Received: 14 October 2021 | Accepted: 12 November 2021

DOI: 10.1111/anec.12918

ORIGINAL ARTICLE

WILEY

Electrocardiographic localization of peripherally inserted central catheter tip position in critically ill patients with advanced cancer: An application study

Yong-Hong Chai[1] | Su-Ya Han[2] | Yu-Xin Zhu[3] | Jin-Jie Hou[4] | Xiao-Hui Guan[5] | Xin-Xin Yin[3] | Feng-Ying Zhang[5] | Qin-Zeng Qiao[6] | Ling-Min Han[7] | JiangHua Li[2]

[1]Department of Ultrasound, Hebei General Hospital For Veterans, Xingtai, China

[2]Department of Oncology, Hebei General Hospital For Veterans, Xingtai, China

[3]Ward II, Department of Oncology, Shijiazhuang People's Hospital, Shijiazhuang, China

[4]Department of Clinical Medicine, Xingtai Medical College, Xingtai, China

[5]Department of Nursing, Hebei General Hospital For Veterans, Xingtai, China

[6]Science and Education Division, Hebei General Hospital For Veterans, Xingtai, China

[7]Department of Geriatrics, Hebei General Hospital For Veterans, Xingtai, China

Correspondence
JiangHua Li, Department of Oncology, Hebei General Hospital For Veterans, No. 293 of Quannanxi Street, Qiaoxi District, Hebei Province, Xingtai 054000, China.
Email: lijianghua_ys@126.com

Funding information
This work was supported by the Fund Project of Xingtai Science and Technology of Hebei Province (No. 2018ZC125)

Abstract

Background: We compared the methods of electrocardiogram (ECG) and X-ray localization of the peripherally inserted central catheter (PICC) tip position, in order to find a more convenient, practical, and safe method.

Objective: To investigate the value of applying electrocardiographic localization of the PICC tip position in critically ill patients with advanced cancer in Hebei Province, China.

Method: Enrolled 137 advanced cancers requiring PICC placement. The position of the catheter tip was localized with the bedside electrocardiogram in real time. Then, the localization was performed using a chest X-ray (the gold standard). The accuracy of electrocardiographic location was checked.

Results: Specific P waves were observed in 130 patients. No change in the P waves was observed for the remaining seven patients. The age of the latter group of patients was more advanced (87.29 [5.15] years), a significant difference to that of the 130 patients with specific P waves (71.58 [14.84] years) ($t = -6.704$, $p < .001$). Specific P waves not only involve ascendance in P waves but also ascendance in QRS waves.

Conclusions: The use of an ECG to localize the PICC tip in critically ill patients with advanced cancer may replace the unnecessary use of chest X-rays. Specific P waves not only involve an increase in P waves but also an increase in QRS waves. If there is no change in the P wave, a chest X-ray film must be obtained. In elderly patients, because there is a possibility of catheter tip malposition, a comprehensive evaluation should be performed before surgery.

KEYWORDS
advanced cancer, application study, critically ill bedridden, electrocardiographic localization, peripherally inserted central catheter, tip position

Yong-Hong Chai and Su-Ya Han contributed equally to this study.

1 | INTRODUCTION

In China, clinical medical staff are unfamiliar with active intravenous therapy (WS/T 433-2013, 2013). For the selection of venous access for patients undergoing cancer chemotherapy, a peripheral venous indwelling needle is often used, and continuous peripheral venous infusion of chemotherapeutic drugs is performed. However, the peripheral veins are often severely damaged, which then affects the parenteral nutritional supportive treatment of patients in advanced stages; eventually, the use of central venous catheters, such as central venous catheter (CVC), peripherally inserted central catheter (PICC), and infusion ports, is required. PICC is a procedure that nursing staff can perform independently. The requirements in the Standard Operating Procedure for PICC (Chinese health industry standard WS/T 433-2013 Nursing Practice Standards for Intravenous Therapy; Monard et al., 2019) states that the length of the catheter delivered into the body is determined according to the length of a pre-placed catheter, as measured on the patient's body surface, before the position of the PICC tip is then determined by a chest X-ray; however, it does not mention that ECG can be used for localization. Critically ill, bedridden patients with advanced cancer are affected by severe conditions and a weak constitution—they are at constant risk and should neither move nor stand. The routine use of chest X-rays for localization has the disadvantages of long duration and being a cumbersome process.

At present, a comprehensive study on electrocardiographic localization of the PICC tip position has been initiated on a global scale (Barton, 2016; Capasso et al., 2018; Elli et al., 2016; Liu et al., 2019), the goal of which is to find a method that is safe, reliable, and accurate for clinical application, and for electrocardiographic localization to be considered as a PICC localization method in the American Infusion Therapy Standards of Practice (2016). In this study, we compared the methods of ECG and X-ray localization of the PICC tip position, in order to find a more convenient, practical, safe, and economical localization method for the PICC tip in critically ill, bedridden patients with advanced cancer, in China.

2 | METHODS

This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of our Hospital. Written informed consent was obtained from all participants.

This study involved three tertiary general hospitals in Hebei Province, China and included critically ill patients with advanced cancer, requiring PICC, from December 2018 to October 2019. The following inclusion criteria were used: (1) age ≥18 years; (2) patients diagnosed with advanced cancer, according to tumor-staging criteria; (3) critically ill patients who required Level I nursing or above, as determined by a combination of conditions and a self-care ability score of ≤40 points; (4) patients who were unable to undergo standing-position chest X-ray localization; (5) patients with upper limb venipuncture placement, based on the PICC; (6) surface ECG showed sinus rhythm; (7) informed consent was obtained for experimentation. Patients in whom the chest X-ray was not clearly visualized and patients with electrolyte abnormalities were excluded.

The necessary equipment included a 12-lead electrocardiograph (model: EDAN SE-1201, manufactured by Shenzhen Libang Precision Instruments Co. Ltd.), color ultrasound (model: BA50, manufactured by Shandong Baiduoan Medical Instrument Co. Ltd.), 4Fr end-opening and three-way valve PICC, Seldinger puncture sheath Ki, sterile alligator lead wire, and disposable sterile surgical bag.

2.1 | Surgical method

2.1.1 | 4Fr terminal opening and triaxial valve of PICC, Seldinger puncture kit

1. Each patient's surface ECG data were collected first: the patients remained quiet and the ECG wave patterns were clearly visible. The investigators checked whether the P waves of leads I, II, AVF, V_4, V_5, and V_6 were upright, with an upward sinus rhythm, then selected the patients with sinus rhythm and printed the first ECG—the surface ECG.
2. Catheterization process: the operator performed PICC puncture, according to the unified operating procedure, evaluated the venous vessels of the upper limb by ultrasound, and selected the elbow as the puncture point, before making a mark. Then, the operator measured the pre-placed catheter length on the body surface, placed the PICC under a maximum sterile barrier, using ultrasound guidance, and withdrew the blood slowly, after the delivery of the catheter to the premeasured length of 8 cm (predictive value of −8 cm). If the blood return was smooth, the following electrocardiographic localization process was performed.
3. Electrocardiographic localization process: the operator clamped one end of a sterile alligator lead wire to the intraductal supportive guide wire, gently pulling out the guide wire by approximately 0.2–0.3 cm to expose it. This was followed by the clipping of the metal tip of the limb lead, removed from the patient's right wrist at the other end, as well as filling the catheter with normal saline solution by injection, via the guide tube—good conductivity was obtained with normal saline and a supportive guide wire. The operator avoided touching the lead and asked each patient to be still. After waiting for the ECG wave pattern to be clear and stable, the operator continued to slowly deliver the catheter (at a rate of 1 cm each time) and carefully observed the change in the P-wave amplitude. When the P wave began to ascend, the operator continued to deliver the catheter (as the P wave continued to ascend, the QRS wave also began to ascend), until a negative q-wave pattern appeared at the initial portion of the P wave.

   At this point, the ascending P wave started to descend, the operator stopped the delivery and an intracavitary ECG was printed—the second ECG—the negative q-wave ECG. The operator slowly withdrew the catheter (still at a rate of 1 cm each

time) and closely observed the change in the P wave. When the negative q-wave pattern of the P wave disappeared, the amplitude of the P wave was at its highest and the amplitude of the ascending QRS wave changed correspondingly, indicating that the catheter tip had reached the most desirable position (at the Cavo-Atrial Junction [CAJ]). The wave at this point was termed the specific P wave. Here, the intracavitary ECG was printed and was the third ECG—the positioning ECG.

No change in the P wave or the QRS wave, meant the possibility of malposition was extremely high. In this instance, the operator withdrew the catheter to 15–20 cm and adjusted the method of delivery to redeliver the catheter, until the negative q wave of the P wave appeared. The other methods remained the same as before.

4. Chest X-ray localization: when the electrocardiographic localization was completed, the Radiology Department was notified and the mobile digital radiography (digital X-ray radiography system) machine was transferred to the ward for bedside supine chest X-ray localization. If no mobile X-ray equipment is available, a patient must be transported to the Radiology Department for supine chest X-ray localization, with constant monitoring of their condition during transport. The criteria for determining desirable positions for catheterization were the sixth to eighth thoracic vertebrae (i.e., T6 to T8), where T6 to T7 is equivalent to the middle and lower segments of the SVC and T8 is at the CAJ. In other words, in this current study, <T6 or >T8 was regarded as catheter malposition and T6 to T8 was the most desirable position.
5. Prompt treatment of catheter malposition: if the tip of PICC was not between T6 and T8, timely adjustments, according to the specific malposition and using strict aseptic conditions, were required.

2.2 | Method of analysis of electrocardiographic localization

1. Patients with sinus rhythm were selected by the first surface electrocardiogram.
2. In the second ECG, if a negative q waveform appeared at the initial portion of the P wave, it indicated that the catheter had just entered the right atrium (RA), beyond the CAJ, meaning that the catheter was placed too deep.
3. The third electrocardiogram was the final localization ECG, that is to say, the ECG with specific P waves. The operator measured the amplitude of the P wave and QRS wave and calculated the amplitude ratio of P wave to QRS wave. According to the multicenter study performed by Sun Hong et al, the position with an amplitude ratio of ascending P wave to QRS wave of 50%–80% was considered the most ideal catheter tip position (called specific P wave). A ratio of lower than 50% or higher than 80% was considered catheterization that was too shallow or too deep, respectively. In accordance with this, the current study divided the P/R ratio during the electrocardiographic localization into three categories according to size (P/R < 50%, 50% ≤ P/R ≤ 80% and P/R > 80%), for localization comparison.
4. If there was no change in the P wave of the ECG, there was no change in the QRS wave, which was consistent with the first surface ECG. If there was still no result after repeated adjustment of the catheter, the possibility of malposition was extremely high. Supine chest X-ray localization was performed as soon as possible. According to the X-ray visualization, if the catheterization was too shallow, the operator measured the length from the tip of catheter to the ideal position and then re-delivered the catheter by the measured length. If the catheter was incorrectly positioned in relation to the ipsilateral or contralateral internal jugular vein, axillary vein refold, or superior vena cava refold, withdrawing the catheter by 15–20 cm and re-adjusting the delivery method was required. The delivery was then slowly advanced until the X-ray film showed that the ideal position had been reached. If the catheter could not be advanced to the ideal position after repeated adjustments, the operator left only the tip of the catheter in the axillary vein and used it as a midline catheter.

2.3 | Statistical methods

SPSS 20.0 software was used for statistical analysis, the enumeration data were expressed as frequency (*n*) and percentage (%), the measurement data were expressed as the mean standard deviation and the mean values of the two samples were compared with *t* test.

3 | RESULTS

3.1 | General data for the study subjects

A total of 159 critically ill, bedridden patients with advanced cancer were hospitalized throughout the study, including 15 patients without sinus rhythm, three patients with the catheter placed at the femoral vein of the lower extremities, and four patients with unclear X-ray imaging. The final number of patients included in the study was 137: 90 males with a mean (SD) age of 71.01 [15.34] years and 47 females with a mean (SD) age of 75 [13.49] years. Participants included 34 cases of lung cancer, 29 cases of gastric cancer, 17 cases of esophageal cancer, 11 cases of pancreatic cancer, 10 cases of colon cancer, 8 cases of rectal cancer, 7 cases of liver cancer, 4 cases of brain tumor, 3 cases of prostate cancer, 3 cases of ovarian cancer, 2 cases of endometrial cancer, 2 cases of cervical cancer, and 7 cases of other types of cancer. The PICC type and inserted veins are shown in Table 1.

3.2 | Age comparison between two groups of patients with specific P waves vs. patients without change in the P wave

The mean (SD) age of the 130 patients with specific P waves was 71.58 [14.84] years and the mean (SD) age of the seven patients

TABLE 1 Basic PICC information ($n = 137$)

Classification	Category	Number of patients	Percentage
Catheter tip type	Opening	101	73.85
	Three-way valve	36	26.15
Placement in upper extremity	Upper left arm	36	23.85
	Right upper arm	100	75.38
	Right cubital fossa	1	0.77
Inserted vein	Basilic vein	86	64.61
	Median cubital vein	1	0.77
	Brachial vein	47	33.85
	Cephalic vein	3	0.77

TABLE 2 Age comparison of patients with specific P waves and patients without P-wave change ($\overline{X} \pm s$ years)

Specific P waves	Number of patients ($n = 137$)	Proportion (%)	Mean age	Standard deviation	*T* value	*p* Value
Yes	130	94.89	71.58	14.84	−6.704	<.001
No	7	5.11	87.29	5.15		

without a change in P waves was 87.29 [5.15] years. The age comparison between the two groups was performed using *t* test and the results are shown in Table 2.

3.3 | Basic P wave information as shown in the localization ECG

Among 137 subjects, 130 patients (94.89%) exhibited a specific P wave during electrocardiographic localization, including 14 patients with P/R <50%, 51 patients with 50% ≤ P/R ≤ 80%, and 65 patients with P/R >80%. A total of seven patients (5.11%) experienced no change in the P wave: three patients with the catheter tip at the SVC inlet, one patient with SVC refolding, one patient with internal jugular vein refolding, one patient with axillary vein refolding, and only one patient with the catheter delivered in place to the lower edge of the sixth thoracic vertebra.

3.4 | The consistency between localization with different specific P waves and chest X-ray localization

The consistency of P-wave localization and chest X-ray localization in 130 cases, with different specificity, is shown in Table 3.

3.5 | Comparison of electrocardiographic localization and X-ray localization

A comparison of electrocardiographic localization and X-ray localization in 137 critically ill, bedridden patients with advanced cancer is shown in Table 4.

4 | DISCUSSION

In the present study, electrocardiographic localization was used to localize the position of the PICC tip in critically ill, bedridden patients with advanced cancers. Compared to the gold standard method (localization by chest X-ray), the total accuracy of localization was 90.51% and the sensitivity was 99.16%. Therefore, it is feasible to localize the position of the PICC tip in critically ill, bedridden patients with advanced cancers, using electrocardiographic localization.

4.1 | Restatement of specific P waves in electrocardiograms

The specific P wave of the third ECG occurred when the catheter tip entered the SVC and reached the CAJ (Yin et al., 2019). At this point, it was closest to the sinoatrial node. The P-wave electrophysiological signal emitted by the sinoatrial node was directly obtained and the wave amplitude was high and sharp and more than 0.25 mv, because there was no attenuation. The P wave of the first surface ECG was obtained by conducting the sinoatrial node-emitted electrophysiological signals to the body surface. After attenuation occurred through the tissue, the electrophysiological signal was low and flat, and the P-wave amplitude did not exceed 0.25 mv. The criteria for determining when the catheter tip exceeded the CAJ and entered the RA were when the second electrocardiogram revealed a negative q-type P wave; the downward movement away from the sinoatrial node, and the opposition to the direction of sinoatrial node depolarization, resulted in the appearance of a negative wave at the initial portion of the P wave and a decrease in amplitude. Specific P waves possess dual functions, serving as criteria for placement and also assisting in PICC tip localization to reach the ideal position.

TABLE 3 The consistency between localization with three types of specific P waves and chest X-ray localization

Specific P waves		Chest X-ray (marked by thoracic vertebra)			
P/R	Number of patients (n)	<T6 (n_1)	T6–T8 (n_2)	>T8 (n_3)	Accuracy (%)
>80%	65	1	62	2	95.38
50%–80%	51	4	43	4	84.31
<50%	14	1	13	0	92.85
Total	130	6	118	6	90.76

TABLE 4 Comparison of electrocardiographic localization vs. X-ray localization (%)

Specific P waves	Number of patients (n)	Ideal position (n_1)	Malposition (n_2)	Accuracy (%)	Sensitivity (%)	Specificity (%)
Yes	130	118	12	124/137	118/119	6/18
No	7	1	6			
Total	137	119	22	90.51%	99.16%	33.33%

In a recent Chinese multicenter study, Sun Hong et al. considered that a P/R ratio between 50% and 80% indicated the most ideal catheter tip position and the wave were considered a specific P wave. This current study found that the localization accuracy of a P/R ratio between 50% and 80% was 84. 31%, the localization accuracy of a ratio <50% was 92. 85%, and the accuracy of a ratio >80% was 95. 38%. This means that as long as the negative q wave appeared among the P waves, and the specific P wave was the P wave when the catheter was withdrawn until the negative wave disappeared, then the catheter tip was considered to have reached the ideal position. The magnitude of the P/R ratio is related to individual patient differences and to the intensity of the electrophysiological signals emitted by the sinoatrial node in each patient. Less than 50% and more than 80% is not representative of a catheter that is too shallow or too deep and, therefore, a wave with a P/R ratio of 50%–80% should not be considered as a specific P wave.

4.2 | Significance of unchanged P wave

In the event of no change in the P wave, the possibility of catheter malposition is high, with an ectopic accuracy of 85.71%, but specificity was only 33.33%. When there is no change in the P wave, the operator should withdraw the catheter to adjust the delivery method, until a specific P wave appears. If there is no specific P wave after repeated adjustment, the operator should immediately perform chest X-ray localization. The operator should adjust the catheter, under chest X-ray guidance, according to the malposition. Therefore, the absence of change in P wave can serve as a criterion for judging catheter malposition.

The mean age of patients with unchanged P waves was significantly more advanced than that of patients with specific P waves ($t = -6.704$, $p < .001$). This indicates that the catheter tip did not enter the SVC and was far removed from the sinoatrial node, thus, the strong electrophysiological signal emitted by the sinoatrial node could not be obtained. The tip might have been incorrectly positioned at the internal jugular vein, axillary vein refold, SVC inlet, SVC refold, and other sites, all of which can be related to factors, such as weak P-wave ECG signal, long-term infusion, thrombosis, vascular variation, vascular destruction, and atresia in elderly patients.

4.3 | Importance of ascended QRS in electrocardiographic localization

At present, most electrocardiographic localization studies (Santacruz et al., 2018; Walker et al., 2015; Xu et al., 2018) only mention P-wave changes without involving the phenomenon of ascended QRS waves. However, the ascendance of P waves only indicates that the catheter tip enters the SVC and is close to the sinoatrial node. When the catheter tip continues to move toward the middle and lower part of the SVC, the phenomenon of ascended QRS wave also occurs, indicating that the catheter tip is close to the RA and receives the QRS wave, electrophysiological signal of ventricular depolarization, adjacent to the RA. Therefore, the occurrence of specific P waves must be accompanied by the ascendance of QRS waves. Simple P-wave ascendance without QRS wave change results in the position of the catheter tip being too shallow, even when the P/R ratio is high. For example, in this current study, there were three cases of simple P-wave ascendance, but the P/R ratio was 60%, 64.7%, and 100%, the catheter tip was at the upper edge of T5, T4, and T5, respectively, and the insertion of the catheter was too shallow. Of course, this is related to inaccurate prediction, absence of negative q wave in the P wave and a limited ECG interpretation level by catheterization technicians.

4.4 | Defects in X-ray localization in critically ill, bedridden patients with advanced cancers

The Chinese health industry standard WS/T 433-2013, Nursing Practice Standards for Intravenous Therapy, requires a chest X-ray

to be performed after the catheterization that occurs after PICC placement. It goes without saying that patients with advanced cancer are in a serious condition; whether it is transporting patients to the radiology department or asking radiology staff to push a mobile radiography machine to a specific location within the hospital, it is a cumbersome and slow process that is also affected by compromised patient safety. Catheterization technicians are subject to radiation injury and catheterization itself may even be carcinogenic (Pittiruti et al., 2012), as a result of the frequent exposure to X-rays as catheters are adjusted. Chest X-rays are taken when the critically ill patients are in the decubitus position and, occasionally, visualization remains unclear and the images cannot be interpreted, directly affecting the localization. The application of chest X-rays in the localization of PICC tips in critically ill, bedridden patients with advanced cancer has the disadvantages of cumbersome localization, time lag, and unclear visualization; however, it is currently still considered as the gold standard for localization of PICC tips in China. A safer, more reliable, and more accurate localization method, in real-time, is urgently needed to compensate for these shortcomings.

4.5 | Advantages of the electrocardiographic localization technique in critically ill, bedridden patients with advanced cancers

The conditions of critically ill, bedridden patients with advanced cancer are serious and, to avoid moving patients from place to place in the hospital, timely and accurate localization after catheterization is crucial. Electrocardiographic localization technology is advantageous, because there is no radiation injury, the localization is timely and can be completed bedside, and the localization is accurate and consistent with X-ray localization (sensitivity of 90.76% and specificity of 85.71%). Additionally, the electrocardiographic localization is performed when a patient is in the supine position for catheterization and their daily infusion position is also in the supine position. Thus, the 2-cm (Liu et al., 2019) margin of error caused by chest X-rays being taken in the standing position is circumvented and, subsequently, so is shallow positioning (due to relative retraction of the catheter by the descending diaphragmatic, when localization is performed at the positioning position).

A localized chest X-ray does provide irreplaceable data—if the catheter undergoes such phenomena as incorrect positioning and refolding, an ECG cannot be used to conclude anything about the specific situation and only inferences can be made. In this situation, it would be necessary to adjust the catheter that is not in the ideal position, according to a localized chest X-ray, so that the catheter runs smoothly into the vessel without bending and so that the tip position reaches the lower third of the SVC or the CAJ. The following revisions are recommended for the Chinese health industry standard WS/T 433-2013, Nursing Practice Standards for Intravenous Therapy: (1) for critically ill, bedridden patients, an ECG has a specific P wave, the delivery process is smooth and it can be used for localization in non-elderly patients and, (2) if there is no change in the ECG, it is difficult to deliver the catheter and the catheter will not reach the predicted length. In this instance, a chest X-ray should be performed to gather additional data and the catheter should be adjusted in a timely fashion, according to its specific malposition. Studies have shown that electrocardiographic localization of PICC is safe, accurate, and occurs in real-time; moreover, if the catheter tip is adjusted to the optimal position by ECG, it may not be necessary to perform additional chest X-rays. Therefore, it is recommended that Chinese health industry standards be amended so that they are in accordance with international standards.

5 | CONCLUSION

Placement of PICCs in critically ill, bedridden patients with advanced cancer allows real-time and accurate bedside electrocardiographic localization, so that the catheter tip reaches the ideal position, without the need for further chest X-ray localization. Specific P waves are not only ascended P waves, but also ascended QRS waves, regardless of the magnitude of P/R values. The proportion of ECG without change were very low, mostly in elderly patients and a comprehensive evaluation was performed before catheterization, such as the presence or absence of long-term infusion, thrombosis, and vascular atresia, so as to prevent the malposition of the catheter. If there is no change in the electrocardiogram, a chest X-ray must be performed to determine the specific malposition. A revision to the provision of the single use of X-ray localization with PICC is recommended for the Chinese health industry standards, particularly in the adoption of electrocardiographic localization in critically ill, bedridden patients.

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

AUTHOR CONTRIBUTIONS

Conception and design: Chai Y-H and Han S-Y. Administrative support: Zhu Y-X and Hou J-J. Provision of study materials or patients: Guan X-H andYin X-X. Collection and assembly of data: Zhang F-Y and Qiao Q-Z. Data analysis and interpretation: Han L-M. Manuscript writing: All authors. Final approval of manuscript: All authors.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was conducted in accordance with the declaration of Helsinki. This study was conducted with approval from the Ethics Committee of Hebei General Hospital For Veterans. Written informed consent was obtained from all participants.

CONSENT FOR PUBLICATION

The manuscript is not submitted for publication or consideration elsewhere.

DATA AVAILABILITY STATEMENT

All data generated or analyzed during this study are included in this published article.

ORCID

JiangHua Li https://orcid.org/0000-0002-8733-9247

REFERENCES

Barton, A. (2016). Confirming PICC tip position during insertion with real-time information. *The British Journal of Nursing*, *25*(Suppl 2), S17–S21.

Capasso, A., Mastroianni, R., Passariello, A., Palma, M., Messina, F., Ansalone, A., Bernardo, I., Brescia, D., Crispino, F., Grassia, C., Romano, A., & Ausanio, G. (2018). The intracavitary electrocardiography method for positioning the tip of epicutaneous cava catheter in neonates: Pilot study. *The Journal of Vascular Access*, *19*, 542–547. https://doi.org/10.1177/1129729818761292

Elli, S., Cannizzo, L., Marini, A., Porcarelli, S., Azzarone, F., Fumagalli, R., Foti, G., Lucchini, A. (2016). Evaluation of tip location reliability of intraprocedural ECG vs. chest X-rays in PICC placement. *Assistenza Infermieristica e Ricerca*, *35*, 174–179. https://doi.org/10.1702/2621.26950

Liu, G., Hou, W. B., Zhou, C., Yin, Y. X., Lu, S. T., Duan, C. H., Li, M., Toft, E. S., & Zhang, H. J. (2019). Meta-analysis of intracavitary electrocardiogram guidance for peripherally inserted central catheter placement. *The Journal of Vascular Access*, *20*, 577–582. https://doi.org/10.1177/1129729819826028

Monard, C., Lefèvre, M., Subtil, F., Piriou, V., & David, J. S. (2019). Peripherally inserted central catheter with intracavitary electrocardiogram guidance: Malposition risk factors and indications for post-procedural control. *The Journal of Vascular Access*, *20*, 128–133. https://doi.org/10.1177/1129729818781266

Pittiruti, M., Bertollo, D., Briglia, E., Buononato, M., Capozzoli, G., De Simone, L., La Greca, A., Pelagatti, C., & Sette, P. (2012). The intracavitary ECG method for positioning the tip of central venous catheters: Results of an Italian multicenter study. *The Journal of Vascular Access*, *13*, 357–365. https://doi.org/10.5301/JVA.2012.9020

Santacruz, E., Mateo-Lobo, R., Vega-Piñero, B., Riveiro, J., Lomba, G., Sabido, R., Carabaña, F., & Botella Carretero, J. I. (2018). Intracavitary electrocardiogram (IC-ECG) guidance for peripherally inserted central catheter (PICC) placement. *Nutricion Hospitalaria*, *35*, 1005–1008. https://doi.org/10.20960/nh.1847

Walker, G., Chan, R. J., Alexandrou, E., Joan, W., & Rickard, C. (2015). Effectiveness of electrocardiographic guidance in CVAD tip placement. *The British Journal of Nursing*, *24*, S4, S6, S8–S12. https://doi.org/10.12968/bjon.2015.24.Sup14.S4

WS/T 433-2013 (2013). Nursing Practice Standards for Intravenous Therapy. Beijing: China Standard Press.

Xu, X. S., Zhang, L. A., Sun, Q. F., Qin, Y. C., & Yu, N. L. (2018). Estimation of the occupational exposure dose for medical diagnostic X-ray workers in Jiangsu, China, using a retrospective dosimetry method. *Journal of Radiation Research*, *59*, 141–148. https://doi.org/10.1093/jrr/rrx073

Yin, Y. X., Gao, W., Li, X. Y., Lu, W., Deng, Q. H., Zhao, C. Y., Liu, X.-R., Zhou, C., Hou, W.-B., Lu, S.-T., Liu, G., Wang, L.-N., Li, M.-Q., & Zhang, H.-J. (2019). Insertion of peripherally inserted central catheters with intracavitary electrocardiogram guidance: A randomized multicenter study in China. *The Journal of Vascular Access*, *20*, 524–529. https://doi.org/10.1177/1129729818819732

How to cite this article: Chai, Y.-H., Han, S.-Y., Zhu, Y.-X., Hou, J.-J., Guan, X.-H., Yin, X.-X., Zhang, F.-Y., Qiao, Q.-Z., Han, L.-M., & Li, J. (2021). Electrocardiographic localization of peripherally inserted central catheter tip position in critically ill patients with advanced cancer: An application study. *Annals of Noninvasive Electrocardiology*, 27, e12918. https://doi.org/10.1111/anec.12918