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Which clinical conditions are most suitable for induction of automated peritoneal dialysis?

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Abstract

This review article is an invited review by both the Japanese Society for Dialysis Therapy (JSDT) and Japanese Society for Peritoneal Dialysis (JSPD).
Automated peritoneal dialysis (APD) using a cycler machine is an alternative choice for patients who are on peritoneal dialysis (PD) for the treatment of end-stage renal disease (ESRD). The main purpose is to allow more free time and an improved quality of life for PD patients versus continuous ambulatory PD (CAPD). However, it remains unclear which modality is a better choice, especially with regard to the induction period of PD, due to a lack of research. When we propose PD therapy to ESRD patients, in addition to the obvious benefit of more free time, we also need to consider the advantages and disadvantages with regard to each patient's medical comorbidities, physical condition, social activities, psychological readiness, and medical economics.
In this review, we attempted to determine which method is more advantageous overall, APD or CAPD.
In conclusion, it is important to consider the medical, social, physical, and economic aspects for each PD patient as well as patient preference when helping patients choose between APD and CAPD.

Keywords: Peritoneal dialysis, APD, CAPD, Advantages, Disadvantages

Background

This review article is an invited review by both the Japanese Society for Dialysis Therapy (JSDT) and Japanese Society for Peritoneal Dialysis (JSPD).

Automated peritoneal dialysis (APD) was introduced in the 1960s using concepts that are similar to current methods. To perform peritoneal dialysis (PD) in patients with end-stage renal failure (ESRD), peritoneal puncture was essential for the insertion of a cannula to access the abdominal cavity each time a patient presented for dialysis, until the development of the silicon-based Tenckhoff catheter introduced by Henry Tenckhoff in 1968 [1]. Therefore, peritonitis occurred very frequently and prevented clinical use of continuous long-term PD therapy. Boen et al. reported that APD was performed intermittently with the use of huge amounts of PD fluid (PDF) [2]. To induce APD, large 12-gal (close to 45 L) glass bottles of PDF were required for the automatic cycler machine. They described that ESRD patients on APD therapy enjoyed more free time as it allowed for the exchange of larger amounts of fluid over shorter periods of time; thus, dialysis could be performed intermittently (once every 3 or 4 days). Moreover, patients experienced less frequent episodes of peritonitis.

In 1972, Tenckoff et al. proposed a much simpler APD system that was more compact and attached to a reverse osmosis unit to eliminate the need for huge bottles [3], and the Drake-Willock PD cycler machine was developed with a reverse osmosis system [4]. The development of the Tenckhoff catheter allowed permanent access to the peritoneal cavity. Glass bottles for containment of PDF evolved into plastic bags that continue to be used today [5]. Because of the induction of continuous ambulatory PD (CAPD), PD therapy became safer and ESRD patients were completely released from bedrest in the hospital and had greater

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freedom. The CAPD system also contributed to a decrease in peritonitis and gastrointestinal injuries caused by repeated puncture with a PD cannula. After that, a system was developed similar to present-day APD. In the 1980s, the automated peritoneal dialysis cycler machine, Pac-X (Baxter Limited, Tokyo, Japan), was introduced worldwide [6] and was also used as a primary cycler for APD in Japan, followed by the Pac-X cycler II (Baxter, Fig. 1a). The Quantum PD dialysis machine (Baxter), a simple automatic bag change system that could perform only one bag change per night, was also used to support nocturnal dialysis regimens in Japan (Fig. 1b). Now, we can choose from four types of much more compact cycler machines from four different PD companies (Fig. 2).

When cycler machine-operated APD was introduced, its greatest advantage was a larger selection of PD treatments options, including continuous cycling PD (CCPD) (Fig. 3), and different types of dialysate solutions could also be mixed in a cycler machine. In the present method of APD, the cycler machine is also advantageous because of the decreased frequency of PDF bag changes needed. Currently, a standardized APD selection does not exist in Japan. Unfortunately, there are a few studies originating in Japan for supporting the use of APD. Therefore, the decision to select induction of APD is often influenced by experiences and preferences of physicians, patients, and/or caregivers. Thus, the question remains, is it better to choose CAPD or APD for patients? In this review, we refer to previous reviews and recent reports and summarize the advantages and disadvantages with regard to medical, socioeconomic, and psychological aspects of care when choosing the best APD system.

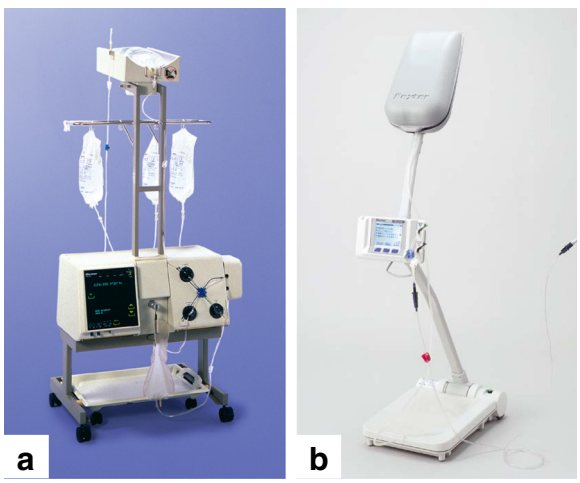

Fig. 1 Earlier-generation machines that have supported automated peritoneal dialysis (APD) in Japan. Before recent models of cyclers, there were several commercially based machines. **a** Pax-X cycler II and **b** Quantum PD dialysis machine. The two types of APD machines were purchased by Baxter Japan and are commonly used in Japan (photo frames courtesy of Baxter Limited (Tokyo, Japan))

Which is more medically advantageous to patients with ESRD: APD or CAPD?

Prognosis for life survival and/or technical survival

In a recent review article summarizing reports concerning life survival and technical survival before 2011 [7], most showed no significant difference between APD and CAPD, except for a retrospective cohort study that demonstrated APD to be more advantageous [8]. Another report that analyzed long-term survival showed CAPD and APD to be similar [9].

After 2011, it has also been reported that there is no difference in life survival and technical survival between APD and CAPD in Hong Kong in 2013 [10]. In contrast, it was reported that technical survival of APD patients is better than for CAPD patients, even if death was excluded as a reason for technical failure, in the UK in 2011 [11]. In a recently published prospective and large-scale national cohort study in Brazil in 2015, technical survival was not different between APD and CAPD, although life survival was better in APD than CAPD [12].

Of note, an interesting report showed that PD patient survival in those in the high transporter category on the peritoneal equilibration test (PET), which is usually performed as an assessment of peritoneal membrane function in PD patients, was better with APD than with CAPD [13]. This finding might support the assumption that frequent PD bag changes with APD could improve total ultrafiltration in PD patients in the high transporter category on the PET. In contrast, survival in those patients in the low transporter category on the PET was reported to be poorer with APD than with CAPD in that study.

As a brief summary, patient survival and technical survival with regard to PD therapy may be similar between APD and CAPD, although a few reports have shown advantages of APD usage, especially in PD patients in the high transporter category on the PET. Summary is shown in Table 1.

Adequacy of dialysis of creatinine and blood urea nitrogen between APD and CAPD

Theoretically, adequacy of dialysis of creatinine and blood urea nitrogen (BUN) is dependent on the frequency of bag changes, dwell time, and amount of PDF. Therefore, it is difficult to compare APD and CAPD. When CAPD therapy is considered in patients with a large body mass with ESRD and who have no residual renal function (RRF), five or more bag changes may be required [14]. Therefore, induction of APD is useful to decrease the number of PD bag changes in those patients. On the other hand, in several reports concerned with the

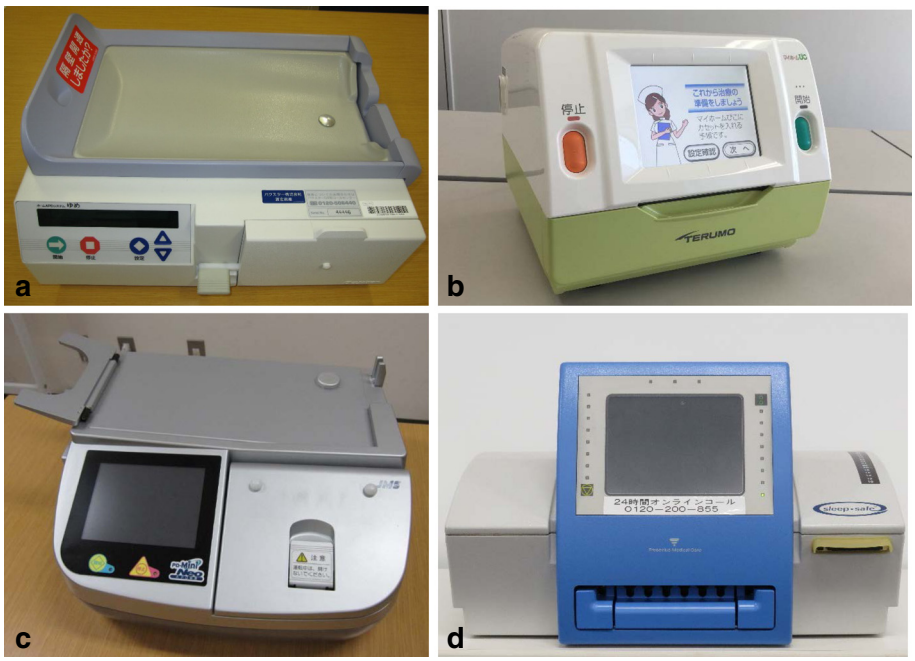

Fig. 2 Recent modern cycler machines for automated peritoneal dialysis delivered from four companies in Japan. In Japan, four companies delivered four different cycler machines, respectively, **a** the "home APD system YUME," which was purchased by Baxter (Tokyo, Japan), **b** the "My Home PICO APD® system," which was purchased by TERUMO Co. (Tokyo, Japan), **c** the "APD system PD-Mini Neo" which was purchased by JMS Co. (Tokyo, Japan), and **d** the "Sleepsafe® APD system" which is purchased by Fresenius Medical Care Japan (Tokyo, Japan)

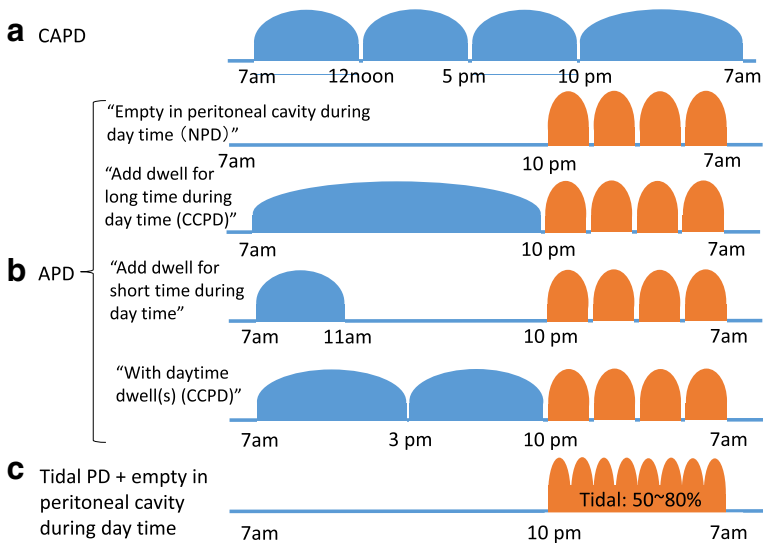

Fig. 3 Various schedules of dwell time in peritoneal dialysis (PD) to help select modalities of PD. Typhical pattern of continuous ambulatory PD is shown in **a**. We have the ability to select various options for PD menus after induction of automated PD (APD), which are shown in **b**. Flexibility in the PD menu allows for adjustment to various lifestyles of PD patients in addition to managing the increase in total PD volume for adequacy of dialysis and shortening each dwell time for enough ultrafiltration. As an alternative methods, tidal PD was a choice of PD (**c**). *Solid orange area* shows dwells of the cyclers. *CCPD* continuous cyclic peritoneal dialysis, *TAPD* tidal automated peritoneal dialysis, *NPD* nocturnal PD

Table 1 Studies of comparison between APD and CAPD for life survival and/or technical survival

Study (published year) [reference]	Study design	Setting countries	Data source	N (CAPD, APD)	Duration of observation	Results
de Fijter CW et al. (1994) [15]	Prospective randomized study	Netherland 1988–1991)	Single center	82 (41, 41)	24 months	Ns.
Guo A et al. (2003) [85]	Retrospective cohort study	USA (1999, 2000, 2001)	Multicenter	>30000 (N/A)	N/A	APD is better within 1 year after PD induction
Badve SV et al. (2008) [86]	National registry	Australia, New Zealand (1999–2004)	Multicenter (ANZDATA)	4128 (2393, 1735)	5 years	Ns.
Liao CT et al. (2008) [87]	Retrospective observational study	Taiwan (1996–2005)	Single center	270 (188, 82)	6 months	Ns.
Sanchez et al. (2008) [8]	Retrospective cohort study	Mexico (2003–2005)	Single center	237 (139, 98)	2 years	APD is better
Mehrota R et al. (2009) [88]	National registry	USA (1996–2004)	Multicenter (USRDS)	66381 (42942, 23439)	2~10 years	Ns.
Michels WM, et al. (2009) [89]	Retrospective cohort study	Netherland (1997–2006)	Multicenter (NECOSAD)	649 (562, 87)	5 years	Ns.
Johnson DW et al. (2010) [13]	National registry	Australia, New Zealand	Multicenter (ANZDATA)	628 (486, 142) in H category	3 months to 10 years	Ns. Fatal risk was decreased in H Category
Balasubramanian G et al. (2011) [11]	Retrospective observational study	UK (2003–2008)	Single center	372 (178, 194)	5 years	APD was better for survival
Conssen TT et al. (2011) [90]	Retrospective observational study	USA (2001–2008)	Multicenter	620 (179, 441)	3 month–7 years	APD was better
Sun CY et al. (2010) [91]	Retrospective observational study	Taiwan (1997–2008)	Single center	282 (121, 161)	3 months–10 years	APD was better
Kwan BC et al. (2013) [10]	Retrospective observational study	Hong Kong (1995–2011)	Multicenter	270 (180, 90)	9.5 months–46.5 months	Ns.
Beduschi GC et al. (2015) [12]	Prospective cohort study	Brazil (2004–2011)	Multicenter	2890 (1445, 1445)	5 years	Life survival of APD was better than that of CAPD. Ns. for technical survival
Mizuno M et al. (2016) [35]	Retrospective cohort study	Japan (2010–2012)	Multicenter	200 (119, 81)	3 years	Ns.

Ref. Bieber SD et al. [7]

Ns. significant differences between CAPD and CAD, *N/A* not available in the text, *ANZDATA* Australia and New Zealand Dialysis and Transplant, *NECOSAD* Netherlands Cooperative Study on the Adequacy of Dialysis, *USRDA* US Renal Data System

comparison of the adequacy of dialysis between APD and CAPD [15, 16], no significant difference was reported.

Removal of sodium, phosphate, or macromolecules

Using a glucose-based PDF, adjustment of body volume is one reason to choose APD [14] because the usage of a cycler machine can perform frequent and short-term changes of dialysate to obtain appropriate ultrafiltration. However, we also have to consider sodium removal with ultrafiltration because sodium sieving sometimes occurs, especially when using high-concentrated glucose PDF for a short dwell time [17, 18]. Sodium sieving, first proposed by Rodriguez-Carmona et al., suggests that water removal is faster than sodium removal through ultra-small pore (aquaporin-1) water channels [18]. In fact, there were a couple of reports showing that total sodium removal in patients on CAPD was more than that on APD, although total ultrafiltration on CAPD might be less than that on APD [14, 18]. When Nakayama et al. reported the comparison of the efficacy of sodium removal among different concentrations of glucose-based PDFs with conventional sodium or low sodium concentration [17], sodium sieving was clearly observed in PD patients using high-concentrated glucose-based PDF over a short dwell time. Therefore, using high-glucose-concentrated dialysate and frequent bag changes with a short dwell time; removal of sodium might not be sufficient because of sodium sieving. In that case, ideally, options to remove an appropriate amount of sodium include increasing dwell time, combining with usage of icodextrin, not using high-glucose dialysate, extending the dwell time of the cycler machine's program, and/or decreasing sodium intake [19].

Concerning the removal of large molecules of uremic toxin, it has been reported that the efficacy of CAPD is better than that of APD for the removal of β2-microglobulin [20–23].

Therefore, the efficacy of the removal of sodium and large uremic molecules is better in CAPD patients with a long dwell time than in APD patients with frequent and short dwell times.

Effects for RRF

Preservation of residual renal function (RRF) is important to prevent lethal cardiovascular events in ESRD patients. It would be better to focus efforts on maintaining RRF in ESRD patients, even if they have chosen maintenance blood purification therapies, including hemodialysis [24]. In PD patients, it has been shown that life survival is better when the rate of decline in RRF is slower [25] and that preservation of RRF is an important factor in decreasing the risk of cardiovascular death [26]. In addition, PD patients who have chosen incremental PD might have better control of body fluid volume and removal of macromolecules, including preservation of RRF [27]. Therefore, it is important to make an effort to prevent factors that worsen RRF such as cautiously using large doses of loop diuretics, avoiding nephrotoxic drugs, minimizing use of frequent radiocontrast dyes, optimizing blood pressure control, using an angiotensin-converting enzyme inhibitor or angiotensin receptor blocker, avoiding hypotension and dehydration, selecting a biocompatible PD solution and/or icodextrin-based PD solution, and preventing PD-related peritonitis [28–30]. As part of incremental PD, low-frequency APD may be a good choice for ESRD patients [31].

However, it has been controversial whether APD or PD is better for preservation of RRF. Several cohort studies have approached this question. Recently, Bieber et al. summarized 20 cohort studies to compare the preservation of RRF between APD and CAPD in literature published between 1994 and 2011 [7], and most of them showed no differences in preservation of RRF between APD and CAPD. In 2015, when usage of APD was started from induction periods for 24 months, the decrease in RRF with APD was reported to be faster than that with CAPD in a multicenter cohort study from a Spanish group [32].

There were generally no differences in the method used for PD between APD and CAPD in most of the literature, but some results showed a slight advantage in the preservation of RRF for CAPD patients. One reason APD might be slightly less advantageous than CAPD, especially during induction periods, is the shorter dwell time and more frequent changes of PDF, which may result in excessive dehydration in patients on APD. Past reports are summarized in Table 2.

Effects on incidence/recovery of PD-related peritonitis

This point has also been controversial until now (Table 3). Briefly, APD may be better, or at least no worse, as far as the incidence of peritonitis compared with CAPD. In a meta-analysis [33], the incidence of peritonitis in patients with APD was lower than those with CAPD because the frequency of PD bag changes in APD was less than in CAPD, meaning that opportunities for contamination in APD were fewer. In contrast, there were several reports that showed no differences in the incidence of peritonitis between APD and CAPD [11]. In another review article, Bieber et al. summarized seven reports that compared the incidence of peritonitis between APD and CAPD. The review showed that three of the reports demonstrated no differences between APD and CAPD, two found APD to be more advantageous compared to CAPD, and one showed advantages of CAPD over APD before 2011 [7]. In a recent multicenter cohort report in Hong Kong [10], peritonitis-free survival in patients on APD was better than peritonitis-free survival in patients on CAPD for up to 2 years after starting PD therapy. Peritonitis-free survival was defined as the duration of PD until first occurrence of

Table 2 Comparison between APD and CAPD for preservation of residual renal function

Study (published year)	Study design	Setting countries	Data source	N (CAPD, APD)	Duration of observation	Results
de Fijter CW et al. (1994) [15]	Prospective Randomized study	Netherlands (1988–1991)	Single	81 (41, 41)	24 months	Ns.
Hiroshige K et al. (1996) [22]	Prospective cohort study	Japan (1992–1994)	Single center	18 (5, 13)	6 months	CAPD was better
Bro S et al. (1999) [16]	Prospective randomized study	Denmark (1995–1999)	Multicenter	34 (17, 17)	6 months	Ns.
Hufnagel G et al. (1999) [92]	Prospective cohort study	France (1995–1997)	Single center	36 (18, 18)	12 months	CAPD was better
Galler P et al. (2000) [93]	Prospective cohort study	Spain (N/A)	Single center	20 (11, 9)	12 months	Ns.
Hamada C et al. (2000) [94]	Prospective cohort study	Japan (N/A)	Single	34 (17, 17)	24 months	Ns. (but decrease of urinary volume was faster in CAPD)
Moist LM et al. (2000) [95]	National Registry data	USA (1997)	USRDS dialysis morbidity and mortality	1032 (722, 310)	8–18 months	Ns.
Singhal MK et al. (2000) [96]	Prospective cohort study	Canada (1994–1997)	Single center	242 (211, 31)	27 ± 14 months	Ns.
Holley JL et al. (2001) [97]	Retrospective database	USA (1991–2000)	N/A	184 (70, 114)	<9 months	Ns.
Hidaka H et al. (2003) [98]	Prospective cohort study	Japan (1995–2001)	Single center	34 (27, 7)	12~42 months	CAPD was better
Johnson DW et al. (2003) [99]	Prospective cohort study	Australia (1995–2001)	Single center	146 (134, 12)	21 ± 15 months	Ns.
Rodriguez-Carmona A et al. (2004) [100]	Prospective observational study	Spain (1995–2001)	Single center	104 (53, 51)	12–24 months	CAPD was better
Balasubramanian et al. (2011) [11]	Retrospective observational study	UK (2003–2008)	Single center	277 (130, 147)	5 years	Ns.
Cnossen TT et al. (2011) [90]	Retrospective observational study	UK (2001–2008)	Multicenter	620 (179, 441)	450 days	Ns.
Michael WM et al. (2011) [101]	Prospective cohort study	Netherlands (1997–2006)	Multicenter (NECOSAD)	583 (505, 78)	3 months–3 years	Ns.
Roszkowska-Blaim M et al. (2012) [80]	Retrospective observational study	Poland (1992–2009)	Multicenter	101 children (44, 57)	36 months	CAPD was better
Pérez Fontán M et al. (2015) [32]	Retrospective observational study	Spain (2000–2010)	Multicenter	493 (365, 125)	6–24 months	CAPD was better when APD was introduced during induction period of PD

Ref. Bieber SD et al. [7]

Ns. not significant between CAPD and APD, *N/A* not available in the text, *NECOSAD* Netherlands Cooperative Study on the Adequacy of Dialysis, *USRDA* US Renal Data System

Table 3 Comparison for effects on incidence of PD-related peritonitis between APD and CAPD

Study (published year)	Study design	Setting countries	Data source	N (CAPD,APD)	Duration of observation	Results
Alliapoulos JC et al. (1984) [102]	Cross-sectional study	USA (N/A)	Single center	10 pediatric patients and subsequently CCPD.	15.0 ± 2.8 months for CAPD vs. 9.3 ± 3.2 months	Ns.
de Fijter CW et al. (1994) [15]	Prospective randomized study	Netherlands (1988–1991)	Single center	82 (41, 41)	24 months	APD was better
Bro S et al. (1999) [16]	Prospective randomized study	Denmark (1995–1999)	Multicenter	34 (17, 17)	6 months	2 cases for CAPD, 1 case for APD
Rodríguez-Carmona A et al. (1999) [103]	Prospective nonrandomized study	Spain (1989–1998)	Single center	328 (213, 115)	3 months–10 years	APD was better
Yishak A et al. (2001) [104]	Prospective observational study	USA (1990–2000)	Multicenter	583 (384, 199)	N/A	Ns.
Oo TN et al. (2005) [105]	National registry data	US (1994–1997)	Multicenter	11,975 (9190, 2785)	6 months–2 years	APD was better
Davenport A. (2009) [106]	Observational cross-sectional study	UK (2002–2003)	Multicenter	863 (538, 325) at the end of 2002, (635, 445) at the end of 2003	2 years	APD was better
Nessim SJ et al. (2009) [107]	Prospective cohort study	Canada (1996–2005)	Multicenter	3180 (N/A)	N/A	Ns.
Balasubramanian G et al. (2011) [11]	Retrospective observational study	UK (2003–2008)	Single center	372 (178–194)	5 years	APD was better
Rüger W et al. (2011) [36]	Retrospective observational study	Netherlands (1993–2007)	Single center	205 (112, 93)	14 years	Ns.
Mizuno M et al. (2011) [108]	Retrospective observational study	Japan (2005–2007)	Multicenter	561 (N/A)	N/A	Ns.
Lee OK et al. (2013) [79]	Retrospective observational study	Korea (1986–2011)	Single center	57 (51, 6), less than 18 years old	6 months–240 months	APD was better in childhood
Kwan BC et al. (2013) [10]	Retrospectiv observational study	Hong Kong (1995–2011)	Multicenter	270 (180, 90)	9.5 months–46.5 months	APD was better for induction period of PD
Nishina M et al. (2013) [109]	Retrospective cohort study	Japan (2001–2011)	Single center	192 (156, 36)	10 years	Ns.
Lan PG et al. (2014) [34]	Prospective observational study	Australia and New Zealand (2003–2011)	Multicenter (ANZDATA)	6959 (2761, 4198)	Mean 1.9 years	Ns.
Beduschi GC et al. (2015) [12]	Prospective cohort study	Brazil (2004–2011)	Multicenter	2890 (1445, 1445)	5 years	Ns. for time to first episode of peritonitis
Mizuno M et al. (2016) [35]	Retrospective observational study	Japan (2010–2012)	Multicenter	200 (119, 81)	3 years	Ns.

Ref. Bieber SD et al. [7]

Ns. no significant differences between CAPD and CAD, *N/A* not available in the text, *ANZDATA* Australia and New Zealand Dialysis and Transplant

peritonitis. However, in 2014, no differences between APD and CAPD were reported with regard to the incidence of peritonitis [34]. Our recent reports also showed no differences between APD and CAPD [35].

Concerning the prognosis of PD-related peritonitis, it has been reported that a difference between APD and CAPD has not been observed [36]. In considering whether to continue using a cycler during treatment for PD peritonitis, the possible selection of antibiotics in APD was limited by the 2010 ISPD guideline [37–39], compared with CAPD therapy. However, when PD-related peritonitis occurs in patients treated with APD, we can transiently change the method of treatment from APD to CAPD until the patient recovers from peritonitis. Of note, it is important to keep in mind the possible difficulty in observing and recognizing slightly cloudy PDF in the early stage of peritonitis in APD therapy because the waste fluid tank might be easily soiled by the drainage of PDF.

From the past literature, it has been suggested that the decrease in the number of PDF bag changes might decrease opportunities for peritonitis caused by contamination in patients with APD. Especially during the early period of PD induction, APD might be associated with a lower incidence of peritonitis than CAPD. However, it remains unclear which method, APD or CAPD, is associated with an overall lower incidence of peritonitis. Large-scale prospective cohort studies might be required in the future to more clearly determine whether APD or CAPD is better.

Effects associated with peritoneal leakage or herniation

When abdominal pressures are increased, the risks of incidence of peritoneal leakage and/or herniation, such as incisional herniation, pericatheter herniation, umbilical herniation, and inguinal herniation, are increased [40, 41]. It is well known that, in humans, abdominal pressure is the lowest in the supine position and the pressure increases in the sitting and standing positions [42]. After starting PD therapy, abdominal pressure in ESRD patients may increase, depending on the dwell volume of PDF in the abdomen [42, 43]. It was also reported that abdominal pressure was increased by coughing and constipation, which induce excessive straining, and by increased intraperitoneal volume of PDF [42]. Although there were some reports that intraperitoneal pressure was not dependent on intraperitoneal volume, the investigated volume was more than 2 L in these reports [41, 44]. In contrast, Twardowski et al. reported that abdominal pressure was observed to increase with the addition of 3 L of fluid to an empty abdomen [42].

Polycystic kidney disease (PKD) was reported as an independent risk factor for peritoneal leakage and herniation in PD patients [41, 45, 46]. In contrast, there was a report that showed no increase in the incidence of herniation in PKD patients [47]. Thus, which type of PD is better to decrease the risk of herniation in PD patients, APD or CAPD? In patients with PKD, the incidence of herniation with APD treatment was less than in patients treated with CAPD [41]. On the other hand, Rabindranath et al. reported that the risk of herniation was not different between APD and CAPD in a meta-analysis [33]. Of note, because obesity has also been reported to increase intra-abdominal pressure [42, 43], extreme obesity might be a disadvantage to PD therapy due to the increased risk of peritoneal leakage and/or herniation.

When abdominal pressure is increased in clinical situations such as PKD and obesity, one could theoretically choose to induce APD to prevent the development of peritoneal leakage and herniation. In fact, there have been several reports showing that APD had a lower rate of herniation than CAPD [41, 44], although other reports have shown no significant difference in the incidence of herniation with APD versus CAPD [48] (Table 4). However, the latter reports compared dwell volumes of more than 2 L. Therefore, it may be useful to maintain only up to approximately 1 L to prevent an increase in abdominal pressure and to decrease the risk of peritoneal leakage and herniation in high-risk patients [49, 50]. A Japanese report showed that intra-abdominal pressure was not significantly increased when dwell volume was less than 1 L in Japanese patients [51]. Because of this data, it may be suggested that a dwell volume of less than 1 L of PDF will prevent leakage/herniation, at least in the Japanese population.

Influences on SAS and respiratory function

Sleep disorders are common complications and factors that shorten life expectancy for ESRD patients due to the associated cardiovascular disease [52–55]. Sleep apnea syndrome (SAS) is a major cause of sleep disorder, hypertension, arrhythmias, and sudden death [56, 57]. Furthermore,

Table 4 Risk of incidence of peritoneal leakage and/or herniation between APD and CAPD

Study (published year)	Study design	Setting countries	Data source	N (CAPD, APD)	Duration of observation	Results
Alliapoulos JC et al. (1984) [102]	Cross-sectional study	USA (N/A)	Single center	10 pediatric patients and subsequently CCPD	15.0 ± 2.8 months for CAPD vs. 9.3 ± 3.2 months	CAPD was higher risk than APD but Ns
del Peso G et al. (2003) [48]	Retrospective observational study	Spain (1995–2000)	Single center	80 (72, 8) 62 with both modalities	5 years	CAPD was higher risk than APD but Ns

Ns. not significant differences between CAPD and CAD, *N/A* not available in the text

concerning SAS, it has been reported that the number of apnea/hypopnea episodes per hour of sleep was suppressed by induction of APD compared with CAPD [58]. They especially mentioned that APD might be more effective for obstructive apnea/hypopnea when SAS is diagnosed in PD patients. However, Sydney et al. reported that SAS was an independent risk factor for subsequent mortality and cardiovascular events when ESRD patient had SAS at the start of PD [59]. Diagnosis and subsequent therapy may be required to decrease mortality.

With regard to respiratory disease, which type of PD therapy is a better choice for patients with severe pulmonary disease, APD or CAPD? It is thought that PD is relatively contraindicated in ESRD patients with severe pulmonary disease [60, 61]. In contrast, some reports have shown that induction of CAPD did not worsen respiratory function [62, 63]. It is therefore not certain which is better, APD or CAPD, in ESRD patients with severe pulmonary disease. A position change from sitting to supine position was reported to decrease 10 % of functional residual capacity and increase closing volume under CAPD therapy [63, 64]. It might be suggested that APD is better than CAPD in severe pulmonary disease, although it is still unclear whether or not it might be suitable to select PD as renal replacement therapy.

Which is more suitable, APD or CAPD, to improve health-related QoL in physical, psychological, and social activity?

Effects for health-related QoL

We believe that current treatment with induction of APD can relieve PD patients from rushing to perform repeated daily bag changes, thus allowing more free time. It was expected that APD might be better than CAPD with regard to physical, psychological, and/or social activities of PD patients. Some studies were evaluated using mental composite scores and physical composite scores in the comparison of APD and CAPD. Surprisingly, most published reports, including prospective cohort studies and RCT studies, showed no significant differences in health-related quality of life (QoL) or depression in PD patients treated with either APD or CAPD [11, 65]. In a review published by Bieber et al. in 2014, several of those reports concerning health-related QoL were summarized [7]. They described that the health-related QoL of ESRD patients was not different between APD and CAPD. For QoL of caregivers, APD might be better than CAPD [66] (Table 5).

Quality of sleep for APD

Disturbance of sleep might occur more frequently with APD than with CAPD. One reason may be the cycler's loud beeping to alert PD patients. The alert is necessary to wake up PD patients in order to resolve any trouble and continue APD therapy. However, although one might expect APD to decrease the quality of sleep [16, 65], there were no significant disadvantages of APD noted with regard to sleep disorders compared to CAPD in previous reports [7, 67, 68]. In fact, both APD and CAPD may equally worsen poor sleep quality [65].

Aspect of medical economics in the selection of APD or CAPD

Compared with CAPD, APD is more expensive. In a report from Denmark in 1999, the running cost for APD was shown to be 123 % of CAPD [16]. The cost of APD was 139 % of that of CAPD in a UK report from the National Health Service [69]. In Spain, it was reported that the cost of APD was approximately 136 to 160 % of CAPD [70]. Japan is not exceptional with regard to the

Table 5 Comparison between APD and CAPD for health-related quality of life and sleep

Study (published year)	Study design	Setting countries	Data source	N (CAPD,APD)	Duration of observation	Results
Bro S et al. (1999) [16]	Randomized controlled study	Denmark (1995–1999)	Multicenter	34 (17, 17)	6 months	APD was better for QoL but more problem for sleep disturbance
de Wit GA et al. (2001) [67]	Cross-sectional study	Netherlands (1993–2001)	Multicenter, (NECOSAD)	96 (59, 37)	N/A	APD was better
Sunder S et al. (2008) [68]	Prospective observational study	India (N/A)	Single center	18	12 months	Ns.
Guney I et al. (2010) [65]	Cross-sectional study	Turkey (N/A)	Single center	68 (48, 20)	N/A	Ns.
Balasubramanian G et al. (2011) [11]	Retrospective observational study	UK (2003–2008)	Single center	224 (111, 131)	5 years	Ns.
Michels WM et al. (2011) [101]	Prospective cohort study	Netherlands (1997–2006)	Multicenter (NECOSAD)	550 (486, 64)	3 months–3 years	Ns.
Losso RL et al. (2015) [110]	Observational cross-sectional study	Curitiba, Parana, Brazil (N/A)	Multicenter	76 (48, 28)	N/A	Ns.

Ref. Bieber SD et al. [7]

Ns. not significant differences between CAPD and CAD, *N/A* not available in the text, *NECOSAD* Netherlands Cooperative Study on the Adequacy of Dialysis

expenses associated with APD. Now, as we face an aging society, annual medical expenses may be further expanded in the future worldwide [71, 72]. We may need to balance the medical and social benefits for each individual PD patient with cost performance. Because APD is significantly more expensive than CAPD, when APD is the preferred choice, it may be better to perform intermittent PD with APD in order decrease the number of APD exchanges. However, to perform intermittent PD alternating with APD, preservation of RRF and control sodium intake might be required and decrease overall cost as the result [73].

Other advantages and disadvantages of APD

PD patients often prefer APD because another advantage is the lessened amount of time required from caregivers [14, 74]. Particularly, APD may be a good choice for caregivers of disabled PD patients [74]. On the other hand, manufacturer's instructions for handling of cyclers may be complicated compared with CAPD. Additionally, if a natural disaster occurs and lifelines including electricity are stopped, CAPD can work more easily than hemodialysis [75, 76]. When the great East Japan earthquake happened and the delivery of both electrical supply and water supply stopped, PD patients could still continue CAPD therapy [77]. However, cyclers require electricity because they do not have batteries. Therefore, CAPD is more efficient during natural disasters, compared with APD. Cyclers for APD are generally heavy and require delicate precision and are thus not suitable for easy carrying. Making space for a cycler and its related equipment in a patient's house is required to initiate APD.

Advantages of APD for children

Until now, there have not been enough reports to recommend selection between APD and CAPD. Generally, induction of APD may be considered in children with ESRD, especially small children who are cared for by their family [66] and can attend school without the need to perform bag exchanges [78]. Comparing children on CAPD with children on CCPD with a cycler, the removal of creatinine, urea, and phosphates is similar and dependent on dwell time and PD volume [66]. To decrease the incidence of peritonitis in younger children, Lee et al. reported that APD was better than CAPD [79]. Therefore, APD may also be important to decrease the risk of bag change contamination for younger children or their caregivers. In contrast, Roszkowska-Blaim et al. showed that RRF was preserved in CAPD more than in APD in children on PD [80]. As another interesting point, analysis of health-related QoL of caregivers, such as patients' parents, was reported. However, even if using APD, it was commented that children's parents might still have felt physiological and emotional stressrelated to supporting their children [81].

Briefly, as the 2011 NICE guideline in the UK recommends, APD may be offered for children, especially those with low RRF [82]. However, it is important to keep in mind that APD may allow reduction of RRF more rapidly than CAPD.

Expectations for APD in the future

A first-generation cycler, the Pac-X cycler II (Baxter), was too large for Japanese houses. After that, cycler machines for APD became more compact and were also functionally improved. In Japan, the home APD systems YUME and YUME plus, My home PICO® APD system, PD-mini Neo APD system, and Sleepsafe® APD system were developed by Baxter Limited, TERUMO Co. (Tokyo, Japan), JMS Co. (Tokyo, Japan) and Fresenius Medical Care Japan (Tokyo, Japan), respectively. Recent cycler machines used in Japan are able to store APD medical records, monitor the time course, and review it later, and the cycler machine can output measurements of body weight and blood pressure (APD system PD-Mini Neo, JMS Co.). However, the manufacturer's information is still complicated and PD patients are required to learn these procedures when a cycler machine is introduced. It might be especially difficult to introduce a cycler machine for disabled patients, especially those with blindness or hearing loss, as well as with older patients. In order to induce APD for patients with hearing loss, a telemetry system as a communication tool might be useful [83].

As a future cycler machine, Bieber et al. described the potential development of a cycler for APD that should be simpler to use and which has a large touchscreen, sterile connecting system, voice operated controls, a data sharing function between patients and medical staff, improved safety, and better cost performance [7]. In Japan, Nakamoto proposed a telemedicine system to manage outpatients on PD therapy at home [84]. In the future, a remote-controlled cycler machine may be developed.

At present, many machines are improving worldwide. Hopefully in the future, a cycler machine for APD will be developed that would enable the user to set everything automatically with one touch, and no complicated procedures for how to use the cycler machine will need to be learned.

Conclusions

At this moment, we still have not had enough evidence to say which is better, APD or CAPD, for every patient on PD therapy; and patient and physician preference may be important in choosing APD. We still need to consider which may be better between APD and CAPD on an individual basis based on medical, socioeconomic, and emotional aspects. Clinically, APD may be a better choice in

infants and young children, although more supporting data is needed. Assisted APD may be a better choice for older patients who require caregiver support. It is also important to consider each patient's preference in the decision to introduce the cycler for APD.

Abbreviations

APD, automated peritoneal dialysis; CAPD, continuous ambulatory peritoneal dialysis; CCPD, continuous cycling peritoneal dialysis; ESRD, end-stage renal disease; PD, peritoneal dialysis; PDF, peritoneal dialysate fluid; PET, peritoneal equilibration test; PKD, polycystic kidney disease; QoL, quality of life; RRF, residual renal function; SAS, sleep apnea syndrome

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Authors' contributions

MM designed and drafted the manuscript. YS, FA and YI helped to draft the manuscript. All authors read and approved the final manuscript.

Competing interests

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Consent for publication

All authors have contributed for this manuscript. This manuscript has been read and approved for submission by all authors and is not under review elsewhere.

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