International Journal of Medical Science and Health Research

Vol.9, No. 02; 2025

ISSN: 2581-3366

Clinical Study on the Application of Rapid Pressurized Flushing Combined With Lidocaine Sealing in the Management of Peritoneal Dialysis Catheter Displacement

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Funding Project：

Self-financed scientific research of Guangxi Zhuang Autonomous Region Health Commission in 2021 (NO. Z20211645)

doi: 10.51505/ijmshr.2025.9201 URL: http://dx.doi.org/10.51505/ijmshr.2025.9201

Received: Mar 03, 2025 Accepted: Feb 12, 2025 Online Published: Mar 21, 2025

Abstract

*Objective***:** To evaluate the clinical efficacy of rapid pressurized flushing and lidocaine sealing in managing peritoneal dialysis (PD) catheter migration.

Methods: 76 PD patients who experienced catheter migration leading to drainage dysfunction between July 2021 and June 2023 were enrolled and randomly assigned to either the experimental group (n = 38) or the control group (n = 38) using a random number table method. The control group received conventional non-surgical repositioning, while the experimental group underwent rapid pressurized flushing combined with lidocaine sealing in addition to the standard approach. The primary outcomes assessed included repositioning success rate, repositioning time, treatment costs, and patient satisfaction.

Results: The repositioning success rate in the experimental group was 97.37%, significantly higher than 73.68% in the control group ($P < 0.01$). Additionally, the experimental group exhibited a significantly shorter repositioning time, lower average treatment costs, and higher patient satisfaction than the control group ($P < 0.01$).

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*Conclusion***:** Rapid pressurized flushing combined with lidocaine sealing is a simple, safe, and cost-effective technique with a high success rate, making it a promising non-surgical approach for PD catheter migration management. Its broad clinical applicability suggests significant potential for widespread implementation in peritoneal dialysis practice.

Keywords: Peritoneal dialysis, Catheter displacement, Non-surgical repositioning, Rapid pressurized flushing, Lidocaine sealing, Clinical study

1. Introduction

Peritoneal Dialysis (PD) as a Renal Replacement Therapy and the Challenge of Catheter Migration. Peritoneal dialysis (PD) is a widely utilized renal replacement therapy (RRT) for patients with end-stage renal disease (ESRD) due to its ease of operation, cost-effectiveness, and feasibility for home-based treatment[1]. According to the Global Kidney Health Report, approximately 38.1 individuals per million population undergo PD treatment worldwide [2]. Additionally, data from the Chinese Medical Doctor Association indicate that the number of PD patients in China increased from 4,380 in 1999 to 152,745 in 2023, representing a 34.87-fold increase over 25 years [3].

Despite its advantages, catheter migration remains one of the most common and severe complications of PD, with an incidence rate ranging from 12.7% to 35.0% [4]. Catheter displacement can lead to poor dialysate drainage, resulting in fluid retention, weight gain, and elevated blood pressure, and severe cases, may necessitate surgical intervention. This complication exacerbates patient discomfort, increases healthcare costs, and may compromise treatment outcomes [5].

Currently, managing PD catheter migration primarily involves non-surgical and surgical repositioning techniques. While surgical repositioning is effective, its invasiveness, risk of infection, and high cost make it less favorable as a first-line option [5]. In contrast, non-surgical repositioning is preferred due to its lower risk and minimal trauma [6]. For catheters with functional migration, the optimal repositioning window is typically within 3 to 5 days, with a maximum timeframe of 7 days [7]. However, traditional non-surgical methods often exhibit lower success rates, prolonged repositioning times, and reliance on patient cooperation. Although interventional repositioning techniques offer higher success and safety rates, their dependence on specialized equipment and technical expertise limits their accessibility, particularly in resource-constrained settings.

This study introduces a novel technique—rapid pressurized flushing combined with lidocaine sealing—as an innovative approach for managing PD catheter migration. Clearing intraluminal obstructions and optimizing catheter positioning through rapid pressurized flushing, along with lidocaine's local anesthetic and neuromodulatory effects, significantly enhances catheter repositioning success rates. Additionally, it offers simplicity, cost-effectiveness, non-

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invasiveness, and high efficiency, making it a promising alternative for PD catheter management, particularly in primary healthcare settings with limited resources.

2. Materials and Methods

2.1 Study Design

A convenience sampling method was used to enroll 76 patients with end-stage renal disease (ESRD) who developed catheter migration after undergoing maintenance peritoneal dialysis (PD) in the nephrology departments of two tertiary general hospitals in Guangxi, China, between July 2021 and June 2023. Patients were randomly assigned to either the experimental group (n = 38) or the control group (n = 38) using a random number table method.

The locations of migrated catheters were confirmed by X-ray imaging, with the following distributions:

- Left upper abdomen: 22 cases
- Right upper abdomen: 41 cases
- Left mid-abdomen: 3 cases
- Middle lower abdomen: 7 cases
- Iliac fossa: 3 cases

Post-intervention X-ray imaging on the following day was used to verify the final catheter position within the peritoneal cavity.
All patients provided written informed consent, and the hospital ethics committee approved the study.

2.2 Inclusion and Exclusion Criteria

Inclusion Criteria

1. Age ≥18 years
2. Patients who had undergone percutaneous catheter insertion or surgical catheter placement
3. Use of a double-cuff straight Tenckhoff PD catheter (manufactured by Baxter, USA)
4. Clinically stable condition and willingness to participate in the study
5. Radiographically confirmed catheter migration by X-ray imaging

Exclusion Criteria

1. Severe infections, heart failure, or respiratory failure
2. Presence of psychiatric disorders, cognitive impairment, or speech/hearing disabilities
3. Non-compliance with treatment or withdrawal from the study

Sample Size Calculation

The sample size was estimated using the formula for comparing two independent proportions. Based on the pilot study results, repositioning success rates were 97.2% in the experimental group and 70% in the control group.

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Assuming:

- $\alpha = 0.05$ (two-tailed test)
- Power $(1-\beta) = 0.90$
- Equal sample sizes in both groups

The following formula was used for sample size estimation:

$$n1 = n2 = \frac{[\mu_\alpha\sqrt{2p(1-p)} + \mu_\beta\sqrt{p_1(1-p_1) + p_2(1-p_2)}]^2}{(p_1 - p_2)^2}$$

Using the PASS 2021 software under the "Tests for Two Proportions" menu, the required sample size per group was calculated as $n_1 = n_2 = 34$. Considering a 10% dropout rate, each group was adjusted to 38 participants, resulting in 76 enrolled patients.

The final allocation of participants was performed using a random number table method, and all 38 patients in the control group and 38 in the intervention group completed the study.

Baseline demographic and clinical characteristics of the two groups of PD patients showed no statistically significant differences ($P > 0.05$), ensuring comparability, as shown in (Table 1).

2.3 Study Protocol

2.3.1 Control Group (Conventional Non-Surgical Repositioning):

1. **Confirmation of Displacement:** Patients and medical staff jointly confirmed the catheter displacement location and assessed bowel function and physical activity levels.
2. **Bowel Regulation and Physical Activity:** Patients were guided to address constipation (if present) and increase daily physical activities, such as walking, hopping in place, tiptoeing, and squatting, to promote intestinal motility and improve catheter positioning.
3. **Dialysate Infusion:** Patients assumed a standing position, and PD fluid bags were manually compressed to create a pulsed pressure effect. Gentle abdominal massage and tapping on the affected side were encouraged to facilitate repositioning.
4. **Post-Infusion Activities:** After infusion, patients walked down staircases, with heel-first landings, to further aid repositioning. Each session included 2–3 cycles of 10 flights of stairs, repeated 2–3 times daily.
5. **Activity Customization:** The activity level was adjusted based on the patient's physical fitness, age, and overall health to ensure safety.

2.3.2 Experimental Group (Rapid Pressurized Flushing and Lidocaine Sealing):

Building upon the protocol used in the control group, the following additional steps were implemented:

1. **Peritoneal Preparation:** Patients were ensured to have 1000 mL of dialysate in the peritoneal cavity before intervention.
2. **Rapid Pressurized Flushing:** Two nurses collaborated, adhering strictly to sterile techniques. One nurse prepared physiological saline, while the other used a 30 mL sterile syringe to inject 500 mL of room-temperature saline in divided doses rapidly. Patients were positioned semi-

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recumbent or standing based on the catheter's displacement. The patient's feedback was monitored during the procedure to evaluate catheter positioning and comfort.

3. **Lidocaine Sealing:** Lidocaine solution (two vials of 5 mL, 100 mg total) was mixed with 20 mL of saline and injected to seal the catheter. The catheter was capped with iodine-soaked caps for at least 30 minutes, and the process was repeated twice daily.

2.4 Outcome Measures

2.4.1 Evaluation Criteria

1. **Repositioning Success Rate:** The proportion of patients achieving successful repositioning, defined by unobstructed dialysate drainage and X-ray confirmation of the catheter's return to the pelvic cavity.
2. **Repositioning Time:** The number of days from intervention initiation to successful repositioning.
3. **Treatment Costs:** Direct medical costs associated with the catheter repositioning process.
4. **Patient Satisfaction:** Assessed via a questionnaire categorized as "very satisfied," "satisfied," or "neutral."

2.4.2 Success Criteria [8]:

1. The sensation of stimulation or suction in the perineum (anal area) during dialysate inflow or outflow.
2. Unobstructed drainage of PD fluid, with outflow times approaching or equaling original times (≤20 minutes).
3. X-ray confirms that the catheter's tip is returning to the true pelvis.

Success rate = (Number of successful cases / Total cases) × 100%

2.4.3 Failure Criteria [8]: Failure was defined as continued drainage obstruction beyond seven days post-intervention, with an X-ray indicating persistent catheter displacement.

2.4.4 Adverse Reactions: Bleeding, pain, catheter exit-site infection, or peritonitis were monitored as adverse reactions.

2.5 Data Collection

Data were collected by a trained research team using paper-based documentation via telephone or face-to-face interviews. Two independent team members performed data entry and cross-validation to ensure accuracy.

The general information questionnaire, designed by the research team based on an extensive literature review, was validated by subject-matter experts, yielding a content validity index of 0.82. The questionnaire included items on gender, age, BMI, education level, occupation, and

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catheter placement method. Both single-choice and multiple-choice formats were employed for ease of response.

2.6 Statistical Analysis

Data were analyzed using SPSS 26.0 software. Continuous variables were expressed as mean ± standard deviation (x ± s) and compared using independent t-tests. Categorical variables were described as percentages and compared using chi-square tests. Statistical significance was set at $P<0.05$.

3. Results

3.1 Baseline Characteristics Comparison

There were no statistically significant differences ($P > 0.05$) between the experimental group and the control group in terms of gender, age, BMI, educational level, occupation type, and catheter placement method, indicating comparability between the two groups **(**Table 1**)**.

Table 1. Comparison of Baseline Characteristics between the Experimental and Control Groups

Variable	Experimental Group (n = 38)	Control Group (n = 38)	T/χ^2	*P-value*
Gender				
Male	15	20	1.324	0.250
Female	23	18		
Age				
≤ 30 years	1	1	5.230	0.156
30–50 years	13	19		
51–70 years	20	18		
70 years	4	0		
Body Mass Index (BMI)				
≤ 18.4	1	1	5.841	0.120
18.5–23.9	18	28		
24.0–27.9	16	8		
≥ 28	3	1		
Educational Level				
Primary school or below	7	4	5.950	0.311
Junior high school	22	19		
Senior high school (including	6	13		

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technical school, vocational school)				
College diploma	1	0		
Bachelor's degree or higher	2	2		
Occupation Type				
Government employees (civil servants, public institution staff)	2	1	5.247	0.513
Healthcare workers	0	1		
Teachers	1	1		
Industrial workers	5	9		
Farmers	20	13		
Freelancers	8	8		
Unemployed	2	5		
Place of Residence				
Rural area	16	13	3.264	0.353
Township	7	13		
Urban area	15	12		
Medical Insurance Type				
Urban resident medical insurance	19	11	3.815	0.148
Rural cooperative medical insurance	10	12		
Urban employee medical insurance	9	15		
Marital Status				
Unmarried	3	7	1.842	0.175
Married	35	31		
Catheter Placement Method				
Percutaneous catheter insertion	19	12	2.670	0.102
Surgical catheter placement	19	26		

3.2 Repositioning Success Rate

The repositioning success rate in the experimental group was 97.37% (37/38), which was significantly higher than 73.68% (28/38) in the control group **(**P = 0.003**) (**Table 2**)**.

Table 2. Comparison of Repositioning Success Rates Between the Two Groups

Group	Cases (n)	Repositioning Effect	
		Successful Repositioning n (%)	Unsuccessful Repositioning n (%)
Experimental Group	38	37（97.37%）	1（2.63%）
Control Group	38	28（73.68%）	10（26.32%）
χ^2		8.610	
P value		0.003	

3.3 Time to Successful Repositioning

The time required for successful repositioning was significantly shorter in the experimental group compared to the control group. Specifically, 97.37% of patients in the experimental group achieved successful repositioning within 1–3 days, whereas only 50% of patients in the control group achieved the same outcome (P < 0.001**) (**Table 3**)**.

Table 3. Comparison of Days Required for Successful Repositioning Between the Two Groups

Group	Cases (n)	Days Required for Successful Repositioning		
		1–3 Days n (%)	4-6 Days n (%)	> 7 Days n (%)
Experimental Group	38	37（97.37%）	1（2.63%）	0（0%）
Control Group	38	19（50%）	15（39.47%）	4（10.53%）
χ^2		22.036		
P value		*P*＜0.001		

3.4 Repositioning Costs

The average repositioning cost in the experimental group was 275.26 ± 179.62 CNY, which was significantly lower than 1084.11 ± 1140.48 CNY in the control group **(**P < 0.001**) (**Table 4**)**.

Table 4. Comparison of Repositioning Costs between the Two Groups

Group	Cases (n)	Average Repositioning Cost (CNY, Mean ± SD)
Experimental Group	38	275.26±179.62
Control Group	38	1084.11±1140.48
t-test		-4.319
P value		*P*＜0.001

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3.5 Patient Satisfaction

Patient satisfaction levels were significantly higher in the experimental group compared to the control group. Specifically, 89.47% of patients in the experimental group reported being "very satisfied," whereas only 39.47% of patients in the control group reported the same level of satisfaction **(**P < 0.001**) (**Table 5**)**.

Table 5. Comparison of Patient Satisfaction Between the Two Groups

Group	Cases (n)	Satisfaction		
		General Satisfaction n（%）	Satisfied n（%）	Very Satisfied n（%）
Experimental Group	38	0（0%）	4（10.53%）	34（89.47%）
Control Group	38	3（7.89%）	20（52.63%）	15（39.47%）
χ^2		21.034		
P value		*P*＜0.001		

3.6 Adverse Events

No serious adverse events were observed in either group, including bleeding, pain, infection, or peritonitis, confirming the safety of the proposed technique.

4. Discussion

4.1 Rapid Pressurized Flushing Combined with Lidocaine Sealing Significantly Improves PD Catheter Repositioning Success Rate

Studies have shown [4] that 60.9% of functional catheter dysfunction cases are caused by catheter displacement, with catheter migration accounting for 65.2% of catheter failures. Under normal conditions, the peritoneal dialysis (PD) catheter is typically positioned in the rectovesical pouch (in males) or the rectouterine pouch (in females). However, its free-floating nature makes it susceptible to displacement due to intestinal peristalsis, omental wrapping, and traction [9]. Common causes of catheter displacement include buoyancy effects, supine positioning, advanced age, diabetes, improper catheter selection, surgical factors, abnormal bowel motility, and increased intra-abdominal pressure. Research indicates that within the first six months of PD treatment, 14% of patients transition to hemodialysis due to catheter dysfunction [10]. The primary treatment for catheter dysfunction involves conservative, minimally invasive approaches to reduce complications and avoid unnecessary invasive procedures [11-12].

Our study demonstrated that rapid pressurized flushing combined with lidocaine sealing significantly enhances the success rate of PD catheter repositioning**.** Compared to conventional non-surgical repositioning techniques, which have a success rate ranging from 50% to 86.1%

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[13-14], our method achieved an impressive 97.37% success rate while significantly shortening repositioning time ($P < 0.001$). This success rate is comparable to invasive repositioning methods, such as guidewire-assisted repositioning [8] and laparoscopic repositioning [7] .

The potential mechanism underlying this approach may be related to the anatomical characteristics of the greater omentum, the most prominent peritoneal fold in the human body, which remains semi-free. Rich in phagocytic cells with immune defense functions, the greater omentum may react to PD catheter insertion by spreading, mobilizing, and enveloping the catheter, leading to dysfunction. By instilling lidocaine into the peritoneal cavity, our method likely acts on omental nerves, inducing contraction around the catheter's side holes, thus dislodging the omental tissue and facilitating repositioning [14]. Rapid pressurized saline flushing generates an instantaneous force, effectively clearing tiny bubbles and debris from the catheter lumen while straightening and extending the catheter tip toward the peritoneal floor, thereby successfully repositioning.

Furthermore, patient positioning plays a crucial role in preventing catheter migration. A semi-recumbent or standing posture during the procedure prevents upward catheter kinking or bending. Throughout the intervention, 1,000 mL of peritoneal dialysate is retained to maintain optimal fluid levels, preventing excessive buoyancy that could cause the catheter to float while ensuring sufficient fluid volume for effective flushing and observation.

For patients in whom this method failed, surgical repositioning revealed complete occlusion of all catheter side holes by tightly adhered tissue. This could be attributed to prolonged ultrafiltration times in patients aiming for higher ultrafiltration volumes, leading to excessive siphoning forces that promote severe omental wrapping. These findings highlight the importance of early intervention in catheter dysfunction. Thus, clinical practice should emphasize enhanced outpatient follow-up, increased patient education, and frequent retraining to improve treatment outcomes.

4.2 Safety and Ease of Use: Key Advantages of Rapid Pressurized Flushing with Lidocaine Sealing

Our study found that none of the enrolled patients experienced severe adverse events, such as bleeding, infection, or peritonitis, indicating this method's low-risk profile and minimal physiological burden. Its non-invasive nature makes it particularly suitable for frail individuals or patients with limited physical activity.

Moreover, this technique is simple to perform, requiring neither advanced skills nor specialized equipment, making it highly adaptable even in resource-limited settings. Minimizing dependence on operator proficiency reduces the risk of procedural complications while increasing patient acceptance. Given its straightforward implementation and minimal training requirements**,** this method is particularly valuable in settings where healthcare providers may lack specialized training in invasive procedures.

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Additionally, avoiding surgical interventions enhances patient adherence to PD treatment, which is a significant challenge in long-term end-stage renal disease (ESRD) management.

4.3 High Patient Acceptance and Broad Clinical Applicability

China is among the fastest-growing countries in terms of PD adoption [15]. However, more than 20% of hospitals cannot manage PD-related catheter complications such as placement and migration [4]. The rapid pressurized flushing with lidocaine sealing technique is highly applicable in these settings due to its simplicity, safety, and non-invasive nature, requiring no additional instruments or equipment. Patients find the method acceptable due to its ease of implementation and minimal discomfort**.**

Compared to guide wire-assisted and surgical repositioning, this method poses lower risks. It has minimal impact on daily life, making it preferable for patients concerned about infection risks, general anesthesia, visceral injury, psychological distress, and financial burdens associated with surgery. Successful implementation relies on effective collaboration between patients and healthcare providers, enhancing treatment confidence and adherence.

4.4 Reduced Repositioning Time and Cost: Economic and Social Benefits

Our findings highlight that this method shortens repositioning time and reduces associated costs. The decrease in procedural time and the necessity for repeated medical interventions significantly alleviate financial burdens on patients and the healthcare system.

Patient satisfaction levels were notably high, likely due to reduced discomfort and improved treatment outcomes, which enhanced long-term adherence and overall quality of life. Since PD is a home-based renal replacement therapy, patients and their caregivers play a critical role in daily management [16]. During repositioning, close nurse-patient interaction, including emotional encouragement and reassurance, helped alleviate anxiety and distress, further improving patient compliance and satisfaction.

Rapid pressurized flushing with lidocaine sealing offers an efficient, cost-effective, safe, and patient-friendly alternative. Compared to conventional methods, it is more advantageous regarding patient acceptance and overall satisfaction.

4.5 Study Limitations and Future Perspectives

Despite its advantages, this method has several limitations. First, the long-term stability of repositioned catheters and the factors contributing to recurrent migration require further investigation. Second, the sample size was relatively small, and the study was conducted within a limited geographic area. Future multicenter, longitudinal studies involving a larger population must validate these findings.

Additionally, integrating this technique with other non-invasive methods could optimize PD catheter management. For instance, automated peritoneal dialysis (APD) improvements have significantly reduced catheter migration rates by enhancing dialysate flow dynamics and minimizing complications [15]. The rapid pressurized flushing technique may benefit from incorporating these optimization strategies, especially for patients undergoing traditional continuous ambulatory peritoneal dialysis (CAPD).

5. Conclusion

Rapid pressurized flushing combined with lidocaine sealing demonstrates significant superiority in non-surgical PD catheter repositioning**.** This method achieves high success rates without requiring additional instruments or specialized techniques**,** allowing nurses to perform the procedure without excessive utilization of healthcare resources**.**

Due to its safety, simplicity, cost-effectiveness, and minimal invasiveness, this technique is an optimal alternative to more invasive repositioning approaches. Incorporating into standard clinical protocols for managing PD catheter migration is strongly recommended.

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