

# Subcutaneous tunneling technique to improve outcomes for patients undergoing chemotherapy with peripherally inserted central catheters: a randomized controlled trial

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## Abstract

**Objective:** To compare the value of the subcutaneous tunneling technique versus the normal technique in improving the outcomes of patients undergoing chemotherapy with peripherally inserted central catheters (PICCs).

**Methods:** One hundred thirty patients were randomly divided into an experimental group (subcutaneous tunneling technique) and control group (normal technique) according to the PICC placement technique, and clinical data were compared between the groups.

**Results:** In total, 129 PICCs were successfully inserted. Compared with the control group, the experimental group had a lower occurrence of complications after placement (especially catheter dislodgement: 3.1% vs. 15.4%, venous thrombosis: 3.1% vs. 15.4%, and wound oozing: 14.1% vs. 27.7%), lower occurrence of unscheduled PICC removal (3.1% vs. 13.8%), greater comfort during placement ( $14.16 \pm 2.21$  vs.  $15.09 \pm 2.49$  on a scale ranging from 6 to 30 points, with higher

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scores indicating lower degrees of comfort), and lower costs of PICC maintenance (median (interquartile range) per-day maintenance cost: 13.90 (10.99–32.83) vs. 15.69 (10.51–57.46) Yuan). The occurrence of complications and amount of bleeding during placement were not significantly different between the two groups.

**Conclusions:** The subcutaneous tunneling technique can improve PICC placement by reducing complications and costs of maintenance with better patient comfort during placement.

### Keywords

Subcutaneous tunneling technique, peripherally inserted central catheter, chemotherapy, complication, randomized controlled trial, patient comfort

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### Introduction

Peripherally inserted central catheters (PICCs) have become widely used in China for patients requiring chemotherapy, parenteral nutrition, and medication administration, especially with the introduction of power-injectable PICCs. Power-injectable PICCs supply rapid intravenous infusion, high-pressure injection of contrast media for radiological examinations, easy central venous pressure monitoring, and a multilumen option for clinical selection that truly realizes a “one-needle” approach to completing all intravenous therapy for patients.<sup>1</sup> Although power-injectable PICCs have further expanded the clinical use of PICCs, PICC use still has limitations and complications associated with patients’ health status, catheter maintenance, catheter implanting techniques, and other factors. Multiple lumen catheters ranging from 4 to 6 Fr are currently available on the market, but the need for an adequate vein size in the upper mid-arm limits their use.<sup>2</sup> The incidence of wound oozing, which is still the most common complication, can be as high as 24.7%.<sup>3</sup> Other complications also remain a matter of concern, including infection, skin injury, catheter dislodgement, and even catheter dislocation.

The subcutaneous tunneling technique has been advocated to improve the outcomes of patients with PICCs and has been proven effective for tunneled central catheters inserted in the internal jugular and subclavian veins.<sup>4</sup> With this method, a short PICC tract can be tunneled subcutaneously to simultaneously obtain both a higher venipuncture site in the upper mid-arm and a more safely positioned exit site. Additionally, this technique creates distance between the puncture site and the exit site, which minimizes micromotion and offers mechanical stability for the long and heavy end of the PICC, thus reducing the risk of catheter dislodgement.<sup>5</sup>

The use of subcutaneous tunnels in vascular access is not a new concept, and its feasibility and safety are well documented.<sup>4,6,7</sup> However, only a few reports have described the use of this technique for PICC placement. The method was first reported by Selby et al.<sup>8</sup> using a hemostat and scalpel for PICC placement in 2001. Thereafter, Pittiruti and Scopettuolo<sup>9</sup> and Elli et al.<sup>2</sup> successively created a quick tunnel with a needle cannula, which was associated with no significant complications. Saijo et al.<sup>10</sup> reported that the use of a tunneled PICC for a small-diameter basilic vein was safe and feasible.

However, these previous studies were single-center clinical trials with small samples.<sup>8,10,11</sup> Moreover, the tunneling devices used in previous studies, such as hemostats, puncture needles, and 14G trocars, are inappropriate<sup>5,12–14</sup>; such devices have a limited effect on catheter fixation and may even exert more trauma to the subcutaneous tissue. Therefore, the present randomized controlled trial was performed to evaluate the impact of the subcutaneous tunneling technique using a proper metal tunneller on the outcomes of patients with PICCs.

## Methods

### *Trial design and ethical considerations*

This prospective randomized controlled trial with long-term follow-up was conducted from July 2019 to January 2020 at Sun Yat-Sen University Cancer Center in Guangzhou, China. Ethical approval was provided by the ethics committee of Sun Yat-Sen University Cancer Center (approval no. B2018-111-01). Written informed consent was obtained from all patients in advance. This study has been registered in the Chinese Clinical Trial Registry (ChiCTR1900021624, <http://www.chictr.org.cn/showproj.aspx?proj=34929>).

### *Participants*

Eligible participants who were candidates for PICC insertion were recruited for the trial. The inclusion criteria were an age of 18 to 75 years, the ability to understand and communicate in Chinese, first-time PICC placement, and scheduled to regularly receive catheter maintenance at our hospital. Patients with any contraindications for PICC placement were excluded.

### *Sample size and randomization*

The sample size was calculated based on the incidence of wound oozing between the two

groups in a previous study (experimental group: 13.3%, control group: 36.7%).<sup>15</sup> According to the two-sided PICC calculations and the formula for comparing a two-sample rate and considering a dropout rate of 20%, 130 patients were needed to achieve 80% power with a two-tailed alpha of 5%, and 65 patients were required in each group. Eligible patients were assigned to the groups in a 1:1 manner according to computer-generated random numbers. The randomization scheme was hidden using the envelope method and managed by a researcher who was not involved in participant recruitment.

### *Intervention*

The PICCs used in this study were open-ended, power-injectable polyurethane PICCs with a proximal valve (PowerPICC SOLO 2; Bard Access Systems, Inc., Salt Lake City, UT, USA). All PICCs were inserted by one experienced PICC specialist, and maintenance was conducted by a uniformly trained intravenous catheter team at our hospital. In the control group, non-tunneled PICC catheterization was performed using the normal PICC placement technique under B-mode ultrasound guidance combined with the modified Seldinger technique. In the experimental group, the PICC was placed using a subcutaneous tunneling technique combined with the normal PICC placement technique for which the puncture site was located 5 cm above the catheter exit site on the patient's upper arm. First, the vein was evaluated by ultrasound, and the catheter exit site and puncture site (5 cm above) were marked on the patient's arm. Second, we used a scalpel to create a 1- to 2-mm skin incision at the puncture site after inserting the guide wire into the vein. Third, using local anesthesia at the puncture and exit sites, a metal tunneller with a blunt end to penetrate the subcutaneous tissue and another end to

connect the catheter was inserted into the subcutaneous tissue from the exit site to the puncture site. Fourth, the catheter was introduced from the tunnel to the puncture site through the tunneller, which was subsequently removed. Finally, we used reinforced sterile skin closures (3M, Saint Paul, MN, USA) to close the skin incision at the puncture site after catheterization. All PICCs were placed under electrocardiographic guidance, and a chest radiograph was obtained to confirm the correct catheter tip position.

### ***Definitions and measures of outcomes***

The primary outcome in this study was the incidence of wound oozing. Complications after placement included wound oozing, venous thrombosis, mechanical phlebitis, medical adhesive-related skin injury, occlusion, infection, catheter dislodgement, and unscheduled PICC removal. Immediate complications during placement were venipuncture failure, injuries to nerves or arteries, primary malpositioning, bleeding from the exit site, and difficulties in catheter or guide wire progression. Other outcomes were the success rate of placement, the duration of cannulation, the patients' degree of comfort during placement, and the patients' costs of PICC maintenance.

Immediate complications during PICC placement, as well as the catheter cannulation length, punctured vein diameter and depth, duration of cannulation, and amount of bleeding, were assessed and recorded by the researcher during cannulation. Complications after PICC placement were inspected and recorded by the uniformly trained intravenous catheter team at each dressing change. The patients' degree of comfort during placement was measured using a revision of the patient degree of comfort questionnaire designed by Li et al.<sup>16</sup> The questionnaire contained six items consisting of pain and fatigue

issues that influence the patient's degree of comfort during insertion. Scoring was performed using a 5-point Likert scale, with 1 representing "strongly disagree" and 5 representing "strongly agree" (Item 2 is scored in reverse). The total score ranged from 6 to 30 points, with higher scores corresponding to lower degrees of comfort. Patients' PICC-related costs included the costs for placement and maintenance. The costs of placement consisted of expenditures related to consumable material, medical devices, and drugs used during the PICC placement procedure. The costs of maintenance included payments for dressing changes, diagnostic examinations, and treatment for complications. The definitions of outcomes and complications of PICC placement are shown in Table 1.

### ***Statistical analysis***

The statistical analysis was performed with IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables are expressed as mean and standard deviation and were assessed using the chi-square test or Fisher's exact test. Categorical variables are reported as percentages and were assessed using the independent-samples *t*-test. The level of statistical significance was set at 0.05.

## **Results**

### ***Demographic and disease data***

In total, 130 patients were recruited and randomized from July 2019 to January 2020. Of these 130 patients, 129 underwent successful PICC insertion; the exception was 1 patient in the experimental group whose procedure was considered a technical failure because of inability to puncture. All PICCs were used for chemotherapy, and all patients had cancer. Most patients had nasopharyngeal carcinoma, followed by

**Table 1.** Definitions of complications and outcomes of PICC placement.

Outcomes	Definitions
Successful placement	Successful placement on first puncture attempt in the control group or successful placement by tunneling on first attempt in the experimental group.
Wound oozing	Oozing that lasted >24 hours after placement. Classified into three grades according to severity: Grade 1, (bleeding lasting for 2 to 3 days), Grade 2, (bleeding lasting for 4 to 5 days), and Grade 3 (bleeding lasting >6 days).
Bleeding from insertion site during placement	Measured by the difference in the weight of sterile gauze before and after insertion. During placement, all blood was absorbed by the sterile gauze.
Depth and diameter of puncture vein	Measured using the same B-ultrasound instrument used to assess the vessel.
Duration of cannulation	Measured from first puncture to complete fixation.
Catheter-related venous thrombosis	The presence of an intraluminal thrombus as confirmed by color Doppler ultrasound. Classified as symptomatic or asymptomatic (symptomatic thrombosis was diagnosed when symptoms occurred). Ultrasound evaluation was performed before catheter removal to check whether asymptomatic thrombosis had occurred.
Mechanical phlebitis	Symptoms of vein irritation including induration, warmth, pain, or tenderness existing around the insertion site. Classified into five grades according to the standards of the Infusion Nurses Society.
Medical adhesive-related skin injury	Skin itching, erythema, bulla, or tearing that persisted for $\geq 30$ minutes after removal of adhesive dressing. <sup>18</sup> Divided into three grades: slight, (slight skin itching and erythema (less than $5 \times 5$ cm)), moderate, (obvious skin itching, erythema, and papules (more than $5 \times 5$ cm)), and severe (unbearable itching accompanied by blisters, corrosion, or exudation (more than $10 \times 10$ cm) that affected sleep, daily life, and even therapy).
Catheter occlusion	Inability to infuse any fluid into the catheter or aspirate blood from the PICC.
Catheter-related infection	Defined according to the Centers for Disease Control and Prevention and classified as local infection or central line-associated bloodstream infection.
Catheter dislodgement	Exposed portion of PICC prolapsed by >2 cm.
Unplanned extubation	Removal of PICC because of complications or for reasons other than completion of the patient's intended treatment.

PICC, peripherally inserted central catheter.

lymphoma or osteosarcoma, with no significant differences between the two groups. Additionally, there were no significant differences in the patients' demographic data,

disease-related data, or coagulation function. This detailed information is shown in Table 2. A CONSORT diagram of patient recruitment is shown in Figure 1.

**Table 2.** Basic characteristics of participants.

Characteristics	Categories	Experimental group (n = 64)	Control group (n = 65)	t/ $\chi^2$	P
Age, years		45.64 ± 11.59	47.95 ± 11.96	-1.115	0.267
Sex	Male	35 (54.7)	39 (60.0)	0.372	0.595
	Female	29 (45.3)	26 (40.0)		
Diagnosis	Nasopharyngeal carcinoma	38 (59.4)	37 (56.9)	3.879	0.923
	Lymphoma or osteosarcoma	10 (15.6)	11 (16.9)		
	Upper gastrointestinal cancer	8 (12.5)	9 (13.9)		
	Gynecological or breast cancer	8 (12.5)	8 (12.3)		
Treatment	Chemotherapy	10 (15.6)	13 (20.1)	3.184	0.374*
	Chemotherapy with radiotherapy	50 (78.1)	50 (76.9)		
	Surgery with chemotherapy	4 (6.3)	1 (1.5)		
	Surgery with chemotherapy and radiotherapy	0 (0.0)	1 (1.5)		
Body mass index, kg/m <sup>2</sup>	≤ 18.4	5 (7.8)	4 (6.2)	0.964	0.617
	18.5–24.9	45 (70.3)	42 (64.6)		
	≥ 25.0	14 (21.9)	19 (29.2)		
Coagulation function <sup>a</sup>					
Platelet count	Low	1 (1.6)	0 (0.0)	2.636	0.268
	Normal	55 (85.9)	61 (93.8)		
	High	8 (12.5)	4 (6.2)		
APTT	Low	4 (6.3)	11 (16.9)	3.575	0.097
	Normal	60 (93.7)	54 (83.1)		
TT	Low	1 (1.6)	0 (0.0)	1.024	0.496
	Normal	63 (98.4)	65 (100)		
PT	Normal	64 (100)	64 (98.5)	0.992	0.319
	High	0 (0.0)	1 (1.5)		
Fibrinogen	Normal	56 (87.5)	60 (92.3)	0.823	0.397
	High	8 (12.5)	5 (7.7)		
D-dimers	Normal	58 (90.6)	62 (95.4)	1.126	0.324
	High	6 (9.4)	3 (4.6)		

Data are presented as mean ± standard deviation or n (%).

<sup>a</sup>Reference ranges: platelet count, 100–300 × 10<sup>9</sup>/L; APTT, 22.5–34 s; TT, 14.0–21.0 s; PT, 9.8–13.5 s; fibrinogen, 1.80–4.00 g/L; D-dimers, 0.00–0.55 µg/mL.

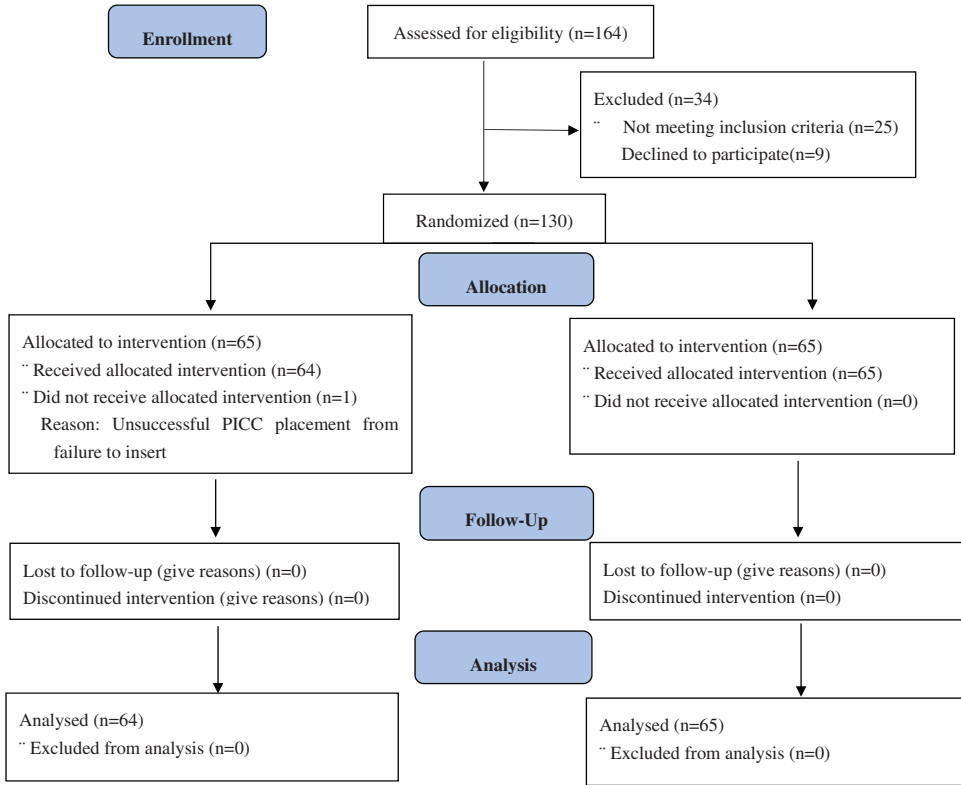
\*Fisher's exact test.

APTT, activated partial thromboplastin time; TT, thrombin time; PT, prothrombin time.

### Data related to PICC placement

The data related to PICC placement in the two groups are shown in Table 3. The total duration of catheter placement was 5451 days with a median (interquartile range) of 88 (8–191) days in the experimental group and 5532 days with a median (interquartile range) of 72 (15–192) days in the control group, with no significant difference

between the two groups. In both groups, most PICCs were placed in the right arm with the insertion site in the basilic vein. The exposure length of most PICCs was 4 cm, and the tip position was parallel to the seventh dorsal vertebra in both groups. No significant difference in vein depth was found between the groups. There was also no significant difference in the vein diameter at the exit site between the two groups.



**Figure 1.** CONSORT diagram of recruited patients. PICC, peripherally inserted central catheter.

The mean length from the puncture site to the cubital crease was significantly longer in the experimental group ( $14.739 \pm 1.528$  cm) than in the control group ( $9.415 \pm 1.304$  cm,  $P < 0.001$ ). Similarly, the median vein diameter at the puncture site was significantly larger in the experimental group (0.50 cm (0.30–1.00 cm)) than in the control group (0.50 cm (0.20–0.70 cm),  $P = 0.001$ ). The mean insertion length was also significantly shorter in the experimental group than in the control group ( $34.44 \pm 3.162$  cm) than in the control group ( $38.72 \pm 3.075$  cm,  $P < 0.001$ ). The median amount of bleeding was slightly higher in the experimental group (2.32 mL (0.15–8.37 mL)) than in the control group (1.42 mL (0.11–7.84 mL)), but the difference was not statistically significant. The median

duration of the maneuver was significantly longer in the experimental group (10.51 minutes (5.57–20.00) minutes) than in the control group (6.43 minutes (3.97–53.13 minutes),  $P < 0.001$ ).

### Complications

Table 4 shows the incidence of complications in both groups. The incidence of complications during placement was not significantly different between the two groups. However, the incidence of complications after placement was significantly lower in the experimental group (32.8%) than in the control group (58.5%,  $P = 0.003$ ). Venous thrombosis occurred in 2 (3.1%) patients in the experimental group

**Table 3.** PICC characteristics of participants.

Characteristics	Categories	Experimental group (n = 64)	Control group (n = 65)	P
Arm for PICC placement	Left	11 (17.2)	8 (12.3)	0.434
	Right	53 (82.8)	57 (87.7)	
Vein for puncture	Basilic	47 (73.4)	51 (78.5)	0.82
	Brachial	10 (15.6)	13 (20.0)	
	Axillary	7 (10.9)	1 (1.5)	
Basal upper-arm circumference, cm		27.258 ± 3.330	26.623 ± 2.330	0.211
Upper arm length, cm		21.961 ± 1.429	21.746 ± 1.335	0.379
Vein diameter, cm	At exit site	0.40 (0.15–0.80)	0.50 (0.20–0.70)	0.160
	At puncture site	0.50 (0.30–1.00)	0.50 (0.20–0.70)	0.001
Vein depth, cm	At exit site	0.725 (0.25–2.00)	0.60 (0.20–2.00)	0.101
	At puncture site	0.70 (0.25–1.50)	0.60 (0.20–2.00)	0.297
Distance from puncture site to cubital crease, cm		14.739 ± 1.528	9.415 ± 1.304	<0.001
Insertion length, cm		34.44 ± 3.162	38.72 ± 3.075	<0.001
Exposure length, cm		4.00 (0.00–17.00)	4.00 (1.00–6.00)	0.644
Amount of bleeding, mL		2.32 (0.15–8.37)	1.42 (0.11–7.84)	0.060
Duration of placement, minutes		10.51 (5.57–20.00)	6.43 (3.97–53.13)	<0.001
Tip position	T6	16 (25.0)	12 (18.5)	0.570
	T7	31 (48.4)	37 (56.9)	
	T8	17 (26.6)	16 (24.6)	
Cannulation duration, days		88.0 (8.0–191.0)	72.0 (15.0–192.0)	0.993

Data are presented as n (%), mean ± standard deviation, or median (interquartile range). PICC, peripherally inserted central catheter.

and in 10 (15.4%) patients in the control group, with a significant difference ( $P=0.030$ ). The main outcome of wound oozing was significantly lower in the experimental group (14.1%) than in the control group (27.7%,  $P=0.032$ ). Catheter dislodgement occurred in 2 (3.1%) patients in the experimental group and in 10 (15.4%) patients in the control group, with a significant difference ( $P=0.030$ ). The incidence of infection was slightly lower in the experimental than control group, although the difference was not statistically significant (1.6% vs. 6.1%, respectively). The incidence of unscheduled PICC removal was significantly lower in the

experimental group (3.1%) than in the control group (13.8%,  $P=0.029$ ). Other complications after placement were not significantly different between the groups.

### Degree of comfort during PICC placement

The degree of comfort during PICC placement in the two groups is shown in Table 5. The mean scores for most items were slightly lower in the experimental group than in the control group, although the differences were not statistically significant. However, the patients' mean total score was significantly lower in the experimental group than in the control group ( $P=0.026$ ).



**Table 4.** Complications of the participants.

Category	Experimental group (n = 64)	Control group (n = 65)	Z/ $\chi^2$	P
Complications during placement	16 (25.0)	19 (29.2)	0.292	0.589
Primary malposition	14 (21.9)	16 (24.6)	3.003	0.391
Nerve or artery injuries	1 (1.6)	1 (1.5)	–	1.000*
Difficulties in catheter or guide wire propulsion	3 (4.8)	8 (12.3)	2.429	0.274*
Complications after placement	21 (32.8)	38 (58.5)	8.548	0.003
Venous thrombosis	2 (3.1)	10 (15.4)	5.745	0.030*
Symptomatic	2 (3.1)	5 (7.7)	6.697	0.027*
Asymptomatic	0 (0.0)	5 (7.7)		
Wound oozing	9 (14.1)	18 (27.7)	–2.140	0.032*
Grade 1	9 (14.1)	8 (12.3)	10.679	0.008*
Grade 2	0 (0.0)	8 (12.3)		
Grade 3	0 (0.0)	2 (3.1)		
Catheter dislodgement	2 (3.1)	10 (15.4)	5.745	0.030*
Medical adhesive-related skin injury	12 (18.8)	11 (16.9)	0.073	0.786
Slight	11 (17.2)	5 (7.7)	–0.046	0.963*
Moderate	1 (1.6)	4 (6.2)		
Severe	0 (0.0)	2 (3.1)		
Infection	1 (1.6)	4 (6.1)	1.825	0.365*
Local	1 (1.6)	3 (4.6)	1.894	0.491*
Central line-associated bloodstream infection	0 (0.0)	1 (1.5)		
Phlebitis	2 (3.1)	1 (1.5)	0.357	0.619*
Catheter occlusion	5 (7.9)	2 (3.0)	1.409	0.273*
Unplanned extubation	2 (3.1)	9 (13.8)	4.572	0.029*

Data are presented as n (%).

\*Fisher's exact test.

### Costs of PICC placement and maintenance

Table 6 shows the costs for PICC placement and per-day maintenance. The PICC placement cost was 17.87 Yuan higher in the experimental group than in the control group. However, the median per-day maintenance cost was significantly lower in the experimental group (13.90 Yuan (10.99–32.83 Yuan)) than in the control group (15.69 Yuan (10.51–57.46 Yuan),  $P < 0.05$ ).

### Discussion

In this study, a subcutaneous tunneling technique was applied for improved PICC

placement, and the results showed that the technique was safe, feasible, and effective. No difference was found in the success rate of catheterization or amount of bleeding between the subcutaneous tunneling technique and the normal technique. However, the PICC-related costs and complications after placement were significantly lower in the subcutaneous tunneling technique group.

The success rate of tunneled PICC placement was 95.3%, which is consistent with previous studies.<sup>5,13</sup> In 2019, Dai et al.<sup>5</sup> reported that the subcutaneous tunneling technique increased the amount of bleeding through creation of the tunnel. However, our study showed no difference in the

**Table 5.** Questionnaire used to assess degree of comfort during PICC placement.

Item	Experimental group (n = 64)	Control group (n = 65)	P
1. The pain at the puncture site is unbearable.	1.81 ± 1.31	2.18 ± 1.52	0.139
2. I can understand the nurse's explanations well and cooperate with the nurse to complete the PICC catheterization.	3.95 ± 0.68	3.95 ± 0.60	0.995
3. The PICC catheterization took a long time, and it was difficult for me to finish because of my discomfort.	2.13 ± 0.49	2.31 ± 0.56	0.050
4. The position in which the PICC is placed is very uncomfortable.	2.20 ± 0.51	2.38 ± 0.68	0.088
5. The first puncture failed and the puncture had to be repeated many times, which caused me a lot of pain.	1.95 ± 0.21	2.03 ± 0.35	0.133
6. I had to keep my jaw close to my collarbone for a long time while the nurse was placing the PICC.	2.11 ± 0.62	2.23 ± 0.55	0.243
Total score	14.16 ± 2.21	15.09 ± 2.49	0.026

PICC, peripherally inserted central catheter.

**Table 6.** Costs of proximal valve power-injectable PICC placement and maintenance.

Item	Experimental group (n = 64)	Control group (n = 65)	Z	P
PICC placement cost, Yuan	3358.87	3341	-11.314	<0.001
PICC per-day maintenance cost, Yuan	13.90 (10.99–32.83)	15.69 (10.51–57.46)	-2.124	0.034

Data are presented as total cost or median (interquartile range).

PICC, peripherally inserted central catheter.

amount of bleeding between the two groups. The difference in these findings might be attributed to the difference in the tunneling instrument. A trocar, hemostat, and puncture needle<sup>5,12–14</sup> might exert more trauma to the subcutaneous tissue. In our study, the tunneller had a blunt tip at one end to penetrate the subcutaneous tissue and a connection system at the other end to connect to a 3- to 6-Fr PICC; this involved fewer incisions and provided better fixation of the catheter. Moreover, the subcutaneous tissue in the experimental group was expanded by infusing local anesthetic before the passage of the tunneler to reduce the severity of

trauma, which also helped to reduce the amount of bleeding.<sup>9</sup>

Multilumen power-injectable PICCs ranging in size from 4 to 6 Fr are being increasingly used in the clinical setting, especially in patients with cancer or severe illness who require administration of many contemporary therapies. According to one study, the catheter-to-vein ratio should range from 33% to 45% to reduce the incidence of thrombosis.<sup>17</sup> However, it is often difficult to find sufficiently large vessels in the middle third of the arm, which limits the use of multilumen PICCs. Our results affirmed that the subcutaneous tunnel technique can reduce the incidence of

thrombosis and expand the use of multilumen PICCs. The subcutaneous tunnel technique allows a higher puncture site in which the vein diameter is larger and maintains an exit site in the middle third of the arm for suitable fixation. The large vessel diameter not only helps to reduce the incidence of thrombosis but also enables use of the multilumen catheter, which otherwise exceeds the optimal catheter-to-vein ratio for suitable vessels.

In our study, the incidence of wound oozing was significantly lower in patients with subcutaneous tunnels than in those who underwent PICC placement using the normal method; this finding is consistent with previous studies.<sup>4,5,14</sup> In the control group, the puncture site was located above the vessels, and the puncture point of the vessels and skin was located at the same position. The tip of the needle caused mechanical cutting injury to the vessels. Moreover, the diameter of the steel needle trocar was larger than that of the PICC. When the needle was withdrawn, blood seeped out around the PICC. However, the distance between the puncture site and exit site created by the subcutaneous tunnel technique not only increased the friction force of pipe sliding but also compressed the site to prevent bleeding. Therefore, the subcutaneous tunnel technique can reduce the incidence of wound oozing.

Catheter dislodgement caused by increased intrathoracic or intra-abdominal pressure, rapid injection, and too much arm movement<sup>13</sup> is a common complication of PICCs. In the present study, the incidence of catheter dislodgement was higher than that reported in other studies.<sup>5,12</sup> The reason for this outcome might be the different types of PICCs used. The power-injectable PICC used in the present study was made of polyurethane, and the epitaxial tube of the catheter was relatively hard, which stimulates the local muscle tissue and is not conducive to healing. In this study,

the incidence of catheter dislodgement was significantly lower in the experimental group than in the control group. This suggests that the subcutaneous tunneling technique can reduce the incidence of catheter dislodgement after placement. The catheter was exported to the outside of the body through the subcutaneous tunnel, which can minimize freedom of movement and supply fixation of the PICC position to reduce catheter dislodgement.

In 2001, Selby et al.,<sup>8</sup> who first reported the subcutaneous tunneling technique, presumed that tunneling may not effectively reduce the infection rate. However, the results of a multicenter retrospective study suggested that subcutaneous tunneling could significantly decrease the rate of central line-associated bloodstream infection.<sup>12</sup> In the present study, only one case of central line-associated bloodstream infection and four cases of local infection occurred in the control group, whereas no cases of central line-associated bloodstream infection and two cases of local infection occurred in the experimental group. We believe that there are two explanations for this low incidence of infection. First, the incidence of infection was low in our patients because of the short duration of catheter use and the strict infection control measures in our hospital. Second, the sample size in this study might not have been sufficiently large to detect significant differences in the low incidence of infection between the two techniques. Further research is needed to determine whether this technology can reduce the incidence of infection.

This study is the first to compare the degree of comfort during placement of a tunneled versus non-tunneled PICC. Interestingly, the overall degree of comfort with the tunneled PICC was not lower than that with the non-tunneled PICC; instead, it was slightly higher. The reason for this result might be the injection of a few

milliliters of local anesthetic, which expanded the subcutaneous tissue to reduce trauma before the passage of the tunneller and might have also helped to reduce patient pain and tension during cannulation. We consider that although the subcutaneous tunnel technique is more complicated than the normal method, it does not result in greater pain or affect the degree of comfort during placement.

The cost of PICC placement was 17.87 Yuan higher in the experimental group than in the control group. This difference was due to the cost of the 3M reinforced sterile skin closures in the experimental group (17.87 Yuan) to close the nick at the tunneled puncture site. However, the per-day maintenance cost was significantly lower in the experimental group than in the control group. The difference was primarily due to the cost related to management of complications and unscheduled PICC removal. Subcutaneous tunnel technology placement increased the cost by only 17.87 Yuan while reducing the incidence of adverse events and the cost of PICC maintenance.

### Limitations

Despite our careful preparation before the study began, certain limitations remain. The first is that double blinding was not possible in our study because the wounds and surgical procedures were different between the groups, which might have influenced the degree of comfort in the two groups. However, blinding was possible for follow-up and diagnosis of complications. The second limitation is the insufficient sample size, which prevented us from determining whether the subcutaneous tunnel technique was effective for reducing the incidence of catheter-related infection. This outcome might have been due to the small sample size in each group, which we calculated based on the incidence of complications after PICC placement; however, it

could also have been caused by the low incidence of catheter-related infection in our hospital. The third limitation is that our study focused only on patients with cancer. Further studies involving patients undergoing PICC placement for different reasons are needed.

### Conclusions

In this study, we evaluated the effect of the subcutaneous tunneling technique on improving outcomes in patients with PICCs. We demonstrated that the subcutaneous tunneling technique is a safe, feasible, and efficient method to expand the use of multilumen PICCs by allowing insertion of a larger PICC without increasing pain during placement. Moreover, this technique can reduce the cost of PICC maintenance and reduce complications after placement, especially with respect to catheter dislodgement, venous thrombosis, wound oozing, and unscheduled PICC removal. Therefore, the subcutaneous tunneling technique should be recommended to improve patient outcomes of PICC insertion.



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The authors declare that there is no conflict of interest.

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