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## A randomized controlled study of bedside electrocardiograph-guided tip location technique & the traditional chest radiography tip location technique for peripherally inserted central venous catheter in cancer patients

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**Background & objectives:** The peripherally inserted central catheter (PICC) has the advantages of higher safety, lower infection rate and longer retention time than peripherally inserted catheter. This study was aimed to evaluate the accuracy and safety of bedside electrocardiograph (ECG)-guided tip location technique in PICC in cancer patients, and compared with traditional chest radiography tip location technique.

**Methods:** Patients were randomly assigned into two groups: The ECG test group patients underwent PICC insertion with ECG-guided tip location, while the control group patients had PICC insertion by the conventional method. The precision of tip location was verified by chest radiography in both groups. The groups were compared with regard to the accuracy of tip placement, anxiety levels before and after the procedure; medical cost and incidence of complications at one week, three months and six months after PICC insertion.

**Results:** Accurate tip location was achieved in 99.30 per cent in the ECG test group vs 92.30 per cent in the control group ( $P<0.001$ ). At 24 h after the procedure, the anxiety level was significantly lower in the ECG test group. The presence of thrombogenesis was significantly lower in the ECG test group at both three months and six months after the procedure ( $P=0.04$  and  $P=0.03$ , respectively).

**Interpretation & conclusions:** The ECG-guided PICC tip location technique was accurate and caused fewer procedure-related complications and less anxiety in patients compared to chest radiography tip location technique. Radiographic confirmation of PICC tip position may not be needed when ECG guidance is used and thus it can help avoid radiation exposure.

**Key words** Anxiety - chest radiograph - complications - electrocardiograph-guided - tip location

Compared to the traditional central venous catheter, the peripherally inserted central venous catheter (PICC), inserted through an upper extremity peripheral vein, has the advantages of higher safety, lower infection rate and longer retention time<sup>1,2</sup>. It is useful for providing long-term parenteral nutrition and intravenous chemotherapeutic drugs and antibiotics<sup>3,4</sup>. Appropriate tip placement of the PICC is important. Racadio *et al*<sup>5</sup> found complication rate was 3.8 per cent if tip location resided in the superior vena cava; however, complication rate rose to 28.8 per cent if tip location resided in other places, which increased the risk of complications. Serious complications with PICC include tip migration, infection, thrombosis and phlebitis<sup>6,7</sup>.

At present, the main techniques of PICC insertion include blind puncture, Seldinger technique and ultrasound-guided modified Seldinger technique<sup>8</sup>. The electrocardiograph (ECG)-guided PICC tip location technique is easy to perform, allows real-time adjustment of tip position and does not involve radiation exposure<sup>9</sup>, which makes it the ideal technique. However, there have been a few studies on the safety and efficacy of bedside ECG-guided PICC tip location in cancer patients. Liu *et al*<sup>10</sup> and Zhao *et al*<sup>11</sup> studied 85 and 116 Chinese patients with ECG-guided PICC, respectively, and reported high accuracy of tip localization, but they did not examine the precision of tip location, procedure related anxiety and PICC-associated complications. This study was aimed to explore the accuracy, precision, safety, procedure-related anxiety and complications associated with bedside ECG-guided PICC tip location compared to traditional chest radiography tip location technique.

### Material & Methods

From June 1, 2014 to April 30, 2016, 294 patients in the Oncology department of the First Affiliated Hospital of Zhengzhou University, Henan, PR China, were approached to participate voluntarily in this randomized controlled clinical trial (Fig. 1). The study was approved by the Ethics Committee of the First Affiliated Hospital of Zhengzhou University (Scientific Research No. 33, 2014). All participants gave written informed consent.

Patients were eligible for inclusion if they were inpatients and cancer patients. Patients were excluded if they had (i) serious bloodstream infection or systemic infection before catheterization; (ii) superior vena cava

compression syndrome; (iii) serious cardiovascular disease (*e.g.*, atrial fibrillation, pulmonary heart disease with abnormal P waves, or severe heart block); (iv) they were  $\geq 18$  yr old, and (v) they were on pacemakers and using implantable defibrillators. Four patients did not meet inclusion criteria, two patients declined to participate and two patients excluded because of other reasons, so 286 participants were found to be eligible for inclusion in the study.

Using a random number table, participants were separated into two groups: (i) the ECG test group (n=143), who underwent PICC insertion with bedside ECG-guided tip positioning, and (ii) the control group (n=143), who underwent PICC insertion by the traditional technique. There were no significant differences between the groups in age, gender, height, weight, upper arm circumference, educational level, diagnosis, co-morbidities, history of prior central venous catheter, history of PICC insertion, platelet count and the prothrombin time (Table I).

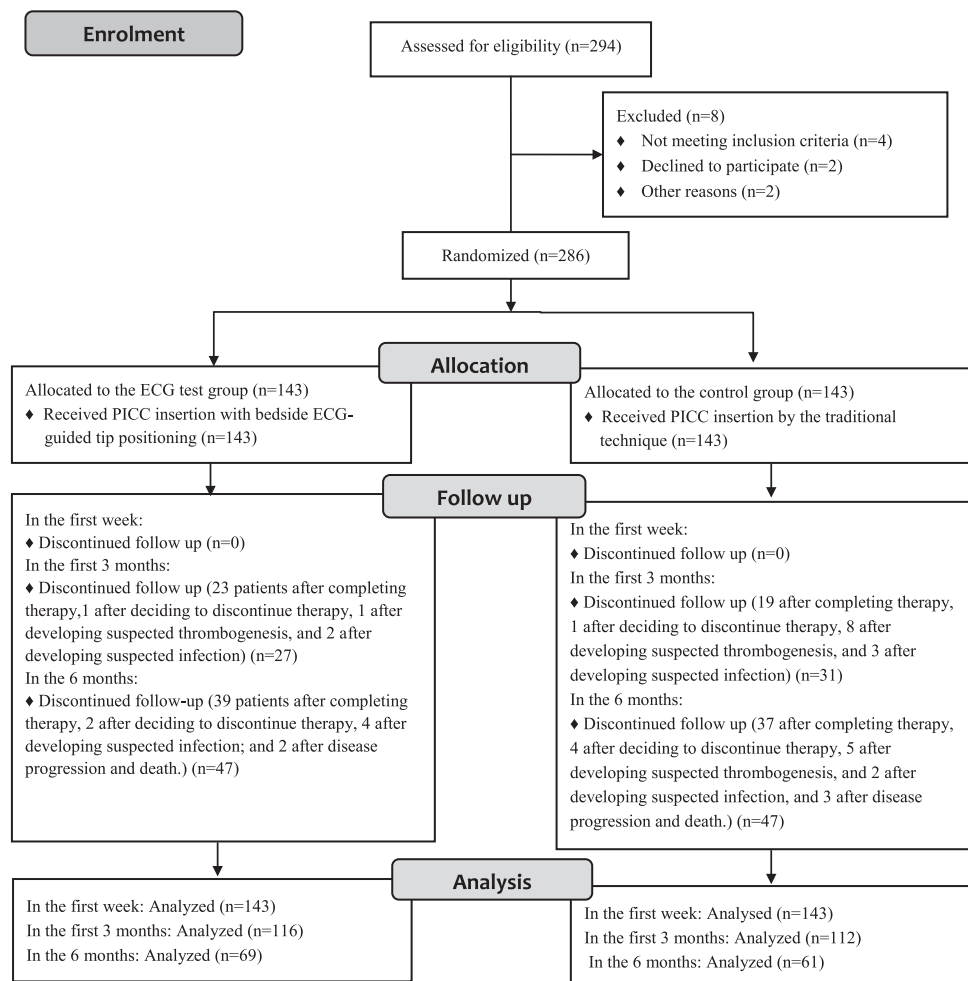
According to the pilot study result, the appropriate tip location rate of the control group was 89.0 per cent; the ECG test group was 98.4 per cent. PASS software (NCSS, LLC, USA) was used to calculate the sample size, and a sample size of 143 participants of each group was calculated with the statistical performance of 0.9093.

### Methods

**Catheterization technique:** In all patients, the 18G (4Fr)  $\times$  65 cm, BD First PICC™ Kits (Becton Dickinson Infusion Therapy Systems Inc., USA) were used. The catheters were inserted by the same specialist nurses with the PICC qualification in a specially confined PICC puncture chamber and maintained in hospital by nurse PICC teams. The distance from the venepuncture point to the right sternoclavicular joint, plus 5-7 cm, was the estimated catheter insertion length. The upper arm circumference was measured 10 cm above the elbow crease. Before ultrasound-guided venepuncture, the arm was cleaned and sterilized three times using 75 per cent alcohol and chlorhexidine.

The basilic vein was the first choice for venepuncture. During the procedure, the length of the catheter in the body, the presence of resistance to removal of the guidewire within the catheter and the time taken for the procedure (from skin disinfection to application of the sticking plaster) were recorded.

In the ECG group patients, the four limb leads of the ECG machine were attached and normal P waves and



**Fig. 1.** Flowchart showing the study design. PICC, peripherally inserted central venous catheter; ECG, electrocardiograph.

sinus rhythm were confirmed on the lead II tracing. When the catheter was inserted almost up to the estimated length, the right arm lead was removed, the clamps sterilized and then attached to the guide wire. The guide wire was now advanced slowly, 0.5-1 cm at a time, while observing the P wave changes on the monitor. Three ECG P waveforms were obtained during the course of the catheterization: (i) the blunt short P wave of normal sinus rhythm; (ii) the biphasic P waves indicating tip location in the right atrium and (iii) high-amplitude P waves indicating tip location at the junction of the superior vena cava and the right atrium (P-wave amplitude 80% of QRS) or tip location in the lower one-third of the superior vena cava (P-wave amplitude 50% of QRS).

**Chest radiography verification:** For verification of tip position, chest radiography is generally accepted to be the gold standard<sup>12</sup>, and accordingly, chest radiographs were taken in all patients to confirm correct tip position.

The ideal position was defined as the middle and lower one-third of the superior vena cava or the junction of the superior vena cava and the right atrium.

**Anxiety levels before and after PICC:** The State-Trait Anxiety Inventory (STAI) prepared by the Gaudry *et al*<sup>13</sup> is a commonly used measure of trait and state anxiety and translated into Chinese in 1988<sup>14</sup>. Each item is graded on a scale of 1 to 4 (1: no, 2: some, 3: moderate and 4: obvious), and the total score ranging from 20 to 80 can be used to quantify an unpleasant short-term emotional experience<sup>15,16</sup>. The Chinese version of the STAI had a Cronbach's alpha of 0.88<sup>17</sup>; in our study, Cronbach's alpha of the STAI was 0.89. The Chinese version of the inventory was used to assess anxiety levels in patients 24 h before and 24 h after catheterization.

**PICC-related complications:** PICC-related complications after one week, three months and six months were

**Table I.** Characteristics of patients in the two groups

Characteristics	ECG test group (n=143)	Control group (n=143)	P
Age	50.48±15.30	49.76±14.23	0.68
Gender (%)			
Male	64 (44.76)	62 (43.36)	0.81
Female	79 (55.24)	81 (56.64)	
Height (cm)	165.52±7.16	166.51±6.61	0.22
Weight (kg)	65.15±10.37	65.76±11.43	0.64
Upper arm circumference (cm)	27.32±2.69	26.93±2.44	2.00
Educational level (%)			
Illiterate	12 (8.39)	13 (9.09)	0.54
Elementary school/junior high school	85 (59.44)	73 (51.05)	
High school/technical school/college	29 (20.28)	37 (25.87)	
Bachelor's degree or above	17 (11.89)	20 (13.99)	
Diagnosis (%)			
Breast cancer	7 (4.90)	6 (4.20)	0.55
Lung cancer	13 (9.09)	11 (7.69)	
Digestive tract cancer	24 (16.78)	20 (13.99)	
Lymphoma <sup>a</sup>	90 (62.94)	89 (62.24)	
Other tumours	9 (6.29)	17 (11.89)	
Co-morbidities <sup>b</sup> (%)			
None	120 (83.90)	124 (86.70)	0.50
≥1	24 (16.10)	19 (13.30)	
History of prior central venous catheter (%)			
Yes	19 (13.30)	15 (10.50)	0.47
No	124 (86.70)	128 (89.50)	
History of PICC insertion (%)			
Yes	20 (13.99)	14 (9.79)	0.27
No	123 (86.01)	129 (90.21)	
Platelet count (10 <sup>9</sup> /l)	220.49±89.25	235.45±93.32	0.17
Prothrombin time (sec)	9.77±1.51	9.96±1.51	0.30

<sup>a</sup>Most patients had lymphoma because this study was conducted in the lymphoma diagnosis and treatment centre of the hospital;  
<sup>b</sup>Co-morbidities include diabetes, hypertension and coronary artery disease. PICC, peripherally inserted central venous catheter; ECG, electrocardiograph

recorded in all patients who had been on regular catheter infusion therapy, with regular maintenance of the catheter. The patients were followed up every two weeks for their health status and the condition of the catheter.

*Statistical analysis:* SPSS 17.0 software (SPSS Inc., Chicago, IL, USA) was used for data analysis. Quantitative data (age, height, weight, upper arm circumference, platelet count, prothrombin time, activated partial thromboplastin time, cost and anxiety level) were expressed as the means±standard deviation. Qualitative data (gender, educational level, diagnosis, co-morbidities, history of

prior central venous catheter, history of PICC insertion and complications) were compared using the chi-square test.

## Results

*Accuracy and precision of tip positioning:* Accurate catheter tip positioning was achieved in 99.3 per cent in the ECG test group versus 92.3 per cent in the control group ( $P=0.003$ ; Fig. 2). The catheter tips flush with the 6<sup>th</sup>, 7<sup>th</sup> and 8<sup>th</sup> intercostal were 20.30, 64.30 and 14.70 per cent, respectively, in the ECG test group versus 32.20, 40.60 and 19.60 per cent, respectively,

in the control group and the difference was significant (Fig. 3 and Table II).

**PICC-associated anxiety:** The anxiety scores 24 h before catheterization in the two groups were not significantly different. However, 24 h after catheterization, the anxiety score in the ECG test group was significantly ( $P < 0.001$ ) lower than that in the control group (Table III).

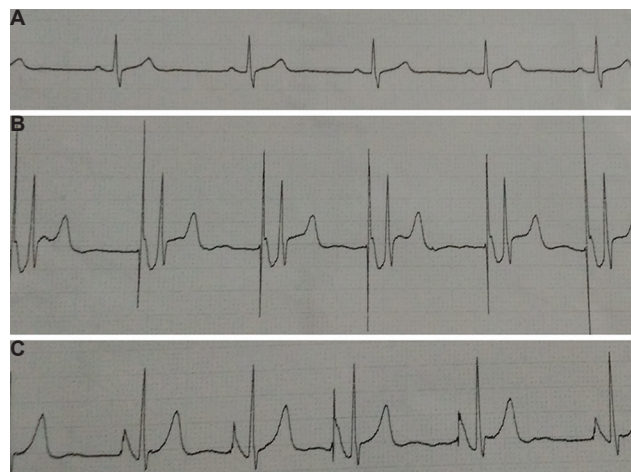
**Procedure-related complications:** In the first week, two patients had thrombogenesis in the ECG test group versus four patients in the control group. No patient in either group had chest discomfort, arrhythmia, or infection. At the end of three months and six months, the incidence of thrombogenesis in the ECG test group was significantly lower than that in the control group ( $P = 0.04$  and  $P = 0.03$ , respectively) (Table IV).

### Discussion

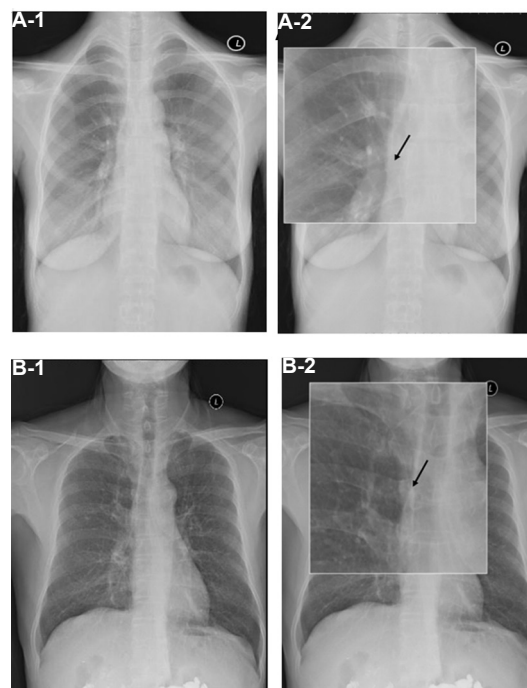
There have been only a few studies to date on the precision of different techniques for PICC tip location. Consistent with other studies<sup>18,19</sup>, our study showed that the accuracy of the ECG-guided method was

better than that of the traditional method. In the ECG test group patients, real-time adjustment of PICC tip position was possible by observing the lead II P wave morphology on the monitor. In the traditional method, a chest radiograph is necessary to confirm correct tip position whenever the PICC tip is readjusted. In this study, 11 patients in the control group needed adjustment of PICC tip position followed by repeat chest radiography to confirm correct positioning. This increased the radiation exposure to the patient.

Patients experience anxiety during PICC insertion procedure<sup>20</sup>, so anxiety levels were assessed 24 h after PICC insertion; anxiety levels were  $40.96 \pm 1.97$  and  $42.06 \pm 1.90$ , respectively. It could be possible that the patients in the ECG test group were reassured



**Fig. 2.** Three electrocardiograph P wave forms seen during catheterization in the electrocardiograph test group. (A) Blunt, low-amplitude, P waves. (B) Biphasic P waves. (C) High-amplitude P waves (50 or 90% of QRS amplitude).



**Fig. 3.** Chest radiographs of patients from the two groups. Arrow indicates the position of the catheter tip. Tip location flush with the 7<sup>th</sup> intercostal in a patient from the electrocardiograph test group. A-1 (chest radiograph); A-2 (magnified image). Tip location flush with the 5<sup>th</sup> intercostal in a patient from the control group. B-1 (chest radiograph); B-2 (magnified image).

**Table II.** Precision of catheter tip positioning in the two groups

Groups	Tip location				P
	6 <sup>th</sup> intercostal	7 <sup>th</sup> intercostal	8 <sup>th</sup> intercostal	Others	
ECG test group (%)	29 (20.30)	91 (64.30)	21 (14.70)	1 (0.70) <sup>a</sup>	<0.001
Control group (%)	46 (32.20)	58 (40.60)	28 (19.60)	11 (7.70) <sup>b</sup>	

<sup>a</sup>The chest radiograph of one participant was not clear; <sup>b</sup>In two patients, the tip was positioned in the internal jugular, in three patients the tip was in the axilla and in six patients the tip was flush with the 7<sup>th</sup> intercostal; ECG, electrocardiograph

by the information provided to them at enrolment that they would be receiving a technologically advanced treatment with high success rates. Moreover, radiological confirmation of success at the end of the procedure would have allayed anxiety further. Once the precision of the ECG-guided technique is established, confirmation with chest radiography will not be necessary, and the cost of the procedure will be correspondingly less; Bream and Gu<sup>21</sup> and Walker *et al*<sup>22</sup> have also suggested the same.

PICC-related complications need to be minimized as they may affect, or even interrupt, the treatment of the patient's underlying condition<sup>23</sup>. In our study, the incidence of procedure-related complications was low and not significantly different between the two groups in the first week after PICC insertion. No patient had chest discomfort, arrhythmia or infection. To secure the safety usage of PICC and reduce the PICC-

related complications, the strict rules of handling, the skill and experience of operator and cooperation of patients are necessary<sup>24</sup>. However, at the end of three and six months, the cases with thrombogenesis were found to be significantly lower in the ECG test group. In the control group, some patients needed repeated adjustment of PICC tip location; this may have caused damage to the vein wall and led to the higher incidence of thrombogenesis.

Our study had some limitations. First, only adult cancer inpatients were included in the study, and thus our findings might not apply to other types of patients (*e.g.*, children, outpatients, or peripheral blood stem cell transplantation patients). Second, most of our study participants were lymphoma patients (because this study was conducted in the lymphoma diagnosis and treatment centre of the hospital).

In conclusion, the bedside ECG-guided PICC insertion method was found to be accurate, it allowed real-time adjustment of the PICC tip, and avoided radiation exposure. Significantly lower post-procedure anxiety levels and fewer postoperative complications are other advantages. With nurses trained in ECG-guided PICC tip location, it can be expected to become the preferred technique for patients without serious cardiovascular disease.

**Table III.** Mean anxiety scores before and after catheterization in the two groups

Groups	Before 24 h	After 24 h
ECG test group	46.64±3.92	40.96±1.97
Control group	46.06±3.73	42.06±1.90
<i>P</i>	0.21	<0.001

ECG, electrocardiograph

**Table IV.** Procedure related complications in the two study groups after PICC insertion

Complication	In first week		<i>P</i>	In first 3 months		<i>P</i>	In 6 months		<i>P</i>
	ECG test group (n=143)	Control group (n=143)		ECG test group (n=116)	Control group (n=112)		ECG test group (n=69)	Control group (n=61)	
<b>Phlebitis (%)</b>									
Yes	0	1 (7.00)	1.00 <sup>^</sup>	0	0	-	0	0	-
No	143 (100)	142 (99.30)		116 (100)	112 (100)		69 (100)	61 (100)	
<b>Thrombogenesis (%)</b>									
Yes	2 (1.40)	4 (2.80)	0.68 <sup>^</sup>	1 (0.90)	8 (7.10)	0.04 <sup>^</sup>	0	6 (9.80)	0.03 <sup>^</sup>
No	141 (98.60)	139 (97.20)		115 (99.10)	104 (92.90)		69 (100)	55 (90.20)	
<b>Infection (%)</b>									
Yes	0	0	-	2 (1.70)	3 (2.70)	0.97	3 (4.30)	4 (6.60)	0.87 <sup>^</sup>
No	143 (100)	143 (100)		114 (98.30)	109 (97.30)		66 (95.70)	57 (93.4)	

At the end of three months, in the ECG test group, 27 patients had their catheters removed: 23 patients after completing therapy, 1 after deciding to discontinue therapy, 1 after developing suspected thrombogenesis and 2 after developing suspected infection. In the control group, 31 patients had their catheters removed: 19 after completing therapy, 1 after deciding to discontinue therapy, 8 after developing suspected thrombogenesis and 3 after developing suspected infection. At the end of six months, in the ECG test group, 47 patients had their catheters removed: 39 patients after completing therapy, two after deciding to discontinue therapy, 4 after developing suspected infection and 2 after disease progression and death. In the control group, 51 patients had their catheters removed: 37 after completing therapy, 4 after deciding to discontinue therapy, 5 after developing suspected thrombogenesis and 2 after developing suspected infection and 3 after disease progression and death; <sup>^</sup>Continuous correction Chi-square value, the minimum theoretical frequency <5; PICC, peripherally inserted central venous catheter; ECG, electrocardiograph

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**Conflicts of Interest:** None.

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