Original Article

A comparative study of two techniques (electrocardiogram- and landmark-guided) for correct depth of the central venous catheter placement in paediatric patients undergoing elective cardiovascular surgery

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ABSTRACT

Background and Aims: The complications of central venous catheterisation can be minimized by ensuring catheter tip placement just above the superior vena cava-right atrium junction. We aimed to compare two methods, using an electrocardiogram (ECG) or landmark as guides, for assessing correct depth of central venous catheter (CVC) placement. **Methods:** In a prospective randomised study of sixty patients of <12 years of age, thirty patients each were allotted randomly to two groups (ECG and landmark). After induction, central venous catheterisation was performed by either of the two techniques and position of CVC tip was compared in post-operative chest X-ray with respect to carina. Unpaired *t*-test was used for quantitative data and Chi-square test was used for qualitative data. **Results:** In ECG group, positions of CVC tip were above carina in 12, at carina in 9 and below carina in 9 patients. In landmark group, the positions of CVC tips were above carina in 10, at carina in 4 and below carina in 16 patients. Mean distance of CVC tip in ECG group was 0.34 ± 0.23 cm and 0.66 ± 0.35 cm in landmark group ($P = 0.0001$). Complications occurred in one patient in ECG group and in nine patients in landmark group ($P = 0.0056$). **Conclusion:** Overall, landmark-guided technique was comparable with ECG technique. ECG-guided technique was more precise for CVC tip placement closer to carina. The incidence of complications was more in the landmark group.

Key words: Carina, central venous catheter, chest X-ray, electrocardiogram, landmark, paediatric

INTRODUCTION

Central venous catheterisation is frequently performed in operating theatres and intensive care units for various reasons such as monitoring in cardiac surgery, during anaesthesia for congenital heart disease and other major surgical procedures in paediatric patients, fluid management and as a route for medication.

To minimise the risk of serious complications such as cardiac tamponade and perforation, pneumothorax, life-threatening arrhythmia, thrombosis, and tricuspid valve damage, it has been suggested that central venous catheter (CVC) tip should be placed just above the superior vena cava-right atrium (SVC-RA) junction, parallel to SVC.[1-3] In addition, the carina is recommended as a useful target level for the CVC tip position.[4,5] Thus, confirmation of correct CVC positioning before starting the case by a simple bedside technique and accurate prediction of optimal

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CVC length would be helpful for patient's safety. This is, especially important in paediatric patients where determining the exact depth of insertion of CVC is important. The puncture site at the lower part of the neck may lead to a dangerous deep insertion of the CVC whereas the higher approach for the CVC insertion may produce a shallow insertion.

There are various methods that have been recommended to decide the proper depth of central venous catheter placement[6-10] based on patient characteristics, anatomical landmarks, electrocardiogram (ECG)-guidance and transoesophageal echocardiography guidance. In our study, we compared the accuracy of CVC tip localisation with respect to carina in post-operative chest X-ray (CXR) between the two methods (ECG and landmark) for CVC placement.

METHODS

After obtaining Institutional Review Board approval and written informed consent from the parents/guardians, we conducted a prospective randomised double-blind study of 60 paediatric patients of <12 years of age undergoing elective cardiovascular thoracic surgery requiring central venous catheterisation. Children were divided into two groups (ECG group and landmark group) of 30 each chosen randomly by computer generated programme.

Patients with altered coagulation parameters, arrhythmias, pacemaker *in situ*, neck burn contracture, cervical spine injury, neck swelling, extracardiac vascular abnormality, dextrocardia, and gross deformity of chest were excluded from the study.

All catheterisations were performed via right internal jugular vein (IJV)(anterior approach).[11-13] The SVC-RA junction was the target level for the CVC tip position. After confirming nil per oral status, intravenous (IV) access was obtained, and standard monitors were attached. Patient was given sedation with IV midazolam (0.02 mg/kg) and premedicated with IV glycopyrrolate (0.004 mg/kg) and IV fentanyl (1–2 μg/kg). After induction of general anaesthesia, the patient was placed in Trendelenburg position with the head turned to the left.

Under aseptic precautions, a 2 ml syringe filled with sterile saline was attached to the cannulation needle and then inserted at the apex of the triangle formed by the clavicle and the clavicular and sternal head of sternocleidomastoid muscle. The needle was advanced in a sagittal plane 30° posterior and caudal towards the ipsilateral nipple at a 45° angle with the frontal plane and gently aspirated until there was free return of venous blood. After that, the guidewire was inserted and then a 10–12 cm long triple-lumen CVC was inserted over the guidewire. The patient was then returned to the supine position, and head and neck were placed in neutral position.

In ECG group, after inserting CVC into right IJV, the guidewire was then withdrawn through the CVC until a mark on the guidewire indicated the tip to be exactly positioned at the tip of the CVC. This was measured before the insertion of the guide wire. The ECG adaptor was connected in-line between the ECG monitor and the right-arm electrode. An alligator clip attached to a cable leading to the ECG adaptor was then placed on the guidewire just above the CVC hub. Now the ECG conduction was then transferred from a regular three-lead surface ECG to an IV ECG.

While lead II was observed on the ECG monitor, the catheter, and guidewire assembly was slowly advanced until the IV ECG indicated a CVC position in the SVC-RA junction (peaked, elevated P-wave) or in the RA (biphasic P-wave).[7] After this, the CVC was withdrawn at 0.5 cm intervals until the P-wave returned to a normal configuration. At that point, the CVC was secured at the skin with suture and dressed with a transparent dressing.

In the landmark group, we used the sternal head of the right clavicle and the nipples as external landmarks for inserting the CVC tip near the carina.[14]

Three points were marked on the patient's skin. Point I marked as an insertion point of the cannulation needle, Point A marked at the sternal head of the right clavicle, one of the most prominent points. A line was drawn connecting both nipples, and then the midpoint of the perpendicular line drawn between Point A and the nipple line was designated as Point B. The distance between Point I and Point A were measured using a sterile disposable paper ruler and the distance between Points A and B was also measured [Figure 1].[14]

The depth of CVC insertion[14] was taken as (distance between Point I and Point A + distance between Point A and Point B) – 0.5 cm.

A portable anteroposterior CXR was taken in all patients immediately after surgery in the intensive care unit. Before CXR was taken, it was ensured that the patient was positioned completely flat in bed with the head and neck in neutral position. CXR was read by one attending anaesthesiologist, who was aware of the study protocol but blinded to the group assignment. After drawing the horizontal line at the level of the carina and the CVC tip, the position of CVC tip was noted, and vertical distance between the two lines was measured on the CXR.[15] In all patients, final insertion depth, the incidence of premature ventricular contraction during CVC placement, arterial puncture, arrhythmia, pneumothorax, and any other complication were recorded.

Sample size of 60 was estimated based on a previous study,[16] assuming clinically meaningful difference of 0.25 cm depth (standard deviation [SD] 0.7 cm) between the two groups with a 5% level of significance and 90% power.

Quantitative data were represented as mean and SD and for qualitative data frequency and proportion was used. Unpaired *t*-test was used as test of significance to find an association for quantitative data. Chi-square test was used as test of significance to find association for qualitative data. The results were analysed using computer generated software SPSS version 16 SPSS Inc, Chicago, Illinois, USA). All tests were two-tailed and the value of $P < 0.05$ was considered statistically significant.

RESULTS

There were 19 female (31.67%) and 41 male (68.33%) paediatric patients in the total study population. The mean age of entire study population was 4.75 years, 4.92 years in ECG group and 4.58 years in landmark group [Table 1]. Thus, both the groups did not differ demographically regarding age.

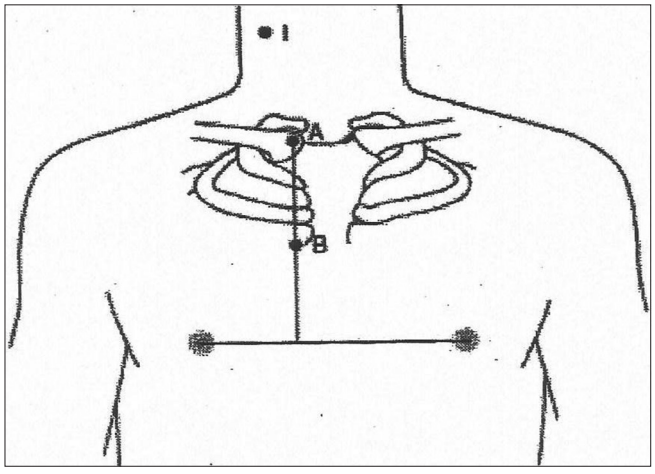

Figure 1: Landmark method for determining the insertion depth of central venous catheter

Positions of the central venous catheter (CVC) tip were comparable between the two groups. In ECG group, positions of CVC tip were above carina in 12, at carina in 9 and below carina in 9 patients. In landmark group, positions of CVC tip were above carina in 10, at carina in 4 and below carina in 16 patients [Table 2].

In ECG group, the positions of CVC tip were above or at or below but within 0.5 cm of carina in all thirty patients and in landmark group, the positions of CVC tip were above or at or below but within 0.5 cm of carina in 17 patients and there were 13 patients in which the position of CVC tip was below but beyond 0.5 cm of carina. There was statistically significant association in the position of CVC tip between the two techniques [Table 2].

Mean distance of CVC tip from carina in the total study population was 0.5 ± 0.39 cm; in the ECG group, it was 0.34 ± 0.23 cm and in the landmark group, 0.66 ± 0.35 cm. There was statistically significant association between methods used for placing central venous catheter with respect to mean distance of CVC tip from the carina [Table 3].

In the age group ≤5 years, the position of CVC tip was above or at carina in 27 patients (67.5%) and below carina in 13 patients (32.5%) and in the age group >5 years, the position of CVC tip was above or at carina in 8 patients (40%) and below carina in 12 patients

Table 1: Age wise distribution of the study population

Group	Mean (age in years)	SD	Independent *t*-test
Landmark	4.58	3.38	*t*=0.39, *P*=0.7
ECG	4.92	3.29	

ECG – Electrocardiogram; SD – Standard deviation

Table 2: Position of central venous catheterization tip versus method of insertion

Position of CVC tip	Number of patients		Total number of patients	*P*
	ECG	Landmark		
Above carina	12	10	22	0.131
At carina	9	4	13	
Below carina	9	16	25	
Above or at or below but within 0.5 cm of carina	30	17	47	0.0000463
Below but beyond 0.5 cm of carina	00	13	13	

ECG – Electrocardiogram; CVC – Central venous catheter

(60%). There was statistically significant association between positions of CVC tip in the two age groups [Table 4].

In ECG group, complication occurred in one patient and in landmark group, complications occurred in nine patients ($P = 0.0056$) [Table 5].

In the age group ≤ 5 years, there were total forty patients in which three patients had complications and in the age group >5 years, there were total twenty patients in which seven patients had complications. There was a statistically significant association ($P = 0.007$) of complications between the patients in the two age groups [Table 5].

There were total 47 patients in whom the position of CVC tip was above or at or below but within 0.5 cm of the carina, among which complication occurred in one patient. There were total 13 patients in whom the position of CVC tip was below but beyond 0.5 cm of carina; among which complications occurred in nine patients. There was a statistically significant association ($P = 0.001$) between the position of CVC tip and incidence of complications [Table 5].

Table 3: Mean distance of central venous catheterization tip from carina

Group	Group statistics for distance of CVC tip from carina		
	Mean (cm)	SD	*P*
Landmark	0.66	0.353	0.0001
ECG	0.34	0.232	

ECG – Electrocardiogram; CVC – Central venous catheter; SD – Standard deviation

Table 4: Position of central venous catheterization tip with respect to carina and age group

Age group (years)	Position of CVC tip (number of patients) (%)		*P*
	At or above carina	Below carina	
≤5	27 (67.5)	13 (32.5)	0.042
>5	8 (40)	12 (60)	
Total	35	25	

CVC – Central venous catheter

Table 5: Incidence of complications

Variables	Complications (number of patients)		*P*
	Yes	No	
Technique			
ECG	1	29	0.0056*
Landmark	9	21	
Age group (years)			
≤5	3	37	0.007*
>5	7	13	
Position of CVC			
At, above or below but within 0.5 cm	1	46	0.001*
Below but beyond 0.5 cm	9	4	

*P<0.05, statistically significant. ECG – Electrocardiogram; CVC – Central venous catheter

DISCUSSION

Cannulation of a central vein is the standard clinical method for monitoring central venous pressure and is also performed for a number of additional therapeutic interventions. Since its introduction into clinical practice, percutaneous puncture of the right IJV has been the method preferred by anaesthesiologists for central venous cannulation.[17-19] Reasons for this preference include consistent, predictable anatomic location of the IJV, readily identifiable and palpable surface landmarks and a short, straight course to the SVC. An IJV catheter is highly accessible during most surgical procedures and has a rate of successful placement of approximately 90–99%.[18,20]

In this study, the CVC tip could be reliably placed near the carina by using the external landmark or by ECG guidance in children without any aid of previous CXR or any knowledge of patient's height and weight.

ECG guided technique is simple and has a short learning curve. It may require 5–6 catheterizations for a new operator to get familiar with the assembly set up, attachment of alligator clip to guidewire and ECG cable and interpretation of *P* waves.

The carina is a reliable landmark which is easy to identify on CXR and can be used as a reference for correct placement of the tip of CVC. This has been proven by previous studies.[21,22] This has also been documented in paediatric patients.[4] After considering the results of the previous studies, we took the carina as the target position for the CVC tip and thus CVC tip placement was considered accurate if it was positioned above or at or below but within 0.5 cm of the carina. The carina is located in the centre of the thorax. Therefore, image distortion and measurement error by parallax effect was less important if we used the carina on CXR as a landmark.

Overall landmark-guided technique was comparable to ECG-guided technique for correct placement with respect to CVC tip positions at, above or below the carina ($P = 0.131$). However when we compared positions of CVC tip above, at or below but within 0.5

cm of carina to below but beyond 0.5 cm of carina, there was a statistically significant difference (P = 0.0000463). This indicated that the ECG guided technique is more accurate for placement of central venous catheter tip with respect to carina.

We found statistically significant difference (P = 0.0001) in mean distance of CVC tip from carina between ECG and landmark-guided technique. ECG-guided technique was more precise than landmark-guided technique for placement of central venous catheter tip closer to carina. This was in contrast to a previous study where authors did not find any significant difference in mean distance of CVC tip from carina between the two techniques.[23]

In ECG group, one patient had carotid artery puncture and in landmark-guided technique, complications occurred in nine of thirty patients, all in the form of ventricular premature contractions. There was statistically significant difference (P = 0.0056) in the complications between ECG and landmark-guided technique. Thus, ECG-guided technique was associated with fewer complications as compared to landmark-guided technique. A similar previous study did not show statistically significant differences in the complications (P = 0.162) between ECG and landmark-guided technique.[23]

The difference in both the above observations could be attributed to the technique of landmark guidance used by the previous authors.[23] They used pre-operative CXR along with external landmarks to decide the depth of placement of CVC tip, whereas, in our study, we used only external landmarks.

We found that nine of ten patients had complications when the position of CVC tip was below but beyond 0.5 cm of carina and one out of ten patients had complication when CVC tip was above or at or below but within 0.5 cm of carina. Hence, the incidence of complications was much more when CVC tips were located below but beyond 0.5 cm of carina.

There are certain limitations to the ECG guided technique. It requires an additional ECG cable with an alligator clip which does not come with all CVC sets. It is monitor specific as it requires ECG cable with detachable red lead from the hub. All the CVCs were inserted through the right IJV as a previous report indicated that intra-atrial ECG was not a reliable method for positioning CVCs inserted through the left IJV.[11,12] Only radiographic definition of the carina was used to evaluate CVC tip positions.

CONCLUSION

With regard to correct placement of central venous catheter, the landmark-guided technique was comparable with the ECG guided technique in paediatric patients. ECG-guided technique was more precise for CVC tip placement closer to carina. Placement of CVC tip was more accurate and complications were less in patients of age group ≤5 years as compared to age group more than 5 years using either ECG or landmark-guided technique. Complications are more likely in landmark-guided technique.

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Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Collier PE, Blocker SH, Graff DM, Doyle P. Cardiac tamponade from central venous catheters. Am J Surg 1998;176:212-4.
2. Kalen V, Medige TA, Rinsky LA. Pericardial tamponade secondary to perforation by central venous catheters in orthopaedic patients. J Bone Joint Surg Am 1991;73:1503-6.
3. Booth SA, Norton B, Mulvey DA. Central venous catheterization and fatal cardiac tamponade. Br J Anaesth 2001;87:298-302.
4. Yoon SZ, Shin JH, Hahn S, Oh AY, Kim HS, Kim SD, *et al.* Usefulness of the carina as a radiographic landmark for central venous catheter placement in paediatric patients. Br J Anaesth 2005;95:514-7.
5. Stonelake PA, Bodenham AR. The carina as a radiological landmark for central venous catheter tip position. Br J Anaesth 2006;96:335-40.
6. Andropoulos DB, Bent ST, Skjonsby B, Stayer SA. The optimal length of insertion of central venous catheters for pediatric patients. Anesth Analg 2001;93:883-6.
7. Yoon SZ, Shin TJ, Kim HS, Lee J, Kim CS, Kim SD, *et al.* Depth of a central venous catheter tip: Length of insertion guideline for pediatric patients. Acta Anaesthesiol Scand 2006;50:355-7.
8. Ryu HG, Bahk JH, Kim JT, Lee JH. Bedside prediction of the central venous catheter insertion depth. Br J Anaesth 2007;98:225-7.
9. Hayashi Y, Maruyama K, Takaki O, Yamauchi J, Ohnishi Y, Kuro M. Optimal placement of CVP catheter in paediatric cardiac patients. Can J Anaesth 1995;42:479-82.
10. Chu KS, Hsu JH, Wang SS, Tang CS, Cheng KI, Wang CK, *et al.* Accurate central venous port-A catheter placement: Intravenous electrocardiography and surface landmark techniques compared by using transesophageal echocardiography. Anesth Analg 2004;98:910-4.
11. Schummer W, Herrmann S, Schummer C, Funke F, Steenbeck J, Fuchs J, *et al.* Intra-atrial ECG is not a reliable method for positioning left internal jugular vein catheters. Br J Anaesth 2003;91:481-6.
12. Ishizuka M, Nagata H, Takagi K, Kubota K. Right internal jugular vein is recommended for central venous catheterization. J Invest Surg 2010;23:110-4.

13. Botha R, van Schoor AN, Boon JM, Becker JH, Meiring JH. Anatomical considerations of the anterior approach for central venous catheter placement. Clin Anat 2006;19:101-5.
14. Na HS, Kim JT, Kim HS, Bahk JH, Kim CS, Kim SD. Practical anatomic landmarks for determining the insertion depth of central venous catheter in paediatric patients. Br J Anaesth 2009;102:820-3.
15. Ryu HG, Bahk JH, Kim JT, Lee JH. Bedside prediction of the central venous catheter insertion depth. Br J Anaesth 2007;98:225-7.
16. Witthayapraphakorn L, Khositseth A, Jiraviwatana T, Siripornpitak S, Pornkul R, Anantasit N, *et al.* Appropriate length and position of the central venous catheter insertion via right internal jugular vein in children. Indian Pediatr 2013;50:749-52.
17. Bailey PL, Glance LG, Eaton MP, Parshall B, McIntosh S. A survey of the use of ultrasound during central venous catheterization. Anesth Analg 2007;104:491-7.
18. Sanford TJ Jr. Internal jugular vein cannulation versus subclavian vein cannulation. An anesthesiologist's view: The right internal jugular vein. J Clin Monit 1985;1:58-61.
19. English IC, Frew RM, Pigott JF, Zaki M. Percutaneous catheterisation of the internal jugular vein 1969. Anaesthesia 1995;50:1071-6.
20. Oliver WC Jr., Nuttall GA, Beynen FM, Raimundo HS, Abenstein JP, Arnold JJ. The incidence of artery puncture with central venous cannulation using a modified technique for detection and prevention of arterial cannulation. J Cardiothorac Vasc Anesth 1997;11:851-5.
21. Schuster M, Nave H, Piepenbrock S, Pabst R, Panning B. The carina as a landmark in central venous catheter placement. Br J Anaesth 2000;85:192-4.
22. Albrecht K, Nave H, Breitmeier D, Panning B, Tröger HD. Applied anatomy of the superior vena cava – The carina as a landmark to guide central venous catheter placement. Br J Anaesth 2004;92:75-7.
23. Lee JH, Bahk JH, Ryu HG, Jung CW, Jeon Y. Comparison of the bedside central venous catheter placement techniques: Landmark vs electrocardiogram guidance. Br J Anaesth 2009;102:662-6.