Clinical Outcomes of Incremental Peritoneal Dialysis in Urgent-Start Peritoneal Dialysis Patients

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Abstract

Objective: To observe the feasibility and clinical efficacy of implementing incremental peritoneal dialysis in patients undergoing urgent-start peritoneal dialysis (USPD).

Methods: This was a single-center retrospective study. Patients with end-stage renal disease who underwent urgent-start peritoneal dialysis at the Department of Nephrology, First Affiliated Hospital of Xi'an Jiaotong University from August 1, 2018 to July 31, 2021 were enrolled. All patients had a pre-dialysis glomerular filtration rate between 4-6 ml/min/1.73m^2. According to different initial dialysis doses, they were divided into an incremental dose group (dialysis dose $ $6000 mL/day) and a standard dose group (dialysis dose $ $8000 mL/day). The incremental dose group had their dialysis regimen adjusted based on residual renal function and dialysis adequacy. Each patient was followed up for 1 year, and clinical biochemical parameters, dialysis dose, dialysis adequacy, urine volume, peritoneal ultrafiltration volume, residual renal function, and peritoneal dialysis-related complications were evaluated at 1 month, 3 months, 6 months, and 1 year of dialysis.

Results: 1. A total of 169 patients were enrolled in this study, including 111 in the incremental dose group with a mean age of $45.01\$\pm12.84 years, and 58 in the standard dose group with a mean ana$
0.05). 2. $Throughout the follow-up period, although the dialysis dose in the incremental dose group remained consis$
0.05), $dialysis adequacy was achieved in both groups. Moreover, at 1 month and 6 months of dialysis treatment, the U$
$0.75\pm0.43 vs. 0.61\pm0.32, P = 0.027; 6 months : 0.68\pm0.53 vs. 0.50\pm0.29, P =$
0.018). 3. $During the follow-up period, blood pressure control and correction of anemia and hypocalcemia were esim$
0.05). $Correction of hyperphosphatemia was achieved in both groups, but serum phosphorus was significantly high$
0.039) $and significantly lower at 1 year (1.39\pm0.36 mmol/L vs. 1.53\pm\$0.35$ mmol/L, P=0.030). 4. During the follow-up period, residual renal function was similar between the two groups. Ultrafiltration volume was higher in the standard dose group than in the incremental dose group, but the differences were not

statistically significant (P>0.05). Urine volume was significantly higher in the incremental dose group, especially at 1 month and 6 months of dialysis (P<0.05). 5. During the follow-up period, no patient died in either group, and there were no significant differences in peritoneal dialysis infection-related complications, mechanical complications, or technical survival rate (P>0.05).

Conclusion: For USPD patients, the therapeutic effect and complication profile of incremental peritoneal dialysis are similar to those of the standard dose group, and incremental peritoneal dialysis does not lead to rapid decline of residual renal function in USPD patients. Therefore, incremental peritoneal dialysis can be used as an initial dialysis modality for USPD patients.

Full Text

Clinical Efficacy of Incremental Peritoneal Dialysis in Patients Undergoing Urgent-Start Peritoneal Dialysis

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Objective: To observe the feasibility and clinical efficacy of implementing incremental peritoneal dialysis in patients undergoing urgent-start peritoneal dialysis (USPD).

Methods

This was a single-center retrospective study that enrolled end-stage renal disease (ESRD) patients who underwent urgent-start peritoneal dialysis at the Department of Nephrology, First Affiliated Hospital of Xi'an Jiaotong University from August 1, 2018 to July 31, 2021. All patients had a pre-dialysis glomerular filtration rate between 4–6 ml/min/1.73 m^2. Based on different initial dialysis doses, patients were divided into an incremental-dose group (dialysis dose $\leq$ 6000 mL/day) and a standard-dose group (dialysis dose $\geq$ 8000 mL/day). The incremental-dose group had their dialysis regimen adjusted according to residual renal function and dialysis adequacy. Each patient was followed for one year, with clinical biochemical indices, dialysis dose, dialysis adequacy, urine volume, peritoneal ultrafiltration volume, residual renal function, and peritoneal dialysis-related complications evaluated at 1 month, 3 months, 6 months, and 1 year after dialysis initiation.

Results

1. This study enrolled 169 patients, including 111 in the incremental-dose group with a mean age of 45.01 $\pm$ 12.84 years, and 58 in the standard-dose group with a mean age of 43.5 $\pm$ 15.62 years. Prior to dialysis, the demographic characteristics, clinical biochemical indices (blood pressure,

albumin, blood urea nitrogen, serum creatinine, potassium, phosphorus, parathyroid hormone, hemoglobin), and residual renal function were similar between the two groups, with no statistically significant differences ($P > 0.05$).

2. Throughout the follow-up period, although the dialysis dose in the incremental-dose group remained significantly lower than that in the standard-dose group ($P < 0.05$), both groups achieved adequate dialysis. Moreover, at 1 month and 6 months of dialysis treatment, the UKt/V in the incremental-dose group was significantly higher than that in the standard-dose group (1 month: 0.75 ± 0.43 vs. 0.61 ± 0.32, $P = 0.027$; 6 months: 0.68 ± 0.53 vs. 0.50 ± 0.29, $P = 0.018$).

3. During the follow-up period, blood pressure control, anemia correction, and hypocalcemia correction were similar between the two groups, with no statistically significant differences ($P > 0.05$). Both groups achieved correction of hyperphosphatemia, but at 1 month of dialysis, serum phosphorus in the incremental-dose group was significantly higher than in the standard-dose group (1.48 ± 0.43 mmol/L vs. 1.34 ± 0.31 mmol/L, $P = 0.039$). At 1 year of dialysis, serum phosphorus in the incremental-dose group was significantly lower than in the standard-dose group (1.39 ± 0.36 mmol/L vs. 1.53 ± 0.35 mmol/L, $P = 0.030$).

4. Throughout the follow-up period, residual renal function was similar between the two groups. Ultrafiltration volume was higher in the standard-dose group than in the incremental-dose group, but the differences were not statistically significant ($P > 0.05$). Urine volume in the incremental-dose group was significantly higher than in the standard-dose group, particularly at 1 month and 6 months of dialysis ($P < 0.05$).

5. During the follow-up period, no patients died in either group. Peritoneal dialysis-related infection complications, mechanical complications, and technical survival rates were similar between the two groups, with no statistically significant differences ($P > 0.05$).

Conclusion

For USPD patients, the therapeutic effects and complications of incremental peritoneal dialysis are similar to those of the standard-dose group, and incremental peritoneal dialysis does not lead to rapid decline of residual renal function. Therefore, incremental peritoneal dialysis can be adopted as an initial dialysis modality for USPD patients.

Keywords: Incremental peritoneal dialysis; Urgent-start peritoneal dialysis; Residual renal function; Dialysis dose; Urine volume

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Peritoneal dialysis is a common renal replacement therapy modality. Incremen-

tal peritoneal dialysis as an initial dialysis approach has become increasingly popular worldwide. First proposed as a concept by Mehrotra et al. in 1997 without actual clinical application at the time, incremental peritoneal dialysis now refers to initiating peritoneal dialysis with fewer than four exchanges per day or a dose less than 8 L/day due to the presence of residual renal function (RRF), with dialysis dose gradually increased as RRF declines to achieve adequate solute and fluid clearance. Numerous studies have confirmed the feasibility and effectiveness of incremental peritoneal dialysis, demonstrating advantages in ESRD patients including better preservation of residual renal function, reduced peritoneal glucose exposure, fewer infection-related complications, preferred transitional modality before renal transplantation, and lower economic burden.

Urgent-start peritoneal dialysis (USPD) refers to newly diagnosed ESRD patients without emergency dialysis indications but requiring dialysis within 14 days, who lack established dialysis access and initiate peritoneal dialysis as their first modality. It differs from planned peritoneal dialysis. Whether USPD patients can also be treated with incremental peritoneal dialysis and how this approach affects their residual renal function remain unclear, prompting this investigation and analysis.

1.1 Study Subjects

This study enrolled ESRD patients who received urgent-start peritoneal dialysis at the Department of Nephrology, First Affiliated Hospital of Xi'an Jiaotong University from August 1, 2018 to July 31, 2021. Inclusion criteria were age > 18 years, any gender, any etiology, and glomerular filtration rate between 4–6 ml/min/1.73 m^2. All patients had no emergency dialysis indications prior to enrollment. Exclusion criteria included acute exacerbation of chronic kidney disease, acute kidney injury, peritoneal dialysis contraindications, and incomplete follow-up data.

1.2 Methods

This single-center retrospective study had a follow-up duration of one year. All enrolled patients underwent peritoneal dialysis catheter placement using the open surgical technique by nephrology specialists, with peritoneal dialysis initiated within 24 hours postoperatively. The initial regimen consisted of 1.5% low-calcium peritoneal dialysate, 1000 mL per exchange with 1-hour dwell time. After one week, the regimen was adjusted to 1.5% low-calcium peritoneal dialysate, 2000 mL per exchange with 4-hour dwell time. Based on initial daily dialysis dose, patients were divided into an incremental-dose group and a standard-dose group. The incremental-dose group had an initial daily dialysis dose $\leq$ 6000 mL or $\leq$ 3 exchanges per day, with dialysis dose adjusted according to residual renal function and dialysis adequacy. The standard-dose group had an initial daily dialysis dose $\geq$ 8000 mL or $\geq$ 4 exchanges per day, with unchanged dialysis dose during follow-up. Demographic characteristics and

clinical biochemical indices (including blood pressure, albumin, blood urea nitrogen, creatinine, potassium, calcium, phosphorus, parathyroid hormone, CO_2 combining power, hemoglobin), residual renal function, urine volume, ultrafiltration volume, dialysis adequacy, dialysis dose, peritoneal transport function, and dialysis-related complications (including exit-site infection, peritonitis, mechanical complications, technical survival) were recorded before dialysis and at 1 month, 3 months, 6 months, and 1 year. Pre-dialysis residual renal function was calculated using the EPI formula, while post-dialysis RRF was calculated using 24-hour urea and creatinine clearance: RRF = 1/2 × (urine urea/blood urea + urine creatinine/blood creatinine) × urine volume/1440. Body mass index (BMI) and body surface area (BSA) were calculated as: BMI = weight (kg)/height $(m)^2$; BSA = 0.0061 × height (cm) + 0.0128 × weight (kg) - 0.1529. Dialysis adequacy was assessed using Kt/V and Ccr, including peritoneal urea clearance index (PKt/V), residual renal urea clearance index (UKt/V), total urea clearance index (TKt/V), peritoneal creatinine clearance rate (PCcr), residual renal creatinine clearance rate (UCcr), and total creatinine clearance rate (TCcr).

1.3 Statistical Methods

SPSS 22.0 software was used for statistical analysis. Continuous variables were expressed as mean ± standard deviation. Measurement data were analyzed using independent samples t-test, and count data using chi-square test. $P < 0.05$ was considered statistically significant.

2.1 General Data

This study enrolled 169 patients, including 111 in the incremental-dose group (70 males, 41 females) with mean age 45.01 ± 12.84 years, and 58 in the standard-dose group (43 males, 15 females) with mean age 43.5 ± 15.62 years. Demographic characteristics including gender, age, proportion of diabetic nephropathy patients, BMI, and BSA were similar between groups, as were pre-dialysis clinical biochemical indices, with no statistically significant differences ($P > 0.05$, see Table 1).

2.2 Peritoneal Transport Function

Standard peritoneal equilibration test was performed at 1 month of regular peritoneal dialysis to assess peritoneal transport function. Based on 4-hour D/P values, peritoneal transport function was classified as low transport, low-average transport, high-average transport, or high transport. Comparison of patient numbers with different peritoneal transport functions between groups showed similar distributions, with no statistically significant difference ($P > 0.05$, see Table 2).

2.3 Comparison of Dialysis Dose During Follow-up

Throughout the follow-up period, the daily dialysis dose in the standard-dose group was significantly higher than in the incremental-dose group (1 month: 5891.89 ± 528.31 ml/d vs. 8034.48 ± 262.61 ml/d, P = 0.000; 3 months: 6159.57 ± 1185.06 ml/d vs. 8080.00 ± 395.80 ml/d, P = 0.000; 6 months: 6468.47 ± 1588.71 ml/d vs. 8155.17 ± 523.21 ml/d, P = 0.000; 1 year: 6900.90 ± 1543.05 ml/d vs. 8051.72 ± 906.55 ml/d, P = 0.000).

2.4 Comparison of Urine Volume and Ultrafiltration Volume

Pre-dialysis urine volume was similar between groups, with no statistically significant difference ($P > 0.05$, see Figure 1 [Figure 1: see original paper]). However, throughout follow-up, urine volume in the incremental-dose group was higher than in the standard-dose group, particularly significant at 1 month and 6 months of dialysis ($P < 0.05$, see Figure 1). Although ultrafiltration volume in the incremental-dose group remained lower than in the standard-dose group throughout follow-up, the difference was not statistically significant ($P > 0.05$, see Figure 2 [Figure 2: see original paper]).

2.5 Comparison of Dialysis Adequacy During Follow-up

Throughout the follow-up period, both groups achieved adequate dialysis with TKt/V > 1.7 and TCcr > 50 L. PKt/V and PCcr in the standard-dose group were significantly higher than in the incremental-dose group ($P < 0.05$, see Table 3 and Table 4). At 1 month and 6 months of peritoneal dialysis, UKt/V in the incremental-dose group was higher than in the standard-dose group, with statistically significant differences ($P < 0.05$, see Table 3), while UCcr was similar between groups ($P > 0.05$, see Table 4). At 3 months of dialysis, TKt/V was similar between groups ($P > 0.05$, see Table 3), but TCcr in the standard-dose group was significantly higher than in the incremental-dose group ($P < 0.05$, see Table 4).

2.6 Comparison of Biochemical Indices During Follow-up

Throughout the follow-up period, blood pressure, hemoglobin, and serum calcium levels were similar between groups, with no statistically significant differences ($P > 0.05$, see Tables 5–8). At 1 month of dialysis, blood urea nitrogen, serum potassium, and serum phosphorus in the incremental-dose group were significantly higher than in the standard-dose group ($P < 0.05$, see Table 5). At 3 months and 6 months of dialysis, serum albumin in the incremental-dose group was lower than in the standard-dose group, while blood urea nitrogen and serum potassium were higher, with statistically significant differences ($P < 0.05$, see Table 6 and Table 7). At 1 year of peritoneal dialysis, serum albumin and phosphorus in the incremental-dose group were significantly lower than in the standard-dose group, while CO_2 combining power was higher, with statistically significant differences ($P < 0.05$, see Table 8).

2.7 Comparison of Residual Renal Function

Pre-dialysis residual renal function was similar between groups. Throughout the entire follow-up period after dialysis initiation, residual renal function remained similar between groups, with no statistically significant differences ($P > 0.05$, see Table 9).

2.8 Comparison of Complications

Infection-related complications, mechanical complications, and technical survival rates were similar between groups during follow-up, with no statistically significant differences ($P > 0.05$, see Table 10). No patient deaths occurred in either group.

Incremental peritoneal dialysis, which initiates treatment with fewer than four exchanges per day or less than 8 L/day due to the presence of residual renal function (RRF), gradually increases dialysis dose as RRF declines to achieve adequate solute and fluid clearance. Current evidence demonstrates that compared with standard-dose peritoneal dialysis, incremental peritoneal dialysis offers several advantages, including better preservation of residual renal function, reduced peritoneal glucose exposure, fewer infection-related complications, preferred transitional modality before renal transplantation, and lower costs. A Korean study found that incremental peritoneal dialysis preserves residual renal function with similar patient survival compared to full-dose peritoneal dialysis. De Vecchi et al. first reported that incremental peritoneal dialysis patients demonstrated better quality of life, work capacity, and rehabilitation compared to standard-dose patients. Regarding survival, Chen et al. found that incremental peritoneal dialysis was superior to conventional continuous ambulatory peritoneal dialysis in fluid removal, volume status, nutritional status, and survival. Additionally, European studies have shown that preserving residual renal function positively impacts survival and quality of life in peritoneal dialysis patients. Due to significantly reduced medical costs, Chinese physicians often prescribe incremental peritoneal dialysis for ESRD patients with residual renal function, particularly those with financial difficulties.

Urgent-start peritoneal dialysis (USPD) is widely used in clinical practice. Due to lack of pre-dialysis education, most newly diagnosed ESRD patients in China choose USPD. Whether USPD patients can be treated with incremental peritoneal dialysis and whether this approach affects their residual renal function compared to standard-dose PD remain unclear. Therefore, we retrospectively analyzed the feasibility and clinical efficacy of implementing incremental peritoneal dialysis in USPD patients.

Our data show that throughout the follow-up period, the standard-dose group had significantly higher dialysis doses than the incremental-dose group. Consequently, PKt/V and PCcr in the standard-dose group were higher than in the

incremental-dose group, which is related to study design without practical significance. However, both groups achieved adequate dialysis during follow-up, with total Kt/V exceeding 1.7 and total Ccr greater than 50 L. This indicates that for USPD patients with residual renal function, incremental peritoneal dialysis can meet adequacy requirements while reducing medical costs. Some scholars have noted that peritoneal dialysis adequacy is not solely determined by urea clearance index (Kt/V), but should also include sufficient creatinine clearance rate, normal blood pressure, normal volume status, anemia correction, optimal nutritional status, electrolyte disorder correction, maintenance of low inflammatory status, prevention of cardiovascular events, and preservation of residual renal function. Our results demonstrate that throughout follow-up, blood pressure control, anemia correction, and calcium-phosphorus abnormalities were similar between groups. Although serum potassium levels in the incremental-dose group were higher than in the standard-dose group during the first 6 months, this may be related to the standard-dose group using more potassium-free dialysate daily, while potassium levels in both groups remained normal. Therefore, dialysis efficacy was similar between groups.

Residual renal function is crucial for ESRD patients. Studies have shown that incremental peritoneal dialysis reduces the rate of residual renal function loss compared to both pre-dialysis status and standard-dose dialysis. Reducing the rate of residual renal function loss can improve fluid overload, enhance nutritional status, control inflammation, thereby improving quality of life and reducing mortality and other complication rates. Additionally, it enables effective removal of large and middle molecular toxins. Maiorca et al. reported that peritoneal dialysis patients with residual renal function had 50% lower mortality. The CANUSA study and its subsequent reanalysis demonstrated that residual renal solute clearance was more predictive of mortality than peritoneal clearance, with each 5 ml/min/1.73 m^2 increase in GFR reducing death risk by 12%. Our study enrolled patients with GFR of 4–6 ml/min/1.73 m^2, and residual renal function was similar between groups both before and throughout follow-up after dialysis, indicating that incremental peritoneal dialysis does not cause rapid RRF decline compared to standard-dose PD.

Additionally, we found that although RRF was similar between groups throughout follow-up, UKt/V in the incremental-dose group was higher than in the standard-dose group at 1 month and 6 months of dialysis. As is well known, dialysis ultrafiltration volume is related to both peritoneal transport function and dwell time, as well as daily dialysis volume. In our center, all peritoneal dialysis patients have strict fluid intake control, not exceeding 1000 mL daily. Under fluid restriction, peritoneal dialysis ultrafiltration volume competes with urine volume, leading to significantly reduced urine output. In this study, the proportion of patients with different peritoneal transport functions was similar between groups, while daily dialysis volume and ultrafiltration volume in the standard-dose group exceeded those in the incremental-dose group throughout follow-up, resulting in lower urine volume in the standard-dose group. Since residual renal Kt/V = [(24-hour urine volume × urine urea nitrogen/blood

urea nitrogen) × number of days]/[weight × 0.6 (males) or 0.55 (females)], urine volume determines residual renal Kt/V value under otherwise identical conditions. Therefore, UKt/V in the incremental-dose group was higher than in the standard-dose group, suggesting that in clinical practice, urine volume may be more important than UKt/V. In Sandrini et al.'s study, survival models for peritoneal dialysis patients showed that urine volume was a significant factor improving survival. Furthermore, the CANUSA study and its reanalysis indicated that each 250 mL increase in urine volume reduced patient death risk by 36%.

Peritoneal dialysis complications significantly impact patient prognosis. Incremental peritoneal dialysis reduces peritoneal exposure to glucose and its metabolites in dialysate, decreases glucose absorption by the peritoneum, thereby slowing peritoneal function decline and reducing hyperglycemia risk. De Vecchi et al. reported that peritonitis risk was related to exchange frequency. With incremental dialysis, patients have fewer dialysate exchanges than the standard-dose group, reducing daily connection procedures and infection risk. Whether incremental peritoneal dialysis differs from standard-dose peritoneal dialysis regarding complications and technical survival in USPD patients remains unclear. Our study found that infection-related complications, mechanical complications, and technical survival rates were similar between groups, with no statistically significant differences.

Additionally, the incremental-dose group had significantly lower daily total dialysis dose than the standard-dose group, reducing dialysis costs and alleviating patient economic burden. Simultaneously, fewer daily procedures reduce psychological burden for patients and families, improve quality of life, and enhance acceptance of and compliance with peritoneal dialysis.

In summary, incremental peritoneal dialysis can be used for urgent-start peritoneal dialysis patients in terms of dialysis efficacy, cost, residual renal function preservation, complications, and technical survival. However, this was a single-center study with a small sample size, and results may have limitations. Multi-center studies with larger sample sizes may better reflect the feasibility of incremental peritoneal dialysis in USPD patients. Furthermore, long-term prognosis assessment of incremental peritoneal dialysis in USPD patients is imperative. Therefore, more multi-center, long-term studies are needed to address these questions.

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Note: Figure translations are in progress. See original paper for figures.