Original Article

Bedside prediction of the central venous catheter insertion depth – Comparison of different techniques

Jayaprakash Jayaraman, Veena Shah

Department of Anaesthesia and Critical Care, Smt. K. M. Mehta and Smt. G. R. Doshi Institute of Kidney Diseases and Research Center, Civil Hospital Campus, Dr. H. L. Trivedi Institute of Transplantation Sciences, Ahmedabad, Gujarat, India

Abstract

Background and Aims: Central venous catheterization is a frequently performed procedure in anesthesia and critical care, and is indispensable in the practice of emergency medicine. Correct positioning of the central venous catheter (CVC) tip is often regarded as a secondary goal and there are various complications that can occur due to abnormal position of the catheter tip. Different methods have been advocated to guide accurate prediction of optimal CVC depth insertion before or during the procedure at the bedside.

Material and Methods: A prospective randomized double blinded study was conducted in 180 patients aged between 18 to 65 years requiring central venous catheterization.The optimal depth of insertion of right internal jugular vein (IJV) catheter using three different techniques, Peres' formula method, Landmark technique and Intra atrial Electrocardiography (ECG) guided technique was performed and the three techniques were compared with respect to optimal positioning using carina as a landmark in post procedural chest radiograph.Correct position of the catheter tip was considered upto 1 cm above or below the carina in post procedure X ray.

Results: The average final depth of insertion was 15.30 ± 0.62 cms in the Formula group, 12.74 ± 0.77 cms in landmark group and 12.64 ± 0.70 cms in ECG group. The vertical distance from carina was 0.91 ± 0.94 cms in formula group, 0.54 ± 0.67 cms in landmark group and 0.53 ± 0.43 cms in ECG group. The CVC tip was properly positioned within 1 cm above and below the carina in 58.33% patients in the formula group, 93.33% patients in landmark group and 96.67% patients in ECG group.

Conclusion: We conclude that both landmark guidance and ECG guidance are comparable with regard to accurate central venous catheter tip positioning when CVCs are placed through right internal jugular vein whereas formula based technique is least accurate and results in over insertion of CVCs.

Keywords: Central venous catheter, intra atrial electrocardiography, Peres' formula

Introduction

Central venous catheterization is a frequently performed procedure in anesthesia and critical care, and is indispensable in the practice of emergency medicine. Correct positioning of the central venous catheter (CVC) tip is often regarded as a secondary goal. Complications that can occur due to misplaced catheters include catheter tip positioned too close to the vein wall, preventing infusion/aspiration, causing thrombosis of the vein, or perforation of the vein, and complications due to over insertion of the catheter tip, like malignant arrhythmias, haemothorax, hydrothorax, damaging the right heart valve or even right atrial[1] or ventricular wall, mediastinal fluid collection and cardiac tamponade.[2] The later two are associated with high mortality rate of 65% to 91%.[3] Different methods have been advocated to guide accurate prediction of optimal CVC depth insertion before or during the procedure at the bedside. These methods may be from simple formulas to transesophageal echocardiography.[4]

Address for correspondence: Dr. Jayaprakash Jayaraman, B-22, Tower Block, Taylor's Road, Kilpauk, Chennai, Tamil Nadu, India.
E-mail: drjayaprakashj@yahoo.com

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The aim of our study was to find the optimal depth of insertion of right internal jugular vein (IJV) catheter using three different techniques Peres' formula method, Landmark technique and Intra atrial Electrocardiography (ECG) guided technique and to compare the three techniques with respect to optimal positioning using carina as a landmark in post procedural chest radiograph.

Material and Methods

Our study is a prospective randomized double blinded study. After obtaining approval from the ethical committee and written informed consent, 180 patients aged between 18 to 65 years requiring central venous catheterization were enrolled in this study. Patients with atrial fibrillation. Multifocal ventricular premature complexes, left bundle branch block, patient with cardiac pacemaker and altered coagulation profile were excluded from our study. Sixty patients were allotted randomly as formula group, landmark group and ECG group (wherein CVC was fixed using formula technique, landmark technique, ECG guided technique respectively).

In all patients pre procedure complete blood counts, CXR, ECG and coagulation profile was obtained. Standard monitors were applied and the patients were placed in a 20 degree Trendelenburg position. After antiseptic preparation, following successful puncture of the right IJV by central approach, a 15/20 cm single lumen CVC (Certofix® Mono 16G, B. Braun Melsungen, Germany) was inserted over 50 cm guidewireby the modified Seldinger technique. If IJV could not be punctured by more than two attempts or in case of arterial puncture ultrasound guidance (logiq book XP, 7.5MHz linear probe, G.E, U.S.A.) was used.

In the Formula group, heights of all the patients were measured prior to the procedure and the catheter was inserted and final insertion depth was kept as per the Peres' formula of "height (in cm)/10".

In the landmark group, before CVC placement, the vertical distance between the right clavicular notch and the carina was measured on the routine preprocedure CXR, using an internal measuring tool available on the hospital's picture archiving communication system. The vertical distance between the insertion point of the puncture needle and the right clavicular notch was measured using a sterile disposable ruler. The final depth of CVC insertion was determined by adding the two measurements (length between skin insertion point and the right clavicular notch plus vertical distance between the notch and the carina).[5] All the measurements were determined at 0.5 cm intervals.

In the ECG group, the guidewire was withdrawn through the CVC until a mark on the guidewire indicated the tip to be exactly positioned at the tip of the CVC. A connection between the guidewire and an ECG adapter (Certodyn® - Universal adapter, B. Braun Melsungen, Germany) was then established in the following fashion as shown in Figure 1. The ECG adapter was connected in-line between the ECG monitor and the right-arm electrode. An alligator clip attached to a cable was placed on the metal guidewire just above the CVC hub and cable was connected to the ECG adapter.[6] Using a switch function in the adapter, ECG conduction was then transferred from a regular three-lead surface ECG to an RA or intravenous ECG.

While lead II was observed on the ECG monitor, the catheter was slowly advanced until the RA-ECG indicated a CVC position in the SVC/RA junction (peaked, tall P-wave) or in the RA (biphasic P-wave).[7] Thereafter, 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 and the depth of insertion noted. If an intra atrial ECG could not be obtained, the CVC was fixed to a depth of 15 cms.

A portable antero-posterior CXR was taken in supine position in all the patients immediately after the procedure. CXRs were read by one attending radiologist, who was aware of the study protocol but blinded to the group assignment. A standardized method was used to describe the position of the CVC tip. The vertical distance between the CVC tip and the carina was measured on the CXR. The tip is assumed to be in properly positioned when it is within 1 cm above or below the

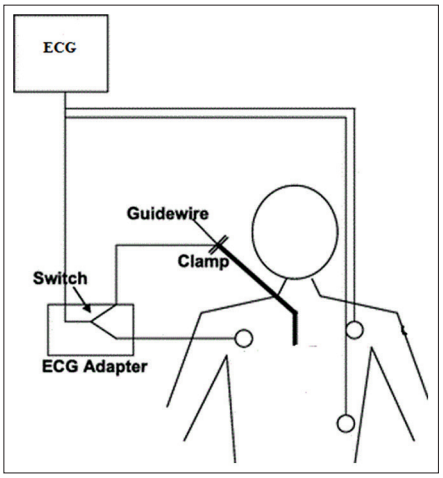

Figure 1: Connections between electrocardiography monitor, universal adapter and the patient

carina. 1 cm below the carina was considered over insertion (which may be in distal SVC or the RA) and more than 1 cm above the carina was considered sub optimal insertion, both of which were considered undesirable in our study. The catheter was considered to be malpositioned when the tip was placed in any vessel other than the superior vena cava.

In all groups, final insertion depth, number of venous puncture attempts, incidence of arrhythmias during CVC placement, and complications such as arterial puncture, malposition of CVC tip, hematoma or pneumothorax were recorded.

Gebhard *et al.*[8] compared ECG and Non ECG guided CVC insertion and concluded 96% and 76% success rates of each group respectively. From this data we calculated the sample size with 90% power using a cut off for statistical significance of 0.05. It was around 60 patients in each group.

All data were analysed by SPSS version 12. Continuous data are described as mean ± SD (standard deviation) and categorical variables were given as no. (%). Continuous variables were compared using ANOVA (analysis of variance). Percentages were compared using Chi-square analysis. *P* value <0.05 was considered to be statistically significant.

Results

Patients characteristics were similar in the three groups. Weight, body mass index and Sex ratio were comparable between the three groups [Table 1].

In our study of 180 patients, right IJV was cannulated at first attempt in 129 patients, whereas 27 patients needed a second venous puncture and 24 patients required USG guidance. The average final depth of insertion was 15.30 ± 0.62 cms in the Formula group, 12.74 ± 0.77 cms in landmark group and 12.64 ± 0.70 cms in ECG group. The vertical distance from carina was 0.91 ± 0.94 cms in formula group, 0.54 ± 0.67 cms in landmark group and 0.53 ± 0.43 cms in ECG group [Table 2].

The CVC tip was properly positioned within 1 cm above and below the carina in 58.33% patients in the formula group, 93.33% patients in landmark group and 96.67% patients in ECG group.

When we compared the depth of insertion, distance from the carina and the success rate between groups, formula group showed statistically significant difference compared to both the landmark and ECG group, whereas *P* values between landmark and ECG group were comparable [Table 3].

Catheters were found to be 1 cm below the carina in 40% patients of the formula group, 5% patients of the landmark group and 3.3% patients of the ECG group. Out of 40% patients in Formula group 5 patients (8.3%) had catheters inserted in the RA and no patients in Landmark group or ECG group had catheter tip placed in the RA [Table 4].

Malpositioned catheter was seen 1 (1.66%) with patient in Landmark group where the catheter tip was located in right brachiocephalic vein and with 1 (1.66%) patient in formula group where the catheter tip entered the right subclavian vein.

Table 1: Demographic data

	Formula group	Landmark group	ECG group	*P*
Age (years)	44.9±17.2	39.23±14.69	40.8±16.22	0.142
Height (cm)	154.08±6.27	156.72±5.80	154.45±8.77	0.093
Weight (kg)	61.11±7.05	61.5±7.87	60.11±8.56	0.613
Body mass index kg/m^2)	25.88±3.75	25.18±3.99	25.39±4.56	0.633
Male/female	41/19	48/12	43/17	0.330

ECG=Electrocardiography

Table 2: Pre- and post-procedural data

	Formula group	Landmark group	ECG group
Number of catheterization attempts (1/2/USG guidance)	42/11/7	45/8/7	42/8/10
Vertical distance from the carina (cm)	0.91±0.94	0.54±0.67	0.53±0.43
Depth of insertion (cm)	15.30±0.62	12.74±0.77	12.64±0.70

ECG=Electrocardiography, USG=Ultrasound

Table 3: Inter group *P* values

	Depth of insertion	Distance from the carina	Properly positioned
Landmark versus formula	<0.001	0.006	0.005
ECG versus formula	<0.001	0.019	0.010
Landmark versus ECG	0.739	0.744	0.712

ECG=Electrocardiography

Table 4: Position of central venous catheter tip corresponding to carina

	Formula group (%)	Landmark group (%)	ECG group (%)
Sub optimal insertion	0	0	0
Properly positioned	35 (58.3)	56 (93.3)	58 (96.7)
Over insertion			
Distal SVC	19 (31.7)	3 (5)	2 (3.3)
Right atrium	5 (8.3)	0	0
Malpositioned IJV catheter	1 (1.7)	1 (1.7)	0

ECG=Electrocardiography, IJV=Internal jugular vein, SVC=Superior vena cava

Overall arterial punctures occurred in 5 patients, with small hematoma requiring no further interventions. No CVC was placed in arterial system and there was no incidence of pneumothorax. VPCs were observed in 3 patients during insertion of guide wire which was transient and was terminated when the guide wire was withdrawn a few centimeters [Table 5].

Discussion

Certain complications such as vessel wall or cardiac perforation are related to tip position. It is reported that the incidence of intra-atrial CVC tip position after conventional placement technique ranges from 8 to 47% and the incidence of vessel perforation seems to range from approximately 0.25% to 0.4%.[9] Even if the complication incidence is low, any method which can reliably predict depth of insertion preprocedure at bedside is desirable from the view of patient safety.

There is appreciable morbidity from CVC tips lying too proximal as well, either in the left or the right innominate vein. Mechanical or chemical irritation of the vessel wall leads to pain on injection of drugs, thrombosis and subsequent infection, which is more likely in the upper SVC or innominate veins, especially on the left side.

Peres'[10] in 1990 utilized patients height to develop formulas to predict the optimum length of the catheter to be inserted for right internal or external jugular catheters, right infraclavicular, subclavian catheters and left external jugular catheters.

In our study we found that using Peres' formula technique, we were able to properly position the CVC tip in 58.33% of the patients, with overinsertion in 40% of patients and malpositioned in 1.66% of patients in the right subclavian vein. Out of 40% overinsertion, 8.3% patients had catheter tip in the RA. The mean depth of insertion using Peres' formula was 15.3 cms which was significantly higher when compared to landmark technique (12.74 cm) and ECG guidance technique (12.64 cm).

When we compared our results with study conducted by Peres, we observed significant over insertion of right sided IJV cannulation. This difference is related to the difference in end point of optimal insertion. They did not use carina as a landmark for positioning the CVC tip. They used SVC-RA junction as a landmark in CXR and this may be a reason for overinsertion in our study using Peres' formula. Secondly the study was conducted in Western population and our study was in Indian population, the anthropometric variations has to be considered.

Table 5: Complications

	Landmark group	ECG group	Formula group
VPC during the procedure	1	2	0
Arterial puncture	2	2	1
Pneumothorax	0	0	0

ECG=Electrocardiography, VPC=Ventricular premature complexes

Thus results of our study show that Peres' formula for right internal jugular vein cannulation can be used with less accuracy in positioning CVC tip but if the catheter is withdrawn 2 cms, that is [height (in cms)/10] – 2 cms, it can avoid right atrial cannulation using central approach. This formula may be used when equipment like ECG adaptor or preoperative CXR for landmark technique are unavailable or in extremely emergent situations.

Ryu *et al.*[5] observed that the CVC tip could be reliably placed when the CVC is inserted via the right IJV or the right SCV using the landmark technique. Using landmark technique we could achieve optimal position in 93.33% of cases and over insertion in 5% and one patient (1.66%) had catheter malpositioned in right brachiocephalic vein. But when compared to Formula group there was no incidence of RA catheterisation. Depth of insertion using landmark technique was considerably low (12.74 cms) compared to formula method.

Ryu *et al.*[5] studied this landmark technique and found that with 13.5cm depth, 98% CVCs were optimally positioned around the carina whereas depth of insertion in our study was 12.74 cm. The difference in depth of insertion was probably related to anthropometric variation.

Thus landmark technique may be a better method with high success rate in optimal positioning of CVC tip with very less possibility of right atrial cannulation, it does not require specialised catheters with connecting wires or an ECG adapter. The disadvantage of the technique is that we need a preprocedure which may not be available in emergency situations as well as post procedure CXR.

Lee *et al.*[6] used right atrial ECG for guiding CVC position. They described that during the ECG-guided central venous catheterization, the peak P-wave is observed when the CVC tip was located at the SVC/RA junction, and the P-wave returns to a normal shape and size at mid SVC level. ECG guidance technique in our study had a success rate of 96.67%, highest amongst the three groups but statistically no difference was found when compared to landmark group. The study published by Lee *et al.* observed 95.9% success rate with ECG guidance and 96% success rate with landmark technique.

Another advantage of ECG guidance is that it can detect aberrant catheter placement in vessels other than the superior vena cava by lack of an increase in P-wave size.

Barnwal *et al*.[11] compared ECG guided technique with landmark technique of central venous cannulation in paediatric patients and concluded ECG guided technique is more accurate with less complications.

ECG guidance can be the ideal technique when the specialised catheter with the connecting wire and the ECG adaptor is available. There is no need for pre procedure and post procedure[12] CXR to confirm the catheter position. It can also be used in intensive care unit where patient's height measurement and preprocedure CXR are not available. Consequently a limitation of ECG guidance is that it cannot be reliably used in patients with atrial fibrillation or other supraventricular arrhythmias.

The limitation of our study was, we selected only right IJV cannulation because 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.[12]

Schuster *et al*.[13] in their study showed that the carina is a reliable landmark for the placement of CVCs. In all cases, the pericardial sac ended below the level of the carina. Due to its fixation with connective tissue, its location is preserved even in pulmonary pathology. The central location and the small sagittal distance between it and the SVC (range 1.5–4.1 cm) limit any parallax effect. Most importantly, the carina is easily visible even in a poor quality portable antero-posterior CXR. Thus, carina as an anatomical landmark having several advantages, was used for confirmation of CVC tip position.

Conclusion

We conclude that both landmark guidance and ECG guidance are comparable with regard to accurate central venous catheter tip positioning when CVCs are placed through right internal jugular vein whereas formula based technique is least accurate and results in overinsertion of CVCs. Modifying the formula to (height of patient)/10 – 2 cm will improve its accuracy. Although landmark technique is simple it requires preprocedure CXR and cannot predict malposition of the catheter tip. RA-ECG technique is superior as it can detect malposition however it requires specialised catheters with wire and adaptor.

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Conflicts of interest
There are no conflicts of interest.

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