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Comparative Outcomes Between Continuous Ambulatory and Automated Peritoneal Dialysis: A Narrative Review

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Abstract

Automated methods for delivering peritoneal dialysis (PD) to persons with end-stage renal disease continue to gain popularity worldwide, particularly in developed countries. However, the endeavor to automate the PD process has not been advanced on the strength of high-level evidence for superiority of automated over manual methods. This article summarizes available studies that have shed light on the evidence that compares the association of treatment with continuous ambulatory PD or automated PD (APD) with clinically meaningful outcomes. Published evidence, primarily from observational studies, has been unable to demonstrate a consistent difference in residual kidney function loss rate, peritonitis rate, maintenance of euvolemia, technique survival, mortality, or health-related quality of life in individuals undergoing continuous ambulatory PD versus APD. At the same time, the future of APD technology appears ripe for further improvement, such as the incorporation of voice commands and expanded use of telemedicine. Given these considerations, it appears that patient choice should drive the decision about PD modality.

INDEX WORDS

End-stage renal disease (ESRD); peritoneal dialysis (PD); continuous ambulatory peritoneal dialysis (CAPD); automated peritoneal dialysis (APD); residual kidney function; peritonitis; mortality; health-related quality of life

Peritoneal dialysis (PD) can be performed either manually, as with continuous ambulatory PD (CAPD), or with the use of a cycler, best termed automated PD (APD). Historically, the choice of PD modality has been driven by peritoneal membrane characteristics of an individual patient: APD, characterized by multiple automated short dwell times over 8–10

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hours often followed by daytime (diurnal) dwells, was largely reserved for patients who were rapid or high transporters and was considered inappropriate for slow or low transporters. However, because it frees the patient for most, if not all, of his or her waking hours, APD has become a desirable PD modality for individuals with other transport characteristics. If one individualizes the therapy by adjusting diurnal dwell times, osmotic agents, and/or dextrose concentration, APD seems to work for patients of all transport types. As a result, patient and physician choice spurred by the availability of convenient automated devices for the delivery of PD recently has skewed the selection of submodality in favor of APD irrespective of peritoneal membrane characteristics. APD use has increased over recent years in both developing and developed countries, with significantly higher rates of APD use relative to CAPD use in developed countries.[1] In the United States, PD is becoming increasingly synonymous with APD because >70% of PD patients are treated with this submodality; in Canada, the proportion of PD patients treated with APD is >60%.[2,3] However, there is significant variability in the use of APD in different programs around the country, which likely is driven by financial considerations.[4] Nevertheless, with the PD population in many parts of the world positioned to expand rapidly, the number of patients treated with APD is expected to become even larger.

Given that this trend seems to have occurred for nonmedical reasons and prior to our complete understanding of the differences in clinically meaningful outcomes in patients treated with CAPD or APD, many investigators have compared these 2 submodalities of PD. This article attempts to summarize the work done in this field to date, as well as identify potential areas for improvement in the delivery of PD through future innovations aimed at improving the health and lifestyle of patients with end-stage renal disease. Articles published in the medical literature pertinent to the topic were selected though PubMed searches and evaluated by the authors for relevance to each of the domains selected for review.

RESIDUAL KIDNEY FUNCTION

Studies of individuals undergoing maintenance dialysis consistently have demonstrated associations between lower mortality in individuals and greater residual kidney function.[5] Moreover, individuals with more rapid loss of kidney function after initiating PD therapy have a significantly higher risk for death.[6] The lower mortality with higher residual kidney function may be explained by differences in solute removal: in dialysis-dependent patients, removal of uremic solutes in the middle-molecular-weight range and protein-bound solutes is dependent to a larger extent on native kidney function.[7–9] Furthermore, euvolemia is easier to attain in individuals with residual urine output.[10] Another plausible explanation could be that the amount of residual kidney function is a surrogate for the presence of metabolically active kidney tissue, which may have a systemic protective effect. Many factors have been implicated in the rate of decline in residual kidney function in individuals undergoing maintenance dialysis, including baseline kidney function at the start of dialysis therapy, ultra-filtration strategy, systemic blood pressure, presence of diabetes and/or congestive heart failure, use of renin-angiotensin-aldosterone system blockers, and type of dialysate.[11–18]

Given the strong association with clinical outcomes, it is desirable that the method of PD not contribute to a more rapid loss in kidney function. By design, there are differences in the patterns of solute removal and ultrafiltration between CAPD and APD. APD has been described as an intermittent therapy more akin to hemodialysis, particularly in individuals undergoing nocturnal intermittent PD. CAPD is thought to be gentler, with dialysis occurring at a near-constant rate over the 24-hour period. Could the mode of PD delivery alter residual kidney function? Table 1 summarizes studies performed to examine this question; while 2 of the studies are post hoc analyses of data from randomized controlled clinical trials, the others are observational cohort studies.[11,12,15,19–30]

As indicated in Table 1, a handful of observational studies have demonstrated faster loss of residual kidney function in individuals undergoing APD.[20,21,24–26] Most of these studies have been small single-center studies with limited adjustment for confounding factors, and most patients were not treated with renin-angiotensin-aldosterone system blockers, now the standard of care. Similarly, a recent study reported that the likelihood of complete loss of kidney function in the first year of PD was higher in individuals undergoing APD compared with CAPD.[30] However, a significantly larger proportion of individuals undergoing CAPD were treated with renin-angiotensin-aldosterone system blockers. Interpretation of observational studies is always limited by concerns for residual confounding and confounding by indication. Moreover, APD is delivered in many different fashions, some of which are considered continuous (continuous cycling PD), and can even differ by types of dialysate solutions (eg, whether the solution has icodextrin and whether it is glucose-based with low concentrations of glucose degradation products). The majority of these studies do not consider the influence of these variations in APD prescription on the rate of decline in residual kidney function. Moreover, notwithstanding some reports associating a faster decline in residual kidney function in individuals treated with APD, the majority of studies do not show a convincing difference by modality (Table 1). Due to these considerations, it appears reasonable to conclude that the evidence that APD leads to more rapid decline in residual kidney function is not persuasive. The difference, if any, is small. It has yet to be proved whether modality-specific effects on residual kidney function are clinically relevant.

PERITONITIS

Peritonitis remains the single most important modality-specific complication for individuals undergoing PD. CAPD and APD differ significantly in the frequency and method of making the connections and disconnections between the PD catheter and dialysate bags. This difference raises the question of whether one technique predisposes to or mitigates against the risk of the patient acquiring a peritoneal infection. The connectology for CAPD has changed significantly over the years, from manually spiking bags with a separate connection and disconnecting with the dialysate bag and drain bag for each exchange to the twin bag systems that presently are standard. The twin bag system consists of a dialysate bag and a drain bag that are preattached to a Y-set, which allows each exchange to consist of a single connection and disconnection; Luer lock technology, which precludes the need for manually spiking the dialysate bag; and routine “flush-before-fill” practice. The twin bag system is the only CAPD setup available today in most parts of the world and is the dominant reason for the reduction in risk for peritonitis in individuals undergoing PD.[31] Improvements in

connection systems for APD lagged behind those for CAPD: for a while, when use of twin-bag systems became the standard of care for CAPD, individuals undergoing APD still had to spike the bags manually. However, connection systems for APD have evolved over time, first with the introduction of connection assist devices and now with the use of Luer lock connections.

Understanding the different evolutions of the connection systems for CAPD and APD is critical when interpreting studies comparing peritonitis rates for CAPD and APD patients during different periods (Table 2).[19,22,28,32–36] Most of the published studies do not include a description of the connection systems used by the CAPD and APD participants included in the analysis. Nevertheless, it is possible to make some broad assessment of these comparative data. In the early days of the therapy, the number of connections and disconnections for performing PD was the single most important determinant of peritonitis rates, and because APD required fewer connections and disconnections than CAPD, peritonitis rates often were reportedly lower with APD than with CAPD. However, improvements in connection systems for CAPD occurred before those for APD. This in turn may be the reason that some studies from this intermediary period reported a higher risk for peritonitis for individuals undergoing APD. Since then, APD connection systems also have improved, and in many contemporary studies using current technology, there is no significant difference in risk for peritonitis between the 2 therapies. Taken together, with the use of contemporary connection systems, PD modality likely has little clinical impact on an individual patient's risk of peritonitis.

We are not aware of studies comparing the severity, response, relapse, and recurrence rates of peritonitis in patients treated with CAPD and APD; this should be a focus of future investigations. Moreover, data for outcomes with continuous or intermittent dosing of antibiotics presently are insufficient, particularly for patients undergoing APD.

VOLUME MANAGEMENT

During the course of a 4- to 6-hour intraperitoneal dwell of dextrose-containing PD solution, up to one-half the total ultrafiltration volume consists of water that has moved across the aquaporins present on the endothelial capillaries without any accompanying salt. The remaining volume consists of solute-rich water that moved across the theoretical "small pores" or clefts between cells. There is a disproportionately larger movement of water across the aquaporins early in the course of the dwell.[37,38] This results in the dissociation between salt and water removal measurable by a reduction in dialysate sodium concentration during the first 60–90 minutes ("sodium sieving"). With longer dwells, there is continued diffusive movement of sodium across the peritoneal capillaries and hence, if the dwell is long enough, the dialysate to plasma ratio for sodium approaches unity. This implies that frequent short dwells with APD may result in greater removal of sodium-free water during cycling and thus there could be lower net sodium removal, which puts patients at risk for hypertension, volume overload, and their sequelae.

Table 3 lists studies that have examined 24-hour sodium and water removal, as well as those that have examined clinically relevant measures of volume status in individuals treated with

CAPD and APD.[19,22,26,34,39–44] Many studies find that CAPD has superior sodium removal compared to APD. However, these studies should be considered with 2 important caveats. First, dialysate bag fill volume is slightly larger than the manufacturers state to allow for the excess fluid of the "flush-before-fill" step prior to each exchange. The flush fluid goes directly into the effluent bag without ever having participated in the exchange. Failure to account for the flush volume, a limitation of many studies that have examined this question, can result in erroneously attributing sodium and water in the flush to what was achieved with the PD modality. CAPD performed with 4 exchanges per day uses a larger cumulative total flush volume over the 24-hour period than a typical APD prescription. Thus, some studies have overestimated sodium and water removal in CAPD. Second, APD prescriptions are heterogeneous: prescriptions with longer dwell times, diurnal exchanges, and icodextrin for long diurnal dwells are associated with significantly higher sodium and water removal.[42,43,45] Given these considerations, it is difficult to support the notion that sodium and water removal in APD is systematically lower than with CAPD.

Moreover, in the studies published to date, there is little difference in the achievement of dry weight or blood pressure control between the 2 modalities. Some studies that have assessed volume control with bioimpedance have not been able to demonstrate a difference in volume status between CAPD and APD patients treated with icodextrin.[43] Hence, our present understanding indicates that individualized and careful prescription management can result in equivalent removal of salt and water, achievement of target weight, and blood pressure control in individuals treated with CAPD and APD. It is important to recognize that peritoneal membrane function probably still influences the selection of PD submodality in individuals at the 2 ends of the spectrum (low or high) of peritoneal solute transport rate. Hence, care must be exercised when judging the comparative efficacy of the 2 submodalities in achieving euvolemia in these patient subgroups.

TECHNIQUE SURVIVAL

When patients transfer from PD to hemodialysis therapy, it is considered "technique failure." Reasons for this transition are complex, and the number of transition failures can be minimized in the right setting with appropriate resources and care providers.[4,46–50] Thus, provider practice patterns complicate technique survival studies, including those comparing CAPD to APD. Table 4 lists available evidence documenting technique survival rates for CAPD and APD.[4,19,29,51–56] Analysis of data from one randomized controlled trial was unable to demonstrate a significant difference in technique survival between individuals treated with the 2 therapies; however, the trial was underpowered to detect an effect of PD submodality on technique survival.[19] Subsequent observational data are split. A large review using data from Baxter pointed toward better technique survival for APD patients, but this benefit seemed to wane over time spent on PD therapy because it was particularly prominent in the first year of therapy.[51] This study also had limited data about patient characteristics and thus was unable to adjust for many important potential differences in patient characteristics. Several small studies, some single center, also have demonstrated higher technique survival in APD. In contrast, 4 large representative cohort studies, 2 from Australia and New Zealand and one each from the United States and the Netherlands, were unable to demonstrate a significant difference in technique survival between CAPD and

APD.[4,52,54,55] Given these data, it is difficult to conclude that PD modality has a meaningful effect on technique survival.

MORTALITY

Available mortality data comparing APD to CAPD also are mostly observational (Table 4).[4,19,29,51–56] Attributing differences in mortality to any therapy is difficult and confounded by measured and unmeasured patient- and facility-specific factors. Studies have suggested that at least 2 potential causal physiologic mechanisms may be differentially affected by the 2 PD submodalities: residual kidney function and serum albumin level. In the only randomized prospective trial to have examined the outcome of mortality, there was no difference in patient survival; however, the clinical trial was significantly under-powered to detect a difference.[19] Similarly, the majority of available large observational studies have not reported differences in mortality between individuals treated with CAPD and APD. However, there are 3 exceptions to this general theme of equivalency. One single-center study revealed a lower death risk in patients younger than 65 years who were treated with APD, whereas elderly patients had similar outcomes on CAPD and APD.[56] A single-center study from Mexico reported lower mortality for individuals treated with APD, particularly in the first year of dialysis.[53] In an analysis of the Australian and New Zealand dialysis registry, there was lower death risk in fast or high transporters treated with APD compared with CAPD, but higher death risk in slow or low transporters.[55] It is important to note that the overwhelming majority of patients have an “average” peritoneal transport type. Thus, based on the available data and these considerations, it appears that the selection of PD modality is not likely to be an important determinant of death risk for the majority of PD patients.

HEALTH-RELATED QUALITY OF LIFE

APD prescriptions seem to be beneficial for patients to maintain their lifestyles because the bulk of the dialysis is performed while sleeping. Conversely, if performed incorrectly and without proper support from dialysis providers, APD may be complicated by frequent machine alarms and drain pain, which can alter sleep patterns and lead to patient frustration and burnout. Thus, it is conceivable that there may be differences in health-related quality of life in individuals treated with the 2 PD submodalities (Table 5).[22,28,30,57–59] A small prospective study found that although individuals undergoing APD reported more time available for work, family, and social activities, they also reported a greater incidence of sleep disturbances compared with CAPD patients.[22] Another cross-sectional survey study suggested better mental health in APD patients and higher rates of anxiety in individuals undergoing CAPD.[57] Notwithstanding these 2 studies, none of the other investigations was able to demonstrate a significant difference in health-related quality of life between the 2 PD modalities. Thus, it is premature to attribute better health-related quality life to selecting APD or CAPD.

FUTURE DIRECTIONS IN INNOVATION IN PD IN THE 21ST CENTURY

The bulk of the studies in the provided tables are observational studies, and limited conclusions can be drawn from them due to the nature of the data, as well as potential flaws

in methodology. It also should be mentioned that there is a paucity of data available regarding the efficacy of different forms of PD, in particular, tidal PD. If one is to accept the available data summarized previously, there does not appear to be meaningful differences in the rate of decline of residual kidney function, peritonitis rate, volume status, technique survival, mortality, or health-related quality of life between CAPD and APD. Hence, patient preference and cost considerations are likely to continue to determine the relative use of the 2 PD submodalities in different parts of the world. In the United States, the use of APD will probably grow, driven in part by increased interest in using PD as the initial modality, even for late-referred patients (urgent-start PD).[60] If the popularity of APD grows or is maintained at present levels, innovations will follow, such as the development of more advanced cyclers that come equipped with easy-to-use features, such as large touch screens, internet connections, and voice prompts to remind patients about the on and off procedure or the steps necessary to achieve a sterile connection. Remote data transfer will improve communication between medical staff and patients, increasing safety and allowing the patient a measure of comfort and assurance that may prevent patient or home care provider burnout. Telemedicine has the potential to deliver PD care and expertise to a larger number of patients who live and work in remote communities. Monitoring and delivering patient care through telemedicine currently is the focus of a grant funded by the newly founded Center for Medicare and Medicaid Innovation in the United States. These and other considerations also will enhance our ability to troubleshoot alarms and other technical problems with the cycler and allow for better monitoring of patient adherence to therapy. PD catheters that are more resistant to infection and/or more biocompatible would be valuable. Regeneration or creation of on-site peritoneal dialysate has the potential to reduce cost and improve PD efficiency. Some of these innovations exist in some form, but the history of slow growth of PD delayed their advancement and/or implementation, a pattern that soon may be reversed.

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Table 1

Studies Comparing Loss of Residual Kidney Function in CAPD and APD

Study (Year)	Study Design	Setting	Data Source	N (CAPD, APD)	F/U	Kidney Function Assessment	Outcome
de Fijter et al[19] (1994)	RCT	Netherlands (1988–1991)	Single center	82 (41, 41)	24 mo	24-h urine CCr in mL/min/1.73 m^2	No significant difference in change: CAPD, 4.0 to 2.8 mL/min/1.73 m^2; APD, 5.4 to 2.1 mL/min/1.73 m^2
Hiroshige et al[20] (1996)	Prospective cohort study	Japan (1992–1994)	Single center	18 (5, 13)	6 mo	24-h urine CCr in mL/min/1.73 m^2	~0.3 mL/min/mo decline in RKF in APD group compared with no significant change in CAPD group ($P < 0.01$)
Hufnagel et al[21] (1999)	Prospective cohort study	France (1995–1997)	Single center	36 (18, 18)	12 mo	24-h urine CCr in mL/min/1.73 m^2	Significantly greater decrease in APD vs CAPD; at 6 mo: APD, −0.28 mL/min/mo vs CAPD, −0.1 mL/min/mo ($P = 0.04$); at 1 y: APD, −0.26 mL/min/mo vs CAPD, −0.13 mL/min/mo ($P = 0.005$)
Bro et al[22] (1999)	RCT	Denmark (1995–1999)	Multicenter	34 (17, 17)	6 mo	24-h urine CCr in mL/min	No significant difference in decline in RKF; mean clearances at end of 6 mo: CAPD, 3.5 mL/min; APD, 3.0 mL/min
Gallar et al[23] (2000)	Prospective cohort study	Spain (NR)	Single center	20 (11, 9)	12 mo	NR	No difference in kidney function at baseline or at 1 y; change in CAPD, 6.11 to 4.9 mL/min; change in APD, 7.1 to 5.5 mL/min
Hamada et al[24] (2000)	Prospective cohort study	Japan (NR)	Single center	34 (17, 17)	24 mo	Daily urine volume in mL/d	Daily urine volume declined significantly more in the CAPD (381 to 147 mL) compared to the APD group (223 to 157 mL), $P < 0.01$
Moist et al[11] (2000)	National registry data	US (1997)	USRDS Dialysis Morbidity and Mortality (Wave 2)	1,032 (722, 310)	8–18 mo	Time to anuria[a]	No significant difference in time to anuria
Singhal et al[12] (2000)	Prospective cohort study	Canada (1994–1997)	Single center	242 (211, 31)	27 ± 14 mo	Mean of 24-h urine urea clearance and CCr in L/wk	PD modality a significant predictor of decline in kidney function only when the volume of PD fluid

Study (Year)	Study Design	Setting	Data Source	N (CAPD, APD)	F/U	Kidney Function Assessment	Outcome
							used daily was not included in analysis
Hidaka & Nakao[25] (2003)	Prospective cohort study	Japan (1995–2001)	Single center	34 (27, 7)	12–48 mo	Mean of 24-h urine urea clearance and CCr in L/wk	More rapid loss in kidney function in APD (APD, 22 mo vs CAPD, 28 mo to 50% reduction in GFR), $P < 0.001$
Johnson et al[15] (2003)	Prospective cohort study	Australia (1995–2001)	Single center	146 (134, 12)	21 ± 15 mo	Mean of timed urine urea clearance and CCr in mL/min/1.73 m^2	No difference in rate of decline in kidney function
Rodriguez-Carmona et al[26] (2004)	Prospective cohort study	Spain (1998–2002)	Single center	104 (53, 51)	12–24 mo	Mean of 24-h urine urea clearance and CCr in mL/min	Independent significant association of treatment with APD to lower RFK at 1 y
Liao et al[27] (2008)	Retrospective study	Taiwan (1996–2005)	Single center	270 (188, 82)	39.4 ± 24 mo	Mean of 24-h urine urea clearance and CCr in mL/min/1.73 m^2	No difference in rate of decline in kidney function
Balasubramanian et al[28] (2011)	Retrospective study	UK (2003–2008)	Single center	277 (130, 147)	5 y	Mean of 24-h urine urea clearance and CCr in L/wk	No differences in rate of decline in kidney function: CAPD, 15.4 L per wk per y; APD, 15.7 L per wk per y
Cnossen et al[29] (2011)	Retrospective study	US (2001–2008)	Multicenter Renal Research Institute	620 (179, 441)	450 d	NR	No difference in time-averaged RFK
Michels et al[30] (2011)	Prospective cohort study	Netherlands (1997–2006)	NECOSAD	583 (505, 78)	3 mo-3 y	Mean of 24-h urine urea clearance and CCr in mL/min/1.73 m^2	No significant difference in rate of decline in kidney function; individuals started on APD had a 2× higher risk of achieving anuria in the first y compared with CAPD

Abbreviations: APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; CCr, creatinine clearance; F/U, follow-up; GFR, glomerular filtration rate; NECOSAD, Netherlands Cooperative Study on the Adequacy of Dialysis; NR, not reported; PD, peritoneal dialysis; RCT, randomized controlled trial; RKF, residual kidney function; USRDS, US Renal Data System.

[a] Anuria defined as urine output < 200 mL/24 h.

Table 2

Studies Comparing Risk of Peritonitis in Patients With ESRD Treated With CAPD and APD

Study (Year)	Study Design	Setting	Data Source	N (CAPD, APD)	F/U	Outcome
de Fijter et al[19] (1994)	RCT	Netherlands (1988–1991)	Single center	82 (41, 41)	24 mo	Overall rate[a]: CAPD, 0.94; APD, 0.54; difference of 0.43 episodes/patient-y (P = 0.03); median time to first episode of peritonitis: CAPD, 11 mo; APD, 18 mo (P = 0.06)
Bro et al[22] (1999)	RCT	Denmark (1995–1999)	Multicenter	34 (17, 17)	6 mo	2 cases of peritonitis in CAPD and 1 case in APD
Oo et al[32] (2005)	National registry data	US (1994–1997)	Multicenter	11,975 (9,190, 2,785)	6 mo-2 y	Average time to first peritonitis longer with CAPD (17.1 mo) compared to APD (16.1 mo); episodes/patient-y: CAPD, 0.70 vs APD, 0.74 (P = 0.008)
Davenport et al[33] (2009)	Retrospective study	UK (2002–2003)	Multicenter	863 (538, 325)	2 y	Average time between peritonitis episodes: CAPD, 14.7 mo; APD, 18.1 mo; episodes/patient-y: CAPD, 0.81 vs APD, 0.66 (P < 0.05); significant variation in peritonitis rates between facilities
Nessim et al[35] (2009)	Retrospective study	Canada (1996–2005)	Multicenter	3,180 (NR)	—	No difference in peritonitis rate ratio between CAPD and APD (RR, 1.03; 95% CI, 0.91–1.16; P = 0.65); CAPD not associated with shorter time to peritonitis than APD (HR, 1.02; 95% CI, 0.92–1.13; P = 0.69)
Balasubramanian et al[28] (2011)	Retrospective study	UK (2003–2008)	Single center	372 (178, 194)	5 y	Peritonitis rate: CAPD, 1:29 patient-mo; APD, 1:37 patient-mo (episodes/patient-y: CAPD, 0.41 vs APD, 0.32); OR, 0.78 in favor of APD (95% CI, 0.63–0.98)
Ruger et al[36] (2011)	Retrospective study	Netherlands (1993–2007)	Single center	205 (112, 93)	Review of cases over 14-y period	Peritonitis frequency: CAPD, 1:18.6 patient-mo; APD, 1:19.4 patient-mo (episodes/patient-y: CAPD, 0.65 vs APD, 0.62); difference is not significant

Abbreviations: APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; CI, confidence interval; ESRD, end-stage renal disease; F/U, follow-up; HR, hazard ratio; NR, not reported; OR, odds ratio; RCT, randomized controlled trial; RR, relative risk.

[a]Of peritonitis episodes per patient-year.

Table 3

Studies Comparing Surrogate Measures of Volume Management in CAPD and APD

Study (Year)	Study Design	Setting	Data Source	N (CAPD, APD)	F/U	Outcome
de Fijter et al[19] (1994)	RCT	Netherlands (1988–1991)	Single center	82 (41, 41)	24 mo	No difference in MAP or mean dry weight over time; antihypertensive drugs used in 60% of CAPD and 74% of APD
Bro et al[22] (1999)	RCT	Denmark (1995–1999)	Multicenter	34 (17, 17)	6 mo	No episodes of weight > 2 kg above dry weight in CAPD group; 2 cases in APD group; mean SBP similar in both groups
Frankenfield et al[34] (1999)	Retrospective study	US (1995–1997)	Multicenter	~1,200 (~700, ~500)	3 different 2-mo periods	No significant difference in proportion of individuals with hypertension
Ortega et al[39] (2001)	Prospective cohort study	Spain (2001)	Single center	36 (16, 20)	24 h (Na balance studies)	In CAPD, daily peritoneal Na removal and net ultrafiltration volume significantly higher and SBP lower
Rodriguez-Carmona & Fontan[40] (2002)	Baseline cross-sectional data and prospective cohort study	Spain (2002)	—	141 (63, 78); 32 before and after change from CAPD to APD	3 mo, 24-h collections for Na balance	In CAPD, Na removal significantly greater, independent of ultrafiltration volume; Na removal decreased significantly after switching from CAPD to APD
Rodriguez-Carmona et al[26] (2004)	Prospective cohort study	Spain (1998–2002)	Single center	104 (53, 51)	12–24 mo	In APD, ultrafiltration and Na removal rates consistently and significantly lower; in CAPD, better SBP control
Bavbek et al[41] (2007)	Cross-sectional study	Turkey (2007)	2 centers	62 (32, 30)	—	In APD, significantly lower daily ultrafiltration volume, higher serum brain natriuretic peptide, and LVM index; no significant difference in BP
Davison et al[42] (2009)	Cross-sectional study	Canada (2004–2006)	Single center	158 (90, 68)	—	No significant difference in Na removal, ultrafiltration, or BP between groups; liberal use of icodextrin, limited no. of nocturnal exchanges and supplemental daytime exchange in APD group
Van Biesen et al[43] (2011)	Cross-sectional study	Europe (NR)	Multicenter	661 (53% APD)	—	Excluded those without access to icodextrin; PD modality not associated with extracellular volume excess[a]
Cnossen et al[44] (2012)	Cross-sectional study	Netherlands (NR)	Multicenter	44 (24, 20)	~21–30 mo	In APD, lower total Na removal; no statistically significant difference in SBP, ultrafiltration volumes, or brain natriuretic peptide ultrafiltration

Abbreviations: APD, automated peritoneal dialysis; BP, blood pressure; CAPD, continuous ambulatory peritoneal dialysis; F/U, follow-up; LVM, left ventricular mass; MAP, mean arterial pressure; Na, sodium; NR, not reported; PD, peritoneal dialysis; RCT, randomized controlled trial; SBP, systolic blood pressure.

[a]As measured by bioimpedance.

Table 4

Studies Comparing Technique Survival and All-Cause Mortality in CAPD and APD

Study (Year)	Study Design	Setting	Data Source	N (CAPD, APD)	F/U	Outcome
de Fijter et al[19] (1994)	RCT	Netherlands (1988–1991)	Single center	82 (41, 41)	24 mo	No significant difference in technique survival or all-cause mortality
Mujais & Story[51] (2006)	Post hoc analysis of prospectively collected data	US (2000–2003)	Multicenter, Baxter Healthcare Corporation On-Call system	909 (40, 869)	—	Better technique survival in APD (mostly concentrated in the first y of therapy); no difference in all-cause mortality
Badve et al[52] (2008)	National registry data	Australia & New Zealand (1999–2004)	Multicenter, ANZDATA registry	4,128 (2,393, 1,735)	5 y	No significant difference in technique survival or all-cause mortality
Sanchez et al[53] (2008)	Retrospective study	Mexico (2003–2005)	Single center	237 (139, 98)	2 y	In APD, better technique survival and significantly lower all-cause mortality
Mehrotra et al[4] (2009)	National registry data	US (1996–2004)	Multicenter, USRDS	66,381 (42,942, 23,439)	2–10 y	No significant difference in technique survival or all-cause mortality
Michels et al[54] (2009)	Retrospective study	Netherlands (1997–2006)	Multicenter, NECOSAD	649 (562, 87)	5 y	No significant difference in technique survival or all-cause mortality
Johnson et al[55] (2010)	National registry data	Australia & New Zealand (1999–2004)	Multicenter, ANZDATA registry	628 high transporters (142, 486); 196 low transporters[a]	3 mo-10 y	Compared APD vs CAPD in high transporters and low transporters; no significant difference in technique survival; lower death risk in high transporters treated with APD and higher death risk in low transporters treated with APD
Cnossen et al[29] (2011)	Retrospective study	US (2001–2008)	Multicenter, Renal Research Institute	620 (179, 441)	3 mo-7 y	In APD, significantly better technique survival; no significant difference in all-cause mortality
Sun et al[56] (2011)	Retrospective study	Taiwan (1997–2008)	Single center	282 (121, 161)	3 mo-10 y	In APD, higher technique survival and lower all-cause mortality; for individuals > 65 y old, APD associated with higher mortality

Abbreviations: ANZDATA, Australia and New Zealand Dialysis and Transplant; APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; F/U, follow-up; NECOSAD, Netherlands Cooperative Study on the Adequacy of Dialysis; RCT, randomized controlled trial; USRDS, US Renal Disease System.

[a]Number of patients receiving APD vs APD not specified for low transporters.

Table 5

Studies Comparing Health-Related Quality of Life in CAPD and APD

Study (Year)	Study Design	Setting	Data Source	N (CAPD, APD)	F/U	Outcome
Bro et al[22] (1999)	RCT	Denmark (1995–1999)	Multicenter	34 (17, 17)	6 mo	In APD, significantly more time for work, family, and social activities but greater problem with sleep disturbances
de Wit et al[57] (2001)	Cross-sectional study	Netherlands (1993–2001)	Multicenter, NECOSAD	96 (59, 37)	—	In APD, better mental health, less depression and anxiety; no difference in physical functioning
Sunder et al[58] (2008)	Prospective observational[a]	India (NR)	Single center	18[b]	12 mo[b]	No significant difference in parameters of physical or mental quality of life
Guney et al[59] (2010)	Cross-sectional study	Turkey (NR)	Single center	68 (48, 20)	—	No significant difference in HRQoL, sleep quality, or depression
Balasubramanian et al[28] (2011)	Retrospective study	UK (2003–2008)	Single center	372 (178, 194)	5 y	No significant difference in health status or physical or mental health scores by SF-36
Michels et al[30] (2011)	Prospective cohort study	Netherlands (1997–2006)	NECOSAD	550 (486, 64)	3 mo-3 y	No significant differences in quality-of-life scores

Abbreviations: APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; F/U, follow-up; HRQoL, health-related quality of life; NECOSAD, The Netherlands Cooperative Study on the Adequacy of Dialysis; NR, not reported; RCT, randomized controlled trial; SF-36, 36-Item Short Form Health Survey.

[a] Fixed crossover design.

[b] All 18 were high or high average transporters who underwent CAPD for 6 months followed by APD for 6 months.