Received: 21 April 2022 | Accepted: 25 April 2022
DOI: 10.1111/sdi.13093

Seminars in Dialysis WILEY

Sustainability and environmental impact of on-line hemodiafiltration

Charles Chazot

AURA Paris, Ivry sur Seine, France

Correspondence
Charles Chazot, AURA Paris, 5 avenue de Verdun, 94200 Ivry sur Seine, France.
Email: charles.chazot@auraparis.org

Abstract

Environment has become a main issue of human activities. Chronic hemodialysis (HD) therapy saves lives but consumes large amounts of water and power and produces a lot of care-related waste. On-line hemodiafiltration (HDF) improves patients' outcomes but increases water consumption from ultra-pure water needs and infusion volume. New-generation water treatment systems have much reduced the proportion of reject water that can also be reused. Reducing the dialysate flow in standard HD decreases significantly the water consumption but impacts negatively dialysis efficiency. When on-line HDF is prescribed, reducing the dialysate flow may be applied to decrease water needs while maintaining dialysis efficiency. Nowadays, dialysis prescription cannot ignore its impact on natural resources and environment.

1 | INTRODUCTION

Health-care activities represent around 5% of global greenhouse gas emissions.[1] Dialysis therapy impact on environment is significant. In 2011, Connor et al.[2] compared standard and home daily hemodialysis (HD) carbon footprint. It was found respectively at 3.8 and 7.2 tons of carbon-equivalent (TCeq), without including medications and machines footprints. In Australia, the yearly emission of hemodialysis therapy per patient has been calculated at 10.2 TCeq, that is two-thirds of the carbon footprint per capita in this country.[3] Another issue of dialysis therapy is the important water consumption. If water carbon footprint in dialysis activities is low,[4] its high consumption is an issue for this crucial natural resource. Many countries are exposed to drought in which water is an environmental issue by itself.[5,6] Sparing water is recommended[7] and implemented in some facilities.[8,9] Few data are available specifically regarding hemodiafiltration (HDF) on its environmental impact. In the next paragraphs, I will focus on water sparing and the interest of post-dilutional HDF.

2 | WATER SPARING IN DIALYSIS UNITS

The first efficient maneuver to reduce water consumption in hemodialysis is to *update the water treatment system* (WTS). Reverse osmosis (RO) is needed to provide high-quality ultra-pure water for hemodialysis, especially for on-line HDF. This type of equipment may last for decades in dialysis facilities. A significant proportion of water is rejected by the device to the waste, up to 70% in the old generation of them. New generations of RO devices have significantly reduced the water reject. Bendine et al.[4] have provided an example illustrating how efficient is the change of the WTS. In a large HD facility, the water consumption per dialysis session fell from above 500 to less than 300 L per dialysis treatment by the change of the WTS. In a recent survey by the Green Nephrology group of the Société Francophone de Néphrologie Dialyse Transplantation, one third of the WTS in 68 dialysis facilities were more than 10 years old (unpublished data). Moreover, the *recycling of RO water reject* may be implemented in different uses according to its high conductivity such as sterilization, gardening, sanitary purpose, or agriculture according to the conductivity that may be a barrier for some of them.[5,6] This is also possible for *spent dialysate*. The experience of manned space flights could be adapted to dialysis when research is able to provide affordable devices.[10] Last but not the least, *sorbent technology* is part of the solution currently developed for the wearable artificial kidney,[11] but it is out of the scope of this topic.

3 | REDUCING THE DIALYSATE FLOW PRESCIPTION IN HEMODIALYSIS

Reducing the dialysate flow (Qd) prescription decreases the amount of the spent dialysate, sparing water. To produce 1 L of ultrapure dialysate, at least 2 L of water are needed.[3] Maduell et al.[12] have reported the expected linear relationship between prescribed Qd and spent dialysate per session, from 117.9 (prescribed Qd at 300 mL/min) to 232.4 L (prescribed Qd at 700 mL/min, a 97% increase). The issue of reducing Qd is its impact on uremic toxin clearance. The relationship between urea clearance rate and Qd has been measured and analyzed by Ahrenholz et al.[13] The authors showed an increase of K_{urea} by increasing Qd at different blood flow rates (Qb), explained by less saturation of the dialysate compartment as well as less preferential dialysate channels that may occur with low Qd. However, the data regarding clearances remain controversial. In the Flugain study, Molano-Trivino et al.[14] compared dialysis parameters in cross-over trial (2 periods of 4 weeks with Qd at 400 and 500 mL/min) including 46 thin HD patients (body weight<65 kilos). No difference regarding predialysis phosphate, potassium, and KT/V were found, whereas 24 L of dialysate was spared per session. On the opposite, Maduell et al.[12] have reported a significant higher urea clearance (Kt), as well as higher percent of urea reduction with increased Qd. Also, these authors did not find a significant impact of the lower Qds on the percent of reduction for creatinine, myoglobin, B2-microglobulin, and α_1-microglobulin. This might be related to the share of convection rather than diffusion in the clearance of these bigger molecules, as mentioned by the Ahrenholz et al.[13] These same authors used three different Qd (300, 500, and 800 mL/min) with three different membranes and reported a significant increase of the single-pool Kt/V_{urea} while increasing the Qd without difference between filters. Also, Kult et al.[15] compared in six patients during 6 weeks using six different dialysis machines and/or prescription. When standard HD (Qd = 500 mL/min) was compared with an HD session with the autoflow device at 1.2 (meaning the Qd was set by the dialysis machine at a value of 1.2 time the effective Qb, this led to a significant decrease of the Qd (500 versus 347 mL/min [−30,4%]) but with a significant reduction of KT/V from 1.34 to 1.19. Then these three late studies question the safety of reducing Qd, especially since Beguin et al.[16] have shown a linear relationship between the Kt_{urea} and HD patient's survival. Additional long-term studies on patient outcomes are needed before being able to advise the reduction of the Qd.

4 | IS IT POSSIBLE TO SPARE WATER WITH ON-LINE HEMODIAFILTRATION?

I address here only post-dilution OL-HDF because it is the main convective technique currently in use and the one with some data about the raised question. On a counterintuitive manner, the answer to this question is a "yes". It is counterintuitive because with on-line production of the substitution solution, at least 21 L per session[17] is added to the dialysate volume representing a 17.5% increase. The reason why OL-HDF may be helpful to decrease dialysate consumption has been reported in the same study mentioned above.[15] When standard HD was compared to post-dilution OL-HDF using a 1.2-auto-flow factor and the auto-sub© driving automatically the infusion volume, the Qd decreased from 500 mL/min to 377 mL/min without a significant change in the single-pool Kt/V_{urea} (1.30 versus 1.34). The global dialysate sparing was −11% taking into account the substitution infusion rate à 67 mL/min. In another study, Mesic et al[18] compared standard HD (Qd 500 mL/min) with post-dilutional on-line HDF with auto-flow (1.2) and auto-sub functions in 54 patients during 956 sessions. With OL-HDF, the dialysate consumption was reduced significantly by 8%, and the dialysis dose increased significantly by 3.5%. However, in this study the average substitution volume was 18 L per session, below the current recommendations issued from the different randomized controlled trials and cohort studies.[19]

5 | CONCLUSIONS

It must be a goal for the nephrology community to implement measures to save water for the HD therapy. It contributes to spare a precious natural resource and to decrease the dialysis carbon footprint.[7] First, whatever the HD modality, WTS update is needed. Second, the water reject recycling from RO has to be developed and in the future for spent dialysate. Beyond its superiority on patient survival, OL-HDF must be also considered as a possibility to spare dialysate (and water) consumption without jeopardizing the dialysis dose delivery.

CONFLICT OF INTEREST

The author has been an employee of Fresenius Medical Care for until 30 September 2021.

REFERENCES

1. Tennison I, Roschnik S, Ashby B, et al. Health care's response to climate change: a carbon footprint assessment of the NHS in England. *Lancet Planet Health*. 2021;5(2):e84-e92.
2. Connor A, Lillywhite R, Cooke MW. The carbon footprints of home and in-center maintenance hemodialysis in the United Kingdom. *Hemodial Int*. 2011;15(1):39-51.
3. Barraclough KA, Agar JWM. Green nephrology. *Nat Rev Nephrol*. 2020;16(5):257-268.
4. Bendine G, Autin F, Fabre B, et al. Haemodialysis therapy and sustainable growth: a corporate experience in France. *Nephrol Dial Transplant*. 2020;35(12):2154-2160.
5. Agar JW. Conserving water in and applying solar power to haemodialysis: 'green dialysis' through wiser resource utilization. *Nephrology (Carlton)*. 2010;15(4):448-453.
6. Tarrass F, Benjelloun M, Benjelloun O. Recycling wastewater after hemodialysis: an environmental analysis for alternative water sources in arid regions. *Am J Kidney Dis*. 2008;52(1):154-158.
7. Tarrass F, Benjelloun O, Benjelloun M. Towards zero liquid discharge in hemodialysis. Possible issues. *Nefrologia (Engl Ed)*. 2021;41(6):620-624.
8. Agar JW. Reusing and recycling dialysis reverse osmosis system reject water. *Kidney Int*. 2015;88(4):653-657. doi:10.1038/ki.2015.213
9. Ponson L, Arkouche W, Laville M. Toward green dialysis: focus on water savings. *Hemodial Int*. 2014;18(1):7-14.
10. Verbeelen T, Leys N, Ganigue R, Mastroleo F. Development of nitrogen recycling strategies for bioregenerative life support systems in space. *Front Microbiol*. 2021;12:700810. doi:10.3389/fmicb.2021.700810
11. Meng F, Seredych M, Chen C, et al. MXene sorbents for removal of urea from dialysate: a step toward the wearable artificial kidney. *ACS Nano*. 2018;12(10):10518-10528. doi:10.1021/acsnano.8b06494

12. Maduell F, Ojeda R, Arias-Guillen M, et al. Optimization of dialysate flow in on-line hemodiafiltration. *Nefrologia*. 2015;35(5):473-478. doi:10.1016/j.nefroe.2015.11.002
13. Ahrenholz P, Winkler RE, Zendeh-Zartochti D: *The Role of the Dialysate Flow Rate in Haemodialysis*. In: IntechOpen. edn. Edited by Suzuki H; 2015. doi:10.5772/58878
14. Molano-Trivino A, Guzman G, Galvan A, Ducuara D, Martinez A, Yunez A. Dialysate flow: is the less the better? *Blood Purif*. 2020; 49(1-2):121-122.
15. Kult J, Stapf E. Changing emphasis in modern hemodialysis therapies: cost-effectiveness of delivering higher doses of dialysis. *Int J Artif Organs*. 2007;30(7):577-582.
16. Beguin L, Krummel T, Longlune N, Galland R, Couchoud C, Hannedouche T. Dialysis dose and mortality in haemodialysis: is higher better? *Nephrol Dial Transplant*. 2021;36(12):2300-2307.
17. Maduell F, Moreso F, Pons M, et al. High-efficiency postdilution online hemodiafiltration reduces all-cause mortality in hemodialysis patients. *J am Soc Nephrol*. 2013;24(3):487-497.
18. Mesic E, Bock A, Major L, et al. Dialysate saving by automated control of flow rates: comparison between individualized online hemodiafiltration and standard hemodialysis. *Hemodial Int*. 2011; 15(4):522-529. doi:10.1111/j.1542-4758.2011.00577.x
19. Canaud B, Barbieri C, Marcelli D, et al. Optimal convection volume for improving patient outcomes in an international incident dialysis cohort treated with online hemodiafiltration. *Kidney Int*. 2015;88(5): 1108-1116.

How to cite this article: Chazot C. Sustainability and environmental impact of on-line hemodiafiltration. *Semin Dial*. 2022;35(5):446-448. doi:10.1111/sdi.13093