Archives of Anesthesiology and Critical Care (Summer 2023); 9(3): 232-237.

Available online at http://aacc.tums.ac.ir

Research Article

Comparison of Landmark Versus ECG-Guided Technique for Correct Insertion of Central Venous Catheter in Paediatric Patients Undergoing Cardiothoracic Surgery

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ARTICLE INFO

Article history:
Received 08 July 2022
Revised 29 July 2022
Accepted 12 August 2022

Keywords:
Central venous catheter (CVC);
Anatomical landmark;
ECG;
Carina

ABSTRACT

Background: Central venous catheters are inserted in internal jugular vein during cardiac surgeries in all patients. However, the length of the catheter should be correctly estimated and the tip of the CVC should be correctly placed to avoid various complications.
The primary objective of this study is to compare anatomical landmark technique versus using ECG-guided technique for the correct insertion length of the Central Venous Catheter.
Methods: Prospective, randomized, interventional study was conducted on 72 patients of <12 years age. Patients were randomly allotted to two groups of 36 patients each (landmark and ECG).
After induction, CVC cannulation was performed using either of the techniques in right IJV in all patients. Correct position of CVC was checked by obtaining post operative chest X rays in all patients. CVC tip position within 0.5cm above/below or at carina was considered as correct position. Using student t-tests and Chi square-tests analyses were performed.
Results: In landmark group, CVC was positioned correctly in 22(61.11%) out of 36 patients as compared to 33 (91.67%) in the ECG group, (P = 0.006). The mean depth of CVC insertion was 9.05±1.66 and 8.26±1.41 in the landmark and ECG group respectively (P= 0.032). The landmark group had 12 (33.33%) patients with complications during the procedure, as compared to 3(8.33%) in the ECG-guided group, (P = 0.020).
Conclusion: ECG-guided CVC insertion, a simple bedside technique was found more accurate with lesser complications for CVC tip placement than the landmark technique. ECG-guided CVC placement is therefore relatively more accurate, efficient, and safe.

Central venous catheters (CVC) are quite routinely inserted in internal jugular vein for various purposes such as for volume resuscitation, taking blood samples, vascular access, measurement of central venous pressure etc in operation theatres and ICU's [1].
Optimal location of tip of CVC is important so that various complications that may be catastrophic can be avoided such as haemothorax, pneumothorax, effusion of pericardium, irritation of the vessel wall due to mechanical or chemical causes that can lead to arrhythmias [2]. CVC can even result in cardiac tamponade, also tip of catheter can perforate walls of right side of heart or large vessels like the SVC [3].
Although the catheter tip in superior vena cava may be accepted for the purpose of administering catecholamine, yet for reliably assessing ventricular filling pressure of right heart, CVC tip must lie at the junction of SVC and right atrium [4].

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But instead of exactly at SVC–RA junction, CVC tip can be located slightly cephalad to decrease the risk of perforation, still it should be as close as possible to the right atrium, so that correct assessment of central venous pressure can be obtained [5].

Recent guidelines suggest that CVC tip must lie outside pericardial sac, in superior vena cava (SVC), but on a normal chest x-ray (CXR) the exact location of the pericardium cannot be seen [6]. Also the pericardial sac is not visible on a CXR, so appropriate landmarks are required to enable reliable radiographic verification of adequate CVC position [3].

In study by Yoon and colleagues in paediatric patients, it was concluded that 1.5 cm below the carina, the SVC–RA junction was situated and the carina level on chest X ray was believed to be the level of junction of SVC-RA [5].

Numerous methods based on patient characteristics such as height and age, anatomical landmarks, electrocardiogram (ECG)-guidance and trans-oesophageal electrocardiography guidance have been suggested to decide the correct depth of CVC placement [7].

In this study, we analyzed the two methods i.e., ECG versus landmark for correct insertion length of CVC in paediatric patients undergoing cardiothoracic surgery and using post-operative CXR, correlated the CVC tip position with respect to carina.

Methods

The procedure was explained in detail to the parents/ guardians of paediatric patients before taking informed and written consent. From the date of approval till the sample size completion was included as study period. It is prospective, randomized, double-blind study comprising of 72 patients aged <12 years requiring central venous catheterization in the internal jugular vein undergoing elective cardiovascular thoracic surgery. Patients were allotted randomly using sealed envelope method.

The sample size needed was 36 patients in each of the study group at confidence interval of 95% and power of 80% to verify the expected difference of 36% in proportion of cases with correct position of CVC tip in both groups [7].

All the patients were divided into two groups on random basis (36 patients each in both the groups).

Group A (n=36): CVC was inserted in paediatric patients by landmark technique.

Group B (n=36): CVC was inserted in paediatric patients by ECG-guided technique.

Exclusion criteria included CVC cannulation through the left internal jugular vein or subclavian vein, abnormal P-waves in the ECG such as atrial fibrillation. Patients with cardiac arrhythmias, pacemaker in situ, cervical spine anomaly, swelling in neck, dextrocardia, and significant chest deformity were also excluded from the study.

In all patients, pre-anaesthetic evaluation comprising of thorough history, blood investigations, complete blood counts, coagulation parameters along with ECG, CXR was obtained before the procedure.

Once inside the operation theatre, intravenous (IV) line was accessed, and standard monitors were attached. Patients were induced with IV fentanyl (2mcg/kg), IV midazolam(0.02mg/kg), etomidate (0.3 mg/kg) and rocuronium (1.2mg/kg). After intubation, the patients were placed in the Trendelenburg position and the head rotated (40°- 45°) to the left.

After ensuring all aseptic measures have been taken, a 5 ml syringe was filled with sterile saline and attached to the cannulation needle. Syringe was then introduced at apex of triangle formed by the clavicle, sternal and clavicular head of sternocleidomastoid muscle in right side of neck making an angle of 30°-45° to the skin. Needle was then advanced towards the ipsilateral nipple and aspirated until free return of venous blood was visualized. Thereafter, the guidewire was introduced, following which a 5-6 Fr triple-lumen CVC was rail-roaded over the guidewire.

All catheterization was done through right internal jugular vein (IJV) using the anterior approach. SVC-RA junction was considered the target level for CVC tip position.

In landmark group, on the patient's skin two points were marked. The sternal end of the right clavicle was marked as point "A". A line was drawn connecting both the nipples on patient's chest. A line was drawn perpendicular between Point A and the nipple line, and the midpoint of this line was labelled as Point "B" (Figure 1). Thereafter, the IJV was cannulated and guide-wire was inserted. The distance between needle entry point(I) and Point A was measured using a sterile disposable paper ruler. Distance between Points A and B was also measured.

The insertion depth of CVC was taken as (distance between Point I and Point A + distance between Point A and Point B) – 0.5 cm. This formula was used to position tip of the CVC at level of the carina.

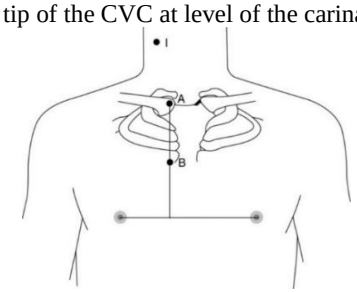

Figure 1- landmarks for calculation of CVC insertion length for landmark-guided CVC cannulation

An electrical instrument was used to monitor the atrial ECG via lead cable to monitor in ECG-guided technique. A universal ECG adapter recorded the ECG from the heart irrespective of the ECG monitor type.

After introducing CVC in right IJV in ECG group patients, the guidewire was withdrawn through the CVC till tip of CVC was positioned exactly at the tip of guidewire, indicated by a mark on guidewire which was measured before the insertion of the guide wire. ECG monitor and right-arm electrode were connected in-line with ECG adaptor in between them. Then, just above the CVC hub, an alligator clip attached to cable leading to the ECG adaptor was placed. This transferred ECG conduction from a regular three-lead surface ECG to an IV ECG (Figure 2).

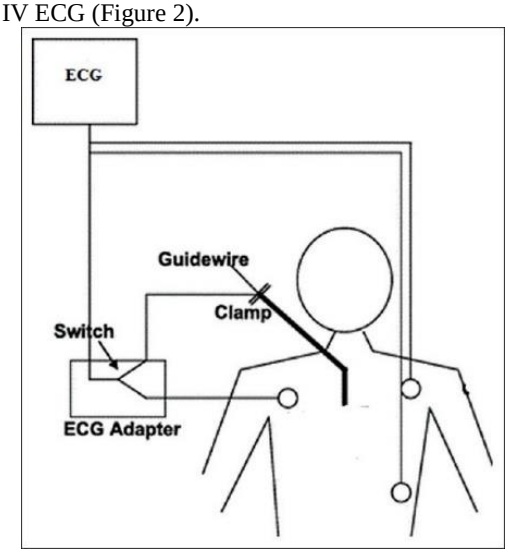

Figure 2- Arrangement of ECG adapter to convert 3-lead ECG to IV ECG

The catheter and guidewire together were slowly advanced until the IV ECG in lead II showed a CVC position in the SVC-RA junction (characterized by elevated, peaked P-wave in ECG) or in RA (biphasic P-wave). Subsequently, until the P-wave returned to a normal configuration, CVC was withdrawn at 0.2 cm intervals. Exactly at that particular point where P-wave appeared normal, the CVC was secured to skin using sutures and sterile dressing was done.

Immediately after surgery, a portable CXR (anteroposterior) was obtained in all patients with the patient completely flat in bed and head and neck in neutral position.

One anaesthesiologist, who was familiar with the study protocol but was blinded to the study group allocated to the patient examined the CXR. Horizontal lines were drawn at the level of the carina and the CVC tip, and vertical distance between the two lines was measured on the CXR to note the position of CVC tip relative to carina.

Final insertion depth, the incidence of cardiac arrhythmias during CVC placement, arterial puncture, pleural puncture, and any other complications were recorded in all patients.

Statistical Analysis

Using SPSS version 21 of Windows statistical software package (SPSS inc., Chicago, IL, USA) statistical analyses was done. Numbers (percent) were considered as categorical data and using Chi square test were compared among groups. The quantitative data was calculated in terms of mean and standard deviation and using Student's t-test were compared. If less than 0.05, probability was considered to be significant.

Results

No statistically significant difference was present between the two groups in terms of demographic parameters of age, weight, height and gender (Table 1) which confirms that there were no confounding factors in the study related to demographic data.

Table 1- shows mean age, sex, height and weight distribution between two groups which shows statistically non-significant difference

Parameter	Landmark Group (n=36)	ECG Group (n=36)	P value
Age (in years)	6.56±3.64	6.50±3.48	0.947
Sex (M/F)	21/15	20/16	1.00
Height (cm)	114.04±22.95	112.79±22.58	0.816
Weight(kg)	19.33±9.40	19.83±8.48	0.810

Out of 36 patients in landmark group, in 22(61.11%) CVC tip was correctly positioned within 0.5 cm above, at or below carina compared to 33(91.67%) out of 36 patients in the ECG group (Figure 3). Statistically significant difference was present in correct position of tip of CVC with respect to carina between the two groups (P= 0.006) with more number of correct position of CVC tip in patients in ECG group.

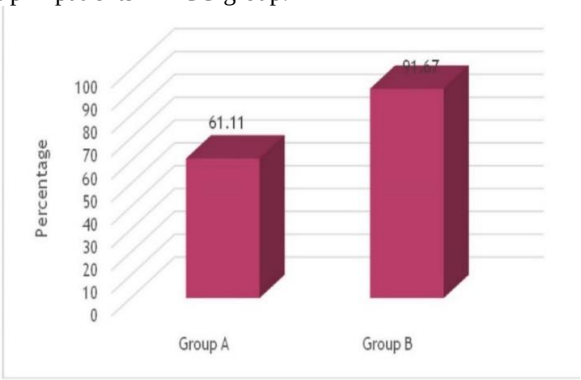

Figure 3- Distribution of correct position of CVC tip

Mean depth of insertion of CVC catheter was 9.05±1.66 cm in landmark group and 8.26±1.41 cm in the ECG group (Figure 4). There was statistically significant difference in the mean depth of CVC insertion between the two groups (P=0.032) suggesting deeper CVC insertion in the landmark group

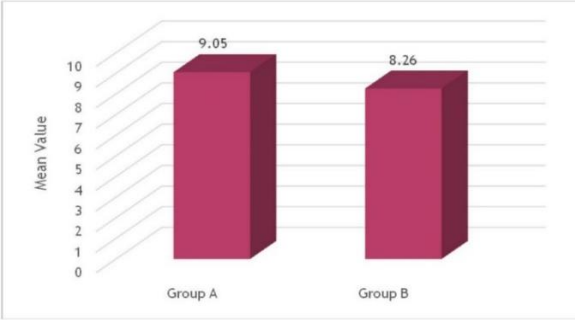

Figure 4- Mean depth of insertion of CVC catheter

The mean CVC tip distance from carina was 0.55±0.34 cm in landmark group and 0.31±0.25 cm in the ECG group (Figure 5). Statistically significant difference in the position of tip of CVC relative to carina was found between the two groups (P=0.001) indicating CVC tip was closer to carina in ECG group compared to landmark group.

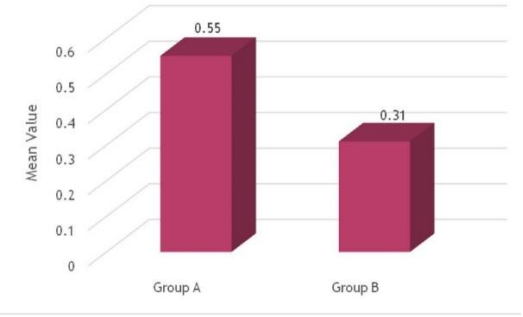

Figure 5- Mean distance of CVC tip from carina (cm)

Arrhythmia occurred in 8 patients in landmark group and in 1 patient in ECG group (Table 2) in study and this was statistically significant (P = 0.033). This might be because of significantly more percentage of over-insertion in landmark group causing arrhythmias. Few incidences of arterial punctures were also observed during insertion of CVC catheter in both the groups and the difference between them was not significant.

Table 2- Shows significantly a greater number of arrhythmias in landmark group (p value= 0-033) while though arterial puncture was also more in landmark group, between the groups difference was statistically non-significant (p value= 0.670).

Complications	Group A (n=36) (Landmark Group)		Group B (n=36) (ECG Group)		Result (p value)
	No.	%	No.	%	
Arrhythmia	8	22.22	1	2.77	0.033 (S)
Arterial Puncture	4	11.11	2	5.55	0.670 (NS)
Result (P value)	0.693 (NS)				

Discussion

To prevent complications such as cardiac perforation at level of right atrium [5], vascular perforations, hydrothorax, pneumothorax, pericardial effusion etc, the tip of a central venous catheter (CVC) should be positioned within the superior vena cava–right atrial (SVC–RA) junction [3].

Most commonly, standard chest-X-rays are used to make sure that the catheter tip is properly positioned in the SVC. However, it is difficult to exactly spot the SVC–RA junction by simple observation of CXR.

The carina can be used in paediatric patients as a radiographic landmark for optimum CVC tip placement [5]. As an anatomical landmark, carina has several benefits; since it is attached with connective tissue, its location is not altered in pulmonary pathologies. Even in a poor quality portable antero-posterior CXR, carina is easily visible [6].

Various methods are used to determine CVC tip placement like anatomic landmark guided methods, formulas based method (e.g. Pere's height formula), right atrial electrocardiogram {RA-ECG}, trans-oesophageal echocardiography {TEE}).

ECG-guided technique provides an edge over other methods since it provides definitive information about the location of the CVC tip directly during the procedure, thus it is time saving and resourceful. By applying the ECG-guided technique, delays in detecting malpositioning by CXR can be avoided.

Satistically significantly more number of CVC tips were correctly positioned in ECG group than landmark group (P=0.006) in study.

Neeraj Kumar Barnwal et al. [7] in their study also found that the nnumber of patients with position of tip of CVC within 0.5 cm above, below or at carina was statistically significantly more in the ECG group than the landmark group (p value=0.0000463).

Chu K S et al. [8] also found that CVC tip was positioned satisfactorily in only 53.3% patients in landmark group but in 100% patients in ECG group, (P<0.001) and found the results to be in accordance with TEE views.

The results of Arun Kumar Krishnan [9] were also similar to our study. 100% of correct CVC tip placements i.e. within 0.5 cm in the ECG-guided group compared to 82% in the landmark group (P= 0.000).

However, Jayaprakash Jayaraman et al, [2] in their study in adults observed that the difference in correct position of CVC tip between two groups i.e., landmark and ECG group was statistically non-significant (P=

0.712). The explanation for comparable results in terms of correct position in both the groups may be because of different landmarks used where they added two distances (length between skin insertion point of needle during CVC insertion and clavicular notch plus distance between clavicular notch and carina vertically). The latter was obtained from pre-op CXR of all patients in landmark group.

J. H. Lee et al [10] also found that CVC was correctly positioned in around 96.1% patients in landmark group and in nearly 95.9% in the ECG group and this difference was comparable between the two groups. This also may be because of their adult age group of patients and different landmarks used.

In this study the mean depth of insertion of CVC in landmark group was significantly more than ECG group.

In the study in adult patients by Jayaprakash Jayaraman et al, [2] average final depth of insertion in landmark group was 12.74 ± 0.77 cm and in ECG group it was 12.64 ± 0.70 cm but the two groups showed statistically non-significant difference (P=0.739)

However, in study in paediatric patients by Mojbata Mansouri et al, [11] mean catheter depth of insertion in landmark group was 6.49 ± 1.02 cm and in ECG group it was 7.34 ± 1.24 cm. Mean depth of insertion using gold standard i.e., located by cardiac surgeon during cardiac surgery was 7.53 ± 1.35 cm. Therefore, although the mean insertion depth was more in ECG group than in landmark group, yet it was closer to the depth of insertion achieved by gold standard method, hence was more accurate.

The CVC tip was closer to carina in ECG group compared to landmark group in this study. This coincides with Neeraj Kumar Barnwal et al, [7] who in their study in paediatric patients found that mean CVC tip distance from carina was 0.66 ± 0.35 cm in landmark group and 0.34 ± 0.23 cm in the ECG group and between the two groups the difference was statistically significant (P= 0.001)

In contrast, Jayaprakash Jayaraman et al, [2] found that the vertical CVC tip distance from carina in landmark group was 0.54 ± 0.67 cm and in ECG group it was 0.53 ± 0.43 cm, statistically non-significant difference was present between two groups(P=0.744).

H. S. Na et al [12] in their study on anatomic landmark method of inserting CVC catheter found that mean distance of CVC catheter above carina was 0.1 cm but the SD was found to be 1 cm which was a relatively wide distribution of position of CVC tip. They also found that no specific relationship existed between the distance of CVC tip from the carina level and the patient's demographic parameters of age, weight or height.

J H Lee et al, [10] found that the mean(SD) CVC tip position relative to the carina in the landmark group was 0.0(1.3) cm in the ECG group it was 0.0 (1.3) cm; and the mean(SD) difference in the vertical CVC tip positions between the two groups was -0.9 (0.17) cm. They concluded with CI of 95% that the two techniques were equivalent.

We noticed that significantly more arrhythmia occurred in landmark group than ECG group (P=0.033). This might be because of significantly more percentage of over-insertion in landmark group causing arrhythmias. Arun Kumar Krishnan et al, [9] in their study also found that the landmark group had 22 (30.6%) patients who encountered complications(arrhythmias) during the procedure, compared to zero complication in the ECG-guided group, result between two groups being statistically significant (P= 0.000).

Neeraj Kumar Barnwal et al, [7] in their study found that complications occurred in 9 patients in landmark group and in 1 patient in ECG group, the two groups showing statistically significant difference (P= 0.0056)

However, J. H. Lee et al, [10] in their study found that there was no significant association of complications between two groups. This may be attributed to their study on adult population and different landmarks used.

Thus, we found that ECG-guided technique for inserting correct CVC length was better compared to landmark technique. Also, ECG-guided method has added advantage that it can be performed bedside and is precise, safe, easy to perform and is non-invasive. The cost and X-ray radiation exposure associated with CXR can also be avoided. The ECG adapter is not much expensive, needs only a single purchase, and can be used multiple times.

Procedure can be appropriately documented and therefore also helpful for medicolegal purposes [13]. Another advantage of ECG guidance is that it can detect aberrant catheter placement in vascular structures other than superior vena cava by lack of an increase in P-wave size [2].

Limitation

We selected only right IJV cannulation since landmark technique cannot be used for left sided IJV cannulation and ECG-guidance is not a reliable method for confirming position of left-sided CVC, thus limiting our study [13]. A limitation of ECG-guidance is that it cannot be relied upon in patients with atrial fibrillation or other supraventricular arrhythmias [2].

Conclusion

ECG-guided technique was found superior for accurate placement of CVC tip than the anatomical landmark technique in terms of correct position, mean depth of insertion and lesser complications. ECG-guided technique additionally, was more precise for placement of CVC tip closer to carina.

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