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The intracavitary electrocardiography method for tip location of jugular internal vein access device in infants of less than 5 kg: A pilot study

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Abstract

Purpose: This is a prospective observational study conducted by neonatologists in neonatal intensive care unit from Sant'Anna and San Sebastiano Hospital, Caserta, Italy. The objective of the study is to verify the feasibility of intracavitary electrocardiography method for tip location of central venous access device in infants of less than 5 kg and evaluate the accuracy of the method in comparison with post-procedural echocardiographical verification of the tip position.
Patients and methods: We enrolled 27 patients weighted between 0.660 and 5 kg, requiring central vascular access. Ultrasound-guided jugular internal vein access was used and after cannulation, we applied the intracavitary electrocardiography for tip location as well as post-procedural echocardiography.
Results: No significant complication related to intracavitary electrocardiography occurred in the studied infants. The increase in P wave on intracavitary electrocardiography was detected in all cases (27/27). In only one case (false positive), the catheter had the tip out of cavoatrial junction–target zone (to post-procedural echocardiography).
Conclusion: The intracavitary electrocardiography method for tip location of central venous access device is safe and accurate in infants, as demonstrated by post-procedural comparative echocardiographic controls. As an alternative to echocardiography, not always achievable, the diffusion of intracavitary electrocardiography method could reduce X-ray exposition and complications of a malpositioned tip.

Keywords

Central venous access device, echocardiography, intracavitary electrocardiography, target zone, tip position

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Introduction

Central venous catheter placement is technically difficult in the pediatric population, especially in the newborns. Many studies in adult and pediatric populations have proven a higher success rate and a decreased incidence of complications when ultrasound techniques by either prelocation or intraoperative guidance are used.[1] The correct tip position of central venous access device (CVAD) is very important but difficult to obtain in adults and even more difficult in infants. The use of the method of intracavitary electrocardiography (IC-ECG) for real-time verification of the tip position appears to be particularly appropriate in children. A recent multicenter study conducted by GAVeCeLT (the Italian Group for Venous Access Devices) in six Italian hospital centers on more than 300 patients has already demonstrated the safety and feasibility of IC-ECG in the positioning of central venous accesses in pediatric patients and has confirmed its accuracy compared with the postoperative chest X-ray.[2] The aim of our study and its particularity is to compare the use of echocardiography

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(ECHO) to the use of the method of IC-ECG for CVAD tip location in a neonatal intensive care unit (NICU).

Methods

This is a prospective observational study conducted by neonatologists from Sant'Anna and San Sebastiano Hospital, Caserta (Italy). The objective of the study was to verify the feasibility of IC-ECG method for tip location of CVAD in infants. IC-ECG is demonstrated safe in children.[2] In particular, we decided to evaluate the feasibility and the accuracy of the method and the safety of the procedure.

Similarly, as reported by Rossetti et al.[2] in their study protocol, we have evaluated the following:

1. The applicability of the method—as the IC-ECG is based on the variations of the shape of the P wave, we defined applicability as the percentage of neonates who had a visible P wave on the surface ECG and thus were eligible for the IC-ECG.
2. The feasibility of the method in technical and operational method terms—"feasibility" was defined as the possibility of successfully bringing the procedure, as described in the conclusion which is the proper identification of the "peak" P wave corresponding to the passage between the superior vena cava (SVC) and right atrium (RA).
3. The safety of the procedure in terms of potential arrhythmogenic risk or other types of risk for the patient or for the operator.
4. The accuracy of the method was defined in comparison with the method widely used in clinical practice: the echocardiographical verification of the tip position at the end of procedure. Accuracy was calculated as the match or mismatch between the position of the tip as assessed by IC-ECG during the procedure ("peak" P) and the position of the tip assessed at the end of the procedure by ECHO.

The study protocol was examined and approved by the Ethics Committee of Campania Nord, Italy (12 July 2017) and parents or guardians of all enrolled patients provided written informed consents.

Patients

We enrolled 27 patients weighing between 0.660 and 5 kg, requiring central vascular access. Ultrasound-guided jugular internal vein access was used and after cannulation, we applied the IC-ECG for tip location as well as post-procedural ECHO.

Inclusion criteria were as follows: (a) infants requiring central vascular access, (b) weight less than 5 kg, and (c) parental informed consent for positioning the CVAD using IC-ECG.

Exclusion criteria were electrocardiographic abnormalities on P wave, epicutaneo-caval catheter, and weight greater than 5 kg.

Intravenous central catheter

The choice of the catheter was based on the diameter of the vein as well as on the clinical complexity of patients. We used two types of catheters inserted by Seldinger technique:

1. Radiopaque polyurethane catheter 2.3-Fr single lumen (Leaderflex Vygon, length 8 cm, introducer needle 21G, metallic straight guidewire);
2. Radiopaque polyurethane catheter 3-Fr 2 lumens (Pediatric Multicath 2 Vygon, length 6 cm, short intravenous cannula 24 and introducer needle 22G, nitinol straight guidewire).

Vascular district was the internal jugular vein. The technique of CVAD placement was performed with ultrasound-guided venipuncture, measuring the length of the section before the procedure. The procedure was performed under mild sedation with intravenous fentanyl citrate (1–2 γ/kg) infused in 5 and 10 min before jugular puncture. For the purposes of this study, all CVADs whose tips were within a target zone corresponding to the lower third of the SVC or at the cavoatrial junction (CAJ) or in the upper third of the RA (see below for the definition of this area with electrocardiographic criteria) were considered as correctly positioned.

Intra-procedural verification of tip position by IC-ECG

In the electrocardiographic method for the positioning of the tip (IC-ECG), the catheter itself is used as an IC electrode and this can be obtained by two different techniques: either the IC electrode is a metallic guide inserted inside the catheter or the IC electrode is a liquid column (saline solution) contained in the catheter. Within this study, only the technique of the liquid column was considered, as it is safer with regard to possible arrhythmias that can be triggered by the J-wire that comes out of the catheter and may come in contact with the atrial walls.

This methodology required devices specifically designed for the IC-ECG and easily available on the market (AlphaCard, B. Braun; Vygocard, Vygon; Arrow-Johans Adapter, Teleflex; Saline Adapter, Romedex). We used Vygocard, Vygon, for easy shifting from surface ECG tracing to IC-ECG tracing and the defibrillator Schiller Defigard 5000 as an ECG monitor. Three electrodes were used: yellow-left shoulder, red-right shoulder, and green-left flank. The IC-ECG focuses on lead II (red to green), which is ideal for the visualization of the P wave. Whenever the P wave is evident on surface ECG

Table 1. Patients' distribution.

Total	27
Sex (male/female)	22/5
Gestational age, mean ± SD (range) (weeks)	34.8 ± 4.9 (24–40)
Weight, mean ± SD (range) (g)	2585.55 ± 1163.67 (660–4.500)
Applicability (%)	100
Feasibility (%)	100

SD: standard deviation.

Table 2. Tip location.

CAJ	19 (70.37%)
SVC	2 (7.41%)
Upper 3° RA	5 (18.52%)
Malpositioned	1 (3.7%)
Total	27

CAJ: cavoatrial junction; SVC: superior vena cava; RA: right atrium.

on lead II, the IC-ECG is applicable. The red electrode is detached from the shoulder and connected to the special Vygocard clip, and then the catheter positioning is proceeded. The catheter is threaded further on into the venous system; when the tip is 2 cm before the optimal measured position, the catheter is filled with saline isotonic solution and attached to the connector of the transducer. The surface ECG is switched to the IC-ECG, and watching the variations of the shape of the P wave on the IC lead II, it is possible to infer the position of the catheter tip. As the catheter proceeds slowly into the SVC, the P wave gets higher, reach its peak at the CAJ, and proceeding further gradually decreases to become diphasic. To be sure that the tip is well-positioned, it is appropriate to insert the catheter until the P wave becomes diphasic and then pull it back until the P is at its peak (position that will correspond to the CAJ). The variations of the P wave may be influenced by the electrodes' position and the interference from other electro-medical devices operating in proximity to the patient.

Post-procedural echocardiographical control

As the radiological landmarks in neonates are unreliable, we used ECHO as a second verification of the tip position. All patients were studied with a 5-MHz semiconvex probe (by Toshiba Aplio XV) in most cases with a subcostal bicaval projection. The target position for the tip was third inferior of SVC, CAJ, or RA.

Collection and analysis of the data

For each insertion, we considered the following data:

1. Patient's data: age, weight, height, sex, and presence of the surface ECG before the insertion;
2. CVAD data: external diameter (Fr) and total length;
3. Insertion data: vein punctured and cannulated;
4. IC-ECG data: identification of the peak of the P wave during the maneuver; final position of the tip (lower third of the SVC = P wave at about half to one-third of his maximum amplitude; CAJ = peak of the P wave; upper portion of the RA = P wave decreasing in amplitude and/or with an initial negative component);
5. Echocardiographical data: type of projection (subcostal bicaval projection or others), type of probe, classification of the tip position as follows: mismatch between IC-ECG and ECHO (tip not within the target zone, specifying where), and a good match between IC-ECG and ECHO (tip location in target zone).

All data were inserted in a software-based database for proper storing and for statistical analysis.

Results

A total of 27 infants in NICU were enrolled in this study. There were 22 male and 5 female, of which 13 term neonates and 14 preterm neonates, with mean gestational age 34.8 ± 4.9 weeks (range: 24–40 weeks). Mean weight at the time of insertion was 2585.55 ± 1163.17 g (range: 660–4500 g).

The applicability was 100% and IC-ECG was performed in all patients. The increase in P wave on IC-ECG was detected in all cases (27/27). In only one case (false positive), the catheter had the tip out of CAJ–target zone (to post-procedural ECHO), so the feasibility, statistically comparable to sensitivity, was 100%. Table 1 shows the distribution of the patients.

In the majority of cases, the planned for the tip was the CAJ (70.37%); the tip was in the lower third of SVC in 7.41% and in the upper third of RA in 18.52%. In one case, the tip was malpositioned. The accuracy was 96% (Table 2).

We described one case of mismatch between IC-ECG and ECHO where the tip location is in the superior third of SVC (possible error during the fastening of the catheter to the skin). With regard to the safety of the maneuver, it was virtually 100%, with no complications during the positioning.

Discussion

Central venous line is often necessary in NICU for total parenteral nutrition, pharmacotherapy, central venous pressure monitoring, and dialysis. Ultrasound-guided central venous cannulation may be safe and effective in the newborns. The use of an ultrasound-guided technique has been shown to increase the success rate of central venous cannulation significantly, reducing the incidence of complications in infants.[3]

However, the use of ultrasound-guided central cannulation is not widely adopted in NICU because difficulty in achieving a satisfactory level of ultrasound training and more concerns due to the lack of a sufficient number of prospective randomized clinical trials in children and infant.[1,4] Success depends on the size of the vessel and the skill of the health professional performing the procedure. The internal jugular vein and the brachiocephalic trunk provide a predictable path for central venous cannulation, although it is more difficult to cannulate infants than adults and even more difficult in the newborns. Montes-Tapia et al.[5] demonstrated that ultrasound-guided internal jugular vein cannulation with real-time visualization to gain access to the central venous circulation in low-birthweight newborns is effective and safe. Another issue inserting a central venous line is related to the confirmation of the catheter position. The correct position of the tip of a central venous access is very important in pediatric patient. Positioning of the tip of a central line in inappropriate site of venous system is associated with a significant increase in complication.[6] The best zone for placing the tip of a central venous access is in the CAJ, in the lower third of the SVC, or in the upper part of the RA.[7] In pediatric patients, surface landmark for estimating the length of the catheter from puncture site to the CAJ is less reliable than in adults; the interpretation of radiological images (both intra-procedural fluoroscopy and post-procedural chest X-ray) is more difficult, as there are no clear-cut criteria for defining where the CAJ is located.[2] Many studies have demonstrated the usefulness of ECHO in adults in placing peripherally inserted central catheter (PICC) lines[8] but the use of ultrasound for CVAD tip location as its use in replacing chest radiographs is controversial in all ages due to small sample sizes in available studies and lack of standardized techniques. Studies have shown that ECHO can be used to find the epicutaneo-caval catheter tips even with the thin catheters used in neonates.

Some studies strongly suggest that ECHO should be considered the gold standard to confirm correct umbilical catheter placement in neonates.[9] ECHO for catheter placement is not the current standard of practice, however, because of limitations of cost of equipment and the perceived high degree of training required to perform ECHO routinely for catheter placement.[10] The use of ECHO can be considered in neonates and in emergency departments when immediate knowledge of the CVAD tip location is beneficial.[11]

In the newborns, the position of the tip of central venous catheters is most often examined by chest radiography. Confirmation of tip location by post-procedural chest radiography remains acceptable practice and is required in the absence of technology used during the procedure. Post-procedural radiography is not necessary if alternative tip location technology confirms proper tip placement.[12] The use of the method of IC-ECG for real-time verification of the tip position appears to be particularly appropriate in children. The IC-ECG method is safe and accurate in the pediatric patients as much as in adults. The concordance with the radiological methods is high (95.8%). If compared with X-ray, IC-ECG has the obvious advantages of allowing an accurate verification of the tip position, that is, intraprocedural, and without X-ray exposure.[2] A few studies describe the use of this method in pediatric patients including infants, while supporting data in neonates are still lacking.[13,14] Our study is the first pilot study investigating use of IC-ECG for tip location of ultrasound-guided internal jugular vein access in an NICU. This study is the first to compare IC-ECG with ECHO for tip location of CVAD. The applicability is 100%; in all patients, we performed IC-ECG and ECHO. The accuracy of the method is 96%.

In only one case, there was a mismatch between IC-ECG and ECHO and the tip location was in the superior third of SVC, although we detected P wave peak.

In this patient, we supposed an error during the fastening of the catheter to the skin.

We have successfully positioned 96.3% of CVAD and tip location was detected in the majority of cases in the CAJ. A minor number of tip locations were in RA and lower third of SVC, indeed well-positioned.

No side effects were registered during procedures for tip location.

No patient has requested X-ray for tip location or complications.

Conclusion

The IC-ECG method for tip location of CVAD is safe and accurate in infants, as demonstrated by post-procedural comparative echocardiographic controls. As an alternative to ECHO, not always achievable, the diffusion of IC-ECG method could reduce X-ray exposition and complications of malpositioned tip.

The IC-ECG method also has the following advantages with respect to ECHO:

1. It reduces the costs because the IC-ECG use–related products are easily available and very cheap.
2. It is a relatively simple and easy-to-learn method.
3. It is a real-time method that can be applied as soon as the vein is cannulated.

Our study is a pilot study on a small number of infants. A new study will be needed in the future.

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