
Analysis on P Wave Morphology for PICC Placement Guided by Intracardiacelectrogram in Chinese Elderly Patients

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Abstract: Objective: PICC can effectively protect upper extremity veins. It can reduce repetitive puncture and the incidence of phlebitis, relieve the pain, and improve the quality of life for those with long-term intravenous infusion, repeated infusion of stimulant drugs and blood products, and poor peripheral superficial vein conditions etc.. Successful PICC tip positioning can effectively avoid catheter-related complications during clinical care. If the catheter tip is misplaced, it may cause malfunction and related complications, such as venous thrombosis, bacteremia, arrhythmia, and heart valve injury etc. To investigate the correlation and clinical significance of monitoring P-wave characteristics, especially the occurrence of double peaks for precise tip positioning of peripherally inserted central catheter (PICC) guided by intracardiacelectrogram (IEGM). Methods: Enrolled 116 PICC patients (age \geq 60, no heart diseases) in our hospital. Conducted retrospective analysis on patients' medical records, PICC catheterization data, IEGM-guided positioning records and nursing records. Observed and recorded patients' P-wave changes (peaked P wave, bi-directional P wave and double-peaked P wave) at different catheter tip positions by real-time IEGM, and then analyzed the case number and positioning accuracy. Used chest X-ray to determine whether the catheter tip had reached the ideal position, the tracheal carina to the cavo-atrial junction (CAJ). Results: Among 116 patients (63 males, 53 females), bidirectional P waves were detected in 112 of them (96.55%) in ECG Lead II; 63 with peaked P waves (53.3%); 49 with double-peaked P waves but no peaked P waves (42.2%), meaning bidirectional P waves were seen when fed in the catheter and returned to double peaks when the catheter was withdrawn; 4 with no significant changes (3.4%). Chest X-ray proved that 49 of 49 cases with double-peaked P waves reached the ideal catheterization position (100% in accuracy), and 43 of 69 cases with peaked P waves succeeded as well (68.2% in accuracy). Conclusions: Double-peaked P waves in IEGM-guided PICC positioning for elderly patients can be considered as an indicator of the catheter tip entering the CAJ and supplementary support of peaked P wave and bidirectional P wave guidance for catheterization.

Keywords: Peripherally Inserted Central Catheter (PICC), Intracardiacelectrogram (IEGM), P Wave Morphology, Double-peaked P Wave, Peaked P Wave

1. Background

PICC can effectively protect upper extremity veins. It can reduce repetitive puncture and the incidence of phlebitis, relieve the pain, and improve the quality of life for those with long-term intravenous infusion, repeated infusion of stimulant

drugs and blood products, and poor peripheral superficial vein conditions etc.. Successful PICC tip positioning can effectively avoid catheter-related complications during clinical care. If the catheter tip is misplaced, it may cause

malfunction and related complications, such as venous thrombosis, bacteremia, arrhythmia, and heart valve injury etc. [1-3]. Chest X-ray used to be the most commonly used method to confirm the position of the PICC tip, regarded as the Gold Standard [4]. However, it has its limitations. For example, it cannot be used for real-time positioning so it may require reposition if the initial point is found to be incorrect by later examination, which will delay the treatment, increase the risk of complications and medical costs. IEGM now becomes another primary method to guide PICC catheterization based on the changes of P waves [5-6]. It can be used as a real-time monitor to determine whether the catheter tip has successfully reached the ideal position in superior vena cava (SVC) [7]. IEGM technology has been widely studied and applied at home and abroad because of its safety and accuracy. However, guide wire-detected electrocardiogram (ECG) is easily interfered by various factors so it requires additional support for tip positioning if peaked P waves and bidirectional P waves are not 100% induced in clinical practice. Retrospective study has conducted on 116 cases of elderly patients with IEGM-guided PICC catheterization to determine the frequency of double-peaked P waves and its clinical significance for tip positioning.

2. Data and Methods

2.1. Data

Clinical data were collected from 116 PICC elderly patients in our department (from August 2019 to August 2020) with 63 males (54.31%) and 53 females (45.68%), average height 157.02 ± 9.60 cm and normal P wave duration 0.11 ± 0.04 s. Diagnosis: 12 cases of pneumonia, 11 cases of cerebral infarction, 6 cases of intracranial infection, 8 cases of gastric cancer, 28 cases of colon cancer, 6 cases of liver cancer, 5 cases of esophageal cancer, 5 cases of ovarian cancer, and 38 cases with other diseases. Retrospective analysis was conducted on patients' medical records, including demographic characteristics, disease conditions, PICC catheterization data, IEGM-guided positioning records and nursing records. Inclusion criteria: 1) patients who required PICC catheterization and aged ≥ 60 years old; 2) patients with normal ECG and P wave, and no heart diseases; 3) patients with good upper limbs function, and no skin damage at the puncture site; 4) patients and their families were informed about this study and signed an informed consent form.

Exclusion criteria: patients with heart diseases such as arrhythmia, pulmonary heart disease, P wave abnormality, installed pacemaker and implantable defibrillator, etc..

2.2. Materials

Site~Rite V ultrasound system and tool kit for PICC (BARD), PICC catheter and introducer (BARD), Multi-parameter ECG monitor (Uyound Company), sterile

alligator clip guided wires.

2.3. Methods

PICC was placed with ultrasound-guided modified Seldinger technique following the operating standards. The catheterization was monitored by IEGM that the PICC catheter's built-in guide wire was connected to the electrode of an ECG monitor through an alligator clip to observe the changes of the P waves at different catheter tip positions and compared that with the initial records. In order to obtain clear positive P waves, the catheter guide wire was on RA Lead, and the monitor was on Lead II. Printed and recorded the changes of P waves in lead II to determine whether the catheter tip had reached the ideal position (the tracheal carina to CAJ) [4]. Chest X-ray was conducted to reconfirm the tip position.

2.4. Outcome Measures

Cases with characteristic P wave changes (peaked P wave, bidirectional P wave and double-peaked P wave) and the accuracy of PICC positioning.

3. Results

3.1. General

Catheterization in 116 patients was all successfully completed under IEGM monitoring and confirmed by chest X-ray. Most cases reached the ideal position with few exceptions that entered the right atrium. No related complications (bleeding etc.) and displacement were found.

3.2. Changes of P Waves in IEGM

Among 116 cases, bidirectional P waves were detected in 112 of them (96.55%) in ECG lead II; 63 with peaked P waves (53.3%); 49 with double-peaked P waves but no peaked P waves (42.2%), meaning bidirectional P waves were seen when fed in the catheter and returned to double peaks when the catheter was withdrawn for 2-3cm; 4 with no significant changes (3.4%).

3.3. Accuracy of Tip Positioning When Having Double-peaked P Waves and Peaked P Waves

Took the ideal position (the tracheal carina to CAJ, lower SVC) as the standard distance and compared the actual distance measured in chest X-ray when having double-peaked P waves and peaked P waves in ECG with that to evaluate the accuracy of tip positioning. Results showed that 49 of 49 cases with double-peaked P waves reached the ideal position (100% in accuracy), and 43 of 69 cases with peaked P waves succeeded as well (68.2% in accuracy) while other 20 cases entered the right atrium when detecting peaked P waves. Statistical analysis on the ratios of P/QRS amplitude showed $P > 0.05$, indicating no statistical significance, see Table 1.

Table 1. Related factors on double-peaked P wave and peaked P wave.

P wave	Case (n)	Age	Gender [(n) %]		Catheterization position [(n) %]		Ratio (%)
			Male	Female	Left	Right	
Double-peaked	49	73.71±9.45	25 (51.0)	24 (49.0)	33 (67.3)	16 (32.7)	32.86±7.91
Peaked	63	70.62±8.90	38 (60.3)	25 (39.7)	30 (47.6)	33 (52.4)	30.79±7.03
<i>P</i>		0.078	0.325		0.037		0.139

4. Discussion

4.1. Principle of IEGM-guided PICC

P waves are basically graphic representations of the heart muscle’s atrial depolarization, and its morphology and amplitude depend on the distance and relative position between the electrode and the atrial integrated vector axis. A high-amplitude upward P wave can be seen on the ECG when the catheter reaches the pacemaker of the right atrium and it disappears once it is withdrawn. Therefore, the potential height and changes of P waves can clearly reflect the tip position [8-9].

4.2. Significance of IEGM-guided PICC

IEGM plays a crucial role in improving the accuracy of PICC positioning. Misplacement may cause malfunction and complications, such as venous thrombosis, arrhythmia, heart valve dysfunction and heart chamber damage etc.. Chest X-ray is one of the most commonly used method to confirm the position of the PICC tip, but more and more studies have shown that real-time position monitoring provided by IEGM can serve the same function or even more effective. Also, it has been proved to be a helpful and promising method to improve the success rate of neonate PICC catheterization as no obvious complication was found in the studies [10]. In general, IEGM-guided PICC has obvious advantages and feasibility in terms of accuracy improvement: patients are not exposed to any radiation; it is easy to perform and provides real-time information of the tip position; it does not delay the time for patients to receive intravenous infusion therapy [7, 11-13].

4.3. Existing studies of IEGM-guided PICC

Existing studies have shown that when the catheter tip entered the middle and lower segment of the SVC, peaked P waves appeared, and when entered the right atrium, bidirectional P waves appeared among which the CAJ is considered as the most ideal tip position. When the catheter tip reaches the entrance of the atrium, a significant increase in P wave amplitude can be seen on the IEGM through infusing normal saline in the catheter. Researchers like Pittiruti conducted a multi-center prospective study, showing that 95.15% PICC cases guided by IEGM in the study reached the ideal position (lower 1/3 SVC to the CAJ) except those with no P waves on ECG, no sinus rhythm, atrial fibrillation or a pacemaker [6]. Similar study was conducted among elderly patients over 60 years old here, which had 96.55% cases with bidirectional P waves, 53.3% with peaked P waves, 42.2%

with double-peaked P waves, and 3.4% with no significant changes, suggesting that double-peaked P wave can be an indicator of the tip reaching the ideal position, confirmed by chest X-ray.

4.4. P Wave Morphology Has Great Significance in Assisting IEGM-guided PICC Catheterization

However, guide wire-detected ECG is easily interfered by various factors so additional support is required for tip positioning if peaked P waves and bidirectional P waves are not 100% induced in clinical practice. P wave is an atrial depolarization wave so a high-amplitude upward P wave will appear on the IEGM when the probe reaches the right atrium pacemaker and disappear when it leaves. Its morphology and amplitude depend on the distance and relative position between the electrode and the atrial integrated vector axis. Therefore, the potential height and changes of P waves can be used to clearly reflect the tip position. Although 42.2% cases in this study showed double-peaked P waves during catheterization without peaked P waves, chest X-ray confirmed that the catheter tip had entered the ideal position when having double-peaked P waves. It is believed that when catheter tip is approaching the free wall of the right atrium in the lower SVC, it can also receive the depolarization wave of the left atrium, generating double-peaked P waves, which is consistent with related literature. Scholars like Li Li analyzed 185 patients using IEGM-guided PICC and found that the incidence of double-peaked P waves was 51.9%, some with no peaked P waves and bidirectional P waves, and 7 cases only with double-peaked P waves but were all accurately positioned. Therefore, double-peaked P wave is believed to be a supplementary indicator of positioning the catheter tip in CAJ [14].

5. Conclusions

In conclusion, Successful PICC tip positioning can effectively avoid catheter-related complications during clinical care. Chest X-ray, it has its limitations. For example, it cannot be used for real-time positioning so it may require reposition if the initial point is found to be incorrect by later examination, which will delay the treatment, increase the risk of complications and medical costs. IEGM has clear advantages on guiding PICC catheterization. It is convenient, accurate and can save more time for the infusion therapy. Results have shown that double-peaked P wave can also be the supporting evidence of catheter tip reaching the ideal position except guidance from peaked and bidirectional P waves. However, more cases are still needed for further research.

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