Clinical Efficacy of Incremental Peritoneal Dialysis in Urgent-Start Patients

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Abstract

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

Methods: This was a single-center retrospective study that included end-stage renal disease patients hospitalized in the Department of Nephrology, First Affiliated Hospital of Xi'an Jiaotong University, who underwent urgent-start peritoneal dialysis from August 1, 2018 to July 31, 2021. All patients had a pre-dialysis glomerular filtration rate between 4~6ml/min/1.73m2. Based on different initial dialysis doses, patients were divided into an incremental dose group (dialysis dose $ $6000mL/day) and a standard dose group (dialysis dose $ $8000mL/day), with the incremental dose group adjusting the dialysis regimen according to the patient's residual renal function and dialysis adequacy. Each patient was followed for 1 year, and clinical biochemical indicators, dialysis dose, dialysis adequacy, urine volume, peritoneal dialysis 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 included in this study, with 111 in the incremental dose group (mean age 45.01$±12.84$years$)$and58inthestandard$dose$group$(mean$age$43.5±15.62$years$)$
$upperiod, although$the$dialysis$dose$in$the$incremental$dose$group$remained$consistently$lower$than$that$in$the$stan$
$0.75±0.43 VS. 0.61±0.32, P = 0.027; 6 months : 0.68±0.53 VS. 0.50±0.29, P =$
$0.018). 3. During$the$follow−upperiod, blood$pressure$control, anemia$correction, and$hypocalcemia$correctionwe
$0.05). Both$groups$achieved$correctionofhyperphosphatemia; however, at1monthofdialysis, serum$phosphorus$
$0.039), while$at1yearofdialysis, serum$phosphorus$intheincremental$dose$groupwassignificantly$lower$thantha
P=0.030). 4. During the follow-up period, residual renal function was similar between the two groups, and ultrafiltration volume in the standard dose group was higher than that in the incremental dose group, but these differences were not statistically significant (P>0.05). In contrast, urine volume in the incremental dose group was significantly higher than that in the standard

dose group, particularly at 1 month and 6 months of dialysis (P<0.05). 5. During the follow-up period, there were no deaths in either group, and peritoneal dialysis infection-related complications, mechanical complications, and technical survival rates were similar between the two groups (P>0.05).

Conclusion: For USPD patients, the therapeutic efficacy and complication profile of incremental peritoneal dialysis are comparable to those of the standard dose group, and incremental peritoneal dialysis does not accelerate the decline of residual renal function. Therefore, incremental peritoneal dialysis may serve as an initial dialysis modality for USPD patients.

Full Text

Title

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

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Abstract

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

Methods: This single-center retrospective study enrolled end-stage renal disease (ESRD) patients who initiated urgent-start peritoneal dialysis at the Department of Nephrology, The First Affiliated Hospital of Xi'an Jiaotong University between August 1, 2018 and July 31, 2021. All patients had an estimated glomerular filtration rate of 4–6 ml/min/1.73 m^2 prior to dialysis. Based on initial dialysis dose, 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 output, peritoneal ultrafiltration volume, residual renal function, and peritoneal dialysis-related complications evaluated at 1 month, 3 months, 6 months, and 1 year.

Results: A total of 169 patients were enrolled, including 111 in the incremental-dose group (mean age 45.01 $\pm$ 12.84 years) and 58 in the standard-dose group (mean age 43.5 $\pm$ 15.62 years). Pre-dialysis demographic characteristics, clinical biochemical indices (blood pressure, albumin, BUN, serum creatinine, potassium, phosphorus, PTH, hemoglobin), and residual renal function were comparable between groups (P > 0.05). Throughout follow-up, the dialysis dose in the

incremental-dose group remained significantly lower than in the standard-dose group ($P < 0.05$), yet both groups achieved adequate dialysis. Notably, UKt/V was significantly higher in the incremental-dose group at 1 month (0.75 ± 0.43 vs. 0.61 ± 0.32, $P = 0.027$) and 6 months (0.68 ± 0.53 vs. 0.50 ± 0.29, $P = 0.018$). Blood pressure control, anemia correction, and hypocalcemia correction were similar between groups ($P > 0.05$). Both groups achieved target hyperphosphatemia correction, though serum phosphorus was higher in the incremental-dose group at 1 month (1.48 ± 0.43 mmol/L vs. 1.34 ± 0.31 mmol/L, $P = 0.039$) and lower at 1 year (1.39 ± 0.36 mmol/L vs. 1.53 ± 0.35 mmol/L, $P = 0.030$). Residual renal function was similar between groups throughout follow-up. Although ultrafiltration volume was higher in the standard-dose group, the difference was not statistically significant ($P > 0.05$). Urine output was significantly higher in the incremental-dose group, particularly at 1 month and 6 months ($P < 0.05$). No patient deaths occurred in either group, and peritoneal dialysis-related infectious complications, mechanical complications, and technical survival rates were similar ($P > 0.05$).

Conclusion: Incremental peritoneal dialysis demonstrates comparable therapeutic efficacy and safety to standard-dose dialysis in USPD patients without accelerating residual renal function decline. Therefore, incremental peritoneal dialysis represents a viable initial dialysis modality for USPD patients.

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

Introduction

Peritoneal dialysis is a common renal replacement therapy modality. Incremental peritoneal dialysis has become increasingly popular worldwide as an initial dialysis strategy. First conceptualized by Mehrotra et al. in 1997 [1], incremental peritoneal dialysis was not initially implemented clinically. Currently, it is defined as initiating peritoneal dialysis with fewer than four daily exchanges or a dose less than 8 L/day, accounting for the presence of residual renal function (RRF), with dialysis dose progressively increased as RRF declines to achieve adequate solute and fluid clearance [2]. Multiple studies have confirmed the feasibility and effectiveness of incremental peritoneal dialysis, demonstrating advantages in preserving residual renal function, reducing peritoneal glucose exposure, decreasing infection-related complications, serving as a preferred transitional modality before renal transplantation, and reducing economic burden in end-stage renal disease (ESRD) patients [3-6].

Urgent-start peritoneal dialysis (USPD) refers to newly diagnosed ESRD patients without emergency dialysis indications who require dialysis initiation within 14 days, lack established dialysis access, and begin peritoneal dialysis as their initial modality. This differs from planned peritoneal dialysis.

Whether USPD patients can be managed with incremental peritoneal dialysis and how this approach affects their residual renal function remain unclear. We

therefore conducted this study to address these questions.

Methods

1.1 Study Subjects

We enrolled ESRD patients who initiated urgent-start peritoneal dialysis at the Department of Nephrology, The First Affiliated Hospital of Xi'an Jiaotong University between August 1, 2018 and July 31, 2021. Inclusion criteria were: age $>$ 18 years, no restrictions on gender or etiology, estimated glomerular filtration rate between 4–6 ml/min/1.73 m^2, absence of emergency dialysis indications, and no prior dialysis access. Patients with acute exacerbation of chronic kidney disease, acute kidney injury, peritoneal dialysis contraindications, or incomplete follow-up data were excluded.

1.2 Study Methods

This single-center retrospective study had a follow-up duration of one year. All patients underwent open surgical placement of a peritoneal dialysis catheter by a nephrology specialist, with dialysis initiated within 24 hours postoperatively. The initial regimen consisted of 1.5% low-calcium dialysate, 1000 mL per exchange with a 1-hour dwell time. After one week, the regimen was adjusted to 1.5% low-calcium dialysate, 2000 mL per exchange with a 4-hour dwell time.

Patients were stratified into two groups based on initial daily dialysis dose: - **Incremental-dose group:** Initial daily dialysis dose $\leq$ 6000 mL or $\leq$ 3 exchanges per day, with dose adjusted according to residual renal function and dialysis adequacy - **Standard-dose group:** Initial daily dialysis dose $\geq$ 8000 mL or $\geq$ 4 exchanges per day, with dose remaining unchanged during follow-up

We recorded demographic characteristics, clinical biochemical indices (blood pressure, albumin, BUN, creatinine, potassium, calcium, phosphorus, PTH, CO_2 combining power, hemoglobin), residual renal function, urine output, ultrafiltration volume, dialysis adequacy, dialysis dose, peritoneal transport function, and dialysis-related complications (exit-site infection, peritonitis, mechanical complications, technical survival) at baseline, 1 month, 3 months, 6 months, and 1 year.

Pre-dialysis residual renal function was calculated using the CKD-EPI formula. Post-dialysis residual renal function was calculated using 24-hour urea and creatinine clearance: RRF = 1/2 $\times$ (urine urea/blood urea + urine creatinine/blood creatinine) $\times$ urine output/1440. Body mass index (BMI) and body surface area (BSA) were calculated as: BMI = weight (kg)/height $(m)^2$; BSA = 0.0061 $\times$ height (cm) + 0.0128 $\times$ 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), resid-

ual 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 categorical data using chi-square test. $P < 0.05$ was considered statistically significant.

Results

2.1 Baseline Characteristics

A total of 169 patients were enrolled: 111 in the incremental-dose group (70 males, 41 females; mean age 45.01 ± 12.84 years) and 58 in the standard-dose group (43 males, 15 females; mean age 43.5 ± 15.62 years). Demographic characteristics including gender distribution, age, proportion of diabetic nephropathy, BMI, and BSA were similar between groups. Pre-dialysis clinical biochemical indices were also comparable ($P > 0.05$, Table 1).

2.2 Peritoneal Transport Function

Peritoneal transport function was evaluated using the standard peritoneal equilibration test at 1 month after initiating regular peritoneal dialysis. Based on the 4-hour dialysate-to-plasma creatinine ratio (D/P), peritoneal transport function was classified as low, low-average, high-average, or high transport. The distribution of peritoneal transport types was similar between groups ($P > 0.05$, Table 2).

2.3 Dialysis Dose

Throughout the follow-up period, the daily dialysis dose in the standard-dose group was consistently and 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 Urine Output and Ultrafiltration Volume

Pre-dialysis urine output was similar between groups ($P > 0.05$, Figure 1 [Figure 1: see original paper]). However, during follow-up, the incremental-dose group maintained significantly higher urine output, particularly at 1 month and 6 months ($P < 0.05$, Figure 1). Although ultrafiltration volume was lower in the incremental-dose group throughout follow-up, the difference was not statistically significant ($P > 0.05$, Figure 2 [Figure 2: see original paper]).

2.5 Dialysis Adequacy

Both groups achieved adequate dialysis throughout follow-up (TKt/V > 1.7, TCcr > 50 L). PKt/V and PCcr were significantly higher in the standard-dose group ($P < 0.05$, Tables 3 and 4). UKt/V was significantly higher in the incremental-dose group at 1 month and 6 months ($P < 0.05$, Table 3), while UCcr was similar between groups ($P > 0.05$, Table 4). At 3 months, TKt/V was comparable between groups ($P > 0.05$, Table 3), but TCcr was higher in the standard-dose group ($P < 0.05$, Table 4).

2.6 Biochemical Indices

Blood pressure, hemoglobin, and serum calcium levels were similar between groups throughout follow-up ($P > 0.05$, Tables 5 –8). At 1 month, BUN, serum potassium, and serum phosphorus were significantly higher in the incremental-dose group ($P < 0.05$, Table 5). At 3 months and 6 months, serum albumin was lower while BUN and potassium were higher in the incremental-dose group ($P < 0.05$, Tables 6 and 7). At 1 year, albumin and phosphorus were significantly lower while CO_2 combining power was higher in the incremental-dose group ($P < 0.05$, Table 8).

2.7 Residual Renal Function

Residual renal function was similar between groups both pre-dialysis and throughout the follow-up period ($P > 0.05$, Table 9).

2.8 Complications

Infectious complications, mechanical complications, and technical survival rates were similar between groups during follow-up ($P > 0.05$, Table 10). No patient deaths occurred in either group.

Discussion

Incremental peritoneal dialysis has gained worldwide acceptance as an initial dialysis strategy. Compared with standard-dose peritoneal dialysis, incremental peritoneal dialysis offers several advantages, including better preservation of residual renal function, reduced peritoneal glucose exposure, lower infection rates, and decreased economic burden [3-6].

Our findings demonstrate that despite significantly lower dialysis doses in the incremental-dose group, both groups achieved adequate dialysis adequacy (total Kt/V > 1.7, total Ccr > 50 L), indicating that incremental peritoneal dialysis can meet adequacy requirements in USPD patients while reducing costs. Dialysis adequacy encompasses multiple parameters beyond small-solute clearance, including blood pressure control, volume status, anemia correction, nutritional status, electrolyte balance, inflammatory status, cardiovascular event prevention, and residual renal function preservation [9,10]. Our results show

comparable blood pressure control, anemia correction, and calcium-phosphorus management between groups. Although serum potassium was higher in the incremental-dose group during the first 6 months, this likely reflects greater use of potassium-free dialysate in the standard-dose group, with both groups maintaining normal potassium levels. Thus, overall dialysis efficacy was similar.

Residual renal function is crucial for ESRD patients. Studies demonstrate that incremental peritoneal dialysis reduces the rate of residual renal function loss compared with both pre-dialysis status and standard-dose dialysis [5]. Preserving residual renal function improves fluid overload, nutritional status, and inflammation control, thereby enhancing quality of life and reducing mortality and complications [11], while also facilitating clearance of middle and large molecular toxins [12]. Maiorca et al. [13] reported that PD patients with residual renal function had 50% lower mortality. The CANUSA study and subsequent reanalysis showed that residual renal solute clearance better predicted mortality than peritoneal clearance, with each 5 ml/min/1.73 m^2 increase in GFR reducing death risk by 12% [14]. Our study, which included patients with GFR 4–6 ml/min/1.73 m^2, found similar residual renal function between groups both pre-dialysis and throughout follow-up, indicating that incremental peritoneal dialysis does not accelerate residual renal function decline.

Interestingly, despite similar residual renal function, UKt/V was higher in the incremental-dose group at 1 month and 6 months. Since ultrafiltration volume depends on peritoneal transport characteristics, dwell time, and total daily dialysis volume, and our center strictly controls fluid intake to $\leq$ 1000 mL/day, peritoneal ultrafiltration competes with urine output. With similar peritoneal transport distributions but higher daily dialysis volumes and ultrafiltration in the standard-dose group, their urine output was lower. As residual renal Kt/V = [(24-hour urine volume $\times$ urine urea nitrogen/blood urea nitrogen) $\times$ days]/[weight $\times$ 0.6 (male) or 0.55 (female)], urine volume determines UKt/V under otherwise equal conditions. Therefore, the incremental-dose group's higher UKt/V reflects their greater urine output, suggesting that urine volume may be more clinically relevant than UKt/V itself. Sandrini et al. [15] identified urine volume as a significant predictor of survival in PD patients, and CANUSA reanalysis showed each 250 mL increase in urine output reduced mortality risk by 36% [14].

Peritoneal dialysis complications significantly affect prognosis. Incremental peritoneal dialysis reduces glucose exposure and absorption, slowing peritoneal function decline and hyperglycemia risk. De Vecchi et al. [4] reported that peritonitis risk correlates with exchange frequency. With fewer exchanges, incremental dialysis reduces connection procedures and infection risk. Our study found no differences in infectious complications, mechanical complications, or technical survival between USPD patients receiving incremental versus standard-dose dialysis.

Furthermore, the incremental-dose group's lower daily dialysis volume reduces treatment costs and patient burden while decreasing daily procedure frequency,

alleviating psychological stress, improving quality of life, and enhancing acceptance and compliance.

In conclusion, incremental peritoneal dialysis is applicable to urgent-start peritoneal dialysis patients, offering comparable efficacy, cost savings, residual renal function preservation, and complication rates. However, this single-center retrospective study with limited sample size has inherent limitations. Multi-center, large-scale studies would better reflect the feasibility of incremental peritoneal dialysis in USPD patients. Long-term outcome assessment is also warranted. We anticipate more comprehensive studies to address these questions.

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