


Intracavitary electrocardiography for femorally inserted central catheter tip location in adult patients

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Abstract

Background: In this study, the intracavitary electrocardiogram (ECG) P-wave and QRS-wave changes during femorally inserted central catheter (FICC) placement in adults were observed with the aim of reducing malposition occurrence. The observed method provides venous access in patients who have limited upper limb venous catheterization potential and require medium-term and long-term infusions.

Methods: A retrospective analysis of 34 adult patients who underwent FICC placement was conducted. After body surface measurements were taken, all patients were connected to an ECG during catheter placement, and the P-wave and QRS-wave changes were observed. Next, the catheter tip position was confirmed with an abdominal X-ray, and an analysis of the changes occurring during the procedure was conducted.

Results: In the 34 patients included in the present study, the catheter tips were located below the diaphragm level in the inferior vena cava. Of the patients, 18 showed negative P waves, biphasic P waves, and positive high-amplitude P waves with increasing the insertion depth. In 16 patients, no P-wave characteristic changes were observed during catheterization, and an abdominal X-ray confirmed that the catheter tip was positioned below the level of the first lumbar vertebra.

Conclusion: Negative P waves, biphasic P waves, and positive high-amplitude P waves appeared during FICC placement in adults. Catheter withdrawal until the P wave reverted to normal indicated that a tip position close to the inferior vena cava above the diaphragm level was ideal.

KEYWORDS

electrocardiogram localization, FICC, P wave, QRS wave, veins of lower limbs

1 | INTRODUCTION

In current clinical practice, peripherally inserted central catheters (PICCs) are usually introduced via the upper arm in adults (Cho et al., 2018). However, it is difficult to establish a venous access in the

upper limb veins in certain patients, such as patients with advanced lung cancer and superior vena cava compression, upper limb flexion, upper limb burn, along with certain patients with aggravated illnesses who require multiple venous accesses. In these cases, medicinal solutions are usually administered via lower limb veins.

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Traditional femoral vein catheters are limited in length; the tip is usually located in the lower part of the common iliac vein or inferior vena cava, and the puncture site is located in the groin area. This limits lower limb movement, leaving the site prone to infection, thrombosis, and other complications. However, the catheter body-indwelling duration is short; thus, it cannot meet the needs of patients who require long-term infusion treatment. In the past, femorally inserted central catheter (FICC) insertion via the lower limb vein was a method commonly used in newborns (Erhard et al., 2017; Uygun, 2016). In recent years, several researchers have also performed PICC placement via lower limb veins, such as the superficial femoral vein (located at mid-thigh) and the great saphenous vein, in adults (Wan et al., 2018; Zhao et al., 2018). This method provides venous access in patients with limited upper limb catheterization potential who require medium-term and long-term infusions. Traditionally, abdominal X-rays are used to locate the tip of the catheter inserted through the lower limbs, but it is difficult to identify malpositioned catheters during catheterization by abdominal X-rays. When the catheter placement is too shallow, the tip can bend back easily to the iliac vein or become malpositioned to the liver, kidney, and other veins; conversely, when the catheter is placed too deep, the tip can easily enter the right atrium, resulting in a series of complications, such as arrhythmia.

The 2021 version of the American INS practice standard recommends that the central venous catheter tip should be located above the diaphragm level in the inferior vena cava when catheter is inserted via lower limb veins (Gorski et al. 2021). The current method for PICC tip positioning via upper limb veins uses changes in the intracavitary electrocardiogram (ECG) P-wave characteristics for tip-positioning guidance during catheter placement (Li et al., 2018). Several researchers have applied this method in neonatal patients and found that P-wave and QRS-wave amplitude changes can effectively monitor whether the tip is malpositioned during catheter insertion (Zhou et al., 2017). However, few studies have been conducted on the use of ECG for FICC tip location in adults. Therefore, in the present study, 34 adult patients who received FICC placement with intracavitary ECG (IC-ECG) tip location were retrospectively analyzed, and the results summarized, in order to explore ECG changes during FICC insertion.

2 | MATERIALS AND METHODS

2.1 | Patient enrollment

This study retrospectively analyzed 34 adult patients who required FICC insertion after a PICC team evaluation in a third-class hospital in Shijiazhuang between January 2016 and January 2020. Clinical data and records relating to FICC placement were consulted, and the length of the catheter estimated on the basis of surface landmarks. Patients were connected to an ECG during FICC insertion to allow P-wave and QRS-wave change observation. The data were collected during the ECG and subsequently retained. Following

insertion, abdominal X-rays were used to locate the catheter tip. The inclusion criteria were as follows: (A) patients who required intravenous chemotherapy drug infusion, parenteral nutrition solution, or other irritant drugs due to their illness and peripheral blood vessel limitation; (B) with diseases complicated by superior vena cava compression, upper limb flexion, upper limb skin injury, etc., for whom PICC insertion via upper limb veins was deemed unsuitable after a PICC team evaluation; (C) with a normal body surface ECG, normal P waves, and no heart disease; (D) with no skin damage at the puncture site; (E) and patients provided their informed consent. The exclusion criteria were as follows: (A) patients with a definite heart disease, such as atrial fibrillation, atrial flutter, and pulmonary heart disease; (B) patients with an abnormal basic body surface ECG P waves; (C) patients equipped with cardiac pacemakers, implantable defibrillators, etc.; and (D) patients who did not provide their informed consent. The present research was approved by the hospital ethics committee.

2.2 | FICC insertion

Suitably qualified PICC specialist nurses were involved in the placement procedures, and the catheter placements were made in accordance with the standardized PICC operation method. The specific procedure was as follows: (A) the patient's case was reviewed and his/her basic body surface ECG was observed and recorded. The patient adopted the supine position, with the lower limb abduction on the puncture side forming a 45° angle with the longitudinal trunk axis; (B) ultrasound was used for the observation of the positional relationship between the femoral artery and the superficial femoral vein. The artery and vein positions were adjusted up/down and left/right by puncture-side limb abduction and internal rotation in order to avoid bleeding and hematoma caused by accidental femoral artery penetration (Wan et al., 2018); (C) all catheters were inserted via superficial femoral vein puncture approximately 5–10 cm below the inguinal groove (Zhu et al., 2019); (D) the present PICC length was measured according to the body surface from the pre-puncture point along the vein to the midpoint of the groin, from the midpoint of the groin to navel, and from the navel to the xiphoid cartilage (Zhao et al., 2018; Zhu et al., 2019). The length of these sections was used as the preset catheter length. Leg circumference was measured and recorded on both sides; (E) the skin was disinfected, and a surgical towel was applied. The pre-puncture point was considered the center for skin disinfection, which was conducted with 75% alcohol and iodophor with an effective iodine concentration of $\geq 0.5\%$. The disinfection process was performed three times on each patient to establish a maximally sterile barrier; and (F) the puncture was made under ultrasound guidance using a modified Seldinger technique. The puncture angle was adjusted according to the superficial femoral vein depth at the puncture site. Following successful puncture, the angle was reduced, and the guide wire was inserted into the introduction sheath after the skin expanded. Next, the catheter was introduced. The ECG limb leads were connected when the tip of the

FIGURE 1 The P wave was negative

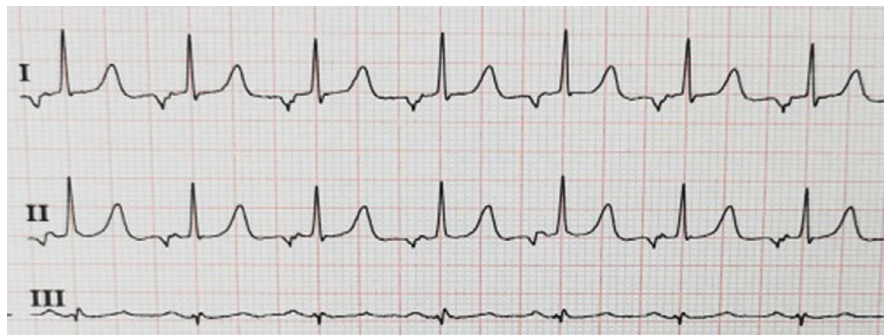
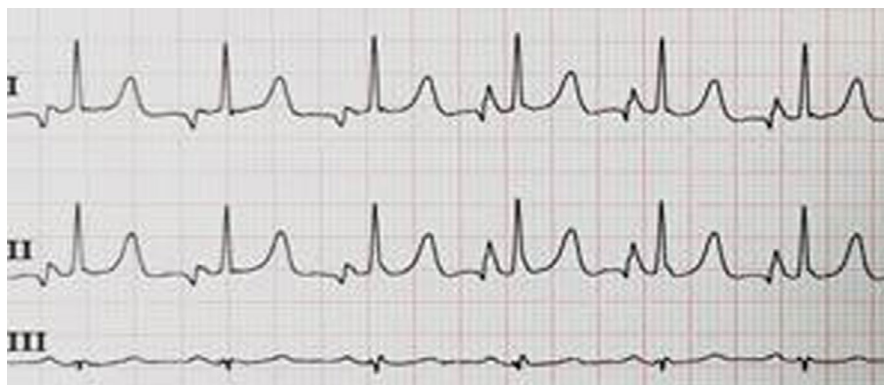


FIGURE 2 The P wave was biphasic



catheter approached the preset length. One end of the lead wire was connected with an aseptic clamp fastened to the end of the PICC stylet, and the other end was connected to the ECG right upper limb red electrode in order to provide an intravenous ECG output. A sterile syringe was used to extract 20 ml of physiological saline, and the catheter was connected for injection. ECG P-wave and QRS-wave amplitude changes were observed, and the ECG was printed. Following insertion, the guide wire was withdrawn, and the catheter was flushed with normal saline. An adapter connector was used in order to lock the catheter with positive pressure. The catheter was then secured with a transparent membrane and fixed with tapes. The entire catheter insertion process was recorded, and an abdominal X-ray was obtained from each patient. Finally, the position of the tip in relationship with the vertebral bodies was assessed and recorded in accordance with the X-ray results.

2.3 | Observation index

2.3.1 | Abdominal X-ray and the changes of P wave and QRS wave

The inferior vena cava above the diaphragm is the optimum location for the FICC tip position (Gorski et al. 2021). Based on the abdominal X-ray results, the vena cava diaphragm hiatus is nearly at the level of the 9th thoracic vertebra. The inferior caval-atrial junction was identified by abdominal X-ray (Xu et al., 2018). The catheter tip position was determined by a professional medical imaging physician and the FICC operator. A tip position above the junction of the inferior vena

cava and the right atrium is considered too deep, while a position in the inferior vena cava below the diaphragm level is considered too shallow. Tip malposition occurs when the FICC tip is located outside the inferior vena cava following catheter insertion. This study needs to collect the relevant data of abdominal X-ray and the changes of P wave and QRS wave.

2.4 | Statistical analysis

We used the software program SPSS 21.0 (IBM, Chicago, USA) to conduct the statistical analysis. The continuous variables of normal distribution were expressed as mean \pm standard deviation and the categorical variables were expressed as frequency (percentage [%]). For two comparisons, each value was compared using t-test when each datum conformed to normal distribution, while the non-normally distributed continuous data were compared using non-parametric tests. The counting data were tested by Chi-square test. A value of $p < .05$ was considered statistically significant.

3 | RESULTS

3.1 | General and disease data

This study retrospectively analyzed 34 adult patients (14 male and 20 female) who underwent FICC insertion. The patients had an average age of 68.85 ± 14.15 years. A total of 24 patients underwent implantation via right lower limb veins, and 10 patients via left lower limb veins.

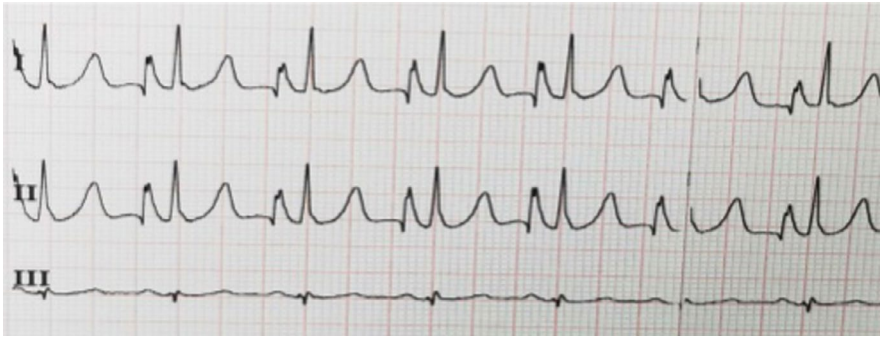


FIGURE 3 The P wave was positive

Among the patients, 10 had lung cancer complicated with superior vena cava compression, 1 had esophageal cancer complicated with superior vena cava compression, 5 had breast cancer complicated with superior vena cava compression, 7 had severe pneumonia and lung infection, 1 had lung metastasis of colon cancer, 2 had parotid cancer, 2 had pancreatic cancer, and 1 had burn injuries on both upper limbs. The average length of the inserted catheter was 41.68 ± 5.68 cm.

3.2 | Abdominal X-ray results and ECG waveform changes

Each patient underwent an abdominal X-ray in order to locate the catheter tip. The results showed that the tips were located in the inferior vena cava below the diaphragm level. There was no occurrence of a primary malpositioned catheter tip. In 18 cases, the P-wave morphology changed, forming a negative wave (Figure 1), a biphasic wave (Figure 2), and a positive high-amplitude P wave (Figure 3). The abdominal X-rays showed the catheter tips at the 11th-12th thoracic vertebrae levels. No P-wave characteristic changes were observed during catheter insertion in the other 16 patients, and the abdominal X-rays showed the catheter tips below the first lumbar vertebra.

4 | DISCUSSION

4.1 | The tip positions of PICCs implanted via lower limb veins in adult patients and associated ECG changes

Malpositioned tip, deep and shallow catheter tip can directly lead to complications, such as venous thrombosis, arrhythmia, and pericardial tamponade (Zhang et al., 2014). In such cases, the catheter position should be readjusted. A characteristic high-amplitude P wave indicates that the catheter tip has traveled through the right atrium from the inferior vena cava to the junction of the superior vena cava and the right atrium. This suggests that the catheter tip was positioned too deep. The catheter was withdrawn until the P waves became consistent with the body surface ECG, indicating that the catheter tip was in the upper part of the inferior vena cava and did not enter the right atrium (Zhou et al., 2017; Weber et al., 2020).

The results of this study revealed that all the FICC tips inserted into adult patients were located below the diaphragm in the inferior vena cava. Negative, Biphasic, and high-amplitude P waves did not appear in 47.1% of the patients during the FICC insertion procedure. An abdominal X-ray revealed that the FICC tips were located in the inferior vena cava, far from the diaphragm. This may be due to the FICCs' limitations of being cut primarily at the front end as well as the large landmark measurement error, which often led to the catheter length being too short. Furthermore, as the adult inferior vena cava is longer than the superior vena cava, the catheter tip may not have reached the inferior vena cava above the diaphragm and the right atrium even if all the cut catheters were inserted. Therefore, there were no changes in the P-wave characteristics.

During FICC insertion in the remaining 52.9% of the patients, negative and biphasic P waves, and positive high-amplitude P waves appeared in the patient ECGs. Abdominal X-rays showed that, although the tip of the catheter was located in the inferior vena cava below the diaphragm, it was close to the diaphragm level. Although abdominal X-rays revealed no malpositioned tips in any patients, and the tips were all confirmed to be located in the inferior vena cava, the changes in the P-wave shapes and amplitudes revealed that the tip positions were close to the caval-atrial junction. Though there were no data supporting, the QRS seems to increase in amplitude while approaching the heart. This was an interesting trend.

This study found that intracavitary ECG technology can assist the positioning of PICC tips inserted via the lower limb veins in adult patients. This finding is significant in terms of providing greater clinical guidance for this procedure. Traditional PICC tip positioning uses abdominal X-rays after catheter insertion. If the tip is malpositioned after insertion, readjustment is necessary. This introduces the risk of infection and adjustment failure. The use of ECGs for procedure guidance is significant for preventing tip malposition and achieving proper positioning during FICC insertion in adult patients.

The main limitation of this study was that limited by the technical and equipment conditions, our hospital uses abdominal X-ray for positioning, not subcostal ultrasound, which was also the way adopted by many hospitals in China. Furthermore, sample size expansion in any future research is necessary. Limited by the technical and equipment conditions, our hospital uses abdominal X-ray for positioning, which is also the way adopted by many hospitals in China.

5 | CONCLUSION

This study preliminarily explored the use of ECGs during FICC insertion in adult patients. This method is simple and economical to operate and harmless to the patients. Furthermore, the FICC tips can be positioned quickly. Thus, the method is worthy of further promotion and application.

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Not applicable.

CONFLICT OF INTEREST

None.

AUTHOR CONTRIBUTIONS

YF Duan has made substantial contributions to conception and design; YX Zhu, X Zhao, and XX Yin: acquisition of data, analysis, and interpretation of data; YF Duan and XY Hu have been involved in drafting the manuscript and revising it critically for important intellectual content; HM Zhang and Y Wang have given final approval of the version to be published.

ETHICAL APPROVAL

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

CONSENT FOR PUBLICATION

Not applicable.

DATA AVAILABILITY STATEMENT

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

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