

Study on the Effects of IC-ECG Method in Neonatal PICC Catheterization

Liu Yintian¹, Liao Qiuying^{1,*}, He Jinai², Lin Na³

¹Department of Cardiovascular Surgery, The First Affiliated Hospital of Jinan University, Guangzhou, China

²Department of Nursing, The First Affiliated Hospital of Jinan University, Guangzhou, China

³Department of Neonatal Intensive Care Unit, The First Affiliated Hospital of Jinan University, Guangzhou, China

Email address:

18928903872@126.com (Liao Qiuying)

*Corresponding author

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Abstract: Objective: To compare the effects of Intracavitary Electrocardiography (IC-ECG) method and in vitro measurement for positioning the tip of Peripherally Inserted Central Catheter (PICC) in neonates, and investigate the influence of these two methods on PICC complications. Methods: Neonates who received PICC in the neonate intensive care unit of the First Affiliated Hospital of Jinan University from January 2015 to August 2019 were analyzed retrospectively. Patients were divided into two groups: the observation group with both IC-ECG method and in vitro measurement and the control group only with in vitro measurement. Chest X-ray were taken for both groups after the catheterization to confirm the catheter tip position. Statistics about catheter tip position, final extubation rate and PICC-related complications were collected and compared. Results: A total of 348 patients were enrolled (181 observation group, 167 control group). Two groups were comparable in terms of gender, gestational age, birth weight, catheterized side and vein during catheterization with no statistical significance. In the observation group, 173 (95.6%) had P-wave amplitude changes, including 4 (2.2%) were positioned at the upper 1/3 of the superior vena cava (SVC), 28 (15.5%) at the middle 1/3 of SVC, 104 (57.5%) at lower 1/3 of SVC; 38 cases (21.0%) at the right atrium or right ventricle, 7 (3.9%) at other parts, and the proportion of above situations in control group were 7 (4.2%), 15 (9.0%), 33 (19.8%), 48 (28.7%), and 47 (38.3%), respectively. The final extubation rate in the observation group was 86.2% (n=156), and the complication-caused extubation rate was 13.8% (n=25) while that in control group was 67.1% (n=112) and 32.9% (n=55), respectively. The differences between two groups were statistically significant ($P < 0.05$). Conclusion: Application of IC-ECG-guided PICC in neonates can improve the accuracy of catheter tip position and final extubation rate, and reduce the incidence of catheter-related complications.

Keywords: Neonate, Intracavitary Electrocardiogram (IC-ECG), Peripherally Inserted Central Catheter (PICC), Catheter Tip Position

1. Introduction

IC-ECG method as a technique to locate the proper catheter tip position during PICC catheterization has been recently introduced. A series of multi-center studies have confirmed that the IC-ECG method can be safely applied to adults and children aged from 1 month to 12 years old [1, 2]. Later, it has also been proved by some scholars that IC-ECG method can serve as accurate as the chest x-ray in determining the catheter tip position [3, 4]. Therefore, it has begun to be applied in the

neonatal PICC catheterization because of its advantages, such as no radiation and easy operation, but still less studies about it were found.

There are some differences in PICC catheterization between neonates and adults. For example, the PICC catheter for neonates has an open end in a smaller diameter (1.9 Fr); neonates may cry during the operation and therefore affect the process; they have a shorter SVC than that of adults, and show obvious P-wave amplitude increase when approaching the right atrium [5]. In this case, more clinical trials are required to identify whether IC-ECG method can serve efficiently to

observe the changes of P-wave amplitude during catheterization so as to accurately locate the catheter tip position.

For this purpose, this study retrospectively reviewed the effects of the IC-ECG method and the traditional *in vitro* measurement method in neonatal PICC, and discussed the feasibility of IC-ECG method. The results are as follow.

2. Objects and Methods

2.1. Study Objects

Neonates that received PICC catheterization in the neonate intensive care unit of the First Affiliated Hospital of Jinan University from January 2015 to August 2019 were enrolled in this study and divided into two groups. Observation group: both the IC-ECG and *in vitro* measurement methods were applied. Control group: only *in vitro* measurement method was adopted to predict the length of PICC before insertion.

Inclusion criteria: neonatal patients with PICC; Exclusion criteria: patients whose catheter tip position was not confirmed by chest X-ray; catheterized patients transferred to other hospitals during treatment; patients failed to insert the PICC.

2.2. Methods

2.2.1. Materials

Control group: Bard, UTA or Unijet 1.9 Fr open end PICC catheter, PICC puncture medical dressing kit with heparin cap, 10ml injector, transparent dressing etc.

Observation group: additional support of PHILIPS GS10 ECG monitor, sterilized EKG clip, Braun intracardiac converter, electrode pad and No. 7 scalp needle on the basis of control group.

2.2.2. Steps of Positioning

Control group: 1) Predict the insertion length: Place the patient in a supine position and have the lateral puncture extremity stretched 90°, and then take the distance from the puncture point to the right sternoclavicular joint and to the third rib as the insertion length; 2) Fix the catheter when it reaches the predicted length; 3) Take a chest X-ray to confirm the final catheter tip position.

Observation group: 1) Export the surface ECG: First adjust the ECG monitor to lead II, paste 3 electrode pads on the midline of bilateral subclavian bones, the left costal margin and the midline of axillary respectively, then connect the lead wires to export the surface ECG. Next, connect the upper left lead wires to the intracardiac ECG converter and the converter to the ECG monitor; 2) Apply the catheter in the same length as that in control group; 3) IC-ECG method: Connect the catheter with the pre-flushed heparin cap after the catheter is inserted to the predicted length, then insert the

scalp needle into the heparin cap and connect the needle to the IC-ECG converter with the sterile ECG clip. Next, turn on the converter. Send in or withdraw the catheter while slowly injecting the saline solution, and observing the P wave at the same time. Then, withdraw the catheter to a P/R amplitude ratio of 50% to 80% and fix it when the P wave reaches the maximal height; 4) Take a chest X-ray to confirm the final catheter tip position.

2.3. Observation Indicators

Catheter tip position: 1) For patients with PICC inserted through the veins of upper extremities, such as arms, neck and head: According to the INS guidelines, the most ideal position for the catheter tip is at the lower 1/3 of SVC or CAJ (chest X-ray shows roughly T5-T6 level); proper (ideal) position is at the SVC (chest X-ray shows roughly T2-T6 level); tip position not reaching SVC is considered to be too shallow (chest X-ray shows in the axillary vein, subclavian vein or brachiocephalic vein) while at the right atrium or deeper is too deep [6] (chest X-ray shows roughly below T7 level). 2) For patients with PICC inserted through the veins of lower extremities, such as saphenous vein or femoral vein: tip position at the junction of the inferior vena cava (IVC) and right atrium is considered to be ideal; position below the junction is too shallow while located inside the right atrium is too deep. Positions not mentioned above are considered to be malposition like locating in the internal jugular vein or the azygos vein etc..

Complications: clogging, leakage, secondary catheter malposition caused by growth and development, catheter rupture, infection, allergy, and local swelling.

2.4. Statistical Methods

In this study, the results were presented in mean values±standard deviation (SD), and analyzed by one sample *t* test. Data were evaluated by one-way analysis of variance (ANOVA), and the comparison between two groups was carried out by the Tukey HSD post-hoc test with the help of Statistical Package for the Social Sciences ver.24.0 software (SPSS, Chicago, IL). $P < 0.05$ was considered statistically significant.

3. Results

3.1. General Information

Among 411 catheterized neonates in our hospital from January 2015 to August 2019, 348 cases were finally enrolled (181 observation group, 167 control group) with 44 cases screened out. Two groups were comparable in terms of gender, gestational age, birth weight, catheterized side and vein with no statistical significance. ($P > 0.05$), as shown in Table 1.

Table 1. General information of the patients.

Project	Observation group (n=181)	Control group (n=167)	χ^2/f	p-value
Gender			1.605	0.205
male	115 (63.5%)	95 (56.9%)		
Female	66 (36.5%)	72 (43.1%)		
Intubation limb			2.125	0.145
left	78 (43.1%)	85 (56.9%)		
right	103 (56.9%)	82 (49.1%)		
Catheterization			6.278	0.179
Basilic vein	114 (63.0%)	95 (56.9%)		
Median cubital vein	26 (14.4%)	31 (18.6%)		
Superficial temporal vein	18 (9.9%)	25 (15.0%)		
Axillary vein	17 (9.4%)	8 (4.8%)		
other	6 (3.3%)	8 (4.8%)		
Gestational age (week)	31.26±2.18	30.44±2.22	0.110	0.915
body weight (Kg)	1.54±0.33	1.30±0.34	1.277	0.259

3.2. Comparison of the P-wave Amplitude Change and Tip Position Between Two Groups

Among all 181 cases in the observation group, 173 cases had changes in P-wave amplitude during PICC catheterization while the rest of them showed no evidence of that. The P-wave amplitude changes of the observation group are shown in Table 2. The comparison of catheter tip position between the two groups is shown in Tables 3 and 4. The differences between the two groups were statistically significant ($P < 0.05$).

Table 2. Changes of P-wave amplitude and catheter tip position in the observation group.

Whether p-wave amplitude changes	Catheter tip position				Total (n=181)
	SVC	RA	Not reaching SVC	Malposition	
appear	136	37	—	—	173
not appear	—	1	5	2	8

Table 3. Comparison of the catheter tip position between the two groups.

Group	Catheter tip position			
	SVC	Not reaching SVC	RA	Malposition
observation group (n=181)	136	5	38	2
control group (n=167)	69	41	48	9
χ^2 value	55.215			
p-value	0.01			

Table 4. The position of the two groups in SVC.

Group	Superior vena cava	
	Ideal position	Non-ideal position
observation group (n=136)	105	31
control group (n=69)	32	37
χ^2 value	10.626	
p-value	0.01	

3.3. Comparison of Treatment Outcomes and the Incidence of Complications Between the Two Groups

Outcomes and incidence of complications of the two groups are compared in Tables 5 and 6, which were both statistically significant ($P < 0.05$).

Table 5. Comparison of treatment outcomes between the two groups.

Group	Outcomes	
	Extubation after treatment	Complication-caused Extubation
observation group (n=181)	156	25
control group (n=167)	112	55
χ^2 value	17.940	
p-value	0.01	

Table 6. Comparison of complications during catheterization between the two groups.

Group	Complications		
	Clogging	Leakage	Others *
observation group (n=25)	19	3	3
control group (n=55)	19	12	24
χ^2 value	12.199		
<i>p</i> -value	0.002		

Others*: include secondary catheter malposition due to growth and development, catheter rupture, infection, allergy and local swelling.

4. Discussion

4.1. Significance of IC-ECG Method in Improving the Accuracy of Catheter Tip Position

In the observation group, 173 (95.6%) cases of neonates had P-wave amplitude changes and 8 (4.4%) cases did not. According to the results of chest X-ray, the ideal tip position rate in the observation group was 57.5% (104/181), which was significantly higher than that of the control group (19.8% (33/167)). In recent years, IC-ECG method has more fully developed in adult PICC catheterization. Foreign studies have reported that the ideal tip position rate can reach 65% (66/102) [7] among adults, and a series of domestic studies have also shown ideal rate ranging from 38.3% (23/60) [8] to 81.3% (1294/1592) [9].

Researches on the application of IC-ECG method in neonatal PICC have shown ideal position rate ranging from 67.9% (19/28) [8] to 74.7% (59/79) [9] while that in this study was lower than the above figures with 20.4% (37/181) cases inserted to the right atrium or right ventricle (non-ideal position) in the observation group, which might be the results of setting the reference value of P/R amplitude ratio in the range of 50-80% during operation as chest X-ray showed that the catheter tip had entered the right atrium when the P/R ratio was within the range of 70% -80% in some patients.

P-wave, also called the atrial depolarization wave, is the potential change generated during atrial depolarization [10]. Its waveform and amplitude reflect the distance and relative position between the probe and the atrial comprehensive vector axis [11]. The IC-ECG method is to convert the body surface ECG into the IC-ECG. Real time catheter tip position is determined through the changes of P-wave amplitude: the saline solution injected during catheterization work as the electrode, and the P wave amplitude increases once the catheter tip enters SVC and reaches the peak when arrives at the CAJ, and a P-wave inversion occurs when enters the right atrium. In this study, 8 cases had no detection of P wave during the PICC catheterization among which 4 cases were caused by catheter length miscalculation (too short), 1 case was interfered by the ventilator, and 3 cases still had no evidence of P-wave after reposition.

This research showed that when the the catheter tip was more likely to be located in the SVC when the P-wave amplitude changes frequently but there were still 21.0% cases catheterized in deep position, indicating that the changes of P-wave amplitude change was an important indicator to identify whether the catheter entered the SVC but

its role in final tip position determination is to be discussed.

4.2. Significance of IC-ECG Method in Reducing PICC-related Complications

In this study, 25 (13.8%) cases in the observation group have complications, which was significantly less than that of 55 (32.9%) in the control group. The differences were statistically significant. Poor catheter tip location was the key factor that caused catheter-related complications and reduced the service life of the catheter [12]. Excessively deep insertion may cause arrhythmia and pericardial tamponade [13], increased cardiac load, cardiomegaly and even heart failure. Excessively shallow insertion (e.g. the catheter tip is located in the subclavian vein where has narrow blood vessel) may cause the catheter to easily have friction with the blood vessel wall, and the liquid constantly stimulates the blood vessel, resulting in complications like fluid extravasation, phlebitis, and fibrin sheath misalignment [13]. Malposition of catheter tip may result in complications like exudation at the puncture point and limb swelling [14]. Secondary position change takes place as the neonates grow, and when the catheter tip gradually moves up and out of the SVC, the incidence of catheter-related complications increases and the service life of the catheter may be shortened. Therefore, placing the neonatal PICC at the optimal position can eliminate the adverse effects brought by the growth of neonates and is particularly important for completing the entire treatment.

4.3. Safety Analysis of IC-ECG Method

No evidence of IC-ECG-related complications (e.g arrhythmia) were found in this study.

5. Conclusion

The IC-ECG method can be safely applied in neonatal PICC to increase the accuracy of catheter tip position and reduce the risks of related complications. The P-wave amplitude change during the catheterization is an important indicator to identify whether the catheter tip enters the SVC but whether IC-ECG method can help determine the optimal position of the catheter tip is still required more clinical trials.

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