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Kidney Res Clin Pract 2021;40(2):325-327
pISSN: 2211-9132 • eISSN: 2211-9140
https://doi.org/10.23876/j.krcp.20.243

KIDNEY RESEARCH AND CLINICAL PRACTICE

The removal capacity of asymmetric cellulose triacetate during post-dilution online hemodiafiltration

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Hypersensitivity reactions to synthetic membranes continue to be observed [1] and typically disappear following replacement of the dialysis membrane with a different type, usually cellulose triacetate. Previous studies have described the low purification ability of β2-microglobulin and its limited use in online hemodiafiltration (OL-HDF) with symmetric cellulose dialyzers [2]. The high ultrafiltration coefficient (K_{UF}) and configuration of asymmetric cellulose triacetate (ACT) allow its use in OL-HDF. However, there is lack of evidence of the performance of ACT dialyzers.

The aim of our study was to evaluate small- and mid-sized molecule clearance and albumin leakage in postdilution OL-HDF using the ACT dialyzer.

Nineteen adult patients with stage-5D kidney disease were enrolled in this study. The inclusion criteria were as follows: older than 18 years, completion of three 4-hour sessions weekly for at least 6 months, blood flow > 400 mL/min in the regular sessions, absence of hospital admission in the 4 weeks prior to the study and signed informed consent. Patients who failed to meet the inclusion criteria were excluded. Details of the dialyzer (Solacea dialyzer®, Nipro Medical Corp., Doral, FL, USA) are as follows: membrane surface area, 2.1 m^2; K_{UF}, 76 mL/hr/mmHg; inner diameter of hollow fiber, 200 μm; and membrane thickness, 25 μm. Ultrafiltration was prescribed according to the patient's needs, and 24 L of substitution volume was programmed. The prescribed dialysis features included a 4-hour duration, blood flow of 400 mL/min, and dialysate flow of 700 mL/min.

Pre- and postdialysis blood samples were collected at the mid-week dialysis session. Removal of urea (60 Da), creatinine (113 Da), β2-microglobulin (11.8 kDa), cystatin C (13 kDa), myoglobin (17.2 kDa), and prolactin (23 kDa) was estimated using the reduction ratio (RR) as follows.

(1) $RR = (C_{pre} - C_{post})/C_{pre}$, where C_{pre} and C_{post} are the pre- and posttreatment concentrations, respectively. Posttreatment concentrations of mid-size molecules were corrected for the haemoconcentration using the Bergström and Wehle formula [3].

β2 microglobulin was measured using a nephelometric immunoassay, and myoglobin and prolactin were assessed via electrochemiluminescence. Albumin was measured using an autoanalyzer. Estimated albumin leakage (EAL) was estimated according to the following formula.

(2) $EAL = [15 \times (C_0 + C_{15})/2 + 15 \times (C_{15} + C_{30})/2 + 30 \times (C_{30} + C_{60})/2 + C_{60} \times (C_{60} + C_{120})/2 + C_{120} \times C_{120}]/240 \times UF + Sust + (Qd \times 240/1,000)]$, where C is the albumin concentration in dialysate at the beginning (C_0) and also at 15 minutes (C_{15}), 30 minutes (C_{30}), 60 minutes (C_{60}), and 120 minutes (C_{120}) (mg/

Received: December 1, 2020; **Revised:** January 10, 2021; **Accepted:** January 26, 2021
Editor: Seung-Yeup Han, Keimyung University, Daegu, Republic of Korea
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L); UF, ultrafiltration (L); Sust, substitution volume (L); and Qd, dialysate flow (mL/min).

Written informed consent was obtained from all patients. All procedures were in accordance with the Declaration of Helsinki and its revisions. Descriptive results are expressed as the mean ± standard deviation for normally distributed continuous variables and the median and interquartile ranges for non-normally distributed continuous variables. Categorical variables are reported as percentages. All analyses were performed using IBM SPSS for Mac version 20.0 (IBM Corp., Armonk, NY, USA).

The baseline characteristics of the 19 patients included are shown in Table 1. All patients had a permanent native or prosthetic arteriovenous fistula. All patients completed the experimental sessions with no technical or clinical problems, no occurrences of blood circuit clotting, and no hypersensitivity reactions. The results are represented in Table 2.

Previous *in vitro* and *in vivo* studies have reported that an ACT membrane provides high diffusive transport rates with high solute clearance and good biocompatibility, but albumin leakage has not been addressed in these studies [4–6]. Although the acceptable upper limit of dialysis-related albumin loss remains unknown, it should be minimized because it may contribute to hypoalbuminemia and adversely affect the patient's prognosis. In this study, we demonstrated that OL-HDF with ACT membrane albumin loss is in the lower range compared to synthetic dialyzers and the removal of small and medium-molecules is similar to the results with synthetic membranes under similar conditions [7]. Although our findings demonstrated less albumin leakage than other authors [8], this difference was probably related to the higher convective volume achieved in other studies.

Our study had several limitations. First, this study was developed as an acute study that focused on the results of one dialysis session. Therefore, prospective studies are needed to assess the clinical impact of the use of ACT membranes. Despite the small sample size and absence of a control group, our results are in line with other authors' [4,5,8] and demonstrated efficacy in solute clearance and also achieved the recommended convective volume while minimizing albumin leakage.

In conclusion, ACT shows excellent behavior in OL-HDF. Although more prospective studies are needed, according to its clearance results and amount of albumin leakage, this dialyzer is not only an alternative for patients with an allergy to synthetic membranes but is also a good option for nonallergic hemodialysis patients.

Table 1. Baseline characteristics of the included patients

Characteristic	Data
Age (yr)	55.0 ± 17.3
Male sex	13 (68.4)
Dry weight (kg)	65.4 ± 14.2
Serum albumin (g/dL)	4.1 ± 0.4
Hemoglobin (g/dL)	11.2 ± 1.2

Data are expressed as mean ± standard deviation or number (%).

Table 2. The performance of asymmetric cellulose triacetate dialyzer

Performance	Data
Total convective volume[a] (L)	27.4 ± 3.4
Dialysance (Kt/V)	1.9 ± 0.4
Reduction ratio (%)	
Urea	83.7 ± 5.2
Creatinine	76.4 ± 5.3
β2 microglobulin	79.3 ± 4.7
Cystatin C	77.3 ± 4.7
Myoglobin	76.6 ± 5.4
Prolactin	73.7 (67.3–77.5)
Estimated albumin loss (mg/session)	481.2 (384.8–596.7)

Data are expressed as mean ± standard deviation or median (interquartile range).
[a]Substitution volume + ultrafiltration.

Conflict of interest

All authors have no conflicts of interest to declare.

Authors' contributions

Conceptualization: NM, AV
Investigation: LC, AV
Methodology: AS
Writing–original draft: AS
Writing–review & editing: LC
All authors read and approved the final manuscript.

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