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Original Article

Application of low position percutaneous puncture plus rectus abdominis anterior sheath tunnel operation for peritoneal dialysis catheterization of end-stage renal disease

Huaiguo Wang[1], Jie Li[2], Jian Li[3]

[1]Department of Hemodialysis, Liaocheng People's Hospital, Liaocheng 252000, Shandong, China; [2]Department of Nephrology, Liaocheng People's Hospital, Liaocheng 252000, Shandong, China; [3]Department of Endocrinology, Liaocheng People's Hospital, Liaocheng 252000, Shandong, China

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Abstract: Objectives: Peritoneal dialysis (PD) is a key treatment for end-stage renal disease (ESRD), with catheter placement being crucial for success. This study evaluates the effectiveness of low-position percutaneous puncture combined with the rectus abdominis anterior sheath tunnel (LPCCISTT) technique, comparing it to traditional open abdominal catheter placement (OACP). Methods: This retrospective study included 420 ESRD patients that came from Liaocheng People's Hospital between the months of January 2020 and February 2022. Patients were divided into two groups: 180 underwent LPCCISTT and 240 received OACP. Data on operative details, recovery, complications, and survival outcome of PD catheter were analyzed. Surgical indicators included incision length, operative time, intraoperative blood loss, and complications. Recovery outcomes focused on length of hospital stay, and postoperative pain. Results: The LPCCISTT group demonstrated significantly shorter incisions, reduced operative time, and less blood loss compared to the OACP group ($P<0.001$). Postoperative recovery was faster, with shorter hospital stays ($P<0.001$) in the LPCCISTT group. The LPCCISTT group demonstrated fewer mechanical catheter complications and infection rates ($P<0.001$), particularly in catheter displacement, non-displacement dysfunction, PD fluid leakage ($P<0.032$), and exit-site/tunnel infections ($P<0.046$). Catheter survival and technical success rates were significantly higher in the LPCCISTT group ($P = 0.034$ and $P = 0.025$ respectively). The obstacle-free survival (OFS) and overall survival (OS) of the catheters were both significantly prolonged ($P<0.001$). Conclusion: LPCCISTT is a safer and more effective method than OACP. It has shorter operation time, faster patient recovery, fewer complications, and makes better use of hospital resources.

Keywords: Peritoneal dialysis, catheter placement, LPCCISTT, minimally invasive, end-stage renal disease, surgical outcomes

Introduction

Peritoneal dialysis (PD) has emerged as a widely accepted renal replacement therapy for patients with end-stage renal disease (ESRD) and offers a range of benefits including improved quality of life, preservation of residual renal function, and greater hemodynamic stability compared to hemodialysis [1]. Its home-based nature allows patients greater flexibility and independence, increasing adherence and satisfaction with the treatment [2]. However, the success of PD largely hinges on the functionality and longevity of the PD catheter (PDC), which serves as the conduit for dialysate exchange [3]. Consequently, the technique of catheter insertion plays a critical role in minimizing complications and ensuring the efficacy of PD [3].

Historically, various methods of PDC insertion have been explored, including open surgical techniques, percutaneous methods, and laparoscopic placement [4]. Each technique has its advantages and limitations, influencing both short- and long-term outcomes for patients undergoing PD [5]. Traditional open surgical methods, while effective, were associated with

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a higher risk of complications such as infections, catheter leaks, and mechanical dysfunction due to their invasive nature [6]. Conversely, laparoscopic techniques offer improved visualization and the ability to address any intra-abdominal issues during placement but require specialized skills and equipment, potentially increasing the cost and limiting availability in resource-constrained settings [7].

Recent advancements have focused on the development of percutaneous insertion techniques that were less invasive, safer, and more cost-effective [8]. These methods have garnered attention due to their simplicity and the reduced requirement for advanced surgical facilities. The percutaneous approach utilizes imaging guidance to accurately place the catheter with minimal disruption to surrounding tissues [9]. However, traditional percutaneous techniques were not devoid of complications such as catheter migration, obstruction, and infection; requiring prompting ongoing efforts to refine the procedure and improve patient outcomes [10].

The combination of low position percutaneous puncture and the creation of a tunnel within the rectus abdominis anterior sheath was a novel approach designed to optimize the PDC insertion process [11]. This technique seeks to harness the advantages of percutaneous methods while mitigating common complications associated with catheter migration and exit-site infections [12]. By establishing a subfascial tunnel, the approach aims to anchor the catheter more securely, reduce tension at the exit site, and minimize the potential for peritoneal leaks and hernias [13].

Compared to ultrasound-guided percutaneous puncture, which relies on real-time imaging to guide catheter placement, low-position percutaneous puncture combined with the rectus abdominis anterior sheath tunnel (LPCCISTT) emphasizes a fixed low-position entry point (6 cm above the pubic symphysis) and the creation of a tunnel within the anterior rectus sheath to enhance catheter stability and reduce displacement. In contrast to laparoscopically assisted techniques, LPCCISTT does not require general anesthesia or abdominal insufflation, thereby minimizing invasiveness and cost while maintaining the benefits of a minimally invasive approach. The unique combination of low puncture site and anterior sheath tunnel in LPCCISTT provides anatomical fixation that may offer advantages in preventing catheter migration and reducing infectious complications, distinguishing it from other percutaneous modifications.

The rationale for investigating this combined technique stems from the need to enhance PDC survival rates and reduce complication-related interruptions in dialysis therapy [13]. Given the pivotal role of catheter function in the success of PD, it was imperative to explore methodologies that enhance catheter stability, reduce infection rates, and improve patient satisfaction [14]. Furthermore, the incorporation of a low position puncture coupled with a rectus abdominis anterior sheath tunnel presents a promising avenue for addressing these issues by potentially offering increased catheter stability and reduced mechanical complications. In this clinical study, we aim to evaluate the effectiveness and safety of the low position percutaneous puncture combined with the rectus abdominis anterior sheath tunnel technique in PD catheterization.

Materials and methods

Case collection and selection

This study was a retrospective cohort study that reviewed the cases of 420 patients who underwent their first catheter insertion and received peritoneal dialysis treatment at Liaocheng People's Hospital between January 2020 and February 2022. The inclusion and exclusion criteria were as follows:

Inclusion criteria: (1) Diagnosis of ESRD [15] necessitating renal replacement therapy. (2) Completion of a preoperative evaluation with consent for PDC insertion. (3) Underwent first-time insertion surgery for a PDC at the PD center. (4) Age of 18 years or older. (5) Availability of complete clinical data. (6) Underwent PD for a minimum of one year. (7) Completed at least one year of follow-up and have complete follow-up data.

Exclusion criteria: (1) Patients with a history of Acute Kidney Injury (AKI). (2) Widespread abdominal wall infection. (3) Irreparable abdo-

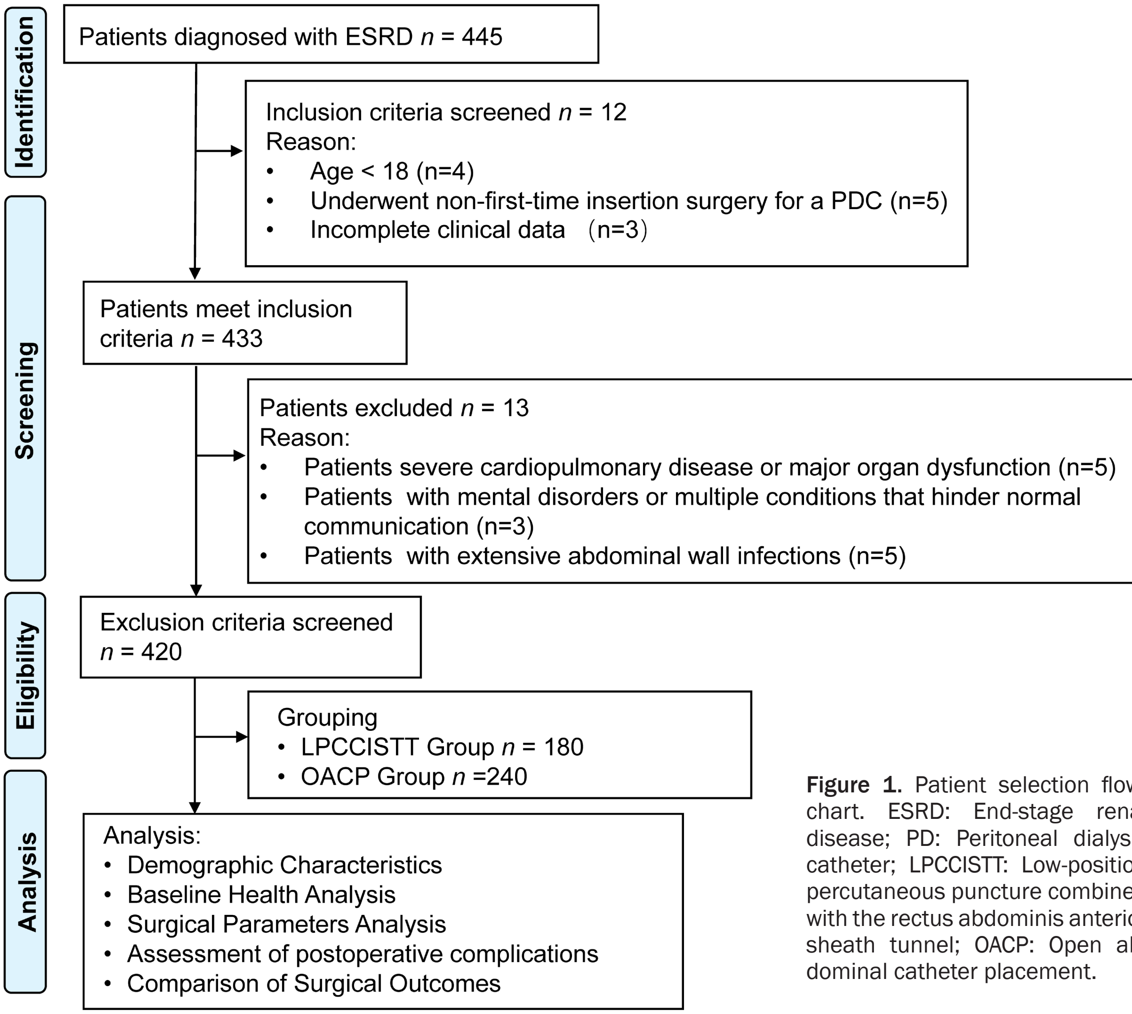

Figure 1. Patient selection flowchart. ESRD: End-stage renal disease; PD: Peritoneal dialysis catheter; LPCCISTT: Low-position percutaneous puncture combined with the rectus abdominis anterior sheath tunnel; OACP: Open abdominal catheter placement.

minal wall defects (such as hernias) existing prior to surgery. (4) Have undergone previous abdominal surgery (including open or laparoscopic procedures, regardless of the time since surgery). (5) Transition to hemodialysis or receipt of a kidney transplant during the study period. (6) Severe Cardiopulmonary Disease or Major Organ Dysfunction. (7) Pregnancy or Lactation. (8) Presence of mental disorders or multiple conditions impeding normal communication.

Patients were divided into two groups based on their treatment regimens: 180 patients who received low-position percutaneous puncture combined with anterior rectus sheath tunnel catheter insertion treatment were classified as the LPCCISTT group, and 240 patients who received open abdominal catheter placement treatment were classified as the OACP group (**Figure 1**).

Data extraction

We collected data from the patients' electronic medical records. The data included the following. Patient demographics. Baseline health status before the procedure. Details of the surgery, such as operation time, cost, and any complications during surgery. Complications after surgery, including mechanical catheter complications and infections. Assessments of pain after surgery. Results from patient follow-up.

Ethics approval and informed consent

This study was approved by the Institutional Review Board (IRB) at Liaocheng People's Hospital. It was a review of past patient records. All patient information used was anonymous. Because the study did not affect patient care and presented no risk to patients, the Liaocheng People's Hospital ethics committee agreed that

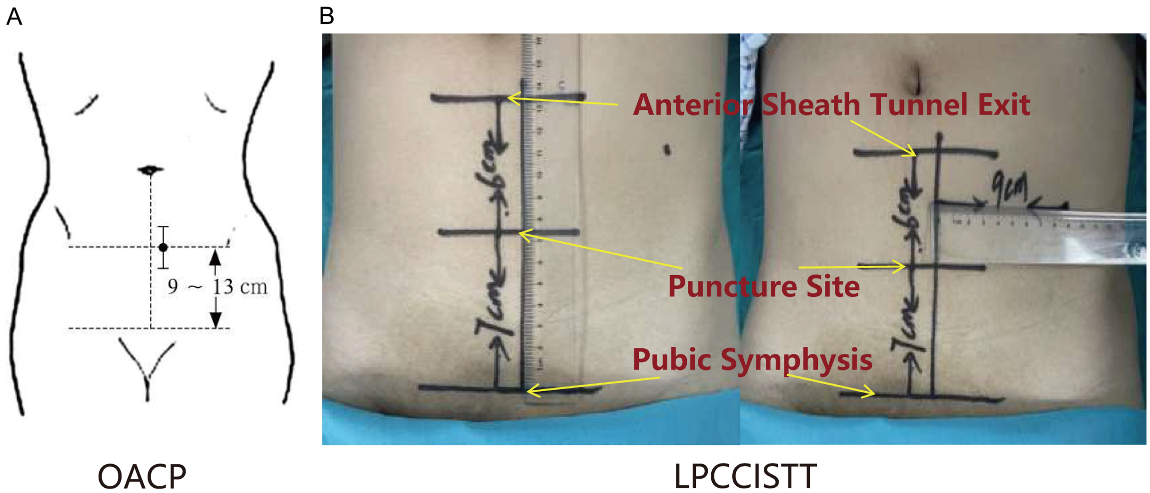

Figure 2. Comparison between two surgical methods. A: OACP group (Open abdominal catheter insertion); B: LPCCISTT group (Low-position percutaneous puncture combined with anterior rectus sheath tunnel catheter insertion).

individual patient consent was not required. This approach followed all necessary ethical and regulatory rules.

Surgical methods

Patients in the OACP group received traditional open surgery for catheter placement. The surgery began by marking the positions for the skin incision and the catheter exit site on the abdomen. After standard disinfection with iodine and placing sterile drapes, local anesthetic was injected. Then a vertical skin incision was made. Next, the subcutaneous tissue was divided to reach the anterior rectus sheath. This layer was cut open and gently separated to expose the posterior rectus sheath. A small opening, just large enough for the catheter, was made through both the posterior rectus sheath and the peritoneum. A purse-string suture was placed around this opening. Finally a stainless steel guidewire was used to direct the tip of the catheter through the small incision and into the correct position inside the abdomen. Concurrently, imaging studies were conducted to confirm successful catheter placement. Following the removal of the puncture needle, the drainage tube was positioned in the target area and secured to prevent displacement or detachment.

The LPCCISTT group underwent a low-position percutaneous puncture combined with a catheter insertion through the anterior sheath of the rectus abdominis muscle tunnel surgery. The patient was placed in a supine position on the operating table. The area was routinely disinfected and draped. Local infiltration anesthesia was performed with lidocaine. A longitudinal incision about 5 cm long was made 2 cm outside the left rectus abdominis muscle and from 6 to 11 cm above the pubic symphysis. The fat layer was bluntly separated with a hemostatic forceps to reach the anterior sheath of the rectus abdominis muscle. The patient was asked to hold their breath. At the position 6 cm above the pubic symphysis, a trocar was inserted obliquely downward into the abdominal cavity. A straight abdominal membrane dissector was inserted into the bladder and rectum with a guide wire. Water was injected to test the patency of the drainage. A deep polyester cuff was placed deep in the anterior sheath of the rectus abdominis muscle. A 1 cm incision was made in the anterior sheath of the rectus abdominis muscle at 11 cm above the pubic symphysis. The catheter was led out from this incision along the anterior sheath of the rectus abdominis muscle. The incision was sutured with purse-string suture. The anterior sheath of the rectus abdominis muscle at 6 cm above the pubic symphysis was sutured intermittently. A subcutaneous tunnel was made to the left. The subcutaneous fat and skin were sutured (**Figure 2**).

All catheter insertions were performed by a single surgical team with extensive experience in both techniques, ensuring consistency in surgical proficiency. The choice of technique was based on patient preference and clinical judgment, not on operator skill level.

Surgical-related indicators

We recorded the following surgical-related indicators. Operative time was measured from the start of the surgery (first cut or puncture) until its end (when the wound was closed). Surgical costs included all costs related to the surgery, such as materials used, hospital stay fees, and any other needed treatments. Intraoperative blood loss was our estimate of how much blood was lost during the procedure. We measured the length and width of the surgical cut. We noted if any internal organs were accidentally damaged during the surgery. We recorded the total number of days the patient stayed in the hospital after surgery. Looking at these indicators, we compared the pros and cons for the use of percutaneous catheter technique compared to the use of the OACP method when inserting PDC.

Postoperative pain assessment

On day 24 post-operation, the amount of pain was measured by Visual Analog Scale (VAS) [16]. This Scale is a straight 10 cm line. With 0 at the left end, indicating "No PAIN", the right end indicated the "WORST pain imaginable", for a final score out of 10. The patient placed a dot on this line to indicate how much there was. We used the following scoring system for the interpretation of pain: Score of 0 = no ache, does not affect sleep. A score of 1-3 suggests the pain was such that it didn't disrupt sleep. Scores of 4-6 indicated disturbed sleep. A score of 7-10 indicated very intense pain, which may cause inability to sleep. In our study, the VAS reliability was decent, with a Cronbach's of 0.796.

Vital signs monitoring

Upon admission, renal function was assessed using an automated biochemical analyzer (Cobas c 501, Roche Diagnostics, Switzerland). The parameters measured and recorded for each patient included serum creatinine, blood urea nitrogen, serum albumin, hemoglobin, 24-hour urine volume, and estimated glomerular filtration rate (eGFR).

Postoperative complications

We recorded data from two groups of patients and compared complications within one year after catheter placement. By reviewing electronic medical records and paper medical charts, researchers extracted complication records for each patient, which included: Mechanical Catheter Complications: Catheter displacement, non-displacement dysfunction (such as catheter blockage, knotting, etc.), bleeding, peritoneal dialysis fluid leakage and hypogastralgia. Infectious Complications: Peritonitis, as well as exit site and tunnel infections. Complications were recorded as individual events; if a patient experienced multiple complications, each was counted separately. Thus, the total number of complications represents the sum of all events, not the number of patients with complications. The aim of the study was to investigate and compare the incidence of major complications between the groups to determine whether percutaneous PDC placement offers a reduction in complications compared to open surgical catheter placement.

Definition and assessment of survival outcomes

Obstacle-Free Survival (OFS): Defined as the time from the date of peritoneal dialysis catheter insertion to the first occurrence of any mechanical complication (e.g., catheter displacement, blockage, occlusion, leakage) or infectious complication (e.g., exit-site/tunnel infection, peritonitis) that led to dialysis interruption or catheter failure. For patients who did not experience such events during the follow-up period, data were censored at the date of their last follow-up.

Overall Survival (OS): Defined as the time from catheter insertion to catheter removal for any reason.

The survival status (occurrence of event) and time-to-event were ascertained by reviewing electronic medical records and scheduled follow-up documentation.

Statistical analysis and processing

Data analysis was conducted using SPSS 29.0 statistical software (SPSS Inc., Chicago, IL,

Table 1. Comparison of demographic characteristics between the two groups

Parameters	LPCCISTT Group (n = 180)	OACP Group (n = 240)	t/χ²	P
Male/Female [n (%)]	98 (54.44%)	125 (52.08%)	0.230	0.631
Age (years)	49.86 ± 7.12	50.23 ± 6.91	0.528	0.598
Height (cm)	165.39 ± 8.13	166.27 ± 9.32	1.009	0.314
Ethnicity (Han/Other) [n (%)]	152 (84.44%)	201 (83.75%)	0.037	0.847
Educational level (High school or below/Junior college or above) [n (%)]	119 (66.11%)	163 (67.92%)	0.152	0.697
Occupational status (Retired/Employed (Manual labor/Service industry))	100 (55.56%)	137 (57.08%)	0.098	0.755
Residence (Urban/Rural)	127 (70.56%)	165 (68.75%)	0.158	0.691
Smoking history [n (%)]	52 (28.89%)	67 (27.92%)	1.413	0.234
Drinking history [n (%)]	22 (12.22%)	28 (11.67%)	0.030	0.862
Diabetes history [n (%)]	57 (31.67%)	73 (30.42%)	0.075	0.784
Hypertension history [n (%)]	48 (26.67%)	61 (25.42%)	0.084	0.772
BMI (kg/m²)	21.93 ± 2.62	22.41 ± 2.83	1.771	0.077
MAP (mmHg)	113.12 ± 16.13	111.09 ± 15.52	1.304	0.193

BMI: Body Mass Index; MAP: Mean Arterial Pressure.

Table 2. Comparison of primary diseases between the two groups

Parameters	LPCCISTT Group (n = 180)	OACP Group (n = 240)	χ²	P
Chronic glomerulonephritis [n (%)]	88 (48.89%)	123 (51.25%)	0.229	0.632
Diabetic nephropathy [n (%)]	54 (30.00%)	68 (28.33%)	0.139	0.710
Arteriolar nephrosclerosis [n (%)]	23 (12.78%)	33 (13.75%)	0.084	0.772
Other causes [n (%)]	15 (8.33%)	16 (6.67%)	0.418	0.518

USA). We first used the Shapiro-Wilk test to check if the continuous data were normally distributed. Data with a normal distribution are shown as the mean plus or minus the standard deviation (Mean ± SD). We compared these data between the two groups using independent samples t-tests. We present categorical data as numbers and percentages [n (%)]. We used the chi-square (χ^2) test to compare these data between groups. We used the Kaplan-Meier method to draw survival curves. These curves show the Obstacle-Free Survival (OFS) and Overall Survival (OS) of the catheters. To find factors that independently affect catheter survival, we performed multivariable Cox regression analyses for both OFS and OS. The results are given as hazard ratios (HR) with 95% confidence intervals (CI). A *P* value of less than 0.05 was considered statistically significant.

Results

Basic data of the LPCCISTT group and OACP group

Table 1 shows the demographic characteristics of patients in this clinical study for both the LPCCISTT group (n = 180) and the OACP group (n = 240). There were no significant differences between the two groups in gender, age, height, ethnicity, education level, occupation, residence location, history of smoking, drinking, diabetes, hypertension, Body Mass Index (BMI), or mean arterial pressure (MAP) (all $P>0.05$). These results suggest that both groups were demographically comparable, supporting the robustness of the subsequent clinical outcome comparisons.

Table 2 shows the comparison of primary kidney diseases between the LPCCISTT group and the OACP group (**Table 3**). We found no statistically significant differences in the rates of chronic glomerulonephritis, diabetic nephropathy, arteriolar nephrosclerosis, or other causes between the two groups (all $P>0.05$). These results suggest a similar distribution of primary renal diseases among participants in both groups, indicating that the baseline renal health status was comparable across the two populations. This comparability is crucial for ensuring that observed outcomes in subsequent analyses are attributable to the interventions rather than pre-existing conditions.

Table 3. Comparison of laboratory values between the two groups

Parameters	LPCCISTT Group (n = 180)	OACP Group (n = 240)	T	P
Serum creatinine (umol/L)	878.61 ± 281.32	866.42 ± 285.31	0.436	0.663
Blood urea nitrogen (mmol/L)	28.52 ± 12.33	27.52 ± 11.63	0.845	0.399
Serum albumin (g/L)	35.00 ± 4.90	34.90 ± 5.90	0.194	0.846
Hemoglobin (g/L)	81.00 ± 16.41	79.20 ± 16.82	1.093	0.275
24 h urine volume (mL)	1155.90 ± 647.30	1154.00 ± 579.10	0.032	0.975
eGFR [n (%)]	5.10 ± 1.80	5.40 ± 2.40	1.493	0.136

eGFR: Estimated Glomerular Filtration Rate.

Table 4. Comparison of surgical procedures between the two groups

Parameters	LPCCISTT Group (n = 180)	OACP Group (n = 240)	t/χ^2	P
Incision length (cm)	1.29 ± 0.42	4.21 ± 0.78	49.020	<0.001
Operative time (mins)	51.04 ± 6.75	84.64 ± 14.91	30.942	<0.001
Intraoperative blood loss (mL)	10.25 ± 5.06	40.22 ± 12.09	34.584	<0.001
Intraoperative organ injury [n (%)]	0 (0.00%)	14 (5.83%)	10.862	<0.001
Surgical costs	1200.00 ± 150.00	2500.00 ± 300.00	58.138	<0.001

Table 3 shows a comparison of several laboratory values between the LPCCISTT group and the OACP group (**Table 3**). No significant differences were found in serum creatinine, blood urea nitrogen, serum albumin, hemoglobin, 24-hour urine volume, or eGFR between the groups (all *P*>0.05). This indicates that renal function and related laboratory measures were similar at baseline in both intervention groups. These comparable findings support the validity of later efficacy and safety evaluations.

Surgical procedures

Statistical differences were found in all measured parameters (**Table 4**). The LPCCISTT group had a shorter incision length than the OACP group (*P*<0.001). The operative time was also lower in the LPCCISTT group compared to the OACP group (*P*<0.001). Intraoperative blood loss was less in the LPCCISTT group than in the OACP group (*P*<0.001). No intraoperative organ injury occurred in the LPCCISTT group, but the OACP group had a 5.56% injury rate; this difference was significant (*P* = 0.001). Surgical costs were clearly lower in the LPCCISTT group versus the OACP group (*P*<0.001). Hospital stay was shorter in the LPCCISTT group compared to the OACP group (*P*<0.001). Postoperative pain scores were lower in the LPCCISTT group than in the OACP group (*P*<0.001) (**Figure 3**). These results indicate that the LPCCISTT technique is more efficient, safer, and less costly for PD catheterization than the traditional OACP method.

Postoperative complications

We compared the LPCCISTT group and the OACP group and found significant differences in several mechanical catheter complications and infection complications (**Table 5**). For mechanical complications, catheter displacement (*P*<0.001) and non-catheter displacement dysfunction (*P*<0.001) both occurred less often in the LPCCISTT group than in the OACP group. PD fluid leakage was also lower in the LPCCISTT group (*P* = 0.032). There were no significant differences in bleeding or hypogastralgia (*P*>0.05). For infection complications, exit-site and tunnel infections were less frequent in the LPCCISTT group (*P* = 0.046), but peritonitis did not differ significantly between the groups (*P* = 0.460). These results indicate that the LPCCISTT method may help lower complication rates and improve treatment safety. The lower number of complications in the LPCCISTT group suggests better outcomes and safer procedures.

Surgical outcomes

The LPCCISTT group had a significantly higher catheter survival rate (87.78%) than the OACP group (80.00%) (*P* = 0.034) (**Table 6**). The technical success rate was also significantly higher

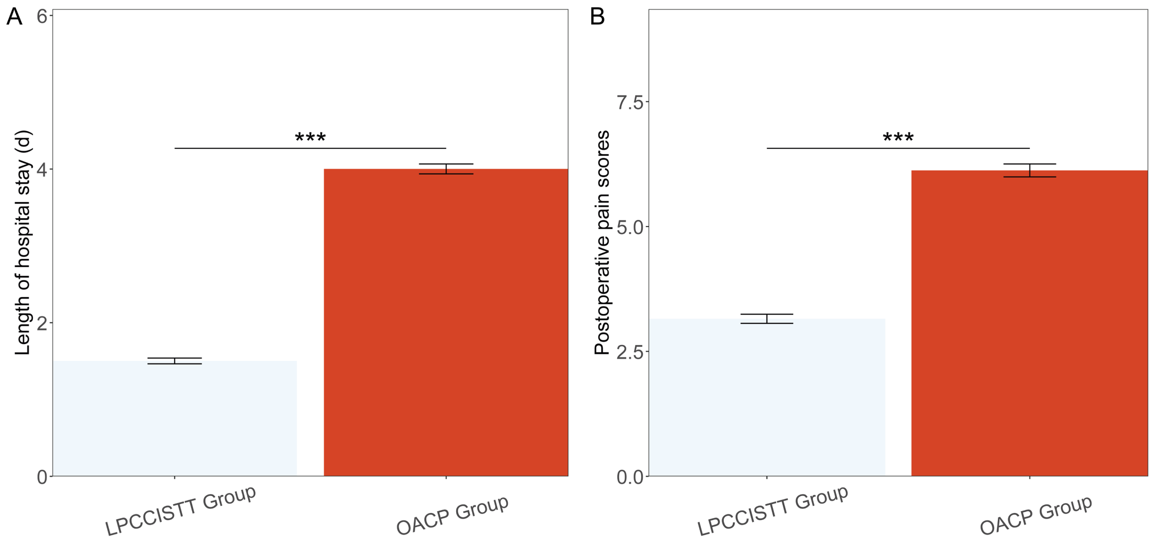

Figure 3. Comparison of postoperative recovery between the two groups. A: Length of hospital stay (d); B: Postoperative pain scores; ***: P<0.001.

Table 5. Comparison of postoperative complications between the two groups

Parameters	LPCCISTT Group (n = 180)	OACP Group (n = 240)	χ^2	P
Catheter displacement	3 (1.67%)	39 (16.25%)	24.306	<0.001
Non-catheter displacement dysfunction	4 (2.22%)	36 (15.00%)	19.489	<0.001
Bleeding	14 (7.78%)	31 (12.92%)	2.839	0.092
PD fluid leakage	9 (5.00%)	26 (10.83%)	4.582	0.032
Hypogastralgia	5 (2.78%)	8 (3.33%)	0.106	0.745
Peritonitis	19 (10.56%)	31 (12.92%)	0.547	0.460
Exit-site and tunnel infections	8 (4.44%)	23 (9.58%)	3.973	0.046
Total	62 (34.45%)	194 (80.83%)	92.999	<0.001

PD: Peritoneal dialysis. Data are presented as number of events (%). Patients with multiple complications were counted separately for each complication type; therefore, the total number of complications represents the sum of all events.

Table 6. Comparison of surgical outcomes between the two groups

Parameters	LPCCISTT Group (n = 180)	OACP Group (n = 240)	χ^2	P
Catheter survival rate [n (%)]	158 (87.78%)	192 (80.00%)	4.480	0.034
Technical success rate [n (%)]	175 (97.22%)	221 (92.08%)	5.042	0.025
Catheter removal rate [n (%)]	14 (7.78%)	33 (13.75%)	3.691	0.055

in the LPCCISTT group (*P* = 0.025). However, the catheter removal rate only showed a trend toward significance (*P* = 0.055). These results show that both methods were effective, but the LPCCISTT method led to better catheter survival and technical success rates. Although not statistically significant, the catheter removal rate was also lower in the LPCCISTT group, suggesting it might help reduce catheter removal. These findings indicate that the LPCCISTT technique could improve patient care and long-term management, with better main outcomes and a possible benefit in lowering catheter removal.

Survival outcome analysis of PD catheter

The LPCCISTT group had a much longer OFS than the OACP group (*P*<0.001) (**Figure 4**). OS was also longer in the LPCCISTT group compared to the OACP group (*P*<0.001) (**Figure 5**). These findings show that the LPCCISTT method works better than the OACP approach at improv-

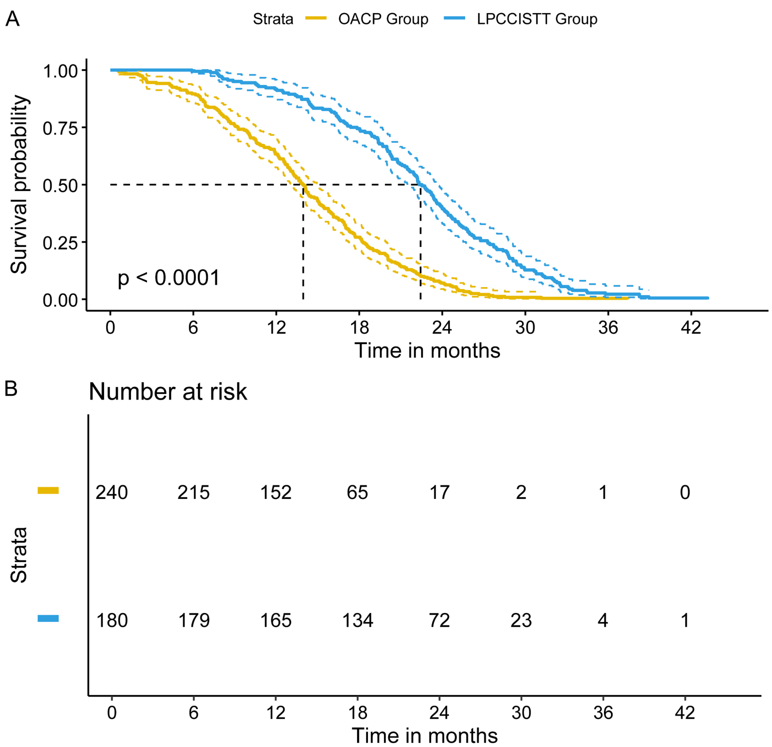

Figure 4. Obstacle-Free survival (OFS) curves. A: Kaplan-Meier survival curve; B: Number at risk table.

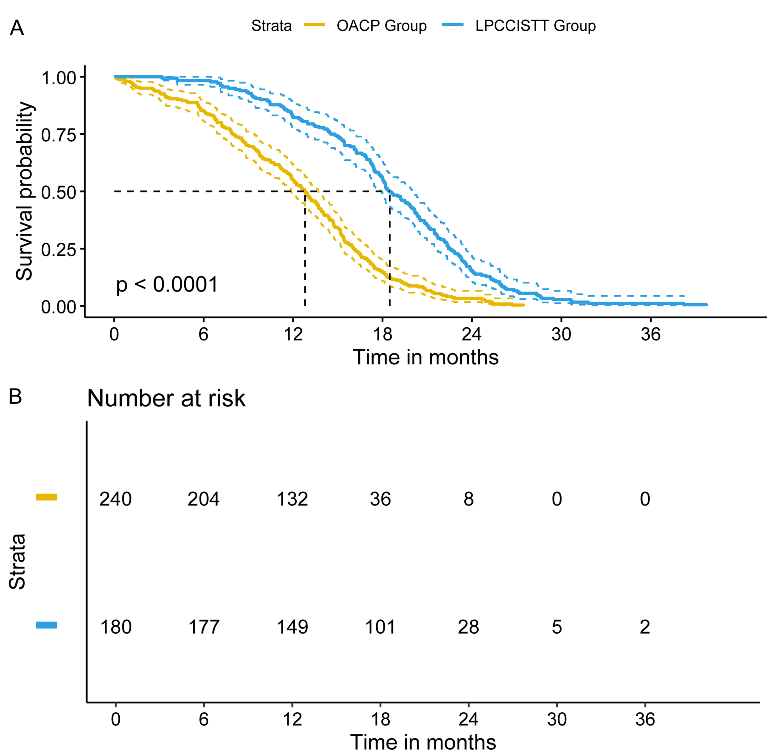

Figure 5. Overall survival (OS) curves. A: Kaplan-Meier survival curve; B: Number at risk table.

ing both OFS and OS. This suggests that LPCCISTT may be a better way to make PD catheters last longer and work better.

Cox proportional hazards regression analysis of the impact on survival outcome

After adjusting for age, gender, BMI, diabetes history, and hypertension history, the LPCCISTT technique remained an independent protective factor for both OFS (HR = 0.422, 95% CI: 0.284-0.632, $P<0.001$) and OS (HR = 0.551, 95% CI: 0.386-0.792, $P = 0.001$). This indicates that compared with the traditional OACP method, patients undergoing LPCCISTT had an approximately 58% lower risk of catheter dysfunction and an approximately 45% lower risk of death. None of the other covariates reached statistical significance in the model (**Tables 7** and **8**).

Discussion

We compared a new low-position percutaneous catheter insertion with sheath tunnel (LPCCISTT) technique to the standard open abdominal catheter placement (OACP) method for peritoneal dialysis access. The results show some important differences, indicating that a small incision is best. In particular, LPCCISTT has a small wound and a short total operation time, and blood loss during surgery was less.

When compared to the traditional OACP method used to place a PD catheter, there are several distinct advantages to using the LPCCISTT meth-

Table 7. Multivariable Cox regression analysis for Obstacle-Free Survival (OFS) of peritoneal dialysis catheters

Variable	HR (95% CI)	*P* Value
Surgical type (LPCCISTT vs. OACP)	0.422 (0.284-0.632)	<0.001
Age (per 10-year increase)	1.081 (0.905-1.293)	0.422
Gender (Male vs. Female)	0.950 (0.692-1.313)	0.756
BMI (per 5 kg/m^2 increase)	1.024 (0.866-1.214)	0.831
Diabetes (Yes vs. No)	1.186 (0.852-1.652)	0.327
Hypertension (Yes vs. No)	1.053 (0.754-1.475)	0.782

HR: Hazard Ratio; CI: Confidence Interval; LPCCISTT: Low-position percutaneous puncture combined with the rectus abdominis anterior sheath tunnel; OACP: Open abdominal catheter placement; BMI: Body Mass Index.

Table 8. Multivariable Cox regression analysis for Overall Survival (OS) of peritoneal dialysis catheters

Variable	HR (95% CI)	*P* Value
Surgical type (LPCCISTT vs. OACP)	0.551 (0.386-0.792)	0.001
Age (per 10-year increase)	1.153 (0.964-1.380)	0.134
Gender (Male vs. Female)	1.014 (0.737-1.402)	0.954
BMI (per 5 kg/m^2 increase)	0.972 (0.825-1.157)	0.726
Diabetes (Yes vs. No)	1.277 (0.910-1.772)	0.164
Hypertension (Yes vs. No)	1.129 (0.804-1.573)	0.512

HR: Hazard Ratio; CI: Confidence Interval; LPCCISTT: Low-position percutaneous puncture combined with the rectus abdominis anterior sheath tunnel; OACP: Open abdominal catheter placement; BMI: Body Mass Index.

od. The smaller incision and the faster surgery occur because the percutaneous technique is designed to be minimally invasive. This method does not create a large open wound. Instead, it uses a small needle puncture to enter the area [17]. This approach causes much less damage and disruption to the patient's tissues. Because there is less cutting and dissection, the surgeon spends less time both opening the site at the beginning and stitching it closed at the end. Naturally, with less tissue injury, there is also significantly less bleeding during the operation [18]. Furthermore, the operation time for LPCCISTT was nearly 50% shorter than for an OACP procedure. This major improvement in surgical efficiency means that the technique requires less use of operating room resources and staff time. This efficient use of resources very likely leads to lower overall costs and represents a meaningful opportunity for financial savings for the hospital [19].

In the LPCCISTT group, no organ injury occurred during surgery. This shows that the technique is safe. The anterior rectus sheath tunnel technique gives clear anatomical guidance. This likely helps to avoid accidental damage to nearby structures. Such damage is more often seen in open surgeries [20, 21]. Our procedure also uses a guidewire and the Seldinger method, helping catheters be placed correctly [22]. There were a few cases of acute surgical complication, which is part of the surgical process.

Patients do better with LPCCISTT, requiring shorter hospital stays and lower pain levels after the surgery [23]. These procedures are not as invasive and patients feel better sooner. In addition, a shorter hospital stay means better recovery with less medical cost and medical resources used [24].

LPCCISTT reduced the number of mechanical catheters and infections. Problems included catheter displaced, not dysfunction, PD liquid leakage, exit-point or tunnel infection. Catheter displacement was <7 mm, which occurred mainly due to precise guidewire placement and Seldinger technique, ensuring the final location of the catheter is secure [25]. LPCCISTT is minimally invasive, and catheter placement is easy, without a lot of tissue maneuvering, so the risk of the catheter shifting is low. Imaging helps placement and causes less inflammation in the tissue [26, 27]. PD fluid leakage is reduced, helping to kept the insertion site intact. Exit site and tunnel infections are less with LPCCISTT as well. Every patient's puncture site was individually chosen [28].

The higher catheter survival and technical success rates observed in the LPCCISTT group further support its efficacy as a preferred method for PD catheter insertion. The prolonged OFS and OS of PD catheters in the LPCCISTT group signify an improvement in the longevity and functionality of the catheters. This outcome is crucial for maintaining uninterrupted dialysis therapy, which is essential for managing ESRD and improving quality of life for affected individuals [29, 30]. The multivariable Cox regression analysis further substantiated that the LPCCISTT technique is an independent favorable factor for both OFS and OS. After adjusting for potential confounders including age, gender, BMI, diabetes, and hypertension, the LPCCISTT group continued to demonstrate significantly lower risks of catheter dysfunction and mortality compared to the OACP group.

The results of this regression correspond with the result of the Kaplan-Meier survival analysis. Data also indicate that the improved survival with LPCCISTT is not due to different starting patient characteristics. The LPCCISTT method has a clinical benefit of better long term dialysis access.

While our study only compared LPCCISTT with the traditional open technique, it is important to contextualize LPCCISTT among other minimally invasive peritoneal dialysis catheterization methods. Unlike ultrasound-guided percutaneous puncture, which requires specialized equipment and expertise in real-time sonography, LPCCISTT relies on fixed anatomical landmarks, making it more accessible in resource-limited settings. Compared with laparoscopy-assisted placement, LPCCISTT avoids general anesthesia and pneumoperitoneum, potentially reducing operative time and costs. However, direct comparative studies between LPCCISTT and these techniques are needed to fully establish its relative efficacy and safety. The present findings demonstrate that LPCCISTT is superior to OACP, but future research should include comparisons with other minimally invasive techniques to better define its role in clinical practice.

While the LPCCISTT technique demonstrates several advantages, it's crucial to recognize potential limitations. As a retrospective study, our work is subject to inherent biases, including selection bias and unmeasured confounding. Although we attempted to adjust for known confounders, residual confounding may remain. The lack of randomization means that causal inferences should be drawn cautiously. While the study included a relatively large sample size, it was conducted at a single center, potentially limiting the generalizability of the findings to other populations or healthcare settings. The procedure requires skill and experience with percutaneous techniques and anatomical variations, which could limit its widespread applicability in settings where such expertise was lacking. Additionally, the one-year follow-up period is insufficient to assess the technique's impact on long-term outcomes such as 3-5 years patient prognosis or peritoneal membrane function. Consequently, the sustainability of the clinical value of LPCCISTT beyond the first year remains to be confirmed in future studies with extended follow-up periods. Our study also lacked subgroup analyses for special populations (e.g., obese, elderly frail, or those with mild adhesions), so caution is needed when generalizing findings to these groups. Future research with larger, more diverse cohorts is needed to address these specific questions. Finally, while our study reported the overall catheter removal rate, which serves as a direct proxy for the reoperation rate related to catheter complications, we did not perform a more granular analysis of event-specific reoperation rates. This limits the detail with which we can evaluate the comprehensive clinical benefits of the technique. Therefore, despite significant improvements in early outcomes, further investigation into long-term functionality and patient quality of life related to PD catheterization was warranted to validate these findings over extended periods.

Conclusion

Overall, the findings of this study suggest that the LPCCISTT technique provides a viable alternative to conventional open techniques, offering improvements in safety, recovery, and postoperative outcomes. These advantages include decreased operative time, less bleeding, lower complication rates, and better recovery metrics - all of which highlight the potential for the LPCCISTT approach to improve clinical outcomes and resource efficiency in PD catheterization. The procedural and postoperative benefits evidenced in this study suggest a paradigm shift towards incorporating less invasive techniques in clinical practice, aligning with broader trends seeking enhanced patient care and cost-effective healthcare solutions.

Future research should aim to further elucidate the mechanisms behind the LPCCISTT technique's improved outcomes, exploring the interplay of anatomical placement, immune response, and patient-specific variables that might influence its success. Additionally, randomized controlled trials with long-term follow-up could provide more definitive conclusions on the durability of these advantages, ultimately guiding practice standards and decision-making in PD catheterization.

Disclosure of conflict of interest

None.

Address correspondence to: Jian Li, Department of Endocrinology, Liaocheng People's Hospital, No. 67 Dongchang West Road, Dongchangfu District, Liaocheng 252000, Shandong, China. E-mail: 13563540765@163.com

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