

Automated Peritoneal Dialysis

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Automated peritoneal dialysis (APD) has become the fastest-growing modality for renal replacement therapy due to an increased demand for higher doses of peritoneal dialysis (PD) treatment and to a need for improving the patients quality of life. The evolution of this treatment modality is closely linked to the development of new automatic machines and to the recent advances in prescription and monitoring of peritoneal dialysis treatment. The development of new generation of PD cyclers represented by microchips and computers allowed a greater programming flexibility of these machines. Thanks to these innovation it is now possible to prescribe individualized fill volumes, variable tidal volumes and additional daytime automated exchanges, tele-dialysis and memorized delivery control. According to industry sources, approximately 26% of the PD patients across the world are managed on APD (1-3).

PD cyclers

The use of sophisticated software and hardware has made the present generation of cyclers safe, reliable and easy to use. Current cyclers offer built-in programmes with options for all the varied modalities of automated peritoneal dialysis, including continuous cyclic peritoneal dialysis (CCPD), classical intermittent peritoneal dialysis (IPD), nocturnal intermittent peritoneal dialysis (NIPD), and tidal peritoneal dialysis (TPD).

The ideal PD machine should not only be able to perform all treatment schedules, but it should also be able to optimize the performance of a selected treatment strategy. The utilization of new solutions in APD with alternative osmotic agents, nutritional integration, reduced sodium content and alternative buffers seems very promising (2,4,5).

Future trends can also regard catheters overcoming the flow limitations with double-lumen catheters specific for continuous flow or recirculated APD performed with a cycler using double pump and on-line monitoring of intraperitoneal pressure (2,3).

Factors influencing selection of APD

The choice of APD over CAPD should initially be based on the patients preference. The increased convenience of these treatments makes them more suitable for patients who have work commitments during the day or are dependent on assistance from others. APD is the modality of choice in children and adolescents. Elderly patients and those with manual or visual impairments, desirous of home peritoneal dialysis are best treated by APD to prevent overwhelming

their partners or helpers. From a physiological standpoint the choice of peritoneal dialysis modality is best guided by the nature of the peritoneal membrane transport characteristics. Optimum therapy is achieved by matching dwell times to the transport type of the patient (3, 6-8).

From a purely medical point of view the reasons for choosing APD may be:

- failure to achieve clearance targets on CAPD
- ultrafiltration failure due to rapid glucose absorption and
- complications due to increased intra-abdominal pressures such as hernias, dialysate leaks, uterine prolapse and back pain.

Optimized prescription and adequacy of different regimens of APD

Continuous Cyclic Peritoneal Dialysis - prescription and power

CCPD just like continuous ambulatory peritoneal dialysis (CAPD) represented basically a continuous regimen of peritoneal dialysis. Dependent on the duration of the nocturnal session ranging from 9 to 10.5h, the length of the long day dwell averaged 13.5-15h. Classic form of CCPD (one day dwell) was shown at best equivalent and even in many instances less efficient than the one of CAPD unless an increment in dialysate flow rate was considered. With introduction «mixed peritoneal dialysis» (Diaz-Buxo, Charlotte, N.C. USA) schedule or CCPD2 (PD Plus therapy, Fresenius and OCPD, Baxter), patients got optimized APD modalities which seem provide the best performance with the lower cost-efficiency ratio (2,3,9). The contribution of day time dialysis to 24-hour total clearance is related to the number of diurnal exchanges (1 or 2) and depends on the drained volume of each day time dwell corresponding to the sum of infused dialysate and net ultrafiltration. Daytime ultrafiltration can be influenced by the choice of the osmotic agent (either crystalloid or colloid), the fill volume which results in various intraperitoneal pressure and the membrane transport characteristics (4,9). Long dwells during the day contribute significantly to the clearance of middle molecules (β_2 -microglobulin or vitamin B₁₂). The clearance of middle molecules in CCPD appears to be similar to CAPD (4).

Body surface area, residual renal function, peritoneal membrane characteristics, volume tolerance and catheter function testing are primary criterias needed for accurate CCPD

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prescription. Just as with CAPD, residual renal function allows an easier achievement of clearance targets during CCPD treatment. CCPD prescription in anuric patients will be by far most influenced by the patients specific characteristics including BSA and membrane transport characteristics. The most anuric patients (80%) achieved the clearance targets (weekly $Kt/V > 2.1$ and weekly creatinine clearance > 63 L corrected to 1.73 m^2 BSA) thanks to a CCPD programme including two day dwell (CCPD2). The larger «low - average» patient ($BSA > 2$) cannot attain the goal and achieve a better result in CAPD with a fifth nocturnal exchange without yet reaching the defined adequacy targets. Some «low» and «low-average» patients need to transfer to hemodialysis when complete anuria has been reached. However, larger «high-average» patients (BSA of 2.35 m^2) easily achieved $65 \text{ liters CrCl}/1.73 \text{ m}^2$ requiring a total infused volume of 19 liters. The need for more ultrafiltration calls for colloido-osmotic agents (glucose polymer) for the longer day dwell (7, 9).

Beside the biochemical markers for adequacy, adequate dialysis should provide the minimum peritoneal target for net ultrafiltration (1L/day for anuric patients), a feeling of well-being, absence of uremic symptoms and a reasonable control of acid-base and electrolyte disturbances. Adequate nutrition, prevention of atherosclerosis and bone disease are equally important considerations (4).

Nightly Intermittent Peritoneal Dialysis

The presence of a dry peritoneal cavity during the day is the crucial feature distinguishing NIPD from other modes of APD. A typical NIPD regime involves 5-10 exchanges of 1.5-2.5 litres, with a total dialysate volume of 10-20 litres per night over a period of 8-12h. Thus, to achieve maximal clearance in NIPD it is essential to optimize cycle times, which may improve clearance in a individual patient without increasing the duration of the nocturnal treatment or total dialysate volumes required (10).

Taking account of the peak concentration hypothesis, which proposes that intermittent treatments require a greater total clearance to achieve equivalent outcome to therapy achieving steady metabolic state, these have been extrapolated to minimum targets for NIPD of Kt/V urea of 2.2 per week and CrCL of 66 litres/week. However, these targets may be difficult to achieve as residual renal function declines. Also, there may be a discrepancy between Kt/V urea and CrCL, with the smaller molecule urea being better cleared by dialysis than creatinine.

For nocturnal cycles glucose concentrations are selected to achieve desired ultrafiltration. Dialysate calcium concentrations are selected according to bone disease parameters. Standard sodium concentrations fluids are generally used, but with short dwells there may be reduced sodium removal due to sodium sieving and lower sodium concentration fluid could be of value in this situation.

However, NIPD is important option of renal replacement therapy which provides satisfactory treatment for certain patients and in some may be the treatment of choice (11-15).

Tidal peritoneal dialysis (TPD) and Continuous Tidal peritoneal dialysis (CTPD)

For clarity, generic TPD performed nightly is called Nightly TPD (NTPD), with additional daytime exchanges covering 24 h it is called continuous (CTPD) and the number of daytime dwells can be specified by adding a number to the abbreviation (CTPD1, CTPD 2 or CTPD3).

Classical 50% NTPD (tidal volume is 50% of initial fill volume) is actually prescribed in a low number of patients and needs a more complex cyclor (able to optimize the performance of a selected treatment regimen), whilst giving equal or inferior results to NIPD using equal prescribed volumes (16,17).

Only «high» transport patients (D/P creatinine > 0.81) can reach adequate creatinine clearance (CrCL); «high average» transport patients do not reach adequate CrCL even with high dialysate volumes prescription and «low-average» and «low» transport patients show a decrease in CrCL with dialysate volumes and cycles increase.

The most interesting advantage that TPD presents over standard APD is the use of high-flow drainage periods for rapid exchanges. Optimized tidal PD is a tidal PD characterized by reserve volume determined by the breakpoint. Optimization of TPD, adapting the tidal volume to individual drainage behavior, shows an improvement over the classical 50% TPD proportional to the number of cycles, increasing overall efficiency of the system by about 10% without additional fluid prescription. This optimization is also particularly indicated in patients with not optimally functioning catheters (11,14,15,17).

Compared to NIPD, optimized TPD showed drain period reduced by 55%, an increase in urea clearance by 8%, a non-significant increase in creatinine clearance by 11% and a decrease in protein loss by 7% (17).

Clinical results with APD

Despite the recent increases in the number of patients being treated with APD, there is little data on long-term morbidity and mortality in comparison with other means of renal replacement therapy. Adequate dialysis can be achieved for most patients with APD, although some patients require a combination of APD with additional daytime exchanges. Hemoglobin and hematocrit were similar in studies comparing APD with CAPD, as were the erythropoietin requirements. Metabolic parameters were well controlled. Hypertension is generally well controlled on APD with one-third to one-half the patients being able to either discontinue or decrease medications.

The incidence of ultrafiltration failure increases from 2.6% after 1 year of CAPD to 30.9% after 6 years of CAPD. The risk of ultrafiltration failure is extremely low on APD. Most workers report that peritonitis rates among APD patients are lower than those among CAPD patients, while others report similar rates, and a few show even higher rates for APD than on CAPD. The rate of peritonitis among APD patients may be lower because of the fewer numbers of connections, the safer environment in which the exchanges are done, and the superior flow dynamics (flush after connec-

tion). The long dwell time may enhance the opsonic activity of peritoneal macrophages and therefore connections are being undertaken at a time when patient resistance to peritonitis is highest. The transfer rate to haemodialysis for APD is between 8% and 12% in the first year, which is significantly lower than the 10-30% transfer rate in the first year for CAPD. Most patients accept APD well and report convenience over CAPD (4,12,15,18).

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