Continuous flow peritoneal dialysis (CFPD): a glimpse into the future

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Background

After years of controversy, there is increasing information that—at least during the first 2–3 years—survival on CAPD is slightly better than on haemodialysis [1–3]. The main shortcoming of CAPD is its limited efficacy when residual renal function deteriorates. Once renal function is lost the efficacy of CAPD is limited first by anatomical constraints, mainly peritoneal surface area and mesenteric blood flow to the peritoneal membrane and second, the ratio of body weight to peritoneal surface area. These factors are beyond the control of the physician.

If one wishes to increase the efficacy of CAPD this can be done only by increasing and optimizing two further parameters: increasing the intraperitoneal volume per exchange and the rate of exchange. With conventional catheters and conventional exchange technology a feasible upper limit is soon reached. It is here that in the recent months innovative and novel approaches have been tried [4,5].

Of course there is nothing new under the sun. In 1965, Shinaberger et al. [6] investigated a technique then called ‘recirculating peritoneal dialysis’. These authors used two catheters. One peritoneal access was used for the inflow of peritoneal dialysis fluid, while the other one transported the peritoneal effluent to a twin coil haemodialyser. The spent peritoneal dialysate was dialysed, thereby regenerated and subsequently returned to the peritoneal cavity via the second catheter. The flow rate for ‘recirculation dialysis’ varied between 20 and 315 ml/min, the glucose concentration used was 1.5%. Using this technique with the highest flow rates Shinaberger et al. [6] found average urea clearances of 57.6 ml/min (creatinine clearances of 34.9 ml/min and phosphate clearances of 34 ml/min).

Why was this technique not used on a wider basis? First, the technique was complex and laborious. Second, no specific catheters for this purpose were commercially available. Third, there were financial constraints. While such considerations prevented this idea from becoming a practical application, the basic concept was elegant, i.e. to achieve higher clearances by increasing peritoneal dialysate flow rates, reducing stagnant layers of the dialysate by creating turbulence and reducing resistance to diffusion. This appealing idea was kept alive, even though it remained on the back burner of nephrologists’ consideration.

Recently, there has been a renaissance of interest in this technique, namely the concept to combine peritoneal dialysis with HD technology. Although it is too early to be definite about the potential role of CFPD (i.e. whether it can be applied on a broad basis as a measure to increase efficacy of PD) the first anecdotal results are quite encouraging [4,5,9]. We feel that it is of interest to the clinical nephrologist to be kept informed about these novel approaches to further develop PD. We hope that within the next 2 to 3 years the definitive answer will be available.

The kinetics of PD and theoretical basis of CFPD

In the early days Boen [10] studied the relationship between peritoneal dialysate flow volume and peritoneal urea clearance. As shown in Figure 1, the latter increases as a function of dialysate flow rate over a wide range of flow volumes. The disadvantage is that at high flow rates clearance efficacy decreases, because more and more time is spent in transit and not in dialysis mode.

It is here that the concept of CFPD sets in. If it were possible to provide high rates of continuous flow, one could increase the peritoneal urea clearance beyond the point of fall-off shown in the study of Boen [10].

How can this be put into practice? Even though a single lumen catheter [4] or two different catheters may be used in experimental settings [9,11], one first requirement for a well functioning and effective CFPD are low resistance double-lumen catheters to guarantee continuous inflow and outflow of the dialysate solution. When such catheters were tried [12], surprisingly, preferential streamlining of solutions did not occur. Presumably this occurred because the high rates of flow guaranteed considerable turbulence in the peritoneal cavity. Indeed, the rate of exchange was limited only by the resistance offered by the catheter. For clinical use flow rates between 150 and 250 ml/min have been discussed.

One of the shortcomings of conventional CAPD is that high concentrations of glucose are needed to remove sufficiently large fluid volumes by osmosis. In CFPD ultrafiltration can be achieved using relatively low-dialysate glucose due to the maintenance of the osmotic gradient by the higher dialysate flow most probably not causing any metabolic or biocompatibility problems [13]. The latter is also expected by the elimination of glucose degradation products [14,15], the use of bicarbonate as buffer [16,17] and the physiological pH [18]. As a final consideration, during conventional CAPD approximately 5–8 g of protein—during episodes of peritonitis even up to 20 g/day—are lost [19–21]. In contrast, with CFPD, because of the closed circulation arrangement, protein loss can be kept to a minimum and if the final volume is re-infused into the peritoneal cavity it can even be prevented completely [22].

Studies on CFPD

A number of authors reported, in a more or less anecdotal fashion, their experience with this old, but recently resuscitated, technique of CFPD. The combined total of the published literature shown in Table 1 covers 41 patients treated mostly in acute comparative studies with either intermittent peritoneal dialysis (IPD) or other modes of conventional PD. The reported peritoneal urea clearance rates varied between 14 and 125 ml/min. Patients were treated on an average for 5–8 h. The only long-term experience was reported by Stephen et al. [23], who treated patients for up to 11 months. Clinical complications were inflow pain when using inflow rates >200 ml/min and infections based on a special subcutaneous peritoneal catheter design used at that time.

Stimulated by these reports, we used the following set-up. A patient with a double-lumen catheter is connected to a modified haemodialysis tubing set and in parallel to a conventional 2 l peritoneal dialysis solution. After inflow and a short dwell of a few minutes CFPD is started with a peritoneal dialysis flow of 200 ml/min and a dialysate flow of 300 ml/min.
Table 1. Overview on CFPD studies with human subjects in the literature

<table>
<thead>
<tr>
<th>Author</th>
<th>No. of patients treated</th>
<th>No. of treatments</th>
<th>Urea clearance ml/min</th>
<th>Creatinine clearance ml/min</th>
<th>Glucose conc. used %</th>
<th>UF ml/min</th>
<th>QPD ml/min</th>
<th>No. of catheters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stephen et al. 1976 [23] (RPD)</td>
<td>10</td>
<td>53</td>
<td>NA</td>
<td>19–33</td>
<td>variable</td>
<td>4–7</td>
<td>150–350</td>
<td>s.c. catheter with two arms</td>
</tr>
<tr>
<td>Towe et al. 1994 [8] (HEPD)</td>
<td>2</td>
<td>8</td>
<td>19–25</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Mineshima et al. 2000 [5] (CRPD)</td>
<td>3</td>
<td>10</td>
<td>14.1±4.4</td>
<td>NA</td>
<td>0.8–1.8</td>
<td>0.5–2.5</td>
<td>100</td>
<td>double-lumen</td>
</tr>
<tr>
<td>Tobe et al. 1994 [11] (CFPD)</td>
<td>1</td>
<td>NA</td>
<td>18% urea reduction over 4 h</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>Raj et al. 2000 [4] (HyD)</td>
<td>8</td>
<td>8</td>
<td>26.5±9.1</td>
<td>24.1±9.1</td>
<td>0.729±0.562</td>
<td>2.9±2.0</td>
<td>141.3±23.7</td>
<td>one; single needle</td>
</tr>
</tbody>
</table>

UF, ultrafiltration; QPD, flow rate of dialysate; NA, not applicable; RPD, recirculating peritoneal dialysis; DPD, recirculating peritoneal dialysis with secondary dialysis; UFPD, ultrafiltration peritoneal dialysis; HEPD, high efficiency peritoneal dialysis; CRPD, continuous recirculating peritoneal dialysis; CFPD, continuous flow peritoneal dialysis; HyD, hybrid dialysis.

Table 2. Preliminary results on CFPD study with four patients

<table>
<thead>
<tr>
<th>No. of patients treated</th>
<th>No. of treatments</th>
<th>Clearance of urea ml/min</th>
<th>Clearance of QPD ml/min</th>
<th>Catheters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raj et al. 2000 [4] (HyD)</td>
<td>4</td>
<td>12</td>
<td>106.6</td>
<td>200</td>
</tr>
</tbody>
</table>

Notes: All patients had chronic type 2 diabetes. The study was performed by authors.