Original Article

Optimal positioning of right internal jugular venous catheter: A randomised study comparing modified Peres' height formula and distance between insertion point and right third intercostal space

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ABSTRACT

Background and Aims: The position of the tip of the central venous catheter (CVC) is important to minimise complications. The aim of our study was to compare modified Peres' height formula and landmark method using distance between puncture site and right third intercostal space (PS-RTICS) and to develop a reliable formula for correct positioning of tip of the CVC. **Methods:** This prospective, randomised study was conducted on 400 patients of either gender, of age 18 years and older, scheduled to undergo right internal jugular venous cannulation. Depending on the technique used for deciding the length of CVC to be inserted, the patients were randomly allocated into two groups: Group A, using modified Peres' height formula, that is, height of patient (cm)/10-2 and Group B, using distance between PS-RTICS and subtracting one from it, that is (PS-RTICS)-1. The carina was taken as the landmark for optimum insertion of CVC, which was confirmed on postprocedure chest X-ray. Data so obtained were tabulated and analysed. P<.05 was considered statistically significant for correlation and regression coefficients. **Results:** In group A, the mean length of catheter inserted was 15.18 ± 0.73 cm and the catheter tip was found to be 2.41 ± 0.85 cm distal to carina (P=0.001). Over-insertion was found in 98.45% patients in group A. In group B, the mean length of catheter inserted was 14.12 ± 0.85 cm and the catheter tip was found to be 0.20 ± 1.18 cm distal to carina. **Conclusion:** Though both landmark and modified Peres' height formula has low accuracy, landmark technique is superior in predicting correct depth of right internal jugular venous cannulation catheter.

Key words: Central venous catheterisation, jugular vein, superior vena cava

INTRODUCTION

Central venous catheterisation is used for central venous pressure (CVP) monitoring, fluid resuscitation, haemodialysis, securing venous access in cases of difficult peripheral venous access and administration of irritant drug therapy and parenteral nutrition.[1] CVP is an estimate of right atrial (RA) pressure and has been used to determine cardiac preload and volume status. Incorrect positioning of catheter can lead to fallacious readings of CVP and potentially fatal complications like cardiac tamponade, atrial and ventricular dysrhythmias, tricuspid valve damage, thrombosis, and pericardial effusion.[2,3] To minimise the risk of complications and accurate CVP monitoring, the tip of the central venous catheter (CVC) should ideally lie in the superior vena cava (SVC), parallel to its long axis

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without abutting the vein wall. It has been shown in a study that an angle of the CVC tip to vessel wall of >40° is more likely to lead to vessel wall perforation.[4,5] The junction of SVC and RA is above the level of the pericardial reflection, which corresponds closely to the level of the carina on a chest X-ray (CXR).[6,7]

Internal jugular venous (IJV) cannulation is the most commonly performed central venous cannulation procedure both in the perioperative period and critical care settings.[8] Different methods have been advocated to guide accurate prediction of optimal depth of CVC insertion before or during the procedure. These methods vary from simple formulas based on height, intra-atrial electrocardiography (ECG) to sophisticated ones like transoesophageal echocardiography.[9] The easily applicable method based on height formula, however, cannot be applied universally for different races and across genders. The primary objective of our study was to find the optimal depth of insertion of right IJV (RIJV) catheter by comparing modified Peres' height formula[10] and landmark technique using distance between puncture site (PS) and right third intercostal space (RTICS)-1 cm.[11] We also aimed to devise a suitable formula, which can be applied to the Indian population.

METHODS

This prospective randomised study was conducted in a tertiary care hospital after approval from the institutional ethics committee (DMCH/P/2018/26) and written informed consent on 400 patients aged 18 years and older requiring CVC. The study was conducted from January 2018 to March 2019 in accordance with the principles of the Declaration of Helsinki. The patients were allotted randomly into two groups by computer-generated random numbers maintained by a statistician not involved in the study [Figure 1]. Allocation sequence was kept in sequential-sealed–coded envelopes. In group A, RIJV cannulation was done using modified Peres height formula, that is, catheter insertion length equal to patient's height in cm/10–2, while in group B, insertion length was kept at 1 cm distance less than that measured between PS taken at the level of the cricoid cartilage to right third intercostal space, that is, (PS-RTICS)–1 cm. The distance from PS to RTICS was measured using a sterile flexible metallic scale. Patients with infection, burns, or trauma at PS, coagulopathy, thrombosis of the RIJV, and history of CVC insertion previously on the same side were excluded from the study.

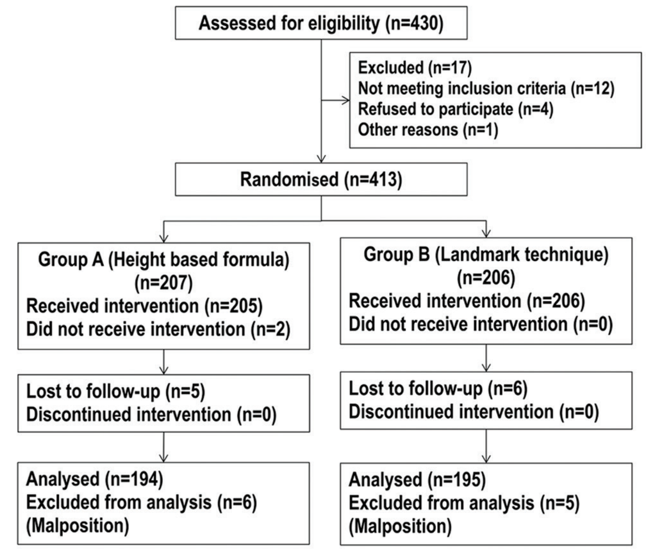

Figure 1: Consolidated Standards of Reporting trials (CONSORT) diagram

Demographic profile including gender, length (in centimetres), and weight (in kilograms) was recorded.

Standard multiparameter monitoring with ECG, heart rate, noninvasive blood pressure and pulse oximetry was done. An anaesthesiologist, experienced in CVC placement performed the procedure on a supine patient with arms by the side and head turned 45° to the left side. After sterile preparation, an ultrasound probe (Colour Doppler ultrasound machine Sonosite) covered with ultrasonic gel and wrapped in a sterile sheath, was placed at the level of cricoid cartilage and then moved laterally.[12] After infiltration with 2 mL of 2% xylocaine, the RIJV was cannulated by modified Seldinger's technique. A 7cm 18-gauge needle (Ven X central venous catheter set-product No. CE-2460) was introduced at an angle of 45° at the level of the cricoid cartilage.[11] The J-tip guidewire 45cm, 0.88 mm diameter was advanced into the vein and was confirmed by sonography. Depending on group allocation, a 16cm 7 Fr triple lumen catheter was inserted.

Any procedural or postprocedure complications were noted. Post-inspiratory CXR was done in supine position with the head held in the neutral position and read by a radiologist who was aware of the study protocol, but blinded to group allocation. The carina and catheter tip were identified and the distance between them was measured using picture archiving communication system [Figure 2]. The optimal distance between the catheter tips to the carina was calculated by adding the distance between catheter tip and carina if the tip was proximal to carina and by subtracting the distance between catheter tip and carina if the tip was distal to the carina. Patients with coiling or catheter malposition were excluded.

Normally distributed quantitative data are presented as means ± standard deviations. Correlations between quantitative data are presented with the Pearson's correlation coefficient (r). The t test was used to test the significance of the correlation and regression coefficients. The F test was used to test the significance of the regression equation. A $P < .05$ was considered statistically significant for the correlation and regression coefficients.

Power analysis was conducted using the software package, G*Power version 3.1.9.2 (Franz Faul, university kiel, Germany). The alpha level used for this analysis was $P < .05$ and beta was 0.20. Based on a previous report by Joshi *et al*.,[10] using the length of CVC insertion as the primary outcome, with a difference of 3.64 and an effect size of 3.93, under the assumption of a 2-sided α error of 0.05 and a power of 80%, the required number of patients for each group was calculated to be 200 patients.

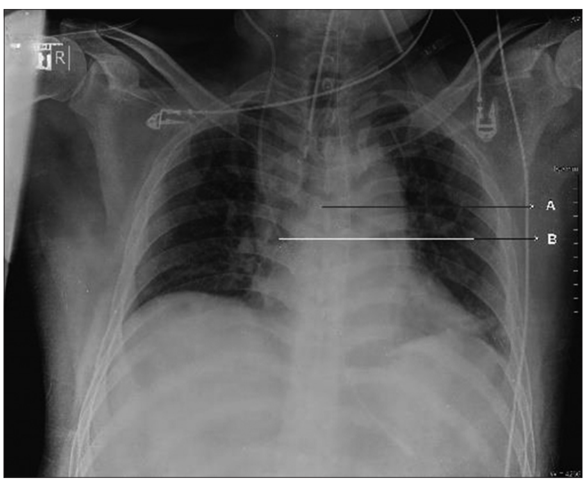

Figure 2: Post procedure CXR showing catheter tip. Line A: At the level of carina. Line B: At the level of the catheter tip

RESULTS

The 2 groups were comparable as regards height, weight, and body mass index. The mean length of catheter insertion was 15.18 ± 0.73 cm in group A versus 14.12 ± 0.85 cm in group B (P =0.001). The mean distance of catheter tip distal to carina by using landmark technique was 0.20 ± 1.18 cm compared with 2.41 ± 0.85 cm using modified Peres' formula (P =0.001, Table 1). Based on data obtained and using height as the predictor in relation with CVC length, the regression equation for describing height-based formula derived was 3.7 + 0.68 × (height/10, P =.001).

The two groups were compared for optimal positioning of CVC. In group A, none of the patients had a properly positioned CVC, with 98.5% patients having an over inserted CVC. In group B, over insertion was found in 51% patients and under insertion in 42% [Table 2]. The CVC was malpositioned in 6 and 5 patients in groups A and B, respectively. When applying Pearson's correlation for optimal catheter length insertion with the actual insertion length, we found a fair correlation with values of r = 0.446, N = 194 in group A and r = 0.390, N = 196 in group B (P =0.001).

We separately compared heights of males and females in both the groups. In females, in group A, length of catheter insertion was 14.38 ± 0.34 cm compared with 13.57 ± 0.77 cm in group B (P =0.001). The mean distance of catheter tip that was distal to the carina was significantly less in group B as compared with group A (0.15 ± 1.25 cm versus 2.29 ± 1.06 cm; P =0.001). Similarly, in males, the mean length of catheter insertion was significantly more; 15.67 ± 0.41 cm in group A compared with and 14.53 ± 0.67 cm in group B (P =.001). Again, the mean distance of catheter tip distal to carina was significantly less in group B compared with group A (0.24 ± 1.14 cm versus 2.47 ± 0.69 cm; P = 0.001; Table 3).

Table 1: Correlations between demographic profile, length of CVC and the distance from the carina

	Group A		Group B		t/Z	P	95% Confidence interval of the difference	
	Mean	SD	Mean	SD			Lower	Upper
Height (cm)	171.98	7.32	171.51	6.88	0.662	0.508	−0.93	1.87
Weight (kg)	76.94	13.86	76.95	12.75	−0.004	0.997	−2.62	2.61
BMI	25.99	4.31	26.10	3.74	−0.281	0.779	−0.91	0.68
Length (cm)	15.18	0.73	14.12	0.85	13.300	0.001	0.90	1.22
Distance of catheter tip from carina (cm)	−2.41	0.85	−0.20	1.18	−21.117	0.001	−2.41	−2.00

CVC=central venous catheter, SD=standard deviation, BMI=body mass index. $P < .05$ (significant)

DISCUSSION

In our study, landmark formula was found to be better than modified Peres' formula, for optimal depth of insertion of RIJV catheters. The mean length of catheter insertion was 15.18 ± 0.73 cm in height-based group versus 14.12 ± 0.85 cm in landmark group.Patients in height-based formula method had an over-insertion of 2.41 ± 0.85cm compared with 0.2 ± 1.18cm in landmark group. Using the regression equation, we found that when using height-based formula, RIJV catheters should not be inserted deeper than height in cm/10-4 in the Indian population.

The ideal location of the CVC tip should be in the SVC, parallel to its long axis and above the level of pericardial reflection, that is, the junction of SVC and right atrium (RA). The level of carina has been shown to be close (1.5 ± 0.7 cm cephalad) to the level SVC-RA junction.[7,13] It is easy to identify carina even in a poor quality anteroposterior CXR and its location is preserved even in pulmonary pathology.[11,14] A limited parallax effect and a smaller sagittal distance between carina and SVC also add to the advantage.[15,16]

Various methods such as anatomical landmarks,[11,17] periprocedural intra-atrial ECG and echocardiography[10] and use of various formulae[18,19] have been tried to ensure correct placement of the CVC tip. There have been studies that have used chest computed tomography (CT) or invasive methods like intra-atrial ECG and transoesophageal echocardiography to determine the catheter tip position of IJV catheters.[15,19] However, in a study by Schummer *et al.*,[16] the SVC-RA junction could not be located accurately using intra-atrial ECG.

A malpositioned CVC can lead to catheter malfunction like incorrect CVP readings and complications like malignant atrial and ventricular arrhythmias, perforation of the cava, atrial or ventricular wall damage, cardiac tamponade, mediastinal haemorrhage and pneumothorax and so on.[2,6] The incidence of these complications is 6.2% to 11.8%. The patient safety can be improved by correct placement of tip of the CVC by using ultrasound and by predicting the ideal length of insertion.[20,21] Various methods have been suggested to estimate the expected length of CVC at the time of insertion. Peres did a study on the Australian population for correct positioning of CVC and utilised patient's height for developing a formula.[18] To avoid CVC placement in RA, he recommended that right infraclavicular subclavian catheters be inserted to (height/10)-2 cm, right internal or external jugular catheters to height/10 cm and left external jugular catheters to (height/10) +4 cm. In a study by Kim *et al.*,[19] on the Korean population, Peres' formula was compared with the distance between the CVC insertion point and the SVC/RA junction that was measured using CT of the chest. For RIJV catheter, an accuracy of 75% was found with Peres' formula compared with 88.6% when using CT-recommended depth.

Czepizak, in his study on the Caucasian race, used Peres' formula and confirmed the CVC tip position on CXR. Although there was 90% accuracy for RIJV catheters, it was suggested that by modifying the formula to (height/10)-1 cm, accuracy could be further improved.[4] However, in a study on Indian subjects, Joshi *et al.*[10] found an accuracy rate of 28% when Peres' formula was compared with intra-atrial ECG-guided placement. They recommended a modification of Peres' formula as: height/10-2 cm for optimal CVC tip placement.

Table 2: Position of central venous catheter

Position of central venous catheter	Group A (*n*=194)		Group B (*n*=195)	
Over insertion	191	98.45%	100	51.28%
Under insertion	3	1.54%	82	42.05%
Properly positioned	0	0%	13	6.66%
Malposition	6	–	5	–

Table 3: Mean distance of catheter tip from carina

	Group A		Group B		*Z*	*P*	95% Confidence interval of the difference	
	Mean	SD	Mean	SD			Lower	Upper
Female								
Length (cm)	14.38	0.34	13.57	0.77	8.455	0.001	0.62	1.00
Distance of catheter tip from carina (cm)	−2.29	1.06	−0.15	1.25	−11.522	0.001	−2.51	−1.78
Male								
Length (cm)	15.67	0.41	14.53	0.67	16.132	0.001	1.00	1.28
Distance of catheter tip from carina (cm)	−2.47	0.69	−0.23	1.14	−18.303	0.001	−2.48	−2.00

SD=standard deviation. *P*<.05 (significant)

We compared this modified Peres' height formula with topographic landmark technique.The varied results from different studies could be due to anthropometric differences (especially height) between each race and population.

RTICS was used as an external landmark by Kim *et al*.[11] to determine the optimal insertion depth of CVC inserted in RIJV in children. The landmarks used were apex of the muscular triangle formed by the sternal and clavicular heads of the sternocleidomastoid muscle and the RTICS. They measured the distance between skin puncture and intercostal space (SK-ICS). In 43% cases, CVC tip was located within 0.5cm of the SVC-RA junction, in 36% cases, 0.5cm above the SVC/RA junction and in the remaining 20%, 0.5cm below it. They postulated a formula for optimal depth of CVC insertion; SK-ICS (cm)-1 and predicted that using this formula, CVC tip would lie above RA in 98.8% of patients.[10] We used this in our study for CVC placement by landmark technique.

Site of insertion, patient's height and body habitus are some of the important factors, which influence the insertion length of CVC. Age does not influence the length of CVC insertion once physical growth stops after adulthood. The average age of patients in our study was comparable in both the groups. Though there were more males than females in both the groups, their distribution across the groups was comparable. In a study by Lum, the accuracy of CVC depth prediction using a formula based on height was also not affected by gender.[22]

In a study by Ezri *et al.*,[17] CVC length was calculated topographically by using thyroid notch and the manubrium sterni as landmarks.This was compared with a fixed insertion length of 15cm. None of the patients had the tip of CVC in the RA in the topographic method. Jayaraman *et al.*[23] in a study on 60 patients, placed the CVC to a length, measured by adding the vertical distance between the right clavicular notch and the carina on preprocedure CXR to the distance between the insertion point and the right clavicular notch. They found a 93.3% accuracy of optimal CVC placement.

Barnwal *et al.*,[24] used the landmark technique in paediatric patients using three points marked on the patient's skin. On comparing landmark technique with intra-atrial ECG technique, the latter was found to be more accurate. These varied results in previous studies compared to our study could be due to the different landmarks used.

In our study, patients in height-based formula method had an over insertion of 2.41 ± 0.85 cm compared with 0.2 ± 1.18 cm in the landmark group. In group A, none of the patients had a properly positioned CVC, and in group B, only 13 were properly placed, and thus both the methods have poor prediction ability. Landmark CVC insertion method offers the advantage of considering the inter-individual anatomic variability and thus, enables matching the CVC insertion length to each patient according to the anatomy. By using an insertion formula that takes into account only the patient's height, there are chances for intra-cardiac placement in a shorter patient.

The strength of our study lies in the fact that our suggested modified formula can be used in emergency situations or when equipment like ECG adaptor, preoperative CXR and transoesophageal echocardiography and so on, are unavailable.

There are a few limitations of our study.The formula used for landmark technique is based on a paediatric population-based study. Also, proper standardisation for insertion point was not done in the height-based formula in the study by Joshi *et al*.[10] The topographic method is not necessarily applicable to CVC insertion performed through other routes (subclavian vein or left-sided IJV insertion). Another limitation is interoperator and interobserver variability. Portable chest radiographs are also subject to variability in technique, exposure and clarity, which may affect the correct measurements.

CONCLUSION

In conclusion, we found that both techniques, that is, landmark based and modified Peres' height formula have poor accuracy; however, landmark technique is better for ideal placement of the CVC tip in the RIJV. When using height-based formula, we recommend inserting RIJV catheters no deeper than height in cm/10–4, in the Indian population.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient (s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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