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Effects of indwelling centrally inserted central catheter on tip location of peripherally inserted central catheter with intracavitary electrocardiogram guidance: A retrospective case-control study

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Abstract

Background: Intracavity electrocardiogram (IC-ECG) guidance is an effective technology for monitoring the tip locations of centrally inserted central catheters (CICCs) and peripherally inserted central catheters (PICCs). However, for patients with an indwelling CICC, there has been no study on whether the CICC affects PICC tip positioning with IC-ECG guidance.

Methods: Thirty people with a CICC requiring PICC insertion, matched with age to controls without a CICC. The stability of IC-ECG waveforms, the amplitude of P-waves, and the accuracy of PICC tip location were compared.

Results: There was no significant difference in the stability of the IC-ECG waveforms ($\chi^2 = 0.22$, $p = 0.64$). The amplitudes of baseline P-waves and ideal P-waves also showed no significant difference ($t1 = 0.06$, $p1 = 0.96$, $t2 = 0.80$, $p2 = 0.43$). Neither the accuracy of tip location ($\chi^2 = 1.40$, $p = 0.50$) nor the distance of PICC tip ($t = -0.03$, $p = 0.98$) were significantly different.

Conclusion: For patients with an indwelling CICC, the position of PICC tip can be accurately determined by the dynamic changes in the P-wave amplitude.

Keywords

Peripherally inserted central catheter, centrally inserted central catheter, intracavitary electrocardiogram, tip location

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Introduction

Both centrally inserted central catheter (CICC) and peripherally inserted central catheter (PICC) belong to central vascular access devices (CVADs). There is no clear evidence that PICC is superior to CICC in acute care settings.[1] When the critically ill patient's condition worsens, doctors preferentially insert the CICC for rescue. However, in the process of CICC catheterization, pneumothorax and hemothorax may easily occur.[2] A cluster-randomized multicenter study of 14 hospitals in 11 European countries showed that the incidence of central venous catheter-related bloodstream infections was as high as 2.4/1000 CICC-days.[3] Once patients are in a stable condition, CICCs are usually replaced with PICCs for long-term intravenous infusion and intravenous drug therapy due to the safe operation, fewer complications, and long-term use.[4–6] To ensure continuity of treatment,

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CICCs are usually removed after successful PICC implantation.

Intravenous Nurse Society (INS) recommends that the tips of CVADs should be preferably placed either in the lower third of the superior vena cava (SVC) or at the transition between the SVC and right atrium (RA), known as the cavoatrial junction (CAJ).[7] Inaccurate tip localization will cause complications such as thrombosis, catheter prolapse, arrhythmias, etc.[8–10] Intracavity electrocardiogram (IC-ECG) guidance has been widely used for monitoring the tip locations of CVADs since the 1960s.[11] This method uses the electrical conductivity of a guidewire, the catheter and blood to determine the position of the catheter tip through specific P-wave changes.[12,13] The accuracy of this technology reaches more than 90%.[14–16]

However, for patients with an indwelling CICC, there has been no study on whether the CICC affects PICC tip positioning with IC-ECG guidance. Therefore, we designed this research to study the effect of an indwelling CICC on the localization of the PICC tip with IC-ECG guidance.

Methods

Study design and setting

This was a retrospective matched case-control study that was conducted at a teaching hospital in China. More than 4000 PICCs are inserted in the hospital every year. This study was performed in accordance with the ethical standards of the Institutional Ethics Committee of the hospital and with the 1964 Declaration of Helsinki.

Study population

We chose 60 patients with an indication for PICC placement from 1 January 2018 to 31 December 2019. Among the 60 patients included, cases were defined as 30 patients with a CICC. We also created a matched control group of another 30 patients who had no CICC implanted. The control group was matched by age (± 3 years), which was performed by searching our PICC database. Inclusion criteria were as follows: (a) age $\geqslant 18$ years old, (b) normal P-wave appearance on the surface ECG recordings, and (c) informed consent and voluntary participation. The exclusion criteria were as follows: (a) a mental behavior disorder and inability to cooperate and (b) cardiovascular conditions such as atrial fibrillation, supraventricular tachycardia, pulmonary heart disease, and pacemaker implantation, which may affect the appearance of the P-waves.

PICC insertion technique and IC-ECG guidance

4Fr single lumen Groshong PICCs (Bard Access Systems, Salt Lake City, UT) and 5Fr Power PICCs (Bard Access Systems, Salt Lake City, UT) were selected. First, qualified intravenous therapy specialists performed precatheterization evaluations and chose a reasonable vein for PICC placement. Precatheterization evaluation included skin condition, venous flow, venous diameter, coagulation indexes, etc. To avoid difficulty in catheter delivery, the side contralateral to the CICC was preferred for PICC implantation. Then, the PICC was inserted by the qualified intravenous therapy specialists with the ultrasound-guided modified Seldinger technique.

After the PICC was delivered to the predicted vessel length, the tip of the PICC was localized using IC-ECG guidance. We used a three-lead ECG machine (model: MAC 1600). Before PICC placement, we connected the limb guides of the ECG machine and retrieved the body surface ECG recording, which was considered the baseline data. Then, we connected the right upper limb lead of the limb II guide to PICC. As the PICC was inserted, the amplitude of the P-wave gradually increased until a bidirectional or negative P-wave appeared. Then, we slowly retracted the PICC 2–3 cm. When the P-wave amplitude of the limb II guide was 50%–80% of the QRS amplitude, which was called the ideal P-wave, the tip of the PICC catheter was estimated to be located in the ideal position.[17,18] At this time, the second ECG recording was obtained. In order to visually see the positional relationship between CICC and PICC, we took chest-X-ray for case group. Meanwhile, the distance between the PICC tip and the tracheal carina on chest-X-ray reflected the accuracy of the PICC tip location.

Data collection

Patient demographic characteristics were obtained from the medical records system. PICC insertion information was obtained by self-designed questionnaires. ECG signals were recorded by ECG machines.

Outcomes

Stability of the ECG waveform

The stability of the EGC waveform was determined by the reading from the limb II guide of the second ECG recording, which reflected the ideal P-wave. If the waveforms were clearly identified without ups and downs, the ECG recording was judged as a stable wave. If the waveforms showed ups and downs, it was judged as a floating wave. If the waveforms were so serrated and coarsened that the amplitude of the P-wave could not be distinguished, it was

Table 1. Demographic characteristics and PICC insertion information.

Variables	Cases	Controls	χ^2/t	p Value
Age	59.80 ± 19.58	61.07 ± 19.53	−0.25	0.80
Gender				
Male	18 (60.00)	22 (73.33)	1.20	0.27
Female	12 (40.00)	8 (26.67)		
Type of PICC				
Single lumen PICC	28 (93.33)	27 (90.00)	0.22	0.64
Power PICC	2 (6.67)	3 (10.00)		
Punctured site				
Basilic vein	24 (80.00)	22 (73.33)	0.37	0.54
Brachial vein	6 (20.00)	8 (26.67)		

judged as a coarse wave. If the waveforms appeared irregular and could not be identified, it was judged as an unidentified wave.[19]

Amplitude of the ideal P-wave

The amplitude of the ideal P-wave was also determined by the reading from the limb II guide of the second ECG recording. We measured the vertical distance from the top to the starting point of the ideal P-wave. To reduce measurement errors, we took the average of three ideal P-waves. On the ECG recording, 10 mm represented 1 mV, which was used to calculate the amplitude of the ideal P-wave.

Accuracy of the PICC tip location

According to the Infusion Nursing Standards of Practice, the PICC tip should be preferably placed either in the lower third of the SVC or at the CAJ.[7] This appropriate position ranges anatomically from 1.6 to 4 cm below the tracheal carina.[20,21] In our research, the tracheal carina on chest X-ray was regarded as the baseline location. The distance between the catheter tip and the carina was considered positive below the structure and negative above it. The distance of 1.6–4 cm indicated an ideal tip position. Meanwhile, the location was considered too shallow at a distance of less than 1.6 cm and too deep at a distance of more than 4 cm.

Statistical analysis

The statistical analysis was performed with SPSS 20.0 software. The measurement data were described using means and standard deviations (SDs). The categorical data were summarized with frequencies and percentages. The comparisons of measurement data were performed using the *t*-test. The comparisons of categorical data were measured using chi-square tests.

Results

Demographic characteristics and PICC insertion information

Table 1 showed the demographic characteristics and PICC insertion information of the two groups. There was no significant difference in demographic characteristics or PICC insertion information between the two groups ($p > 0.05$). The average age of the 60 patients was (60.43 ± 19.40) years, and most were male (40, 66.67%). There were 15 patients (25.00%) with respiratory diseases such as respiratory failure, pneumonia, and COPD, 9 patients (15.00%) with digestive system diseases such as gastrointestinal bleeding and esophageal cancer, 8 patients (13.33%) with septic shock, 7 patients (11.67%) with cardiocerebrovascular diseases, and 7 patients (11.67%) with reproductive system diseases such as ovarian cancer. 4Fr single lumen Groshong PICCs were inserted in 55 patients (91.67%), and 5Fr Power PICCs were inserted in 5 patients (8.33%). Basilic veins were chosen as the puncture site in 46 patients (76.67%), while brachial veins were chosen in 14 patients (23.33%). In the case group, 23 patients (76.67%) retained a CICC in the right cervical region, while 7 patients (23.33%) retained a CICC in the left cervical region. The distance between the tip location of the CICC and the tracheal carina was (−0.41 ± 1.08) cm.

Stability of the ECG waveform

In the case group, stable waves accounted for 90.00% of all recordings; two patients (6.67%) showed a drift wave and one patient (3.33%) showed a coarse wave. In the control group, stable waves accounted for 96.67% of all recordings, with one patient (3.33%) showing a drift wave and one patient (3.33%) showing a coarse wave. There was no significant difference in the stability of the ECG waveform between the two groups ($\chi^2 = 0.22$, $p = 0.64$) (Table 2).

Table 2. Stability of the ECG waveform.

Group	Unstable waves (*N*, %)	Stable waves (*N*, %)	χ^2	*p* Value
Cases	3 (10.00)	27 (90.00)	0.22	0.64
Controls	2 (6.67)	28 (96.67)		

Table 3. Amplitude of the *P*-waves.

Amplitude (mV)	Cases	Controls	*t*	*p* Value
Baseline P-wave	0.14 ± 0.14	0.14 ± 0.11	0.06	0.96
Ideal P-wave	0.72 ± 0.47	0.64 ± 0.20	0.80	0.43

Table 4. Accuracy of the PICC tip location.

Group	PICC tip location (*N*, %)			Distance (cm)
	Accuracy	Shallow	Deep	
Cases	28 (93.33)	1 (3.33)	1 (3.33)	2.43 ± 1.51
Controls	29 (96.67)	1 (3.33)	0	2.47 ± 1.20
χ^2/t	1.40			−0.03
p Value	0.50			0.98

Amplitude of the P-wave

The amplitudes of both the baseline P-waves and the ideal P-waves of the two groups were compared, and no significant difference was found for either amplitude between the two groups ($t_1 = 0.06$, $p1 = 0.96$, $t_2 = 0.80$, $p2 = 0.43$) (Table 3).

Accuracy of the PICC tip location

The average accuracy of the PICC tip location in the two groups was 93.33% for the case group and 96.67% for the control group. In addition, the average tip location of the PICC was (2.25 ± 1.35) cm, (2.43 ± 1.51) cm for the case group, and (2.47 ± 1.20) cm for the control group. Table 4 showed no significant difference either in the accuracy of the tip location ($\chi^2 = 1.40$, $p = 0.50$) or in the distance of the tip location ($t = -0.03$, $p = 0.98$) between the two groups. Figure 1 showed the position relationship between CICC and PICC.

Discussion

In this case-control study, we identified that the indwelling CICC had no effect on the stability of the ECG waveform or on the dynamic change in P-wave amplitude. To our knowledge, this was the first study to explore the effect of an indwelling CICC on the tip location of a PICC.

The P-wave in an ECG recording represents the depolarization wave of the atrium, and its morphological characteristics and amplitude are associated with the distance between the recording electrode and the synthetic axial vector of the atrium. In other words, when the catheter tip is implanted in the SVC and near the pacing point of the RA, a positive P-wave with a high amplitude appears. The amplitude of the P-wave increases with the depth of the catheter tip. When the tip reaches the CAJ, the P-wave shows a maximal peak. If the catheter tip continues to enter the RA, a bidirectional or negative P-wave occurs.[22–24] The technique of IC-ECG guidance is meant to determine the catheter tip location by the changes in the P-wave based on the conductivity of the guidewire, catheter, and blood. The sensitivity of this technique has been reported as high as 99.30%.[24] In our study, the accuracy of IC-ECG guidance was 95.00%, similar to the results of previous studies.[14–16] In addition, this technique has been reported to cause less anxiety and fewer procedure-related complications, to reduce the duration of catheter placement.[22,25–27]

In our study, the tip of the CICC was located in a fixed position in the SVC, so the CICC did not affect the dynamic changes of the P-wave amplitude. The P-wave amplitude only changed dynamically with the depth of the PICC tip. Therefore, the PICC tip could be accurately localized by observing the dynamic change in the P-wave amplitude for patients with an indwelling CICC. Because of the above, our study showed no significant difference in either the amplitude of the ideal P-wave ($t = 0.80$, $p = 0.43$) or the accuracy of the PICC tip location on chest X-ray ($\chi^2 = 1.40$, $p = 0.50$).

Additionally, the chest X-ray indicated that there was no entanglement of the CICC and PICC in the case group, and the ECG recordings also indicated no significant

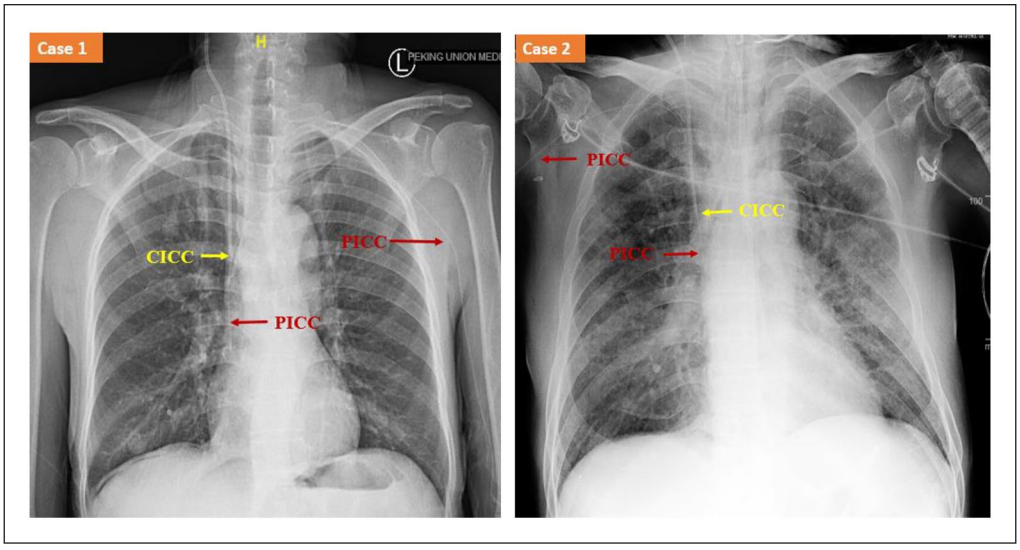

Figure 1. The position relationship between CICC and PICC.

difference in the stability of the waveform ($\chi^2 = 0.22$, $p = 0.64$). These results might be attributed to the anatomical structure and blood flow characteristics of the SCV. The diameter of the SVC can reach up to 20 mm, it has no venous valve, and the blood flow velocity can reach up to 2000–2500 ml/min.[28] This makes the PICC and CICC parallel in the SVC, with rare entanglements and tips that all point in the direction of the venous blood flow to the heart. In other words, the routing of the CICC in the SVC seems to have no effect on the routing of the PICC in the SVC.

Limitation

Our study is a single-center study with a small number of patients, which weakens the strength of our conclusion. Multicenter, large sample size studies will be carried out in the future.

Conclusion

The CICC was parallel to the PICC in the SVC, and the location of its tip was fixed and had no significant influence on the stability of the ECG waveform or the dynamic change of the P-wave amplitude. Our study indicated that the position of the PICC tip can be accurately localized by the dynamic changes of the P-wave amplitude for patients with an indwelling CICC.

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Author contributions

WYS: Conceptualization, methodology, data curation, writing–original draft. JQL: Methodology, formal analysis, writing–original draft. BL: Investigation, writing–original draft. YL, RBG, KW, JYZ: Investigation, visualization. XJW: Conceptualization, supervision, project administration.

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Ethical approval

This work was performed in accordance with the ethical standards of the Institutional Ethics Committee of Peking Union Medical College Hospital.

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References

1. Turcotte S, Dubé S and Beauchamp G. Peripherally inserted central venous catheters are not superior to central venous catheters in the acute care of surgical patients on the ward. *World J Surg* 2006; 30: 1605–1619.
2. Matsushima K and Frankel HL. Detection of central venous catheter insertion-related complication using bedside ultrasound: the CVC sono. *J Trauma Acute Care Surg* 2011; 70: 1561–1563.
3. Kooi TVD, Sax H, Pittet D, et al. Prevention of hospital infections by intervention and training (PROHIBIT): results of a pan-European cluster-randomized multicentre study to reduce central venous catheter-related bloodstream infections. *Intensive Care Med* 2018; 44: 48–60.

4. Chen W, Yang Y, Li H, et al. Adherence to Central-Line Insertion Practices (CLIP) with Peripherally Inserted Central Catheters (PICC) and Central Venous Catheters (CVC): a prospective study of 50 hospitals in China. *Infect Control Hosp Epidemiol* 2018; 39: 122–123.
5. Nicholson J. Royal college of nursing's standards for infusion therapy: an overview. *Br J Nurs* 2018; 27: S12–S14.
6. Kang J, Chen W, Sun W, et al. Peripherally inserted central catheter-related complications in cancer patients: a prospective study of over 50,000 catheter days. *J Vasc Access* 2017; 2: 153–157.
7. Gorski LA. The 2016 infusion therapy standards of practice. *Home Healthc Now* 2017; 35: 10–18.
8. Parienti JJ, Mongardon N, Megarbane B, et al. Intravascular complications of central venous catheterization by insertion site. *N Engl J Med* 2015; 373: 1220–1229.
9. Kai W, Sun W and Shi X. Upper extremity deep vein thrombosis after migration of peripherally inserted central catheter (PICC): a case report. *Medicine* 2017; 96: e9222.
10. Gapp J, Krishnan M, Ratnaraj F, et al. Cardiac arrhythmias resulting from a peripherally inserted central catheter: two cases and a review of the literature. *Cureus* 2017; 9(6): e1308.
11. Robertson JT, Schick RW, Morgan F, et al. Accurate placement of ventriculo-atrial shunt for hydrocephalus under electrocardiographic control. *J Neurosurg* 1961; 18: 255–257.
12. Liu G, Hou W, Zhou C, et al. Meta-analysis of intracavitary electrocardiogram guidance for peripherally inserted central catheter placement. *J Vasc Access* 2019; 6: 577–582.
13. Oliver G and Jones M. ECG-based PICC tip verification system: an evaluation 5 years on. *Br J Nurs* 2016; 25: S4–S10.
14. Elli S, Cannizzo L, Marini A, et al. Evaluation of tip location reliability of intraprocedural ECG vs. chest Xrays in PICC placement. *Assist Inferm Ric* 2016; 35: 174–179.
15. Ling Q, Chen H, Tang M, et al. Accuracy and safety study of intracavitary electrocardiographic guidance for peripherally inserted central catheter placement in neonates. *J Perinat Neonatal Nurs* 2019; 33: 89–95.
16. Rossetti F, Pittiruti M, Lamperti M, et al. The intracavitary ECG method for positioning the tip of central venous access devices in pediatric patients: results of an Italian multicenter study. *J Vasc Access* 2015; 16: 137–143.
17. Butts R. CNS led implementation of ECG Guided PICC placement technology decreases patient radiation exposure, nursing time and cost. *J Assoc Vasc Access* 2015; 20: 255.
18. Lowrie A, Kirmse J, Gana C, et al. Catch a wave: using Ecg waveform to confirm PICC tip location. *J Assoc Vasc Access* 2016; 21: 242.
19. Liu YJ, Dong L, Lou XP, et al. Evaluating ECG-aided tip localization of peripherally inserted central catheter in patients with cancer. *Int J Clin Exp Med* 2015; 8: 14127–14129.
20. Pittiruti M, La Greca A and Scoppettuolo G. The electrocardiographic method for positioning the tip of central venous catheters. *J Vasc Access* 2011; 12: 280–291.
21. Zhang X, Jia D, Ke N, et al. Excellent inter-observer agreement between radiologist and nurse: tracheal carina-based identification of peripherally inserted central catheter tip position. *J Vasc Access* 2018; 19: 28–33.
22. Santacruz E, Mateo-Lobo R, Vega-Pinero B, et al. Intracavitary electrocardiogram (IC-ECG) guidance for peripherally inserted central catheter (PICC) placement. *Nutr Hosp* 2018; 35: 1005–1008.
23. Zhou LJ, Xu H, Xu MF, et al. An accuracy study of the Intracavitary Electrocardiogram (IC-ECG) guided peripherally inserted central catheter tip placement among neonates. *Open Med* 2017; 12: 125–130.
24. Yin YX, Gao W, Li XY, et al. Insertion of peripherally inserted central catheters with intracavitary electrocardiogram guidance: a randomized multicenter study in China. *J Vasc Access* 2019; 20: 524–529.
25. Li A, Jiao J, Zhang Y, et al. 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. *Indian J Med Res* 2018; 147: 477–483.
26. Albertini F, Struglia M, Faraone V, et al. Effectiveness of the ECG method in the correct positioning of PICC type central venous catheters in patients with atrial fibrillation. *Minerva Cardioangiol* 2019; 67: 207–213.
27. Yuan L, Li R, Meng A, et al. Superior success rate of intracavitary electrocardiogram guidance for peripherally inserted central catheter placement in patients with cancer: A randomized open-label controlled multicenter study. *Plos One* 2017; 12: e171630.
28. Bennett WF, Altaf F and Deslauriers J. Anatomy of the superior vena cava and brachiocephalic veins. *Thorac Surg Clin* 2011; 21: 197–203.