Comparison of Volume Overload with Cycler-Assisted versus Continuous Ambulatory Peritoneal Dialysis

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Background and objectives: Cycler-assisted peritoneal dialysis (CCPD) has been associated with decreased sodium removal compared with continuous ambulatory peritoneal dialysis (CAPD) as a result of peritoneal sodium sieving during the short dwells that are associated with CCPD. This may have adverse consequences for management of extracellular fluid volume (ECFV). This study compared ECFV in patients who received CAPD or CCPD; CCPD dwell times were maximized by limiting the number of exchanges, and the use of icodextrin for the long daytime dwells was widespread.

Design, setting, participants, & measurements: This was an observational, cross-sectional study of 158 prevalent patients (90 CAPD, 68 CCPD). Demographic data, blood work, and 24-h dialysate and urine samples were collected from all participants between January 2004 and July 2006. They subsequently underwent assessment of ECFV by multifrequency bioimpedance spectroscopy analysis. Multivariate analysis was used to determine the relationship between peritoneal dialysis modality and ECFV. Potential cofounders including age, comorbidity, time on dialysis, residual renal function, and icodextrin use were identified a priori.

Results: There were no differences in BP, use of antihypertensive medications, or the presence of peripheral edema between CAPD and CCPD patients. Similarly, there was no difference in the ratio of ECFV to total body water between CAPD (51.8%) and CCPD (51.9%) patients (P = 0.929).

Conclusions: There is no difference in BP, sodium removal, or volume control in patients who use a contemporary approach to CCPD that uses fewer night cycles and liberalizes the use of icodextrin when compared with CAPD.


The control of extracellular fluid volume (ECFV) is a central objective in the provision of adequate renal replacement therapy to patients with ESRD. During the past decade, the proportion of peritoneal dialysis (PD) patients who perform cycler-assisted PD (CCPD) has increased compared with continuous ambulatory PD (CAPD). There are multiple reasons for this, including lifestyle, the increasing age and decreased manual dexterity of patients who start PD, and factors related to peritoneal membrane transport characteristics and dialysis adequacy (1).

Although a randomized trial that compared CCPD and CAPD showed no difference in mean BP or survival between the two modalities (2), several challenges have been identified with the use of CCPD (3). Sodium (Na) removal during both the rapid nighttime and the long daytime exchanges in CCPD is lower as compared with CAPD (4–6). In addition, CCPD may be associated with a more rapid loss of residual renal function, although the published literature in this area is discrepant (5,7–10). These differences may lead to an increase in ECFV in CCPD patients, which is increasingly believed to be a central mechanism in the increased cardiovascular mortality of patients with ESRD. Patients are also increasingly selecting CCPD for lifestyle reasons rather than because they have high transport membrane characteristics, resulting in an increasing proportion of CCPD patients’ having low transport membrane characteristics.

Patients in our PD unit typically select CCPD for lifestyle reasons and are not started on CCPD on the basis of clinical criteria. Given the previously mentioned concerns, our program moved away from the historical practice of high-frequency nighttime exchanges for CCPD users in 2003. Instead, automated nighttime cycles are prescribed as three to four cycles during 9 to 10 h, based on patient characteristics and needs. All patients have a wet day. Icodextrin for the long daytime dwell is used for any patient who is believed to be at risk for volume overload. CCPD patients are prescribed an additional exchange in the evening, 3 to 4 h before starting the cycler, either to increase small solute clearance (primarily those who have low transport membrane characteristics) or when ultrafiltration is believed to be inadequate. The objective of this study was to compare ECFV, using the previously validated technique of bioimpedance spectroscopy (BIS) (11), of patients who used CAPD and our contemporary approach to CCPD. We hypothesized that there would be no difference in BP, Na+ removal, or ECFV between our CAPD and CCPD patients.
Materials and Methods

The Research Ethics Board of the University of Alberta approved this observational, cross-sectional study, and all study procedures were in adherence to the Declaration of Helsinki. Prevalent PD patients in the Northern Alberta Renal Program, a Canadian university-based renal program, were consecutively recruited between January 2004 and July 2006 at the time of their routine adequacy assessment, which includes a 24-h urine and dialysate collection and peritoneal equilibration test. This is done annually for patients with no residual renal function and every 6 mo for those with a urine output of ≥250 ml/d. Patients were excluded when they were younger than 18 yr, were unable to give consent, had been on PD for <2 mo, or had an episode of peritonitis within the previous 2 mo.

All patients were using dialysis systems from Baxter Healthcare Corp. (Deerfield, IL). CCPD was performed using the Home Choice Pro System. The program uses a variety of dextrose glucose solutions as well as icodextrin. The Na content is 132 mmol/L for the glucose solutions and 133 mmol/L for the icodextrin solution.

After we obtained consent, we collected demographic data including age, gender, and comorbidity. We determined the modified Charlson Comorbidity Index as a measure of comorbid conditions (12,13). Systolic and diastolic BP, diuretic and antihypertensive medication use, the presence of subjective symptoms of volume overload such as dyspnea and peripheral edema, the use of icodextrin solution, and biochemical indices were assessed during the clinic. This clinical assessment was blinded to subsequent data collection and BIS measurements. Dialysate/plasma (D/P) creatinine ratio values were obtained from standard peritoneal equilibration test studies. Ultrafiltration, GFR, creatinine, and Na removal were calculated from 24-h urine and dialysate collections according to standard methods (14).

All study participants underwent ECFV measurement using a Hydra 4200 bioimpedance analyzer (Xitron Technologies, San Diego, CA). Electrodes were placed on the wrist and ankle in the standard manner (15). Measurements were made with the patients lying supine. Fifty frequencies were measured from 5 to 500 kHz. Data were analyzed with the software provided by Xitron Technologies, which uses the Cole-Cole model for computation of total body water (TBW) and ECFV. The intracellular fluid volume (ICFV) was calculated as the difference between TBW and ECFV. Two readings were taken on each patient, and the mean values for TBW and ECFV were recorded. Measurements were taken with indwelling intra-abdominal dialysate fluid, which has been shown not to affect BIS measurements (11). We confirmed this by taking readings with and without indwelling dialysate for the first 20 patients, and no differences in readings were observed. ECFV measurement using BIS measurements have been validated in dialysis patients and are correlated with the gold standard measurement by isotope dilution (11,16).

SPSS 15.0 for windows (SPSS, Chicago, IL) was used to perform statistical analyses. P < 0.05 was considered statistically significant. Patient characteristics and other measurements were described as percentages for categorical variables and as mean (SD) for continuous variables. BIS values were reported in a standard manner as ECFV/TBW. Pearson correlation coefficients between ECFV/TBW ratio and all continuous variables were computed. The mean ECFV/TBW ratio was compared between PD modalities and all other dichotomous variables by two independent samples t test. Bivariate regression analysis was conducted to find the variables associated with ECFV/TBW. Independent variables that met an initial statistical level of ≤0.2 were examined in the multivariate regression analysis. Variables found to be statistically significant in the multivariate regression model (P < 0.05) were kept in the final model. The model was adjusted by forcing PD modality group (CAPD or CCPD) into the final parsimonious model. Model diagnostics such as residual plots were examined to test that the model assumptions were not violated.

Results

Of 181 eligible patients, 158 (90 CAPD and 68 CCPD; 87% response) were enrolled. Patient characteristics are shown in Table 1. On average, patients were 56.7 yr of age. Compared with patients on CAPD, patients on CCPD had been on dialysis longer (29.6 versus 24.2 mo; P = 0.001), used more dialysate (9498 versus 8265 ml; P = 0.001), had higher D/P creatinine ratios (0.75 versus 0.69; P < 0.001), and had less urine Na excretion (31.1 versus 42.7 mmol/d; P = 0.006). There were no differences in residual or dialysate creatinine clearance, residual estimated GFR (eGFR), residual urine volume, or dialysate Na concentration between these patient groups. CCPD patients were prescribed a mean of 3.7 exchanges (range two to five) during 8.9 h (range 7.0 to 10.5). Forty-eight percent of patients were prescribed an additional daytime exchange, and 78% used icodextrin during the long daytime dwell. Mean total daily Na removal was 109 mmol/d for patients on CAPD and 130 mmol/d for those on CCPD (P = 0.232; Table 1). Forty-one percent of CAPD patients had a total Na removal of <100 mmol/d compared with 33.8% of CCPD patients (P = 0.365). There was a trend toward greater ultrafiltration (811 versus 572 ml/d; P = 0.092) and dialysate Na removal (98.7 versus 66.1 mmol/d; P = 0.069) with CCPD, but neither of these reached statistical significance.

No differences in the clinical assessment of volume status as defined by BP, use of diuretics or antihypertensive medications, the presence of peripheral edema, or BIS values were identified between patients on CAPD and those on CCPD (Table 2). The mean ratio of ECFV to TBW was 51.8% for CAPD patients and 51.9% for CCPD patients (P = 0.929). These values are in keeping with published BIS values for PD patients (17). Results did not change whether diuretic use was analyzed as an independent variable or included as an antihypertensive agent.

Expanded ECFV was significantly associated with a number of variables; however, in the multivariate regression analysis, only lower serum albumin, older age, lower lean body mass (LBM), decreased residual eGFR, and higher D/P creatinine were independently associated with increased ECFV, accounting for 59.1% of the variability of ECFV (Table 3). In the multivariate regression model, the most significant predictor was serum albumin, which accounted for 40.1% of the variability in ECFV, age an additional 11.6%, LBM 3.6%, eGFR 2.2%, and D/P creatinine the last 1.6% of the variability seen in the ECFV.

Discussion

There is an ongoing controversy in the literature as to whether CCPD is associated with less effective control of volume as compared with CAPD. To our knowledge, these are the first data of Na removal, BP control, and volume status of patients using the described modified approach to CCPD com-
pared with CAPD. Our results demonstrate that in our PD program, patients who have a modified CCPD prescription that limits the number of nocturnal exchanges in conjunction with a liberal use of icodextrin and a supplemental evening exchange in select patients do not exhibit greater ECFV than CAPD patients.

Previous studies showed that patient outcome in PD is not well predicted by dialysis dosage (18,19). Rather, residual renal function and, more specific, total Na and fluid removal seem to be the most important predictors of outcome in this patient population (19,20). The Canada-USA (CANUSA) study, a large prospective cohort study of incident PD patients, demonstrated that urine volume superseded renal small solute clearance as a predictor of mortality (19). The apparent importance of residual renal function is likely a proxy for adequate volume control, although a direct link between intravascular volume and cardiovascular mortality in PD patients has yet to be established. For these reasons, normalization of ECFV is central to the definition of PD adequacy (21).

CCPD was initially introduced for patients with high transport membrane characteristics but has become increasingly popular, primarily for lifestyle reasons (22). The increasing age of the dialysis population has also led to increased use of this technique because it is less time consuming for caregivers to

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>CAPD (n = 90)</th>
<th>CCPD (n = 68)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>age (yr)</td>
<td>56.7 (15.8)</td>
<td>56.2 (15.6)</td>
<td>0.858</td>
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<td>time on dialysis (mo)</td>
<td>24.2 (20.7)</td>
<td>29.6 (17.3)</td>
<td>0.001</td>
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<td>weekly Kt/V</td>
<td>2.20 (0.45)</td>
<td>2.24 (0.48)</td>
<td>0.588</td>
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<td>dialysis prescription (L/d)</td>
<td>8.265 (1.088)</td>
<td>9.498 (1.625)</td>
<td>&lt;0.001</td>
</tr>
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<td>nighttime exchanges (n)</td>
<td>N/A</td>
<td>3.7 (0.6)</td>
<td>N/A</td>
</tr>
<tr>
<td>time on CCPD (h)</td>
<td>N/A</td>
<td>8.9 (0.7)</td>
<td>N/A</td>
</tr>
<tr>
<td>residual CrCl (L/wk)</td>
<td>39.4 (30.2)</td>
<td>36.2 (32.9)</td>
<td>0.822</td>
</tr>
<tr>
<td>dialysate CrCl (L/wk)</td>
<td>43.8 (8.4)</td>
<td>43.9 (7.8)</td>
<td>0.924</td>
</tr>
<tr>
<td>ultrafiltration (ml/d)</td>
<td>572 (1013)</td>
<td>811 (661)</td>
<td>0.092</td>
</tr>
<tr>
<td>residual GFR (ml/min)</td>
<td>4.3 (3.5)</td>
<td>4.1 (3.7)</td>
<td>0.745</td>
</tr>
<tr>
<td>urine volume (ml/d)</td>
<td>654 (498)</td>
<td>682 (673)</td>
<td>0.761</td>
</tr>
<tr>
<td>D/P creatinine</td>
<td>0.69 (0.10)</td>
<td>0.75 (0.08)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>urine Na (mmol/d)</td>
<td>42.7 (26.9)</td>
<td>31.1 (24.2)</td>
<td>0.006</td>
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<tr>
<td>dialysate Na concentration (mmol/L)</td>
<td>125 (13)</td>
<td>124 (14)</td>
<td>0.580</td>
</tr>
<tr>
<td>dialysate Na removal (mmol/d)</td>
<td>66.1 (127.5)</td>
<td>98.7 (82.0)</td>
<td>0.069</td>
</tr>
<tr>
<td>total Na removal (mmol/d)</td>
<td>109 (124)</td>
<td>130 (75)</td>
<td>0.232</td>
</tr>
<tr>
<td>weight (kg)</td>
<td>75.3 (17.6)</td>
<td>75.0 (16.1)</td>
<td>0.933</td>
</tr>
<tr>
<td>LBM</td>
<td>63 (16)</td>
<td>59 (11)</td>
<td>0.068</td>
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<tr>
<td>protein catabolic rate</td>
<td>0.88 (0.24)</td>
<td>0.84 (0.19)</td>
<td>0.243</td>
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<td>Charlson comorbidity index</td>
<td>5.9 (2.3)</td>
<td>6.1 (2.5)</td>
<td>0.538</td>
</tr>
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<td>albumin (g/L)</td>
<td>35.7 (4.6)</td>
<td>35.3 (3.6)</td>
<td>0.615</td>
</tr>
<tr>
<td>hemoglobin (g/L)</td>
<td>115.8 (11.9)</td>
<td>114.7 (10.2)</td>
<td>0.521</td>
</tr>
<tr>
<td>calcium (corrected for albumin; mmol/L)</td>
<td>2.36 (0.19)</td>
<td>2.33 (0.15)</td>
<td>0.478</td>
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<tr>
<td>phosphorous (mmol/L)</td>
<td>1.70 (0.36)</td>
<td>1.74 (0.34)</td>
<td>0.480</td>
</tr>
<tr>
<td>parathyroid hormone (pmol/L)</td>
<td>30.8 (26.2)</td>
<td>30.0 (20.6)</td>
<td>0.818</td>
</tr>
<tr>
<td>Na (mmol/L)</td>
<td>136.9 (3.2)</td>
<td>135.9 (3.0)</td>
<td>0.039</td>
</tr>
<tr>
<td>CRP</td>
<td>8.5 (11.4)</td>
<td>8.8 (12.2)</td>
<td>0.895</td>
</tr>
<tr>
<td>% of patients</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>male gender</td>
<td>57.8</td>
<td>50.0</td>
<td>0.331</td>
</tr>
<tr>
<td>CCPD patients with additional daytime exchange</td>
<td>48.5</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>icodextrin use</td>
<td>55.6</td>
<td>77.9</td>
<td>0.002</td>
</tr>
<tr>
<td>ischemic heart disease</td>
<td>23.3</td>
<td>22.1</td>
<td>0.850</td>
</tr>
<tr>
<td>peripheral vascular disease</td>
<td>12.2</td>
<td>16.2</td>
<td>0.477</td>
</tr>
<tr>
<td>cerebrovascular disease</td>
<td>13.3</td>
<td>10.3</td>
<td>0.561</td>
</tr>
<tr>
<td>diabetes</td>
<td>40.0</td>
<td>54.4</td>
<td>0.072</td>
</tr>
<tr>
<td>hypertension</td>
<td>77.8</td>
<td>73.5</td>
<td>0.536</td>
</tr>
</tbody>
</table>

*CAPD, continuous ambulatory peritoneal dialysis; CCPD, cycler-assisted peritoneal dialysis; CrCl, creatinine clearance; CRP, C-reactive protein; LBM, lean body mass.
administer. The movement to increase use of home dialysis modalities is likely to result in even greater use of CCPD. An early randomized trial of 82 patients showed no difference in BP, technique, or patient survival between CCPD and CAPD (2). A second randomized trial that compared CCPD and CAPD in 34 patients demonstrated that CCPD was associated with significantly more time for work, family, and social activities compared with CAPD, although there was no difference in health-related quality of life scores measured by the Short Form-36 (22). Recent registry data on 4128 patients in Australia and New Zealand showed no significant difference in patient survival and death-censored technique failure between patients who were on CAPD and CCPD (23); however, numerous observational studies have highlighted potential problems with CCPD. CCPD may be associated with an increased rate of decline of residual renal function compared with CAPD, although the published literature in this area is discrepant (5,7–10). The short dwell times seem to be associated with significant changes in hemodynamics and BP; these changes may affect GFR (24). CCPD has also been associated with more frequent hypertension and less Na and fluid removal compared with GFR (24). Loss of GFR in conjunction with inadequate Na and fluid removal may result in ECFV expansion in patients who are on CCPD and CCPD (23); however, numerous observational studies have highlighted potential problems with CCPD. CCPD may be associated with an increased rate of decline of residual renal function compared with CAPD, although the published literature in this area is discrepant (5,7–10). The short dwell times seem to be associated with significant changes in hemodynamics and BP; these changes may affect GFR (24). CCPD has also been associated with more frequent hypertension and less Na and fluid removal compared with GFR (24). Loss of GFR in conjunction with inadequate Na and fluid removal may result in ECFV expansion in patients who are on CCPD and CCPD (23); however, numerous observational studies have highlighted potential problems with CCPD. CCPD may be associated with an increased rate of decline of residual renal function compared with CAPD, although the published literature in this area is discrepant (5,7–10). The short dwell times seem to be associated with significant changes in hemodynamics and BP; these changes may affect GFR (24). CCPD has also been associated with more frequent hypertension and less Na and fluid removal compared with GFR (24). Loss of GFR in conjunction with inadequate Na and fluid removal may result in ECFV expansion in patients who are on CCPD and CCPD (23); however, numerous observational studies have highlighted potential problems with CCPD. CCPD may be associated with an increased rate of decline of residual renal function compared with CAPD, although the published literature in this area is discrepant (5,7–10). The short dwell times seem to be associated with significant changes in hemodynamics and BP; these changes may affect GFR (24). CCPD has also been associated with more frequent hypertension and less Na and fluid removal compared with GFR (24).

### Table 2. Comparisons of volume status by CAPD and CCPD

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CCPD (n = 68)</th>
<th>CAPD (n = 90)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECFV/TBW (%)</td>
<td>51.8 (5.7)</td>
<td>51.9 (4.4)</td>
<td>0.929</td>
</tr>
<tr>
<td>systolic BP</td>
<td>132.9 (19.1)</td>
<td>129.9 (17.4)</td>
<td>0.323</td>
</tr>
<tr>
<td>diastolic BP</td>
<td>78.6 (10.5)</td>
<td>76.4 (11.3)</td>
<td>0.223</td>
</tr>
<tr>
<td>% of Patients</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BP medication use</td>
<td>69.3</td>
<td>58.8</td>
<td>0.174</td>
</tr>
<tr>
<td>diuretic use</td>
<td>39.8</td>
<td>33.8</td>
<td>0.446</td>
</tr>
<tr>
<td>peripheral edema</td>
<td>36.4</td>
<td>38.2</td>
<td>0.810</td>
</tr>
</tbody>
</table>

*ECFV, extracellular fluid volume; TBW, total body water.

Expanded ECFV of both CCPD and CAPD patients was highly associated with lower serum albumin. This was most likely due to dilution (28). Less likely, the low serum albumin may have been a result of inflammation associated with ECFV expansion. ECFV expansion may directly cause inflammation (29,30). Conversely, an inflammatory process may generate ECFV expansion by the associated increase in peritoneal membrane permeability, which in turn may lead to fluid retention. C-reactive protein was not associated with ECFV in this study. Increased ECFV was also associated with increased age. This is likely due to a limitation in the method of volume assessment using BIS. ICFV is related to body cell mass, which decreases with age; the result is a higher ECFV/TBW ratio. This is supported by our finding that lower LBM was independently associated with a higher ECFV/TBW ratio. Although residual GFR remains an independent predictor of ECFV, its importance is limited relative to age and serum albumin in the overall model accounting for only 2.2% additional variability of the overall variability of the ECFV. Similarly, high transporter status was associated with ECFV, although it predicted only 1.6% of the variability in ECFV. High D/P creatinine is associated with less fluid and solute removal, higher protein loss, and increased glucose absorption (31). Na removal was not associated with ECFV expansion. This is consistent with previously published data on a group of CCPD patients who used icodextrin (25). Increased ECFV was also associated with increased age. This is likely due to a limitation in the method of volume assessment using BIS. ICFV is related to body cell mass, which decreases with age; the result is a higher ECFV/TBW ratio. This is supported by our finding that lower LBM was independently associated with a higher ECFV/TBW ratio. Although residual GFR remains an independent predictor of ECFV, its importance is limited relative to age and serum albumin in the overall model accounting for only 2.2% additional variability of the overall variability of the ECFV. Similarly, high transporter status was associated with ECFV, although it predicted only 1.6% of the variability in ECFV. High D/P creatinine is associated with less fluid and solute removal, higher protein loss, and increased glucose absorption (31). Na removal was not associated with ECFV expansion. This is consistent with previously published data on a group of CCPD patients who used icodextrin (25). This is not overly surprising, because ECFV is the result of Na and fluid intake as well as less. There are limitations to this study. First, this was not a randomized study. Although patients were not selected for CCPD by clinical criteria (*i.e.*, modality selection was driven by patient preference), CCPD prescriptions were adjusted on clinical grounds, and, as such, biases can be introduced. Unmeasured confounders could potentially mask the relationship between PD modality and ECFV; however, further randomized
trials comparing CAPD and CCPD will be difficult to conduct because these modalities are increasingly being selected for reasons related to patient preference, lifestyle, and availability of caregiver assistance compared with the initial randomized trials that were done almost two decades ago at a time when clinical indications such as peritoneal membrane transport characteristics drove modality selection. Second, this was a study of prevalent patients, which may lead to survivor bias. Ideally, for confirmation of these results, longitudinal follow-up of incident patients is warranted; however, 34 (21.5%) of the 158 participants had been on dialysis for <1 yr. The volume status of these patients was no different from that of patients who had been on dialysis for >1 yr. Third, although multifrequency BIS has been validated as a method by which to measure body water distribution, it is associated with a residual error of 2 to 4% (bias of 2.5 to 3.0 L) when compared with the gold standard of deuterium dilution (32). It is therefore possible that smaller but clinically significant differences in

<table>
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<tr>
<th>Variable</th>
<th>Bivariate Regression Analysis</th>
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<th>Multivariate Regression Analysis</th>
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<tbody>
<tr>
<td></td>
<td>Slope (95% CI)</td>
<td>R² (%)</td>
<td>P</td>
<td>Slope (95% CI)</td>
<td>R² (%)</td>
<td>P</td>
</tr>
<tr>
<td>Modality CAPD (versus CCPD)</td>
<td>-0.07 (-1.73 to 1.59)</td>
<td>&lt;0.1</td>
<td>0.931</td>
<td>0.71 (-0.44 to 1.86)</td>
<td>59.1</td>
<td>0.224</td>
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<tr>
<td>Age</td>
<td>0.16 (0.12 to 0.21)</td>
<td>24.8</td>
<td>&lt;0.001</td>
<td>0.10 (0.06 to 0.14)</td>
<td></td>
<td>&lt;0.001</td>
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<tr>
<td>Male gender</td>
<td>-0.77 (-2.41 to 0.88)</td>
<td>0.6</td>
<td>0.357</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>-0.06 (-0.11 to -0.01)</td>
<td>4.6</td>
<td>0.016</td>
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<td>LBM</td>
<td>-0.18 (-0.23 to -0.13)</td>
<td>24.9</td>
<td>&lt;0.001</td>
<td>-0.07 (-0.12 to -0.03)</td>
<td>0.001</td>
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<tr>
<td>Protein catabolic rate</td>
<td>-5.92 (-9.54 to -2.30)</td>
<td>6.4</td>
<td>0.002</td>
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<tr>
<td>Time on dialysis (mo)</td>
<td>1.29 (0.13 to 2.45)</td>
<td>3.0</td>
<td>0.030</td>
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<tr>
<td>Weekly Kt/V</td>
<td>-0.83 (-2.60 to 0.94)</td>
<td>0.6</td>
<td>0.356</td>
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</tr>
<tr>
<td>Residual CrCl</td>
<td>-0.04 (-0.07 to -0.02)</td>
<td>7.1</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dialysate CrCl</td>
<td>0.11 (0.01 to 0.21)</td>
<td>3.1</td>
<td>0.029</td>
<td></td>
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</tr>
<tr>
<td>Daily ultrafiltration, per 100 ml</td>
<td>-0.07 (-0.16 to 0.02)</td>
<td>1.5</td>
<td>0.127</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Residual GFR</td>
<td>-0.41 (-0.63 to -0.19)</td>
<td>8.2</td>
<td>&lt;0.001</td>
<td>-0.28 (-0.45 to -0.12)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Daily dialysis prescription, per 1 L</td>
<td>0.22 (-0.34 to 0.77)</td>
<td>0.4</td>
<td>0.439</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Daily urine volume</td>
<td>-0.23 (-0.36 to -0.09)</td>
<td>6.5</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D/P creatinine</td>
<td>8.83 (0.44 to 17.22)</td>
<td>2.8</td>
<td>0.039</td>
<td>7.64 (1.36 to 13.9)</td>
<td>0.018</td>
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<tr>
<td>Daily urine Na</td>
<td>-0.04 (-0.07 to -0.01)</td>
<td>5.2</td>
<td>0.004</td>
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</tr>
<tr>
<td>Daily dialysate Na</td>
<td>-0.02 (-0.10 to -0.05)</td>
<td>0.3</td>
<td>0.498</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Albumin</td>
<td>-0.78 (-0.93 to -0.63)</td>
<td>40.1</td>
<td>&lt;0.001</td>
<td>-0.49 (-0.64 to -0.34)</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Hemoglobin</td>
<td>-0.04 (-0.12 to 0.03)</td>
<td>0.9</td>
<td>0.250</td>
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<tr>
<td>Calcium (corrected for albumin)</td>
<td>3.79 (-1.10 to 8.68)</td>
<td>2.2</td>
<td>0.100</td>
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<tr>
<td>Phosphorus</td>
<td>-3.12 (-5.39 to -0.86)</td>
<td>4.6</td>
<td>0.007</td>
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<tr>
<td>Parathyroid hormone</td>
<td>-0.05 (-0.08 to -0.01)</td>
<td>4.7</td>
<td>0.007</td>
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<tr>
<td>Na</td>
<td>-0.53 (-0.78 to -0.29)</td>
<td>10.8</td>
<td>&lt;0.001</td>
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<tr>
<td>CRP</td>
<td>0.10 (0.02 to 0.18)</td>
<td>4.3</td>
<td>0.016</td>
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<tr>
<td>Icodextrin use</td>
<td>0.40 (-1.32 to 2.12)</td>
<td>&lt;0.1</td>
<td>0.649</td>
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<tr>
<td>Ischemic heart disease</td>
<td>1.71 (-0.27 to 3.70)</td>
<td>1.9</td>
<td>0.090</td>
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<tr>
<td>Congestive heart failure</td>
<td>3.73 (1.46 to 6.01)</td>
<td>6.4</td>
<td>0.001</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.49 (-0.13 to 3.12)</td>
<td>2.1</td>
<td>0.072</td>
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<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>0.71 (-1.21 to 2.63)</td>
<td>0.3</td>
<td>0.465</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charlson comorbidity index</td>
<td>1.08 (0.78 to 1.38)</td>
<td>24.6</td>
<td>&lt;0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic BP</td>
<td>0.02 (-0.02 to 0.07)</td>
<td>&lt;0.1</td>
<td>0.376</td>
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</tr>
<tr>
<td>Diastolic BP</td>
<td>-0.10 (-0.17 to -0.02)</td>
<td>4.2</td>
<td>0.012</td>
<td></td>
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<tr>
<td>Antihypertensive medication use</td>
<td>-2.56 (-4.23 to -0.88)</td>
<td>5.7</td>
<td>0.003</td>
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</tr>
<tr>
<td>Peripheral edema</td>
<td>1.11 (-0.59 to 2.80)</td>
<td>1.1</td>
<td>0.198</td>
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</tr>
</tbody>
</table>

*CI, confidence interval.
ECFV may be missed with BIS. The assessment of volume status using BIS is limited by the relatively low accuracy of ICFV estimation compared with ECFV measurement. This is because ICFV depends on differences in individual body composition (15). ECFV/TBW ratios, therefore, may be elevated as a result of malnutrition and obesity rather than volume expansion (32). Although mean weight was similar in CCPD and CAPD patients, CCPD patients had a trend to lower LBM ($p = 0.068$); however, lower LBM would elevate the ECFV/TBW ratio independent of volume status, strengthening the suggestion that ECFV is not expanded in patients who are on CCPD compared with CAPD.

As more patients with lower membrane transport characteristics use CCPD for lifestyle reasons, it will become increasingly important to optimize the prescription to ensure effective Na and fluid removal. We found no difference in BP, Na removal, or ECFV control in our CCPD patients compared with CAPD when using this contemporary approach to CCPD, which uses fewer night cycles to lengthen night dwells, liberalizes the use of icodextrin for the long daytime dwell, and supplements with an additional daytime exchange in select patients.

**Disclosures**

None.

**References**


