Received: 28 February 2022 | Accepted: 5 March 2022

DOI: 10.1111/sdi.13070

SPECIAL ISSUE ARTICLE

Seminars in Dialysis WILEY

Prescription of online hemodiafiltration (ol-HDF)

Bernard Canaud[1,2] | Andrew Davenport[3]

[1]School of Medicine, Montpellier University, Montpellier, France

[2]Global Medical Office, FMC Deutschland, Bad Homburg, Germany

[3]University College London Department of Renal Medicine, Royal Free Hospital, University College, London, UK

Correspondence
Bernard Canaud, Montpellier University, School of Medicine, Montpellier, France.
Email: canaudbernard@gmail.com and bernard.canaud@fmc-ag.com

Abstract

HDF prescription should be able to satisfy the delivery of an optimal dialytic convective dose. Several factors are implicated in this endeavor. High blood flow rate is crucial to warranty processing an adequate blood volume and to ensure the highest shear rate per fiber needed to cleanse and prevent membrane fouling. A highly permeable dialyzer is needed with a surface area aligned to blood flow and performance needs. Anticoagulation requires specific adaptation in case of low molecular weight heparin use. By default, HDF prescription modality should ideally start by postdilution mode with a stepwise increment of convective dose by probing patient tolerance and efficacy. Alternative substitution modality should be considered if dialytic convective dose could not be achieved in the usual time frame. Convective dose prescription relies either on a manual mode (pressure control or volume control) or on automated mode (ultrafiltration control) depending on the technical options of the HDF machines. Dialysate flow rate is regulated by the HDF machine but should preferably keep constant dialysis fluid flowing the dialyzer with a Qb:Qd ratio of 1.4. Treatment time should not be reduced with HDF prescription. Treatment time should fit with patient tolerance (hemodynamic, osmotic, and solute shifts) and overall solute removal efficiency. Electrolytic prescription does not require specific adjustments as compared with conventional dialysis, but the patient needs to be monitored regularly and dialysate electrolyte adjusted to lab tests. A stepwise approach for implementing ol-HDF is preferable depending on the initial condition of the patient. Three particular cases may be considered: late-stage chronic kidney disease patient transitioning to renal replacement therapy, stable dialysis patient switching to HDF, and unstable or fragile patient or specific treatment schedule. Optimal dosing of HDF and personalized care to ensure treatment adequacy is the main goal for renal replacement therapy to improve patient outcomes. That should be ensured with HDF treatment.

1 | DIALYTIC CONVECTIVE DOSE CONCEPT

Delivering the optimal dialytic convective dose is the main objective of the ol-HDF prescription to achieve the potential improvements in patient outcomes reported with ol-HDF.[1–5] Prescription of HDF based on a sessional basis should be integrated into the global treatment schedule that matches patient metabolic requirements, volume control, and electrolyte balance and provides good overall tolerance.[6,7]

2 | CONVECTIVE DOSE THRESHOLD AS COMPONENT OF DIALYSIS ADEQUACY

Based on a conventional thrice weekly treatment schedule, recent interventional randomized multi-center-controlled trials have shown that convective dose, or its surrogate, total ultrafiltered volume per session, has a minimum threshold value of 23 L per session in postdilution HDF mode to provide clinical advantages to adult dialysis patients.[8–10] Further, fine-tuned adjustment must be considered

according to patient's anthropometrics and/or to fit with regional practices. This is why it is recommended to scale convective dose to body surface area, a surrogate of muscle mass and physical activity. In that case, the minimum targeted total ultrafiltration volume per session to improve patient outcome has been set to 23 L per 1.73 m^2.[11]

Dialytic convective dose is only one component of the multi-targeted parameters required to judge efficacy and/or adequacy of dialysis treatment.[6] Indicators used to evaluate dialysis adequacy are out of the scope of this review. However, it is of upmost importance to highlight the fact that they belong to several categories[12]: lack of symptomatology and patient well-being, fluid volume and blood pressure control, optimal dialysis dose delivery (including small and larger uremic compounds),[4,5] electrolyte balance (plasma sodium and potassium concentrations), correction of acidosis, mineral bone disease control including phosphate and calcium concentrations, anemia and iron correction, and nutritional preservation.

3 | HDF PRESCRIPTION: FACTORS TO BE CONSIDERED

HDF prescription is designed to satisfy the delivery of an optimal dialytic convective dose.[3,13] Several clinical factors are implicated in this endeavor. For practical reasons, these factors are described analytically and then implemented synthetically in a stepwise clinical approach.[3,14,15] Baseline patient's clinical condition represents the guiding factor of HDF prescription and initiation.

3.1 | Factors and their role in dialytic convective dose

3.1.1 | Extracorporeal blood flow management

Blood flow rate (Qb) is crucial to ensure delivery of dialysis dose and treatment efficacy in conventional hemodialysis. Extracorporeal Qb is of upmost importance in convective based therapies such as HDF, since it facilitates ultrafiltration flow. Indeed, Qb is positively correlated to shear rate, contributing to reducing the second protein boundary layer formation, so minimizing membrane fouling and maintaining dialyzer membrane permeability and sieving capacity.[16,17] High Qb is thus a critical component for achieving the targeted convective dose. Extracorporeal Qb should fit with dialyzer geometry (number of fibers, fiber diameter, and length) and dialyzer surface area to ensure an optimal shear rate per fiber. As a simple rule of thumb, a Qb of 200 ml/min per 1.0 m^2 of dialyzer surface area (DSA) that equates to 400 ml/min for a 2.0 m^2 dialyzer is required with the currently available capillary dialyzers to ensure full perfusion of all fibers in the bundle and providing an optimal shear rate and stress per fiber to reduce membrane fouling.[18,19] In this context, the size of fistula needles or the inner lumen diameter of central venous catheters is important as the resistance to blood flow is proportional to the fourth power of the inner lumen radius (Hagen-Poiseuille law). Accordingly, a 15- or 14-gauge dialysis needle is required to achieve Qbs ≥ 400 up to 450 ml/min or central venous catheters with an inner diameter lumen ≥ 2 mm are required.[20–22]

3.1.2 | Dialyzer choice

The choice of a dialyzer for HDF prescription should meet three main objectives: first, be adapted for high Qb; second, meet purification standards; third, has a low internal resistance to blood flow to optimize the filtration fraction. The EUDIAL group suggested that a capillary dialyzer fitted with a highly permeable membrane (i.e., Kuf > 50 ml/h/mmHg; sieving coefficient of ß2M > 0.6), adequately sized and with relatively low internal blood flow resistance (i.e., fiber diameter > 200 μm, length < 30 cm) is the ideal clinical choice to start postdilution HDF.[23,24] Alternatively, higher permeable membranes may be used to enhance HDF clinical performances. However, it is important to highlight that not all high-flux dialyzers meet these specifications and there is a potential risk of increased albumin losses in the presence of high hydraulic membrane stress.[25] Dialyzer surface area should be adapted to HDF performances and extracorporeal Qb delivered.[26] This is discussed later in the section of optimization of HDF clinical prescription.

3.1.3 | Extracorporeal anticoagulation management

Preventing clotting in the extracorporeal circuit in HDF is part of good clinical practice. When unfractionated heparin (standard heparin) is used, no specific adaptation is required as compared to high-flux hemodialysis. Loading dose and maintenance dose (IV infusion) does not require particular adaptation. When a fractionated heparin (low molecular weight heparin) is used as a single bolus dose at initiation, injection of the compound should be performed either directly into the venous needle or in the venous blood line, or delayed if injected into the arterial blood line, for preserving an optimal antithrombotic efficiency. It has been clearly shown that immediate injection of the LMWH into the arterial blood line is associated with 20 to 30% loss of the active compound, reduced antithrombotic capacity or higher dosing required to maintain the same efficacy.[27,28]

3.1.4 | HDF prescription modality

HDF substitution mode (post-, pre-, or mixed-dilution) relies on few principles: First, post-dilution mode is by default the first line option. It provides the highest efficacy per liter of substituted volume, cost-effectiveness considering reduced water, and electrolytic consumption. Its implementation may however be impeded by failure to achieve the higher Qb required; alternatively, pre-dilution or mixed-dilution mode may be used when an adequate convective dose cannot be delivered with post-dilution HDF.[29–33] These conditions are frequently met with slower Qb, central venous catheters,

pediatric patients, and small adults. Although pre-dilution is the most commonly used alternative to post-dilution mode, mixed-dilution may also be used as an alternative since this substitution mode has the capacity of addressing limitations of other HDF modalities.[30,34] However, mixed-dilution HDF requires a specific three pump dialysis machine, controlled by a proprietary captive software.[32,33]

3.1.5 | Transmembrane pressure (TMP) management

Transmembrane pressure (TMP) handling relies on technical options and proprietary software of the HDF machine. Currently, there are two options for managing ultrafiltration and substitution flow rates: first, the manual prescription relying on two options: pressure controlled and volume-controlled.[32,35,36] In pressure-controlled mode, TMP is prioritized and fluctuates in a preset pressure corridor (i.e., with minimum and maximum limits set) and ultrafiltration/substitution flow follows, so that the convective dose delivered may decrease depending on the pressure regimen. In volume-controlled mode, ultrafiltration/substitution flow is prioritized and TMP will increase according to membrane fouling but the convective dose is more likely to be achieved. For safety reasons, a maximum TMP is usually set at 350 mmHg. The automated prescription is more attractive from a care giver perspective for ensuring optimal dialytic convective dose delivery.[21,22] However, this option relies on a specific and proprietary HDF machine software which continuously monitors viscosity changes within the dialyzer and controls the ultrafiltration flow by adjusting TMP and so maximizes the filtration fraction.

3.1.6 | Dialysate flow adjustment

Dialysate flow rate (Qd) is usually set by default 600 ml/min by the dialysis machine manufacturer. Depending on the online HDF manufacturer, Qd may be altered or adjusted to substitution flow bypass to keep constant dialysis flow crossing the dialyzer. This feature should be known as it may reduce diffusive clearances. Alternatively, Qd can be increased with some HDF machines. A recent study has shown that increasing Qd up to 800 ml/min was associated with a slight increase in urea clearance, but with no change in the removal of medium and larger molecular weight compounds and no impact on convective dose.[37] Qd remains therefore to be determined automatically by the HDF machine with a flow ratio of Qd:Qb at 1.5 for optimal performance, while keeping a constant Qd through the dialyzer. Although with some dialysis machines, when using a combination of high Qb, and targeting high convection volume exchange, then a higher total Qd and water flow setting may be required to maintain an optimal Qd:Qb within the dialyzer, as an increased substitution flow rate leads to a corresponding reduction in Qd.

3.1.7 | Treatment time

Weekly treatment time is the product of session treatment time by the number of sessions per week. Treatment time is a crucial and independent component of blood purification since it conditions the overall efficacy and tolerance of renal replacement therapy. Extended treatment times have several confirmed clinical benefits that equally apply to HDF[38–41]: Longer session times improve the solute removal capacity of compounds with low intracorporeal mass transfer coefficients, decrease osmotic shifts, reduces the required ultrafiltration rate, and increases convective dose delivery. Personalized treatment adjustment is required for both HD and HDF and will not be further discussed.

3.1.8 | Electrolytic prescription

Electrolytic prescription must be adapted to patient tolerance and treatment outcomes. Concentrations of dialysate sodium, potassium, calcium, magnesium, and buffer (bicarbonate) are prescribed on clinical basis and tolerance. In a recent study assessing sodium mass balance in HD and online post-dilution HDF, it has been shown that sodium mass removed was nearly identical, provided dialysate sodium prescription was lower than the predialysis plasma sodium concentration.[42] Usually, no specific adaptation is required for most electrolytes when compared with stable patients on maintenance high-flux HD.[43] However, in particular cases, dialysate electrolytes prescription must be probed to patient results: particularly with more frequent or longer HDF treatment schedules and when larger convective volumes are delivered as with pre-dilution HDF, especially when treating vulnerable populations (elderly and children), and specific conditions (parathyroid disorders, calcimimetics, and alkalotic patients).

3.2 | Clinical implementation of HDF therapy—Stepwise approach to fit with patient's clinical condition

A stepwise approach for implementing online HDF has been successfully achieved in several recent studies.[3,14,15] For practical reasons, prescription and clinical implementation of HDF is discussed according to three clinical conditions: first, in an incident dialysis patient; second, in a prevalent, stable, and regularly dialysis patient; third, in unstable patient or in case of unusual treatment schedule. This is presented in Figure 1.

3.2.1 | HDF prescription in a dialysis naive incident patient transitioning from ESKD to dialysis (after first month)

Initiation of dialysis treatment in adult end-stage kidney disease patients may be performed with support of HDF. In this case, it is

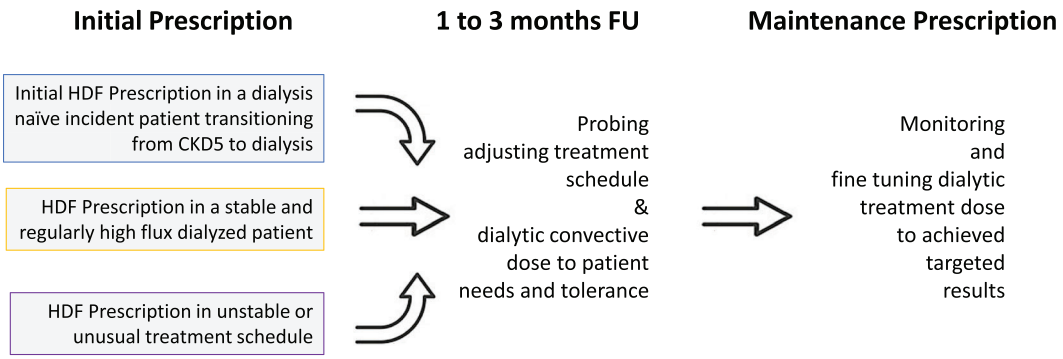


FIGURE 1 HDF treatment adjustment according to patient clinical presentation

recommended to implement HDF treatment in a stepwise approach while probing patient response and tolerance. The different steps are summarized here:

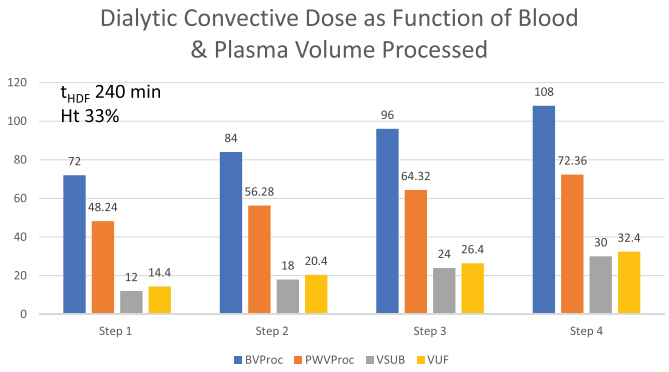
1. Select treatment time (3 to 4 h) and frequency (1 to 4 session per week) to fit with patient needs and tolerance.
2. Choose highly permeable capillary dialyzer and a medium dialyzer surface area of 1.6 m^2.
3. Adapt extracorporeal antithrombotic dosing and site of injection to prevent dialyzer clotting and to preserve performances.
4. Optimize extracorporeal Qb to vascular access type (i.e., arteriovenous fistula or graft, tunneled central venous catheter) and flow limits. Qb is progressively increased from 200 ml/min by step of 50 ml/min over a week period to reach 350–400 ml/min within 1 month.
5. Probe patient response and tolerance to this initial treatment after 1 month. Clinical performance and tolerance are assessed on reduction rate of selected solutes (i.e., urea, creatinine, phosphate, and ß2M) and intradialytic morbidity as well as patient perception.
6. Launch of optimized post-dilution HDF after this initial probing HD period. Initial prescription relies preferably on manual mode and volume-controlled option. Substitution flow, mirroring ultrafiltration flow, will start at 50 ml/min and progressively increased by a 25 ml/min step per week up to 125 ml/min that could be achieved within 1 month. Clinical performances and patient tolerance of optimized HDF therapy is then assessed on previous indicators and include hydraulic permeability parameters. After this probing period of high volume HDF, the prescription may be switched to the automated ultrafiltration control mode.[22] If optimized post-dilution cannot be achieved, then pre-dilution HDF should be considered.
7. Assess HDF clinical performances and tolerance on a monthly basis using conventional key parameter indicators of dialysis efficacy (dialysis dose assessed by urea Kt/V, fluid volume and hemodynamic control, electrolytic balance including potassium and bicarbonate, phosphate and metabolic bone disease control, anemia and iron status, and nutritional indicators) and add to this panel of indicators some more specific biomarkers (i.e., ß2M; alfa-1-Microglobulin, a1M) reflecting the higher permeability of HDF.
8. Increase treatment time and/or frequency if key parameter indicators are not in target or if hemodynamic tolerance is not achieved. Increase dialyzer surface area if solute removal is below target.[21,22] Dialysate electrolytes prescription should be adjusted according to clinical results and patient tolerance.

A schematic example of a stepwise implementation of HDF treatment prescription is given in Figure 2 with a fixed treatment time of 240 min.

3.2.2 | HDF prescription in a stable and regularly dialyzed patient

Switching prevalent and stable dialysis patient to HDF is easier than initiating a new patient in HDF. The probing period is relatively shorter since the pre-HDF testing is not required. In that case, initiation of HDF requires in fact only a few steps:

1. Increase and probe sustainable maximum Qb. When Qb exceeds 350 ml/min, post-dilution HDF may be envisaged. When Qb is lower that this threshold value, pre- or mixed-dilution HDF should be preferred.
2. Choose the most appropriate capillary dialyzer: Dialyzer surface area between 1.6 and 1.8 m^2; Low internal blood flow resistance (capillary diameter >200 μm). Choose an appropriate online HDF machine.
3. Initiate HDF program. Prescribe substitution/ultrafiltration flow on manual mode. Start with a 50 ml/min in post-dilution mode (100 ml/min in pre-dilution). Increase progressively by step of 25 ml/min per week (50 ml/min in pre-dilution) to achieve 125 ml/min (250 ml/min in pre-dilution). Consider switching to automated ultrafiltration-controlled mode once stable parameters are maintained.
4. Assess HDF clinical performances and tolerance on a monthly basis using conventional key parameter indicators of dialysis efficacy and specific biomarkers (i.e., ß2M and a1M).
5. Increase treatment time and dialyzer surface area is results are below those expected. Dialysate electrolytes prescription should be adjusted to clinical results and patient tolerance.



	Step 1	Step 2	Step 3	Step 4
QB, ml/min	300	350	400	450
QSUB, ml/min	50	75	100	125
QUF, ml/min	60	85	110	135
DSA, m^2	1,6	1,8	2,2	2,4
Needle size, G	16	15	15	14

Abbreviations:
QB, Blood Flow Rate
QSUB, Substitution Flow Rate
QUF, Ultrafiltration Flow Rate
DSA, Dialyzer Surface Area
BVProc, Blood Volume Processed
PWVProc, Plasma Water Volume Processed
VSUB, Volume Substituted
VUF, Volume Ultrafiltered

FIGURE 2 Stepwise implementation of HDF in clinical setting

3.2.3 | HDF prescription in unstable or unusual treatment schedules

Specific HDF prescription may be considered in particular clinical cases or to fit with unusual treatment schedules.

- Clinical cases represent several subgroups of patients that belong and reflect more vulnerable populations. These include elderly subjects, cardiac or hemodynamic unstable patients, diabetic patients, malnourished patients and the pediatric population. It is not our intent to review specific HDF prescription in each of these cases. However, it is important to highlight that treatment schedules (time, frequency, blood flow, and dialyzer surface area), ultrafiltration rate, dialytic convective dose or electrolytes prescription should be personalized on an individual basis to meet patient needs and tolerance for their particular circumstances.
- Unusual treatment schedules include extended dialysis treatments (i.e., short daily, nocturnal, or alternate day dialysis) or incremental dialysis (i.e., increasing number of dialysis sessions according to residual kidney function) or mixed modalities (i.e., association of HD and HDF in emerging countries). In those cases, HDF may be easily used as a more efficient and better tolerated alternative to conventional hemodialysis. HDF prescription has to be adjusted to treatment performances, patient tolerance and targeted parameters.

4 | HDF TREATMENT ADEQUACY

Treatment adequacy and quality control for HDF treated patients follow the standard best clinical practice guidelines and fulfill conventional multitarget criteria. In brief, lack of clinical symptomatology, patient well-being, fluid volume homeostasis, hemodynamic and blood pressure control, dialysis dose delivery, electrolyte control, acid–base correction, divalent ions homeostasis, anemia, and nutritional correction. In addition, and more specifically related to HDF treatment, convection volume as surrogate of dialytic convective dose delivered should be equal or higher than 23 L per 1.73 m^2 (postdilution mode) and/or ß2M reduction rate per session higher than 80% or ß2M Kt/V ≥ 1.5 or predialysis ß2M concentrations lower than 25 mg/L and predialysis serum albumin concentration higher than 35 g/L (considering the hemodilution factor associated with fluid overload).

5 | CONCLUSIONS

Optimal dosing of HDF and personalized care is the main goal for renal replacement therapy to improve patient outcomes. In this chapter, we have discussed the minimal dialytic convective dose required to achieve such goals, provided an analytic review of factors contributing to the delivery of appropriate convective dose and propose a stepwise approach to achieve these targets. Following this clinical approach, it is likely expected that an optimal HDF treatment may be delivered to almost all end-stage kidney disease patient profiles.

ORCID

Bernard Canaud https://orcid.org/0000-0001-6854-2816
Andrew Davenport https://orcid.org/0000-0002-4467-6833

REFERENCES

1. Canaud B, Bowry SK. Emerging clinical evidence on online hemodiafiltration: does volume of ultrafiltration matter? *Blood Purif*. 2013;35(1-3):55-62. doi:10.1159/000345175
2. Blankestijn PJ, Grooteman MP, Nube MJ, Bots ML. Clinical evidence on haemodiafiltration. *Nephrol Dial Transplant*. 2018;33(suppl_3): iii53-iii58. doi:10.1093/ndt/gfy218
3. Chapdelaine I, de Roij van Zuijdewijn CL, Mostovaya IM, et al. Optimization of the convection volume in online post-dilution

haemodiafiltration: practical and technical issues. *Clin Kidney J*. 2015; 8(2):191-198. doi:10.1093/ckj/sfv003
4. Group ObotEW. II.1 Haemodialysis dose quantification: small solutes. *Nephrology Dialysis Transplantation*. 2002;17(suppl_7):17-21. doi:10.1093/ndt/17.suppl_7.17
5. Group ObotEW. II.2 Haemodialysis dose quantification: middle molecules (MM). *Nephrology Dialysis Transplantation*. 2002;17(90007): 21-23. doi:10.1093/ndt/17.suppl_7.21
6. Canaud B. Adequacy target in hemodialysis. *J Nephrol*. 2004;17(Suppl 8): S77-S86.
7. Locatelli F, Canaud B. Dialysis adequacy today: a European perspective. *Nephrol Dial Transplant*. 2012;27(8):3043-3048. doi:10.1093/ndt/gfs184
8. Peters SA, Bots ML, Canaud B, et al. Haemodiafiltration and mortality in end-stage kidney disease patients: a pooled individual participant data analysis from four randomized controlled trials. *Nephrol Dial Transplant*. 2016;31(6):978-984. doi:10.1093/ndt/gfv349
9. Canaud B, Vienken J, Ash S, Ward RA. Hemodiafiltration to address unmet medical needs ESKD patients. *Clin J Am Soc Nephrol*. 2018; 13(9):1435-1443. doi:10.2215/CJN.12631117
10. Ward RA, Vienken J, Silverstein DM, Ash S, Canaud B. Regulatory considerations for hemodiafiltration in the United States. *Clin J Am Soc Nephrol*. 2018;13(9):1444-1449. doi:10.2215/CJN.12641117
11. Davenport A, Peters SA, Bots ML, et al. Higher convection volume exchange with online hemodiafiltration is associated with survival advantage for dialysis patients: the effect of adjustment for body size. *Kidney Int*. 2016;89(1):193-199. doi:10.1038/ki.2015.264
12. De Palma JR, Bolton CF, Baltzan MA, Baltzan RB. Adequate hemodialysis schedule. *N Engl J Med*. 1971;285(6):353-354. doi:10.1056/NEJM197108052850618
13. Chapdelaine I, Mostovaya IM, Blankestijn PJ, et al. Treatment policy rather than patient characteristics determines convection volume in online post-dilution hemodiafiltration. *Blood Purif*. 2014;37(3): 229-237. doi:10.1159/000362108
14. Guedes M, Dambiski AC, Canhada S, et al. Achieving high convective volume in hemodiafiltration: lessons learned after successful implementation in the HDFit trial. *Hemodial Int*. 2021;25(1):50-59. doi:10.1111/hdi.12891
15. Kim DH, Lee YK, Park HC, et al. Stepwise achievement of high convection volume in post-dilution hemodiafiltration: a prospective observational study. *Semin Dial*. 2021;34(5):368-374. doi:10.1111/sdi.12966
16. Henderson LW, Colton CK, Ford CA. Kinetics of hemodiafiltration. II. Clinical characterization of a new blood cleansing modality. *J Lab Clin Med*. 1975;85(3):372-391.
17. Colton CK, Henderson LW, Ford CA, Lysaght MJ. Kinetics of hemodiafiltration. I. In vitro transport characteristics of a hollow-fiber blood ultrafilter. *J Lab Clin Med*. 1975;85(3):355-371.
18. Lorenzin A, Neri M, Clark WR, et al. Modeling of internal filtration in theranova hemodialyzers. *Contrib Nephrol*. 2017;191:127-141. doi:10.1159/000479261
19. Lorenzin A, Neri M, Lupi A, et al. Quantification of internal filtration in hollow fiber hemodialyzers with medium cut-off membrane. *Blood Purif*. 2018;46(3):196-204. doi:10.1159/000489993
20. Parisotto MT, Schoder VU, Miriunis C, et al. Cannulation technique influences arteriovenous fistula and graft survival. *Kidney Int*. 2014; 86(4):790-797. doi:10.1038/ki.2014.96
21. Marcelli D, Kopperschmidt P, Bayh I, et al. Modifiable factors associated with achievement of high-volume post-dilution hemodiafiltration: results from an international study. *Int J Artif Organs*. 2015;38(5):244-250. doi:10.5301/ijao.5000414
22. Marcelli D, Scholz C, Ponce P, et al. High-volume postdilution hemodiafiltration is a feasible option in routine clinical practice. *Artif Organs*. 2015;39(2):142-149. doi:10.1111/aor.12345
23. Tattersall JE, Ward RA. Online haemodiafiltration: definition, dose quantification and safety revisited. *Nephrol Dial Transplant*. 2013; 28(3):542-550. doi:10.1093/ndt/gfs530
24. Maduell F, Ojeda R, Belmar L, et al. Evaluation of the dialyser inner diameter in online haemodiafiltration. *Nefrologia (Engl Ed)*. 2018;38(1): 34-40. doi:10.1016/j.nefroe.2017.11.015
25. Potier J, Queffeulou G, Bouet J. Are all dialyzers compatible with the convective volumes suggested for postdilution online hemodiafiltration? *Int J Artif Organs*. 2016;39(9):460-470. doi:10.5301/ijao.5000525
26. Maduell F, Ojeda R, Arias-Guillen M, et al. Assessment of dialyzer surface in online hemodiafiltration; objective choice of dialyzer surface area. *Nefrologia*. 2015;35(3):280-286. doi:10.1016/j.nefro.2015.05.003
27. Dhondt A, Pauwels R, Devreese K, Eloot S, Glorieux G, Vanholder R. Where and when to inject low molecular weight heparin in hemodiafiltration? A cross over randomised trial. *PLoS One*. 2015; 10(6):e0128634. doi:10.1371/journal.pone.0128634
28. Hebibi H, Attaf D, Cornillac L, et al. Arterial versus venous port site administration of nadroparin for preventing thrombosis of extracorporeal blood circuits in patients receiving hemodiafiltration treatment. *Kidney Int Rep*. 2021;6(2):351-356. doi:10.1016/j.ekir.2020.11.020
29. Canaud B, Lévesque R, Krieter D, et al. On-line hemodiafiltration as routine treatment of end-stage renal failure: why pre- or mixed dilution mode is necessary in on-line hemodiafiltration today? *Blood Purif*. 2004;22(Suppl 2):40-48. doi:10.1159/000081874
30. Masakane I, Kikuchi K, Kawanishi H. Evidence for the clinical advantages of predilution on-line hemodiafiltration. *Contrib Nephrol*. 2017; 189:17-23. doi:10.1159/000450635
31. Tsuchida K, Minakuchi J. Clinical benefits of predilution on-line hemodiafiltration. *Blood Purif*. 2013;35(Suppl 1):18-22. doi:10.1159/000346221
32. Pedrini LA, Cozzi G, Faranna P, et al. Transmembrane pressure modulation in high-volume mixed hemodiafiltration to optimize efficiency and minimize protein loss. *Kidney Int*. 2006;69(3):573-579. doi:10.1038/sj.ki.5000110
33. Pedrini LA, De Cristofaro V. On-line mixed hemodiafiltration with a feedback for ultrafiltration control: effect on middle-molecule removal. *Kidney Int*. 2003;64(4):1505-1513. doi:10.1046/j.1523-1755.2003.00240.x
34. Kikuchi K, Hamano T, Wada A, Nakai S, Masakane I. Predilution online hemodiafiltration is associated with improved survival compared with hemodialysis. *Kidney Int*. 2019;95(4):929-938. doi:10.1016/j.kint.2018.10.036
35. Maduell F, Rodriguez N, Sahdala L, et al. Impact of the 5008 monitor software update on total convective volume. *Nefrologia*. 2014;34(5): 599-604. doi:10.3265/Nefrologia.pre2014.Apr.12508
36. Albalate Ramón M, Pérez García R, de Sequera Ortiz P, et al. Clinical application of Ultracontrol®: infusion volume and use with different dialyzers. *Nefrologia*. 2011;31(6):683-689. doi:10.3265/Nefrologia.pre2011.Sep.11122
37. 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.nefro.2015.06.019
38. Maduell F, Arias M, Durán CE, et al. Nocturnal, every-other-day, online haemodiafiltration: an effective therapeutic alternative. *Nephrol Dial Transplant*. 2012;27(4):1619-1631. doi:10.1093/ndt/gfr491
39. Maduell F, Navarro V, Torregrosa E, et al. Change from three times a week on-line hemodiafiltration to short daily on-line hemodiafiltration. *Kidney Int*. 2003;64(1):305-313. doi:10.1046/j.1523-1755.2003.00043.x
40. Maduell F, Ojeda R, Arias-Guillen M, et al. Eight-year experience with nocturnal, every-other-day, online haemodiafiltration. *Nephron*. 2016; 133(2):98-110. doi:10.1159/000446970

41. Roux A, Fumeron C, Petitclerc T, Cp C. Clinical and biological benefits of daily online hemodiafiltration. *JSM Renal Med*. 2016;1:1005-1011.
42. Rodriguez A, Morena M, Bargnoux AS, et al. Quantitative assessment of sodium mass removal using ionic dialysance and sodium gradient as a proxy tool: comparison of high-flux hemodialysis versus online hemodiafiltration. *Artif Organs*. 2021;45(8):E280-E292. doi:10.1111/aor.13923
43. Montagud-Marrahi E, Broseta J, Rodriguez-Espinosa D, et al. Optimization of dialysate bicarbonate in patients treated with online haemodiafiltration. *Clin Kidney J*. 2021;14(3):1004-1013. doi:10.1093/ckj/sfaa058

How to cite this article: Canaud B, Davenport A. Prescription of online hemodiafiltration (ol-HDF). *Semin Dial*. 2022;1-7. doi:10.1111/sdi.13070