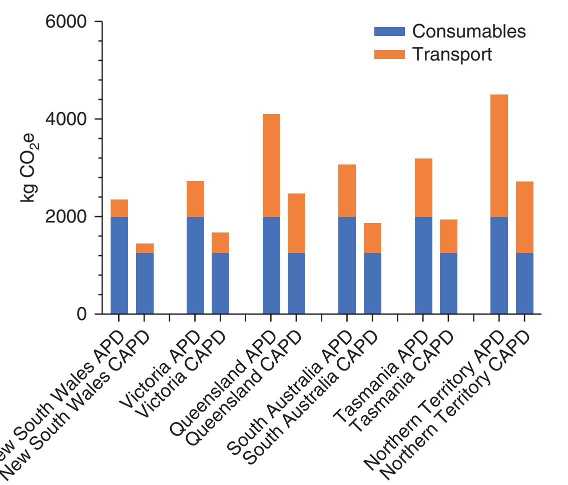

Figure 4. Annual greenhouse gas impacts of the provision of automated peritoneal dialysis and continuous ambulatory peritoneal dialysis per patient by state.

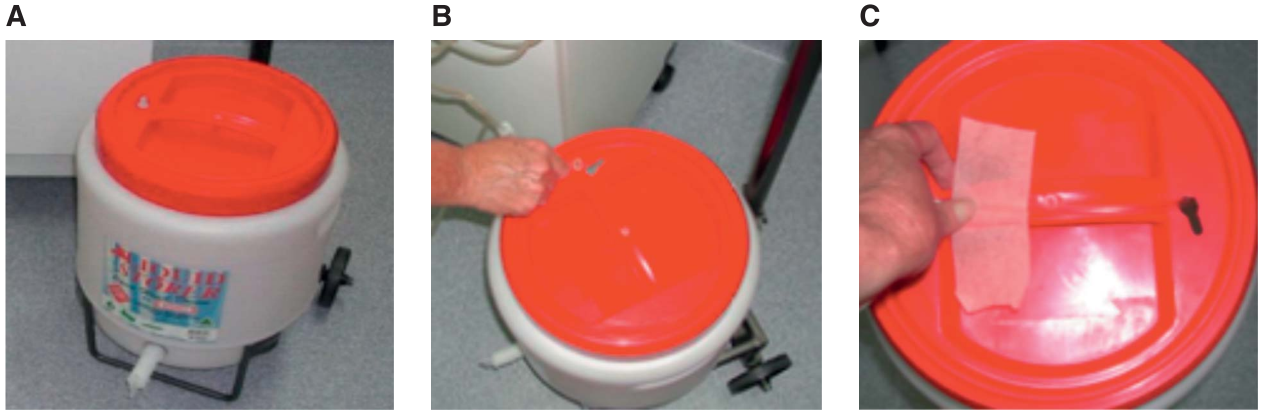

Figure 5. Use of a reusable reservoir for automated peritoneal dialysis effluent drainage. (A) Example of a reusable drum. (B) Inserting the automated peritoneal dialysis drain line into the drum. (C) Securing the drain line with tape.

carbon emissions from transport accounted for approximately 50% of PD's total impact.

Importantly though, patients living in rural and remote areas are among those who serve to benefit the most from PD, as it allows them to remain at home rather than relocating to metropolitan centers for HD. As such, the carbon impact of transporting fluid and consumables as shown herein should not be considered a disincentive to offering PD, but rather it should motivate a search for innovative, patient-centered solutions.

A potential opportunity lies with novel dialysis systems that allow point-of-care dialysate generation instead of requiring movement of fluids. An example is the Ellen Medical PD system that utilizes a compact distiller to produce medical grade sterile water at any location.[21] This water is then combined with a concentrate to produce conventional PD fluid. While consumables for this system (the concentrate and empty fluid bags) would still require transport to patients, they are 10–20 times lighter than the fluids and consumables used in conventional PD. This system is at the stage of clinical trials, with promising results observed to date.[22] Similarly, Baxter Healthcare has developed an "on-demand" solution technology, which, if approved for use, would also obviate the need for transportation of large dialysate volumes.[23]

In the future, electrification of road transport will also undoubtedly help reduce emissions from transport. This said, there is still uncertainty about the feasibility of truck electrification for longer transport distances such as to state warehouses and to patients living in rural and remote areas.[24]

Our data also show that to some extent PD emissions can be mitigated by PVC recycling.[24] Indeed, in CAPD, where PVC fluid bags comprise most of the consumable waste, the potential for emissions reductions of up to 30% was observed depending on the state of origin of the patient and therefore the distance between the site of PVC waste generation and the recycling center.

PVC recycling involves waste PVC being melted down and then reformed into new PVC product. By contrast, the manufacture of virgin PVC involves a range of material inputs and treatment processes, which together imbue a higher carbon footprint.[25] The environmental benefit from PVC recycling is seen because each ton of recycled PVC can replace a similar weight of virgin PVC, thus off-setting the impact of new products.

In Australia, however, PVC recycling is currently only offered to PD patients supplied by Baxter who live in urban areas, and owing to the logistics of PVC pick-up and drop-off from nonurban areas, Baxter has indicated that this is unlikely to change in the foreseeable future. In Australia, investment to build recycling capability and capacity is needed, particularly in regional and remote locations. Government policies offering financial incentives to the health industry for recycling of plastics may also have a role to play. Importantly, to our knowledge, there are no similar PD PVC recycling programs in other countries. Establishment of such programs should be considered.

Our study further demonstrates the potential for carbon savings from incremental PD, a strategy in which less than "full-dose" PD is prescribed until such time as residual kidney clearance declines and/or symptoms develop.[26] Incremental PD is promoted in the latest International Society for Peritoneal Dialysis guidelines because it imposes a lower treatment burden and thereby may enable better quality of life, while achieving clinical outcomes that are

Table 6. Comparison of the waste and carbon emissions generated and the cost of automated peritoneal dialysis effluent drain methods

Drain Option	Waste Generation/Year	Carbon Emissions/Year	Cost/Year
Baxter 15-L drainage bag	148.6 kg	155.1 kg CO_2e emissions	AUD$4927.60
Reusable drum	Nil (1.2 kg when drum is no longer required)	4.1 kg CO_2e emissions	One-off cost of AUD$30

CO_2e, carbon dioxide equivalent.

at least as good.[27] The magnitude of carbon benefit from incremental PD will depend on the chosen regimen for each patient. However, it may be significant; for instance, we found that omitting an icodextrin exchange reduced the carbon footprint of APD by 15% and CAPD by 26%.

This study did not examine the carbon footprint of HD. However, previously published studies have shown annual patient emissions ranging from 3.8 tons CO_2 equivalent emissions in the United Kingdom to 9.1 tons in the United States and 10.2 tons in Australia.[28–30] Comparing these data with data from our study, PD overall appears to be the substantially less carbon-intense therapy.

There are several limitations to this study. We only modeled a single local manufacturer (Baxter Healthcare) with a dominant market share in Australia (90%). The Baxter Sydney plant uses a highly energy-efficient trigeneration energy source; other producers may therefore have differing manufacturing impacts. Impacts from fluid packaging will also be different for those manufacturers using non-PVC plastics.

The transport impacts demonstrated in this study are influenced by both the manufacture of fluid within Australia by Baxter and Australia's large land mass. Different transport impacts would be expected where fluids are manufactured overseas and in countries with shorter distribution distances.

We did not include noncarbon environmental impacts, including the potential for plastics in landfill to break down and form microplastics that end up in leachate, although it appears that PVC is more resistant to breakdown compared with other plastics.[31] Finally, we did not include the impacts of pharmaceuticals used by PD patients, owing to the paucity of environmental information available for the vast majority of drugs.

As the impacts of climate change are increasingly felt globally, it is essential that the health care sector plays its part to reduce its carbon footprint. A critical first step in this is targeted measurement of greenhouse gases attributable to highly utilized and high-impact clinical care pathways such as PD. This study has demonstrated a higher carbon impact of APD compared with CAPD, which should factor into decision making about PD modality. Transport contributed substantially to emissions, particularly in rural and remote areas, while PVC recycling has the potential to partially mitigate them.

We believe the methods we have used to study the carbon impact of PD can and should be applied more widely to medical practice in hospitals and in the community, with information obtained used alongside clinical and cost data to inform health care policy and practice. In turn, this will enable the health care system to undertake the necessary transition to net zero carbon emissions, thereby contributing to a safe climate future for all.

Disclosures

Disclosure forms, as provided by each author, are available with the online version of the article at http://links.lww.com/JSN/E676.

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Data Sharing Statement

The data supporting the findings of this study can be provided by the authors in response to reasonable requests.

Supplemental Material

This article contains the following supplemental material online at http://links.lww.com/JSN/E675.

Supplemental Table 1. Life-cycle inventory assumptions for automated peritoneal dialysis fluid and consumables used per session.

Supplemental Table 2: Fluid and consumables used per session for automated peritoneal dialysis, n=45 patients.

Supplemental Table 3. Fluid and consumables used per session for continuous ambulatory peritoneal dialysis, n=22 patients.

Supplemental Table 4. Life-cycle inventory assumptions for continuous ambulatory peritoneal dialysis fluid and consumables used per session.

Supplemental Table 5. Life-cycle inventory assumptions for icodextrin solution.

Supplemental Table 6. Life-cycle inventory assumptions for transport.

Supplemental Table 7. Transport distances for each state.

Supplemental Table 8. Annual greenhouse gas impacts of transporting automated peritoneal dialysis fluids and consumables to the average patient distance (kg carbon dioxide equivalent emissions).

Supplemental Table 9. Annual greenhouse gas impacts of transporting CAPD fluids and consumables to the average patient distance (kg carbon dioxide equivalent emissions).

Supplemental Table 10. Annual greenhouse gas impacts of excluding icodextrin for automated peritoneal dialysis and continuous ambulatory peritoneal dialysis (kg carbon dioxide equivalent emissions).

Supplemental Table 11. Annual greenhouse gas impacts of undertaking automated peritoneal dialysis and continuous ambulatory peritoneal dialysis for 5 days per week instead of 7 days per week (kg carbon dioxide equivalent emissions).

Supplemental Table 12. Annual greenhouse gas impacts of using 9 L automated peritoneal dialysis fluid instead of 12 L (kg carbon dioxide equivalent emissions).

Supplemental Table 13. Annual greenhouse gas impacts of performing a single 2 L glucose continuous ambulatory peritoneal dialysis exchange per day rather than 4×2 L exchanges (kg carbon dioxide equivalent emissions).

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